LOW IMPACT SOLAR DEVELOPMENT

A GUIDE FOR SITING GROUND MOUNTED SOLAR ON LOW IMPACT SITES ON LONG ISLAND

YALE SCHOOL OF FORESTRY & ENVIRONMENTAL STUDIES
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Background

This guide was produced by Nina Lagpacan, Master of Environmental Management and Master of Business Administration Candidate '17 and Jessica Leung, Master of Environmental Management Candidate '17 as part of Yale University's Land Use Clinic. The final guide was created in May 2017. The clinic allows students to explore a variety of community land use topics and partner with a client on a specific project to apply their knowledge and interest to a work product. The students worked with The Nature Conservancy as their client to create this guide on evaluating potential solar development projects in Long Island, New York.

Introduction

A transition towards renewable energy sources provides a great opportunity to move away from a dependence on fossil fuels. Utilizing renewable energy sources such as wind, solar, and geothermal will be critical in combating the effects of a changing climate and also provides benefits for people's health and the economy ("Benefits of Renewable Energy", 2013).

Although renewable energy development provides many positive benefits for the environment, locating and finding strategic areas to site renewable energy development poses many challenges. For example, large scale solar development can alter landscapes by fragmenting sensitive wildlife habitat and can alter vegetation regimes (Huntley). In addition to natural resource management concerns, there are also aesthetic and nuisance considerations that should be taken into account before siting renewable energy development.

This guide presents some of the challenges of solar development on public lands using Suffolk County in Long Island, New York as a case study. In an effort to limit the environmental impact of solar development, we focused our study on low impact sites, which we defined as sites that have previously been developed. These included airports, landfills, and parking lots. Each type of land use poses its own unique challenges for solar development, which are explored in further depth throughout this report.

Methodology

The purpose of this study is to inform residents, municipal governments and solar developers about the limitations and opportunities for ground mounted solar development on publicly owned lands in Suffolk County. In order to minimize the environmental impact of solar development, we focused our study on low impact sites, which we defined as land previously developed or utilized for human use. Specifically, we analyzed airports, landfills, and parking lots.

The focus of our study did not take into account economic factors in siting solar development, but we do provide general guidance about the cost considerations that should be examined when installing solar on the different land uses described in this report.

We hope that our findings and analysis can be used by municipalities outside of Suffolk County to provide guidance for siting ground mounted solar on low impact sites.

Figure 1: NY REV
Source: New York State

Executive Summary

In recent years, New York has instituted a portfolio of environmental and energy driven goals. One of the major initiatives, Reforming the Energy Vision (REV), is composed of two other important targets: 1) a greenhouse gas (GHG) reduction goal of 40% by 2030, and 2) a Renewable Portfolio Standard of 50% by 2030 (Lee, 2017). The REV is Governor Cuomo's vision for "rebuilding, strengthening, and modernizing New York's energy system" (New York State, 2017). Specifically, it is a plan to decentralize the electricity grid, install more renewable energy sources, improve efficiency, and lower energy costs for customers (Lee, 2017).

Prior to REV, NY-Sun was another directive from Governor Cuomo aimed to improve efficiency, affordability, and reliability of energy systems in the state (NYSERDA). It aimed to install more than 3 GW of solar energy systems by 2023 by providing incentive programs like the Megawatt Block Incentive Structure, which offers subsidies for commercial and residential solar installations. As of February 2017, Long Island has reached the capacity for the residential category, but there is still currently $1,500 of available incentives for small non-residential users on Long Island (Tarbi, 2017).

Net metering is an important incentive that has helped scale up solar in the state (Tarbi, 2013). It is a method for earning money for the electricity your solar panels overgenerate during a given month. If you are consuming less electricity than what your solar panels produce, you are eligible to receive a credit on your utility bill. If you consume more than what your panels produce, you will be charged your normal utility rate for the quantity of additional electricity consumed.

Currently, there is a new opportunity to move forward with solar development on non-residential property in Suffolk County. Long Island has already reached their capacity for the Megawatt Block Incentive, and residential pricing for solar has been historically higher than non-residential pricing (City University of New York, 2015). Thus, alternative methods of installing solar capacity on the land and price-constrained Long Island market is needed.

Suffolk's Planning Commission has instituted guidelines for solar development that limits projects to industrial sites, limits arrays over 100-year-flood zones, and requires residential setbacks and panels to only cover 60% of a lot (Long Island Press, 2015). In addition, 35% of a proposed site cannot be cleared and instead must remain "natural and undisturbed" (Long Island Press, 2015).

In Brookhaven, the Solar Energy Production Code has enacted even more stringent limitations to solar production. It restricts solar development on or adjacent to any airport, within 100 feet of wetlands, and on a space not to exceed five acres (Solar Energy Production Facilities, N.Y., Code § 85-813, 2016). Most significantly, it prohibits land from being cleared for new projects, which forces solar proponents to search elsewhere for opportunity.

This report looks at municipally owned, low impact sites in Suffolk County as new candidates for solar development. Our project examines airports, landfills, and parking lots and the table below summarizes our findings:

Land Use	Benefits	Challenges
Airports	• Supplement lighting needs • Use energy for snow and ice removal needs from runways	• Glint and glare
Landfills	• Increased land value	• Landfill slope + stability • Landfill cap and waste settlement • High costs
Parking Lots	• Shade and cooling for covered cars • Unshaded • Limited aesthetic effects	• High costs • Logistical challenges

Overview of Solar

How does sunshine turn into electricity?

Sunlight contains small packets of energy called photons that are converted to direct current (DC) electricity by photovoltaic (PV) cells ("Get the Facts", 2017). Multiple PV cells make up a PV panel or module, which are then connected together to create an array (U.S. EPA, 2013). The array generates DC electricity that is converted to alternating current (AC) by an inverter. The alternating current can be used to power buildings and homes (U.S. EPA, 2013).

What is the difference between DC and AC?

For example, direct current is produced by batteries where the current only flows in one direction whereas alternating current is the power that comes from a wall socket and the current can change directions (Brain, Harris & Lamb, 2004). It's easier to change the voltage of alternating current, which makes it less expensive to transmit power over long distances using very high voltages and then converting the power to a lower voltage for people to use in their homes (Brain et al., 2004).

PV systems

PV systems range from 2-10 kilowatts (kW) for residential systems, 100-500 kW for commercial systems, and 10 megawatts (MW) or greater for large scale utility solar systems (U.S. EPA, 2013). In order to put these numbers in perspective, 2 MW of energy are needed to power 200-400 residential homes (Huntley). For the purposes of this report, we focus on opportunities to site large scale utility solar systems where the electricity generated is often sold back to the grid (Huntley).

