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Incorporating Alternative Energy into NJDOT's Physical Plant

FINAL REPORT
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16. Abstract

The objective of this research was to clarify the technical, financial, regulatory, and environmental feasibility of incorporating renewable, on-site energy infrastructure into three selected NJDOT facilities (the Ewing Headquarters campus, the Mt. Arlington Regional Headquarters, and the Newark Maintenance Yard). Seven site configurations were analyzed, with a crystalline silicon (panel) and thin film photovoltaic version for each – yielding fourteen total scenarios (10 of which involve facilities at the Ewing Headquarters campus).

For each scenario, the Final Report presents potential first costs, yearly utility savings, years to payoff (discounted), estimated net present value (NPV) of each investment after 10 years, and greenhouse gas equivalent Car Years. Supporting documentation is included in three appendices, first created as technical memoranda.

It was determined that any one of the scenarios analyzed may make sense for NJDOT, depending on circumstances and objectives. The Report recommends that NJDOT move forward by 1) establishing expectations for financial returns, electricity costs, greenhouse gas impacts, and/or other criteria, 2) coordinating with the New Jersey Office of Energy Savings (OES) in order to benefit from OES's statewide renewable energy activities, and 3) seeking implementation assistance, which may mean soliciting competitive bids from third-party solar developers for a Power Purchase Agreement.

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EXECUTIVE SUMMARY

This report provides a framework for understanding the financial feasibility of incorporating solar photovoltaics (PV) at three New Jersey Department of Transportation (NJDOT) facilities (the Ewing Headquarters Complex, the Mt. Arlington Regional Headquarters, and the Newark Maintenance Yard). The results are intended to serve as realistic, but ballpark potential outcomes for power production, costs, and financial return and should not be considered "investment-grade."

This report is underpinned by a trio of previous memoranda, included as appendices to this document, and should be viewed as the final installment of a series. The three previous memoranda were:

- ***Existing Energy Profiles* –** An analysis of monthly utility data, with a focus on electricity, for the three selected sites.

- ***Summary Scan of Scalable Renewable Energy Technologies* –** A scan of scalable, alternative energy technologies currently in use in the United States. Out of this analysis, a recommendation was made to proceed with solar photovoltaics.

- ***Solar Photovoltaics Focused Review* –** Context for photovoltaic project development at NJDOT. It includes an overview of critical factors, including Power Production and Impacts, Project Implementation, Zoning and Permitting, State Policy and Planning, Interconnection and Net Metering, and Renewable Energy Incentives.

This report outlines the methodology, inputs, and assumptions relating to power production, financial results, and greenhouse gas emissions, which were employed to generate scenario-specific results using a standard benefit-cost spreadsheet model. While these assumptions are not made explicit in each scenario analysis, they were fundamental to the final outputs.

Seven site configurations were analyzed for power production and financial return, with a crystalline silicon (panel) and thin film version for each – yielding a total of fourteen scenarios. The results are summarized in Table 1.

Table 1 - Summary of results

Description	First Cost	Yearly Utility	Lifetime Incentives	Pay back	NPV 10 YRS	Lbs. of CO2 Reduced
Thiokol Roof – Crystalline	$682,061	$32,478	$1,378,254	**6**	**$284,928**	**235,861**
Thiokol Roof – Thin Film	$314,483	$18,269	$778,593	**5**	**$226,352**	**132,672**
Thiokol Full Area – Crystalline	$3,967,532	$188,922	$7,979,112	**6**	**$1,507,219**	**1,371,997**
Thiokol Full Area – Thin Film	$2,632,460	$154,313	$6,529,320	**5**	**$1,891,131**	**1,120,660**
E&O – Crystalline	$1,066,455	$45,149	$2,154,968	**7**	**$301,930**	**368,787**
E&O – Thin Film	$491,718	$25,396	$1,210,764	**5**	**$323,209**	**207,443**
F&A – Crystalline	$375,375	$15,765	$763,018	**6**	**$134,669**	**129,807**
F&A – Thin Film	$173,077	$8,868	$464,122	**4**	**$151,176**	**73,016**
E&O and F&A – Crystalline	$1,441,830	$60,914	$2,913,486	**6**	**$507,205**	**498,594**
E&O and F&A – Thin Film	$664,795	$34,264	$1,636,886	**5**	**$474,385**	**280,459**
Newark – Crystalline	$857,143	$42,573	$1,732,045	**6**	**$347,227**	**296,405**
Newark – Thin Film	$672,221	$40,732	$1,655,268	**5**	**$487,615**	**283,592**
Mt Arlington – Crystalline	$975,000	$48,628	$1,966,041	**6**	**$392,341**	**337,161**
Mt Arlington – Thin Film	$449,550	$27,353	$1,108,669	**5**	**$328,658**	**189,653**

Any one of the 14 scenarios may make sense for NJDOT, depending on circumstances and objectives. This report recommends that NJDOT:

- Establish expectations for financial returns, electricity costs, greenhouse gas impacts, and/or other criteria, depending on NJDOT's needs and resources.
- Coordinate with the New Jersey Office of Energy Savings (OES) in order to benefit from OES's statewide renewable energy activities.
- Seek implementation assistance, which may mean soliciting competitive bids from third-party solar developers through a power purchase agreement.

It also is recommended that NJDOT explore other, complementary renewable energy technologies and work with a professional energy auditor to identify potential energy efficiency and conservation measures. These activities may serve to enhance the potential contribution of solar photovoltaics to meeting the energy needs and lowering the energy costs of NJDOT's facilities.

INTRODUCTION

This report provides a framework for understanding the financial feasibility of incorporating solar photovoltaics (PV) at three selected New Jersey Department of Transportation (NJDOT) facilities (the Ewing Headquarters Complex, the Mt. Arlington Regional Headquarters, and the Newark Maintenance Yard).

The task of determining potential financial performance requires clarification of the potential capacity, power production, costs, direct revenues, and incentives pertaining to PV at each site. In turn, such clarifications require knowledge of siting and project implementation, technical feasibility, regulatory constraints (and opportunities), and environmental implications. At a more fundamental level, the selection of PV over, or in concert with, other promising on-site renewable energy technologies necessitates a balanced, New Jersey-specific review.

This report is underpinned by a trio of previous memoranda, which can be found in the appendices. These documents provide insights into the existing power usage and needs of NJDOT's facilities, set out the original process used to select PV as the renewable technology for analysis, and treat a host of technical, environmental, regulatory, and policy factors critical to PV project implementation. Although abstracts of these memoranda are included herein for easy reference, this Report relies on the full-fledged versions for context, and should be viewed as the final installment of a series. Ideally, this Report will be read last. The content of the three previous Memoranda is summarized as follows:

Existing Energy Profiles

An analysis of monthly utility data was conducted, with a focus on electricity, for three selected sites: NJDOT Headquarters campus (Ewing), the Newark Maintenance Facility (Newark), and the Mt. Arlington Regional Headquarters (Mt. Arlington). Because, under New Jersey state law, current electricity demand characteristics limit the potential size of net metered renewable energy installations, this analysis comprised an important step in evaluating the feasibility of renewable energy at a specific facility.

Preliminary review identified five large accounts offering the greatest potential for renewable energy integration:

- Mt. Arlington's account.
- The larger of Newark's two accounts.
- Thiokol 2-5 and 9 (Ewing).
- E&O (Ewing).
- F&A/Fernwood (Ewing).

The figures of greatest importance in determining the potential nameplate capacity of a renewable energy installation are “Peak kW” and “Average Cost/kWh.” “Consumption,” especially on an annual basis, is of minor importance in sizing an array, particularly when there is little expectation of generation exceeding consumption (as is the case with all of the facilities analyzed).

- **Peak kW:** New Jersey’s net metering law limits the capacity of on-site renewable energy installations to customers’ annualized peak demand. In practice, this means that a given meter’s peak reading dictates the maximum nameplate capacity of the PV array to which it is connected. For this reason, only the larger accounts merited serious evaluation.

- **Avg. Cost/kWh:** The financial feasibility of on-site renewable energy favors high-utility charges (the cost of renewable energy must be competitive relative to grid-supplied power). Average cost provides a broad annual look at several monthly cost components, namely peak- and off-peak kWh charges and demand charges.

Appendix A presents a complete review of utility data for the three properties.

Summary Scan of Scalable Renewable Energy Technologies

The scan of scalable renewable energy technologies establishes the foundation for subsequent project tasks. It summarizes scalable, alternative energy technologies currently in use in the United States and recommends proceeding with solar photovoltaics. Based on the application of New Jersey- and NJDOT-specific selection criteria, the following renewable energy technologies were included in this review:

- Solar Photovoltaics (also known as PV, semiconductor panels that convert sunlight into electricity).

- Solar Thermal (air or water heated by sunlight and used in building heating or cooling systems).

- Small Wind (small-scale, tower-mounted wind turbines or building-integrated turbines that generate electricity).

- Ground Source (Geothermal) Heat Pumps (loops of fluid-filled tubing that use stable ground temperatures as a heat source or sink to lower building heating and/or cooling loads).

- Energy Efficiency and Energy Conservation Measures (a wide variety of technologies and strategies used to reduce energy consumption and increase equipment/building systems efficiency).

Each technology was assessed relative to one another through the employment of a simple screening matrix. Solar photovoltaics was the technology recommended for further study, due to its composite performance across four screening categories:

- **Site:** PV is highly scalable, and can be installed in a variety of configurations, with few restrictions.

- **Energy:** While New Jersey has only modest solar resources, a sizeable array could contribute meaningfully to building loads and could be exported to the grid. Additionally, maximum PV production often occurs during peak periods, helping to "shave" loads when power is most expensive. Finally, electricity, the energy product from photovoltaics, is much easier to integrate into existing buildings than thermal energy (the direct product of two of the four methods of energy generation assessed).

- **Cost:** Unincentivized PV payback periods are often longer than for thermal energy technologies, but electricity can be exported to the grid and is eligible for Renewable Energy Certificates (RECs). New Jersey provides a particularly supportive financial environment for PV.

- **Local** (Policies, skill sets, and availability)**:** New Jersey has the second most installed PV capacity in the country, behind only California (which has far superior solar resources and a much higher load). New Jersey has a plethora of manufacturers, installers, and developers that specialize in large-scale solar. This situation is the direct product of a policy framework that champions solar energy in New Jersey.

The scan recommends considering energy efficiency and energy conservation measures as complements to photovoltaics. These strategies can provide cost-effective solutions to reducing energy loads, thereby reducing the size or increasing the efficacy of PV installations.

Appendix B presents the complete review of scalable renewable energy technologies.

Solar Photovoltaics Focused Review

This review builds on the general overview of solar photovoltaics (PV) described in the summary scan above. It provides context for photovoltaic project development at NJDOT by providing an overview of critical factors, including:

- Power Production and Impacts*:* The quantity of electricity generated by PV depends primarily on the quality of solar resources (amount of daily direct sunlight), as well as the quantity and efficiency of the panels and complementary equipment. Although New Jersey has the second most installed PV capacity in the country, the State possesses only modest solar resources.

- Project Implementation*:* PV siting and module orientation must maximize the amount of direct sunlight collected while protecting the system from hazards. A variety of additional equipment is required to integrate PV into on-site facilities and into the grid, most notably direct current (DC) to alternating current (AC) inverters.

- Zoning and Permitting*:* As a state agency, NJDOT is exempt from municipal land use law, instead relying on the New Jersey Department of Property Management and Construction for plan review and the New Jersey Department of Community Affairs for permitting. PV is not mentioned as a hazard to air safety in the Federal Aviation Administration code.

- State Policy and Planning*:* State policies have created a environment favorable to PV manufacture and development in New Jersey, with an ambitious Renewable Portfolio Standard which sets specific targets for solar energy and imposes stiff penalties for noncompliant utilities. The State also offers support for potential customer-generators through the New Jersey Office of Clean Energy and, for state agencies, through the Office of Energy Savings.

- Interconnection and Net Metering*:* New Jersey features relatively accommodating laws for customer-generator interconnection to the grid and net metering. The primary restriction on PV capacity is that the system nameplate, in AC, may not exceed the customer's annualized peak demand.

- Renewable Energy Incentives*:* New Jersey and its regulated utilities offer a broad array of incentive programs to increase the financial competitiveness of renewable energy. Of particular interest is the Solar Renewable Energy Credit (SREC), which customer-generators can sell via auction to Load Serving Entities seeking to fulfill their Renewable Portfolio Standard (RPS) obligations. Federal incentives are available as well, although many, including tax credits and accelerated depreciation, will only benefit NJDOT if a private, third-party solar developer owns the PV system.

Appendix C presents the solar photovoltaics focused review.

METHODOLOGY, INPUTS, AND ASSUMPTIONS

The projected financial results presented for each PV scenario were derived through an initial analysis of potential on-site power production, which then informed a discounted analysis of benefits and costs. Although the analyses were performed using a standard benefit-cost spreadsheet model, a host of inputs and assumptions – some general, some scenario-specific – were required to operationalize the model. General inputs and assumptions, especially those related to potential power production and system costs, were sourced from Federal research agencies, reliable industry publications, and two New Jersey PV manufacturers. The overarching methodologies, inputs, and assumptions detailed in this section were applied to each scenario analyzed. While these assumptions are not made explicit in each scenario analysis, they were fundamental to the final outputs. Instead, a full review of these assumptions is undertaken in this section.

Although data were carefully validated, many model inputs are inherently variable, whether due to unique, real-world conditions (such as the suitability of roofs or roofing systems for PV) and/or specific installer preferences (related to PV siting, orientation, coverage, density, and power production capabilities). Reasonable adjustment of a few key inputs may significantly affect results, especially for scenarios with larger PV systems. The goal of the exercise was not to generate investment-grade results, but rather to provide realistic, ballpark estimates of power production, costs, and financial return to demonstrate the potential value of on-site renewable energy systems at three separate NJDOT facilities.

A note on approach: A site-specific, investment-grade study would involve the choice of a specific PV system, including panels/films, racking, inverters, other balance of service components, contractor, and more. This level of detail would provide relatively definitive inputs for siting, component quantities, power production, hard and soft costs, and total return, although some uncertainty would remain. This level of customization, however, is not considered desirable for achieving the goals of this study, which are broader in scope. Therefore, the inputs and assumptions employed herein are scalable, based on accepted ratios or unit-based costs and benefits. For example, the project-specific PV capacity (in kW or MW) could be determined exactly by multiplying a given panel's rating by the exact quantity of panels installed. This study derived installation sizes by multiplying the area (square feet) of panel/film installed by an industry-derived watts-per-square-foot (W/sf) calculation, which differs between panel and thin film.

Power Production

The power production (kWh) of PV is dependent on a number of factors both internal and external to the system. The primary external generation factor is insolation (incidence of solar radiation), a measure of the solar radiation energy reaching a given space in a given time. For PV, insolation is commonly expressed in kilowatt hours per square meter per day (kWh/M^2/day). Areas with fewer average hours of sunlight (Direct Normal Irradiance (DNI)) and cloudy, hazy, or polluted atmospheric conditions receive less insolation. New Jersey's DNI is modest – approximately 4.2 hours/day – with a correspondingly modest insolation rate. Although slight variations in average insolation exist between each site, the NREL 30-year average rates for Trenton were employed for all analyses, given the potential for fluctuations in actual insolation at each site on a year-to-year basis. The inclusion of site-specific insolation rates, therefore, would have confused, rather than clarified, the results.

Beyond natural and geographical factors relating to the incidence of sunlight, the tilt and tracking characteristics of PV systems can greatly affect insolation, depending on the season. First, PV is almost always oriented to the south, unless shading or building features cause obstructions. PV systems can be positioned horizontally (lie flat) or be tilted at a variety of angles, most often referenced to latitude (for example, latitude plus or minus 15 degrees). Horizontal systems sacrifice insolation during colder months, when the sun sits lower in the sky, whereas tilted panels allow for significantly greater insolation during winter. However, horizontal PV receives marginally more insolation during high summer, when the sun passes overhead.

Figure 1 (following page) shows average monthly insolation curves (measured in daily kWh/M2) from January to December for horizontal (light blue) and latitude tilt (dark blue) PV systems in Trenton, New Jersey. Compared with a horizontal system, latitude tilt PV maintains moderate energy production during winter months and yet allows for significant summer “peak shaving” – the removal of a portion of the expensive peak of the utility-purchased power curve by substituting electricity generated on-site. Greater tilt angles (for example, latitude plus 15 degrees) offer greater potential energy production in midwinter months, but will generally produce less power during summer months.

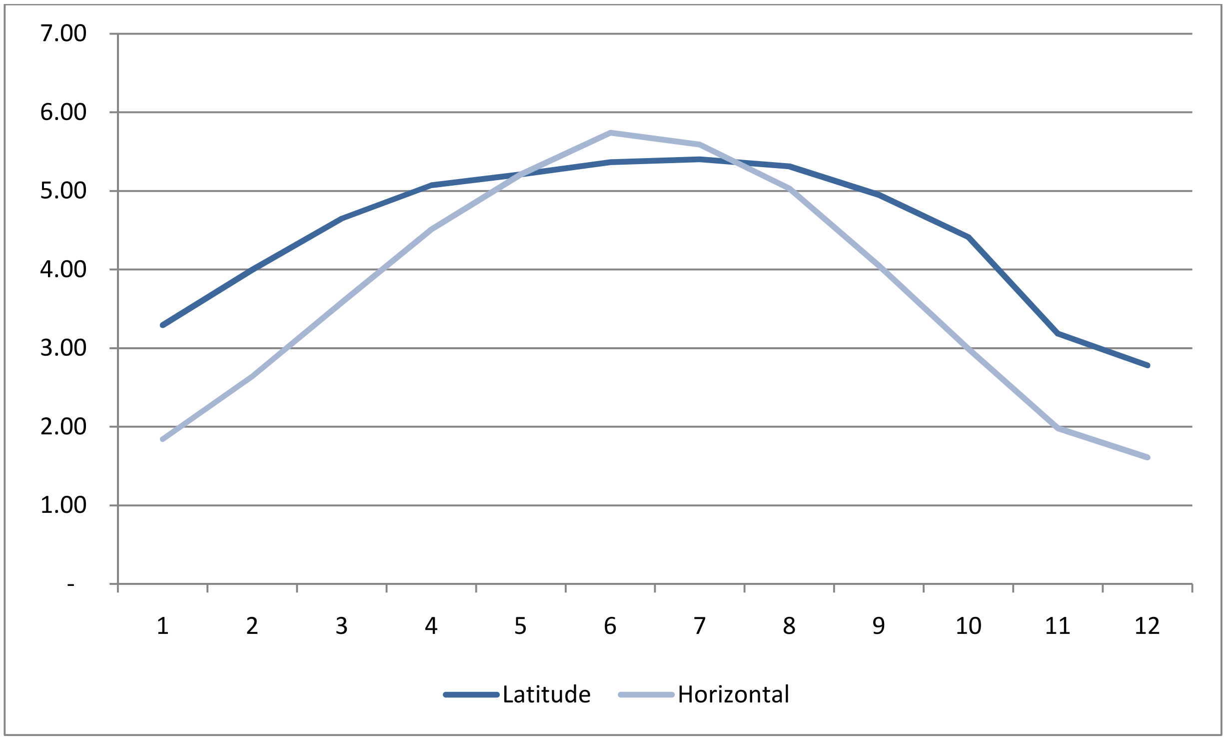


Figure 1. Average monthly insolation curves

Advanced one- or two-axis mounting systems boost insolation by tracking the sun's path across the sky, compensating for either the arc or the angle above the horizon, or both. These variable tilt mounts present more PV surface area to the sun for longer periods of time than fixed mounts, thus increasing insolation. However, they come with additional complexity, expense and maintenance requirements.

For the purposes of this analysis, average insolation for a latitude tilt system was used, returning the monthly insolation figures displayed in **Table 2**, measured first in kWh/M2 daily and then converted into monthly kWh/sf of PV (note that longer, 31-day months may return marginally greater monthly insolation than shorter, adjacent months with greater daily insolation).

Table 2 - Monthly insolation, Trenton, New Jersey

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOT
kWh/m2/day	3.4	4.1	5.1	5.3	5.6	5.6	5.5	5.5	5.3	4.7	3.5	3.2	4.7
kWh/sf/day	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	
kWh/sf/month	9.7	10.7	14.7	14.7	16.0	15.6	15.7	15.7	14.7	13.7	9.8	9.1	**160.2**

With insolation rates established, the total insolation (the sun's total power) available at a given facility depends on the collective surface area of PV cells. Surface area may be constrained by two primary factors – the gross area available for installation or the peak annualized electricity demand registered by the relevant feed-in meter.[1]

For systems constrained by space, the calculation is anchored by a measurement of the unshaded, unobstructed area available for PV installation, whether roof, ground or both. Rooftop mechanical equipment, overhangs, surrounding structures, tree cover and vegetation will limit areas where PV should be installed. See Appendix C, "Project Implementation," for further guidance.

The gross square footage underpinning each scenario evaluation was measured from high-resolution aerial photographs, and was generally restricted to structures sharing a single meter (although a second wave of cross-meter analyses were performed for the Thiokol and E&O and F&A buildings). The gross square footage figures derived should be considered conservative, in that they do not include surfaces that are irregular, substantially disrupted by mechanical equipment, or prone to shading – all factors that contractors could decide to work around or with. The Thiokol ground area, which features tree cover, is an exceptional case that will be treated subsequently, in Results.

PV area (the actual square footage of energy producing material) is typically a substantial fraction of gross square footage available for installation. Tilted photovoltaics, for example, may necessitate the separation of rows in order to avoid self shading (steeper angles require greater spacing), and horizontal photovoltaics often require aisles of uncovered space for maintenance and ventilation. Moreover, most systems are not purely photovoltaic – the "package density" of PV, a ratio of PV cells to total panel area, will cause modest further reductions in PV area. In order to account for these and other potential losses, PV area is assumed to be 75 percent of available gross square footage for flat roof and ground mounted PV, and 85 percent for pitched roofs (such as the Newark facility).

A given system's capacity, measured in kW, is then approximated by multiplying the PV power rating (W/sf) by the PV area. Based on specifications obtained from PV manufacturers, panels were assigned a rating of 13 W/sf, and thin film 6.66 W/sf. For example, 100 square feet of PV area would yield a 1.3 kW panel system, and a.66 kW thin film installation (both measured in direct current).

