Feasibility Study
Siting of PV Solar Panels on a Landfill and Adjoining Land in Bethel, NY

Final Report

Prepared By

Cornell Spring CEE 5910 PV Solar Team

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5/19/2017

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II. Executive Summary

The Town of Bethel, NY's proposed PV solar project was further assessed in this report. As is explained in length in the following report, the project is indeed feasible. It would also contribute to the town's goal of being greener and more environmentally friendly via offsetting significant amounts of greenhouse gas emissions as well as achieving various tasks set forth by the climate smart community certification checklist. The geotechnical part of this project in regard to securing these PV solar panels on top of the landfill also seem to yield promising results. However, the sheer cost of the project and finding a solar developer who will be willing to partner with the Town of Bethel on a somewhat economically risky project will be the real challenge. Making the project economically attractive will be difficult, but it could be possible to make money from this project under the right conditions. As is shown by the economic models used in the below report, the regular incentive program is not enough to make it economically feasible and yields many negative net present value results. The general trend for renewable energy incentive programs is that they are consistently decreasing with time, thus the longer the project is delayed the less money that will be received from these incentive programs. However, requesting an extension to the local incentive programs available or acquiring outside grant money could make this project a reasonable investment option. Different scenarios are discussed in the following report.

1. Introduction

1.1 Project Understanding

The Town of Bethel, NY approached Cornell University in order to further assess a local PV solar project that would be primarily on landfill land as well as some adjoining small plots of land. The project consists of 5.45 acres of landfill land (78% of total) as well as 1.55 acres of non-landfill land, as can be seen in the overhead view shown in Figure 1 below on the next page.

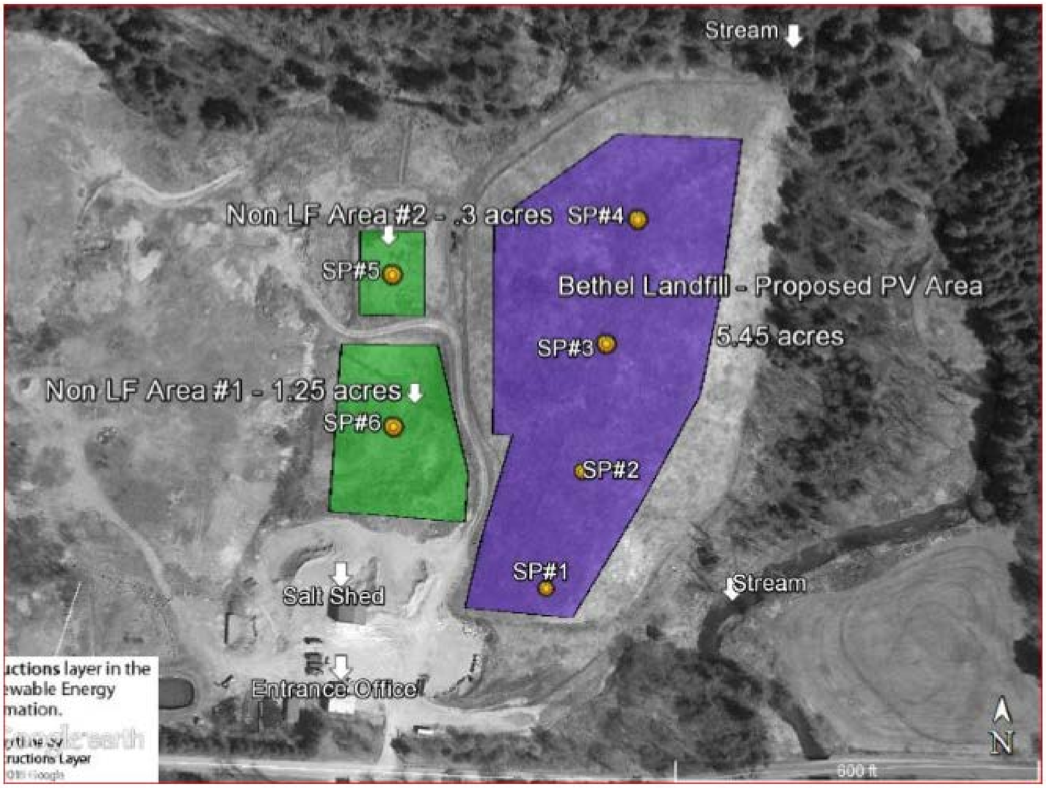

Figure 1: Overhead Aerial Screenshot of the Proposed Project Site
(Rosado)

An initial assessment had already been carried out by the EPA, but there were still some lingering concerns. Further research in technological, economic, and geotechnical aspects of this project could still be further looked into. Thus, the Project Management Master of Engineering program here at Cornell University during the Spring 2017 semester accepted this assignment and formed a project team to look into these areas. The Town of Bethel's overarching goals for this project are to earn money and meet its environmentally friendly goals. Thus, this report was created in hopes to answer the question of whether this project was feasible and if it was, then whether it would satisfy these goals. This report is under the assumption that the actual installation will be conducted sometime during 2018.

1.2 CEE 5910 PV Solar Team Mission Statement

Over the course of the spring 2017 semester, our project team planned to further assess the feasibility of a proposed solar power array on a landfill in Bethel, NY. The team was affiliated with Cornell University's Civil and Environmental Engineering Department Engineering Management Project course and is under the guidance of John Finn, P.E.

Researching and implementing methods that will help us all achieve a sustainable future is an essential part of our mission. However, reducing the United States' carbon emissions, and transitioning away from fossil fuel-based technology is too daunting of a task to try and solve when looking at the big picture. Meeting an ever-growing energy demand, mitigating and adapting to climate change, and doing this in an economical fashion are the three corner stones to a better future. We believe that this starts at the local government level.

Our goal is for Bethel, NY to set an example for towns with unused open space, such as towns with large landfills. By setting an example, other local governments will start to consider taking similar actions all over the U.S. and in other developed areas around the world. Through the precedent set by past engineering project teams and the expertise of environmental researchers, such as Mr. Finn, projects like this one are born and molded.

The mission of our organization is to thoroughly assess the feasibility of projects that may promote sustainability, financial profitability, and social demands via the best science available and within reasonable means. Second, it is vital to us as an organization that all team members stay involved, work to their strengths, be efficient, communicate effectively, and never stop learning.

1.3 Motivation

Our motivation and inspiration originally stems from Cornell University itself. Cornell owns a substantial amount of property in the Ithaca area that has now developed into large fields of solar arrays. Despite, challenges, such as dealing with protected wetlands, Cornell innovatively developed their solar array around the wetland portion of the property. The university has always kept sustainable development in mind. This sort of forward and sustainable thinking is what motivates us. We want to follow this precedent when analyzing the landfill site in Bethel, NY.

Another motivating factor in the initiation of this project is to meet an established need. The population of Bethel, NY is around 4,300 people (City-Data, n.d.). Therefore, this project aims to provide a source of renewable energy for a portion of the energy demand of the Town of Bethel, whether that be just for the municipalities' buildings or also for part of the town's population as well. This project would provide energy in a renewable and sustainable manner, especially considering that the town just recently passed a favorable law for local solar energy. The Town of Bethel has pledged to be a "Climate Smart Community" (CSC) and is striving to achieve Bronze-level certification (or higher) under the NYS Department of Environmental Conservation's Climate Smart Communities program. As a CSC, the Town strives to reduce greenhouse gas (GHG) emissions from its municipal operations as well as encourage its residents, farms and businesses to do the same. Utilization of the Town's capped landfill site for a solar installation, if feasible, would transform this otherwise unusable acreage into a source of renewable energy for the Town and other energy users while lowering GHG emission levels and overall energy costs. Building the solar farm on a landfill also has benefits in that Not In My Backyard (NIMBY) movements are extremely unlikely.

1.4 Objectives

The objective of this project is to analyze the feasibility of a solar energy ground-mounted installation on the Town of Bethel's closed landfill site. The site contains 5.45 acres of closed landfill territory as well as 1.55 acres of adjoining useable territory as well.

The town representatives are hoping that this project will achieve the following objectives:

1. Create a revenue stream for the town via the leasing the landfill site territory to a solar developer
2. Secure a local renewable energy source for municipal operations, small businesses and industry, as well as other participants
3. Advance the Town of Bethel's goals for sustainability, especially with respect to their "Climate Smart Community" certification
4. Improve how their town is viewed by the public via creating a "green community" identity.

They have also requested that certain feasibility topics be addressed in the study including geographical and local considerations, policy considerations, financing options, other costs and economics, and potential risks associated with the project.

This report will address the town's objectives and satisfy the objectives of the graduate course in which the members of the project team are enrolled. The primary course objective that must be integrated into the town's objectives is to incorporate modeling skills taught by the Master of Engineering Management program into the project.

To achieve our objectives, we researched the energy demand in Bethel. We considered industry as well as priority and non-priority sections of the population. We also have considered how the project can avoid any setbacks and try to predict any concerns. Although this was not done, it may also be worth considering how many jobs that such a solar project could create in Bethel. Additionally, solar energy output data models were created, forecasting how much energy output was expected annually from this project on average. These models were created by scaling up or down energy data from similar projects: Cornell University and Newquay, U.K. These forecasting models compared to the National Renewable Energy Laboratory's PV Watt estimation model, thus validating our model and their model. Plus, this information was helpful when evaluating how siting solar panels on a landfill may skew our expected results. It would also be useful to the Town of Bethel if they used these models to then compare this power output to the municipal energy needs of the Town. If there is any excess energy, then it would be interesting to know how locals could potentially participate in using up the remaining extra energy. Finally, direct studies and literature regarding landfill solar projects were analyzed in order to see how this may affect the data. Landfill solar projects by PSE&G in Parklands and Bordentown New Jersey are just 2 examples. Studies involving landfill solar were also be used to assess and predict potential geologic issues.

From an environmental perspective, we assessed the greenhouse gas emissions for the town of Bethel. This helped satisfy the modeling aspect of the course, as well as investigated the magnitude of the environmental benefits of the project, which could be useful statistics to advertise when trying to promote a place as an environmentally-friendly tourist attraction. Also, a brief review of the NY state renewable energy outlook proved useful. The reduction in carbon dioxide on an annual and foreseeable basis was be assessed. This will be useful because the Town of Bethel had goals to reduce its greenhouse gas emissions by 20% by 2020.

From an economic and financial perspective, with federal funding or some other sort of funding, an undertaking such as this project can become significantly more economically enticing. To take advantage of all opportunities such as the Federal and State tax credits, the Town of Bethel assumes that solar installation would be developed and owned pursuant to a Lease and Power Purchase Agreement with a for-profit entity. For example, at the moment there is a 30% federal investment tax credit. This credit shaves 30% off the amount needed to be paid for federal income tax by the business/entity that owns the Bethel landfill solar farm. This tax credit will decrease after the year 2020. The NY-Sun Initiative is another possibility. This incentive program in the best-case scenario would cover up to 50% of the cost, but based on other similarly priced projects, it is more likely that this initiative could cover around $1 million. Of course, there are other potential incentives, but these are just a couple of examples. A more comprehensive list of possible incentives is as follows: the Federal and State Investment Tax Credits, the Modified Accelerated Cost Recovery System, the NY-Sun Solar Electric Incentive Program, the NY-Sun Initiative for PV Systems Greater than 200 kW, the Community Solar NY Round 2, and the Clean Energy Financing Arrangements. Some other important economic factors that were evaluated and considered are: PV arrays/tilt, orientation and balance of the system (BOS) components, inverter and electrical supply/equipment costs, installation cost, system size, potential geographic location costs, mounting structure type, and other soft costs.

1.5 Scope

The major topics that we modeled and researched pertained to the economic feasibility, environmental impacts through reductions in greenhouse gas emissions, and physical outputs of electricity generation that were to be expected on average year round in Bethel.

Pricing and net present value analysis were both assessed within multiple economic feasibility assessment models. These models provided an economic and financial feasibility assessment over various plausible scenarios, which were beneficial for our modeling objective and for the town's financial assessment objective. Additionally, an environmental impact model was built that looked into the carbon footprint of the town through average household energy usage in Bethel. However, it is worth noting that estimation of the energy usage in the Town of Bethel was difficult because of the significant seasonal, rather than year-round, population. By looking into how energy was generated by Bethel area and how much carbon dioxide was emitted to generate this electricity, our team approximated the town's current carbon footprint. This model helped further the modeling objective of the project, but also potentially helped promote the "environmentally friendly vibe" that the town wishes to create. A minor part of the project was the energy output forecast model. This model is more of a validation check to ensure that online tools that are frequently used are relatively accurate and can be trusted in the case of this project. This model extrapolated a lot based on a separate area's climate creating a lot of uncertainty, but based on other respected models such as the PVWatts and the System Advisor Model the results came out looking reasonable. We estimated and assessed how much energy was to be expected from the solar landfill project with decent confidence, and an updated carbon footprint model for the future was created to show the carbon offset.

The above paragraphs explain the direction that the project and final report took with respect to the modeling aspects of the project. However, there is of course some more textual and analytical parts of the final report that are based around research. Some examples of topics that were researched and assessed in the final report are: the geologic and soil aspects of the site and how this may interact with the base structure of the solar panel systems (i.e. needing a ballasted base structure), other landfill project case studies in comparison to this project, further economic and policy speculation, potential risks / hazards, etc. Finally, multiple aspects of the project satisfy different climate smart community certification standards. For example, installing solar photovoltaic technology on public property could be one such standard because the landfill is owned by the Town of Bethel (Climate Smart Communities Certification Action Checklist Version 2.4, 2016). There are also multiple certification standards regarding reducing greenhouse gas emissions of the town, which this project will assess in depth. More specific's regarding these standards can be viewed from a video of our presentation that was likely posted on Francis Vanek's website.

One major area that we deemed outside the scope of this project was looking into the actual permitting concerns in regard to the landfill. This could have taken some long conversations with NYSERDA or the NYDEC and may have required information that we might not have, thus this portion of the project was not considered within our research.

1.6 Key Assumptions

This study assumed that there were be no social, political, or economic barriers that will inherently prevent the project from occurring. These aspects could all potentially thwart the project from ever even being considered past the first few steps, but in this report, they were assumed to be negligible. However, this does not mean that risks and potential problems that could arise and hinder the project were not considered.

We attempted to assess the soil in the area of Bethel, NY, but due to a lack of data, we likely assumed that the landfill site is acceptable and safe to hold solar PV systems on top of it. Additionally, we brought on a new team member, Deigo Almaral, in order to address some of the geotechnical, geographical, and soil concerns. A comprehensive analysis of the base structure of the solar panels and their interaction with the landfill's land and sub-soil was included within the report below. It is worth acknowledging ahead of time that a lack of soil data is possible and likely for such a small town and that with few project team members having geologic/soil-chemistry backgrounds that this may have been a limiting factor. A brief overview of such analysis is provided below:

A landfill inspection report had been done in 2015, and due to this report, there is no concern about settlement, flooding, or erosion. There is an evaluation about the slope of the landfill based on a topographic map. One major barrier that had been mentioned in the report is ballast blocks for the PV solar farm. Concrete may pose a problem and create limitations, because concrete is the part that contains most of the external forces. An alternative method, could potentially be a "flashed mount", which is another common method for installation of PV solar. This method digs holes into ground to hold the loading feet, but the depth of these holes will need to be further assessed. To consider this method, a soil profile will be needed for this method because it requires you to estimate lateral forces as well as the water table. Based on preliminary research, concrete might be the biggest issue that we need to focus on in the report, second to soil investigation issues.