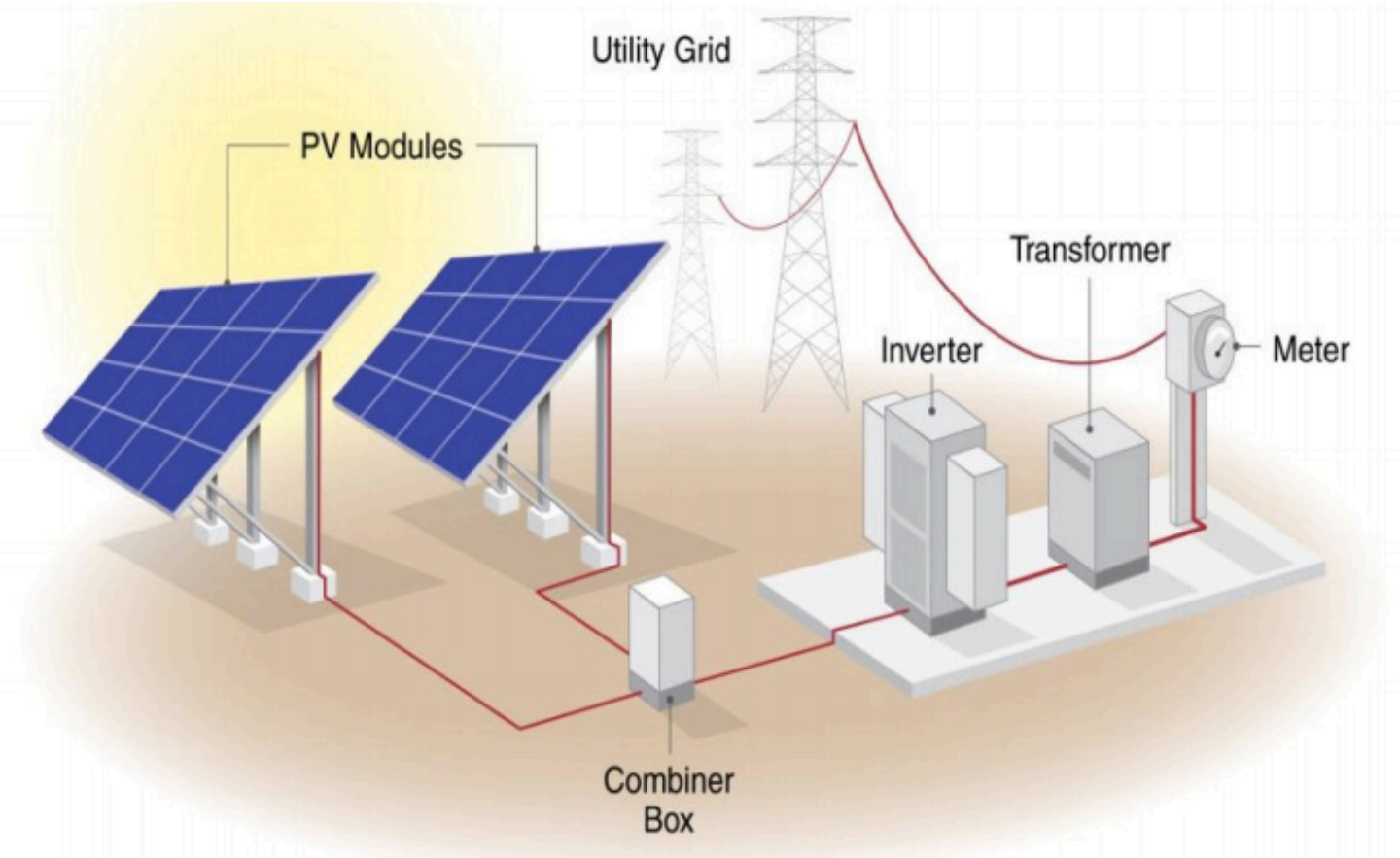

Figure 2: Overview of solar energy system
Source: National Renewable Energy Lab

Solar in New York

The state of New York has a goal of producing 50% of its electricity from renewable sources by 2030 in order to support the initiative to reduce greenhouse gas emissions by 40% from 1990 levels ("2015 New York State Energy Plan", 2015). This would amount to generating about 3 gigawatts (GW) of energy from renewable sources (Lee, 2017). What will the renewable energy landscape in New York State look like in order to reach these goals?

If we assume that one residential system produces 10 kW of energy, this would amount to 300,000 homes required to generate 3 GW of energy. A more efficient strategy to produce a large amount of energy is to focus on large scale utility solar developments; however, large scale utility systems require expansive, cleared swaths of land.

As a rough estimate, six acres of land is required to generate 1 MW of energy from solar (Lee, 2017). This amounts to 18,000 acres of suitable land needed to generate the statewide goal of 3 GW of renewable energy.

Converting 18,000 acres of green space and open land to solar development would largely impact wildlife, watersheds and opportunities for recreation. Instead of changing existing land uses to attain renewable energy goals, this report discusses options for solar development on previously developed sites in an attempt to best conserve the diverse natural resources New York State has to offer.

Figure 3: Rooftop solar installed in New York
Source: Crain's New York Business

REV Clean Energy Goals for 2030

40% Reduction
in greenhouse gas emissions from 1990 levels

50% Generation
of New York State's electricity must come from renewable energy sources

23% Decrease
in energy consumption of buildings from 2012 levels

Siting Solar Projects

For siting any solar project, there are multiple factors that should be taken into consideration to determine if the site is suitable for solar development.

The amount of solar radiation that reaches the site every day is one of the most important factors to consider. The site must receive a sufficient amount of sun in order for the solar project to be cost effective. The following map gives a general sense of the amount of sun available in different parts of the U.S. According to this map, Long Island and most of New England receive 4 - 5 kWh/m2 /day of solar radiation. Most solar projects require a minimum of 3.5 kWh/m2 /day of solar radiation (U.S. EPA, 2013).

A site specific evaluation is generally conducted because the amount of solar radiation can be affected by shade from nearby buildings and infrastructure. Similarly, slope and topography should also be considered. Installing ground mounted solar on slopes that are less steep is best. The aspect or the direction the slope is facing also affects the amount of solar radiation received. In general, open, unshaded, flat and south facing slopes are the best sites for solar development (U.S. EPA, 2013).

Beyond the geophysical characteristics of the site, the distance to the nearest transmission infrastructure should be taken into account. The previous siting considerations can help determine the energy generation potential, but delivering the energy produced is equally important. Moreover, one of

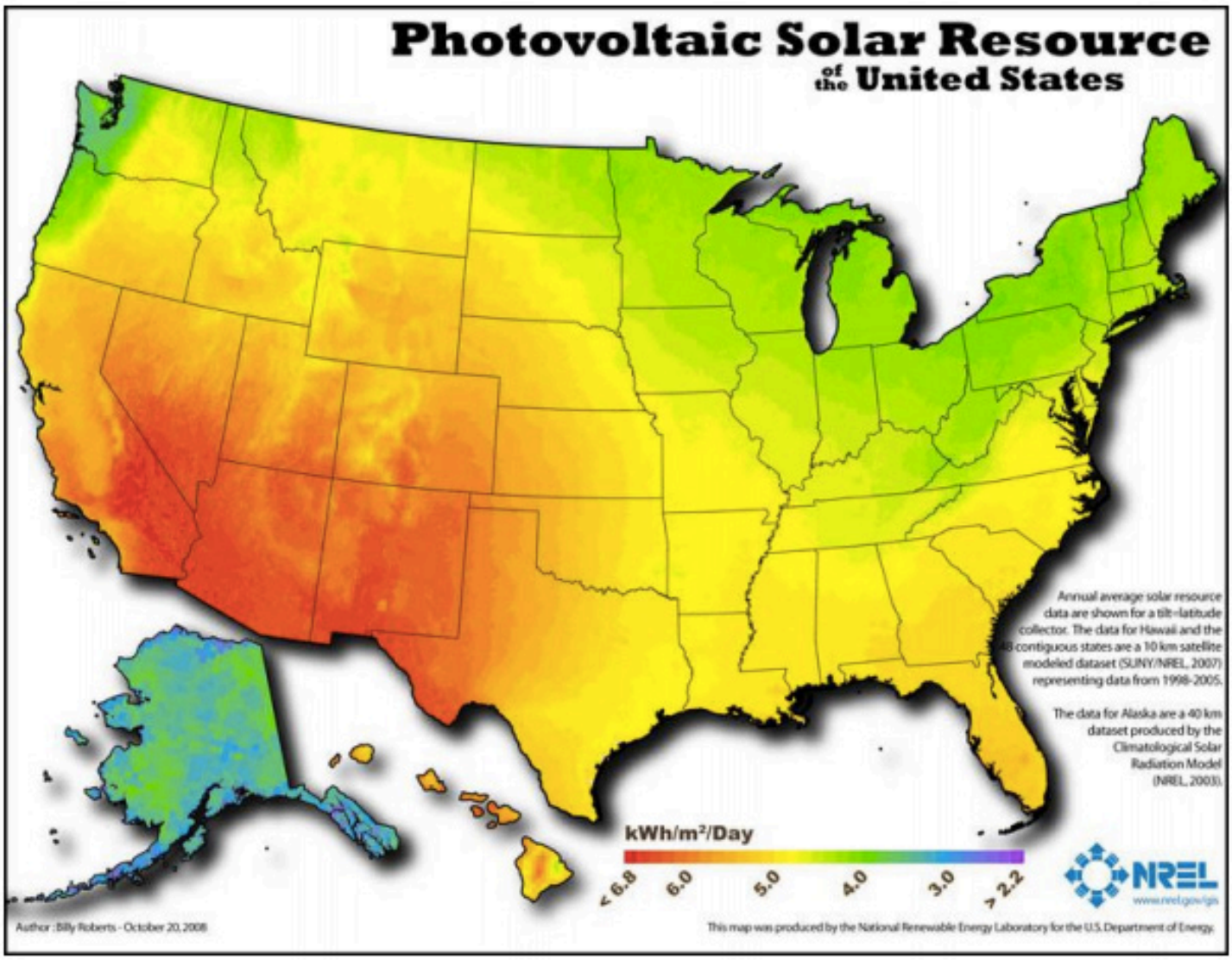

Figure 4: Sunlight in the U.S.
Source: National Renewable Energy Lab

the interviews conducted for this study sheds light on another concern: the capacity of the existing infrastructure and the permitting and approval timeline to connect to the existing grid.