Where sufficient space exists, the constraining factor becomes the facility's peak annualized electricity demand, as measured by the utility meter. New Jersey's interconnection and net metering laws (explained in Appendix C) restrict a customer-

[1] PV installations at NJDOT facilities are not constrained by local zoning: as properties of a State agency, all selected facilities are exempted from municipal zoning and development review requirements. Plan and code review for NJDOT facilities is conducted by the New Jersey Department of Property Management and Construction, rather than local inspectors. All permitting – including building, electrical, fire, and plumbing – is conducted by the NJ Department of Community Affairs. Moreover, based on FAA standards and the New Jersey *Air Safety and Zoning Regulations*, no facility under review is situated within an airport safety zone, nor would PV systems exceed the heights of surrounding structures.

generator from returning more power (measured in alternating current) to the grid than was supplied by the utility over "an annualized period." In this instance, the system capacity is designed to equal the peak demand. If the customer-generator wishes peak generation to exceed peak demand, the PJM Interconnection process must be undertaken, which entails significant complexity and was not considered in this study (see Appendix C).

Because demand is measured in AC and system size in DC, a "derate" factor of .77 is applied (NREL) to compensate for the inefficiencies inherent in conversion. The result is a modest upsizing of the hypothetical system's Standard Test Condition (STC) rating (DC nameplate capacity), and therefore a greater PV area. For example, a peak demand of 100 kW (AC) yields a nearly 130 kW DC system (100kW AC/.77). Rather than depending on a facility's gross square footage, PV area is derived by dividing the W/sf rating by overall system size (DC). A 130 kW panel system would require about 10,000 square feet of PV area (or 13,333 square feet of available flat roof space), whereas a comparable thin film system would require over 19,500 square feet of PV area (over 26,000 gross square feet). Given the differential in W/sf ratings between crystalline silicon and thin film photovoltaics, several facilities are limited by interconnection rules for panel systems and by space for thin film systems.

The sun's potential power is calculated monthly for each scenario by multiplying PV area, however derived, by insolation rates. Continuing with the previous 130 kW panel system example, the equivalent of 15.6 kWh of sunlight could be expected (on average) to strike each square foot of PV material in the month of June, totaling 156,000 kWh.

Unfortunately, even quality, modern photovoltaics are able to transform only a small fraction of the sun's total energy into electricity – of the photons that strike the PV cell, only a certain portion are absorbed and produce power. These losses are expressed by an "efficiency factor." A key factor in determining efficiency is the semiconductor used, although other factors (such as the inverters) remain important when assessing actual power production. Panels and thin film photovoltaics have substantially different typical efficiency ranges. This study employed efficiency factors of 16 percent for panels and 9 percent for thin film, figures achieved by current PV models produced by New Jersey-based manufacturers and confirmed as reasonably representative by recent NREL technology surveys. Therefore, of the 156,000 kWh of sunlight available, the hypothetical panel system will convert 16 percent to direct current electricity, or just under 25,000 kWh. In order to account for DC-AC conversion losses, the resulting power production is adjusted downward by a derate factor of.77 (the NREL PVWatts default), yielding a final production figure of 19,200 kWh for June. This operation is performed for each month of the year in order to determine the monthly quantity (in kWh) of avoided utility-provided electricity for each scenario.

Finally, a compounded performance degradation factor of 1 percent, an industry standard, is applied to production for each year beyond Year 1. While virtually unnoticeable initially, this adjustment reduces output significantly toward the end of system life (usually 25-30 years).

Financial Return

Benefits

Monthly power production anchors several critical inputs into the benefit-cost calculus of each scenario. First, each kWh produced by PV displaces one kWh of electricity from the utility provider, whether that power is consumed on-site or returned to the grid through net metering. It is important to calculate on-site energy production by month, rather than as a yearly aggregate, because both electricity rates and consumption change throughout the year. Generally, for a typical office facility, consumption and peak demand are greatest during summer months, and both demand charges and unit costs rise accordingly. Therefore, for example, 19,200 kWh produced in June is likely to result in greater avoided cost than an equivalent amount produced during winter months (over a longer period of time).

For each scenario, the avoided utility cost is calculated separately for each month, and then aggregated to determine yearly savings, which then serves as a key benefit-cost input. Using an approximation of the U.S. Energy Information Agency's 2010 *Annual Energy Outlook* electricity cost projections, utility costs are escalated 0.5 percent per year.

A more significant source of revenue, also stemming directly from kWh production, is the sale of Solar Renewable Energy Credits (SRECs). New Jersey's Renewable Portfolio Standard (RPS) currently requires electricity suppliers or providers serving retail customers (collectively Load Serving Entities or LSEs) to obtain a percentage of their energy from qualifying renewable sources. New Jersey is one of a few States requiring a specific solar RPS target, currently 306 GWh (formerly 0.305 percent of total) and rising to 2,518 GWh by 2020 (formerly 2.12 percent of total). SRECs allow suppliers to purchase energy credits from producers of solar electricity in order to meet the RPS requirements. Currently, any utility-connected and metered customer-generator producing more than one MWh of solar power may be authorized to sell SRECs for up to 15 years on a single system. A Solar Alternative Compliance Payment (SACP), currently $693/MWh, is in place as a penalty should LSEs fail to achieve the mandated solar RPS. Given the currently tight supply of SRECs in relation to the solar RPS, the top auction price of SRECs has remained stable at around 95 percent of the SACP over the past year. In January 2010, the top auction price for SRECs was $675, with a weighted average of $533. Certificates are valid for two years from the date of issue.

For this study, the current weighted average price ($533/MWh in Year 0) was reduced by 2.5 percent for each out year. Year 1, for example, assumes that SRECs will sell at $519.82/MWh ($533.15 multiplied by [1-0.025]), with Year 15, the last year SRECs would be valid, selling at $364.69. Following the hypothetical 10,000-square-foot panel system, 19,200 kWh of June production in Year 1 might result in a $9,981 SREC sale ([19,200/1,000] multiplied by 519.82), which compares favorably to potential utility savings of around $3,260, based on fairly typical a 17 cent per kWh combined demand and consumption charge. Even in Year 15, SRECs might yield $7,000 in June, although future SREC costs are difficult to project with confidence. However, such substantial early year SREC revenues lead to reasonably rapid paybacks (full return on equity), shifting a bulk of the risk to out years when maximizing net present value (NPV) becomes a greater consideration.

Modest initial incentives, based on the size of the PV array and associated components, are also factored. The Renewable Energy Manufacturing Incentive (REMI) program provides rebates for homeowners and businesses that install photovoltaic system components manufactured in New Jersey (this study assumes that they are). There is no limitation on the size of eligible projects but incentives are limited to the first 500 kW for nonresidential systems. In order to receive incentives applicants must apply through the Solar Renewable Energy Certificate program. Equipment must be made by a program-certified manufacturer. Total incentives, as stated in a draft version of REMI circulated for comments by the New Jersey Board of Public Utilities, range from $0.08 to $0.14 per watt DC for panels, depending on sector and system size, and $0.05-$0.09 per watt for inverters, racking, and other equipment, again depending on sector and size. Commercial/industrial projects are divided into three tiers by size, with the smallest projects receiving the largest per-unit incentives.

In addition, the BPU maintains a customer-sited renewables rebate program for homes, businesses, institutions and nonprofits. As of the beginning of 2010, the rebate was set at $0.90 per watt (DC) of capacity. The rebate is available for systems with no more than 50kW.

Both REMI and the customer-sited renewables rebate are credited to Year 0 (the design and construction year), and result in especially rapid paybacks for smaller projects, particularly the F&A/Fernwood thin film scenario – the only project qualifying for the customer-sited rebate. REMI is structured to provide proportionately less benefit to larger projects, and, as a result, upfront incentives are less important to their success.

Should a private solar developer undertake and own a solar project at a NJDOT facility (under a power purchase agreement or PPA), a number of state and Federal tax incentives and financing programs could apply – which should result in lower energy costs for NJDOT. Although these incentives do not apply to NJDOT and therefore are not included in the benefit-cost analysis, they are detailed in Appendix C.

Costs

The capital costs of photovoltaic systems have fallen significantly in the past decade, but still constitute a substantial cost outlay. In order to calculate capital costs, a simple per-watt unit cost is multiplied by the total system size. The unit cost reflects a materials cost of $3.50 per Watt for PV panels or $3.00 per Watt for thin film, with components, installation, and other soft costs adding $1.50/W for each. These figures were quoted by a New Jersey PV manufacturer as reasonable estimates, and confirmed through NREL and an industry source that conducts cost surveys. A 100 kW panel system would therefore cost approximately $500,000 ($5 x 100,000 W).

Interconnection costs, which are negligible (less than $1,000 for each scenario), were not included in first costs.

Yearly operations and maintenance costs, while modest, are included in the benefit-cost matrix at a rate of 0.3 percent of total upfront costs, the default for NREL's Solar Advisor Model (SAM). This analysis assumes that inverters will require replacement every 10 years and will cost 51 cents per Watt (AC). In other words, a 100kW (DC) system will incur nearly $40,000 in inverter-related expenses each decade (100kW DC multiplied by .77 derate = 77 kW AC multiplied by 1,000 = 77,000 Watts multiplied by $0.51).

Financial Assumptions

Operations and maintenance expenses (O&M) are escalated by 4 percent each year, and a modest 5 percent discount rate is applied.

Each scenario is analyzed over 21 years, with capital costs allocated to Year 0, the design-build year, and Years 1-20 being the payback years. Particular emphasis is placed on the first 11 years – net present value (NPV) is calculated for Year 10, although a Year 20 NPV also is derived. A greater discount rate would reduce NPV, which becomes particularly noticeable in the later out years, whereas a smaller discount rate would yield greater paybacks. A levelized cost of electricity (LCOE) figure is not included for each scenario, due to debate on the proper calculation methodology, but is expected to be modestly more for panels than for thin film systems.

A more easily digestible measure, discounted payback, also is included. Payback, which is rounded to the nearest year, is simply the point when total discounted cash flows meet Year 0 costs. In all scenarios, paybacks are realized within the first seven years, with a few paybacks coming in just over four years.

Generally, smaller scenarios (in terms of system capacity and production) return faster paybacks, due to proportionately larger upfront incentives, but significantly smaller NPVs. Conversely, larger systems generally require more time to break even, but yield large cash flows until the cessation of SRECs at the conclusion of Year 15. With incentives expired, all systems still return relatively small, but positive cash flow from Years 16 to19, but dip into negative territory with the second replacement of inverters at Year 20 (inverter replacement costs at the end of Year 10 reduce cash flow, but are outweighed by the sale of SRECs).

Greenhouse Gas Emissions

Each scenario includes a simple calculation of estimated carbon dioxide savings in Year 1, before panel deterioration begins. The total CO^2 reduction is a function of the quantity of kWh produced by photovoltaics (which offsets grid-supplied energy) multiplied by the average CO^2 emissions associated with one kWh of utility generated electricity in New Jersey (currently 1,139 lbs/MWh, according to U.S. EPA).

In order to make this figure more easily relatable, it is converted into "car years," symbolizing the removal of the CO2 equivalent of one car from New Jersey's roads for one year. For the purposes of this exercise, the average car is assumed to travel 20.3 miles per gallon of gasoline, and each gallon of gas consumed results in the emission of 19.4 pounds of CO^2 equivalents (both figures are from U.S. EPA). The representative car travels 12,000 miles per year. "Car year" reductions can be converted into VMT reductions simply by multiplying by 12,000.

RESULTS

Fourteen scenarios were analyzed for power production and financial return: a crystalline silicon (panel) and thin film system for each selected site (E&O, F&A and Fernwood, Thiokol 2-5 and 9, the Newark Maintenance Yard, and Mt. Arlington Regional Headquarters). For Thiokol 2-5 and 9, the only site with significant surrounding open space, four scenarios were evaluated: rooftops only (panel and thin film) and all potentially available space, including adjacent ground area and the entire Thiokol print shop roof space (again, panel and thin film). Two additional scenarios evaluated PV for E&O with the addition of the nearby F&A rooftop for both panel and thin film – both the E&O and F&A Fernwood meters experience sufficient demand to easily accommodate the potential production from all available nearby roof space.

A summary of results is produced in **Table 3**, with the analysis for each scenario detailed subsequently. **Figure 2** graphs both 10- and 20-year projected NPVs.

Table 3 - Summary of results

ID	Description	First Cost	Yearly Utility	Lifetime Incentives	Pay back	NPV 10 YRS	Lbs. of CO2 Reduced
			(COST)/SAVINGS				
1	Thiokol Roof – Crystalline	($682,061)	$32,478	$1,378,254	**6**	**$284,928**	**235,861**
2	Thiokol Roof – Thin Film	($314,483)	$18,269	$778,593	**5**	**$226,352**	**132,672**
3	Thiokol Full Area – Crystalline	($3,967,532)	$188,922	$7,979,112	**6**	**$1,507,219**	**1,371,997**
4	Thiokol Full Area – Thin Film	($2,632,460)	$154,313	$6,529,320	**5**	**$1,891,131**	**1,120,660**
5	E&O – Crystalline	($1,066,455)	$45,149	$2,154,968	**7**	**$301,930**	**368,787**
6	E&O – Thin Film	($491,718)	$25,396	$1,210,764	**5**	**$323,209**	**207,443**
7	F&A – Crystalline	($375,375)	$15,765	$763,018	**6**	**$134,669**	**129,807**
8	F&A – Thin Film	($173,077)	$8,868	$464,122	**4**	**$151,176**	**73,016**
9	E&O and F&A – Crystalline	($1,441,830)	$60,914	$2,913,486	**6**	**$507,205**	**498,594**
10	E&O and F&A – Thin Film	($664,795)	$34,264	$1,636,886	**5**	**$474,385**	**280,459**
11	Newark – Crystalline	($857,143)	$42,573	$1,732,045	**6**	**$347,227**	**296,405**
12	Newark – Thin Film	($672,221)	$40,732	$1,655,268	**5**	**$487,615**	**283,592**
13	Mt Arlington – Crystalline	($975,000)	$48,628	$1,966,041	**6**	**$392,341**	**337,161**
14	Mt Arlington – Thin Film	($449,550)	$27,353	$1,108,669	**5**	**$328,658**	**189,653**

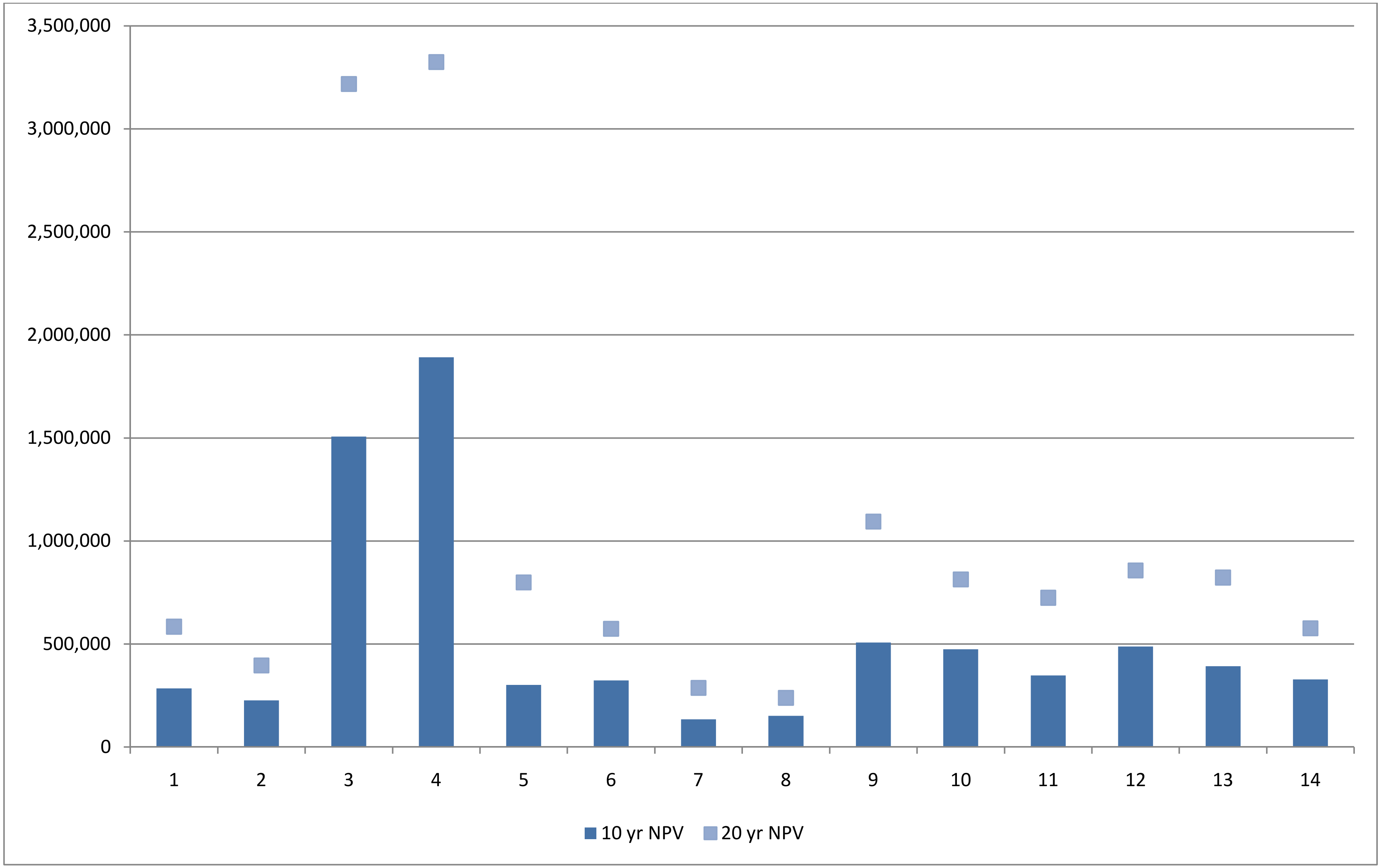
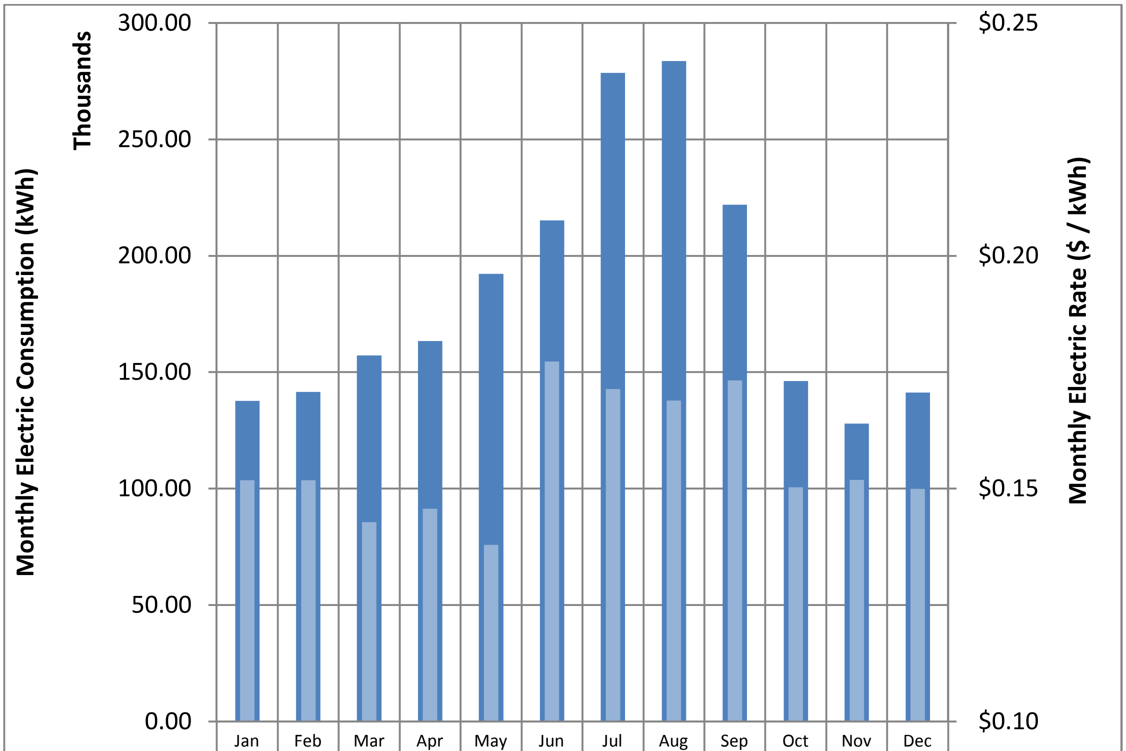


Figure 2. Estimated 10- and 20-year Net Present Value, by Project ID
(blue bars indicate 10-year NPV, light blue dots indicate 20-year NPV)

Ewing: Thiokol 2-5 and 9 (roof only)

<u>Existing Energy Profile</u>

The Thiokol account follows the classic bell shaped profile, with pronounced increases in consumption in July and August, tapering off quickly thereafter (**Figure 3**). Total consumption was 2,206,704 kWh (almost 16 percent of Ewing's total), with a peak of 611 kW, yielding a load factor of 41 percent. Electricity rates rise significantly from June through September as summer demand charges take effect. The total annual energy cost was estimated to be $349,951.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	137652	141503	157225	163372	192303	215251	278593	283582	221907	146140	127915	141261
Rate ($ / kWh)	$0.151	$0.151	$0.142	$0.145	$0.137	$0.177	$0.171	$0.168	$0.173	$0.150	$0.151	$0.149