2. Economic Assessment

The economic analysis of a PV Solar farm installed on a landfill and non-landfill site was implemented based on reasonable assumptions, relevant background information, industry-specific inputs and PV-Solar market research from multiple credible studies. This economic assessment was mainly depended on a software simulation model developed by NREL, the System Advisor Model (SAM). SAM allows a user to model various types of renewable energy projects as well as different contractual arrangements for several individual project options (System Advisor Model (SAM), 2017). This software gives a simulated result for a specific PV-Solar project based on the project-specific inputs, and calculates important financial parameters regarding to project economic performance, such as annual cash flow, project internal rate of return, and net present values. This helped us to evaluate the economic feasibility of the project.

The Town of Bethel wanted to lease the land property to Solar developer for them to bear the burden of the investment for this project. Thus, a PV-Watts single ownership model was used. PV-Solar farm annual energy production is heavily reliant on the site-specific weather and location profile. Location, past solar and weather data were downloaded from the NREL website for the Bethel, NY area. These data were issued in 2015, thus they are relatively recent and relevant.

2.1 Model Parameters and Assumptions

SAM requires the input of values for the basic expected system design. The siting study done by the Environmental Protection Agency (EPA) included such technical specifications. The system parameters for the solar array modules, the tilt, and the azimuth were all retrieved from the EPA's study. The array-type is standard and is a fixed open rack system with tilt of 20 degrees. And finally, the azimuth is 180 degrees facing south. Based on a case study, which also used SAM, for a PV Solar farm on landfill land in Cleveland (Salasovich et al, 2013), we found a reasonable DC to AC ratio value of .86 and inverter efficiency of 96% for a typical PV solar system. This would correspond to total system losses of roughly 14% as a result. We assumed shading would only be a minor issue on both landfill and non-landfill sites. This assumption is based on the fact that there should be minimal trees and vegetation that would block light in the area and with a decent layout and spacing the solar panels should only minimally shade each other. In addition, further preparation was requested to eliminate additional vegetation in other two non-landfill areas before solar system installation in order to provide more energy production. (Town of Bethel EPA Study, 2016).

Based on the location and weather profile at Bethel NY, and the system design inputs, SAM simulated the annual energy production for the PV-Solar farm over its 25-year analysis period, as well as the monthly energy production in the first year of operation. Figure 2 shows the yearly energy generation provided by the PV Solar farm during the project life. In the model, a 0.5% system degradation every year was estimated, therefore, the annual energy production decreases linearly over the life-time of the project. Figure 3 shows the energy production varying in months in the first year of operation. Higher energy generation was observed in summer season, and lower energy generation in winter season.

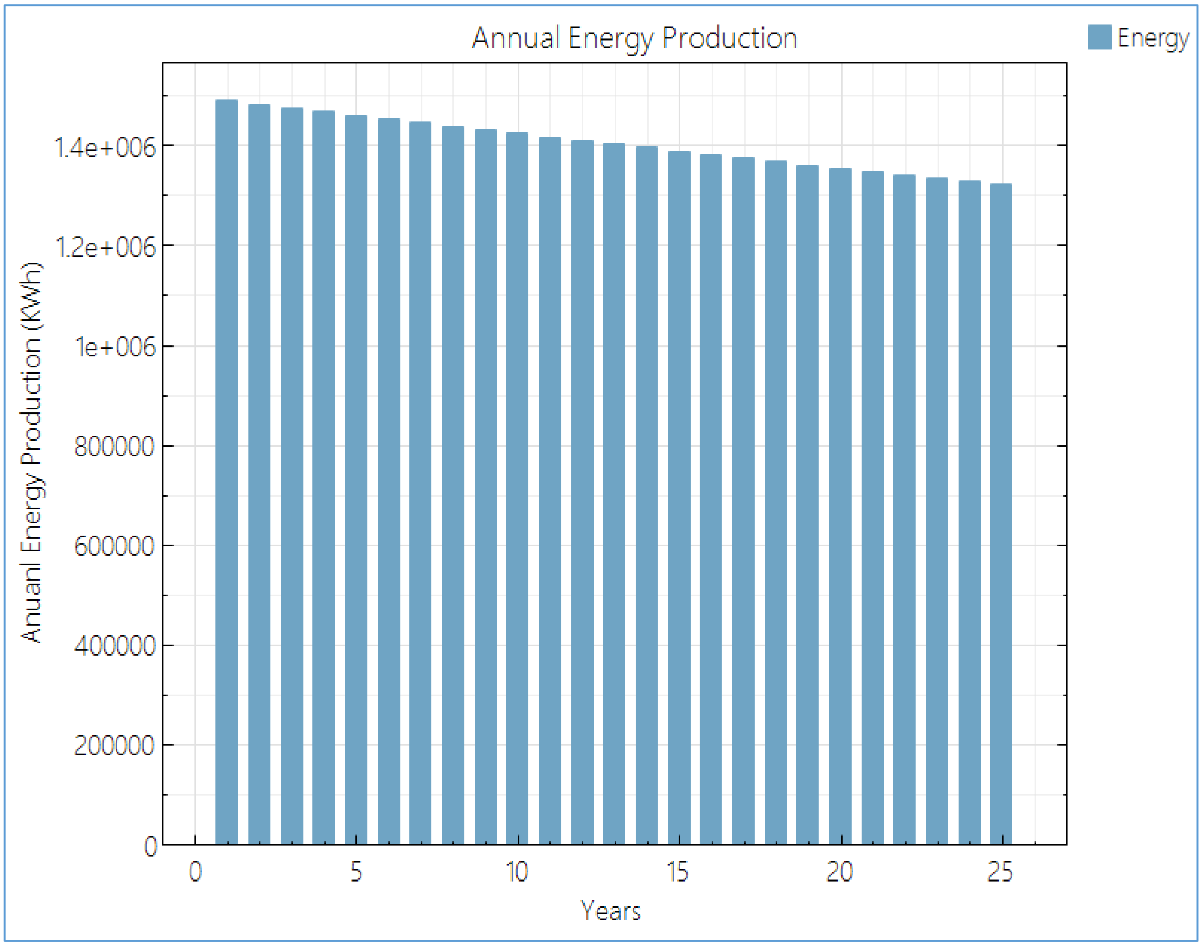

Figure 2: Modeled annual energy production for 25 years of analysis period

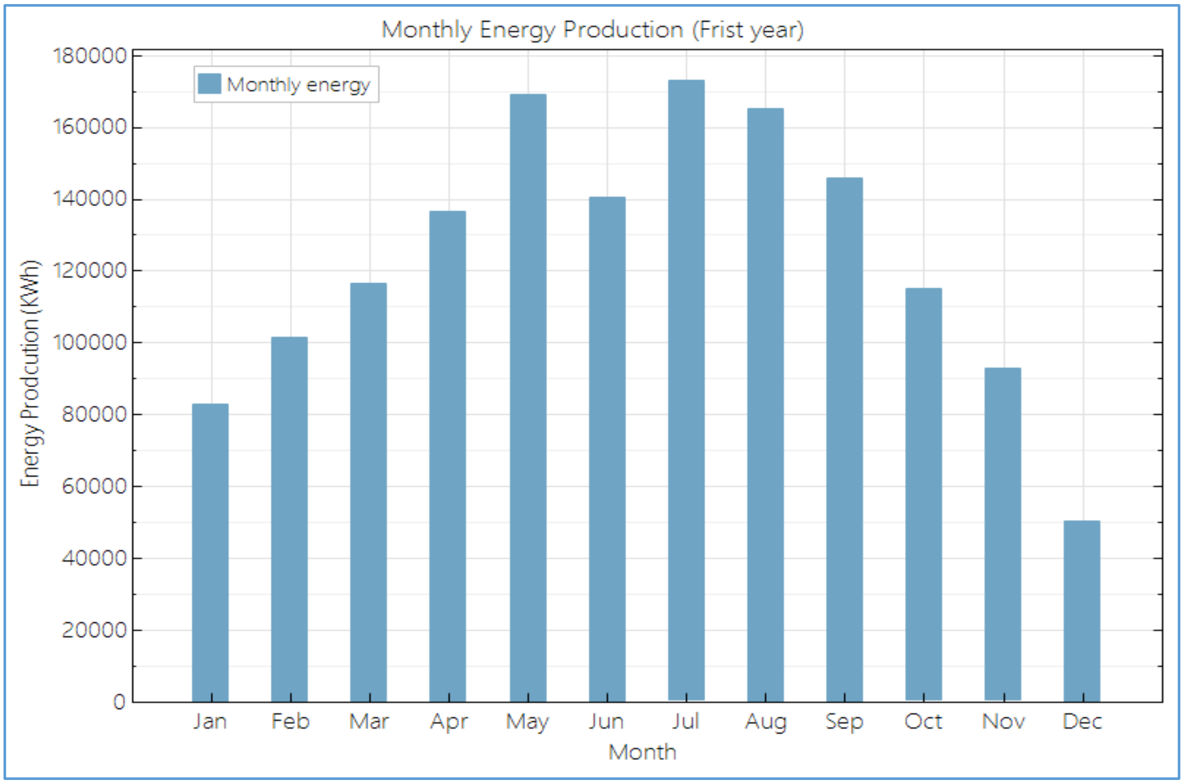

Figure 3: Monthly Energy Production in the first operating year

The next step in the process for completing the SAM was to input the system cost parameters. The cost parameters for the solar array module, inverter, balance of system equipment, installation labor costs, and installer margin and overhead are all measured in terms of dollars per Wdc (Watt of DC energy). These values were determined by referencing other case studies that use the SAM model, and a recent photovoltaic market research and cost breakdown study. (Chuang, 2015).

According to the market research on a Utility-Scale System Benchmark PV-Solar system, the cost of constructing a PV-solar system declined significantly since the fourth quarter of 2011. In the first quarter of 2015, a utility-scale PV system U.S. average benchmark purchase price was modeled from \$1.53/Wdc to \$1.77/Wdc for a fixed tilt system. (Chuang et al, 2015). According to the study, this benchmark price will continue to drop approximately 2% in the future one to two years. Thus, we assumed the cost for a fixed tilt PV system will be approximately \$1.49/Wdc to \$1.73/Wdc in 2017. In addition, according to Chuang et al (2015), if the racking structure uses a ballast anchoring system to mount on the ground, the cost would increase by 25%. For the PV Solar project proposed by Town of Bethel, 78% of the land used is landfill site, which requires ballast system, and 21% of total area is non-landfill site. On an average scale, using linear interpolation calculation, additional 20% increase in the unit system installation cost of was estimated for the project. Thus, we estimated that the installation cost of the PV-Solar system that falls between \$1.78/Wdc to \$2.07/Wdc would be reasonable. This cost cover both direct capital costs and indirect capital costs. The direct capital costs involve model cost, inverter cost, balance of system equipment, installation labor, and installer margin & overhead (all in units of $/Wdc). The indirect capital costs parameters involve the following areas: permitting and environmental studies, engineering and developer overhead, grid interconnection, land purchase, and land preparation and transmission (all in units of $/Wdc). Table 1 summarizes the cost breakdown.

Table 1: Installed costs breakdown and summary for PV-solar system at Bethel

Direct System Cost Parameter:	Cost in ($/Wdc):
Module Cost:	0.65
Inverter Cost:	0.11
Balance of System Equipment Cost:	0.2
Installation Labor Cost:	0.19
Installer Margin and Overhead Cost:	0.1
Indirect System Cost Parameter:	
Permitting and Environmental Studies	0.05
Engineering and Developer Overhead	0.41
Grid Interconnection	0.03
Total cost per capacity	**$ 1.86/Wdc**
Contingency	4%
Sales tax	5%
Total installed cost	**$2,226,000.00**

For a potential future event that may not be foreseeable, it is prudent to have a contingency plan. We assumed that a value of 4% of the total direct project cost would be reasonable. Permitting and environmental studies were assumed to be a relatively low value considering that the EPA has already conducted a siting study and the Town of Bethel has requested Cornell assist with this project as well.

There is also a sales tax that is a percent of direct cost. A conservative value was already given by SAM as a default value. This value is a 100% sale tax basis at a sales tax rate of 5%. Although the sales tax rate in New York state is 8.5%, we assumed that since the project was proposed by the Town of Bethel, the solar developer might be able to become exempt from this sales tax. To be compromise and be conservative, we applied sales tax rate of 5% (between 0% and 8%). The last cost parameter needed is an all-inclusive parameter for operation and maintenance (O&M) costs. Based on data from the NREL website for solar projects between 1 to 10 MW's an O&M cost of $16/kw-year is reasonable ("Distributed Generation Renewable Energy Estimate of Costs", 2016).

With all these cost parameters inputted into SAM, it was estimated that the total installed cost would be approximately $2,226,000. The EPA study estimated that the cost of the project would be $2,865,863. The different between two cost estimations is approximately 22%, therefore we concluded that the SAM model's cost prediction is reasonable.

The final step of completing the SAM was to input financial parameters and incentives. Firstly, various financial rates needed to be specified for PV-solar project. Table 2 lists all the financial rate inputs based on the team's research and reasonable assumptions.

Table 2: Summary of financial rate parameters in SAM

Financial Rate Category	Rates
Inflation rate	2.5%/year
Real discount rate	5.5%/year
Federal income tax rate	35%/year
State income tax rate	7%/year
Sales tax	5% of total direct cost
Insurance rate	0.5% of installed cost

In addition, different financial modes can be applied to developing a PV solar project. For Bethel specifically, we communicated with the client, and determined that the Power Purchase Agreement (PPA) will be used. A typical PPA was determined to be a 25 year, 8.6 cent PPA price, with a 1% escalation rate for New York projects such as this one (Finn, 2017). Based on a PV solar construction blog that tracks new projects in New York and various other states, we found that a high estimate for PPA's in New York would be around 12 cents (Rafalson, 2017). A low estimate of 5 cents PPA price was used based on market research and reference from other studies. A PPA of 5 cents can be relatively common in some other states, but in New York this would be a true lower bound. In addition, the solar developer can choose to whether take debt or not to cover its initial investment. Using SAM, we specified the three scenarios of 0% debt, 25% debt and 50% debt taken by developer to evaluate the economic feasibility of this project.

The tax incentives incorporated into the model only accounted for the 30% federal tax incentive/credit as well as for the New York Sun Initiative's Commercial/Industrial Incentive Program. The New York Sun program offers production-based tax credits for the first 3 years of the project. The monetary rate listed online is $0.097 / kWh, but since the project is on a strategic location this monetary rate is increased by 20%, thus becoming about $.12 / kWh ("NY-Sun Commercial/Industrial Incentive Program", 2015). If a special extension could be acquired which would extend the time that this production-based tax credit could apply to the project by additional 3 to 4 years, then this would substantially improve the financial viability of the project. Both the base scenario model and the optimistic incentive extension version of the model were assessed. Additional information regarding potential incentives (that were not included within our model) can also be found within the Appendix section of the report.