The existing capacity is critical because this could determine if the current infrastructure can handle additional power or if additional upgrades are required due to congestion near that specific location because of high demand in the area. The permitting and approval required to connect to the grid is sometimes not realized until the late stages of a project, which makes this an even greater challenge to overcome.

The surrounding land use of the potential site should also be taken into consideration. The built environment could shade the solar PV system and reduce the amount of energy generated. The surrounding land use can also help evaluate the impact of any visual impairment caused by the project and the resulting response from the local community (U.S. EPA, 2013).

The proximity to fragile and sensitive ecological systems such as wetlands is another siting factor. These resources also provide valuable ecosystem services such as water filtration, flood protection and provide habitat for diverse wildlife populations.

Similarly, the distance to transportation infrastructure such as roads is important for evaluating the ease of access during the construction phase of the project (U.S. EPA, 2013).

Often times, agricultural fields are good candidates for ground mounted solar development because they are relatively flat, open and unshaded. However, these sites are also suitable for other land uses and offer other ecosystem services and values such as food production and the preservation of rural character.

As an alternative to siting solar on valuable landscapes such as forested land and prime farmland, this study focuses on opportunities for solar development on land that has been previously developed and offers little natural resource value or has already experienced environmental degradation.

Siting Solar in New York

Long Island is a good candidate for considering the best locations to concentrate solar development in New York because it receives a fair amount of solar irradiance (Lee, 2017). At the same time, there are many land use challenges to consider when looking for suitable sites for ground mounted solar on Long Island because there are a limited number of open spaces that could support a large scale utility solar project.

Tools such as the NY Solar Map can be used to determine a site's solar potential based on a number of assumptions including roof area, slope of roof and the average amount of solar radiation received ("NY Solar Map", 2015). Users can determine their solar potential by inputting an address or latitude and longitude coordinates. The NY Solar Map tool can be found here: https://www.nysolarmap.com/.

Siting Solar on Low Impact Sites

The siting considerations mentioned above can be applied to siting solar on many types of sites; however, the following discussion explores the unique challenges that have to be considered when siting a solar project on a low impact site. The following sections of this report discuss these challenges in more detail and explores the advantages of establishing solar on previously developed sites. This report focuses on three types of low impact sites: airports, landfills and parking lots. Relevant case studies are provided for each of the sites.

Siting Solar on Airports

Advantages of Siting Solar on Airports

Over 100 airports around the world have installed solar systems to provide power for their needs. In sum, these installations are generating over 400 MW of energy, which is equivalent to taking 2,200,000 cars off the road every year (Built Well Solar Corp, 2016).

The largest solar plant installed at an airport is at Cochin International Airport in Kerala, India. It has a capacity of 12.5 MW with over 76,000 PV panels to fully power the airport (Built Well Solar Corp, 2016).

In the U.S., a 2010 joint study by the Federal Aviation Administration (FAA), U.S. Department of Agriculture (USDA), and U.S. Fish and Wildlife Service (USFWS) noted there was immense potential for solar development at approximately 15,000 airports domestically (Kandt & Romero, 2014). There is roughly 3,306 square kilometers of grassland on 2,915 airport properties that represent idle lands with solar potential. Using the assumption that 1 MW requires 6 acres of grassland, there is 136,155 MW of solar PV potential on these lands.

At airports, solar installations may occur for these unique applications:

- Deicing runways: snow and ice removal is typically an expensive and energy intensive process. As such, installing solar panels to power the electrodes inside the cement runway could potentially be a cost-effective measure (Kandt et al., 2014).

- Incorporating panels into a building's facade: In Switzerland, Geneva's airport has recently incorporated PV panels as part a balustrade inside the terminal. This provides an energy source and energy efficiency improvement to the building (Kandt et al., 2014).

- Airport lighting: PV can power the lighting used for approach, taxi, and runway purposes, wind cones, and runway guard lights (Kandt et al., 2014).

Challenges and unique considerations

There are also a number of challenges that arise from siting solar, predominantly glint (short flash of light) and glare (continuous flash of light) (Kandt et al., 2014). In 2013, the FAA published an interim policy on the safety concerns from siting solar at airports, setting standards for measuring glint and glare in addition to when it is considered a hazard to aviation safety (FAA, 2013). Key highlights from this guidance include:

- Notify the FAA when constructing any solar project
- Request FAA review on a project that will significantly change the airport layout plan (ALP)
- Demonstrate your project will not pose a visual risk to aviation safety
- Demonstrate your project will not interfere with other airport telecommunication systems (Kandt et al., 2014).

The standard tool to measure ocular impact of a solar project is the Solar Glare Ocular Hazard Plot, or SGHAT. The tool is intended to give a quantifiable assessment of 1) when and where the glare will occur throughout the year and 2) potential effects of glare on the human eye (Kandt et al., 2014). The project sponsor is required to refer to this tool and use the program's hazard analysis tool to measure glare and glint (Kandt et al., 2014). SGHAT is available on Sandia's website.

Two criteria must be met in order for the FAA to approve a solar project and/or give a "no objection" opinion to the Notice of Proposed Construction Form 7460-1 (Kandt et al., 2014):

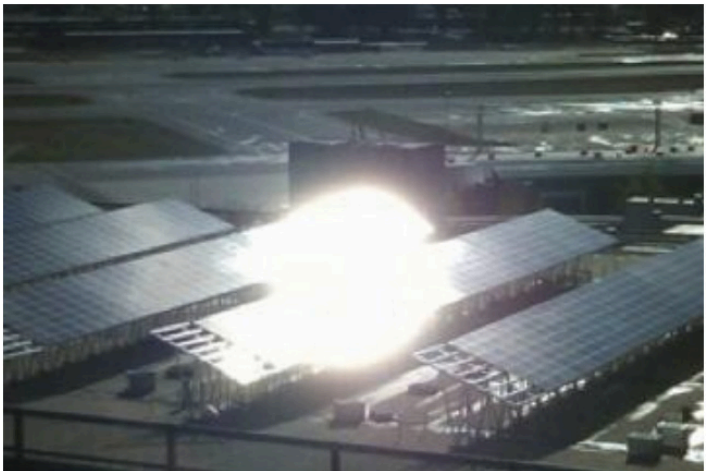

Figure 5: Glare from solar panels installed at Manchester-Boston Regional Airport
Source: National Renewable Energy Lab

- No glint or glare potential in the airport traffic control tower cab
- No potential glare or "low potential for afterimage" along the path of final approach for existing or future landing thresholds (final approach = 2 miles from 50 feet above the landing threshold using a 3° glide path) (Kandt et al., 2014).

The best way to mitigate glare and glint is through appropriate design and siting of the solar project (Ho, 2013). Textured glass and anti-reflective coatings can also reduce reflectance between 1-2% (Ho, 2013). In addition, screens and blinds may be possible methods for mitigating glint and glare but are not as practical for air traffic controllers (Ho, 2013).

Glare was a major problem at the Manchester-Boston Regional Airport in Manchester, New Hampshire where every morning a glare lasting for roughly 45 minutes would be visible from the air traffic control tower (Kandt et al., 2014). Although not a distraction to pilots, it was a hinderance to those working in the tower. Experts from Sandia National Labs assisted with coming up with a solution using the SGHAT tool (Kandt et al., 2014). Ultimately, the solar array was reconstructed with a 90° rotation from the original tilt. Although it eliminated glare problems, it also resulted in a 10% decrease in efficiency (Kandt et al., 2014).

Another potential minor challenge concerns wildlife, who may seek perches or shade on solar projects. A 2013 study done by the USDA National Wildlife Research Center found a low number of birds on PV arrays (DeVault, 2013). They also found that converting airfield habitat to a solar project could also potentially decrease the risk to bird strikes by planes as opposed to on grass or other types of land cover at airports (DeVault, 2013). Installing spikes and/or barriers behind the panels may reduce the number of bird perches on the system as well (DeVault, 2013).

Although solar development is generally thought to have negative effects on wildlife due to the modification of their habitat, airports are also a rare land use in which reducing wildlife and habitat may be needed to reduce wildlife collision risk with aircraft (DeVault, 2013).

