# CREATING A SOLAR CITY

## Determining the Potential of Solar Rooftop Systems in the City of Newark

**FINAL REPORT**

**A Renewable Energy Applications for Delaware Yearly (READY) Project**

**Center for Energy and Environmental Policy**
**University of Delaware**

**August 2009**

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**Final Report**

**Renewable Energy Applications for Delaware Yearly (READY) Project**


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## ABBREVIATIONS

BCR – Benefit Cost Ratios
BIPV – Building Integrated Photovoltaics
CEEP – Center for Energy and Environmental Policy
DOSPC – Delaware Office of State Planning Coordination
GIS – Geographic Information System
IEA – International Energy Agency
NPV – Net Present Values
NREL – National Renewable Energy Laboratory
READY – Renewable Energy Applications for Delaware Yearly
RPS – Renewable Energy Portfolio Standard
SREC – Solar Renewable Energy Credits
TMY – Typical Meteorological Year

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## EXECUTIVE SUMMARY

This report summarizes the efforts of the Center for Energy and Environmental Policy (CEEP) to create an assessment method for estimating the potential of solar electricity generation to serve the needs of communities in Delaware. The City of Newark provides a case study of the method's use. The project quantifies the solar electric generation potential of the building inventory of the City by integrating Geographical Information System (GIS) data with financial and energy data compiled for use in the renewable energy analysis software program *PV Planner*.[1]

This project examines the financial and technical feasibility of rooftop photovoltaics (PV) in the residential, commercial/industrial and university building sectors of the City. The project can serve as a model approach to assess the potential of solar electric systems for communities throughout the State of Delaware.

To assess the rooftop PV peak capacity and energy generation of the building inventory within the municipal boundary of the City of Newark, CEEP researchers identified and digitized all available roof space for PV installations using Delaware False Color Infrared Digital Orthophotographs. Availability of a rooftop for PV use was based on architectural and solar suitability, taking into account shading, roof orientation (only roofs facing south, southeast and southwest were used), building obstructions (presence of HVAC systems, chimneys, air vents, needed walkways, etc.) and other architectural considerations (e.g., presence of prominent roof dormers). In addition to the use of digital orthophotographs, the CEEP team conducted walkabout surveys to validate or correct shading and other adjustments. The resulting roof area from the various sectors was used to determine sizes of PV systems that could potentially be installed on roofs in the City.

The results from the digitizing of rooftops show a peak solar power capacity potential of 96.4 MW for the City of Newark (Table 1). A distributed solar power plant of this magnitude could supply more than 75% of the City's annual electricity needs during daylight hours (9 am to

[1] See CEEP's 2006 report on this software program developed by Center faculty, staff and students. Available at: http://ceep.udel.edu/publications/energy/reports/2006_es_READY_PV_Planner_software_BIPV_analysis.pdf

6 pm).[1] This estimate of solar electric potential is conservative since allowances for shading and other factors that would reduce roof area calculations were intentionally generous. Moreover, it does not include the use of PV as shade roofing for parking lots and it does not consider ground-mount PV applications on non-forest and non-park land in the City.

**Table 1. Solar Power Potential Estimates for Newark, Delaware**

| Building type | PV Potential (MW) |
|---|---|
| University | 13.2 |
| Residential | 14.5 |
| Commercial and Utility | 29.2 |
| Industrial | 39.5 |
| Total | 96.4 |

Based on 18% module efficiency.[2]

The potential electrical output and associated benefits and costs of these rooftop PV installations were calculated using *PV Planner* software. *PV Planner* simulates the performance of PV systems and utilizes technical, economic, financial and policy data to analyze the overall feasibility of grid-connected PV installations. Of particular interest in the simulations was the use of solar renewable energy credits (SRECs) as part of the policy scenario. SRECs are included in the recent amendments of the Delaware Code, increasing the State's Renewable Energy Portfolio Standard (RPS) to 20% by 2019 with 2% required from PV installed in the State.[3] This information was integrated with *PV Planner* to determine the financial feasibility of these installations. The results of the modeling of the PV installations in the City show financial feasibility of PV installations for all building sectors – residential, commercial/industrial and university (Table 2). All configurations are found to be viable, attaining positive net present values (NPV) and benefit-cost ratios (BCR) of greater than 1.00 at both SREC values of $150 and $250.

[2] SunPower has marketed for some time an 18% efficient module (Rose et al, 2006). Recently it has begun sales of a module with an efficiency above 20%. In this report, it is assumed that PV modules with an average efficiency of 18% are ready for installation in Newark over the 3-year period when a Solar Community project could be completed.

[3] SRECs created by PV systems operating in Newark (or other jurisdictions in the State) can also be sold into the PJM Interconnection (the electric grid serving Delaware and 12 other states, all of which have RPS policies) or bilaterally to companies or other buyers.

**Table 2. Summary of Economic Feasibility of Rooftop Photovoltaics (energy-only configuration) for All Building Sectors in Newark -- Residential, Commercial/Industrial and University**

| RECS @ $150 for 10 years with REC prices de-escalated annually by 3% | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | Commercial / Industrial | | | | University | | | |
| Capacity | 3 kW | 5 kW | 7 kW | 20 kW | 45 kW | 250 kW | 6 kW | 15 kW | 30 kW | 100 kW |
| Yearly Generation | 3,894 kWh | 6,490 kWh | 9,085 kWh | 25,957 kWh | 58,404 kWh | 324,469 kWh | 7,786 kWh | 19,467 kWh | 38,937 kWh | 129,788 kWh |
| Initial Net Capital Cost (after tax benefits and rebates) | $10,890 | $17,626 | $18,495 | $49,541 | $111,467 | $516,052 | $16,349 | $37,156 | $74,311 | $206,421 |
| BCR | 1.00 | 1.02 | 1.00 | 1.02 | 1.02 | 1.07 | 1.02 | 1.05 | 1.05 | 1.10 |
| Payback Year | 12.65 | 12.40 | 8.20 | 7.63 | 7.63 | 6.22 | 7.84 | 7.06 | 7.06 | 5.85 |
| RECS @ $250 for 10 years with REC prices de-escalated annually by 3% | | | | | | | | | | |
| | Residential | | Commercial / Industrial | | | | University | | | |
| Capacity | 3 kW | 5 kW | 7 kW | 20 kW | 45 kW | 250 kW | 6 kW | 15 kW | 30 kW | 100 kW |
| Yearly Generation | 3,894 kWh | 6,490 kWh | 9,085 kWh | 25,957 kWh | 58,404 kWh | 324,469 kWh | 7,786 kWh | 19,467 kWh | 38,937 kWh | 129,788 kWh |
| Initial Net Capital Cost (after tax benefits and rebates) | $10,890 | $17,625 | $18,495 | $49,541 | $111,467 | $516,052 | $16,349 | $37,156 | 74,311 | $206,421 |
| BCR | 1.20 | 1.22 | 1.08 | 1.10 | 1.10 | 1.16 | 1.10 | 1.13 | 1.13 | 1.18 |
| Payback Year | 7.49 | 7.32 | 5.83 | 5.57 | 5.57 | 4.90 | 5.75 | 5.37 | 5.37 | 4.76 |

The overall impact of rooftop PV on the City electrical demand is significant. Displacement of conventional electricity by cost-effective rooftop solar energy systems is more than 75% during daylight hours, and over 30% across all hours. Despite the conservative method of rooftop inventorying used in the study, the City's daylight electrical demand could be substantially supplied economically by solar rooftop systems (Table 3).

**Table 3. Total Electricity Displaced by Photovoltaics in Newark from All Options**

| All Options (Residential, Commercial/Industrial, University) | Conventional Electricity Displaced |
|---|---|
| Option 1: All hours-based displacement | 32.0% |
| Option 2: Daylight period displacement | 76.2% |

The assessment method presented in the study offers a powerful tool for estimating solar electric contributions to localities in the State of Delaware. There are considerable educational and public awareness benefits that can derive from the application of this tool throughout the State. The ability to demonstrate the potential of building rooftops to utilize PV technology will help advance its use in the State. The techniques developed under this READY project can be transferred and applied to other communities and cities throughout the State.

The assessment method can also help in the planning process when new buildings are being considered for construction. Including solar access in planning decisions will enable a community to capture environmental and local development benefits associated with solar rooftop utilization. The assessment method also provides a platform for communities in Delaware to prepare for wider adoption of renewable energy technologies. A web-based interface to enable solar rooftop assessment is presently being investigated by CEEP researchers.

Based on a detailed analysis of Newark's solar electric potential, the research finds that a *Solar City Newark* is technically and economically feasible. Issues of financeability under existing national and state policy arrangements are examined and are found to pose a barrier to the widespread creation of solar cities throughout Delaware and the U.S.

## 1. INTRODUCTION

The energy influx from solar radiation is widely regarded as sufficient to meet the present primary energy needs of the world many times over (Brower, 1992). Solar energy is intercepted by the earth's atmosphere at an annual average rate of about 1.3 – 1.4 kW/m$^2$ (Rogner, 2000; Sorensen, 2000). Accounting for the fraction reflected back into space, it is estimated that the maximum influx at the earth's surface is about 1 kW/m$^2$. At this rate, the ratio of potentially useable solar energy to current primary energy consumption is approximately 9,000 to 1 (Rogner, 2000: 162).