2.2 SAM Economic Assessment Results

Usually the New York state Production Tax Credit (PTC) incentives only covers the first three years of investment in a renewable energy project. Based on the regular PTC, we used SAM to calculate the simulated Net Present Value (NPV) and Project Internal Rate of Return (IRR) with respect to five PPA prices ($.05/kwh, $.07/kwh, $.086/kwh, $.09/kwh, $.095/kwh, $.12/kwh), 0% or 1% annual PPA price escalation, and 0%, 25% and 50% debt. The economic performance of project under different PPA prices and PPA price escalations is analyzed first with the scenario that 0% debt is taken by developer to cover its initial investment. The result is summarized in Table 3.

Table 3: NPV and IRR of the project for regular incentive, 0% debt at various PPA price

Debt %: 0%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	NaN	-892,155
0%	0.07	-3.20%	-709,598
0%	0.086	0.35%	-563,553
0%	0.09	1.05%	-527,042
0%	0.095	1.86%	-481,403
0%	0.12	5.20%	-253,207
Debt %: 0%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	-7.50%	-853,507
1%	0.07	-0.96%	-655,491
1%	0.086	2.00%	-497,079
1%	0.09	2.62%	-457,476
1%	0.095	3.35%	-407,972
1%	0.12	6.44%	-160,452

With regular incentives program and 0% debt, no reasonable PPA price would offer this project a positive NPV, which indicates that the project is economically not feasible. This is a result of large initial investment in the first year of project. Figure 4 shows the project cash flow under 0% debt, $0.086/kwh PPA price, and 0% annual price escalation. The developer would invest a large amount of capital to install PV-Solar system, leading to large negative cash flow. Since the debt interest payments are tax deductible, the project funded with no debt may have much lower net-after tax annual cash flows.

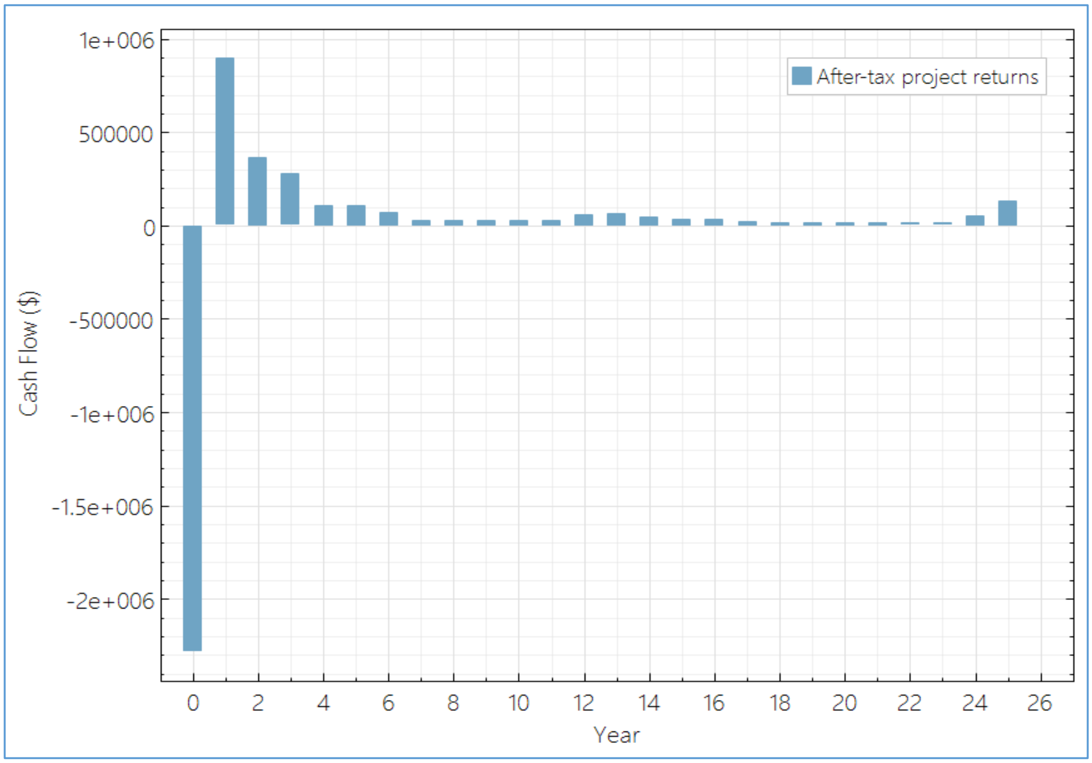

Figure 4: Project Cash Flow (0% debt, PPA price = $0.086/kwh, 0% price escalation)

Next, the team evaluated the economic performance by model the project with different percentage of debt ---25% debt and 50% debt. SAM calculated the NPV and IRR for each of scenario as can be seen in Figure 5 and Table 4 below.

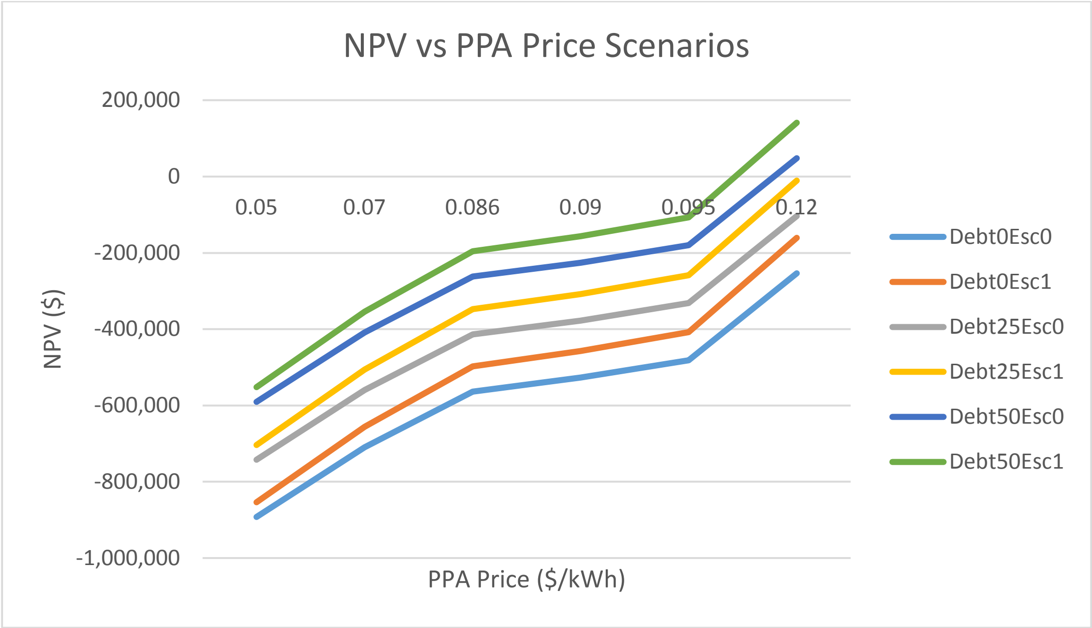

Figure 5: NPV vs PPA price under different debt percentage and PPA price escalation

Table 4: NPV and IRR of the project for regular incentive, 25% and 50% debt at various PPA price

Debt %: 25% (% of total capital cost taken as debt)			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	NaN	-742,473
0%	0.07	NaN	-559,917
0%	0.086	-4.03%	-413,872
0%	0.09	-2.34%	-377,360
0%	0.095	-0.49%	-331,721
0%	0.12	6.00%	-103,526
Debt %: 25%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	NaN	-703,825
1%	0.07	-6.20%	-505,810
1%	0.086	0.13%	-347,397
1%	0.09	1.33%	-307,794
1%	0.95	2.69%	-258,290
1%	0.12	7.95%	-10,771
Debt %: 50%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	NaN	-590,908
0%	0.07	NaN	-408,352
0%	0.086	NaN	-262,307
0%	0.09	NaN	-225,795
0%	0.095	-9.68%	-180,156
0%	0.12	12.08%	48,039
Debt %: 50%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	NaN	-552,260
1%	0.07	NaN	-354,245
1%	0.086	-7.01%	-195,832
1%	0.09	-4.81%	-156,229
1%	0.095	-1.40%	-106,725
1%	0.12	15.49%	140,794

The SAM model indicates that if only 25% of capital cost is taken as debt, there is no reasonable PPA can achieve a positive project NPV. The initial investment is too large to be leveraged by the debt. In order to be profitable and make the NPV positive, the contractor would need to have more than 50% of capital cost taken as debt. According to the simulation result generated by SAM, with 50% of capital cost taken as debt, the project can achieve a positive NPV at a particularly high PPA price, which is $0.12/kwh. This PPA price is much higher than typically achievable PPA price in real world operations. From Figure 5, the project can breakeven at a PPA price around $0.106/kwh to $0.112/kwh with 50% of capital cost taken as debt. The SAM model shows that with the usual Production Tax Credit, which is 3 years, the project can only break even at a PPA price $0.106 or higher, and with 50% leverage.

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The SAM model shows that with the usual Production Tax Credit, which is 3 years, the project can only break even at a PPA price $0.106 or higher, and with 50% leverage. However, if we could extend our Production Tax Credit to 7 years, we will get a much better result. Again, we calculated the Net Present Value and Internal Rate of Return based on five PPA prices ($.05/kwh, $.07/kwh, $.086/kwh, $.09/kwh, $.095/kwh, $.12/kwh), 0% or 1% annual PPA price escalation, and 0%, 25% and 50% debt, but this time, we changed the term of the Production Tax Credit to 7 years.

Before we considered different debt structures, we first analyzed the investment without debt.

Table 5: NPV and IRR of the project for 7-year PTC incentive, 0% debt at various PPA price

Debt %: 0%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	N/A	-595,253
0%	0.07	N/A	-412,696
0%	0.086	N/A	-266,651
0%	0.09	N/A	-230,140
0%	0.095	N/A	-184,501
0%	0.12	1.71%	43,695
Debt %: 0%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	N/A	-556,605
1%	0.07	N/A	-358,589
1%	0.086	N/A	-200,177
1%	0.09	N/A	-160,574
1%	0.095	N/A	-111,070
1%	0.12	9.60%	136,450

The table above summarizes the IRR and NPV for different PPA prices if the investment has 0% debt. The upper part of the table is under the condition of 0% PPA price escalation, and the lower part of the table is under the condition of 1 % PPA price escalation. According to the

table, the model generates positive NPV at PPA price $0.12 for both 0% PPA price escalation and 1% PPA price escalation. On the other hand, the NPV with the regular incentive are negative for all PPA prices for both 0% escalation and 1% escalation.
We then looked at the IRR for the cases with positive NPV. At a price of $0.12 and 0% PPA price escalation, the project is estimated to achieve a 1.71% IRR, indicating the project merely breaks even. However, at a price of $0.12 and 1% PPA price escalation, the project achieved 9.60% IRR, which is an attractive return considering there was no debt involved.

Next, we compare the NPV and IRR for different debt structures.

Table 6: NPV and IRR of the project for 7-year PTC incentive, 25% and 50%debt at various PPA price

Debt %: 25% (% of total capital cost taken as debt)			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	N/A	-445,571
0%	0.07	N/A	-263,015
0%	0.086	N/A	-116,970
0%	0.09	N/A	-80,458
0%	0.095	N/A	-34,819
0%	0.12	11.99%	193,376
Debt %: 25%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	N/A	-406,923
1%	0.07	N/A	-208,908
1%	0.086	N/A	-50,495
1%	0.09	N/A	-10,892
1%	0.95	8.85%	38,612
1%	0.12	13.18%	286,131
Debt %: 50%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
0%	0.05	N/A	-294,006
0%	0.07	N/A	-111,450
0%	0.086	13.72%	34,595
0%	0.09	15.92%	71,107
0%	0.095	17.95%	116,746
0%	0.12	24.68%	344,941
Debt %: 50%			
PPA Price Escalation	PPA Price	IRR at end of project	NPV
1%	0.05	N/A	-255,358
1%	0.07	N/A	-57,343
1%	0.086	16.31%	101,070
1%	0.09	17.86%	140,673
1%	0.095	19.51%	190,177
1%	0.12	25.66%	437,696

According to Table 6, with 25% debt and 0% PPA price escalation, the project achieves positive NPV at a price of $0.12. With 25% debt and 1% PPA price escalation, the project achieves positive NPV at prices higher than $0.95. With 50% debt and 0% PPA price escalation, the project achieves positive NPV at prices higher than $0.086. With 50% debt and 0% PPA price escalation, the project achieves positive NPV also at prices higher than $0.086. For a better illustration of these results, we plotted the NPV of different scenarios versus various PPA prices and the IRR of which cases achieve positive NPV versus various PPA Prices, as shown in Figures 6 and 7.