Ground-mounted solar systems have performed well on airport land that does not affect aeronautical planning or competitive uses. In addition, they have also been deemed successful if sited on land that has an aeronautical purpose but is not actively being used for development (FAA, 2010). Some examples of

Figure 6: Cochin Airport in Kochi, India
Source: BBC

spaces to use at airports are: noise buffers, flat areas near the runway, or potentially the roofs of hangars (FAA, 2010).

Roof-mounted solar projects on airports will typically be ideal for a site without a level of high on-site energy demand or without large tracts of land available. Since roof-mounted systems are close to a building's existing electrical system, the distance to electrical infrastructure is very close and the costs to connect to an existing network is low (FAA, 2010).

Estimated Costs

PV systems at airports will be costlier than other locations, where airport specific costs related to project planning and coordination with FAA are likely to occur (Built Well Solar Corps, 2016). For financing options, one may elect to do a third-party financing in which one finances, owns, and operates the system with relatively little amounts of capital. In addition, the FAA administers the Voluntary Airport Low Emissions Program (VALE), which assists airports with meeting state-related air quality responsibilities under the Clean Air Act ("Voluntary Airport Low Emissions", 2017). VALE is a potential vehicle for accessing funds to support the installation and contracting of PV systems ("Voluntary Airport Low Emissions", 2017).

Another possible way to offset costs is to provide more electricity and thus collect more revenue than the fixed costs of the project, such as for equipment or land (FAA, 2010).

One example of an airport that used public and private incentives to lower the cost of electricity is Massachusetts Port Authority (FAA, 2010). The Authority received funds from the federal stimulus package, which it allocated towards capital costs of building a solar project in Terminal A of Boston Logan International Airport (FAA, 2010). Then, it went through an RFP process with private solar companies who wanted to own and operate the system. The winning developer executed a Power Purchase Agreement (PPA) with the Authority and has been able to monetize additional federal tax credit benefits as well (FAA, 2010).

There are private and public ownership models for airports to consider. Since this is outside of the scope of this guide, it is suggested that interested parties refer to the FAA's 2010 "Technical Guidance for Evaluating Selected Solar Technologies on Airports" for more information.

Figure 7: Solar project at Indianapolis International Airport
Source: Ind Solar Farm

Case Study: Gabreski Airport

In Suffolk County, there are 36 airports in total, 12 are public and 14 are private ("Suffolk County"). Some airports, like MacArthur Airport in Islip, have installed solar as a statement for showcasing renewable energy to local residents (Galluci, 2010). Others are in the process of installing solar. The following case study is a sample site for solar development.

Project Summary

Completion Date: TBD
Acreage: 30 acres
Energy generation: 4.2 MW
GHG reduction: 5,480 metric tons/year

Location

Gabreski Airport is located in Southampton on the eastern part of Long Island, covering 1,451 acres ("Suffolk County", 2016). The airport is owned and operated by Suffolk County, and used by a mix of private aviation, air taxi services, and businesses. It is also the home base to the 106th Rescue Wing of the Air National Guard, who supports disaster relief and state emergencies ("Suffolk County", 2016).

Siting Background

In October 2013, the Long Island Power Authority issued a Feed-In Tariff for 100 MW. The program was a way to get more solar projects on the grid by incentivizing owners of eligible PV projects to sell power over a 20 year period to the utility, Public Service Enterprise Group (PSEG).

In response, Suffolk County issued an RFP for solar projects, and SunEdison, a global solar developer, successfully secured the bid. The company was set to pay the county $315,000 annually in lease payments, summing to $6.3 million over a 20 year period. SunEdison would then be responsible for permitting, construction, and operation. They would sell the power through a long-term PPA with PSEG Long Island.

The Project: Planned Capacity and GHG Savings

Originally, the solar project was accepted at 6.8 MW, although later it was decreased to 4.2 MW due to interconnection constraints (Broughton, 2017). The project takes up about 30 acres on Suffolk County's property, located on opposite diagonals of the airport runway, as shown in the figure below ("Suffolk County", 2014). It is not visible to neighboring commercial or residential properties, and studies have demonstrated glare and glint to not have an impact.

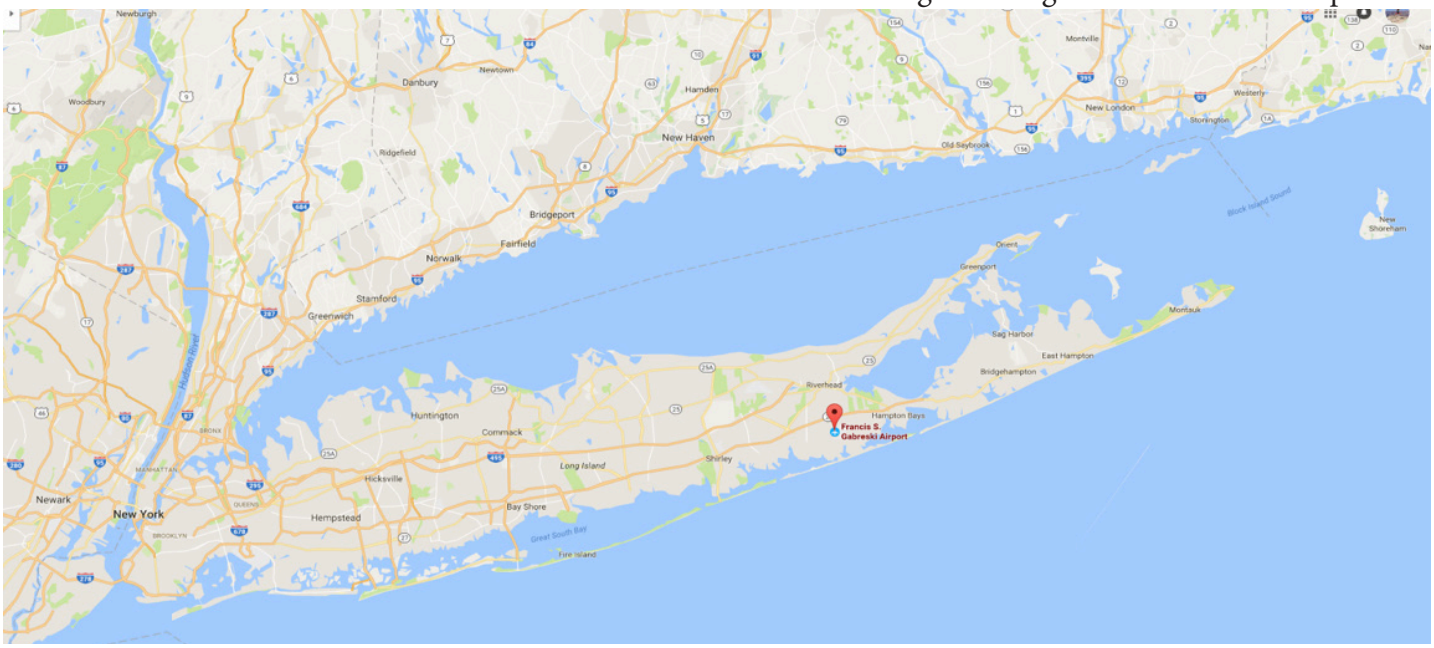

Figure 8: Location of Gabreski Airport
Source: Google Earth

The project also imposes no long-term negative impacts on the environment (Wehner, 2015). It is estimated about 5,480 metric tons of CO2 would be reduced per year from this project, equivalent to taking approximately 1,158 cars off the road each year (Wehner, 2015).

The Pine Barrens Joint Planning and Policy Commission approved the Land Use Plan for the project in 2012, and the project is subject to FAA approval since it needs to adhere to the Airport Master Plan. The Agency currently allows short term leases of five years for non-aviation reasons, but has approved other solar project leases at other airports around the country (Wehner, 2015).

Challenges and unique considerations

The project's biggest obstacles has been the change in its developer and a chemical cleanup problem. In April 2016, SunEdison declared bankruptcy, and the county was left without a lessee. Currently, a vendor (who will remain confidential) has been acquired, and they will take over the lease from Suffolk County and be a counterparty to PSEG in order to sell them power. Lease revenue has decreased to $186,000 per year, summing to $3.7 million over 20 years (Broughten, 2016). Additionally, it has been recently discovered that the Air National Guard has been using a fire suppression foam known as perfluorooctanesulfonic acid, or PFOS, which has negative health and environmental impacts (Pubchem). The vendor would like to complete additional testing and verify cleanup is completed with the EPA prior to continuing development.