Useable solar influx is limited by diurnal variation, geographic variation and weather conditions (Rogner, 2000). Thus, worldwide, the yearly average values of effective solar irradiance reaching the earth's surface varies from a low of 0.06 kW/m$^2$ (~500 kWh/m$^2$/year), at the highest latitudes, to a high of 0.25 kW/m$^2$ (~2,200 kWh/m$^2$/year) in some desert areas of Africa and Australia (de Vries et al., 2007).

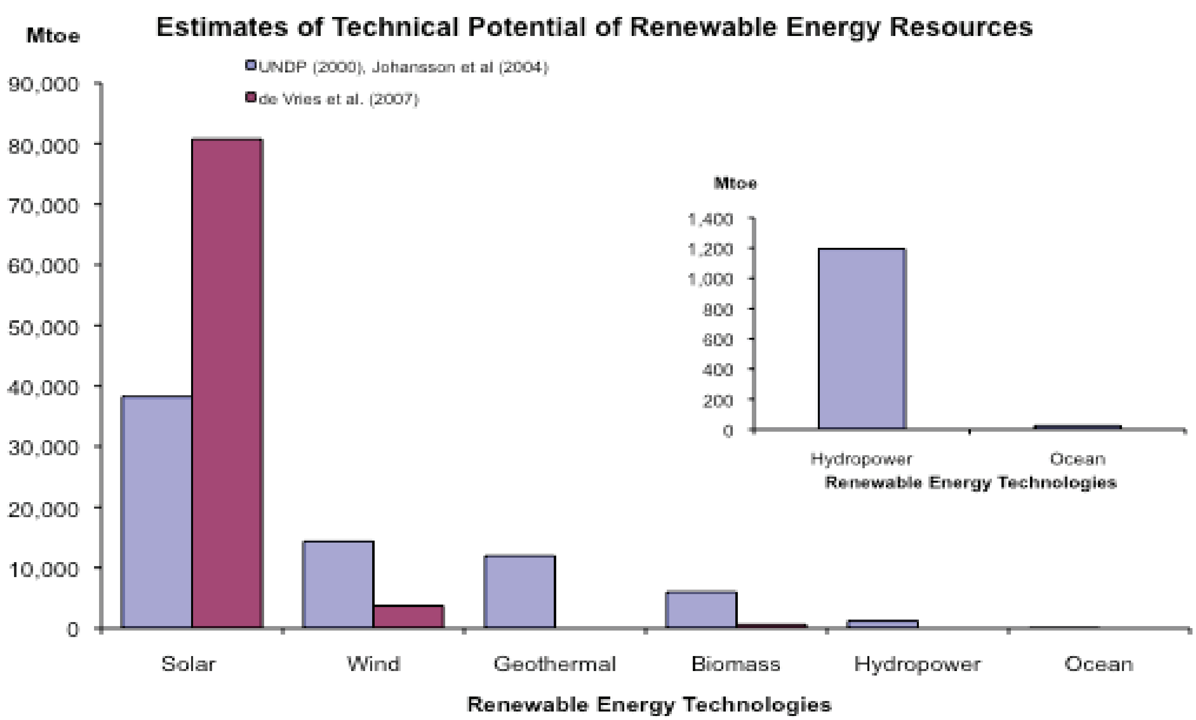


**Figure 1. Technical Potential of Renewable Energy Technologies.**
Data sources: Goldemberg, 2000; Johansson et al., 2004; de Vries et al., 2007

Conversion of this potential into secondary forms, such as electricity or process heat, depends upon technical constraints (e.g., efficiency of converters such as photovoltaic (PV) cells or thermal collectors), economic constraints (e.g., absolute and relative costs of technology and fuels), and suitability considerations (e.g., the availability of land and the appropriateness of its use to locate the collection infrastructure).

Even so, the abundance of solar energy compared with other sources of renewable energy is substantial. Estimates of the technical potential of solar energy versus wind, biomass, geothermal and ocean options are presented in Figure 1. Solar energy represents our largest source of renewable energy supply and solar technologies offer the greatest potential among renewable energy options to lower worldwide carbon emissions.

The electricity industry is an essential and critical component of the nation's economy and quality of life. Still, rising costs and the environmental impacts of electricity generation are of major concern to federal and local governments, the public and even industry representatives. In many parts of the country, utilities face frequent excess demand which strains transmission capacity. Further, significant efficiency losses are observed in transmission as grid power is delivered to end-users. To address these issues, researchers and industry analysts have begun to stress the role of distributed energy resources (DR) to produce clean, efficient, and reliable energy services. DR consists of demand response, demand management and supply strategies employed by customers or utilities to lower electricity costs. A wide range of technologies are included in DR — from improved lighting and motor efficiency upgrades to micro-turbines and photovoltaic (PV) panels. Strategically sited distributed resources systems can allow an electric utility to defer investment in upgrading transmission and distribution facilities.

DR offers a long menu of benefits (Byrne et al., 2005):

- Reduced peak load
- Enhanced reliability
- Stabilized and lower electricity prices in wholesale markets
- Reduced transmission losses
- Reduced uncertainty accompanying bulk power generation
- Improved customer choice
- Enhanced energy security
- A boost to local economies, especially in the form of significant numbers of green jobs
- Reduced emissions (e.g., $CO_2$, $NO_x$, $SO_x$, $H_g$, Pb).[4]

[4] Distributed Resources systems cut grid electricity demand and, therefore, reduce grid power emissions. When renewable energy options are deployed as grid supply sources, they slow emission rates but do not reduce them unless they are substituted for fossil fuel generation (leading to plant closures or cut backs in operating hours.

Building integrated photovoltaics (BIPVs) integrate photovoltaic arrays into roofs or façades, thereby providing electricity as well as acting as a multi-functional building component. The system serves as an architectural element having both functional (electricity production) and aesthetic value (replacing conventional construction material). The financial benefits of this configuration are often substantial: not only is electricity being produced but, in some cases, expensive façade or roofing materials are displaced and can be expressed as an "avoided cost." This "avoided cost" can effectively reduce the capital cost of the PV system.[5]

The PV industry provides an important source of high-skill jobs in research and development, manufacturing, distribution, and system integration and installation in the U.S. For every 1 million dollars spent in the U.S. PV industry, 16 new direct and indirect jobs are created. This is higher than other clean energy technologies (e.g., wind creates 12 jobs, geothermal creates 11, hydropower only 5 and energy efficiency about 9) (Bezdek, 2007). Moreover, the number of direct jobs created by PV installations is much higher than for conventional fossil fuel power plants. After adjusting for power output (i.e., number of jobs created according to typical capacity factors) PV can create 7.4 to10.6 jobs per average installed megawatt (MWa), while power plants operating on coal and natural gas can provide only 1.0 job per MWa (Kammen et al., 2006).

There is significant energy collection potential from building roof space in the U.S. After considering rooftop orientation, structural adequacy, shading and building architecture, it was estimated that 27% of total residential rooftop area and 65% of total commercial and industrial rooftops are suitable for converting sunlight into electricity (Paidipati et al., 2008). The study estimated the technical potential of roof space PV at 539 GW by 2010 and 712 GW by 2015 (the increase in potential is the result of expected improvements in PV system efficiency and new building construction methods). Based on a typical annual PV system output per unit of installed capacity (i.e., 1,500 kWh per $kW_p$), rooftops can provide up to 27% of current U.S. electricity needs. Utilizing even a fraction of this potential can provide significant benefits for U.S. energy security and sustainable development.

## 1.1 READY Project Mission

The Renewable Energy Applications for Delaware Yearly (READY) project has the mission of "identifying high-value, high-visibility renewable energy applications; determining

[5] Such benefits are not included in this study. However, *PV Planner* has the capability to evaluate them.

approaches to encourage renewable energy suppliers to enter Delaware markets; developing creative and effective education and consumer outreach regarding renewable energy technologies."

## 1.2 Rooftop Applications of Photovoltaics in Delaware

This report explores the economic and technical feasibility of rooftop photovoltaics in the City of Newark. This project serves as a model approach that can be applied to assess the potential of solar electric applications of this kind throughout the State of Delaware.[6] In this way, it serves the mission of READY.

[6] An estimate of the energy value of rooftop solar systems in the City of Newark is provided with details of the supporting analysis. Scaling this value to a larger geographic unit (such as the state) is complex and should not be attempted by using simple approaches.