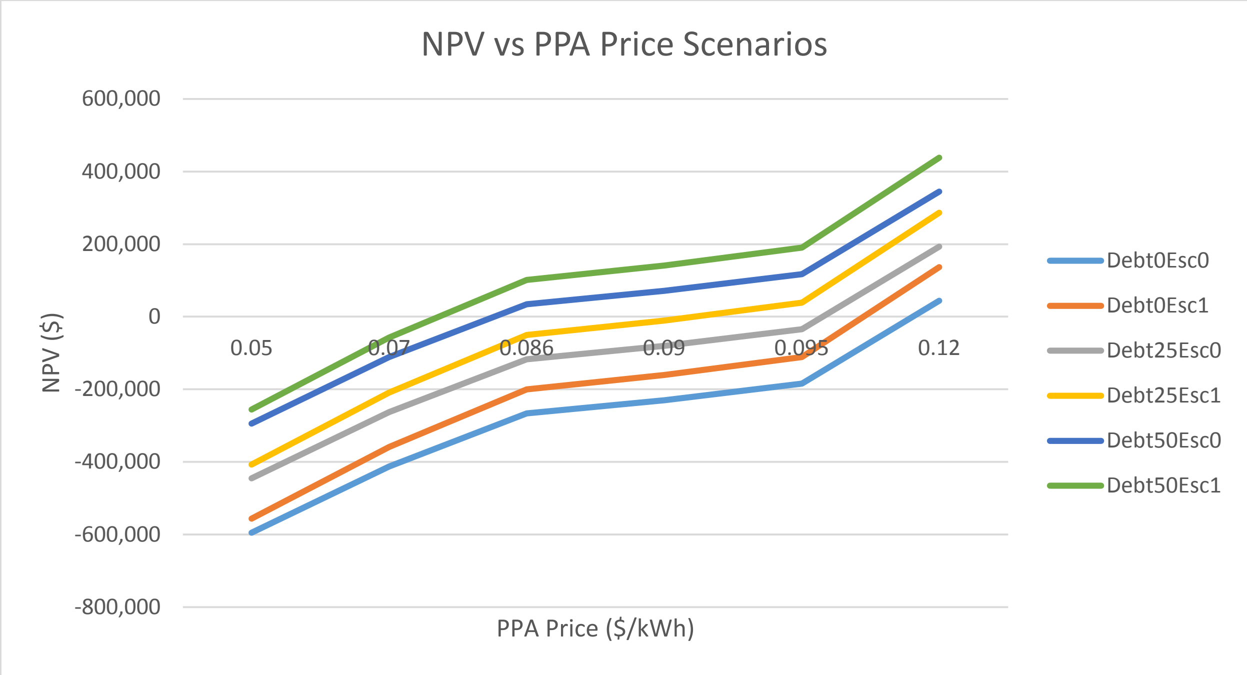

Figure 6: Graph of Net Present Value v. Power Purchase Agreement Scenarios

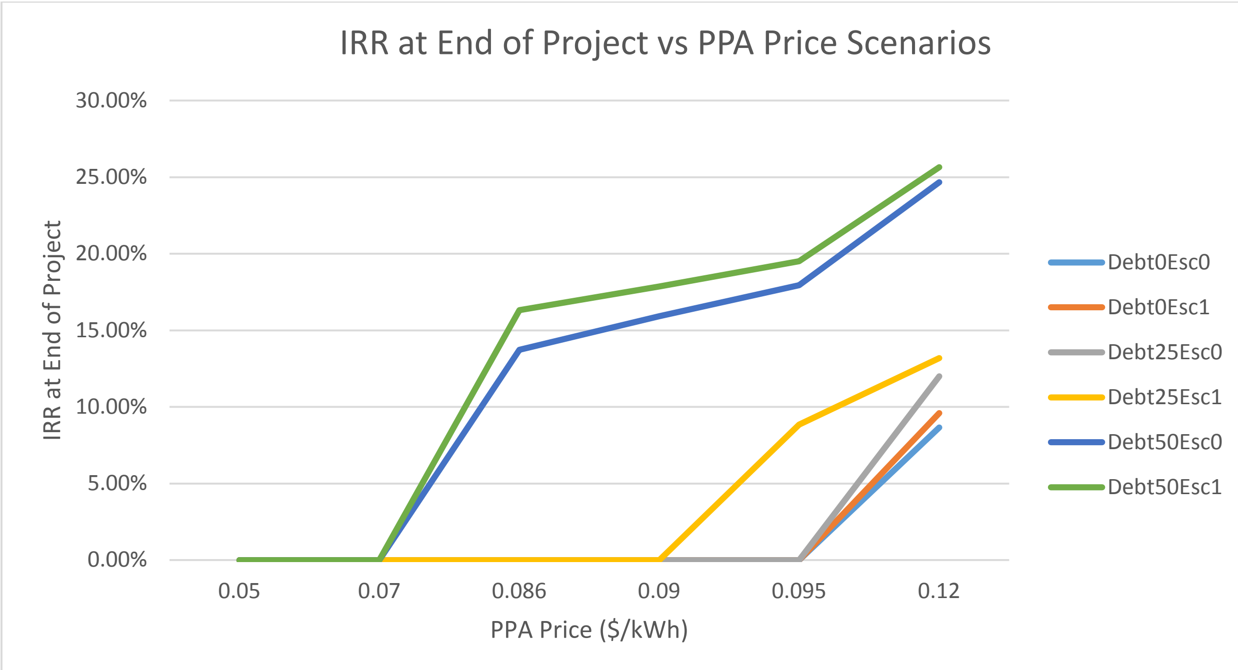

Figure 7: Graph of IRR v. Power Purchase Agreement Scenarios

The graph of NPV versus PPA price shows that while the project has quite high breakeven PPA prices for the 25% leverage scenarios, the project can make profit at majority of PPA prices with 50% leverage, and the breakeven PPA prices for 0% PPA price escalation and 1% PPA price escalation are around $0.08 and $0.075 respectively. Both $0.08 and $0.075 are reasonable PPA prices in for the Bethel, NY location at this time.

The graph of IRR versus PPA Prices shows that if the project could get 50% leverage, at PPA price $0.86, which is about the average PPA price, we would achieve around 15% IRR.

In conclusion, the result of the project is very sensitive to incentive terms, PPA price and Debt structure. If we only the usual PTC is available, which is a three-year term, the project would not break even in almost all the cases. However, if a seven-year PTC incentive term is available and 50% leverage for the project were used, it could achieve a positive NPV and an IRR around 15% at an average PPA price. Thus, the key to the economic model is to obtain a seven-year PTC incentive term and 50% leverage.

3. Technological Background and Assessment

3.1 PV Systems and PV Overview

Solar photovoltaic (PV) systems convert sunlight directly into electricity. Solar PV cells are the basic working units in a PV system. When the sunlight strikes a PV cell, a direct current (DC) is generated. With a closed-loop connection, this current can power various loads according to its performance. In a real-world system, PV cells work collectively as a PV panel or module. Multiple PV modules are connected together - to create a solar array. To supply power to the electric grid, DC power has to be converted to alternating current (AC), which requires an inverter to provide the conversion (Salasovich, 2013).

Electricity production efficiency from PV systems is primarily a function of PV panel orientation, tilt, and DC to AC conversion losses. If the PV system connects to the local power grid, then losses on the way to nearest accessible power infrastructure and other transmission losses will also affect its overall performance (Murray et al., 2012). These factors usually depend on the exact location of the PV system. In the case of the Bethel project, a previous assessment was done by EPA (EPA, 2016).

3.2 Major System Components-PV Module

3.2.1 Crystalline Silicon

Crystalline Silicon is the most widely used and conventional material for PV systems. There are two sorts of crystalline silicon in the market; they are monocrystalline and multi-crystalline. The PV industry has been collecting data on the performance of crystalline silicon for tens of years (Salasovich, 2013). According to the industry data, crystalline silicon modules have a lifespan of about 25-30 years. They can still operate after this lifespan. After its lifespan, the performance will typically be higher than 80% according to the industry's prediction. But there is no sufficient data to determine exact efficiency of the solar panel after 25 years, because most of the field tests conducted are not longer than 25 years. When selecting different manufacturers of crystalline silicon solar cells (module), the manufacturer usually gives a guarantee on metrics such as “25-year performance not less than 80.7%” (“NY-Sun”-1, 2017).

According to the industry data, polycrystalline solar panels often yield a lower efficiency compared to the monocrystalline solar panels. For monocrystalline panels, the efficiency is typically from 15-20%. But for polycrystalline solar panels, it is typically 14-16% (Jordan et al., 2012). Though monocrystalline has a higher efficiency, its cost is usually higher than the polycrystalline. A suggested solar industry recommendation is to make decisions based upon brands but not the category of crystalline silicon. This is because the outcome will be mostly determined in terms of the quality of solar panels. Selecting a good brand of solar panels can bring about a lower decline in the efficiency and consequently increase electricity production.

3.2.2 Thin Film

Unlike crystalline silicon, thin-film PV uses amorphous silicon or non-silicon materials for generating electricity. Due to their unique nature, thin-film cells are constructed into flexible modules. According to a publication of National Renewable Energy Laboratory, the thin-film PV can apply to landfills by covering it like a layer of geomembrane system (NREL, 2013). This system poses less load on the landfill compares to other two types of PV module, though it has a lower efficiency, between 6% and 12% (Salasovich, 2013). The thin film is usually used in projects which have shading problems or where extra weight (load) on soil tends to be problematic. Since there are not concerns of severe shading problems or load problems, thin film would not be a favorable choice for Bethel's project due to its low efficiency. Thin film and crystalline type PV arrays are compared in Table 7 below.

3.3 Inverter

There are two primary types of inverters for a grid-connected PV array, string inverters and micro-inverters. String inverters typically have a capacity of 1.5-1000kW. For projects larger than 1000kW, they can operate in parallel to meet the load of the PV array. Commercial string inverters have an industry standard warranty of 10 years which is about half to one third of the expected life of PV panels. Micro-inverters are usually used in small projects with irregular modules and shading issues. But micro-inverters are not suitable for Bethel project because they would result in high operation and maintenance costs. This is because micro-inverters usually have a much smaller capacity. The typical capacity is about 175-380W (Salasovich, 2013). For Bethel project, there would be a huge amount of micro-inverters which would lead to much higher operation and maintenance costs. Consequently, string inverters should be the better choice.

3.4 Tilting system

A PV module will achieve more of its potential if a tracking system is used. A single-axis tracking system can provide a production boost of 25% or more. A dual-axis system has a substantial increase of more than 35%. However, if a tracking system is in place, there will be additional costs of maintenance and a problem of shading. The additional costs occur in the maintenance of moving parts. Additionally, tracking results in a problem of shading. If the panel has to track the sun, its shadow will be constantly changing over time. This change will consequently induce a shading problem between panels if the lay-out of solar array does not include spacing between modules. When shading is considered, the fixed-tilt system is actually more efficient in terms of energy density per square foot of land area since a well-organized tracking PV system needs more space to avoid shading.

Table 7: Energy Density of Different Types of System

System Type	Energy Density	
	Fixed-tilt (DC-Watts/ft²)	**Single-axis tracking (DC-Watts/ft²)**
Crystalline Silicon	4.0	3.3
Thin Film	3.3	2.7
Hybrid High Efficiency	4.8	3.9

(Salasovich, 2013)

3.5 Operation and Maintenance

A PV system can operate at a low operation and maintenance cost. The panel itself has a 5-10 year warranty as well as at least 25 years of performance (Murray et al., 2012). The maintenance work for a PV system usually includes an annual inspection of the wire and rack connections. The approximate cost for fixed-tilt system is about $20/(kW·year) (Salasovich, 2013). In addition, the inverter will often have to be replaced once during the life time of solar panels. This cost is dependent on the capacity of system and the model of inverter. The expected cost of a replacement of the inverter in year 15 will be about $0.25/W. (Salasovich, 2013) These are separate estimates than what were used in the System Advisor Model, but are similar.

3.6 Shading Considerations

Initial concerns regarding siting were assessed in the EPA screening study; they inspected the site and concluded that the site was free from sunlight obstructions (Rosado, 2016). Additional siting considerations are discussed in the geotechnical assessment portion of the report, Section 1 "Geotechnical Assessment".

3.7 Interconnection

The PV system has to connect to the grid at the local utility interconnection point. The system design has to be reviewed by the local distribution utility to determine the technical viability of connection and its potential cost. Following factors are usually the major concerns (Murray et al., 2012),

- The voltage of nearby electric distribution lines
- Presence of single phase vs. three phase power
- Electricity usage of nearby end-users connected to the distribution grid
- Nearby electricity generators that are connected to the distribution grid
- Proximity to substations and other utility-owned hardware
- Distance to and cost of upgrading distribution lines to handle proposed project.

In previous EPA report, it suggested that there was a transmission line nearby with a distance of approximately 427 feet. In general, the distance from the proposed solar PV system to the point of interconnection with electrical transmission should be within a half mile distance in order to yield more viable economic conditions. But a more detailed assessment has to be made because there are considerable aspects to be assessed before generating electricity to the grid. A website describing interconnection further within a case study is shown below: http://www.nyseg.com/MediaLibrary/2/5/Content%20Management/Shared/SuppliersPartners/PDFs%20and%20Docs/Bulletin%2086-01.pdf.

3.8 Net Metering

Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. This mechanism uses the energy generated in the property subtracts the energy consumed at the property, and provides credits to the owner according to the net energy use. Net metering is available on a first-come, first-served basis to customers of the state's major investor-owned utilities. Publicly-owned utilities are not obligated to offer net metering. New York State law allows net metering for solar photovoltaic systems up to 25 kW in residential buildings, and up to 2 MW in commercial and industrial settings, including systems serving nonprofit organizations, schools, governments and agricultural operations.

For Bethel project, net metering is a favorable mechanism which has the following advantages. First, the net metering system is easy and inexpensive. It gives a convenience access to the grid for customers. Secondly, it allows the power company as well as the customer to monitor the net energy produced. Consequently, it gives information on the revenue of that property, which helps the owner to further examine the economic issue of the property (Watsons, 2009). Lastly, only 20-40% of PV system's output ever goes into the transmission grid (SEIA, 2017). By using net metering, most of the solar electricity will serve nearby customers' loads, which promotes the overall environmental friendliness of the community.

4. Environmental Assessment

This environmental assessment was conducted purely to assess how much energy output that this proposed PV solar project may produce. The actual environmental concerns regarding land nearby the landfill were, decidedly, not within the scope of this report. We recommend that a wetlands specialist, biologist, or natural resources related field be hired to survey the surrounding land and see how it might affect any special areas, such as forest land, wetlands, wilderness, etc. They should specifically look into how this project might affect local indicator species. Based on the EPA study there are not likely any major concerns and a finding of no significant impact is probable. Additionally, the permitting concerns with respect to the landfill were also deemed to be out of the scope of this report and were not analyzed in this section. This would be a good area for further research and investigation. We recommend investigating with the NY DEC. The areas researched in this environmental assessment involved coming up with a method other than NREL's PVWatts model to approximate the annual energy output of this project. The system advisor model in the economic section also has an annual energy output approximation, which ends up being the highest (least conservative) estimate at around 1,500,000 kWh per year. Our rough and somewhat uncertain model (due to it being based off another similar area's climate) gives a much more conservative estimate for total annual energy output. After using our model and validating with SAM and NREL's PVWatts we plugged the expected annual energy output into various carbon offset models. These models were then compared graphically in order to show minimum and maximum greenhouse gas emission scenarios.

4.1 Expected Energy Output Model Background

Using modeling techniques from the Cornell CEE 5930 course, taught by Dr. Linda Nozick, a forecasting model was generated for the purpose of assessing the validity of the National Renewable Energy Laboratories' (NREL) PVWatts model (Nozick, 2016). This was done to double check the calculations made in the NREL model to make sure that they were giving a reasonable estimate for a relatively remote area like Bethel, NY. Secondarily, it was also very beneficial because it provided a more conservative estimate of the expected energy output from the siting of PV solar panels at Bethel, NY. Thus, the results will be more realistic and will not exaggerate the production potential of the system.

4.2 Energy Output Model Methodology

The main challenge the team had in developing this model was in acquiring a complete and relevant data set. The closet thing that was found was a public data set for a small weather station in Newquay, U.K. At first glance this seemed like a good fit considering that the U.K. is known for being a relatively rainy place. However, based on graphically looking at average climate and temperature data for both areas we reconsidered this choice (Ithaca, Ny Climate & Temperature, 2017) (Plymouth, England Climate & Temperature, 2017). This was due to the fact that the precipitation in each area happens at very different times of the year. The time of the year when the most precipitation occurs in Ithaca is during the late Spring, Summer, and early Fall. While, in Newquay the most precipitation occurs in the winter months primarily and early Spring and late Fall. However, when summing the total average precipitation in each area they are roughly equivalent. Thus, although Ithaca (representing Bethel's climate) and Newquay may not be exactly the same, they were deemed similar enough to draw a valid comparison.