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Figure 10: Proposed location of solar arrays
Source: Suffolk County

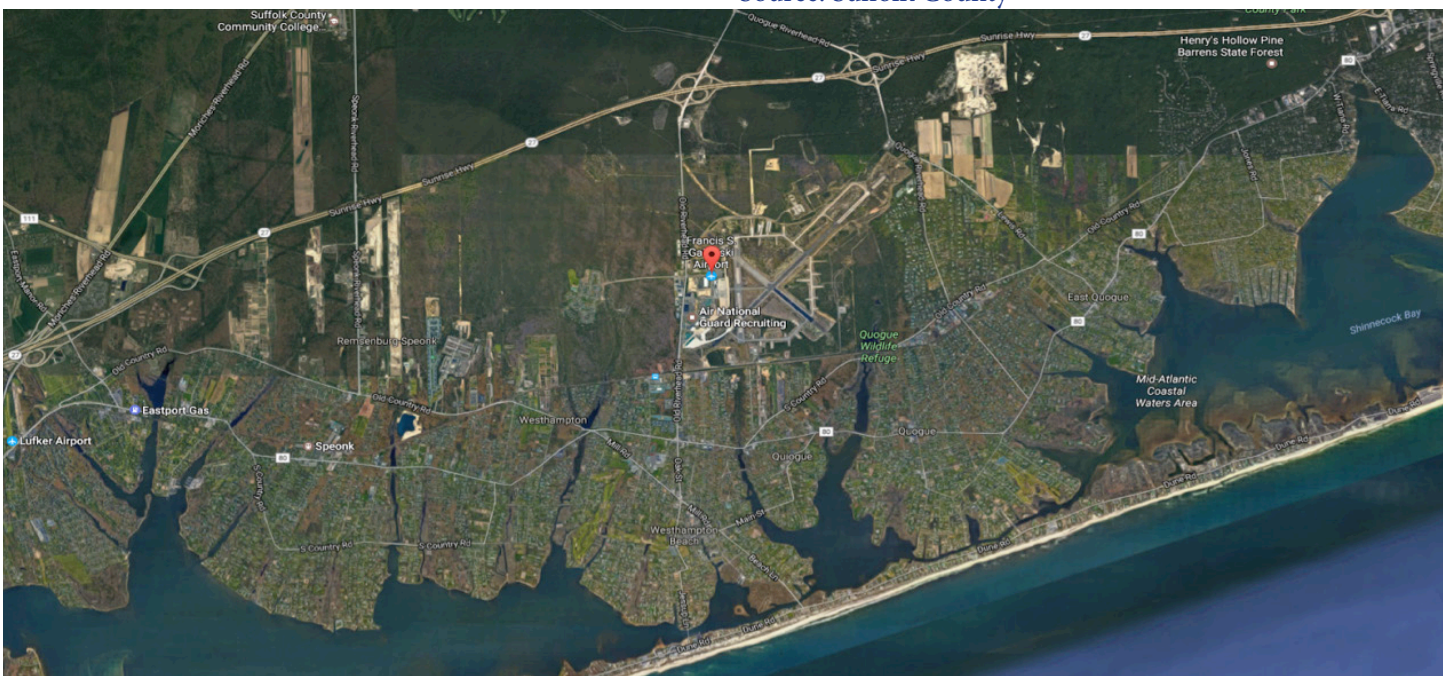

Figure 9: Satellite view of Gabreski airport location
Source: Google Earth

Siting Solar on Landfills

Advantages to siting on landfills

Installing solar projects on top of closed landfills offer an opportunity for revitalizing land that may have high cleanup costs and thus degraded real estate value (EPA & NREL, 2013). Landfills are often located in large spaces with a minimal grade that do not impact with other land uses or environmentally sensitive areas. There is also an existing number of roads to allow for easy access to the site, which assists in the efficiency of construction and materials transportation (Szabo et al., 2017). Security and monitoring measures are also typically in place, which will be advantageous for protecting the installation.

In addition, landfills often have existing connections to the electricity grid which eliminates the long lead time and costs of interconnection from the installation costs (Szabo et al., 2017). If the landfill previously produced landfill gas, it is additionally likely there is adequate capacity for transmitting the solar generated electricity from the landfill site to demand centers. If the landfill gas is still actively being produced, there is potential for a hybrid system where solar is produced during the day and landfill gas is produced at night (Szabo et al, 2017).

The graphic below illustrates how a hybrid system would function at a landfill.

Challenges and unique considerations

There are multiple criteria to consider when siting solar on a landfill, which include:

- Integrating with existing engineering systems
- Landfill closure
- Landfill cap characteristics
- Landfill slope and stability
- Waste composition and settlement
- Erosion control
- Leachate and gas collection
- Stormwater Management

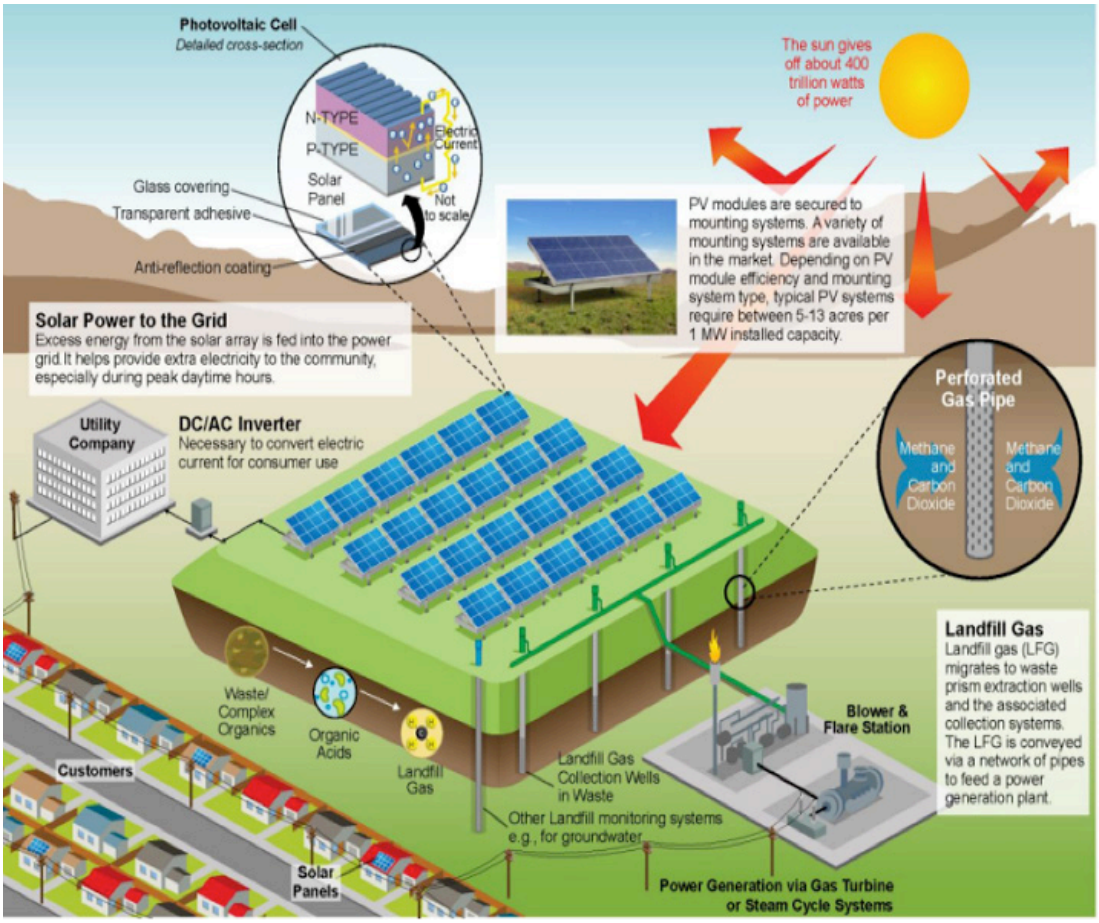

Figure 11: Landfill solar system
Source: PV Navigator

The following sections will focus on 1) landfill closure 2) slope issues, 3) waste composition and settlement, and 4) cap characteristics. For additional detailed information on other siting criteria, refer to EPA and NREL's 2013 guidance in the report Best Practices for Siting Solar PVs on MSW Landfills.