Figure 3. Ewing Thiokol monthly kWh consumption and composite electricity rate

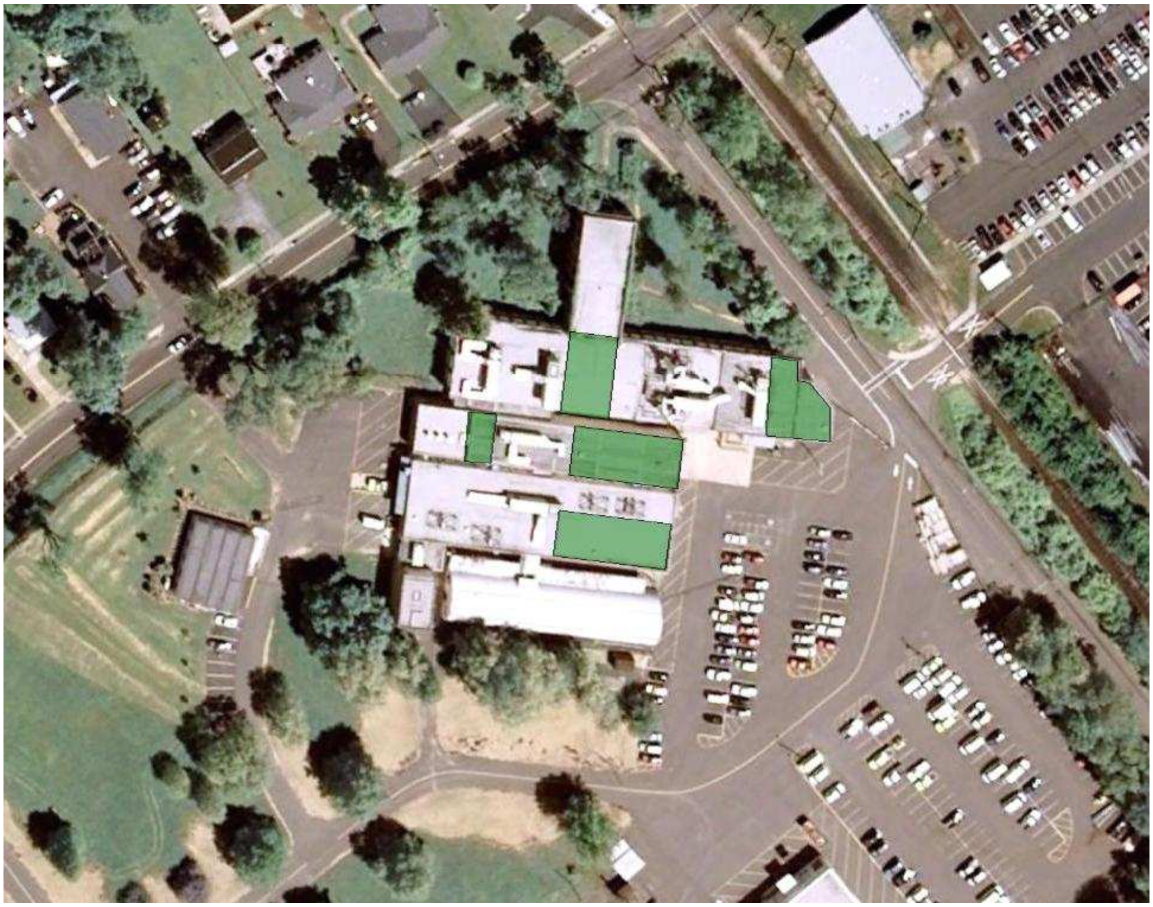


Figure 4. Ewing Thiokol gross roof area

Power Production

A total of 13,991 square feet of unshaded, unobstructed rooftop space was identified, corresponding to the areas highlighted in green in **Figure 4**. Given the substantial demand peak, system size is limited by roof area available, not the amount of electricity used. Available PV area is estimated to be approximately 10,500 square feet. For a panel system, this yields a system size of 136 kW (DC), costing $682,000. For thin film, system size is 70 kW (DC), costing $314,500.

For the panel system, estimated yearly power production is over 207,000 kWh, about 9.4 percent of total facility electricity consumption. The thin film system is expected to generate about 116,500 kWh per year, or 5.3 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 5**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $32,500 in electricity costs, while thin film would save almost $18,300 (see **Figure 6**).

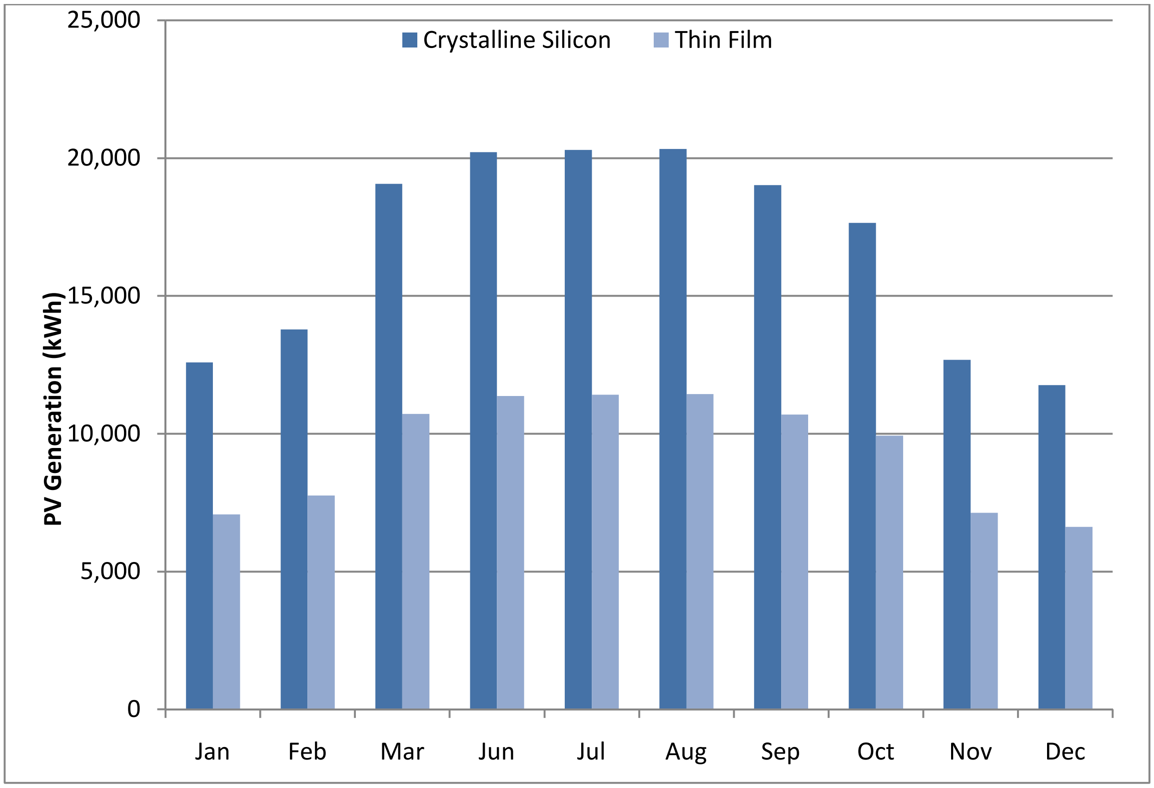


Figure 5. Ewing Thiokol monthly production

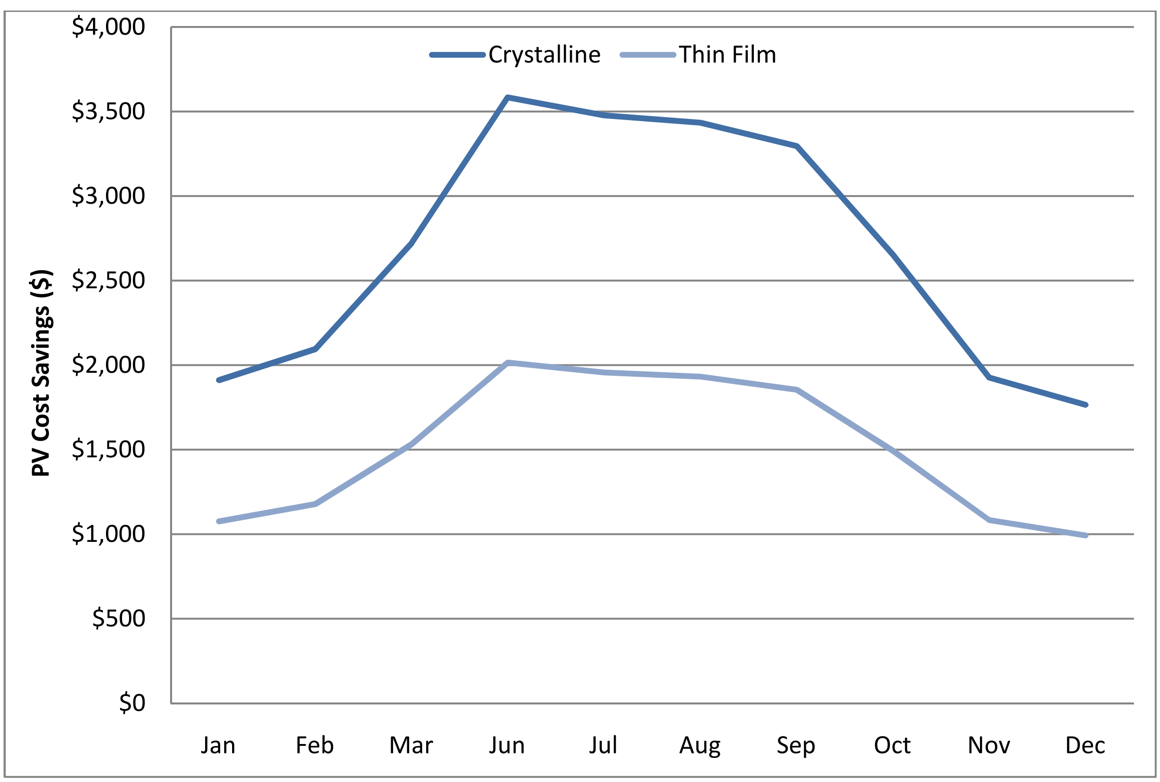


Figure 6. Ewing Thiokol PV monthly electricity cost savings

Financial Return

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $285,000 (**Figure 7**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of $226,000 (**Figure 8**).

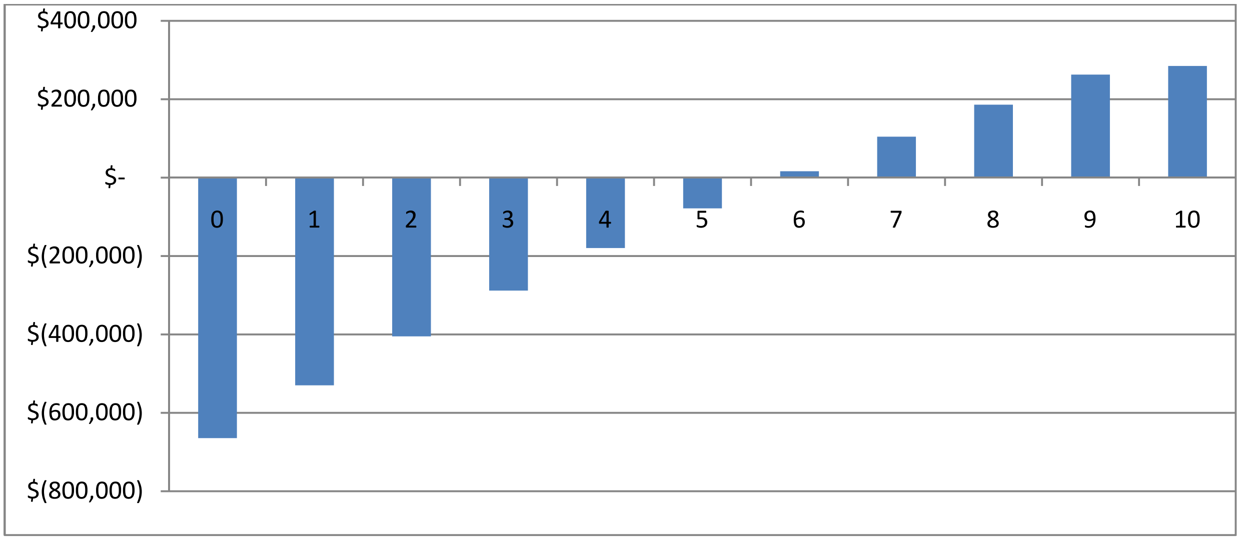


Figure 7. Ewing Thiokol panel system year-by-year payback

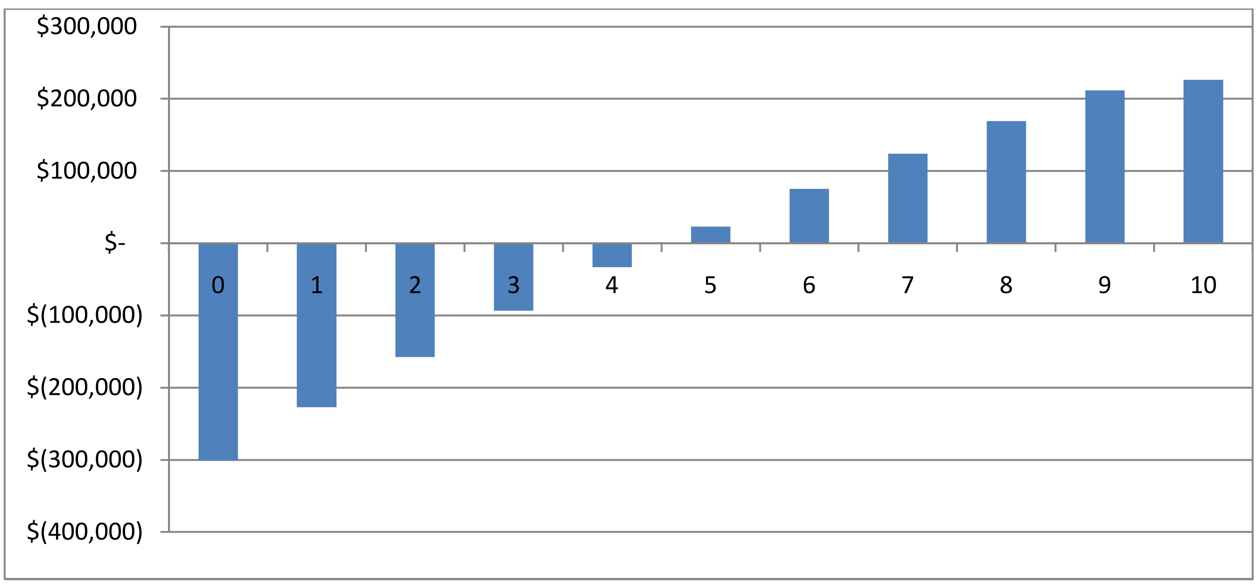


Figure 8. Ewing Thiokol thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 236,000 pounds of carbon dioxide, or about 20.5 cars traveling 12,000 miles each. The thin film system yields a reduction of about 133,000 pounds, or 11.5 cars (**Figure 9**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

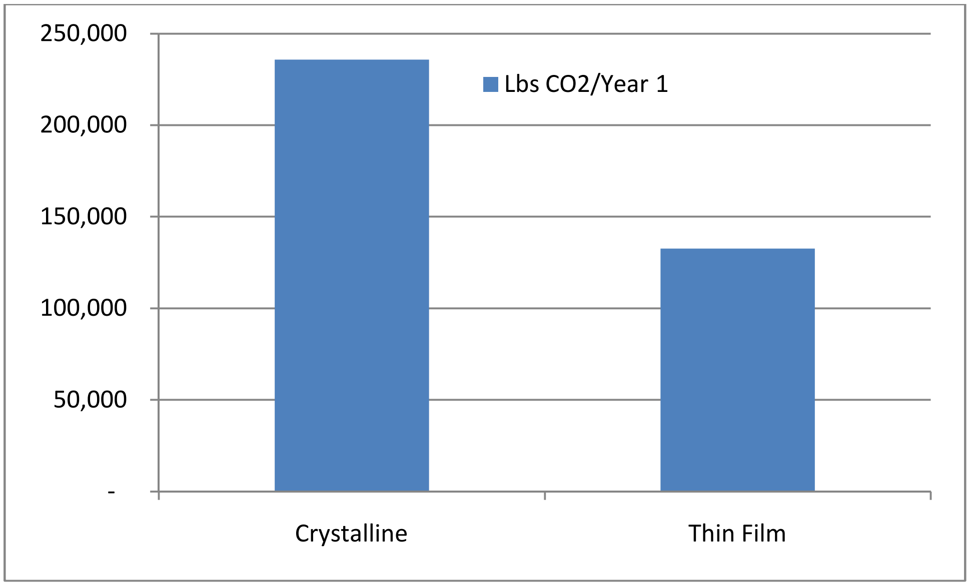


Figure 9. Year 1 CO_2 reductions

Ewing: Thiokol 2-5 and 9 (roof, ground, and Print Shop roof)

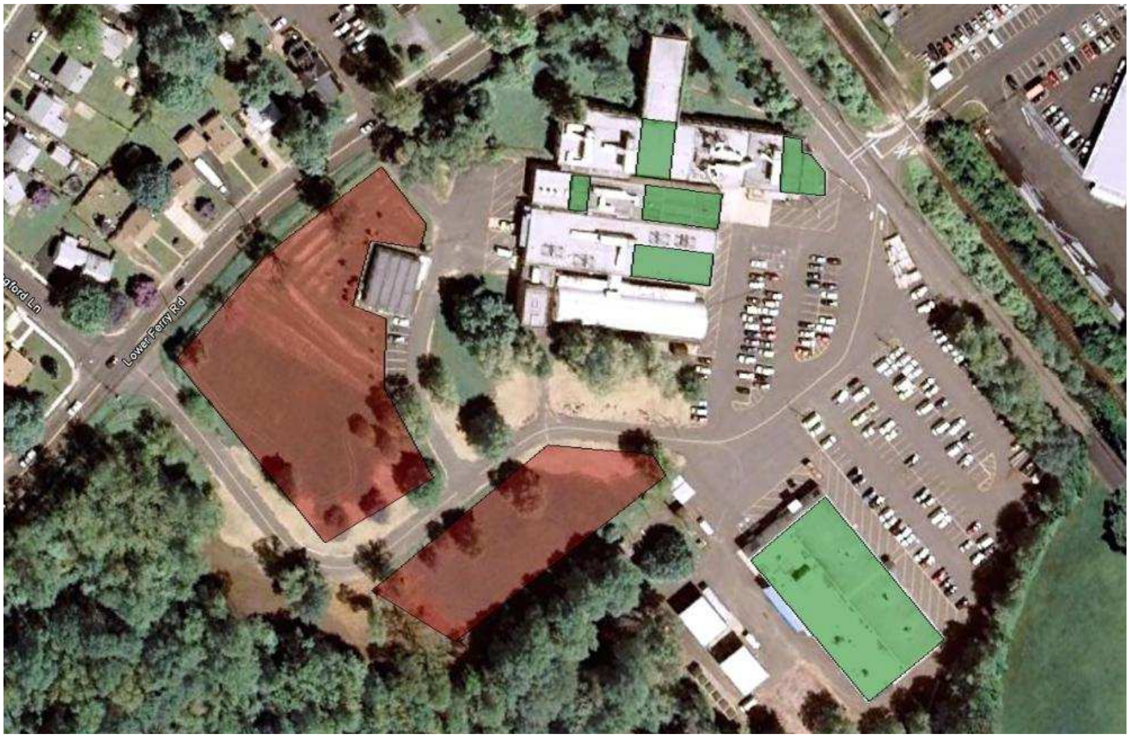


Figure 10. Ewing Thiokol gross roof and ground area

Power Production

A total of 118,000 square feet of space was identified, corresponding to the areas highlighted in green and brown in **Figure 10**. While roof space highlighted is unobstructed, the ground space selected includes trees and may not be available for solar generation without significant preparation. Due to the greater production of crystalline silicon panels versus thin film, this scenario is limited by peak demand for panels and by space constraints for thin film. Only 88,600 square feet of gross area (amounting to PV area of about 61,000 square feet) is required in order for a panel system to reach the demand peak (611 kW DC), yielding a 794 kW system with the DC to AC derate factor included. The estimated cost, the largest of any scenario, is $3.968 million.

The thin film system is limited by available area for PV (81,400 square feet), allowing for a system size of 585 kW (DC), costing $2.632 million.

For the panel system, estimated yearly power production is over 1.2 million kWh, almost 55 percent of total facility electricity consumption. The thin film system is expected to generate about 984,000 kWh per year, or 45 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 11**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $189,000 in electricity costs, while thin film would save over $154,000 (**Figure 12**).

