GBT Facility Expansion and Improvement Project

Photovoltaic Power Generation Study
November 2009

Executive Summary

This report evaluates the use of solar energy to produce electricity through the installation of silicon photovoltaic (PV) collectors on the roof of the bus storage and maintenance facility of the Greater Bridgeport Transit Authority (GBTA). Crystalline silicon structure PV modules are recommended for their efficiency and durability.
A system capable of generating 200,000 watts of power is considered the base case based on the parameters of the proposed project. This size system will easily fit on the proposed roof and at peak generation will produce enough power to supply the entire facility.

The cost to install such a system is estimated at approximately $1.2 million.
Presently there is no available incentive funding options from either the Connecticut Clean Energy Fund or state federal incentive programs. It may be possible to offset some of the original purchase and installation cost in the future through new or re-funded programs but at this time it is only conjecture.

The simple payback, a measure that calculates the energy savings from the system versus the cost of the system, yields a return of 35 years based on the electricity cost savings. If the simple payback is modified to account for an increase in electrical energy cost by 3% annually the payback drops to only 23 years. Although this length of a payback is not typically recommended some non-intrinsic value may be considered such as the environmentally “Green” public relations perception. The renewable energy produced by the PV will offset energy primarily produced through the burning of carbon releasing fossil fuels. The amount of energy expected to be produced by the PV will reduce the amount of carbon emissions by 125 metric tons of carbon dioxide per year.

Since one of the goals of the future renovation of the Bridgeport facility is to obtain LEED Silver Certification, one non-intrinsic value to consider for the PV system is the potential to earn seven points towards the minimum 50 points required to obtain the Silver certification rating.

Introduction

Photovoltaic (PV) technology uses the sun’s energy to make electricity. PV technology produces electricity directly from electrons that are “freed” by the interaction of sunlight with certain semiconductor materials, such as silicon, in the PV module. The electrons are collected to form direct current (DC) electricity similar to battery power.
By electrically connecting PV modules into panels and panels into solar arrays, usable PV power generation can be accomplished.

PV panels sold commercially typically range in power output from as little as about 10 watts up to 300 watts. A complete PV system usually consists of an array of panels that are connected to an inverter. The inverter changes the PV's DC electricity to alternating current (AC) electricity. The AC power is connected to the facility power distribution system that is used to power electrical equipment and is compatible with the utility electric grid.
In locations where either the utility is unavailable or less reliable, batteries are sometimes included in a system to provide a means to provide back-up power during dark hours or in case of utility power outages.

PV cells can be made from several different manufacturing processes or technologies. They all do the same job — produce electricity from sunlight. The PV cells can be applied through differing technologies including roof membrane, fixed panels and sun tracking mechanisms.

The electrical performance of a PV system is based primarily on the amount of solar radiation received and the type of PV product used. During the summer months the angle of the solar radiation incident on the panels and the number of hours of daylight greatly improve the overall performance of the system when compared to the performance during the winter months. Thin film PV systems will typically generate approximately 6 watts per square foot compared to the more expensive crystalline PV that produces approximately 10 watts per square foot. The outputs of the cells can be marginally improved through various means such as tilting them to a more perpendicular angle to the sun or by providing a mechanical means to pivot the panel to track the path of the sun. Both of these methods require a significant increase in installation cost as well as increases in maintenance and potential failure modes. A fixed tilt PV Panel system is considered in the following evaluation.

Controls and Equipment

The equipment required for a complete installation includes the following

- Silicon Photovoltaic (PV) Roof Panels; These generate DC power from the light of the sun.
- Combiner Boxes; These are used to 'combine' (add) the outputs of the individual PV panels to create a usable DC output power.
- Inverters; These are used to convert the DC power from the PV panels into AC power which is usable by the facility electric loads.
- Transformers; These are used to either step up or step down the inverter output voltage. The transformers condition the output power to match the facility system voltage and they also provide a means of grounding the PV electric system.
- Over current protection that will safely interrupt power under fault conditions.

Additional equipment such as safety disconnect switches, conduit, wire and any system interconnection equipment deemed necessary by the local utility as well as the National Electric Code will also be required.

The features offered with the inverter equipment package are the standard controls for the operation of the photovoltaic system. These standard features typically include:

- Over and under voltage trip and alarm (protects the PV system and electric distribution system from inappropriate voltage outputs from the PV panels or the inverter equipment
- Over and under frequency trip and alarm (required by the national electric code and UL to protect the utility from a nominal 60 Hz frequency excursion).
- Anti-islanding protection (required by the local utility to prevent energization of the utility electric system upon a loss of normal utility power).
- Self-synchronization output control (required with poly-phase electric systems to ensure synchronized and proper phase rotation of the power being supplied to the electric distribution equipment).

Additional controls and monitoring devices such as;
Power output monitoring,
Weather and sunlight monitoring information and
Data tracking, etc.
may be desired or required based on the needs of the facility or the conditions of a funding program's specific installation requirements.

Installation Requirements

The electrical equipment, with the exception of the PV panels and combiner boxes, would likely be installed within the bus storage area of the facility. The inverters, transformers, over current protection and safety disconnect switches will be located in a designated area of the building. Roof penetrations would be minimized and could be located such that their impact to the aesthetics of the building and consequences of failure are negligible. The final location, including the type and quantities of equipment required, will not be determined until the project is approved and the detailed design is performed.

Implementation Cost

Approximately 20,000 – 25,000 square feet of usable roof space would be necessary for the installation of PV roof panels for the proposed capacity system. There is more than adequate space on the bus storage facility building for the installation.