This Newquay weather station data was only for a small set of 16 solar panels totaling to about 4 kW of energy ("Solar PV Generation - Live Performance Data", 2017). This was scaled up 1.2 MW of energy as would be the case in Bethel, NY. The reason that this publicly available Newquay data was used instead of Cornell's data is because Cornell's data was too intermittent, which prevented us from being able to accurately predict energy output throughout an entire year. Newquay had data available from 2013 to 2016. Thus, multiplicative and additive seasonal models were created. They both used the year of 2013 to initialize the seasonal estimates and trends. Then, years 2014 through 2015 were used to assess how the forecast model was working. Lastly, a validation test was done for 2016 in order to see how the model was performing in the year closest to the current year. Due to climate change, it is especially useful to use the most recent data (which is part of the reason it was so useful to do a validation test for data from only 2016). Thus, we took the monthly forecast values from 2016 in our model and used these as the estimate for the annual energy output for the near future. Lastly, based on metrics used to evaluate these models such as the mean square error, cumulative forecast error, mean of absolute deviation, and mean absolute percent error, it was determined that the additive model was giving better predictions.

4.3 Annual Energy Output

The annual energy output predicted by our seasonal additive model based on Newquay's data was roughly 1,310,000 kWh per year. This was the lowest approximation for the annual energy output of this project and thus was the most conservative estimate. The project will likely produce more energy than this estimate most years. The PVWatts model predicted an annual energy output of 1,430,000 kWh per year for the Bethel area. This was the middle estimate for the annual energy output of this project. The last method of validation was using NREL's irradiation TMY data set for the year of 2015 and plugging it into our System Advisor Model. This gave an approximation of 1,500,000 kWh per year of energy output. This is the highest estimate for annual energy output. The following greenhouse gas model was kept more conservative by taking the PVWatts annual energy output approximation and the Newquay additive model's energy output approximation and averaging them. This results in an estimate of 1,370,000 kWh of energy output per year for this Bethel PV solar project.

4.4 Carbon Offset Model

Greenhouse gas emissions are a problem. The U.S. Energy Information Administration posted carbon dioxide emission data related with electricity generation data for 2015. Coal is the major source of carbon dioxide emissions. There are 1,364 million metric tons of carbon dioxide released due to coal power plant in the U.S., and it is 71% of the total CO2 for that year, which is 1,364 million metric tons CO2 released in 2015. Although, it is at the lowest emissions since 1993; it is still a huge number for the environment. Natural gas is also a big source of greenhouse gasses. In 2015, there were 530 million metric tons of CO2 released, which was 28% of all carbon dioxide emissions. However, a PV solar power plant does not contribute any carbon dioxide to the environment. PV solar is classified as the "Other" category which contributes only less 1% of carbon dioxide in 2015. Now that the problem has been identified let's look at the model we developed.

The carbon offset model is a model that was created for the purpose of assessing the greenhouse gas emissions (specifically carbon dioxide) that will be offset by the proposed project in Bethel, NY. Based on data from the U.S. Energy Information Administration the amount of pounds of carbon dioxide emitted per kWh of energy produced (assuming a similar heat rate) was found (U.S. Energy Information Administration - EIA, 2017). The total annual energy output that was approximated by NREL's PVWatts model and the conservative estimate from our own additive seasonal forecast energy output model were averaged (PVWatts, 2017). This gives us a conservative and realistic estimate for the total expected annual energy output for the solar renewable project proposed for the Town of Bethel's landfill and adjoining property. At first simple estimates were done assuming that 100% of the energy being offset by the project would come from the same type of fuel. The results are shown in Table 8 below:

Table 8: Coal Type and Offset

Offset by Source:	Approximate Carbon Dioxide Offset (lbs)
Coal Type 1 (Bituminous)	2,839,290
Coal Type 2 (Subbituminous)	2,962,737
Coal Type 3 (Lignite)	2,976,453
Natural Gas	1,673,398

Obviously, the dirtiest form of coal, lignite, would yield the best results as far as offsetting carbon emissions, since lignite coal would emit the most carbon when burned when compared to any of the other fuels in the above table. However, it is worth noting that the estimate for natural gas does not include an upward adjustment for the effect of natural gas leakage during the harvesting process. Rather than burning natural gas as is what is represented in the number in the table above, leakage of natural gas during acquisition (via fracking and other methods) is also a major problem that also contributes to climate change in its own way. This leakage factor was not accounted for in this model, but it is worth noting that natural gas isn't completely as clean as the number above seems to show (due to this extraction error). Even with this extraction error, natural gas is almost certainly still more clean than coal though.

Table 8 gives the simple models for greenhouse gas emissions being offset. Natural gas, which burns the cleanest of any of the fuels stated above, would have less greenhouse gas emissions offset (even when natural gas leakage is included), while lignite would be the maximum expected greenhouse gas emissions offset (for reasons stated above). The last and most important step is to create a model that will give a more realistic approximation of the greenhouse gas emissions being offset. Our team researched the sources of fuel that New York uses to generate its electricity (U.S. Energy Information Administration - EIA, 2017). It can be seen in Figure 8.

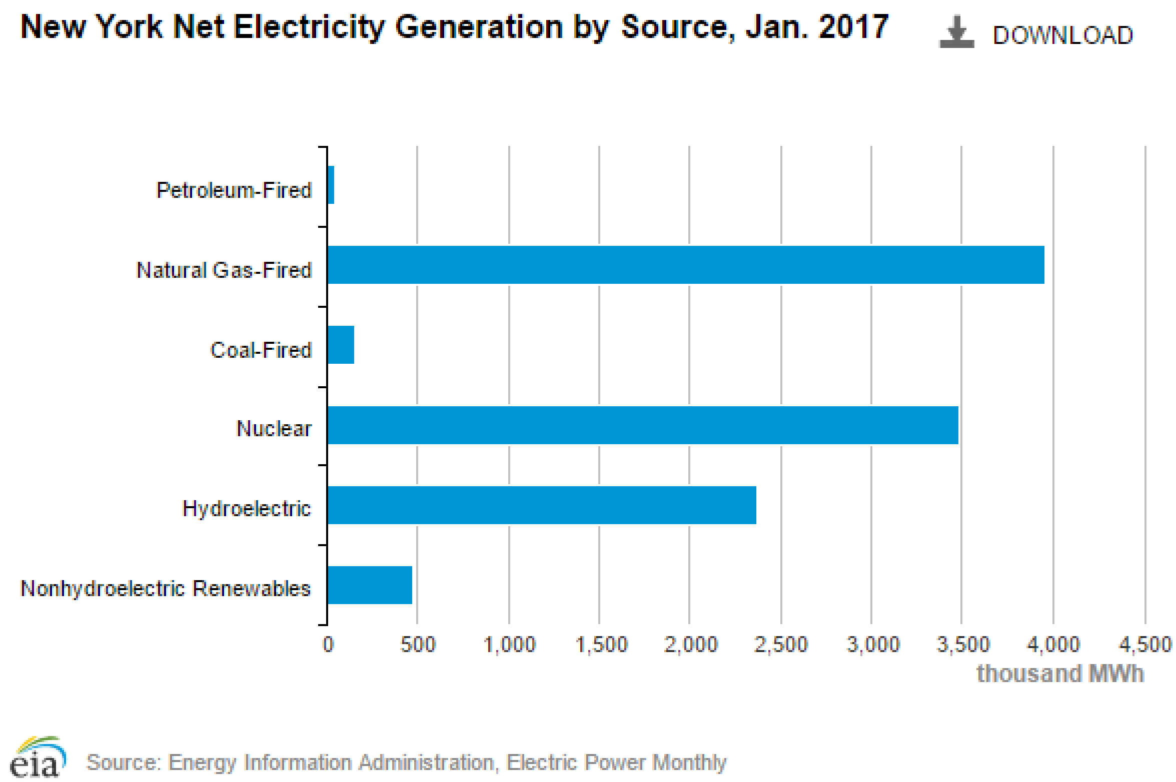

Figure 8: NY Net Electricity Generation Partitioned by Source
("New York Profile State Profile and Energy Estimates", 2017)

Petroleum-fired was assumed to be negligible and was not included within our model (and it was also not included in the version of the table we were looking at when creating the environmental model, since the U.S. Energy Information Administration updated this graph recently to include 2017 data). The other sources electricity in the above figure for were all included within the model. Then, the "coal-fired" section on the above graph was split into 3 categories (for each type of coal: bituminous, subbituminous, and lignite) ("Coal 101: The 4 Types of Coal and Their Uses", 2017). Bituminous is the most abundant type of coal and was assumed to be used in roughly 40% of coal power plants. Subbituminous is the rarest type of coal and was assumed to be around 0.5% of the total coal used in power plant activity. Finally, lignite the most common coal used in power plants was approximated to be about 59.5% of the total coal used in power plant activity. These percentages were then extrapolated to the State of New York's coal power plant activity. With this data, the model was able to approximate how much energy was coming from each energy source in Sullivan County (Bethel, NY area) based on New York averages. A graph of the different models can be seen in Figure 9. The figure shows the amount of greenhouse gas emissions offset each year.

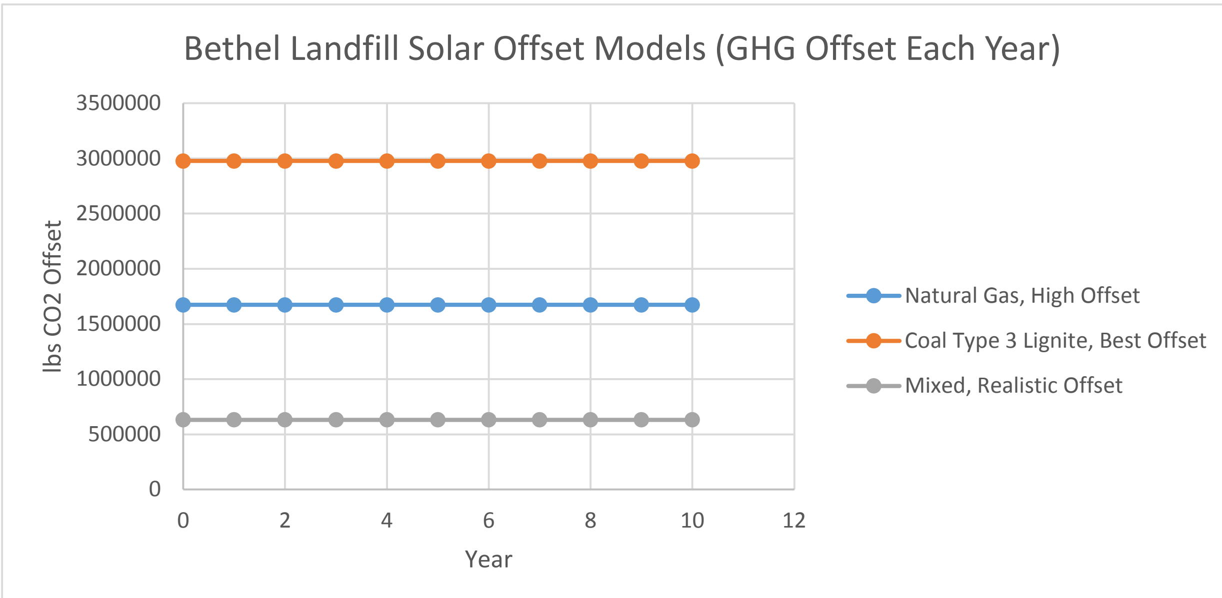

Figure 9: Graph of All Bethel Landfill Solar Carbon Dioxide Offset Models (Yearly)

Figure 10 shows the cumulative greenhouse gas emissions that would be offset over a 10 year period.

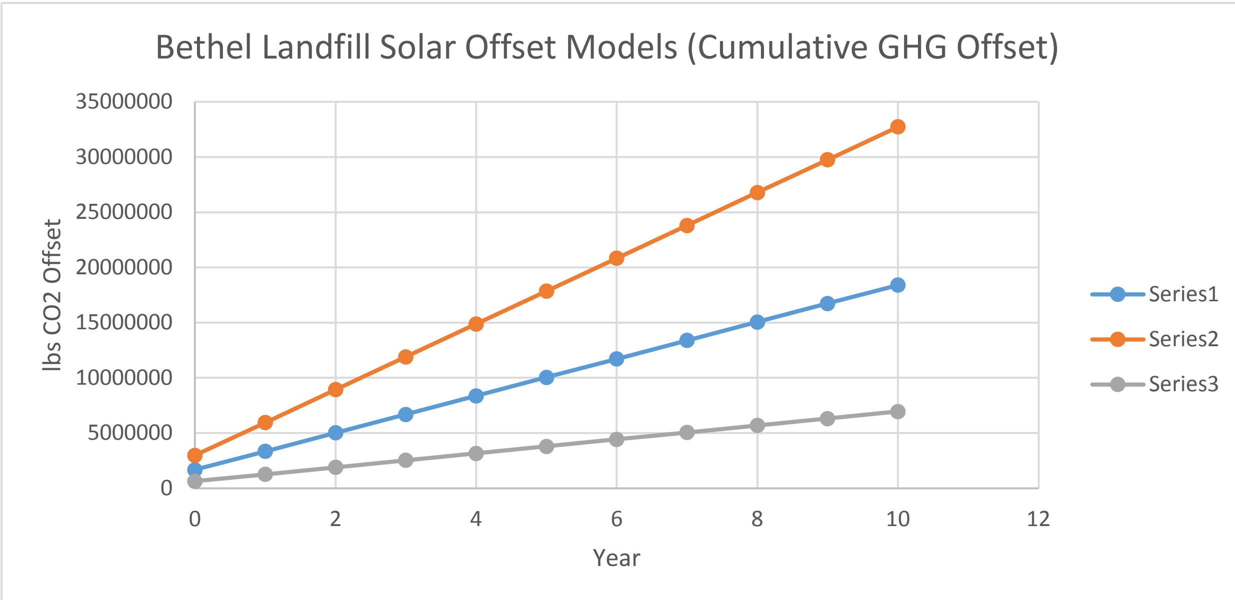

Figure 10: Graph of All Bethel Landfill Solar Carbon Dioxide Offset Models (Cumulative)

There are other methods for approximating the greenhouse gas emissions offset in Bethel, NY as well. Alternatively, a comparison can be drawn between the Town of Clarkstown, NY and the Town of Bethel, NY.

The first PV landfill in New York was built in town of Clarkstown, it was a 2.364 MW solar array built on a 13 acres of landfill area. The system in Clarkstown can generate an excess of 2,800,000 kilowatt hours of clean energy per year, while at the same time, it can offset 2,030 metric tons of carbon dioxide annually. From this example, it is clear that greenhouse gas emissions will be reduced due to a clean power plant.

For our project, a PV landfill power plant which will generate 1.2 MW can be easily compared to a 2.364 MW PV solar landfill power plant. The power plant in Bethel would reduce about half of the 2030 metric tons of carbon dioxide annually. Since, Clarkstown is located in the northwest 250 miles away from Bethel, and these two towns are located in a very similar latitude, the sunlight time would not be very different. The weather conditions for these two towns are slightly different, but the PV solar power plant in Bethel will be built 6 years after the Clarkstown plant, thus we assume the facilities in Bethel will have higher efficiencies and will generate more electricity. As a result, it is reasonable to estimate the carbon dioxide reduction will be approximately half of the Clarkstown plant's emissions offset. This a simple approximation based off of a case study.