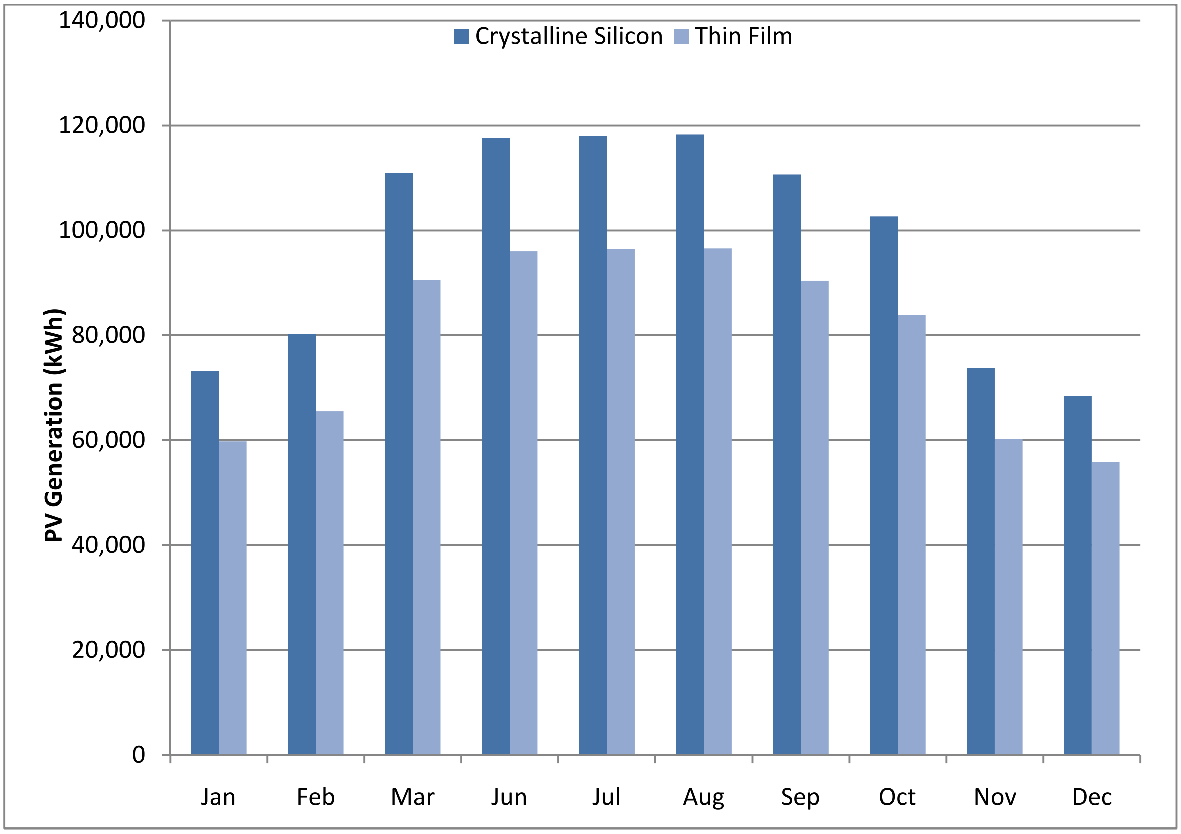


Figure 11. Ewing Thiokol monthly production

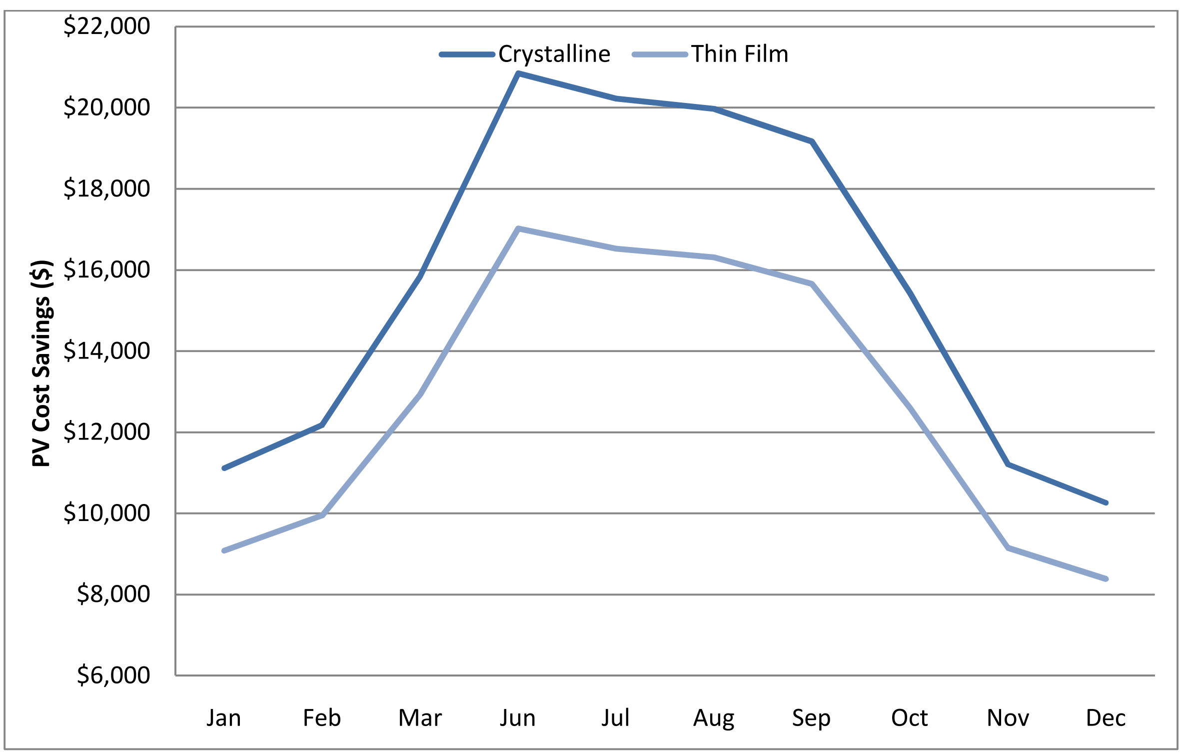


Figure 12. Ewing Thiokol PV monthly electricity cost savings

Financial Return

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $1,507,000 (**Figure 13**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of $1,891,000 (**Figure 14**).

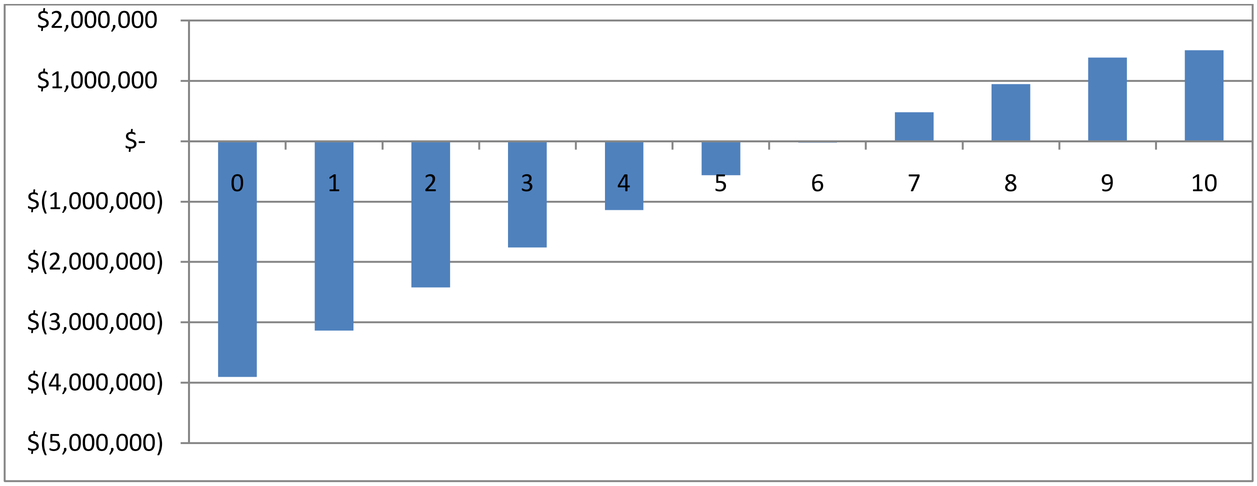


Figure 13. Ewing Thiokol panel system year-by-year payback

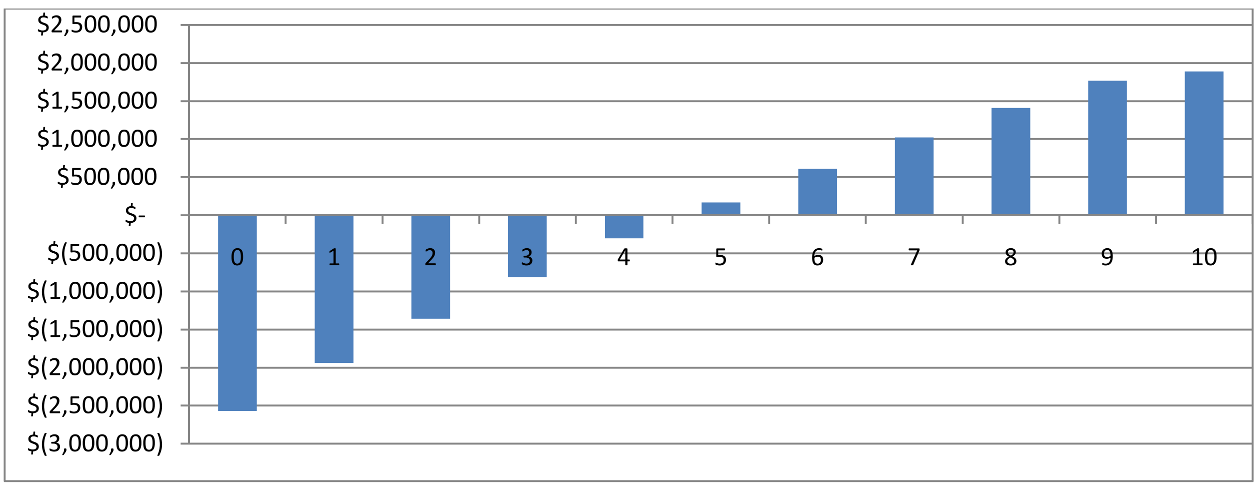


Figure 14. Ewing Thiokol thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 1,372,000 pounds of carbon dioxide, or about 120 cars traveling 12,000 miles each. The thin film system yields a reduction of about 1,121,000 pounds, or 98 cars (**Figure 15**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

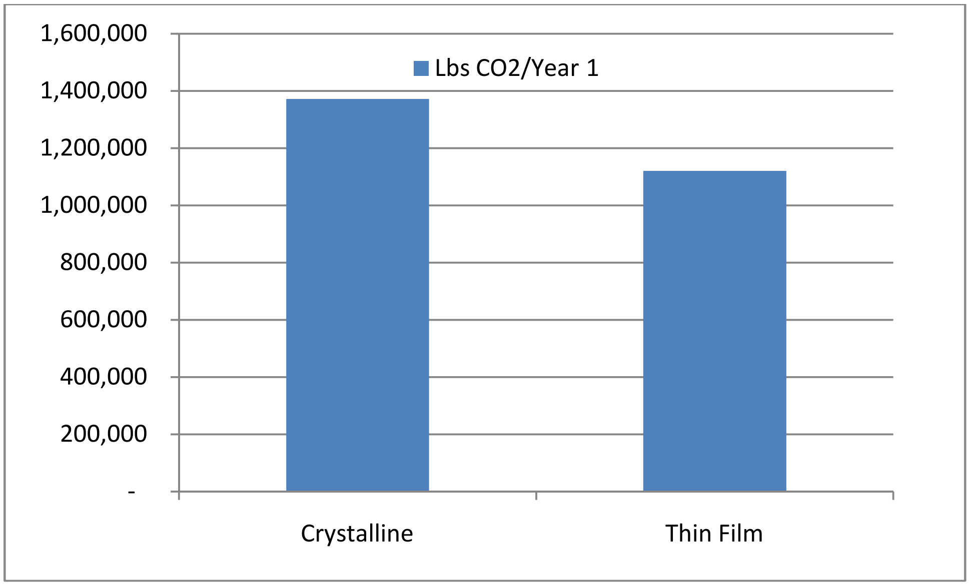
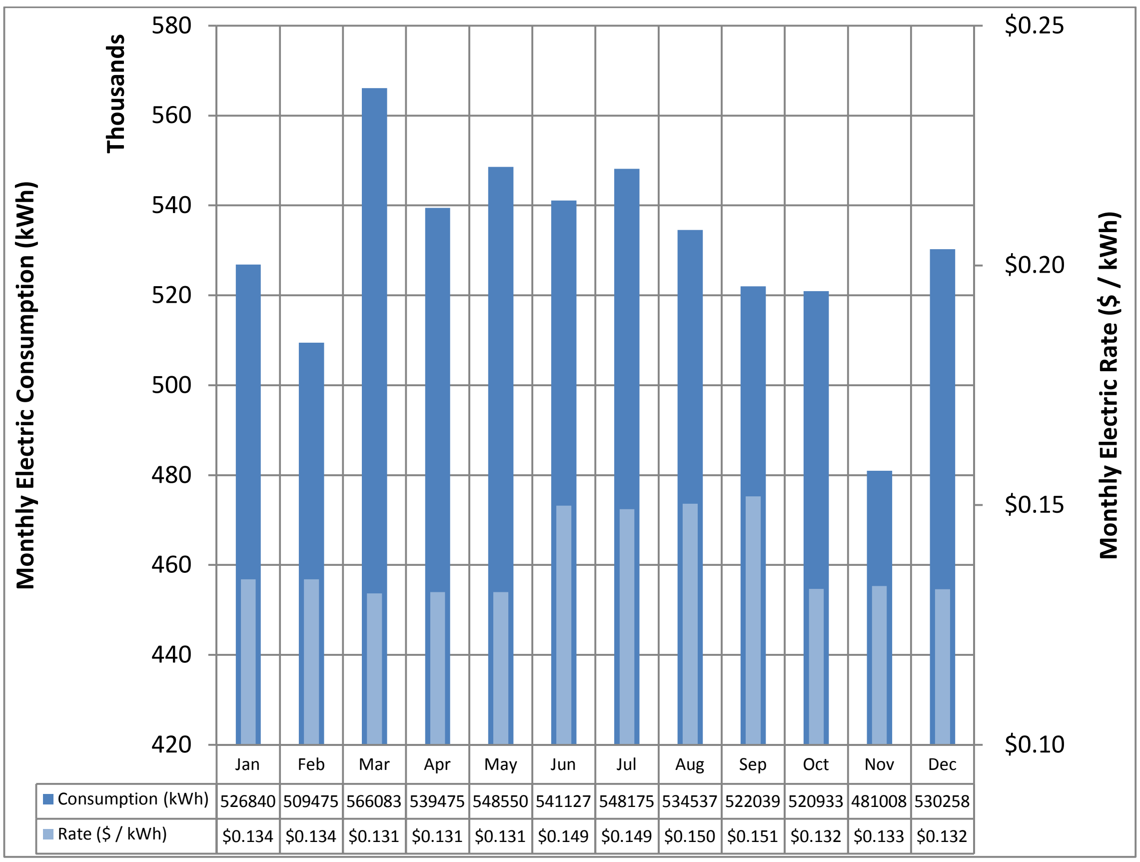


Figure 15. Year 1 CO2 reductions

Ewing: E&O

<u>Existing Energy Profile</u>

The E&O account, which covers most of the MOB and E&O buildings, is Ewing's single largest account in terms of consumption: 6,368,500 kWh, or over 45 percent of total consumption. Peak demand was 1.17 MW (load factor was 62 percent). The greatest monthly consumption occurred in March, for unknown reasons, although the peak occurred in August and summer months show, on average, modestly higher consumption than fall or winter months (**Figure 16**). This account is supplied by Pepco, which leads to a fairly uniform month-to-month rate per kWh, except from June through May, when rates increase due to the application of summer demand charges. Total yearly charges are estimated to be $883,159.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	526840	509475	566083	539475	548550	541127	548175	534537	522039	520933	481008	530258
Rate ($ / kWh)	$0.134	$0.134	$0.131	$0.131	$0.131	$0.149	$0.149	$0.150	$0.151	$0.132	$0.133	$0.132

Figure 16. Ewing E&O monthly kWh consumption and composite electricity rate

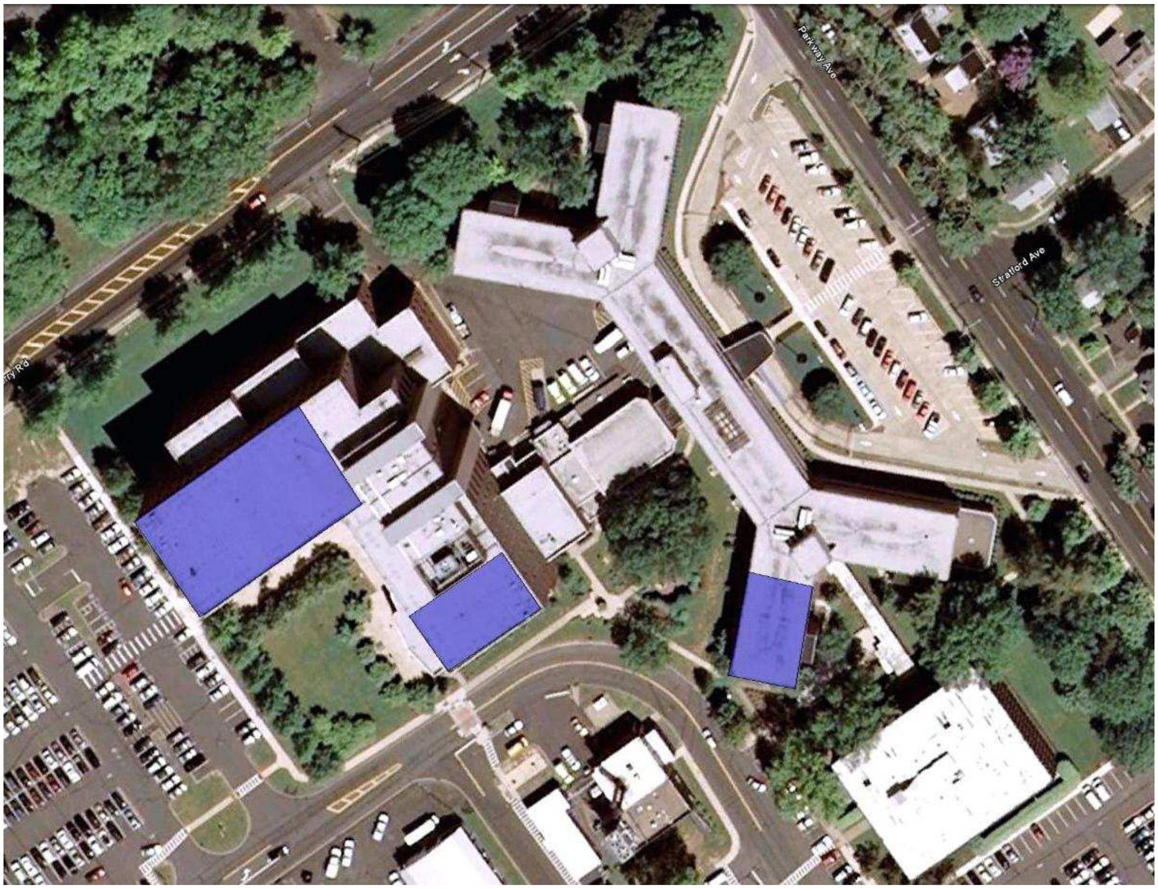


Figure 17. Ewing E&O gross roof area

Power Production

A total of 21,876 square feet of unshaded, unobstructed rooftop space was identified, corresponding to the areas highlighted in purple in **Figure 17**. Given the high demand peak, system size is limited by area. Therefore, available PV area is estimated to be approximately 16,400 square feet. For a panel system, this yields a system size of 213 kW (DC), costing $1.07 million. For thin film, system size is 109 kW (DC), costing $491,000.

For the panel system, estimated yearly power production is almost 324,000 kWh, or just over 5 percent of total facility electricity consumption. The thin film system is expected to generate about 182,000 kWh per year, or 3 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 18**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $45,000 in electricity costs, while thin film would save almost $25,500 (see **Figure 19**).

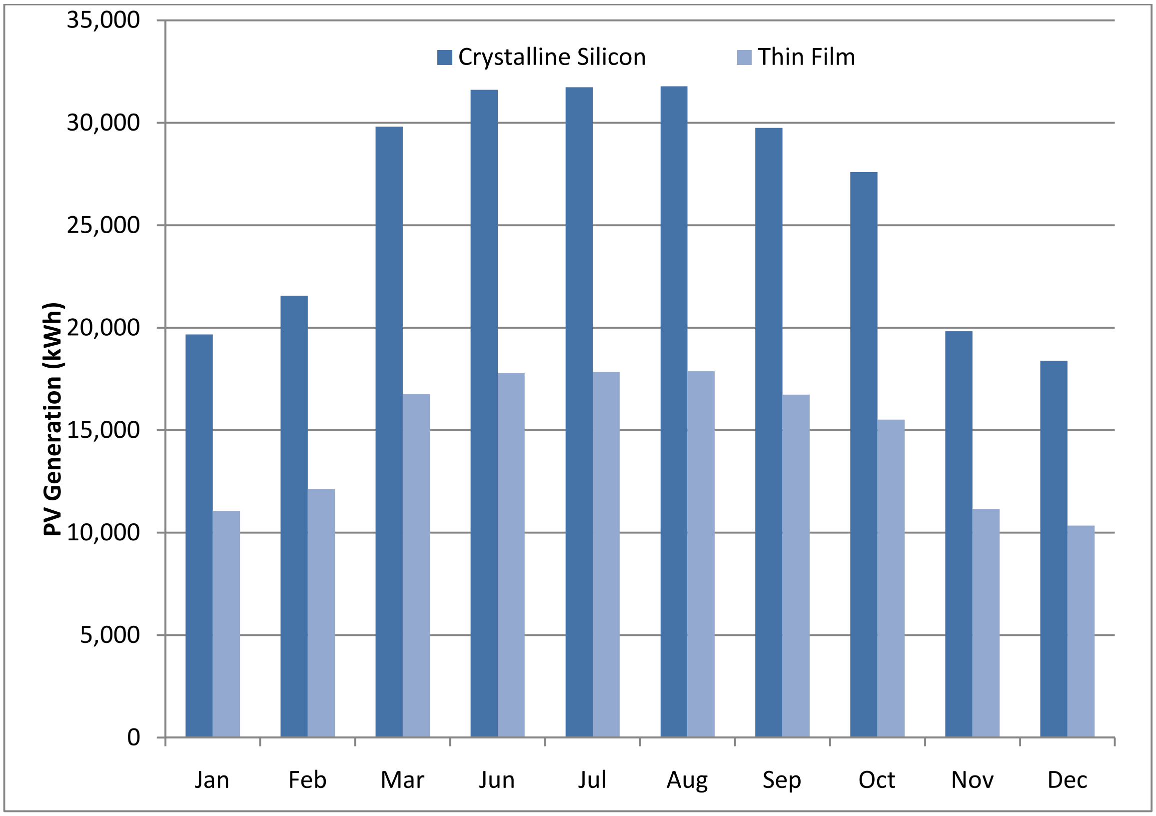


Figure 18. Ewing E&O PV monthly production

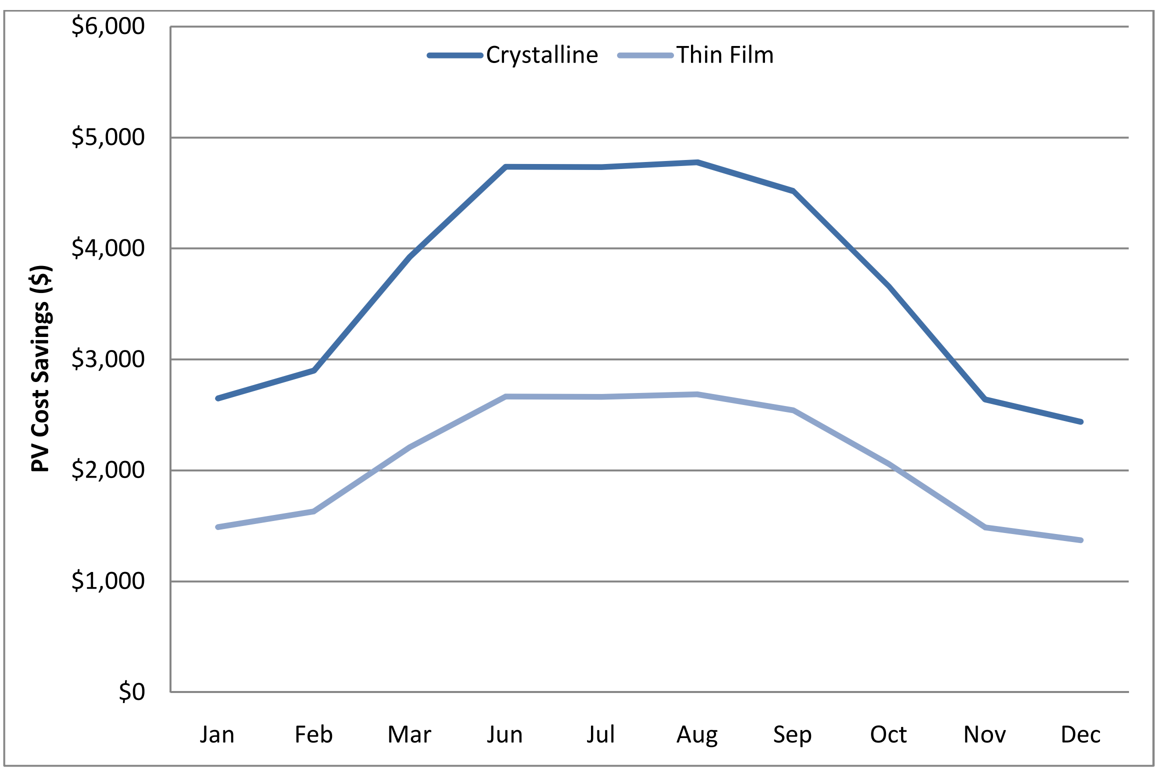


Figure 19. Ewing E&O PV monthly electricity cost savings

Financial Return

Payback for panels is estimated to occur in Year 7, with a 10-year NPV of $302,000 (**Figure 20**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of $323,000 (**Figure 21**).