## 2. BACKGROUND

### 2.1 Solar-Powered Buildings

Solar-powered buildings integrate photovoltaic arrays into the roofs or façades of buildings, thereby providing electricity as well as acting as a multi-functional building component. The system serves as an architectural element containing both functional (electricity production) and aesthetic value (replacing conventional construction materials) (Miller et al., 2003). The financial benefits of this configuration are multi-dimensional, as not only is electricity being produced but, in some cases, expensive façade or roofing materials are displaced and can be expressed as an "avoided cost." This "avoided cost" can effectively reduce the capital cost of the PV system. The PV system can also provide the benefits of peak-shaving demand and non-polluting electricity generation, which has become a commodity under carbon markets (CEEP, 2006; Hoff et al., 2007). As well, with the addition of a modest amount of storage (for example, a battery bank), a PV system can serve emergency power and uninterruptible power supply. This configuration also enhances the peak-shaving capability (CEEP, 2006; Byrne et al., 1996b, 1997, 1998 and 2001; Hoff et al., 2004; Walker et al., 2003).

In Newark, Delaware (which includes, in this study, all Newark zip codes), there has been a limited but important number of solar installations, including a 1.2 kW system on a University of Delaware building rooftop (Graham Hall, which houses CEEP) and several residential and commercial systems (Table 4).[7]

**Table 4. List of PV Installations in Newark**

| Type of Installation | Size of installation (kW) | Date Installed |
|---|---|---|
| University | 1.2 | 1999 |
| Commercial | 29.0 | 2002 |
| Commercial | 30.0 | 2002 |
| Commercial | 341.0 | 2002 |
| Residential | 4.0 | 2002 |
| Residential | 5.2 | 2006 |
| Residential | 6.0 | 2006 |
| Residential | 5.0 | 2006 |
| Residential | 5.0 | 2006 |
| Residential | 5.0 | 2006 |
| Residential | 4.6 | 2006 |
| Residential | 3.6 | 2006 |
| Residential | 4.8 | 2007 |

Source: Delaware Energy Office, 2007

[7] The Delaware Energy Office reports that there have been over 100 PV installations (installed capacity of approximately 800 kW) in the State from 2002 to 2007.

Numerous studies on the technical and economical feasibility of rooftop solar applications at the local level have been conducted across the U.S. Several are briefly described below.

In California, the Marin Solar Program investigated the energy potential of rooftop PV systems for commercial and institutional facilities in Marin County. The study integrated insolation data, orthographic aerial photographs and county tax parcel information with a database containing building information. Using Geographic Information System (GIS) visualization software, rooftop structures located in optimal solar corridors throughout Marin County were identified and catalogued. Because Marin County encompasses an area of high topographic variability ranging from tidal flats to narrow valleys and hilly slopes, the use of GIS to identify zones of high and low solar intensity was also required. The major implication of topographical variation is its effect on insolation due to shading issues. The study found the PV potential[8] for Marin County was 58 MW from the commercial sector, 25 MW from parking lots, and 13 MW from institutional facilities (Johnson and Armanino, 2004).

Other solar rooftop studies using GIS include New York City and San Diego, California. Ahmed et al. (2006) estimate the total solar PV potential for New York City at 6,080 MW assuming 40% of the city's rooftop space is suitable for PV installation. Using this metric, the residential sector accounted for 79% of the total, with the remainder supplied by industrial and commercial buildings. In San Diego, Anders and Bialeck (2006) investigated the commercial and residential rooftop PV potential for the city and then extrapolated their results to San Diego County. Their study concluded a city PV potential of 769 MW from the commercial sector if all solar-suitable and architecturally suitable space was utilized. Extrapolating their data to the county level, a PV total was estimated at 1,726 MW for solar rooftop applications in the commercial sector, and 2,539 MW from the residential sector. To account for future housing and commercial development and less than full rooftop utilization, the study also provided projections at 1%, 5% and 10% market penetration rates for both sectors through the year 2010.

On the national level, the National Renewable Energy Laboratory (NREL) commissioned a study by Navigant Consulting that estimated the PV market potential in the U.S. (Paidipati et al., 2008). The report concludes that 27% of total rooftop area can be used in warmer areas and 22% in colder climates for PV rooftop installations in the residential sector and 60% of commercial and industrial rooftops in warmer areas and 65% in colder climates are suitable for

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[8] Only solar energy from PV was estimated; solar thermal and concentrating solar were not included in the analysis.

converting sunlight into electricity.  It concludes that more than 500 GW of rooftop PV development exists in 2009.

## 3. DATA AND METHODOLOGY

### 3.1 Research Design

This study has two objectives: (i) to undertake an initial assessment of the rooftop solar PV potential of the City of Newark, Delaware; and (ii) to determine the financial benefits of rooftop PV applications for the City. Software models have been introduced to calculate available rooftops for solar applications. These software applications often require a complex series of assumptions that can limit the reliability of results, particularly when applied on a small scale (Gadsen et al., 2003a; Gadsen et al., 2003b; Mardaljevic, 2003; Rylatt, 2003). The project provides a model for determining the technical and financial feasibility of rooftop PV applications that can be applied to other cities and jurisdictions across the State of Delaware.

An assessment of rooftop PV energy capacity and energy generation requires compiling an inventory of building stock by sector; assessment of rooftop architectural and solar suitability for PV installation; estimation of solar energy potential based on available rooftop area and technical performance of PV systems; and analysis of the economic feasibility of rooftop solar applications given existing market and policy parameters.

The project was conducted in two phases. In the first phase, CEEP researchers used GIS to identify and digitize all rooftops by sector (residential, commercial, industrial, and university) in the City of Newark. Architectural and solar insolation factors that might reduce rooftop solar energy potential were included in the analysis to calculate the total suitable rooftop area for PV installations. In the second phase, CEEP utilized the *PV Planner* software package[9] (initially developed with support from the National Renewable Energy Laboratory) to assess the technical and economic feasibility of rooftop PV systems across all sectors. This section describes the GIS and data collection process used for the study.

### 3.2 Study Area

The City of Newark was selected as the study area for determining the potential of solar resources in Delaware communities (Figure 2) because of its size (which is typical of small cities in Delaware), easy access to electricity load data for the area and its proximity to the Center, which allowed for visual ground-truthing of spatial information. The City of Newark is located in the northern part of the State near the Pennsylvania and Maryland borders and occupies an

[9] This software has undergone extensive development at CEEP with contributions from faculty and several research staff and graduate students. A summary of its capabilities can be found at: http://ceep.udel.edu/publications/energy/reports/2006_es_READY_PV_Planner_software_BIPV_analysis.pdf. A newer version will shortly be released.

area of 9.3 sq miles. It has a total population of approximately 28,000 persons.[10] Newark is a small college town comprised primarily of residential, low-rise commercial buildings and a few industrial complexes.

Residential housing statistics for Newark are summarized in Table 5.

**Table 5. Housing Unit Information for the City of Newark**

| | |
|---|---|
| Total Housing Units (includes multi-family type units) | 9,039 |
| Single Family Dwellings | 6,342 |
| Single Family Rental Dwellings | 1,173 |
| Median Household Income in 1999 | $54,395 |

Source: City of Newark, 2009[11]

### 3.3 Use of GIS and Data Collection

#### a. Rooftop data

In order to obtain an inventory of total rooftop space, the Newark municipal boundary was divided into quintiles using False Color Infrared Digital Orthophotographs (0.25 m spatial resolution) obtained from the Delaware Office of State Planning Coordination (DOSPC). The orthographic photographs were supplemented with Google Earth imagery in order to account for seasonal vegetation changes. Ground-truthing was also undertaken, particularly to investigate shading affecting residential buildings since the aerial photographs were taken during the autumn season and most deciduous trees would not have had all of their leaves. The shading effect of trees during spring and summer seasons would have been underestimated if the investigators only relied on aerial photographs. The shading effect was found not to be a significant factor for most commercial buildings but was significant for residential buildings, particularly in older neighborhoods. From the quintiles, all available rooftop space within the municipal boundary was identified and catalogued. This study used ESRI ArcGIS 9.1 to integrate the spatial and attribute data.

#### b. Digitizing of polygons

Once identified and catalogued, rooftops and polygons representative of PV installations were derived. This established methodology is appropriate because the perimeter of a rooftop area is mathematically mapped as a polygon (Wittman et al, 1997).

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[10] Includes students living on campus at the University of Delaware.
[11] City of Newark, *Facts & Figures*. http://www.cityofnewarkde.us/index.asp?NID=281

Not all buildings are suitable for PV installation due to a variety of technical and architectural factors. Solar suitability includes relative solar radiation of a given surface area due to orientation, inclination and location of existing rooftops; and the technical performance of the PV system (IEA, 2002). Architectural suitability refers to corrections for limitations due to mechanical systems and other construction on roofs (e.g., HVAC systems, chimneys, air vents, etc.); shading effects due to seasonal vegetation or nearby building structures; and historical considerations (IEA, 2002). Only those sites that met the following well-defined architectural and solar suitability criteria were included in the study:

1. *Orientation.* Only south facing (south, southeast, and southwest) residential buildings were included for digitizing in order to account for the reduced solar factor of tilted or sloped roofs. Because nearly all commercial buildings in Newark are constructed with flat rooftops, building orientation was not a major consideration in this sector.
2. *Shading.* Rooftop areas shaded by other buildings, structures or vegetation that affected the solar yield were not included in the study.
3. *Building obstructions.* Rooftop areas with structures such as HVAC systems, chimneys, air vents, etc., which would obstruct installation and maintenance of PV panels, were excluded.
4. *Architecture.* Rooftops with prominent roof dormers or other architectural considerations that would impact installation and maintenance of PV panels were excluded.[12]

In some cases, other factors affecting the suitability of rooftop PV systems can include historic preservation ordinances and the type of rooftop construction material. These, however, are not major issues in the City of Newark. A significant factor is the estimation of building façade for PV use. Such an estimate would require site-specific and complex analysis of building structures that is beyond the scope of this study. Thus, wall surfaces that could be covered with PV are not included in the study's estimate and, therefore, the potential solar electric contribution to the needs of the City of Newark is understated.