Landfill Closure

If a developer is planning on siting solar on a landfill that has not yet closed, there may be an opportunity to design the solar project to integrate it with the landfill closure (EPA et al., 2013). This will be important since re-adjusting engineering systems to fit a new PV system may be cost-prohibitive (EPA et al., 2013).

On the other hand, if a site has yet to be closed, one can design the PV system to be part of the landfill cap and consider additional factors such as stormwater flows and treatment systems. Further, since landfill closure includes requirements with permits, one needs to ensure the PV design, construction, and operation will still allow the landfill to be compliant (EPA et al., 2013).

Slope Issues

Many landfills are made of large mounds of capped waste with steep slopes, which then requires a more complicated design for the solar system to adjust for the steep slopes, resulting in higher costs (EPA et al., 2013). A grade of 2-3% can provide a stable foundation for the PV system to be anchored, minimize rainwater from infiltrating through the landfill cap, reduce erosion, and avoid ponding of water. Realistically, most solar developers do not install PV systems above 5-10% grade since costs for accommodating the more complicated design needs will rise (EPA et al., 2013).

In addition to the slope grade, the angle of the slope relative to the sun is equally important. Systems that are within 20-30 degrees of facing due south are ideal for solar production (EPA et al., 2013).

There are several ways to manage slope issues: using lighter PV modules with adjustable racking, installing heavier foundation to support the panels, regrading the landfill, using a PV integrated geomembrane, and installing a fixed tilt mounting system (EPA et al., 2013).

Waste Composition and Settlement

There are two types of settlement: uniform and differential. Uniform settlement is where the waste decays evenly across a large area. Differential settlement is when waste decays at varying rates, usually due to the composition of the waste (EPA et al., 2013). This can lead to an uneven cap, which can be a major impediment for mounting systems since it can cause uneven settlement of the array foundation, which the panels get mounted on. This could then potentially lead to panels that do not align, resulting in decreased energy production (EPA et al., 2013).
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Settlement will have a greater effect on the landfill cap shortly after closure, as the rate of settlement decreases over time. It is possible for solar developers to avoid landfills that have been capped in recent years or to forecast estimated settlement rates in order to avoid potential misalignment risks (EPA et al., 2013).

The mitigation measures for managing slope are also useful for managing waste. In addition to the solutions previously mentioned, one may consider compacting the soil or applying geogrids (EPA et al., 2013).

Cap Characteristics and Penetration

Landfill caps have different functionalities, must meet certain regulatory requirements, and can have different compositions such as the one presented below:

Each layer serves a unique purpose (not all layers listed below correspond to the graphic):

- Surface layer: stops water and wind erosion, provides a medium for vegetation if needed

- Protection layer: protects layers beneath from degradation due to changes in weather, serves as a temporary reservoir for water, and prevents intrusion from humans, animals, or plants

- Drainage layer: prevents a hydraulic head, minimizes percolation through the hydraulic layer, improves slope stability by reducing seepage forces in the layers above it

- Hydraulic layer: prevents percolation into the waste

- Gas venting layer: helps move the gas to vents, wells, and trenches

- Foundation layer: helps control the grade for the cap, provides bearing capacity for above layers, used for installing geosynthetic material (EPA et al., 2013)

There are potential risks to all of the layers stated above. Waste settlement will be dependent on the waste composition, how deep it is in the ground, placement methodology, and the age of the landfill cap (Sampson, 2009). If landfills have just been recently capped, it is likely there will be higher rates of settlement (EPA et al., 2013).

The detailed information regarding landfill design and maintenance plan can be found in the post-closure documentation. Site visits are also highly recommended to evaluate the waste composition, landfill construction, and stormwater management practices before deciding on a PV design (EPA et al., 2013).

Estimated Costs

Landfills typically have a low load demand, so systems are most likely to sell their electricity to a local utility through a PPA (EPA et al., 2013). If landfills have a higher load demand, it may consider taking advantage of net metering to offset their electricity costs (EPA et al., 2013).

There are two options for ownership: the municipality can either own the project or only lease the land to a vendor. For more information on the two types of ownership models and the associated benefits and risks, refer to Massachusetts Department of Energy Resources' The Guide to Developing Solar PVs at Massachusetts Landfills.

Ultimately, the economics of a landfill solar project will depend on the price the local utility is willing to offer plus any additional government grants, tax benefits, and other financial incentives the project can take advantage of (Munsell, 2013). In addition, since landfills vary largely in type, the costs of engineering studies including compaction tests and methane monitoring (if applicable) can dramatically add to the normal project development costs.

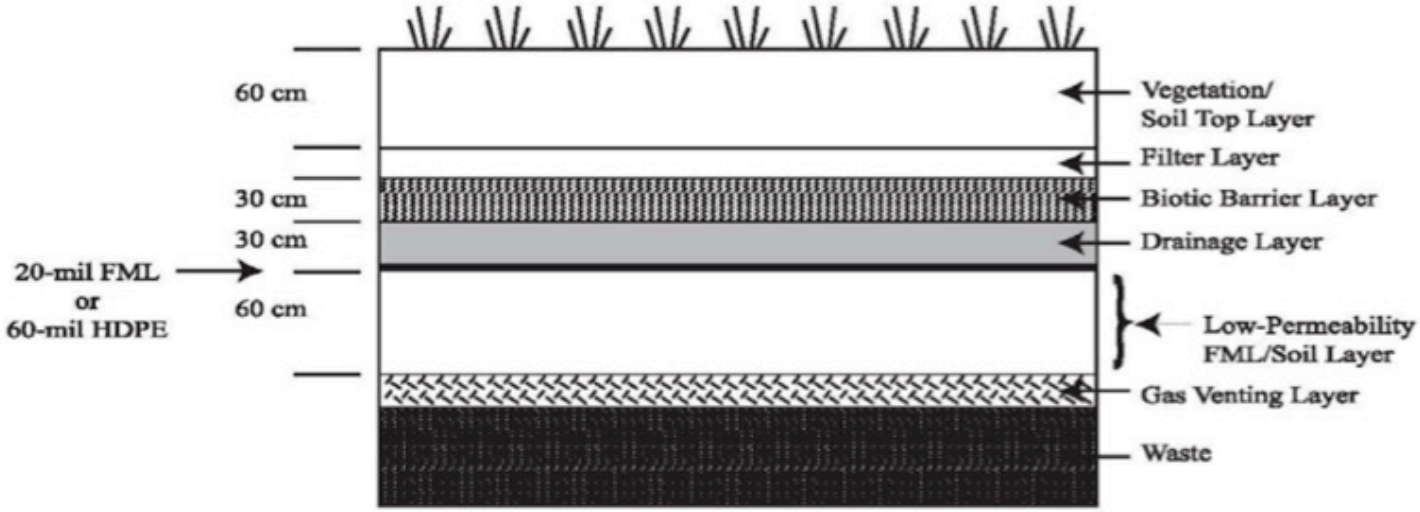

Figure 12: Landfill composition
Source: U.S. EPA

Case Study: East Hampton Landfill

Long Island has a mix of municipal solid waste, construction and demolition, industrial/commercial waste, and ash monofill landfills (New York State Department of Environmental Conservation, 2010). Long Island landfills are also subject to a Long Island Landfill Law, which phases out landfills in certain aquifer zones and encourages resource recovery and recycling practices (New York State Department of Environmental Conservation, 2010). There have been several attempted solar installations on different landfills within Suffolk County, but due to a variety of reasons they have not all been successful. These reasons include: contracts with SunEdison that have been delayed or complicated due to their bankruptcy status, landfill cap and slope issues that were incompatible with solar panel design, and transmission capacity constraints.

Accabonac Road in East Hampton

In 2015, two brush dumps and one closed landfill were set to be developed by SunEdison into solar projects, totaling 3.2 MW. Since the majority of engineering studies were only completed after these contracts were signed, the developer realized it was not worthwhile to pursue two out of the three planned projects. Only the former brush dump on Accabonac Road in the hamlet of Springs in East Hampton is going forward as of May 2017 (Shaw, 2017).