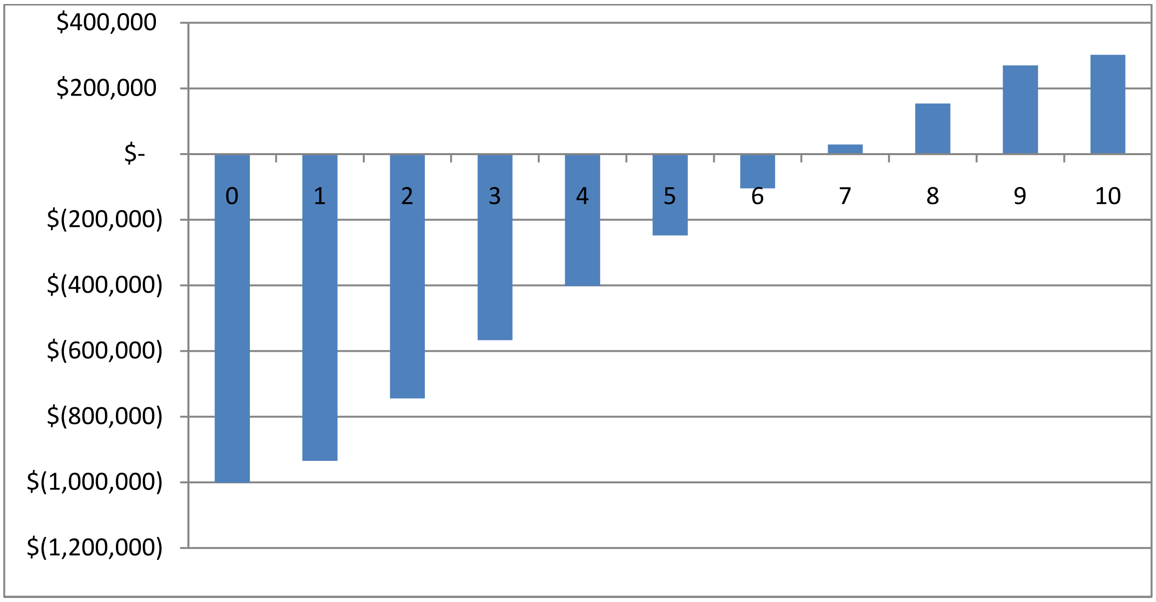


Figure 20. Ewing E&O panel system year-by-year payback

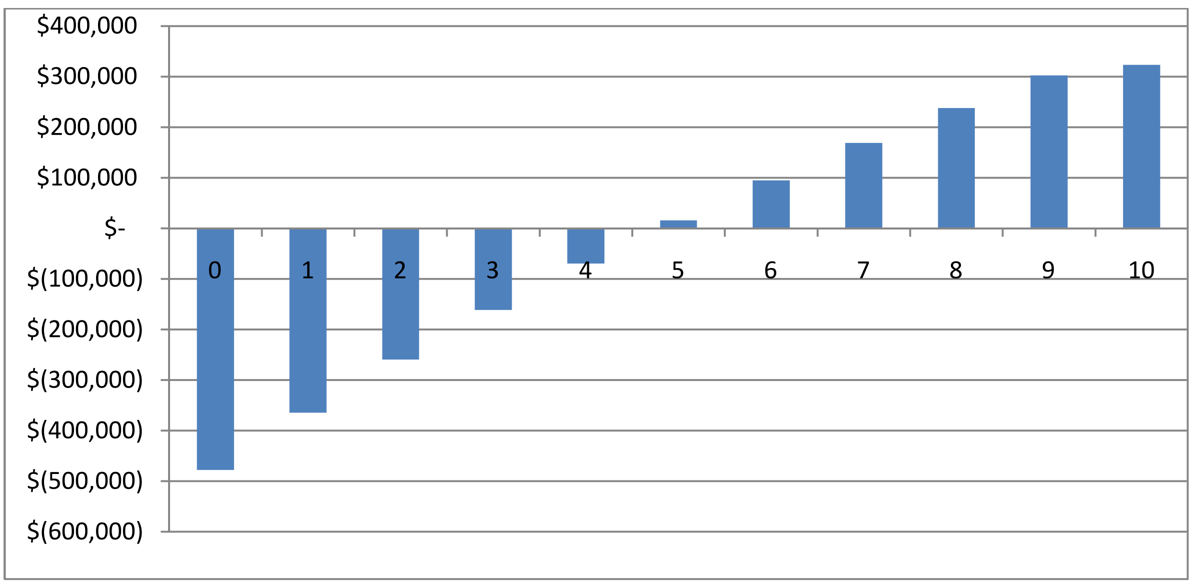


Figure 21. Ewing E&O thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 369,000 pounds of carbon dioxide, or about 32 cars traveling 12,000 miles each. The thin film system yields a reduction of about 207,000 pounds, or 18 cars (**Figure 22**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

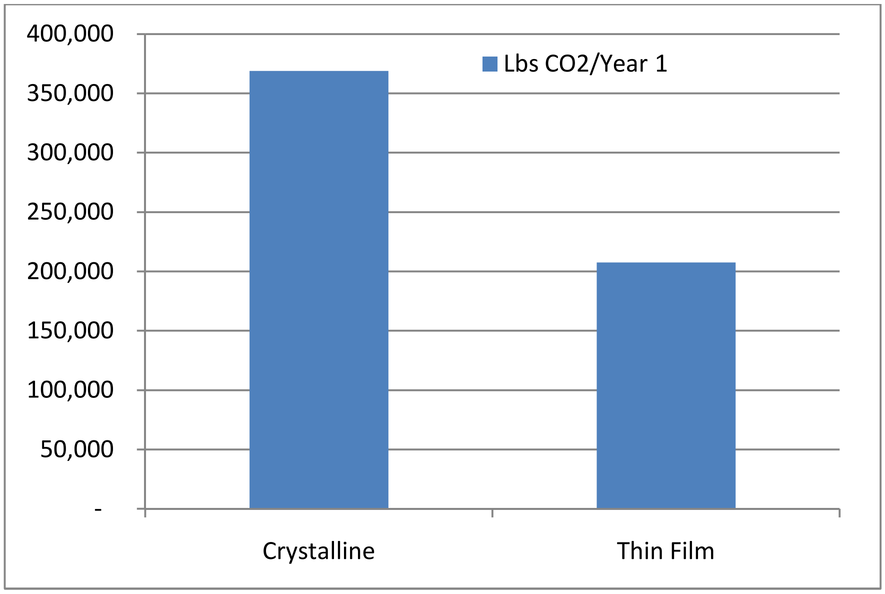
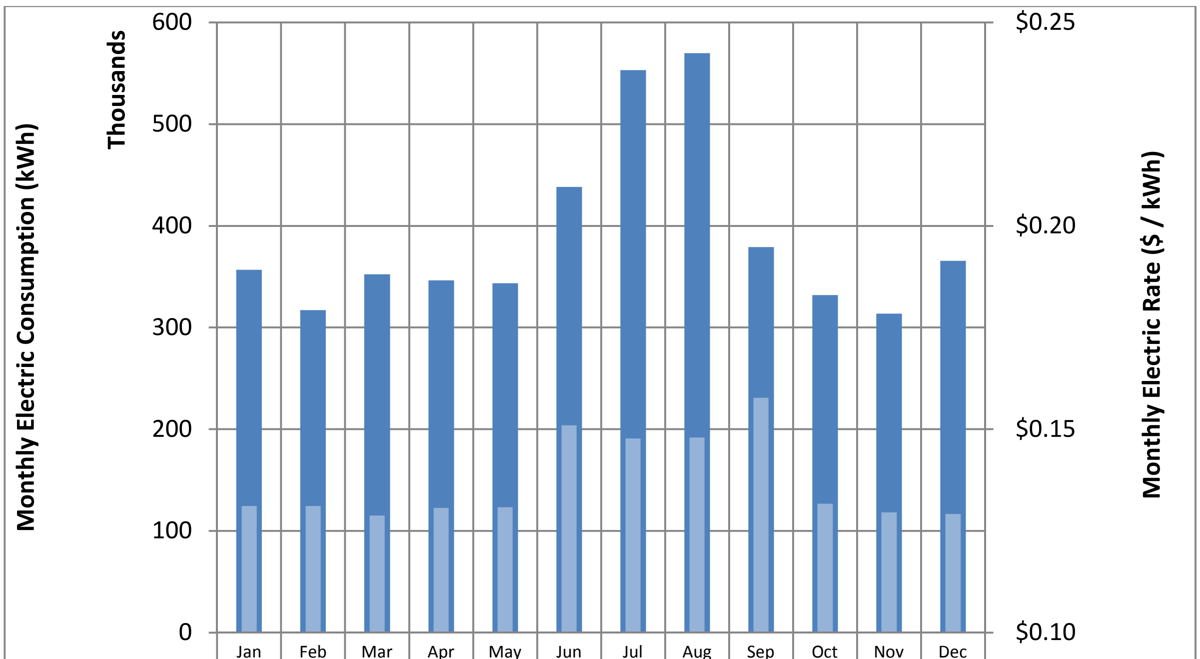


Figure 22. Year 1 CO2 reductions

Ewing: F&A plus Fernwood

<u>Existing Energy Profile</u>

The F&A account covers a multitude of facilities with a variety of physical configurations and usage characteristics, including the F&A building, most of the Fernwood facilities, parking lot B, and the vacant Foran buildings. F&A accounts for over 33 percent of Ewing's consumption, with 4,667,898 kWh, and possesses the highest peak demand of any account examined, at 1.21 MW (load factor of 45 percent). F&A's consumption profile is conventional, with easily distinguishable peaks for July and August and more moderate peaks for June and September (**Figure 23**). Like E&O, because this facility is supplied by Pepco, the rate per kWh is stable from month to month, save for June to September. Total annual charges are estimated to be $647,516.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	356714	317191	352434	346300	343587	438106	553216	569880	379146	331969	313681	365674
Rate ($ / kWh)	$0.131	$0.131	$0.128	$0.130	$0.130	$0.150	$0.147	$0.148	$0.157	$0.131	$0.129	$0.129

Figure 23. Ewing F&A monthly kWh consumption and composite electricity rate

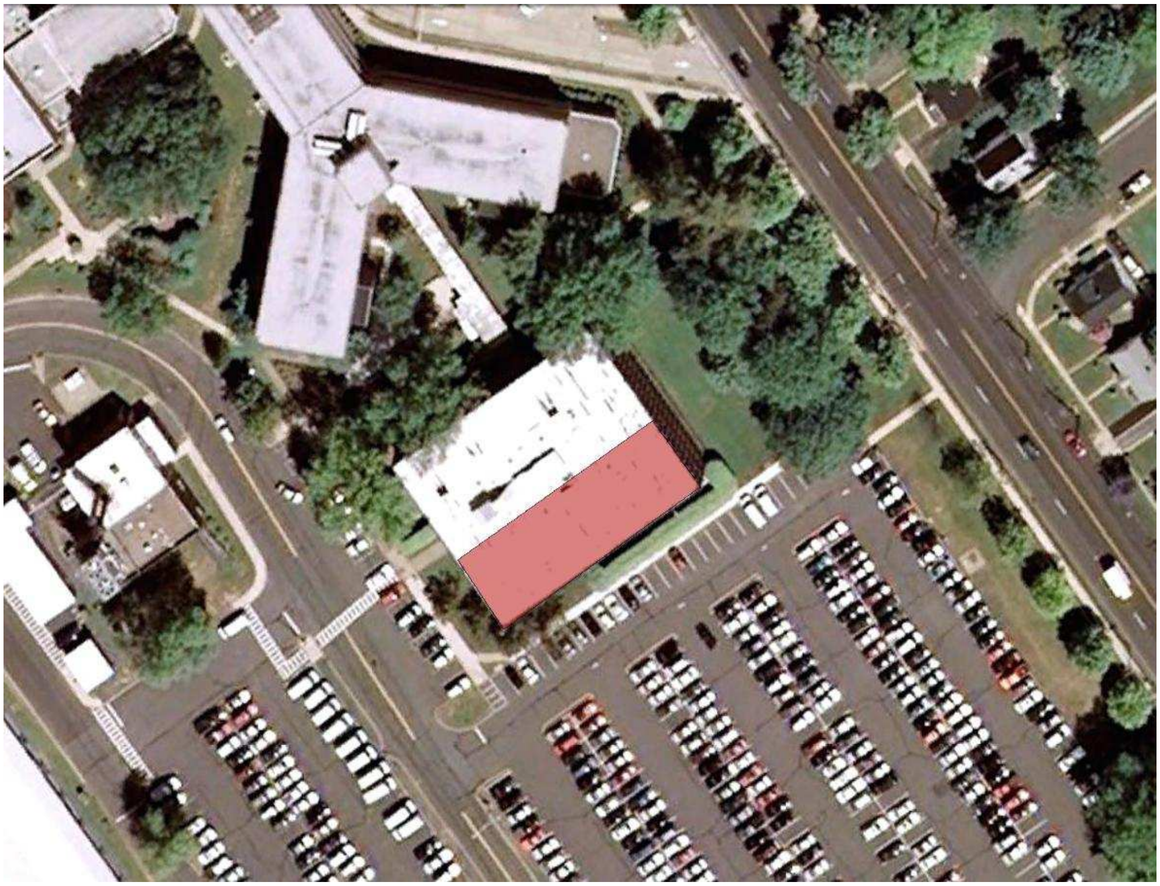


Figure 24. Ewing F&A gross roof area

Power Production

Although F&A plus Fernwood offers a large amount of roof space, due to shading, orientation issues, and building vacancies (Foran) only 7,700 square feet of unshaded, unobstructed rooftop space was identified (on the F&A building rooftop, see **Figure 24**). Given the high demand peak, system size is limited by area. Therefore, available PV area is estimated to be less than 5,800 square feet. For a panel system, this yields a system size of 75 kW (DC), costing $375,000. For thin film, system size is 38 kW (DC), the smallest scenario, costing $173,000.

For the panel system, estimated yearly power production is about 114,000 kWh, or 2.4 percent of total facility electricity consumption. The thin film system is expected to generate about 64,000 kWh per year, only 1.4 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 25**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $15,800 in electricity costs, while thin film would save almost $8,900 (see **Figure 26**).

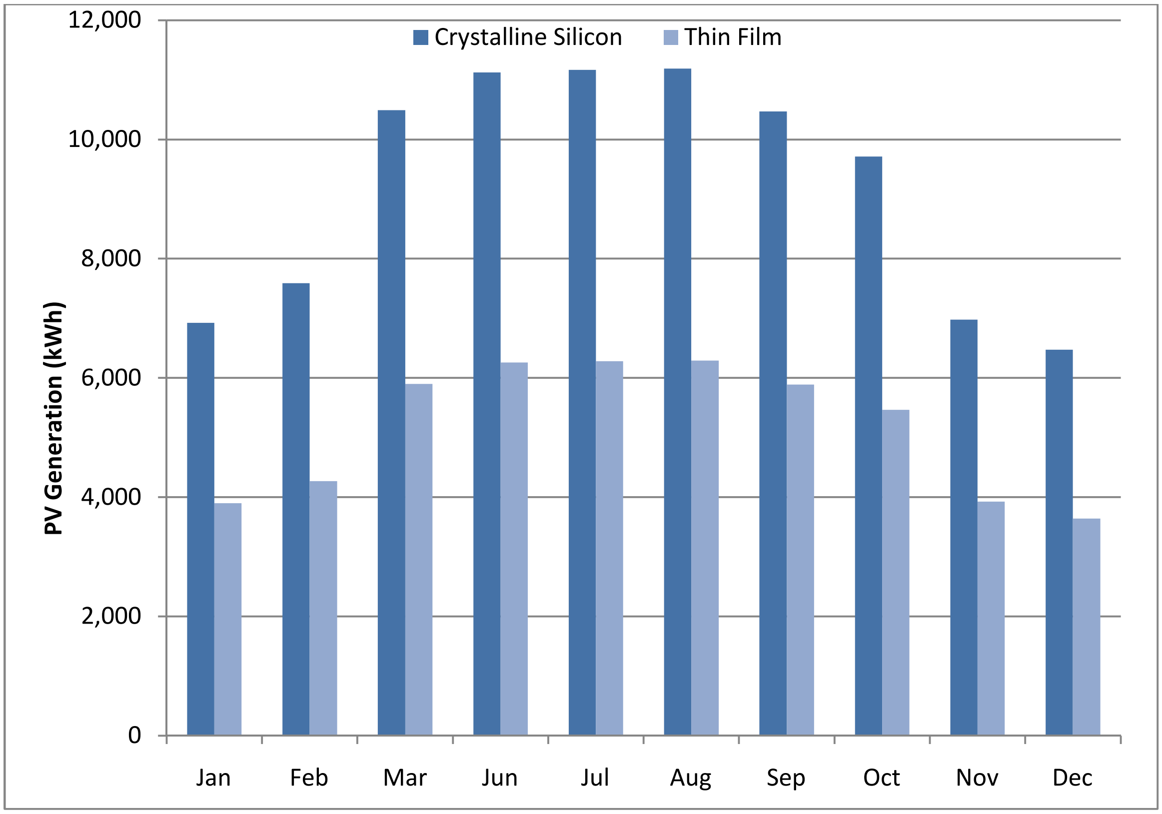


Figure 25. Ewing F&A plus Fernwood PV monthly production

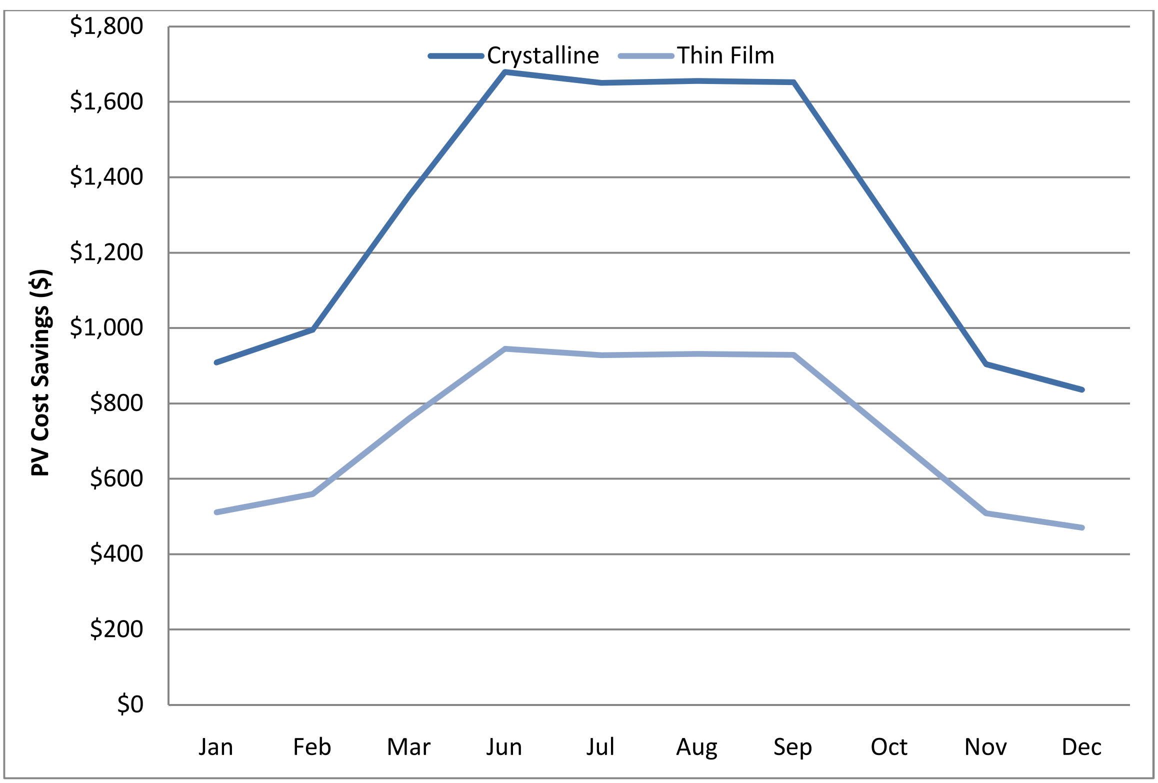


Figure 26. Ewing F&A plus Fernwood PV monthly electricity cost savings

Financial Return

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $135,000 (**Figure 27**). Payback for thin film is estimated to occur in Year 4, with a 10-year NPV of $151,000 (**Figure 28**).