Cost estimates provided from two manufacturer representatives of the proposed PV products have ranged from $6 to $8.50 per watt based on the type of PV and the power rating of the system. The variances in costs arise from the different types of PV modules available (Thin film vs. Crystalline vs. Ribbon String) as well as the specific type of installation. The size of the installation is also a factor of the cost due to the economies of scale.

"Thin film" PV products average 6 watts per square foot and cost approximately $5 to $7 per watt installed (equipment and installation price is based on a 200kW design output system).

"Crystalline" and "Ribbon String" PV products average 10 watts per square foot and cost approximately $6 to $8 per watt installed (equipment and installation price is based on a 200 kW design output system).

The use of the less expensive thin film PV technology is not recommended. Variations in manufacturing quality, product reliability and the fragility of the finished product all point to a less durable more troublesome application. Crystalline and ribbon string PV panel products are recommended for this application. They are easier to clean and maintain, (important given the local seagull population) and provide a better power density than alternative technologies.

Utilizing the "crystalline" type PV (recommended), over the available 20,000 square feet, would yield a nominal 200 kW output. The installation cost of the complete system, based on $6.00 per watt, would be approximately $1.2 million.

Estimated Savings

Savings will be realized in a few ways.

- Savings could be realized through displaced costs associated with the typical roof construction. Some materials that would normally be installed for the roof will not be required since PV roof tiles could be installed in their place. This is estimated at approximately $0.15 per square foot or approximately $3000 for the estimated 20,000 square feet application.
- Savings could be realized due to the extended roof life associated with the shading of the roof membrane provided by the PV tiles. The replacement roof can be delayed years beyond the normal life expectancy of the typical roof.
- The majority of the savings associated with a PV system are in the reduced amount of utility provided electricity required to serve the facility. On a bright sunny summer day, a 200 kW crystalline silicon PV type system could likely provide enough power to support the entire facility. An estimate of the electric energy savings based on a 200 kW crystalline PV system, applied flat on the storage building roof, is approximately $34,000 per year.

During the month of June, the proposed 200 kW system in Bridgeport could be expected to produce approximately 28,000 kilowatt-hours of electricity. During the month of December the same system could be expected to produce 17,000 kilowatt hours. The sample system has the potential to produce a total of 298,000 kilowatt-hours over the course of one year.

The aforementioned calculations are performed using a program available through the National Renewable Energy Laboratories called PV Watts. The monthly and yearly energy production is modeled using the input PV system parameters and the weather data typical of the area where the system is proposed. Based on this information the effective output of the system is calculated. The programs input parameters include the AC output rating of the system, the type of PV system, the tilt angle of the panels and the local cost of the electricity. A sample of the program calculation output is attached.

Simple Payback

Assuming no further incentive subsidy, the simple payback of the system is calculated by dividing the cost of the installation by the yearly amount of incremental savings associated with the measure. The incremental cost of the extended roof life has not been included in this calculation.

$1,200,000 equip. and install. - $3,000 offset roof mat'ls
$34,000/year electric bill savings =35 years

It should be noted that the normal life expectancy of the PV panels is approximately 25 years.

A modification to the simple payback to account for anticipated escalation in the cost of electricity follows. The assumption is that the cost of electricity will increase 3% annually. The result increases the amortized electric savings to $52,000/year. The payback is now calculated;

$1,200,000 equip. and install. - $3,000 offset roof mat'ls
$52,000/year electric bill savings =23 years

Funding Sources

Presently there are no available funding sources to assist or offset the cost of the installation of a PV array for generating power at the Bridgeport facility. As a proven technology, PV research and development funding has significantly decreased but the popularity and usefulness of the application has promoted its use. This increased use has effectively decreased the cost of the equipment and installations due to market competitive influences.

Some of the typical funding incentives include Renewable Energy Federal tax credits or tax offsets. Since GBTA does not pay Federal tax, this project is not eligible for those types of funding incentives.

GBTA may be able to obtain a funding subsidy from the Connecticut Clean Energy Fund (CCEF) through their On Site Distributed Generation (OSDG) program. The OSDG program is a financial support program for new or refurbished generating equipment for renewable energy generating systems at Commercial, Industrial, and Institutional facilities in Connecticut. Through the OSDG Program, CCEF offers financial support to buy down the cost of renewable energy generating equipment for projects that are still in their development phase and have yet to commence their construction phase. The level of support for individual awards is not a fixed amount based on size or cost, but will vary based on the specific technology, efficiency and economics of the installation.

At the time of this report the CCEF OSDG program has been completely spent and no new applications are being accepted. There is a possibility of a new round of funding in the future but at this time no information on the revised program is available.

Leadership in Energy Efficient Design (LEED)

LEED Silver Certification is the intended goal of the new building project. To meet that goal a total of 50-59 total points are required.

Under the LEED Energy and Atmosphere category there is a potential to obtain up to seven points for renewable energy. Solar power through the PV system proposed would qualify for the renewable points under LEED. Seven points would be awarded if the renewable system can provide an offset of 13% to the buildings energy costs . Although the system and the building have not been designed, this cost offset is certainly achievable.
The seven point award for the renewable energy would represent 14% of the LEED Silver Certification goal.

Although the PV System proposed does not necessarily achieve a favorable simple payback, the added benefit of the LEED certification points and the perception that the project and the owner as a steward for the environment may justify and ultimately overcome the lack of a strict financial incentive.