Project Summary

Completion Date: TBD
Acreage: 2 acres of solar panels
Energy generation: 1.6 MW
GHG reduction: 2,433 metric tons/year

Location

The project would be located on two acres of land on Accabonac Road, just north of Abrahams Path and south of Harrison Avenue. See maps below for exact location:

Siting Background

East Hampton was initially enthused to select the three original sites for solar projects since it was an opportunity to turn the properties into beneficial reuse sites, which would both increase the land value and provide revenue for the town (Shaw, 2017). However, i is important to note the solar developer was not flexible in considering potential future retrofits to the project for any improvements in solar panel efficiency or technology, an important land use consideration for any solar project (typically 20-40 years).

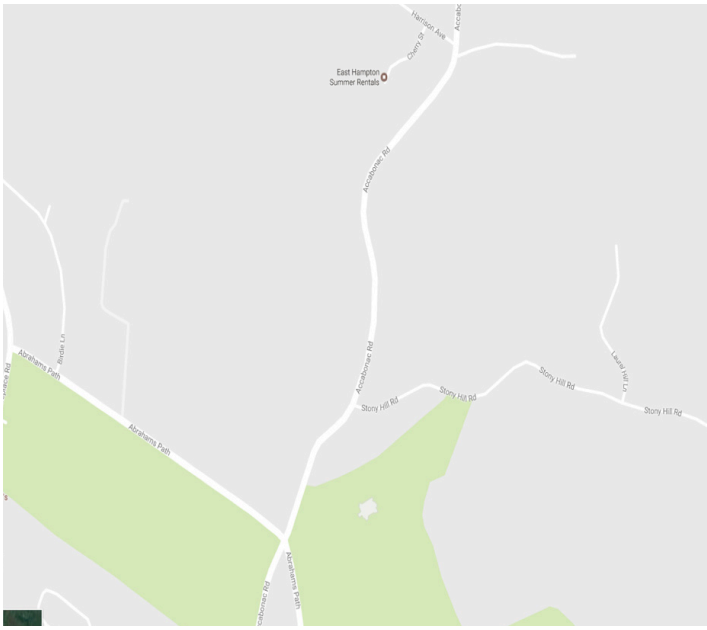

Figure 13: Location of East Hampton Landfill
Source: Google Earth

Figure 14: Aerial view of East Hampton Landfill
Source: Google Earth

The Project: Planned Capacity and GHG Savings

The project is approximately 1.6 MW in size, and roughly covers two acres of land (Planning Board, 2015). The lot is zoned as residential, and currently vacant with natural vegetation growing on the lot (Planning Board, 2015). The project has been determined to have no negative impacts on the environment (Planning Board, 2015). It is estimated approximately 2,433 metric tons of CO2 would be reduced per year from this project, equivalent to taking 514 cars off the road per year (Environmental Protection Agency, 2017).

Challenges and unique considerations

Although the prior lessee, SunEdison, is currently in bankruptcy proceedings, the project has received all necessary approvals and is only awaiting a new solar developer to construct and operate the project. This legal obstacle is the only major delay, but otherwise the project is shovel-ready.

With regards to the other two previously considered projects, it was revealed after signing the contract with SunEdison certain challenges such as the landfill slope were going to be cost-prohibitive to resolve.

In addition, the town was set to receive approximately $900,000 per year in lease payments for all three projects, but PSEG ended up reducing these amounts by 40 - 70%. Thus, this specific project will likely get less than $60,000/year in lease payments (Shaw, 2017).

On the bright side, New York Power Authority (NYPA) has been in discussions with East Hampton to assist in evaluating additional sites for solar development. NYPA is offering services including site analysis, conceptual designs and interconnection review to develop a solar road map for the most advantageous sites. Other municipalities can look into consulting with NYPA for future solar project development opportunities (Shaw, 2017).

Figure 15: Map of site plan for East Hampton landfill
Source: East Hampton

Siting Solar on Parking Lots

Advantages of Siting Solar on Parking Lots

Parking lots can make for optimal sites for either a ground mounted solar system or a rooftop mounted system. In general, parking lots are often unshaded allowing for maximum sunlight and are already aesthetically displeasing and adding a solar system shouldn't take away from the overall aesthetics of the site ("The Case for Solar Energy", 2015).

There are two options for siting solar at a parking lot: either a ground mounted solar system that utilizes unused space of a parking lot or mounting solar modules on the roof of a covered carport structure.

In general, there are two main advantages of a ground mounted system compared to a roof mounted solar system. Ground mounted systems are easier to access for maintenance and troubleshooting purposes than a rooftop installation, which can reduce overall maintenance costs (Porter, 2014). Ground mounted systems also allow for more airflow that keeps the temperature of the system cooler, leading to less energy lost and greater efficiency ("Solar Electric Services", 2017).

Although a rooftop solar system may come with extra costs compared to a ground mounted system, the carport structure offers additional benefits. Covered carports provides shade and keeps parked cars cooler during hot summer months and provides protection from weather events like snow, rain, and hail ("The Design Basics", 2016). Design features can be added to covered carports that redirect rain and snow to strategic areas and can reduce the level of ice that accumulates in a parking lot, thus decreasing maintenance costs ("Solar Carports", 2017). In addition, rooftop mounted solar on top of carports can easily power electric vehicle charging stations (Porter, 2014b).

Challenges and unique considerations

There are various design and engineering challenges that must be considered before installing a carport solar system. The solar support structure needs to be

Figure 16: Solar carport structure
Source: Solar Thermal Magazine

robust enough to safely support the PV modules but should be constructed at a low enough cost to make the project financially attractive ("The Design Basics", 2016). For example, in considering the tilt angle of the PV modules, a tilt angle between 5 - 10 degrees is best for balancing support structure costs and optimal solar production ("The Design Basics", 2016). Spanning support posts farther apart without compromising the structure can also help reduce costs ("Park-onomics", 2016).

The existing layout of the parking lot and how the parking lot is currently being utilized should also be considered in the design of the solar carport system. Parking lot utilization considerations can include the frequency and use by special vehicles such as delivery trucks and garbage trucks ("Park-onomics", 2016).

The existing layout of the parking lot and how the parking lot is currently being utilized should also be considered in the design of the solar carport system. Parking lot utilization considerations can include the frequency and use by special vehicles such as delivery trucks and garbage trucks ("Park-onomics", 2016).

Estimated Costs

The cost of a "bare bones" carport system can be as low as $0.80/ watt. A bare bones structure is a system that meets the minimum structural requirements with no additions such as snow guards, lights or a water management system ("Park-onomics", 2016). As more structural and aesthetic aspects are added to the carport system the cost increases, which can be around $1.50/ watt or more ("Park-onomics", 2016).

Figure 17: Ground mounted solar at a parking lot
Source: Clean Technica

Case Study: Eastern Long Island Solar Project

The Eastern Long Island Solar Project is the largest solar installation in New York State and includes 21 acres of solar panels located at six parking lot sites owned by Suffolk County ("Eastern Long Island", 2017). The parking lot sites are located at the H. Lee Dennison Building and the North County Complex in Hauppauge, the Cohalan Court Complex in Islip, the Riverhead County Center and Long Island Railroad stations in Brentwood and Deer Park (Bray, 2010). Collectively, the six sites generate 12.8 MW of energy to Long Island Power Authority customers ("Eastern Long Island", 2017).

This solar project installation provides economic and environmental benefits for the local community. The lease agreement will generate $8 - 9 million for Suffolk County and $1.2 million for local school districts and towns. EnXco, a renewable energy company based in California, will make lease payments based on the amount of energy generated for the next 21 years (Civiletti, 2010). During the construction phase, an average of 30 new jobs were created at each site (Bray, 2010). On a global scale, the project reduces carbon emissions by more than 12,973 metric tons per year ("New York's Power Lots", 2010). This is equivalent to removing 2,447 cars from the road every year ("New York's Power Lots", 2010).

Project Summary

Completion Date: November 2012
Acreage: 21 acres of solar panels
Energy generation: 12.8 MW
GHG reduction: 12, 973 metric tons/year

The design and installation of the carports does not impact the number of parking spots available, aligns with Suffolk County's long term transportation planning efforts, and allows for regular maintenance (Gallucci, 2010).

Some insights into siting solar on parkings lots were revealed after conducting interviews with those involved in executing the Eastern Long Island Solar Project. The costs related to the Eastern Long Island Solar Project don't amount to typical costs for a solar parking lot project because this was a pilot project for Suffolk County and a lot of learning was done along the way. One important lesson that was made apparent through our interviews was that parking lots are not ideal surfaces to build solar. Blacktop is not perfectly flat and presents drainage issues that have to be

Figure 18: Carport structure at Cohalan Court Complex in Islip
Source: Blue Oak Energy

overcome in the design phase.