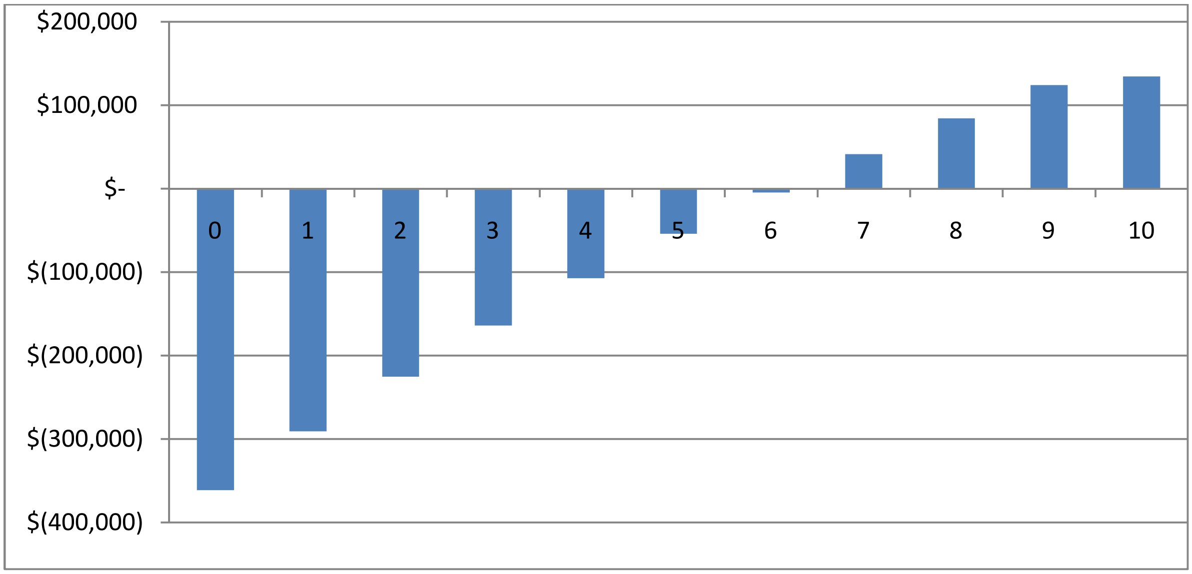


Figure 27. Ewing F&A plus Fernwood panel system year-by-year payback

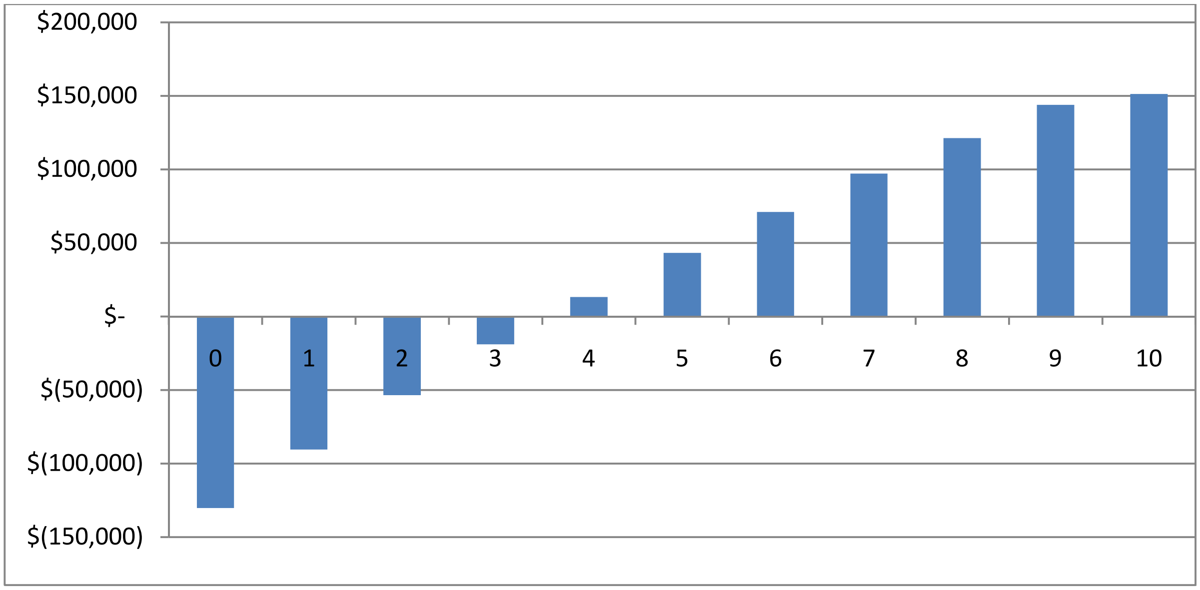


Figure 28. Ewing F&A plus Fernwood thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 130,000 pounds of carbon dioxide, or just over 11 cars traveling 12,000 miles each. The thin film system yields a reduction of about 73,000 pounds, or about 6 cars (**Figure 29**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

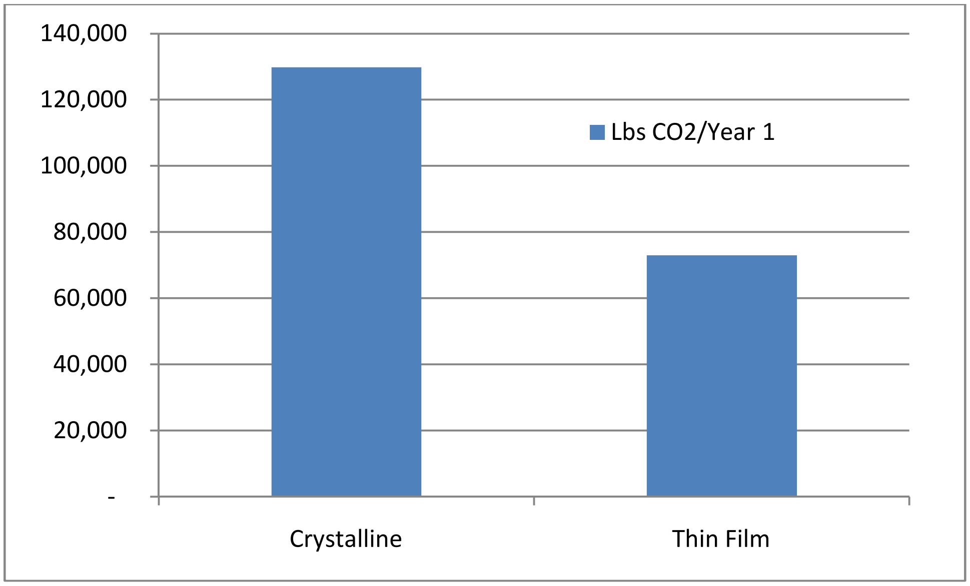
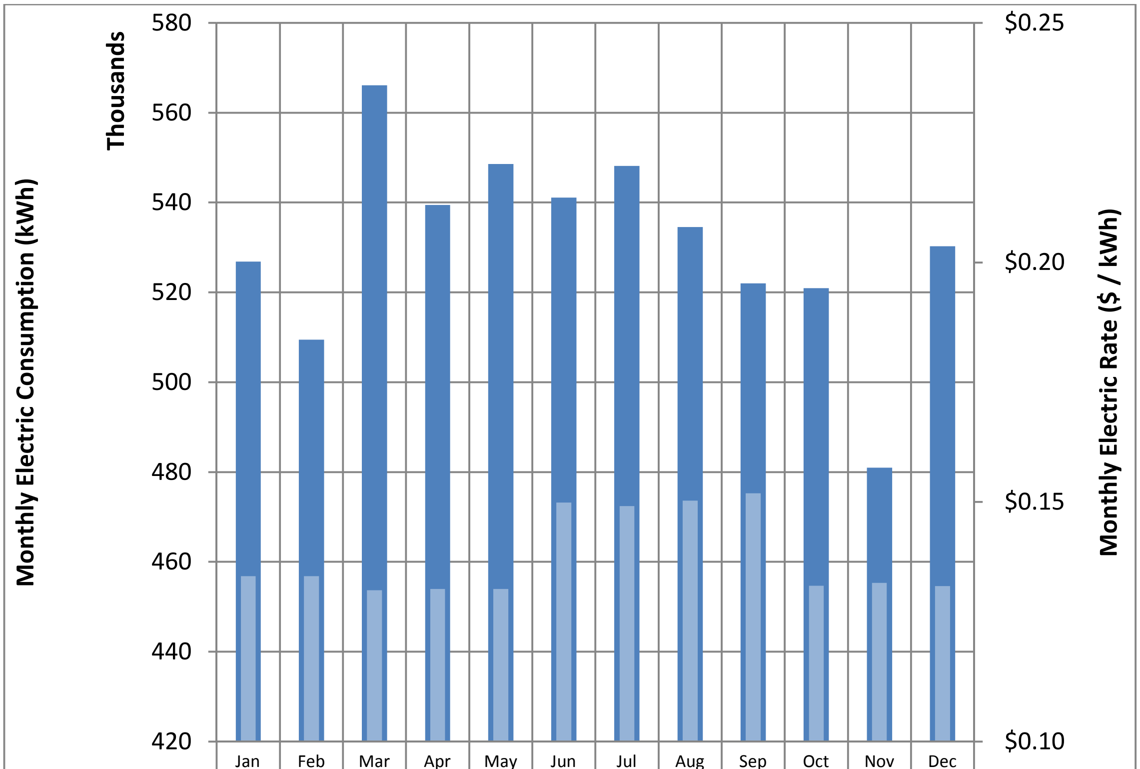


Figure 29. Year 1 CO2 reductions

Ewing: E&O and F&A plus Fernwood

Existing Energy Profile

This scenario combines the available roof space of both E&O and F&A in order to capitalize on their proximity and each account's high-peak demand. Although the scenario uses the E&O meter, peak, and associated electricity rates, in practice the F&A account could also be used. E&O consumption was 6,368.500 kWh and peak demand was 1.17 MW. Again, the greatest monthly consumption occurred in March, for unknown reasons, although the peak occurred in August and summer months show, on average, modestly higher consumption than fall or winter months (**Figure 30**). Total yearly charges are estimated to be $883,159.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	526840	509475	566083	539475	548550	541127	548175	534537	522039	520933	481008	530258
Rate ($ / kWh)	$0.134	$0.134	$0.131	$0.131	$0.131	$0.149	$0.149	$0.150	$0.151	$0.132	$0.133	$0.132

Figure 30. Ewing E&O monthly kWh consumption and composite electricity rate

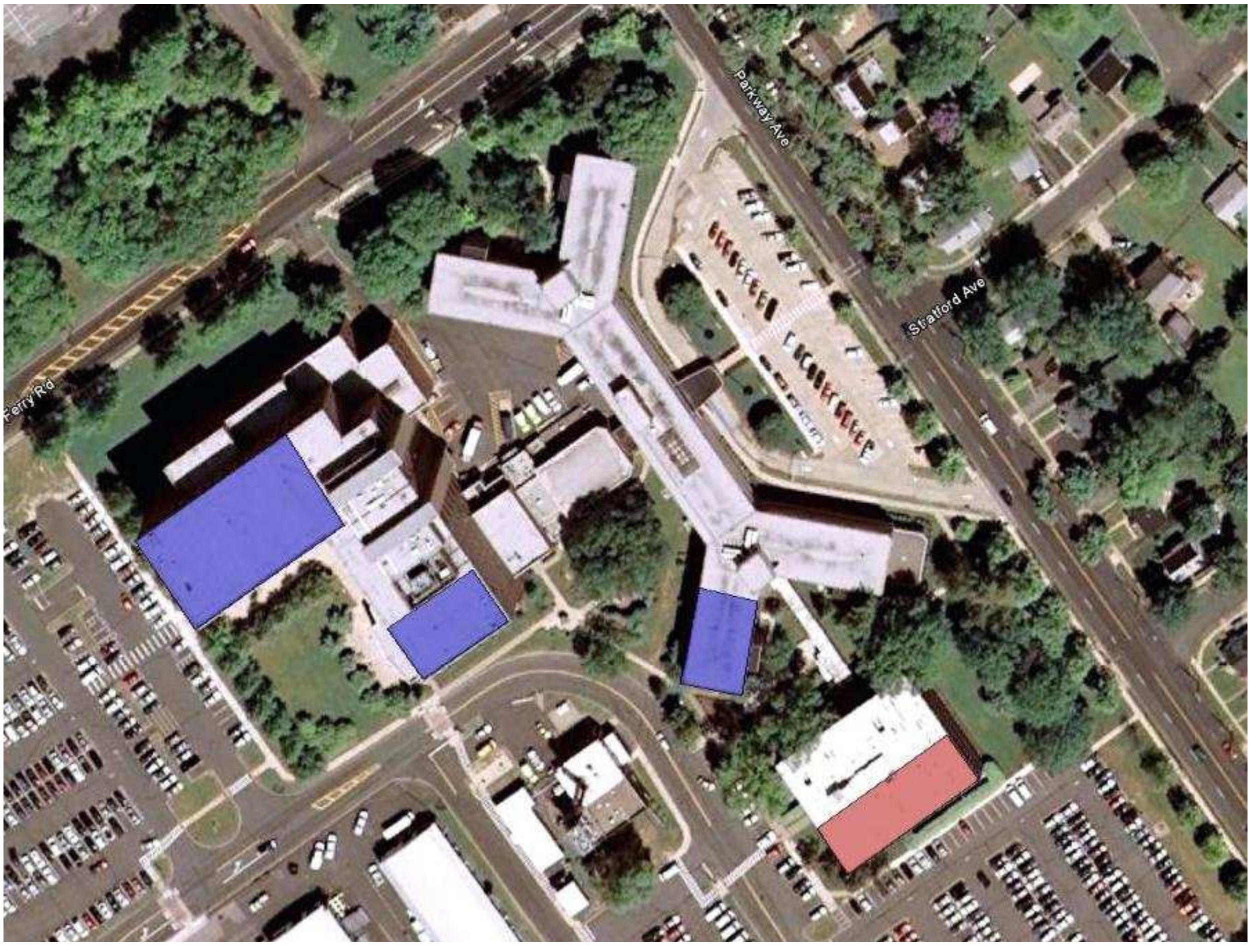


Figure 31. Ewing E&O plus F&A gross roof area

Power Production

By combining the identified roof areas suitable for the installation of solar of both E&O and F&A, 29,500 square feet of gross area is created, yielding almost 22,200 square feet of PV area (**Figure 31**). Given the high demand peak of E&O, the system remains limited by area. However, maximum system sizes are considerably greater than E&O alone: 288 kW for a panel system, costing $1.442 million, and 147 kW for a thin film system, costing $665,000.

For the panel system, estimated yearly power production is almost 438,000 kWh, not quite 7 percent of total facility electricity consumption. The thin film system is expected to generate about 246,000 kWh per year, or nearly 4 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 32**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of approximately $61,000 in electricity costs, while thin film would save a little more than $34,000 (see **Figure 33**).

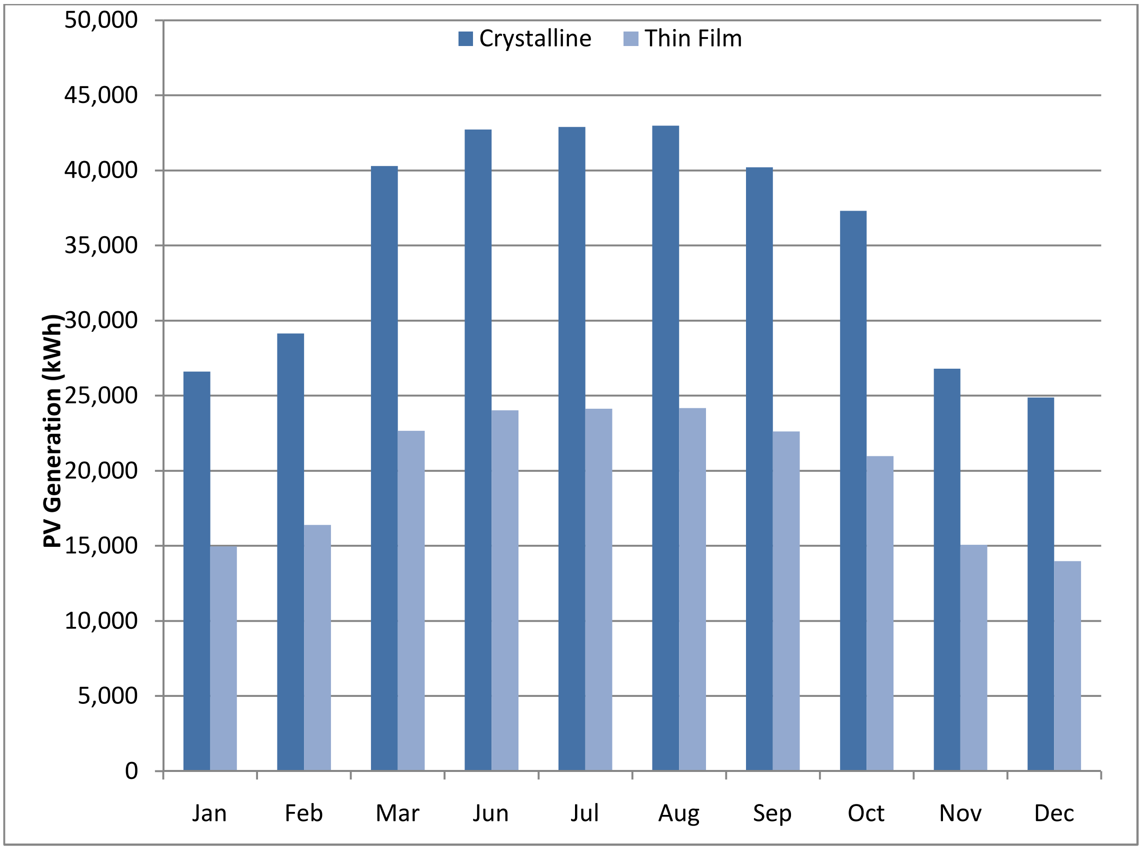


Figure 32. Ewing E&O plus F&A plus Fernwood PV monthly production

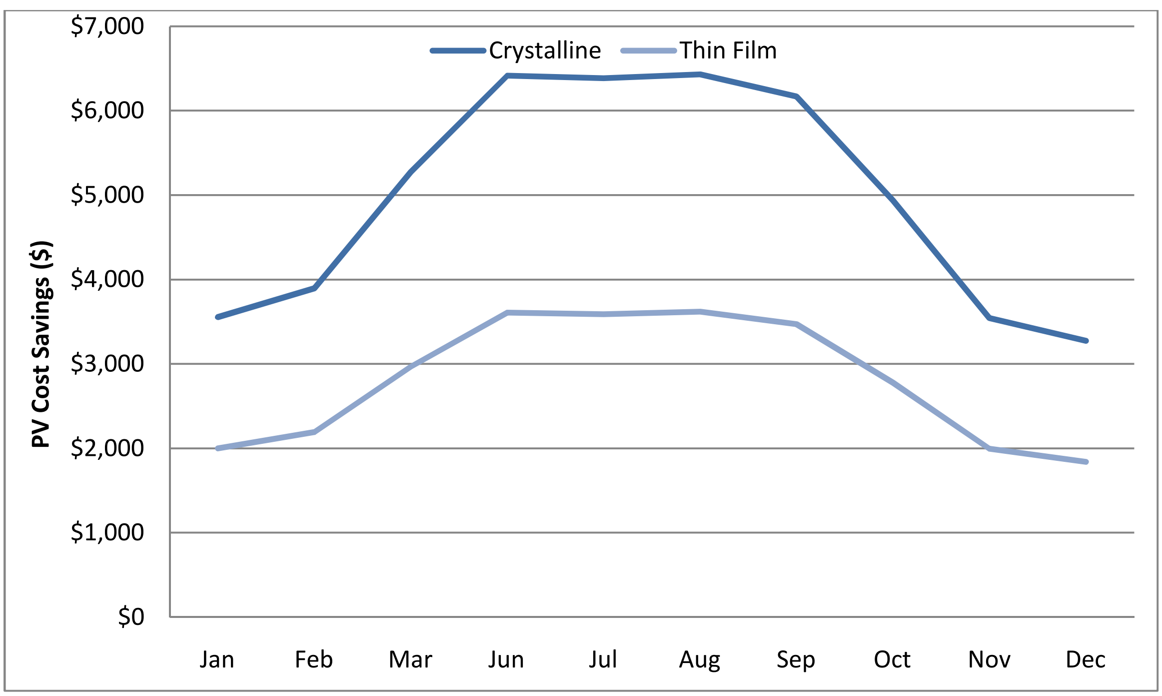


Figure 33. Ewing E&O plus F&A plus Fernwood PV monthly electricity savings

Financial Return

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $507,000 (**Figure 34**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of nearly $475,000 (**Figure 35**).