[12] Roof dormers are windows that protrude from the roofs of buildings to provide additional light, space or ventilation.

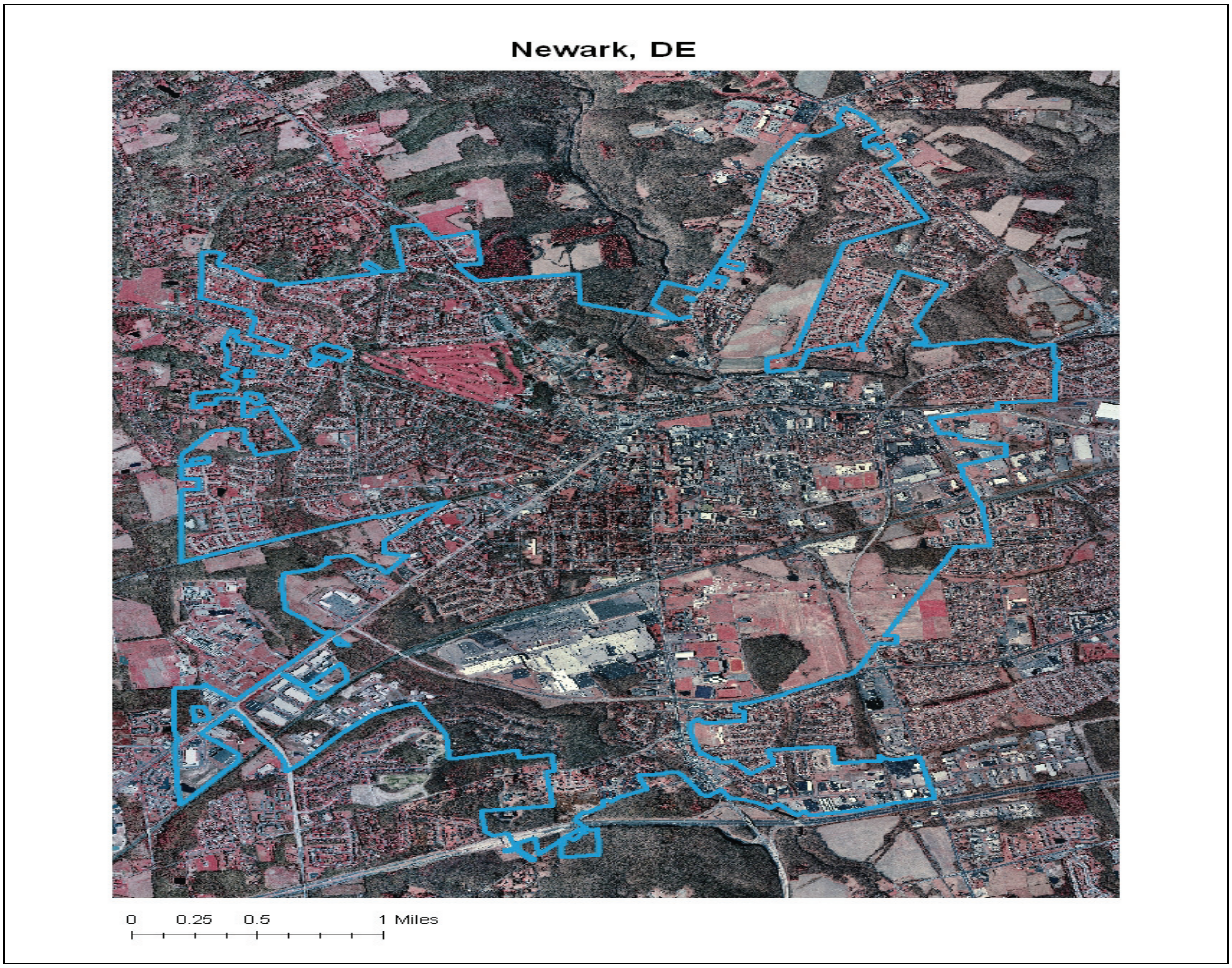


**Figure 2. City of Newark, Delaware**

Digitizing of polygons was based on visual analysis of rooftop sites using aerial photographs. Sufficient setback space from the edges of roofs and rooftop structures was required to ensure proper installation and maintenance of PV arrays and to correct for shading. The square footage of the various polygons represents the possible aggregate area for PV installations.

While the use of floor area as a proxy for roof area poses no problems for flat-roofed buildings, structures with sloped roofs present difficulties in the use of roof area. There is no standardized roof slope for buildings in the city which can be used to calculate roof area and a "floor area to roof area" aspect ratio. Using floor area as a proxy for roof area leads to an underestimate of the true solar roof area or available solar roof space. Some studies have used a general "rule of thumb" ratio of suitable architectural area to resolve this issue. Their results indicate that floor area underestimates available roof space by 20% (Anders and Bialek, 2006) to

45% (IEA, 2002). No adjustment was made in the study and, therefore, the solar electric potential estimated for residential buildings underestimates the true value.

### c. Integration of tax parcel information

Once the architecturally suitable solar collection roof area was determined, an estimate of roof area by sector was calculated. A map of New Castle County tax parcel data was overlaid onto the orthographic photo layer to identify the different building types. The County GIS Tax Map contains tax parcel information for all properties within the City of Newark using the following classifications:

a. **RS – Residential**
b. **ER – Exempt Residential**
c. **C – Commercial**
d. **EC – Exempt Commercial**
e. **I – Industrial**
f. **A – Agricultural**
g. **U – Utility**

Results from the digitizing of polygons are presented in Tables 6 and 7. The tables show the rooftop area of the various building types according to the number of polygons that they cover, and their total and average areas. The number of polygons does not represent the number of buildings because some rooftops may have more than one polygon drawn on them (e.g., a roof area with multiple south-facing roof members can include two or more PV systems). Buildings in the Commercial, Industrial and Exempt Commercial classes contain the largest suitable roof area (measured in total square footage). The Exempt Commercial class is primarily comprised of buildings owned by the University of Delaware. The residential rooftop area of 685,692 square feet is roughly one-third the size of the Industrial class.

For simplification, this analysis grouped non-university Residential, Exempt Residential and Agriculture properties into a single Residential classification. Similarly, non-university Commercial and Exempt Commercial properties were grouped into one Commercial classification. Industrial and Utility properties are unchanged in classification in Tables 6 and 7. The resulting five building sector classifications used for the study are: [13]

a. **Residential**
b. **Commercial**
c. **Industrial**

[13] The analysis also included buildings belonging to the "Utility" category but for Newark this includes only one parcel with 2 corresponding polygons.

d. **University**[14]
e. **Utility**

Using the collapsed five-sector classification system yielded the results shown in Table 6. Industrial buildings furnish 41% of the total suitable rooftop square footage in Newark. The commercial sector hosts 30% of the suitable roof area, while the University building stock has 14% and the residential sector approximately 15% of the total suitable rooftop square footage.

**Table 6. Suitable Rooftop Area by General Building Type for the Collection of Solar Energy**

| Polygon Type | Number of polygons* | Total area in square feet ($ft^2$) | Total area in square meters ($m^2$) | Average area in square feet ($ft^2$) | Average area in square meters ($m^2$) |
|---|---|---|---|---|---|
| RS | 1,530 | 685,692 | 63,703 | 448 | 42 |
| ER | 40 | 42,010 | 3,903 | 1,050 | 98 |
| A | 160 | 154,136 | 14,320 | 963 | 89 |
| C | 374 | 1,366,158 | 126,921 | 3,653 | 339 |
| EC | 475 | 1,146,584 | 106,521 | 2,418 | 225 |
| I | 308 | 2,358,832 | 219,144 | 7,659 | 712 |
| U | 2 | 9,619 | 894 | 4,809 | 447 |
| Total | 2,889 | 5,765,021 | 535,591 | 1,996 | 185 |

*The number of polygons does not equal the number of buildings. Also, total roof area in the City is much larger than the reported area in the table because non-south facing roofs and shaded or obstructed areas are excluded.