5. Energy Demand Assessment

The population of Bethel, NY is around 4,250 people (Bethel, New York, 2017). The average monthly energy consumption per household in New York is 601 kWh based on data from 2015 (which can be seen in Table 9 below).

Table 9: Average Monthly Energy Consumption in New York

2015 Average Monthly Bill- Residential

(Data from forms EIA-861- schedules 4A-D, EIA-861S and EIA-861U)

State	Number of Customers	Average Monthly Consumption (kWh)	Average Price (cents/kWh)	Average Monthly Bill (Dollar and cents)
New York	7,079,097	601	18.54	111.32

(Table 5a: 2015 Average Monthly Bill- Residential, 2017)

As can be seen in the below figure, Figure 11, the average family size in the Town of Bethel is approximately 3 people.

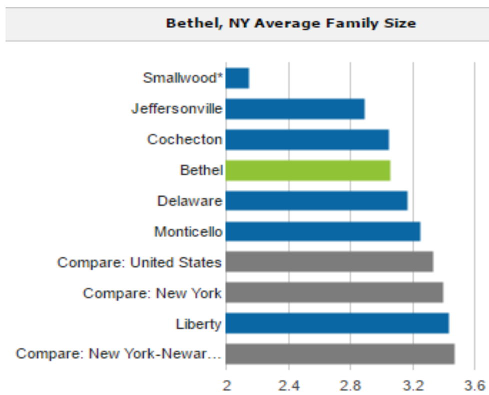

Figure 11: Average Family Size in Bethel, NY
(Bethel NY Demographics Data, 2017)

Thus, by dividing 4,250 people by 3 we estimated the approximate number of households in the Town of Bethel as1416 households. Assuming that all people in Bethel live in households, then by multiplying 1416 by 601 kWh per household we you estimated the residential energy demand within the area. This neglected energy use by business and municipal operations. Thus, this approximation would give a residential energy demand, which would be a conservative estimate of energy demand (meaning the actual energy demand might be slightly higher). This residential energy demand is 851,016 kWh per month. Due to the fact that Bethel has a significant seasonal visiting population this number should be adjusted. Assuming that during the months of nicer weather that the Town of Bethel's population increases by 50% due to visitors, then that would be 4,250*1.5 = 6,375 people. This is equivalently 2,125 households, or about 1,277,125 kWh of residential demand per month. Based on the averaged PVWatts model and additive seasonal Newquay model, it was estimated that the Bethel landfill PV solar project would generate roughly 1,371,638 kWh per year. Thus, this project would equivalently power the Town of Bethel residents and visitors for one month, which is relatively significant. An additional area of research would be for the Town of Bethel to use this knowledge and compare it to their own municipal energy usage. If they are somewhat similar then the town could consider using the project solely to meet the energy needs of the local government buildings. This information was not easily found, even if it is publicly available, thus doing an analysis in regard to public municipal energy usage was not carried out. This is an area of future research for the Town of Bethel itself. However, hopefully this rough assessment will be useful and aid them in their decision-making.

6. Geotechnical Assessment

6.1 Geotechnical Considerations for Designing/Developing Solar on a Landfill

There are some advantages and disadvantages when choosing to build a solar farm on a landfill. Some of the advantages include the large open location, simple access for construction, limited shading and low property cost. On the other hand, some of the problems include settlement issues and permitting restrictions.

The amount settlement is one of the key evaluations needed to be done in an early stage of any feasibility assessment because it can cause an entire system collapse. Primary settlement typically occurs10 to 15 years after the landfill closed (Deval, Timothy and Richard, 2017). The extent and timing of settlement will vary from landfill to landfill depending on the depth of waste, types of waste, chemical reactions in the landfill and operational history.

For this feasibility report, an initial prediction of settlement was done. A complete evaluation of settlement contains three primary factors: compression, biodegradation and creep. Using this assessment and on-site geotechnical testing, a system foundation plan would be generated during the design stage of the project. The foundation must be sufficiently stable, capable of accommodating the loading of PV system itself and placed with enough separation to avoid possible collision between panels if differential settlement occurs.

In addition, some extra loads including snow and wind need to be considered. These two forces are not typically of extremely high value, but they contribute some weight for settlement. The town of Bethel has an average snowfall approximately 60 inches each year. In this project, snow will contribute weight for settlement. It has over one million cubic foot snow over the 5.45 acres of landfill area. The load is high since average weight of snow is 15 pounds per cubic foot. However, this analysis only covered the impact of the solar panel and it’s supporting structure loads on top of the landfill, since snow is not an incremental force (the same amount of snow load will fall on the landfill regardless of the PV farm). In addition, the wind provides a relatively low load since it can be derived into horizontal and vertical directions, so for the entire project, we determined that wind load was not a major force contributing to settlement.

There are no current concerns about storm water and erosion based on the EPA study from 2016. We focused on analyzing total settlement due to added load instead of “primary settlement” of the landfill, most of which has already occurred in the first 10 years after capping.

6.2 Settlement

A complete settlement process contains three steps. First, an immediate settlement created by the compression of air voids and the deformation of waste particles. Then the primary settlement is the middle stage of the whole process. The speed of settlement for this part is directly related with the rate of expulsion of liquid from the voids. Lastly, a secondary settlement which is a long-term process, biodegradation and mechanical creep are two mechanisms that are involved in this section.

A solar PV array on a landfill is typically connected to a mounting system that is anchored to a uniformly loaded ballast concrete foundation system (EPA, 2016). In this scenario, additional settlement might occur with additional load added from the PV system and ballast foundation. Based on the information from a recent study, landfill settlement can vary considerably but can be as high as ~40%.

"Settlement in landfill waste occurs due to loading and other processes including chemical and microbial actions." (University of Southampton, 2017).This process depends on several factors, including the duration that waste is present, leachate composition, pH, and temperature. Thus, an accurate prediction of either the magnitude or time for settlement is extremely complex and difficult.

The difficulty of predicting landfill settlement was especially true for this feasibility study, since the team had no information as to the geotechnical characteristics and materials of the subsurface at the Bethel landfill. Estimation of settling provided in this report should be considered preliminary, as we do not have a professional background in geotechnical engineering (see Report Disclaimer). However, we used theoretical methods to provide an initial, very approximate estimate of the settlement of for a typical landfill in the US.

Landfill settlement is divided into two main categories: uniform and differential.

6.2.1 Uniform Settlement

To predict the settlement of the PV structure on the landfill site, we used average values and information for US landfills and the Power Creep Law for estimating, which refers to approximation of creep behavior of engineering materials. Due to the lack of site-specific field data, the team did not make another calculation by other methods. However, the team found several other methods for estimating settlement as shown in Appendix A. The Town of Bethel or the solar developer should use field data for future more accurate estimates.

We applied the method, using the following assumptions:

- The ballast used for the system are two 1500 lb. concrete footings. (see appendix)
- The weight of each solar PV system is 500 lb. (see appendix for dimensions)
- The m and n values are constants obtained by geotechnical lab results. We used the values closer to old refuse (3x10^-5).
- Height of the landfill is not indicated in the report. We assumed a constant slope of 5% for an 800’ length and approximated a height of 8 m. This value can be adjusted after factual data is obtained.

We found a total uniform settlement of **1.65 inches** in a period of 25 years. This value **should not** concern the town of Bethel.

6.2.2 Differential Settlement

Differential settlement is when a foundation settles unequally. Differential or uneven settlement occurs when the soil beneath the structure expands, contracts or shifts away. The settlement of a structure is the amount that the structure will "sink" during and after construction. (Rodriguez,2016)

Differential settlement may occur on the landfill site since the mixed materials in the landfill have varying load bearing capacities across the landfill. In practice, empirical and semi-empirical approaches of estimating the landfill settlement are commonly used side by side with field observations. Refuse settlement in a landfill is a complex process and is dominated by secondary compression (settlement). (Edil, 1990)

It is difficult to calculate potential differential settlement, as there are no clear methods or theories for calculating the values. However, Bethel is a relatively old landfill, closed over 10 years ago; thus, most of the settlement will have already occurred. From this perspective, although we cannot make an estimate of differential settlement, we can provide some ideas to prevent damage to the solar array from differential settlement.

The potential damage that differential settlement could have on the solar array is shifting the angles of the panels and racking system. Therefore, the differential settlement could make the solar panels to collide with each other, which can result in the reduction of the shading area, cracking some of the PV panels, and positioning them in less optimal angles.

From this point, the team suggests placing ballast concrete footings separately, providing a more evenly distribution on the ground. In addition, we recommend leaving a few inches between each solar panel or rack. This would allow for movement of panels without having them impact each other or cause shading. With these two methods, the potential problems created by differential settlement should be avoided.

6.2.3 Foundation Alternatives

In general, a PV solar power plant on a landfill will use precast ballast concrete as footing to support the system. For this project, the concrete can cost up to 25% of the entire capital cost, which a huge amount can lead to a financial infeasibility for the entire project. From the PV solar plant from Cornell, the driven mini u piles system was implemented, however, this system may compromise the integrity of the cap on the landfill.

Compared to a concrete ballast footing, the driven mini u piles system will be cheaper. However, we were not able to obtain clear cost information for the cost due to no response from TERRASMART, the manufacturer of the alternative foundation system. (Terrasmart, 2017). Also, it is not clear that the landfill closure permit from NYSDEC would allow penetration of piles into the clay cap that sits on top of the landfill for optimal closure. These two issues should be resolved during the future feasibility evaluations. But there is one problem that the Town of Bethel needs to be aware of: the screw pile (if used for additional support) has a length which is longer than the clay layer on top of the landfill, a large portion of the screw will be in direct contact with unknown material. So, the piles and screw perhaps could be corroded over a long time period. However it has great potential for reducing the cost of the foundation part of this project.

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Appendix A: Geotechnical Calculations

In this Appendix, we have listed the most popular equations that been used for estimating settlement in past decades. Others evaluating this project may use some of them to validate the values that we have estimated. Also, this is a good reference for general use.

For Soil Mechanics-Based Settlement Approaches, three equations have been developed:

The first equation was developed Sowers in 1975.

$\Delta H = HC_c^* \log\left(\frac{\sigma_0+\Delta\sigma}{\sigma_0}\right) + HC_\alpha \log(\frac{t_2}{t_1})$ Equation 1

ΔH: settlement due to primary and secondary consolidation

H: initial thickness of the layer

C_c^*: primary compression ratio

σ_0: existing overburden pressure acting at midlevel of the layer

$\Delta\sigma$: increment of overburden pressure acting at midlevel of the layer from the construction of an additional layer

C_α: secondary compression index

t_1: time for completion of initial compression

t_2: ending time period for which long-term settlement of layer is desired.

The second equation was developed by Bjarngard and Edgers in 1990. In this equation, secondary compression was divided into two phases which were called the intermediate and final phase.

$\Delta H = HC_c^* \log\left(\frac{\sigma_0+\Delta\sigma}{\sigma_0}\right) + HC_{\alpha 1} \log\left(\frac{t_2}{t_1}\right) + HC_{a2}\log(\frac{t_3}{t_2})$ Equation 2

C_{a1}: intermediate secondary compression ratio

C_{a2}: long-term/final secondary compression ratio

T_2: time for intermediate secondary compression

T_3: time for total period considered in modeling

Lastly, a third equation was released in 2005 by Hossain and Gabr.

$\frac{\Delta H}{H} = C_{ai} \log\left(\frac{t_2}{t_1}\right) + C_\beta \log\left(\frac{t_3}{t_2}\right) + C_{\alpha f}\log(\frac{t_4}{t_3})$ Equation 3

C_{ai}: compression index

t_1: time for completion of initial compression

t_2: time duration for which compression is to be evaluated

C_β: biodegradation index

t_3: time for completion of biological compression

$C_{\alpha f}$: creep index

t_4: time for the creep at the end of biological degradation

In addition, empirically-based settlement approaches are also provided from the Al-Hashemi's paper:

The first equation was called the rheological model which was developed by Gibson and Lo in 1961.It is a good reference to estimate primary compression and secondary compression.

$$\frac{\Delta H}{H_0} = \Delta\sigma a + \Delta\sigma b\left(1 - e^{-\left(\lambda/b\right)t}\right) \qquad \text{Equation 4}$$

$\Delta\sigma$: compressive stress depending upon waste height, density, and external loading

a: primary compressibility parameter

b: secondary compressibility parameter

$\frac{\lambda}{b}$: rate of secondary compression

t: time since load application

Then the next equation is the logarithmic function which expressed as:

$$\Delta H = H_f[\alpha + \beta \log\left(t - \frac{t_c}{2}\right)] \qquad \text{Equation 5}$$

H_f: initial height of the landfill

α: fitting parameter

β: fitting parameter

t: time since beginning of filling

Lastly, the Power Creep Model was developed by Edil, Ranguette and Wuellner in 1990. The equation was represented as:

$$\Delta H = H_0 \Delta\sigma M' (\frac{t}{t_r})^{N'} \qquad \text{Equation 6}$$

M': reference compressibility

N': rate of compression

T: time since load application

T_r: reference time is typically introduced to make time dimensionless.

A.1 Power Creep Law

The Power Creep Law is used to estimate the transient creep behavior of many engineering materials. The time-dependent settlement using this method can be estimated from a simple expression in Table A-1:

Table A-1: Equations and Parameter Descriptions

S(t) = H Dsig m (t/tr)^n
m = (s(t)/H) (1/Deltasig) @t=tr
n = -.256 logm - .662
S(t) = Settlement at any time t
H = Initial Height of refuse
Delta Sigma = applied compressive stress
m = reference compressibility
n = rate of compression parameter
tr = reference time to make time dimensionless (tr can be used as 1 day or 1 year)
t = time since load application

The reference compressibility, as used with the Power Creep Law, is defined as the ratio of the strain and the applied stress at a time, *t*, and equal to the reference time.

If parameters *m* and *n* are known or can be estimated for a site, the settlement of a municipal landfill of known height (H) at any time (t) can be calculated using equation (1). To avoid confusion in between reference compressibility, *m.* and rate of compression parameter, *n,* during reading of this paper, these parameters have been identified as parameters *m* and n. Equation (1) is likely to give unrealistic results at very high values of time (t). Therefore, it is the original paper author's opinion that the use of equation (1) should be limited to time periods less than 50 years.

A.2 Procedure for Calculations

(Shown in Figure A-1)

S(t) = H Dsig m (t/tr)^n

S(25)=	0.04	m
	1.65	inch

m = (s(t)/H) (1/Deltasig) @t=tr

n = -.256 logm - .662

S(t) = Settlement at any time t
H = Initial Height of refuse
Delta Sigma = applied compressive stress
m = reference compressibility
n = rate of compression parameter
tr = reference time to make time dimensionless (tr can be used as 1 day or 1 year)
t = time since load application

variable	magnitude	units
H=	8	m
Dsig=	2.34029357	KPa
m=	0.00003	
n=	0.473	
tr=	1	days
t=	9125	days

the resulting average values of parameter m for fresh and old refuse are 1.4X1o-• 1/kPa
and 3.7X1Q-5 1/kPa, (from experimental data)
respectively.