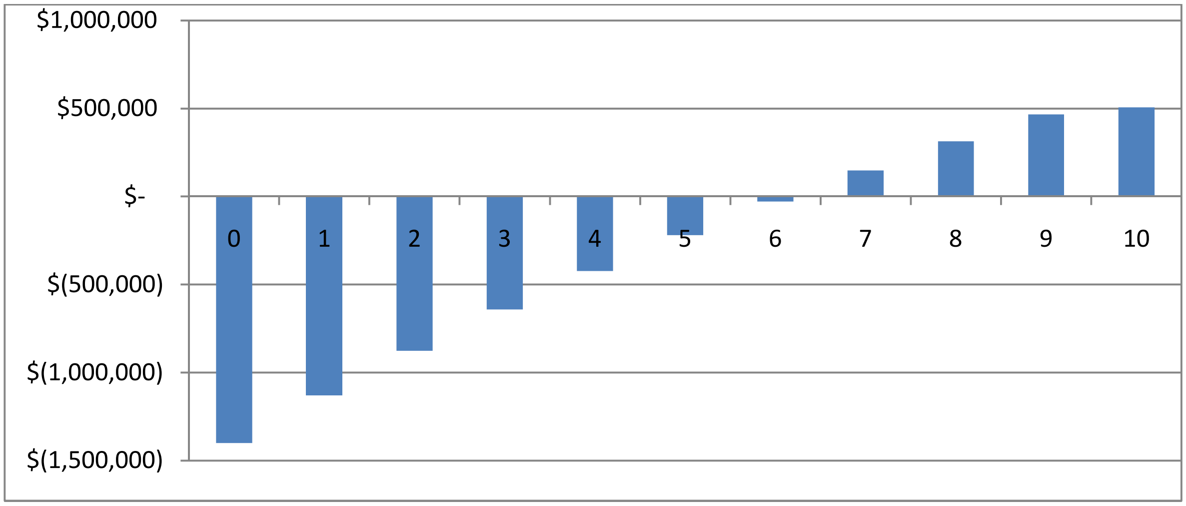


Figure 34. Ewing E&O and F&A plus Fernwood panel system year-by-year payback

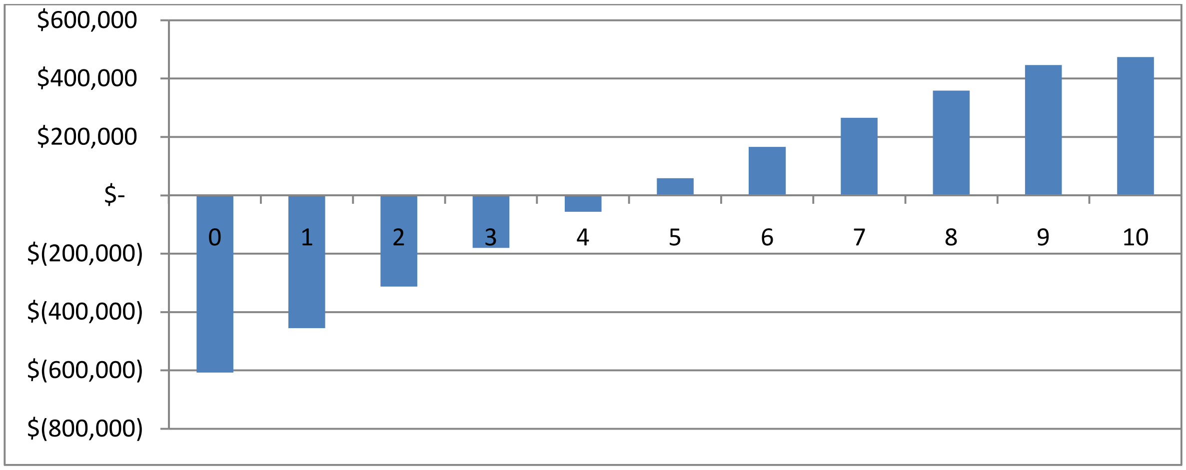


Figure 35. Ewing E&O and F&A plus Fernwood thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 499,000 pounds of carbon dioxide, or about 43.5 cars traveling 12,000 miles each. The thin film system yields a reduction of about 280,000 pounds, or about 24.5 cars (**Figure 36**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

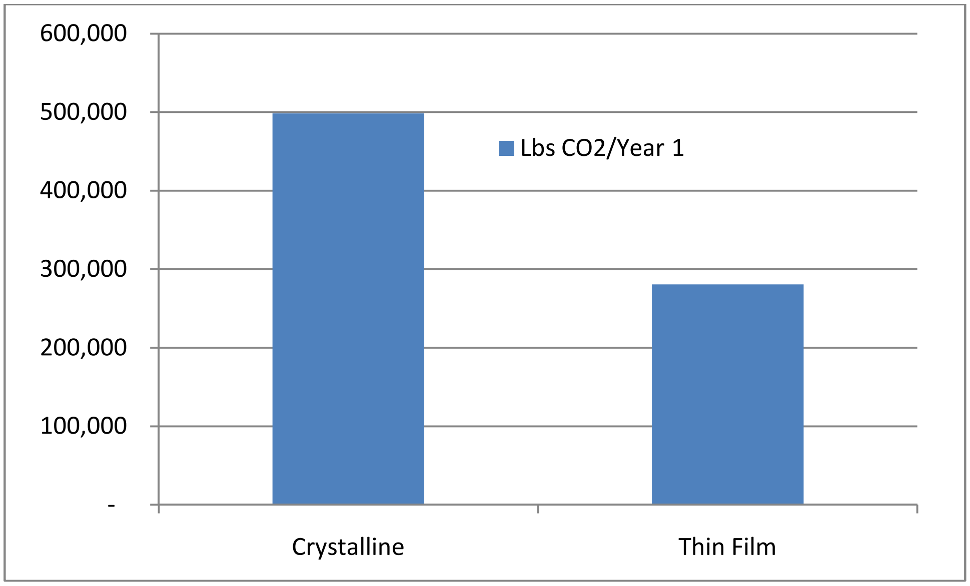
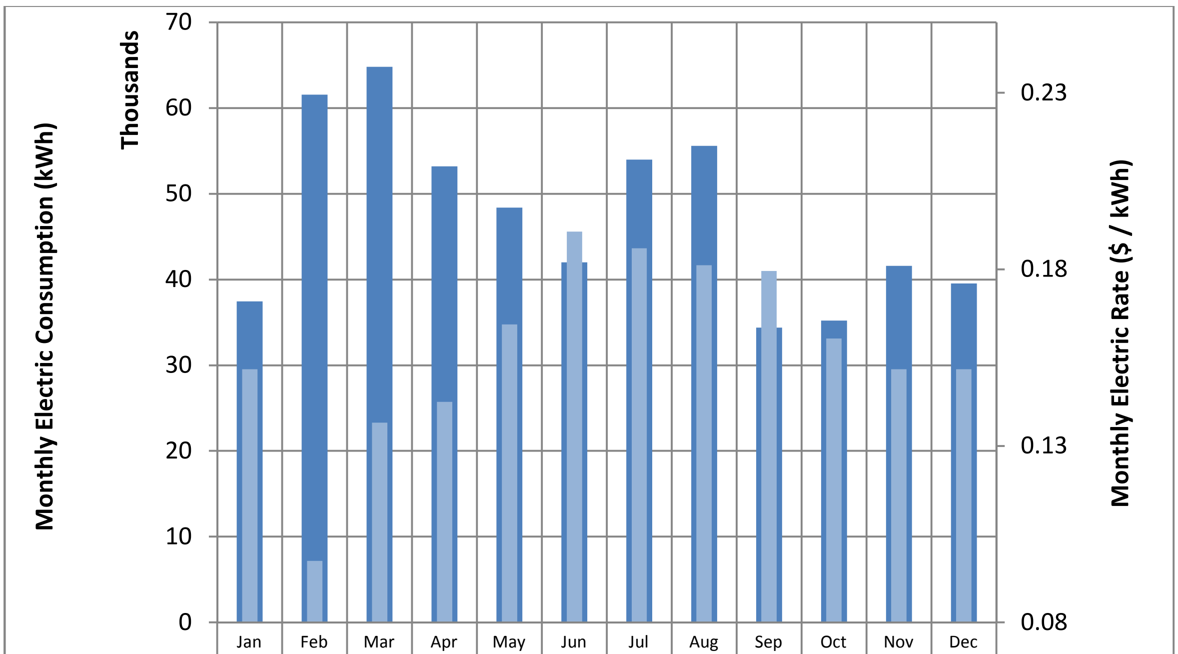


Figure 36. Year 1 CO2 reductions

Newark Maintenance Yard

<u>Existing Energy Profile</u>

Of Newark's two electricity accounts, one handles almost 99.8 percent of the facility's total consumption of 568,899 kWh (the other appears to be connected to a light in the storage yard). Peak demand was 132 kW, and total costs were estimated to be $88,545. The load factor was 49 percent. The consumption profile for this facility was atypical, showing heavy usage in late winter and early spring and modest summer peaks (**Figure 37**). This pattern may result from the maintenance facility's unique usage characteristics.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	37440	61560	64800	53200	48400	42000	54000	55600	34400	35200	41600	39520
Rate ($ / kWh)	$0.1517	$0.0974	$0.1366	$0.1425	$0.1644	$0.1907	$0.1860	$0.1812	$0.1795	$0.1604	$0.1517	$0.1517

Figure 37. Ewing F&A monthly kWh consumption and composite electricity rate

Figure 38. Newark gross roof area

<u>Power Production</u>

A total of 26,388 square feet of unshaded, unobstructed rooftop space was identified, corresponding to the areas highlighted in red in **Figure 38**. Due to the greater production of crystalline silicon panels versus thin film, this scenario is limited by peak demand for panels and by space constraints for thin film. Only 17,582 square feet of gross area (amounting to PV area of about 13,187 square feet) is required in order for a panel system to reach the demand peak of 132 kW DC, yielding a 171 kW system with the DC to AC derate factor included. The estimated cost is $857,000. The thin film scenario is limited due to available PV area, a maximum of 22,430 square feet. This results in a 149 kW system at an estimated cost of $672,000.

For the panel system, estimated yearly power production is over 260,000 kWh, or almost 46 percent of total facility electricity consumption. The thin film system is expected to generate about 249,000 kWh per year, or nearly 44 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 39**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $42,600 in electricity costs, while thin film would save approximately $40,700 (see **Figure 40**).

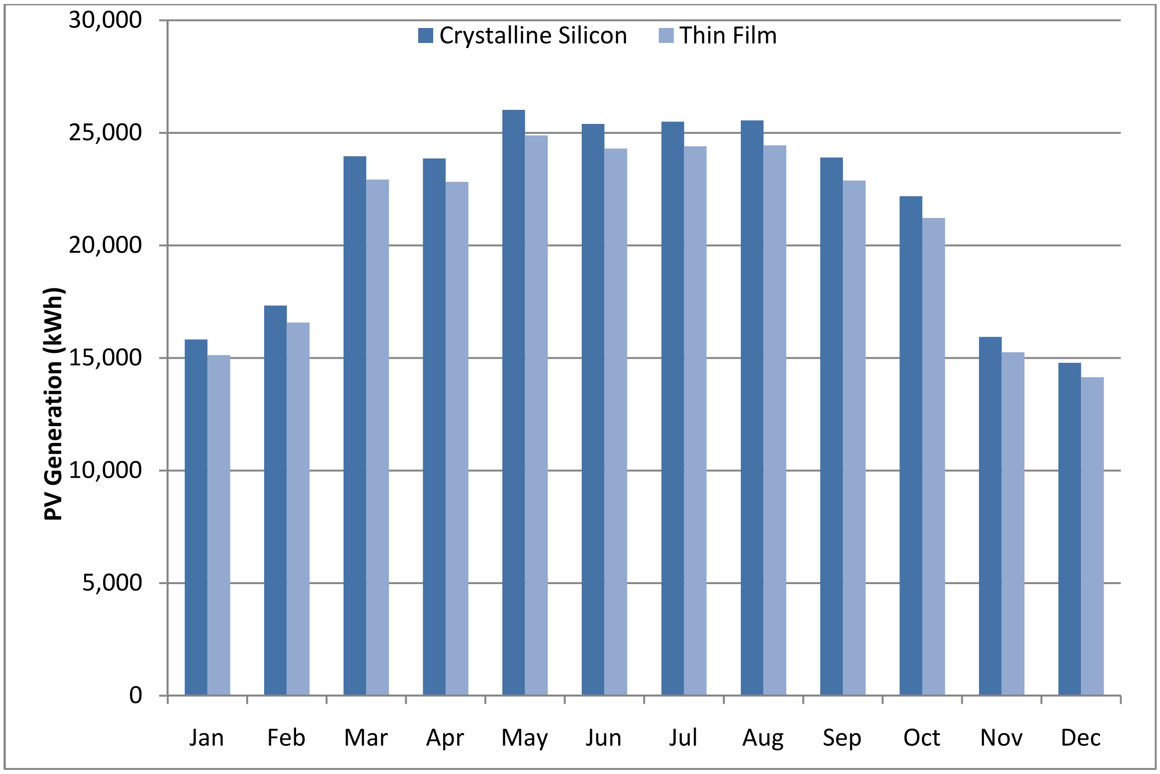


Figure 39. Newark PV monthly production

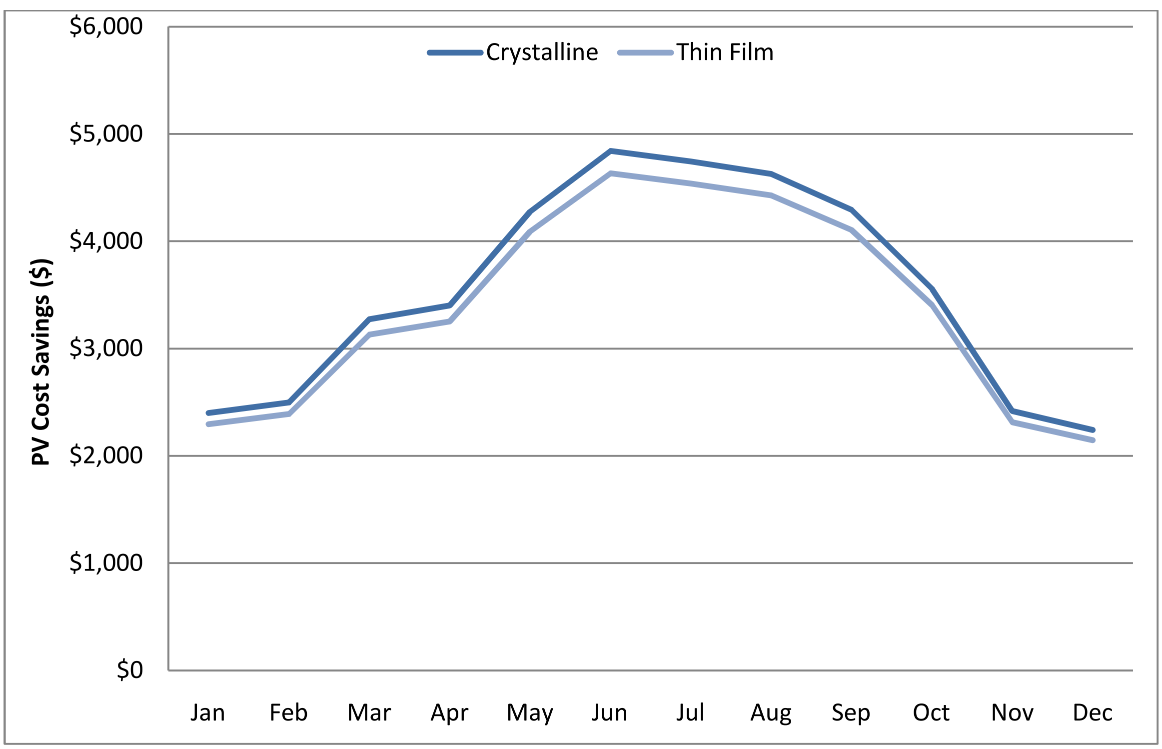


Figure 40. Newark PV monthly electricity cost savings

Financial Return

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $347,000 (**Figure 41**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of $487,600 (**Figure 42**).

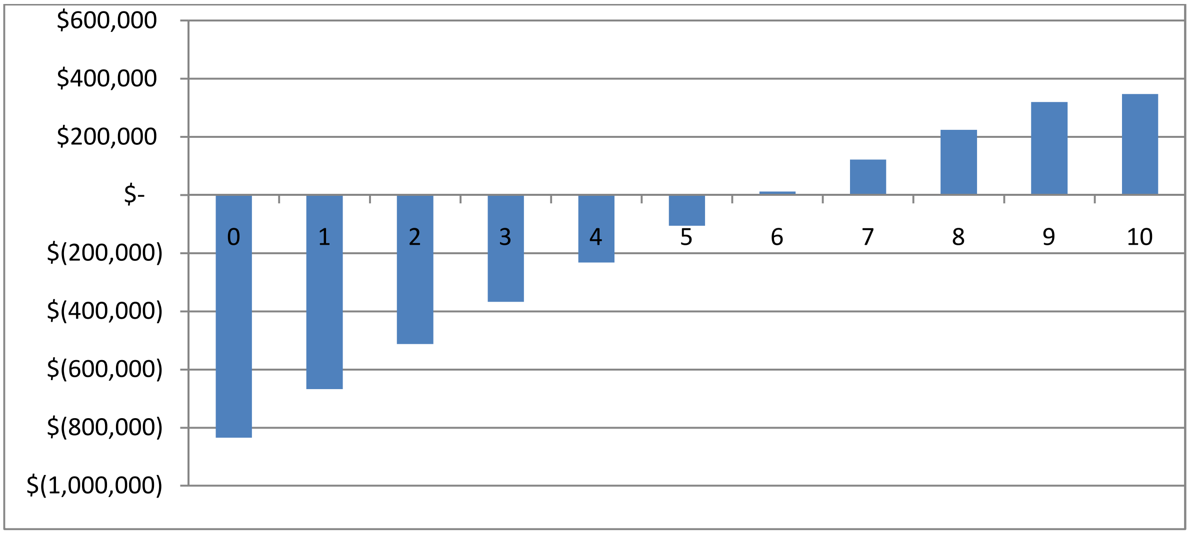


Figure 41. Newark panel system year-by-year payback

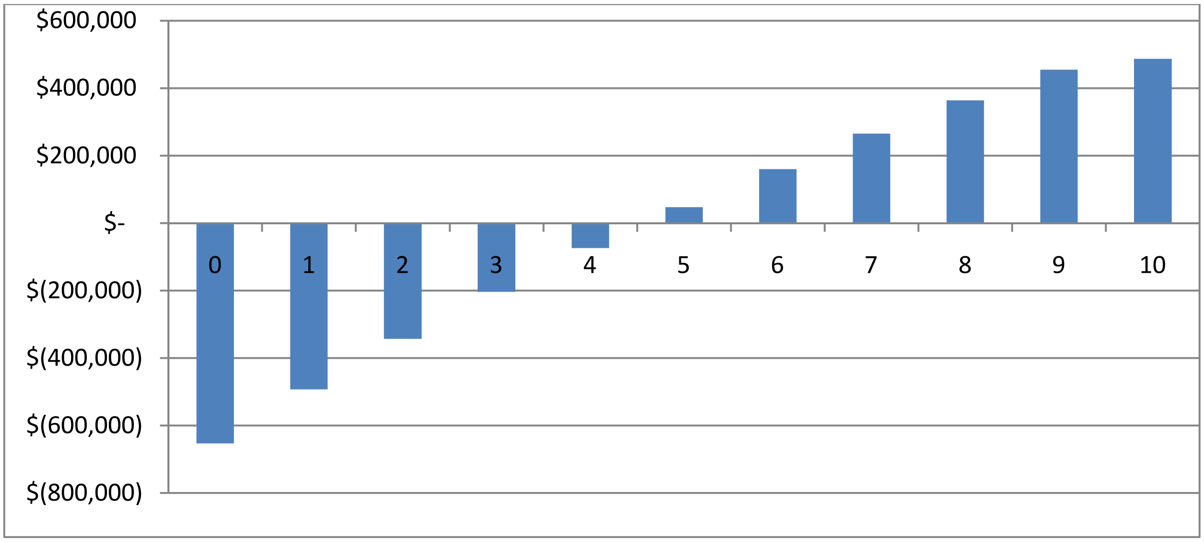


Figure 42. Newark thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 296,500 pounds of carbon dioxide, or just over 26 cars traveling 12,000 each. The thin film system yields a reduction of about 283,500 pounds, or about 25 cars (**Figure 43**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

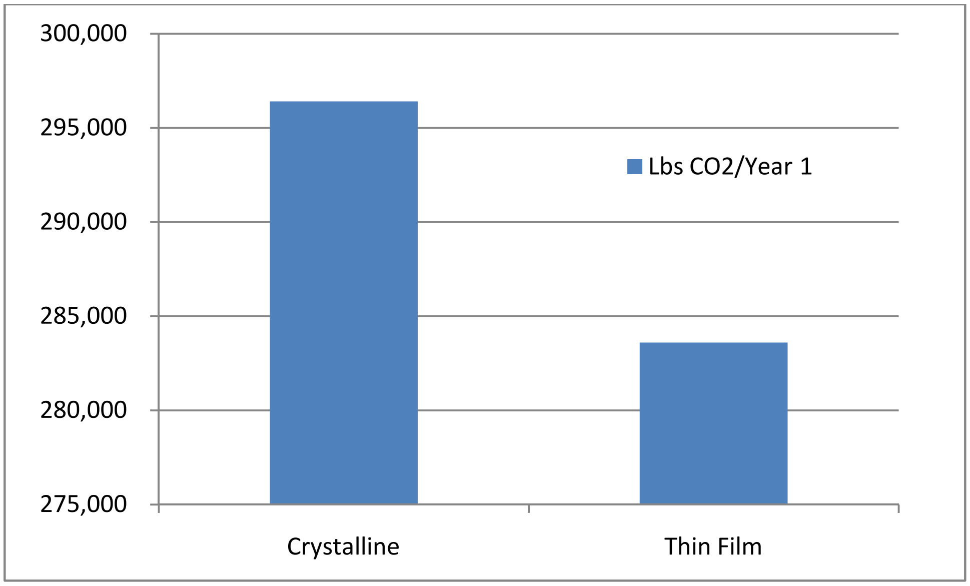
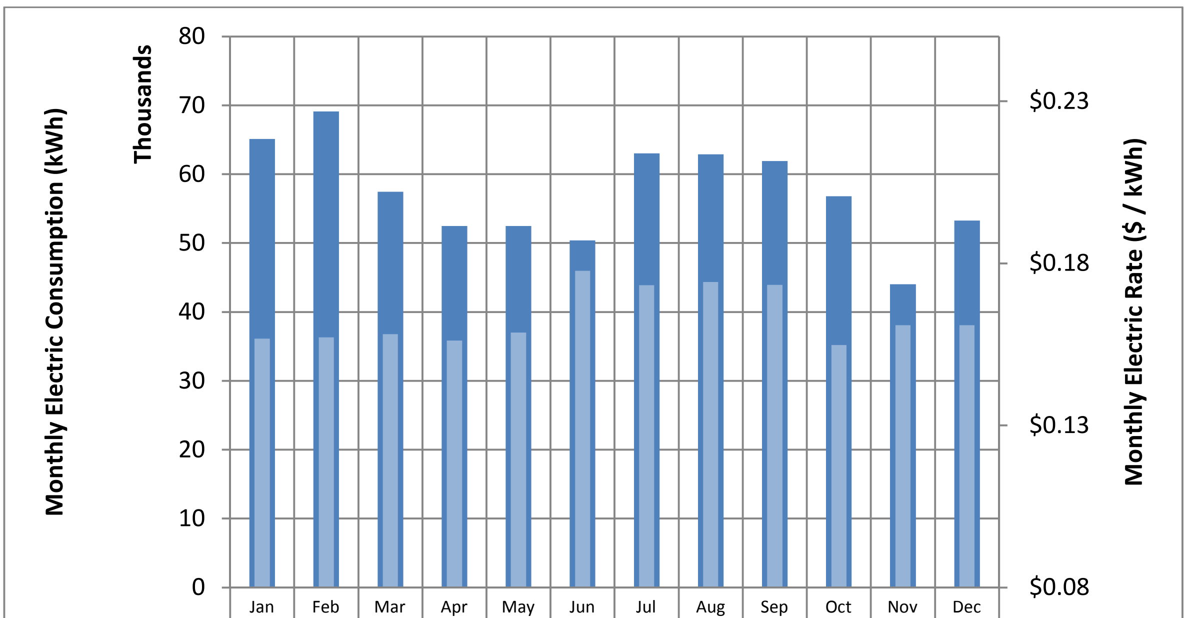