**Table 7. Suitable Rooftop Area by Selected Building Type for the Collection of Solar Energy**

| Polygon Type | Number of polygons * | Total area in square feet ($ft^2$) | Total area in square meters ($m^2$) | Average area in square feet ($ft^2$) | Average area in square meters ($m^2$) |
|---|---|---|---|---|---|
| University | 342 | 789,326 (14%) | 73,331 | 2,308 | 214 |
| Residential | 1713 | 870,580 (15%) | 80,880 | 508 | 47 |
| Commercial | 524 | 1,736,674 (30%) | 161,158 | 3314 | 308 |
| Industrial | 308 | 2,358,832 (41%) | 219,144 | 7,659 | 712 |
| Utility | 2 | 9,619 (~0%) | 894 | 4,809 | 447 |
| Total | 2,889 | 5,765,021 | 535,591 | 1,996 | 185 |

*The number of polygons does not equal the number of buildings. Also, total roof area in the City is much larger than the reported area in the table because non-south facing roofs and shaded or obstructed areas are excluded.

[14] The University of Delaware is a major property owner in the city. It was decided to analyze its properties as a separate category. This illustrates how building inventories can be segmented to reflect analytical concerns.

The overlay of the first two data layers (digitized polygons of rooftop and tax parcel information) produces a third layer, a shapefile of rooftops suitable for the installation of PV panels (Figure 3). In other studies, an additional data layer representing solar intensity was used to correct for topographic variation within the study area. However, because both the City of Newark and the State of Delaware exhibit very small topographic (valleys and hillsides) or microclimate variations, this was not necessary. CEEP used solar radiation data derived from the *PV Planner* software database, which relies on Typical Meteorological Year (TMY) weather data developed by the National Renewable Energy Laboratory (CEEP, 2006).

### 3.4 Use of *PV Planner* to Estimate Solar Electric Potential and Economic Feasibility

The potential electrical output and associated benefits and costs of rooftop PV installations were calculated using *PV Planner* software developed by the Center for Energy and Environmental Policy. *PV Planner* simulates the performance of PV systems and utilizes technical, economic, financial and policy data to analyze the overall feasibility of grid-connected PV installations. The software assesses economic benefits and costs using the same methods employed by utilities and commercial enterprises. Economic performance is measured as net present value, payback period, internal rate of return and benefit-cost ratio. *PV Planner* calculates payback period as the year when cumulative cash flow (including annualized O&M costs) first becomes zero. A summary of the parameters used to run *PV Planner* for this study is provided in Appendix I.

#### a. Electricity rate and load data

Electricity rate and load data were provided by the City of Newark's Electric Department. This included sample electricity consumption load data for 30 residential units and 20 commercial facilities. Load consumption and demand data for University of Delaware buildings were used in the analysis. The data were provided by the Facilities Department (Maintenance and Operations) of the University as part of the University's Climate Action Plan conducted by CEEP (University of Delaware, 2009).

#### b. Installation cost

Recent forecasts of PV installation costs for residential and commercial users are summarized in Table 8.

**Figure 3. Photos of polygons showing potential PV installations in Newark**

**Table 8. PV System Installed Price Projection for 2010 (Unit: $/W_p$)**

| Source | | Residential | Commercial |
|---|---|---|---|
| NREL[15] | Business as Usual (BAU) | $5.90 | $5.50 |
| | Solar America Initiative (SAI) | $3.86 | $3.60 |
| U.S. DOE[16] | | ~$4.60 | ~$3.50 |
| Energy Foundation[17] | | $5.30 | $4.65 for small medium size<br>$4.25 for large size |

Based upon these forecasts, the research assumes system installation prices for different considerations, as reported in Table 9.

**Table 9. Installation Costs for Residential, Commercial/Industrial and University PV Systems**

| | |
|---|---|
| **Residential** | 3kW $7,000/kW$_p$<br>5kW $6,800/kW$_p$ |
| **Commercial/Industrial** | 7kW $6,400/kW$_p$<br>20kW $6,000/kW$_p$<br>45kW $6,000/kW$_p$<br>250kW $5,000/kW$_p$ |
| **University** | 6kW $6,600/kW$_p$<br>15kW $6,000/kW$_p$<br>30kW $6,000/kW$_p$<br>100kW $5,000/kW$_p$ |

Data on operation and maintenance costs were derived by contacting local PV contractors (see Appendix I for specifics).

### c. Determining the economic potential of PV power

Using results derived from the digitizing phase of the project, the CEEP research team developed two scenarios to calculate the technical and economic potential of rooftop PV systems for the City of Newark. The first scenario is based on a renewable energy credit (REC) value of $150/MWh, which reflects the mid-point of estimates provided by a National Renewable Energy Laboratory study (Holt and Bird, 2005). The second scenario is based on current market value in

[15] Paidipati, J., Frantzis, L., Sawyer, H, and Kurrasch, A. 2008. Rooftop PV Market Penetration Scenarios. Subcontract Report for NREL.
[16] U.S. DOE. 2008. Solar Energy Industry Forecast: Perspectives on U.S. Solar Market Trajectory.
[17] Energy Foundation. 2004. PV Grid Connected Market Potential under a Cost Breakthrough Scenario.

Delaware and Pennsylvania of $250/MWh. Delaware legislation creating solar RECs is modeled on approaches in the Mid-Atlantic region.

There is uncertainty regarding possible fluctuations in the price of solar RECs but it is expected that RECs will be an important contributor to the growth of the PV market (Anthony and Vickerman, 2007). The analysis here assumed that REC prices will de-escalate by 3% every year, and RECs will be marketable only for 10 years. Both assumptions are conservative.

In evaluating the technical and economic potential for the residential sector of Newark, CEEP evaluated PV system capacities based on the GIS analysis of total suitable rooftop space in Newark. The research team calculated financial feasibility using first-year solar REC prices of $150/MWh and $250/MWh.

In all cases, REC prices were assumed to fall each year by 3%. See Table 10.

**Table 10. Parameters Used for Valuing Residential PV Installations in Newark**

| **Scenario 1 (suitable roof area)** | **Scenario 2 (suitable roof area)** |
|---|---|
| Larger PV Array<br>5 kW | Larger PV Array<br>5 kW |
| $150/MWh REC | $250/MWh REC |

In determining the technical and financial potential of the commercial and industrial sectors, it was decided to treat these sectors as one analytical unit, as it was not possible to obtain specific consumption data for the limited but varied industrial activities within the City. Analyses were conducted of commercial/industrial rooftop PV potentials using REC values of $150/MWh and $250/MWh. The sizes of the PV system used in the calculations for the combined sector were determined by dividing the wide range of possible commercial/industrial roof sizes into quartiles and then finding the PV area equivalents for the average size in each quartile. The following quartile sizes naturally bound the wide range of rooftop sizes in this combined sector. The average of each quartile is used as the possible installation size for roofs in that quartile (Table 11).

**Table 11. Parameters Used for Valuing Commercial/Industrial PV Installations in Newark**

| **Quartile Ranges** | **Average Size** | **Approximate Share of Rooftop Area** |
|---|---|---|
| $1^{st}$ (1.9 – 11.8 kW) | 7 kW | 2.1% |
| $2^{nd}$ (11.9 – 29.5 kW) | 20 kW | 6.0% |
| $3^{rd}$ (29.6 – 68.1 kW) | 45 kW | 13.9% |
| $4^{th}$ (68.2 – 4,082.8 kW) | 250 kW | 78.0% |

The University of Delaware is a significant consumer of electricity and manages a substantial building inventory in the City of Newark. Because of these two factors, the impact of university decisions regarding PV could be considerable. Analyses of the university sector were conducted using REC values of $150/MWh and $250/MWh. As in other sectors, REC prices were de-escalated by 3% per year and were assumed to be marketable for only 10 years. The sizes of PV systems used in the calculations for the university were determined by dividing the wide range of roof sizes into quartiles and then finding the PV area equivalents for the average size in each quartile. The following quartile sizes naturally bound the wide range of rooftop sizes in the university building stock. The average of each quartile is used as the possible installation size for roofs in that quartile (Table 12).

**Table 12. Parameters Used for Valuing University PV Installations in Newark**

| Quartile Ranges | Average Size | Approximate Share of Rooftop Area |
|---|---|---|
| 1st (1.7 – 9.8 kW) | 6 kW | 3.7% |
| 2nd (9.9 – 20.5 kW) | 15 kW | 9.6% |
| 3rd (20.6 – 42.2 kW) | 30 kW | 20.1% |
| 4th (43.3 – 473.3 kW) | 100 kW | 66.6% |

The solar power potential of rooftop PV installations is determined using the following equation:[18]

$$P \text{ (Watts)} = 1000 \text{ (Watts/m}^2\text{)} \times \text{Module Efficiency (\%)} \times \text{Area (m}^2\text{)}$$

The results of each solar energy scenario are described in detail in the following section.

[18] Nameplate capacities of PV modules are measured according to standard test conditions (STC), based on an irradiance intensity of 1000 Watts/$m^2$ (SEI, 2004).

# 4. RESULTS

## 4.1 PV Power Potential for Newark

If the suitable rooftop area of each sector is installed with photovoltaic panels, the total power capacity potential for the City of Newark is 96.4 MW. Industrial buildings would account for 39.5 MW or 41% of this total capacity, 30% would come from commercial buildings, 15% from residential buildings and 14% from university buildings (Table 13).