	Solar Module					
	Height	Length	Width	Area	Weight	
Ft	5.00	13.50	5.00	67.50	500.00	Lb
M	1.67	4.50	1.67	6.75	226.80	Kg

	Concrete ballast						
	Height	Length	Width	Area	Volume	Weight	
Ft	1.00	2.00	5.00	10.00	10.00	1500.00	Lb
M	0.33	0.67	1.67	1.11	0.37	888.89	kg

Stress Calculation		
Module Area	6.75	SM
Separation Area	1.65	SM
Weight Ballast x 2	1777.77778	kg
Weight of the module w ballast	2004.57	Kg
Stress	**238.639735**	Kg/SM

Figure A-1: Calculations and Spreadsheet Snapshot

Reference dimensions of PV system obtained from www.Northerntool.com
Concrete ballast designed based on size of PV system.

Appendix B: Additional Tax Incentive Information

New York State and federal government offer several tax incentives to encourage solar energy. If the participant is going to operate under a PPA, the tax credit will be based on your contract's detail.

B.1 New York State's Solar Equipment Tax Credit

If the investor is pursuing a PPA to run the solar PV, there are two sorts of PPA lease which will result in different ways to calculate the amount of tax reduced. The percentage of eligible tax credit is 25% of the annual solar expenditure, with a cap of $5,000 or a time span of 15 years whichever comes first. Here the solar expenditure usually means the payments made to the company which owns the system. The company can also be the one who sells the power generated by the PV solar plant ("New York States solar tax credit for PPA", 2017).

For a custom down-payment PPA, during the first year, people can get 25% of the down-payment together with the annual payment in the first year. Here, people must provide eligible proof of state tax liability which exceeds the amount you want to claim. And for the following years, the tax credit will simply be the 25% proportion of the annual expenditure.

For a $0-down-payment PPA, people can get 25% of the annual expenditure throughout the payment period as long as it is not exceeding 15 years or a total of $5,000. This calculation is relatively easier but will result in a higher long-term rate as well as a less credit during the first year.

To apply for the tax credit, the website to download the application form is https://www.tax.ny.gov/pit/credits/solar_energy_system_equipment_credit.htm

B.2 Federal Solar Tax Credit

Apart from a tax credit provided by New York State, there are also an eligible federal tax credit for the solar PV system. Recently in December 2015, the latest amended version of federal Business Energy Investment Tax Credit (ITC) was released. ITC covers a considerable range of sectors; it can be applied to commercial, industrial, investor-owned utility, municipal utilities and so on. In this tax credit, solar PV has the best policy with a maximum federal tax credit of 30% ("Solar Programs", 2017). The date regarding this tax credit refers to the date when construction begins. This can be seen in Table B-1 below.

Table B-1: ITC details for PV related systems

Technology	12/31/16	12/31/17	12/31/18	12/31/19	12/31/20	12/31/21	12/31/22	Future Years
PV, Solar Water Heating, Solar Space Heating/Cooling, Solar Process Heat	30%	30%	30%	30%	26%	22%	10%	10%

("Federal Income Tax Credits for Energy Efficiency", 2017)

ITC is arguably the most important nation-wide incentive for solar. However, people must be noted that speaking of ITC, it is the company that owns the system who may claim this credit. In reality, investors can argue with the company to pass some credit savings to them. But the company is not bound to do so. For the company, it can pass the credit to the next year if it does not have enough tax liability to claim all the credit, which is a great advantage for the company.

B.3 Solar Incentives Program

In New York State, there is a bundle of incentives aim to promote solar development. As of 04/22/2017, the applicable incentive for Bethel solar PV project is Commercial and Industrial Incentive in the NY-Sun Incentive program. This program is set to help customer reduce the installation cost (NY-Sun Initiative Commercial/Industrial Program Manual). In this program, there are two parts. One is the commercial and industrial incentive which can be applied to Bethel solar PV project. The other one is Residential and Small Commercial Incentive, which is only available to systems up to 200 kW. The commercial one will provide incentives based upon the performance of PV system as a function of annual energy production. Except for this performance-based incentives, there also comes with an additional installation incentives which will only be initiated if the project installation location is a utility-identified strategic locations (NY-Sun Initiative Commercial/Industrial Program Manual).

B.4 Commercial and Industrial Incentive

In this program, the incentive is designated to different Megawatt Block ("NY-Sun"-2, 2017), which means there are different levels of incentives and the amount of the incentives will be decided by which block the project is in. The Megawatt Block can be well illustrated as an accumulative bar chart. It follows a rule of the earlier the project is submitted, the higher incentive there will be. For instance, the first block is set as a maximum of 120MW. Consequently, the first 120MW submitted will get a highest incentive. And the following 130MW project, which belongs to the 2nd block, submitted will get a lower incentive. A project does not have to fill the whole megawatt block at once. This is just a measure of NYSERDA and the applicants are the ones who fill the block accumulatively, like a project of 2MW plus another project of 5MW equals to 7MW in the block.

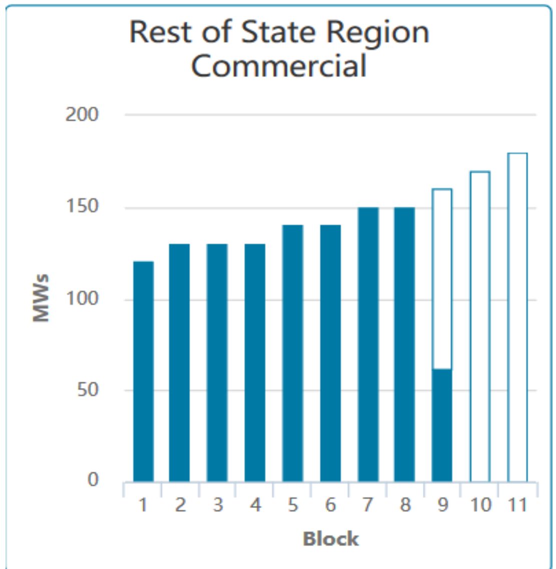

Figure B-1: Commercial and Industrial Incentives Megawatt Block as of 04/24/2017

The title of Figure B-1, says: "Rest of State Region". This is because the incentive consists two areas, one under the service of Consolidated Edison and the other is the rest of New York State. The figure suggests that NYSERDA has proceeded to the 9th block, which gets a performance based incentive (PBI) of $0.06/kWh ("NY-Sun"-2, 2017). According to the rate of application, the blocks are generally occupied on a two-month basis and the 9th block was opened in March, 2017.

In rest of state region, the two sorts of PBI are monetary incentive and volumetric incentive. Normally the monetary incentive is designed for the remote net metered projects that receive monetary crediting from a non-demand host meter. And the volumetric is going to be applied to all other projects (NY-Sun Initiative Commercial/Industrial Program Manual) ("Solar Rebates and Solar Tax Credits for New York", 2017). If a remote met metered project wants to claim volumetric incentive, it has to provide proof of Investor Owned Utilities in order to proceed with their application. For Bethel project, as of 04/24/2017, it will most likely claim the volumetric incentive of the PBI. A comprehensive list is shown in Table B-2 below.

Table B-2: Commercial and Industrial Incentives Detail

Block	PBI ($/W) Monetary Crediting[1]	PBI ($/W) Volumetric Crediting[2]	Block Volume (MW-dc)
1	$0.34	$0.40	120
2	$0.28	$0.40	120
3	$0.21	$0.39	130
4	$0.15	$0.39	130
5	$0.11	$0.37	140
6	$0.06	$0.35	140
7	$0.05	$0.33	150
8	$0.04	$0.28	150
9	$0.02	$0.22	160
10	$0.01	$0.16	170
11	$0.01	$0.09	180

(NY-Sun Initiative Commercial/Industrial Program Manual) The formulas for calculating incentives are shown below (NY-Sun Commercial/Industrial Incentive Program)

Estimated Annual Production = System Size × Capacity Factor × Hours per Year

Maximum Total Incentive = PBI Rate × System Size × Capacity Factor × Hours per Year × 3 Years

Up-Front Operational Payment = 0.25 × Maximum Incentive Amount

Estimated Yearly Performance Payment = 0.75 × PBI Rate × Estimated Yearly Metered Production (kWh)

B.5 Additional Incentive Program Details

This program acts with a contractor and the investor. According to NYSERDA, the participating contractors will review the site and determine specifications of the system. Then, the contractor will have to assist with paperwork and apply to this incentive program. Most of the paperwork, including paperwork required by interconnection, will be finished by the contractor, which provides a relatively smooth process for the investor. The participating contractors are also obliged to assess the availability of net metering and deal with the effective management of all technical issues for interconnection with the utility (NY-Sun Initiative Commercial/Industrial Program Manual). On the website of NYSERDA, there is a list of participating contractors. They can be found according to the address on NYSERDA's website (“NY-Sun”-3, 2017).

Appendix C: Project Management Materials

C.1 Example Project Weekly Task Report

Project Team: PV Solar Team
Report for Week of: 3/20 – 3/26

Table C-1: Copy of Task Report Write-up

New Tasks	**Engineer**	**Current Status**	**Comments**
SAM model building	Kaiwen Adam Bolun Diego	Started	Estimated time budget: 10hrs
Midterm reports	All members	Start on Sunday	Estimated time budget: 5 hrs
Individual evaluation	All members		Estimated time budget: 3 hrs
Regulation research	Fangzheng	Start on Saturday	Estimated time budget: 3 hrs
Economic Incentives	Bolun Kaiwen	Start on Saturday	Estimated time budget: 4 hrs
Continuing Tasks		**Current Status**	**Time Budget**
Project Proposal		Completed	15 hrs
Economic Search		Initial research	8 hrs
Carbon Dioxide Model		On going	10hrs
Soil / settlement Research		In progress	10 hrs

C.2 Description of Meetings

During the team's weekly meeting we kept tabs on changes and evolutions to the project via meeting minute sheets. These notes described updates to project scope, project objectives, and project scheduling. However, most importantly these meeting minute's tracked if the team is staying on track with respect to the Gantt chart schedule and how long the tasks ended up actually taking us. An example of these meeting minute updates is kept in the appendix of the report for future review.

C.3 End of Semester Time Budget Comparison

(See Table C-2 below)

Table C-2: Final Time Budget Comparison

Task	Estimated time budget	Actual time budget	Percent of budget
Market Research	70 hrs	60 hrs	86%
Data collection	50 hrs	65 hrs	130%
Project Background Investigation	50 hrs	75 hrs	150%
Carbon Footprint Model	150 hrs	30 hrs	30%
Economic and Financial modeling	200 hrs	150 hrs	75%
Slideshow and Rehearsal	75 hrs	25 hrs	33%
Final Report (Appendix, Results, Graphs, Conclusions, Recommendations, Edits)	150 hrs	150 hrs	100%

C.4 Expected Schedule and Timeline for the Project (Gannt Chart)

(See Figure C-1 below)

Task Name	Start Date	End Date	Duration
Additional Market Research	3/6/2017	3/13/2017	7
Data Collection	3/13/2017	3/20/2017	7
Project Background Investigation	3/20/2017	3/27/2017	7
Carbon Footprint Model	3/27/2017	4/10/2017	14
Demand Model	4/10/2017	4/17/2017	7
Economic/Cost Model	4/17/2017	5/1/2017	14
Slideshow and Rehearsal	3/27/2017	4/3/2017	7
Final Report	5/1/2017	5/15/2017	14

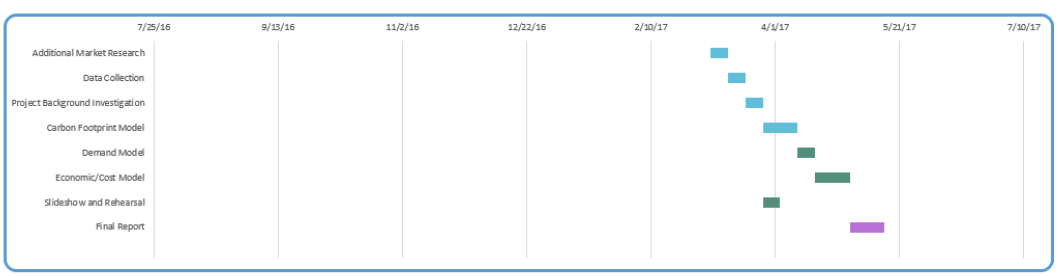

Figure C-1: Team Gantt Chart
(TeamGantt, 2017)

C.5 End of Semester Scope Comparison

The scope of the project has changed throughout the semester via only slight incremental changes. The scope of the geotechnical assessment was narrowed down to assessment of the landfill settlement as well as the structural base that will be needed to secure the PV solar panel systems. The scope of the financial analysis was expanded. The model used in this report attempts to look very holistically at the situation. The scope of the energy demand analysis was narrowed to be relatively broad and somewhat vague. This is because there was not an abundant amount of public data regarding how much energy a commuting/seasonal population uses. Thus, assumptions were made and a basic analysis was carried out. The scope of the environmental analysis was narrowed to primarily focus upon how much greenhouse gas emissions would be offset via this project. Analysis of hypothetical situations such as carbon tax legislation were side-lined and would be a good area for future research.

C.6 End of Semester Schedule Comparison

The schedule adhered to in the midterm progress report and outlined in the project proposal has remained relatively steadfast. The project team's deadlines have remained consistent with the tasks outlined in the original schedule we outlined for ourselves. No major new tasks arose that needed to be added to the list.

At this point, 14 weeks into the term, we have expended ≈7% of the budget hours pertaining to market research.
At this point, 14 weeks into the term, we have expended ≈8% of the budget hours pertaining to data collection.
At this point, 14 weeks into the term, we have expended ≈9% of the budget hours pertaining to project background investigation.
At this point, 14 weeks into the term, we have expended ≈4% of the budget hours pertaining to the carbon footprint model.
At this point, 14 weeks into the term, we have expended ≈18% of the budget hours pertaining to economic and financial modeling.
At this point, 14 weeks into the term, we have expended ≈3% of the budget hours pertaining to slideshow creation and rehearsal.
At this point, 14 weeks into the term, we have expended ≈18% of the budget hours pertaining to the final report.

Thus, we were relatively efficient with our time and did not need the full 825 man hours necessary for the project, since we only used roughly two-thirds of the allotted hours. However, there is a great deal of uncertainty associated with these numbers considering that sometimes time feels like it moves faster or slower depending on circumstances. Thus, this could be somewhat exaggerated or somewhat under-shot.

C.7 Team Background

Adam Schecter- Adam is originally from Ridgefield, CT. He graduated Cornell University in 2016 with a Bachelor's Degree in Environmental Engineering. He is currently finishing up his graduate degree in Water Resources. In undergrad, he was a member of the fraternity, AEPi, and was the president of a student group organization/club on campus called American Academy of

Environmental Engineers (AAEE). He will likely be working in the office construction industry upon graduation.