Figure 43. Year 1 CO_2 reductions

Mt. Arlington Regional Headquarters

Existing Energy Profile

The electricity account at this facility features a substantial 2009 peak demand figure of 163 kW, although this is down from over 200 kW the previous year. Consumption was 688,960 kWh, costing $104,119. Monthly kWh consumption does not follow the typical bell shaped profile showing lower electricity consumption during winter months and progressively higher summer consumption due to increased cooling loads and operating durations for air conditioning, usually peaking in August or July. Instead, Mt. Arlington's greatest consumption is in February, followed by January, July/August, and September (**Figure 44**). However, 2008 data yields a more conventional profile. Overlaying the demand and consumption curves for 2008 and 2009 shows that, while winter, spring, and fall months track very similarly (with modest aberrations expected), summer figures from 2008 are notably higher that their 2009 counterparts. Assuming that these billings are accurate, this may indicate a drastic change in summertime use or, more likely, the replacement, modification, and/or rebalancing of major building systems, such as chillers.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	65120	69120	57440	52480	52480	50400	63040	62880	61920	56800	44000	53280
Rate ($ / kWh)	$0.16	$0.16	$0.16	$0.16	$0.16	$0.18	$0.17	$0.17	$0.17	$0.15	$0.16	$0.16

Figure 44. Ewing F&A monthly kWh consumption and composite electricity rate

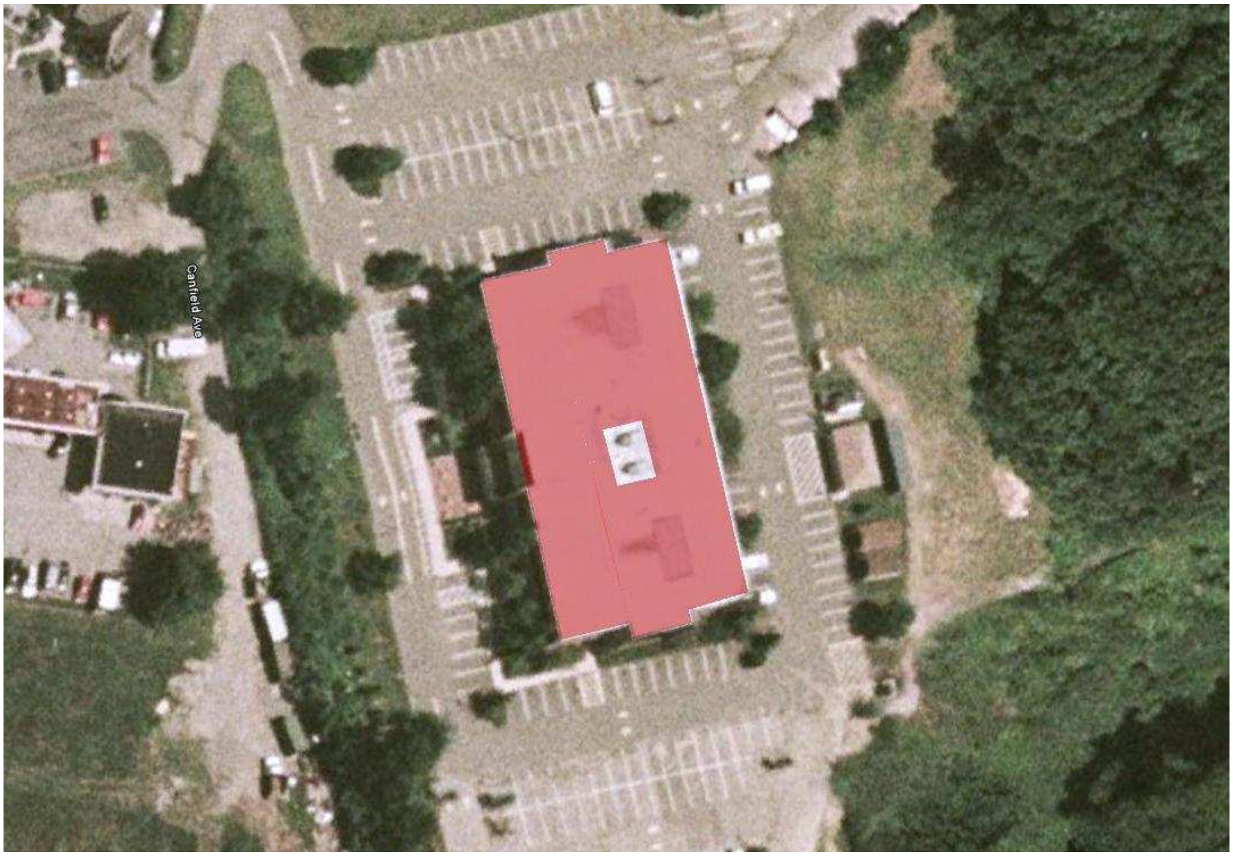


Figure 45. Mt. Arlington gross roof area

Power Production

Most of Mt. Arlington's roof space appears suitable for solar, totaling about 20,000 square feet of unshaded, unobstructed rooftop space (corresponding to the areas highlighted red in **Figure 45**). System size is limited by area, although a panel system could nearly achieve the peak of 163 kW AC. Available PV area is approximately 15,000 square feet. For a panel system, this yields a system size of 195 kW DC (150 kW AC), costing $975,000. For thin film, system size is 100 kW (DC), costing $450,000.

For the panel system, estimated yearly power production is 296,000 kWh, or 43 percent of total facility electricity consumption. The thin film system is expected to generate about 166,500 kWh per year, or 24.2 percent of consumption. Monthly production for each system, in kWh, is detailed in **Figure 46**.

Based on these monthly generation estimates, the panel system would result in the yearly avoidance of about $48,600 in electricity costs, while thin film would save almost $27,400 (see **Figure 47**).

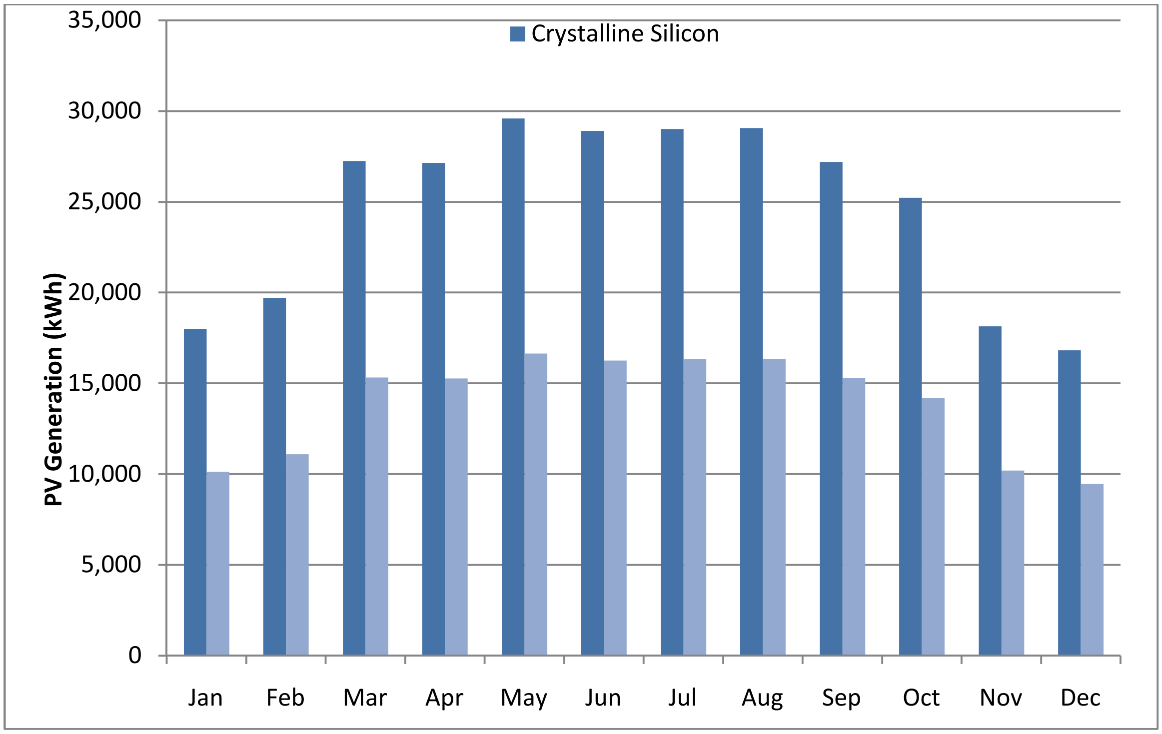


Figure 46. Mt. Arlington PV monthly production

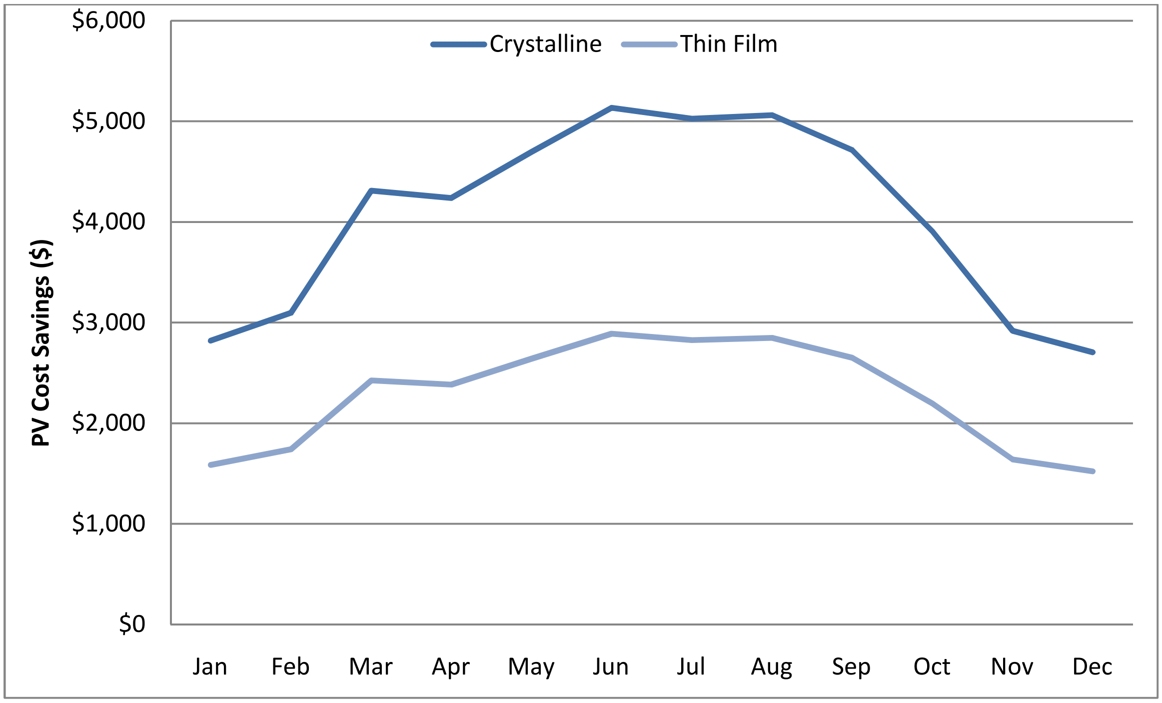


Figure 47. Mt. Arlington PV monthly electricity cost savings

<u>Financial Return</u>

Payback for panels is estimated to occur in Year 6, with a 10-year NPV of $392,000 (**Figure 48**). Payback for thin film is estimated to occur in Year 5, with a 10-year NPV of $329,000 (**Figure 49**).

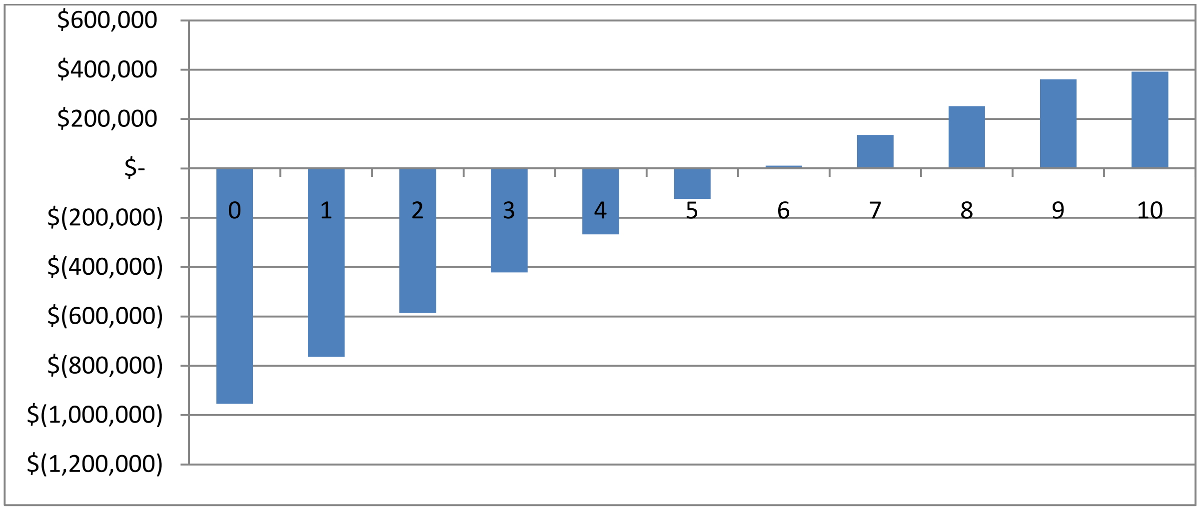


Figure 48. Mt. Arlington panel system year-by-year payback

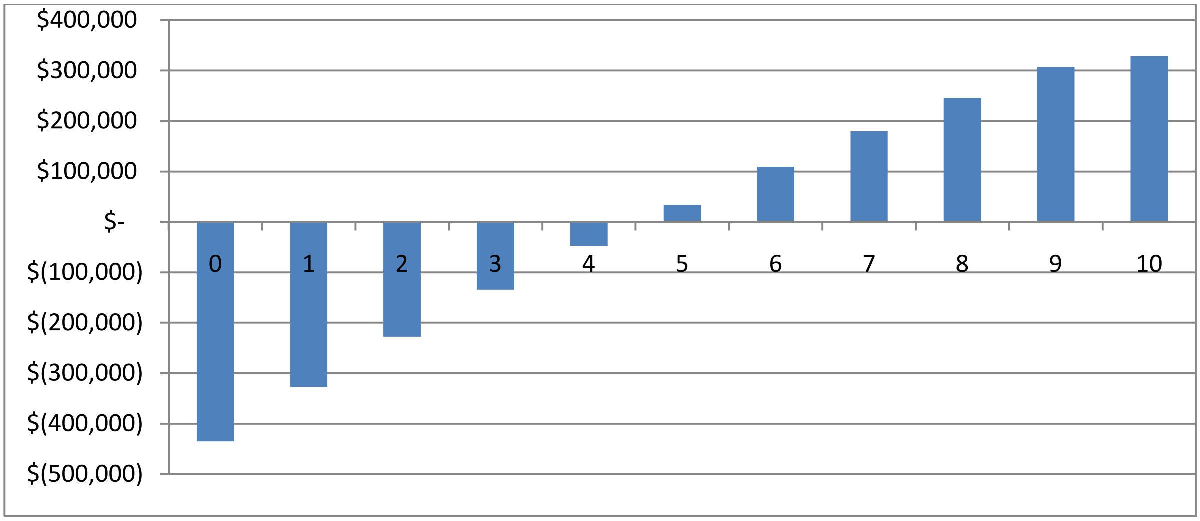


Figure 49. Mt. Arlington thin film system year-by-year payback

Greenhouse Gas Emissions

In Year 1, the panel system would eliminate an estimated 337,000 pounds of carbon dioxide, or almost 29.5 cars traveling 12,000 miles each. The thin film system yields a reduction of about 190,000 pounds, or 16.5 cars (**Figure 50**). Due to panel degradation, each subsequent year produces a marginally smaller benefit.

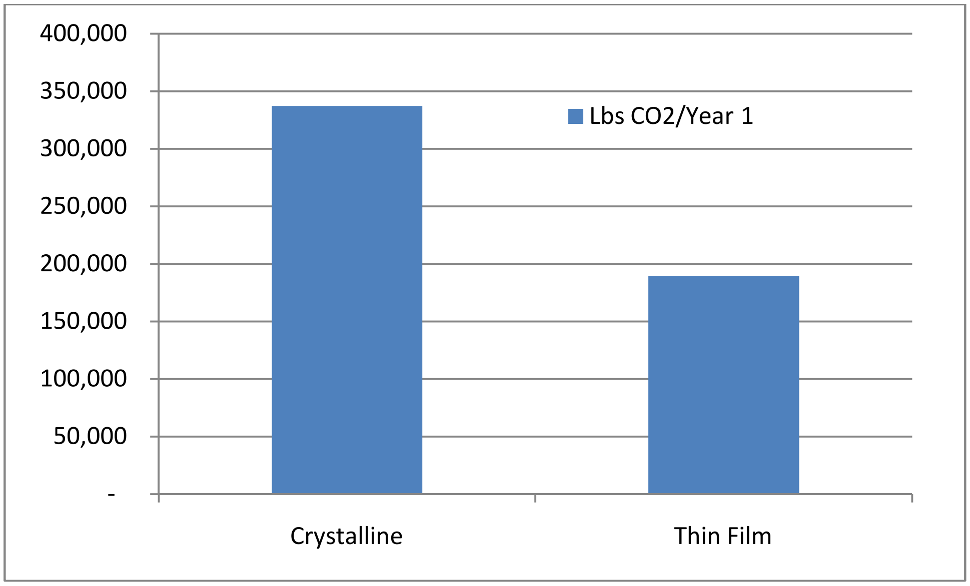


Figure 50. Year 1 CO2 reductions

RECOMMENDATIONS AND NEXT STEPS

Although this report does not determine what constitutes an acceptable return on investment or offer a project justification, all of the 14 scenarios appear to produce a positive financial return. Each scenario may make sense for NJDOT to pursue, depending on circumstances and objectives. Smaller projects generally require small initial outlays and entail relatively rapid returns on equity; larger projects return greater net present values in out years (particularly after Year 10). Thin film offers faster paybacks and larger NPVs per kW of nameplate capacity, but silicon crystalline panels generate more electricity per square foot. For sites that are space constrained, thin film installations cannot reach their maximum potential output. Thanks to New Jersey's generous solar incentives, deciding between scenarios is likely to be a contest of good and better, rather than borderline and unworkable.

While there are potentially several avenues forward for NJDOT, this report recommends three steps:

- **Establish project expectations:** Should a PV project minimize upfront expenses, maximize future revenues, or achieve stable utility rates through a power purchase agreement (PPA)? Should it maximize environmental benefits? Coincide with a major capital project (such as a roof replacement)? The top priority project may be identified when it is found to achieve all or most of NJDOT's primary objectives. A selection matrix (with weighting, if preferred) could be constructed to help organize this exercise.

- **Coordinate with the New Jersey Office of Energy Savings (OES):** NJDOT's current efforts would ideally align with and be informed by the Office of Energy Savings' statewide renewable energy activities. The OES is a potential partner in both project identification and implementation.

- **Seek implementation assistance:** NJDOT will require expert guidance in order to successfully establish a solar project. OES and the New Jersey Office of Clean Energy (OCE) are more likely to assist NJDOT in the selection of a third-party project developer than to assume development duties themselves. A solar developer will analyze the sites made available to them, create highly detailed, investment-grade pro formas (including financing), and offer NJDOT a predictable unit price for the resulting energy, most likely without upfront costs or maintenance responsibilities. With a well-structured RFP, NJDOT might even be able to command competitive bids in order to select the most advantageous offer. This report provides a base for the future efforts of solar developers. It is important to note, however, that technology changes rapidly, limiting the shelf life of this Report to no more than 24 months.

Finally, while PV is a promising option for reducing energy consumption, peak demand, and greenhouse gas emissions at NJDOT and in the State of New Jersey, it is important to recognize that PV is one solution among many. Not only can PV be employed in concert with other renewable energy technologies, it should be complemented by energy efficiency and energy conservation measures (ECMs). ECMs, as identified by professional energy auditors, can be cost effective and are often simple to perform. A concurrent program of ECMs could serve to lower electric loads, thereby enhance the potential contribution of solar photovoltaics to meeting the energy needs and lowering the energy costs of NJDOT's facilities.