**Table 13. Solar Power Potential Estimates for City of Newark**

| Building type | PV Potential (MW) |
|---|---|
| University | 13.2 (14%) |
| Residential | 14.5 (15%) |
| Commercial and Utility | 29.2 (30%) |
| Industrial | 39.5 (41%) |
| Total | 96.4 |

## 4.2 Energy Potential and Benefits and Costs of PV Installations

The economic analysis results for residential, commercial/industrial and university building types are provided below (see Appendix I for general parameters).

### 4.2.1 Residential Sector

Based on our analysis, the potential residential rooftop PV generated electricity in Newark is significant and represents a viable alternative to electricity generated by conventional sources. The residential option for the City of Newark would supply a portion of the electricity consumed during daylight hours through the use of PV systems installed on residential buildings. According to data provided by the Electric Department of the City of Newark, residential electricity consumption averages more than 91 million kWh and approximately 42% of the consumption occurs between the hours of 9:00 am and 6:00 pm. The typical size of a PV system that could be installed based on the GIS analysis of total suitable residential rooftop space in Newark is 5 kW. This system generates approximately 6,490 kWh/year according to the *PV Planner*. A 5 kW system will occupy an area of 27.8 $m^2$ (based on a yield of 180 $W/m^2$ of PV panel). The total area of suitable residential rooftop in the City of Newark is 80,880 $m^2$ (see Table 6). This area of suitable residential rooftop space could yield 18,881,698 kWh of electricity generated within a year[19] and would displace 49% of conventional electricity generation during daylight hours (Table 14).

**Table 14. Summary of Residential PV Electricity Displacement Using the Maximum Suitable Residential Roof Area in the City of Newark**

| Residential PV Potential | Conventional Electricity Displaced |
|---|---|
| Option 1: All hours-based period displacement | 20.7% |
| Option 2: Daylight period displacement | 49.3% |

Results of the *PV Planner* analysis for the residential building sector for 3 kW and 5 kW PV configurations are shown in Tables 15 and 16. The size of the 5 kW system was calculated based on the average size of a residential system from the digitized residential rooftops in Newark, assuming that the available roof space was covered with PV panels.[20] The 3 kW system corresponds to the average installation size based on national trends for residential PV installations. The analysis indicates that under a scenario in which RECs sell in the PJM market area for $150/MWh in the first year, both systems are economically viable with positive NPVs (i.e., the present worth of the benefits exceeds the present worth of the costs) and benefit cost ratios (BCRs) of greater than one (the ratio of the present worth of the benefit stream to present worth of the cost stream exceeds one). However, both have payback periods of approximately 12 years.

The feasibility of both PV configurations significantly improves when the payment for RECs is increased to $250/MWh in the first year. Recent sales are near this price.[21] In this scenario, the 3 kW and 5 kW residential systems are economically viable as a result of the additional revenue generated from higher priced RECs (Table 16). These outcomes assume that the value of RECs would decrease over time at a rate of -3% as more RECs become available with increased installations of PV systems.

[19] Electricity generated /$m^2$ * total area.

[20] A 5 kW system would cover a roof area of approximately 27.8 $m^2$ based on a yield of 180 watts per square meter of PV panel; a 3 kW system will cover 16.7 $m^2$ of roof area.

[21] Based on personal communications with PV owners and developers.

**Table 15. PV Planner Results for Residential PV Applications in Newark for RECs @ $150/MWh**

| 1st Year RECs @ $150/MWh | | |
|---|---|---|
| **Capacity** | **5 kW (Possible)** | **3 kW (Probable)** |
| | | |
| **RE System Generation*** | | |
| Average daily | 17.78 kWh | 10.67 kWh |
| Yearly | 6,490 kWh | 3,894 kWh |
| | | |
| **Costs** | | |
| Initial Capital Project Cost (installed) | $34,000 | $21,000 |
| O&M Cost** | $3,046 | $1,827 |
| | | |
| **Benefits** | | |
| Energy Bill Saving** | $8,066 | $7,138 |
| Energy Sale to the Grid Revenue** | $6,891 | $1,838 |
| Investment Tax Credit** | $7,650 | $4,785 |
| RECs** | $6,363 | $3,818 |
| System Rebate | $8,500 | $5,250 |
| | | |
| **Economic Performance Indicators** | | |
| Net Present Value (NPV) | $623.99 | $0.00 |
| Internal Rate of Return (IRR) | 6.28% | 6.00% |
| Benefit Cost Ratio (BCR) | 1.02 | 1.00 |
| Payback Year | 12.40 | 12.65 |

*This is net of system losses from inverters.
**Present values at 6% discount rate.

**Table 16. PV Planner Results for Residential PV Applications in Newark for RECs @ $250/MWh**

| 1st Year RECs @ $250/MWh | | |
|---|---|---|
| **Capacity** | **5 kW (Possible)** | **3 kW (Probable)** |
| | | |
| **RE System Generation*** | | |
| Average daily | 17.78 kWh | 10.67 kWh |
| Yearly | 6,490 kWh | 3,894 kWh |
| | | |
| **Costs** | | |
| Initial Capital Project Cost (installed) | $34,000 | $21,000 |
| O&M Cost** | $3,046 | $1,827 |
| | | |
| **Benefits** | | |
| Energy Bill Saving** | $8,066 | $7,138 |
| Energy Sale to the Grid Revenue** | $6,891 | $1,838 |
| Investment Tax Credit** | $7,650 | $4,785 |
| RECs** | $10,604 | $6,363 |
| System Rebate | $8,500 | $5,250 |
| | | |
| **Economic Performance Indicators** | | |
| Net Present Value (NPV) | $4,661 | $2,546 |
| Internal Rate of Return (IRR) | 9.36% | 9.00% |
| Benefit Cost Ratio (BCR) | 1.22 | 1.20 |
| Payback Year | 7.32 | 7.49 |

*This is net of system losses from inverters.
**Present values at 6% discount rate.

### 4.2.2 Commercial/Industrial Sector

Based on our analysis, the potential commercial/industrial rooftop PV generated electricity in Newark is significant and represents a viable alternative to electricity generated from conventional sources. We define two options for the City of Newark on the basis of supplying a portion of the electricity consumed in the City through the use of PV systems installed on commercial/industrial buildings. According to data provided by the Electric Department of the City of Newark, commercial/industrial electricity consumption averages more than 165 million kWh. The average sizes of PV systems that could be installed based on the quartiles of the range of possible PV installations are 7kW, 20kW, 45kW and 250 kW. Each system would occupy the following roof space and generate the following kilowatt hours/year of electricity (results are from *PV Planner*):

**Table 17. Average Sizes and Annual Generation of PV Systems for Commercial and Industrial Buildings in Newark**

| PV System Size | Roof Area | Annual Solar Generation |
|---|---|---|
| 7 kW | 38.89 $m^2$ | 9,085 kWh/year |
| 20kW | 111.11 $m^2$ | 25,957 kWh/year |
| 45 kW | 250.00 $m^2$ | 58,404 kWh/year |
| 250 kW | 1388.89 $m^2$ | 324,469 kWh/year |

The total area of suitable commercial/industrial rooftops is equal to 380,301 $m^2$ (see Table 6). If the total area is divided into four segments determined by the percentage of roof space falling under each quartile[22] and each segment represents the roof space covered by the four possible sizes of PV installation, the total amount of electricity generated from available commercial/industrial rooftop space in the City of Newark would equal:

1. Electricity generated = (9,085 kWh/year / 38.89 $m^2$)*8,001.1 $m^2$ = 1,869,118 kWh
2. Electricity generated = (25,957 kWh/year / 111.11 $m^2$)*22,919.3 $m^2$ = 5,354,300 kWh
3. Electricity generated = (58,404 kWh/year / 250.00 $m^2$)*52,916.5 $m^2$ = 12,362,141 kWh
4. Electricity generated = (324,469 kWh/year / 1388.89 $m^2$)*296,464 $m^2$ = 69,259,176 kWh

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**Total electricity generated** = 88,844,735 kWh/year

The total amount of solar generated electricity would constitute 53.9% of the commercial/industrial electricity demand for the City of Newark. According to daily electricity consumption data provided by the Newark Electric Department, approximately 42% of the consumption of electricity occurs between the hours of 9 a.m. and 6 p.m. The electricity generated from all four commercial/industrial applications (88,844,735 kWh) could displace 128.3% of daylight consumption by this sector; that is, commercial and industrial building roof area can generate a surplus of electricity supply during daylight hours.

A summary of C & I PV generation is provided in Table 18.

**Table 18. Summary of PV Options for Electricity Displacement Using Available Commercial/Industrial Roof Area in the City of Newark**

| Options | Conventional Electricity Displaced |
|---|---|
| Option 1: All hours-based displacement | 53.9% |
| Option 2: Daylight period displacement | 128.3% |

[22] The percentages were calculated from the polygons in the GIS analysis.