Kaiwen Deng- Kaiwen obtained his bachelor degree in Mechanical Engineering at University of Wisconsin Madison. He is pursuing his master's degree at Cornell University in Engineering Management. In his undergraduate studies, he was a member of American Society of Mechanical Engineers, and specialized in automotive engineering. As he is pursuing his master's degree at Cornell, he shows great interests in engineering economics and finance, as well as supply chain management. He is hoping to build his skills in engineering economics and finance via this project.

Shiqi Fan - Shiqi graduated from Virginia Tech in 2015 with a Bachelor's Degree in Civil and Environmental Engineering. He is currently enrolled in the Master of Engineering Management program at Cornell. In his undergraduate studies, he was a member of ASCE and Chi Epsilon. During his undergraduate studies, he was working on undergraduate research, which focused upon land cover use change for the town of Blacksburg. He is hoping to make contributions to the project with respect to topics involving civil, environmental, and economic research.

Fangzheng Peng- Fangzheng graduated from Huazhong University of Science and Technology with a Bachelor's Degree in Electrical Engineering. He has an ongoing degree in Master of Engineering Management. During his undergrad, he specialized in "Power Systems" and had a few courses in renewable energy. His participation in renewable energy research led to contributions like writing a chapter of the report regarding energy markets in the U.S and an overview in regard to pumped-storage power plants cooperating with renewable energy development. He had dabbled in research pertaining to the power industry and will likely to work in that industry in the future.

Bolun Xu- Bolun is from Shanghai, China. He graduated from Cornell University with a Bachelor of Science Degree in Operations Research. He is currently in the Master of Engineering-Engineering Management Program. He interned at the investment banking department of Citi Orient Securities Company Ltd Shanghai in the summer of 2016, and he is going to work in financial services upon graduation.

C.8 Structure

We divided the workload by creating a few tasks that need to be worked on. Then we broke up these overarching topics into subtopics as the semester progresses. People were of course able to work on any aspect of the project that they want, but people were assigned specific aspects of the project that were their primary responsibility in order to ensure that all necessary and required work got completed. See "Time Budget" and "Team Groupings / Pairings" for more details in regard to the structure.

C.9 Team Groupings / Pairings

Below is a list of topics and the people who were primarily responsible for that topic.
Demand and forecast models - Adam, Kaiwen, Shiqi
Finances/economics, regulations, and funding programs - Bolun, Kaiwen, Shiqi
Environmental analysis and carbon footprint – Fangzheng, Adam
Social and societal aspects of the project- Fangzheng, Adam

C.10 Skills Matrix

(See Table C-3 below)

Table C-3: Skills Matrix

Skills / Names	Matlab	R	MS Excel	Economics	Research	Renewable Tech.	Regulations and Law
Adam Schecter	X	X	X	X	X	X	X
Shiqi Fan	X		X	X	X		
Fangzheng Peng	X		X		X	X	
Bolun Xu	X		X	X	X		
Kaiwen Deng			X	X	X	X	

Appendix D: Health and Safety

D.1 Health and Safety Minutes

1. U.S. Department of Labor and the Occupational Safety and Health Administration (OSHA) has released personal protective equipment standards and has required the training and education of employees, where necessary. OSHA uploaded a checklist for establishing a personal protective equipment program as well as a checklist for whether personal protective equipment might be necessary in a certain situation. These checklists can be found here (PPE Assessment, 2017):
   -https://www.osha.gov/dte/library/ppe_assessment/ppe_assessment.html
   Personal protective equipment and these types of checklists could definitely be useful in regard to employees interacting with a landfill and with construction of the PV solar project.
2. The U.S. Department of Labor through OSHA has released a document pertaining to common hazards that occur with "Green Jobs" ("Green Job hazards: Solar Energy-Crane and Hoist Safety", 2017). For instance, crane operation can be risky with incorrect protocol on a construction site. This document would be useful for the engineering manager overseeing the construction of a green energy project such as ours. Delegating proper protocol could save the lives of his or her workers.
3. OSHA released a document online regarding personal protective equipment in different situations. This document looked at electrical personal protective equipment specifically. This document is the most pertinent to construction of a renewable energy project such as the one being discussed for Bethel. Understanding the voltage limit of one's equipment could be information that saves someone's' life. Here is a relevant direct quote from the document (Electrical Protective Equipment, 2017):

   > "Equipment shall be capable of withstanding the ac proof-test voltage specified in Table I-1 or the dc proof-test voltage specified in Table I-2
   > The proof test shall reliably indicate that the equipment can withstand the voltage involved.
   > *General*. Electrical protective equipment shall be maintained in a safe, reliable condition."

4. OSHA has a section of its website devoted to how to file a safety and health complaint (How to File a Safety and Health Complaint, 2017). This is especially useful in situations where an engineering manager may not be using his due diligence to inform everyone about safety protocol and standards that may be necessary to keep people healthy and safe. Knowing how to do this and that this is an option for workers is especially relevant to the project and for the workers especially.
5. Health and safety engineers have a sub-section devoted to them on the Bureau of Labor Statistic's website ("Health and Safety Engineers: Occupational Outlook Handbook", 2017). This part of their website outlines how to become a health and safety engineer and what they do (such as the fields of work they typically work in). They work in a

wide array of fields such as fields that deal with natural disasters, as well as fields that manage products, or fields that manage some sort of system. This is valuable knowledge, because this promotes awareness of the existence of health and safety engineers. Having one work on a project, such as the landfill PV solar project for the Town of Bethel, could be immensely useful.

6. Landfill Safety is another aspect of health and safety that could definitely apply to this project. Some common hazards from being on a landfill site are listed in the direct quote from a landfill health and safety plan ("SITE HEALTH AND SAFETY PLAN for the NORMAN LANDFILL TOXIC SUBSTANCES HYDROLOGY PROGRAM")

   > "Ground-Water Sampling:
   > Absorbtion of toxic chemicals from landfill leachate.
   > Slipping on wet or muddy surfaces.
   > Possible water splashing in eyes during sampling.
   > Exposure to vapors of volatile organics when the well head is initially opened. "

7. Safety in other developed nations could also be valuable. In the United Kingdom they have the Health and Safety Executive (Health and Safety Executive, 2017). This functions very similar to OSHA in the U.S. and it has many relevant and useful areas on its website that provide good information. One such example of this would be its frequently asked questions section of its website.

Appendix E: Future Research Areas

E.1 Future Research

One area of future research that could prove to be valuable, that has already been alluded to, is how the implementation of a carbon tax would affect this project. Obviously, it would only be beneficial, since the project would offset greenhouse gas emissions and these rights could be sold to greenhouse gas emitters, thus adding additional revenue to the project. However, a full analysis of this could be useful. Climate change is expanding more and more and as a global issue the problems will only grow, whether people want to believe in it or not. Thus, a carbon tax may not be as radical of an idea as some people may think it is. Assuming different values for this carbon tax and seeing how it effects the financial viability of the project could give insight into the project's viability if it is postponed well into the future.

Another area where future research would be beneficial would be in relation to assessing the Town of Bethel's energy demand. Seasonal commuters use different amounts of energy than someone who lives their full time. Accounting for seasonal commuters in a more realistic and time-sensitive way could be very insightful into giving an even more realistic estimation of Bethel's monthly and annual energy demands. Then using this more accurate residential data and the municipal energy demand data for Bethel they can attempt to draw conclusions as to what this project should be used for.

Landfill permitting concerns are another additional area of research that should be investigated. This should be done by contacting a NY DEC representative.

Assessment of wildlife, natural resources, and areas that need special protections like wetlands would also be a valuable area for future research. The EPA study does look into this vaguely, but contracting an expert to further assess any environmental concerns could also be beneficial.

Accounting for natural gas leakages within the carbon offset model would create an even more realistic model. It would more holistically account for greenhouse gas emissions. However, if the estimates given in this report do not need to be exact or extremely precise, then the numbers within the report are likely good enough. It is worth noting that there is some room for improvement.

Appendix F: Cumulative Team Market Survey

F.1 Market Survey

1. EPA Screening Study, Bethel, NY August, 2016. Provides basis for available acreage, conceptual array characteristics, and basic economics. Presents next steps for feasibility considerations. Provided by Professor Finn.

2. Solar Energy Industries Association, New York Solar, General Website. Gives general overview and facts regarding solar in NY, showing viability and growth.

(http://www.seia.org/state-solar-policy/new-york)

3. Cornell Sustainability, Ithaca, NY. This source provides direct data from the Cornell Solar farm. Could be useful data to help create models of Bethel, NY site. Carbon dioxide avoided is just one example of some useful data provided.

(https://solarems.net)

4. Cornell EMCS Portal, Ithaca, NY. This provides total demand data and solar data. This website allows for downloads of this data. Also, gives much more specific and smaller break downs of energy sources and metering.

(http://portal.emcs.cornell.edu/)

5. AP, Mary Esch, Ithaca, NY, April 3, 2016. This article shows that NY is likely to be extending its federal tax credit (30%) with the Governors renewable energy plan. Shows viability of solar, but also the risks of being a land owner and being baited into a prosperous project, but losing all property rights over your land. Risks shown.

(http://bigstory.ap.org/article/b12ab3f5300b4b66a0a50e35de280ff1/solar-farm-developers-target-new-york-lease-offers)

6. Newquay, Cornwall, U.K. This article provides solar data from a much smaller solar array setup in England. I used this data and scaled it to be equivalent to Bethel, NY to create a forecast model.

(http://www.newquayweather.com/wxsolarpv.php)

7. Climatetemps.com. Newquay and Cornwall are nearby to the town/city of Plymouth. Thus, these two links below from the same website show weather data for both Ithaca and Plymouth. This was to see if England was at all comparable to Ithaca. To some degree it is.

(http://www.plymouth.climatemps.com/index.php)

(http://www.ithaca.climatemps.com/index.php)

8. Cornell Library Search, Journal of Public Affairs, Peter Jones et al., "Spotlight on Solar Farms" Article. This article provides an overview of solar farms. It defines what a solar farm is and explains how he U.K. has made it successful and what lands are typically used. It mentions that landfills have indeed been used.

9. Cornell Library Search, Energy Weekly News, "Two New PSE&G Landfill Solar Farms in Service. This article discusses some of the social and economic issues surrounding landfill solar arrays.

10. Cornell Library Search, Business Insights: Essentials, Meghan Greenwalt, "Solar Renewable Energy Projects Provide Second Lives for Landfills". This source provides additional economic information as well as construction issues that needed to be worked out due to building solar farms on landfills.

11. Climate Smart Communities, Bethel, NY, Nov. 2015. This source provides information about policies Bethel is working on, some of which involve solar and may be worth including and mentioning in the report. Also, gives some useful town data.

(http://www.midhudsoncsc.org/profiles/Town%20of%20Bethel%20-%20Community%20Profile.pdf)

12. Google Maps, Bethel, NY, February, 2017. Google maps can help identify major industry or other energy demand loads that may not be described by simply looking up the population of Bethel.

(https://www.google.com/maps/place/Bethel,+NY/@41.6841912,-74.8766229,14.75z/data=!4m5!3m4!1s0x89dcaf4a43b5d1b1:0x7b37a1d5e3fa0a1!8m2!3d41.6837659!4d-74.8719284)

13. Wikipedia, Bethel, NY, February, 2017. Household numbers, population density, and other potential useful information is listed in Wikipedia. May be helpful. (https://en.wikipedia.org/wiki/Bethel,_New_York)

14. NYS Government, NYSERDA Program. This is the New York State government's website for solar system installed in New York State. This link gives an overview about the incentive

programs for commercial solar farm. (https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Customers/Available-Incentives)

15. "How Much Energy Does A Solar Panel System Produce? | SolarCity." How Much Energy Does A Solar Panel System Produce? | SolarCity. N.p., n.d. Web. 16 Feb. 2017.

This article provides a very brief idea how solar pv system works, and a general idea how much power could be generated.

http://www.solarcity.com/residential/solar-energy-faqs/solar-energy-production

16. Massachusetts Dept. of Energy Resources, “The Guide to Developing Solar Photovoltaics at Massachusetts-Landfills”.

This is a report for PV at Massachusetts Landfills, there are some references cost profile and incentives.

http://www.mass.gov/eea/docs/doer/green-communities/ems/guide-to-developing-solar-pv-at-massachusetts-landfills.pdf

17. “Solar Landfills: One Person’s Trash Is Another’s Treasure.” Clean-Technica, 8 Oct. 2014, cleantechnica.com/2014/10/09/solar-landfills-one-persons-trash-anothers-treasure/. Accessed 16 Feb. 2017.

This provides why landfill area be a popular place for solar PV program.

https://cleantechnica.com/2014/10/09/solar-landfills-one-persons-trash-anothers-treasure/

18. National Renewable Energy Laboratory, James Salasovich et al., “Feasibility Study of Economics and Performance of Solar Photovoltaics at the Kolthoff Landfill in Cleveland, Ohio”, June, 2013.

This document is a complete feasibility report for a solar farm located on a landfill land in Cleveland. It can be used a great reference for our project including cost analysis, financial analysis, and other issues including the social impacts as well.

http://www.nrel.gov/docs/fy13osti/58760.pdf

19. NYSISO, “Data Graphs and Fuel Mix Chart”.

This website demonstrates the locational-based marginal price for Mohawk Valley where Bethel is located. The graph gives a possible pricing solution of our contract with NYISO.

http://www.nyiso.com/public/markets_operations/market_data/graphs/index.jsp

20. PV Navigator LTD, “Solar Power on Landfills”.

This article provides technique that involved in landfill process.

http://www.pvnavigator.com/solar-on-lf.htm

21.The Goulburn Group, “A study into the feasibility of a community owned solar farm in Goulburn NSW”, April, 2016.

This is also a feasibility study for solar farm constructed for community use. We can use it as reference.

http://www.ce4g.org.au/CE4G%20-%20Goulburn%20Community%20Solar%20Farm%20Feasibility%20Study.pdf

22. NYSERDA and Meister Consultants Group, Ryan Cook et al., December, 2015.

This comprehensive government report covers some policies regarding the solar installation in New York State and a few special concerns in solar procurement etc.

https://training.ny-sun.ny.gov/images/PDFs/Municipal_Solar_Procurement_Toolkit/PVTN_Solar_Procurement_Guidelines_for_Local_Governments.pdf

23. EPA assessment contact: Fernando (CCd) 212 -637- 4346 Rosado.Fernando@epa.gov

Fernando prepared the report and has full working knowledge of the NREL tools that were employed in its preparation.

24. DEC Regional contact in New Paltz: james.lansing@dec.ny.gov 845- 256- 3123

The DEC has been a partner in the effort to reuse LF’s as solar farms and Jim or a staff member can provide insight if there are any issues specific to this site.

25. NYSERDA has contract assistance specific to landfill solar projects and they may be able to provide some insight relative to challenges and overcoming them. Also, NYSERDA can provide info on financial incentives which the state/federal governments can offer.

26. PVWatts calculator - NREL, Bethel, NY. This will help define the specifics of the system and hence, calculate a month-wise output, thereby, determining the technical costs involved in the procurement and installation of specified solar panels.