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Greenhouse Gases Emissions and Energy Payback of Large Photovoltaic Power Plants in the Northeast United States

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DISCLAIMER

GREENHOUSE GASES EMISSIONS AND ENERGY PAYBACK OF LARGE PHOTOVOLTAIC POWER PLANTS IN THE NORTHEAST UNITED STATES

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ABSTRACT

Most of the major large scale solar farms so far have been constructed in the Southwest of the United States due to the higher insolation. However, the high cost of electricity and the desire to increase the portion of renewables have resulted in developing large area solar farms in the Northeast US and Canada. The environmental impact of large scale solar farms in these areas have not been evaluated so far.

This works presents the life cycle environmental impact related to the construction and operation of a 37 MWdc solar farm on the forested campus of Brookhaven National Laboratory. The results from the life cycle greenhouse gases emissions are then used to compare with those displaced by solar electricity in the region to assess the net impacts of photovoltaic life cycles in areas where trees are removed.

INTRODUCTION

There is an interest in increasing the renewable portfolio standard in many states of the United States. In the Northeast for example, New Jersey which is pursuing a goal of 22.5% renewable by 2021 and New York, 24% by 2013 [1]. In order to reach these objectives, large-scale power plants will be necessary. So far, the largest photovoltaics solar farm have been installed in the Southwest and little assessments have been made for large area power plants in the Northeast. The published LCA results for CO_2 emissions range from 16-40 g CO_2 KWh-1 [2–4] but these numbers do not account for the lower insolation as well as deforestation which constitutes the main difference between these two types of installations.

This work uses the example of the recently completed solar photovoltaics power plant constructed on Brookhaven National Laboratory grounds to estimate the greenhouse gases emissions associated with the preparation of the site including deforestation, construction of the solar plant and production over the next 30 years and the beneficial impact of the farm in terms of greenhouse gases emissions. Assuming the same type of system but in other locations, the avoided emissions will be calculated for various areas in the Northeast region.

METHODS

The following diagram illustrates the boundaries of the system considered.

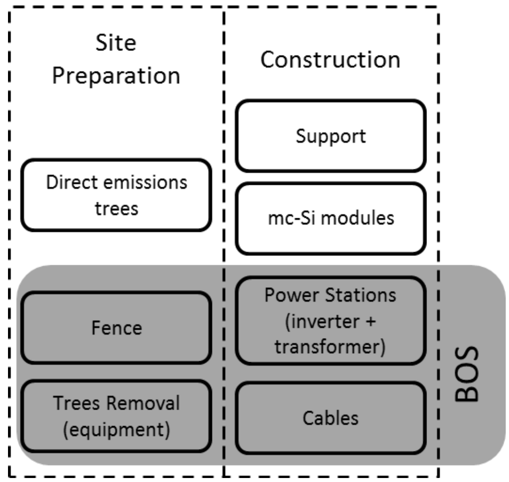

Figure 1 SYSTEM BOUNDARIES

The solar panels are made of muti-crystalline silicon (mc-Si) for an average efficiency of (13.5%) and a total power of 37 MWdc for single-axis panels, assuming a 30 year lifetime and performance ratio of 80% as suggested in the IEA guidelines [5].

The life-cycle GHG emissions over the life-cycle of the system is calculated using inventory databases such as Ecoinvent for the mc-Si panels using country specific electricity for manufacturing, raw materials and processes. The transport range for all the components except the panels is assumed to be 2000 km, with 50% made by railroad and 50% by truck while 14, 000 km (68% by boat, 16% by rail and 16% by train) for the panels. The US electricity production mixture is used for manufacturing of all components.

The area of deforestation is assumed to be 130 acres and corresponds to 260,000 kg C/ha, calculated according to previously published method [4]. The greenhouse gases emissions associated with electricity production are considered according to the grid regions defined by the NERC in 2007 [6]. The insolation for the particular area is taken from [7].

Table 1: CHARACTERISTICS OF THE CITIES CONSIDERED

City	Energy grid	Insolation (kWh/m^2 year)	PV system (MW)
Upton, NY	NPCC	1575	32.0
Boston, MA		1540	32.7
Atlantic City, NJ	RFC	1720	29.3
Chicago, IL		1640	30.7

RESULTS

The details of the materials considered for the analysis is given in Table 1 and normalized for a 1 MWp power plant. Each power station consists of inverters, transformers and junction boxes. The amount of fence is based on an estimate of the perimeter while the cable information combined high and low power cables for connection to the grid.

Table 1 Material Inventory (kg) for a 1 MWp PV plant

Component	Steel	Aluminum	Copper	Plastics	Other
Supports	113205	12453			
Power stations	9962	1484	1288	125	81 (fiberglass) + 2959 (oil)
Concrete					576461 (concrete)
Fence	11180				
Cable		402	2237	1670	
Diesel (construction)					253636 (diesel)

Figure 2 illustrates the average greenhouse gases emissions in Long Island compared to the average New York state generation according to previously published data . The complete analysis of the material inventory will provides a better estimate of the system under study but from Figure 2, the removal of trees increases the total greenhouse gases emissions, but overall, there is at least a 80% reduction of GHG compared to current LI electricity production and 65% for the NPCC region.

CONCLUSION

This works study for the first time the greenhouse gases impact using specific data from a large scale photovoltaics power plant in the Northeast of the United States, in area where forest removal is necessary. Investigations are in progress to assess the specific impact from the life cycle inventory data and the analysis will be extended to include data about energy payback.

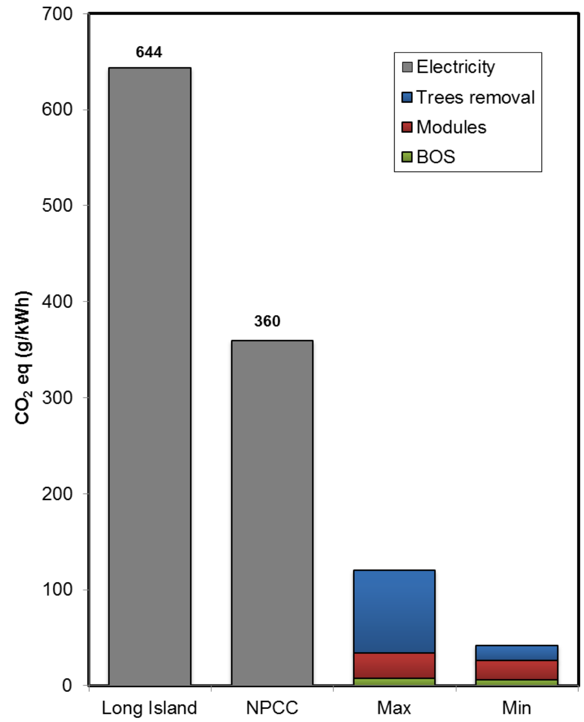

Figure 2 GREENHOUSE GASES EMISSIONS FROM LARGE SCALE POWER PLANT IN LONG ISLAND

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