Results of the *PV Planner* analysis for the commercial/industrial building sector for 7 kW, 20 kW, 45 kW and 250 kW PV configurations are shown in Tables 19 and 20. The analytical results of all four PV options indicate that all commercial PV applications in Newark are financially feasible for both REC values of $150/MWh and $250/MWh (Tables 20 and 21, respectively). Not included in this analysis are additional benefits such as dispatchable peak-shaving, emergency power and architectural material displacement (Byrne et al, 1998; 2001) that would further improve the economics of all four configurations.

**Table 19. PV Planner Results for Commercial/Industrial PV Applications in Newark for RECs @ $150/MWh**

| ENERGY ONLY | RECs @ $150/MWh | | | |
|---|---|---|---|---|
| **Capacity** | 7 kW | 20 kW | 45 kW | 250 kW |
| | | | | |
| RE System Generation* | | | | |
| Average daily | 24.89 kWh | 71.12 kWh | 160 kWh | 889 kWh |
| Yearly | 9,085 kWh | 25,957 kWh | 58,404 kWh | 324,469kWh |
| | | | | |
| **Costs** | | | | |
| Initial Capital Project Cost (installed) | $44,800 | $120,000 | $270,000 | $1,250,000 |
| O&M Cost** | $2,618 | $7,479 | $16,827 | $93,483 |
| | | | | |
| **Benefits** | | | | |
| Bill Saving** | $10,331 | $29,517 | $66,414 | $368,966 |
| Energy Sale to the Grid Revenue** | $83.93 | $239 | $539 | $2,992 |
| Investment Tax Credit ** | $13,440 | $36,000 | $81,000 | $375,000 |
| Tax Deduction** | $15,207 | $40,938 | $92,109 | $433,288 |
| RECs** | $7,503 | $21,435 | $48,230 | $267,945 |
| System Rebate | $11,200 | $30.000 | $67,500 | $312,500 |
| | | | | |
| **Economic Performance Indicators** | | | | |
| Net Present Value (NPV) | $42.54 | $1,643 | $3,698 | $68,119 |
| Internal Rate of Return (IRR) | 10.10% | 11.44% | 11.44% | 15.61% |
| Benefit Cost Ratio (BCR) | 1.00 | 1.02 | 1.02 | 1.07 |
| Payback Year | 8.20 | 7.63 | 7.63 | 6.22 |

*This is net of system losses from inverters.
**Present values at 10% discount rate.

**Table 20. PV Planner Results for Commercial/Industrial PV Applications in Newark for RECs @ $250/MWh**

| **ENERGY ONLY** | **RECs @ $250/MWh** | | | |
|---|---|---|---|---|
| **Capacity** | 7 kW | 20 kW | 45 kW | 250 kW |
| | | | | |
| RE System Generation* | | | | |
| Average daily | 24.89 kWh | 71 .12kWh | 160 .01kWh | 888.96 kWh |
| Yearly | 9,085 kWh | 25,957 kWh | 58,404 kWh | 324,469kWh |
| | | | | |
| **Costs** | | | | |
| Initial Capital Project Cost (installed) | $44.800 | $120,000 | $270,000 | $1,250,000 |
| O&M Cost** | $2,618 | $7,479 | $16,827 | $93,483 |
| | | | | |
| **Benefits** | | | | |
| Bill Savings** | $10,331 | $29,517 | $66,414 | $368,966 |
| Energy Sale to the Grid Revenue** | $83.93 | $239 | $539 | $2,992 |
| Investment Tax Credit ** | $13,440 | $36,000 | $81,000 | $375,000 |
| Tax Deduction** | $15,207 | $40.938 | $92,109 | $433,288 |
| RECs** | $12,504 | $35,726 | $80,384 | $446,576 |
| System Rebate | $11,200 | $30,000 | $67,500 | $312,500 |
| | | | | |
| **Economic Performance Indicators** | | | | |
| Net Present Value (NPV) | $2,844 | $9,646 | $21,704 | $168,152 |
| Internal Rate of Return (IRR) | 17.11% | 18.90% | 18.90% | 24.35% |
| Benefit Cost Ratio (BCR) | 1.08 | 1.10 | 1.10 | 1.16 |
| Payback Year | 5.83 | 5.57 | 5.57 | 4.90 |

*This is net of system losses from inverters.
**Present values at 10% discount rate.

### 4.2.3 University Sector

Our analysis of the potential university rooftop PV generated electricity indicates that it is significant and represents a viable alternative to electricity generated from conventional sources. We define two options for the University on the basis of supplying a portion of the electricity consumed in the City through the use of PV systems installed on selected university buildings. According to data provided by the Facilities Department of the University, the Newark campus of the University of Delaware consumes about 134 million kWh of electricity. Based on GIS analysis, 38.5% of university roof space can be used for PV applications. The average sizes of PV systems that could be installed based on the quartiles of the range of possible PV installations are 6kW, 15kW, 30kW and 100 kW. Each system would have different roof space requirements and electricity generation capacity, as presented in the following table (results are from *PV Planner*):

**Table 21. Average Sizes and Annual Generation of PV Systems for University Buildings in Newark**

| PV System Size | Roof Area | Annual Solar Generation |
|---|---|---|
| 6 kW | 33.33 $m^2$ | 7,786kWh/year |
| 15 kW | 83.33 $m^2$ | 19,467 kWh/year |
| 30 kW | 166.67 $m^2$ | 38,937 kWh/year |
| 100 kW | 555.56 $m^2$ | 129,788kWh/year |

The total area of suitable university rooftops is equal to 73,331 $m^2$ (see Table 4). If the total area is divided into four segments determined by the percentage of roof space falling under each quartile and each segment represents the roof space covered by the four possible sizes of PV installation, the total amount of electricity generated from available university rooftop space in the City of Newark would equal:

1. Electricity generated = (7,786 kWh/year / 33.33 $m^2$)*2,733.6 $m^2$ = 638,578 kWh
2. Electricity generated = (19,467 kWh/year / 83.33 $m^2$)*7,032.7 $m^2$ = 1,642,933kWh
3. Electricity generated = (38,937 kWh/year / 166.67 $m^2$)*14,758.8 $m^2$ = 3,447,911 kWh
4. Electricity generated = (129,788 kWh/year / 555.56 $m^2$)*48,806.0 $m^2$ = 11,401,888 kWh

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**Total electricity generated** = 17,131,310 kWh/year

The total amount of electricity generated would constitute 12.8% of the electricity consumption of the University of Delaware. According to the Newark Electric Department, approximately 42% of the consumption of electricity occurs in the city during the hours of 9:00 am and 6:00 pm. The electricity generated from a University of Delaware rooftop PV program (17,131,310 kWh) could displace 30.5% of the institution's electricity use during daylight hours.

A summary of solar electric generation is provided in Table 22.

**Table 22. Summary of Scenarios of Electricity Displacement Using Maximum Possible Roof Area for University-Based PV Applications in the City of Newark**

| Options | Conventional Electricity Displaced |
|---|---|
| Option 1: All hours-based displacement | 12.8% |
| Option 2: Daylight period displacement | 30.5% |

Results of the *PV Planner* analysis for the University of Delaware for 6 kW, 15 kW, 30 kW and 100 kW PV configurations are shown in Tables 24 and 25. The analytical results of all four PV options indicate that all university rooftop PV applications in Newark are financially feasible for both REC values of $150/MWh and $250/MWh (Table 23 and 24, respectively). To maximize tax benefits (e.g., federal tax credit, modified accelerated cost recovery system) it is assumed that the University of Delaware would pursue a third party ownership model, described in the following section.

**Table 23. PV Planner Results for University of Delaware PV Applications in Newark for RECs @ $150/MWh**

| ENERGY ONLY | RECs @ $150/MWh | | | |
|---|---|---|---|---|
| **Capacity** | 6 kW | 15 kW | 30 kW | 100 kW |
| | | | | |
| RE System Generation* | | | | |
| Average daily | 21.33 kWh | 53.34kWh | 106.68 kWh | 355.58 kWh |
| Yearly | 7,786kWh | 19,467 kWh | 38,937 kWh | 129,788kWh |
| | | | | |
| **Costs** | | | | |
| Initial Capital Project Cost (installed) | $39,600 | $90,000 | $180,000 | $500,000 |
| O&M Cost** | $2,244 | $5,609 | $11,218 | $37,393 |
| | | | | |
| **Benefits** | | | | |
| Bill Saving** | $10,410 | $26,025 | $52,054 | $173,512 |
| Energy Sale to the Grid Revenue** | $0 | $0 | $0 | $0 |
| Investment Tax Credit ** | $11,880 | $27,000 | $54,000 | $150,000 |
| Tax Deduction** | $13,411 | $30,703 | $61,406 | $173,315 |
| RECs** | $6,430 | $16,076 | $32,154 | $107,179 |
| System Rebate | $9,900 | $22,500 | $45,000 | $125,000 |
| | | | | |
| **Eocnomic Performance Indicators** | | | | |
| Net Present Value (NPV) | $638 | $3,309 | $6,620 | $41,096 |
| Internal Rate of Return (IRR) | 11.60% | 13.61% | 13.61% | 17.90% |
| Benefit Cost Ratio (BCR) | 1.02 | 1.05 | 1.05 | 1.10 |
| Payback Year | 7.84 | 7.06 | 7.06 | 5.85 |

*This is net of system losses from inverters.
**Present values at 10% discount rate.