Logistical challenges such as finding space for alternative parking during the construction phase and coordinating construction schedules without disrupting everyday business activity can also slow down progress on parking lot solar projects. For example, scheduling construction was particularly challenging during the construction phase for the H. Lee Dennison site. Construction during the day would be disruptive to local government activity housed in the Dennison building, but site planners also had to consider the additional premium costs involved if construction was done primarily at night. However, community programs and government services often operate after normal business hours. For instance, the baseball field adjacent to the Dennison building had to be left open for evening baseball practice.

Constructing this project at the county level does have some advantages. This particular project did not have to go through the city or town zoning and permitting process because the project was developed on county property. This is advantageous because it allows for the project to take full advantage of the site's space. If a solar carport were to be built on private property, then the built carport structure would need to follow city zoning requirements, which includes setback and height requirements. This limits the amount of useable space and ultimately makes the solar project less attractive and economically unfeasible. Most city and regional plans do not address renewable energy and as a result zoning laws are not well suited to fit the needs of solar development (Bacher, 2016).

If a solar carport were to be built on private property then the built carport structure would need to follow city zoning requirements, which includes setback and height requirements. This limits the amount of useable space and ultimately makes the solar project less attractive and economically unfeasible. Most city and regional plans do not address renewable energy and as a result zoning laws are not well suited to fit the needs of solar development (Bacher, 2016).

Site Summary

H. Lee Dennison Building (Hauppauge)
- 1.75 MW solar power generated
- 7,737 solar modules on 24 solar arrays

North County Complex (Hauppauge)
- 0.5 MW generated
- 3,431 solar modules on 9 arrays.

Cohalan Court Complex (Islip)
- 3.5 MW generated
- 15,113 solar modules on 27 arrays

Riverhead County Center (Riverside)
- 3 MW generated
- 11,536 solar modules on 31 arrays.

Brentwood Long Island Railroad Parking Lot
- 1 MW solar generated
- 3,924 solar modules on 11 arrays

Deer Park Long Island Railroad Parking Lot
- 2.25 MW solar generated
- 3,924 solar modules on 39 arrays

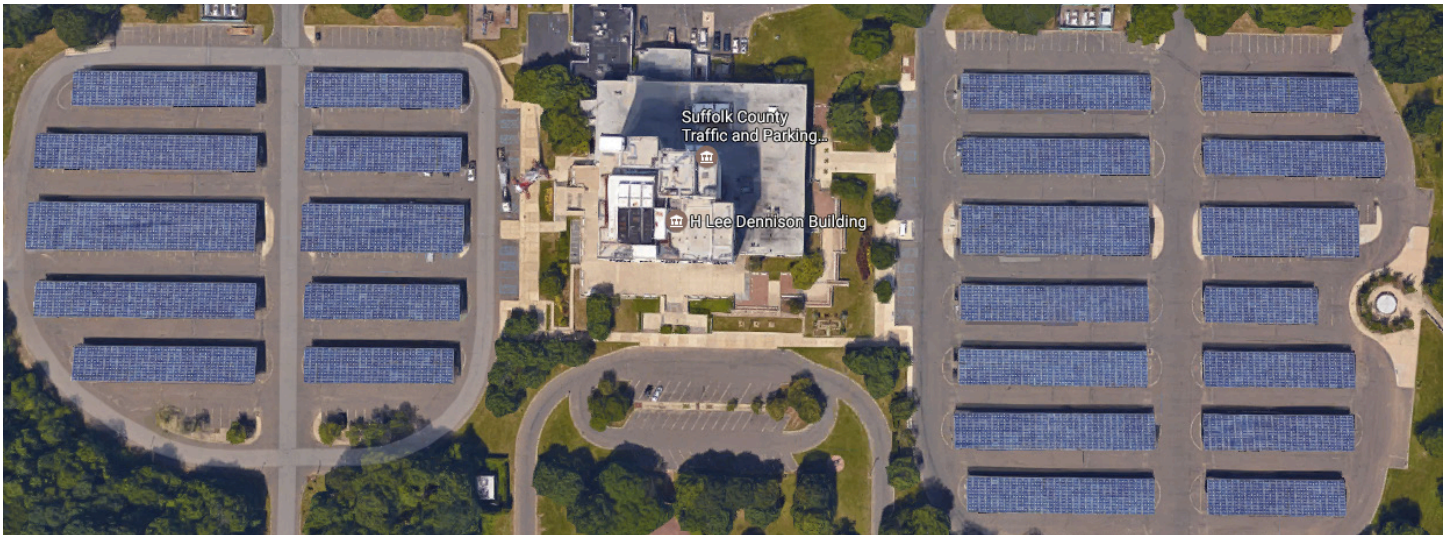

Figure 19: Aerial view of solar carports at H. Lee Dennison Building
Source: Google Earth

Summary of Solar Sites in Suffolk County

The following table summarizes some of the advantages and disadvantages of siting solar on the three land use types discussed through the Suffolk County case studies presented in this report. Costs are generalized on a scale from low to high and distance to infrastructure is characterized on a scale from near to far.

The Eastern Long Island Solar Project was particularly more expensive than most parking lot solar projects because it was a pilot project. Some of the challenges that arose are discussed above.

The exact distance to transmission infrastructure is difficult to determine because this information is not readily publicly available for Long Island. We considered the distance to transmission infrastructure for the East Hampton landfill site to be "far" because energy generated will likely not be used onsite, but it is important to remember distance to infrastructure is not the only factor. Despite proximity to transmission, there may also be congestion at certain locations, and performing engineering studies can precisely indicate to what degree it will be an obstacle to the project.

Land Use	**Case Study**	**Location**	**Energy Generation**	**Acreage**	**Distance to transmission infrastructure**	**Cost**
Airport	Gabreski Airport	Westhampton Beach	4.2 MW	30 acres of solar panels	Near	Medium
Landfill	Accabonac Road	Spring, East Hampton	1.6 MW	2 acres of land	Far	High
Parking Lot	Eastern Long Island Solar Project	7 sites - Hauppauge, Islip, Riverside	12.8 MW	21 acres of solar panels	Near	High

Conclusion

Opportunities to site solar on low impact sites can minimize the environmental impact of large scale utility solar while protecting the ecosystem services provided by more valuable land uses such as agricultural fields, forests and green space. For the purposes of this report, we focused our study on three low impact sites for further analysis: airports, landfills and parking lots.

Other previously developed sites that could lend themselves to solar development could include prison lands, brownfields, gravel mines and transportation rights of way. Further research should be conducted to evaluate the potential for solar development on these additional low impact sites. These studies should also try to incorporate different forms of analysis in order to consider solar siting issues from a multitude of perspectives. Forms of such analysis could include geospatial, economic and land use issues.

This report did not include an in-depth analysis of the economic factors that should be considered before planning for solar development on a low impact site. This is another key area of research, as evidenced by the revenue impacts it had on municipalities.

Siting solar on these sites presents many challenges, and we hope this report highlights opportunities for future community engagement, policy and planning actions to support strategic solar and renewable energy development. New York has demonstrated its commitment to reaching its ambitious renewable energy goals, and we hope the information presented in this report can help with the collective effort to attain the 2030 goals: reduce greenhouse gas emissions by 40% and achieve 50% renewable energy on the grid.

Additional Resources

EPA's Re-powering program - lists renewable energy projects on contaminated sites
https://www.epa.gov/re-powering/re-powering-your-community#projects

NY Solar Map - tool that can calculate solar potential in your area
https://www.nysolarmap.com/

U.S. DOE Sunshot - briefing papers for planning for solar development
https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/research/solar/briefingpapers/pdf/solarpaperscompendium.pdf

U.S. EPA - guide for solar development while considering environmental factors
https://www.epa.gov/sites/production/files/2015-04/documents/handbook_siting_repowering_projects.pdf

NY REV - learn more about New York's energy goals for 2030
https://rev.ny.gov/

Solar Projects in NY - map showing all completed and in progress solar projects in NY
https://data.ny.gov/Energy-Environment/All-PV-Projects-Completed-and-Pipeline-Reported-by/njm5-8gee

NYSEG - distributed interconnection map for NY
http://iusamsda.maps.arcgis.com/apps/webappviewer/index.html?id=2f29c88b9ab34a1ea25e07ac59b6ec56

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