**Table 24. PV Planner Results for University of Delaware PV Applications in Newark for RECs @ $250/MWh**

| ENERGY ONLY | RECs @ $250/MWh | | | |
|---|---|---|---|---|
| **Capacity** | 6 kW | 15 kW | 30 kW | 100 kW |
| | | | | |
| RE System Generation* | | | | |
| Average daily | 21.33 kWh | 53.34kWh | 106.68 kWh | 355.58 kWh |
| Yearly | 7,786kWh | 19,467 kWh | 38,937 kWh | 129,788kWh |
| | | | | |
| **Costs** | | | | |
| Initial Capital Project Cost (installed) | $39,600 | $90,000 | $180,000 | $500,000 |
| O&M Cost** | $2,244 | $3,041 | $11,218 | $37,393 |
| | | | | |
| **Benefits** | | | | |
| Bill Savings** | $10,410 | $26,025 | $52,054 | $173,512 |
| Energy Sale to the Grid Revenue** | $0 | $0 | $0 | $0 |
| Investment Tax Credit ** | $11,880 | $27,000 | $54,000 | $150,000 |
| Tax Deduction** | $13,411 | $30,703 | $61,406 | $173,315 |
| RECs** | $10,717 | $26,793 | $53,590 | $178,632 |
| System Rebate | $9,900 | $22,500 | $45,000 | $125,000 |
| | | | | |
| **Economic Performance Indicators** | | | | |
| Net Present Value (NPV) | $3,038 | $9,310 | $18,624 | $81,109 |
| Internal Rate of Return (IRR) | 18.10% | 20.73% | 20.74% | 26.25% |
| Benefit Cost Ratio (BCR) | 1.10 | 1.13 | 1.13 | 1.18 |
| Payback Year | 5.75 | 5.37 | 5.37 | 4.76 |

*This is net of system losses from inverters.

**Present values at 10% discount rate.

## 4.3 Technical and Economic Feasibility

Detailed analysis by building sector supports a finding of technical and economic feasibility of the use of rooftop PV to serve a significant share of the electricity demand of residents, businesses and the university community in the city of Newark. The analysis reported here is based upon project-scale evaluations. That is, the research considered the technical and economic feasibility of solar electricity "rooftop by rooftop."

In the next section of this report, the possibility of a citywide approach is considered. Under this approach, city residents, businesses and the university community could establish a "solar share" program in which participants pay monthly for solar electric service. The distributed solar power plant is managed by a third party that builds, owns and operates the plant on behalf of participants.

## 5. *SOLAR CITY NEWARK*

### 5.1 Potential: A Solar-Powered Newark

Table 25 summarizes the total electricity that could be displaced using PV from all buildings sectors in Newark under all hours-based and daylight period (9 am-6 pm) benchmarks. The City's technical potential for PV is 96.4 $MW_p$. A distributed solar plant of this scale would serve more than 75% of the city's annual electric needs during daylight hours.

**Table 25. Total Electricity Displaced by Photovoltaics in Newark from All Options - Residential, Commercial/Industrial and University Sectors**

| Building Type | PV Potential ($MW_p$) | PV Annual Generation Potential (MWh) | Electricity Consumption (MWh) | All Hours Grid Electricity Displaced | Daylight Hours Grid Electricity Displaced* |
|---|---|---|---|---|---|
| Residential | 14.5 | 18,882 | 91,268 | 20.7% | 49.3% |
| Commercial & Industrial | 68.7 | 88,845 | 164,908 | 53.9% | 128.1% |
| University | 13.2 | 17,131 | 133,634 | 12.8% | 30.5% |
| **All Sectors** | **96.4** | **124,858** | **389,810** | **32.0%** | **76.3%** |

* Approximately 42% of the consumption of electricity occurs in the city between the hours of 9:00 am and 6:00 pm (Newark Electric Department).

### 5.2 Third Party Finance Model

Non-profit entities, cities and governmental agencies can use a third party development / finance program that leverages their credit capacity while placing the burden of raising capital to purchase PV installations on a private, for-profit actor. This approach has been found by researchers to be the most effective and efficient way to acquire PV systems (see, for example, Bolinger (2009) and Cory (2008)). The approach outsources the development and financing liability to the third party. Under this arrangement, a non-profit or government agency hosts, but does not initially own a solar PV system and is able to secure, on average, 15- to 25-year fixed-price power at or below current retail rates (Cory, 2008). This approach takes legal form in a Power Purchase Agreement (PPA). It has been used for decades in the electricity sector to acquire renewable, as well as conventional electricity supply. Currently, the City of Newark, through its partnership with the Delaware Municipal Electric Corporation, utilizes a PPA approach to acquire its electricity.

This financing method monetizes available federal and state tax subsidies and grants that the tax-exempt entity (host) cannot capture, in order to provide the most capital efficient and competitive program in the market today. Further, the private sector company can take advantage of the newest financing techniques available, which include an inverted lease, a sale-leaseback, or a partnership-flip structure (see Bolinger, 2009; Troutman Sanders, 2009). Other entities, from homeowners and business owners to larger corporations that do not wish to expend capital on non-business related expenses, are using the third party model as well. Since this has become a dominant structure for the ownership of PV assets, we will describe its general advantages and illustrate the benefits that flow from the use of such a structure.

### 5.2.1 General Description

While there are several types of ownership structures available in a third party finance model, all have common elements of efficiently monetizing federal and local tax incentives and grants, as well as bringing other equity and debt into play that the host either cannot access or does not wish to allocate from its resources. The credit quality of the host entity determines the available leverage within the debt market that ultimately establishes the transaction's equity component and the host's energy costs.

Taxpaying entities can take advantage of a 30% federal investment tax credit.[23] Therefore, for every $1,000 of capital cost of a PV system, the investment tax credit (ITC) furnishes a grant or credit of $300. Owners of certain renewable energy assets are also eligible to take accelerated depreciation under the modified accelerated cost recovery system (MACRS). This means that instead of depreciating the asset over its useful life (approximately 25-30 years), the owner of the asset can depreciate its value over a 5-year period, thereby increasing the present value of the economic benefit and correspondingly the internal rate of return of the investment.

Currently, the U.S. lacks a comprehensive renewable energy policy. As a result, several incentives for producing renewable energy have been created by the states. These include marketable Renewable Energy Credits ("RECs") and utility grants that also benefit the host by reducing the PV asset cost. RECs are a major mechanism for compliance with renewable portfolio standards (RPS). RPS compliance typically requires each load serving entity[24] to

[23] Currently, an owner of a solar PV system, which has been certified as producing power, can either take the Federal ITC as a credit in their overall capital structure or receive a cash grant from the federal government.

[24] This includes the vertically integrated utility under a regulatory structure or the distribution (wires only) utility in a restructured power sector. Delaware has a restructured power sector.

gradually increase the share of renewable energy sources (including solar) in the electricity supply mix. As of July 2009, 34 states and the District of Columbia have adopted a mandatory or voluntary RPS, and 14 states and Washington D.C. include minimum solar or customer sited renewable energy requirements (DSIRE, 2009).

### 5.2.2 Benefits of a Third Party Finance Model

In certain instances, the various tax incentives and grants available to a taxable third party owner of a PV asset can pay for well in excess of 50% of the capital cost of the project. The taxable owner (usually a partnership) then finances the rest of the cost of the installation by securing debt from a commercial lender and equity from investors. The debt service on the loan (which is normally 15 years in term) and the return to the equity investor is then paid through a combination of the cash-flow from a Power Purchase Agreement (PPA) entered into with the host and the sale of RECs to utilities and other load serving entities.[25]

Since so much of the system can be paid for by monetizing available tax incentives and grants, the third party model is able to make projects much more economically viable. The model enables the host to avoid having to put any of its own capital into the project. Particularly in today's economic environment, this is a real advantage to many institutions and individuals looking to participate in the renewable energy transition.

There are other advantages of the third party model. For example, in a PPA signed with the third-party owner, the host gains certainty about the electric bill. Normally a PPA contains an agreed upon annual escalator for the purchase of power (typically from 1% to 5%) (Bolinger, 2009). Also, many institutions, companies, and homeowners may not want to operate and maintain a PV installation. Outsourcing the operation, maintenance, and repair to a third party is therefore often seen as desirable. Lastly, under a third party model there are many ways for the host to negotiate the final ownership of the PV installation. This allows the host to purchase the asset for much less at some time in the future, after tax credits and subsidies have brought down the cost of the system.[26]

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[25] RECs are purchased to comply with RPS standards. But this is only part of the available market. Companies and organizations seeking to support renewable energy development may also buy RECs. This so called voluntary market usually clears at a lower price than the REC compliant market.

[26] This option is usually not exercised when the host believes it lacks the expertise to operate and maintain the plant.

From a legal and tax point of view, a third party model can be complex, but the structure is now well-known and works as a platform to simplify the host's responsibility, which is to make monthly payments associated with the PPA. Below is a diagram that depicts this structure.

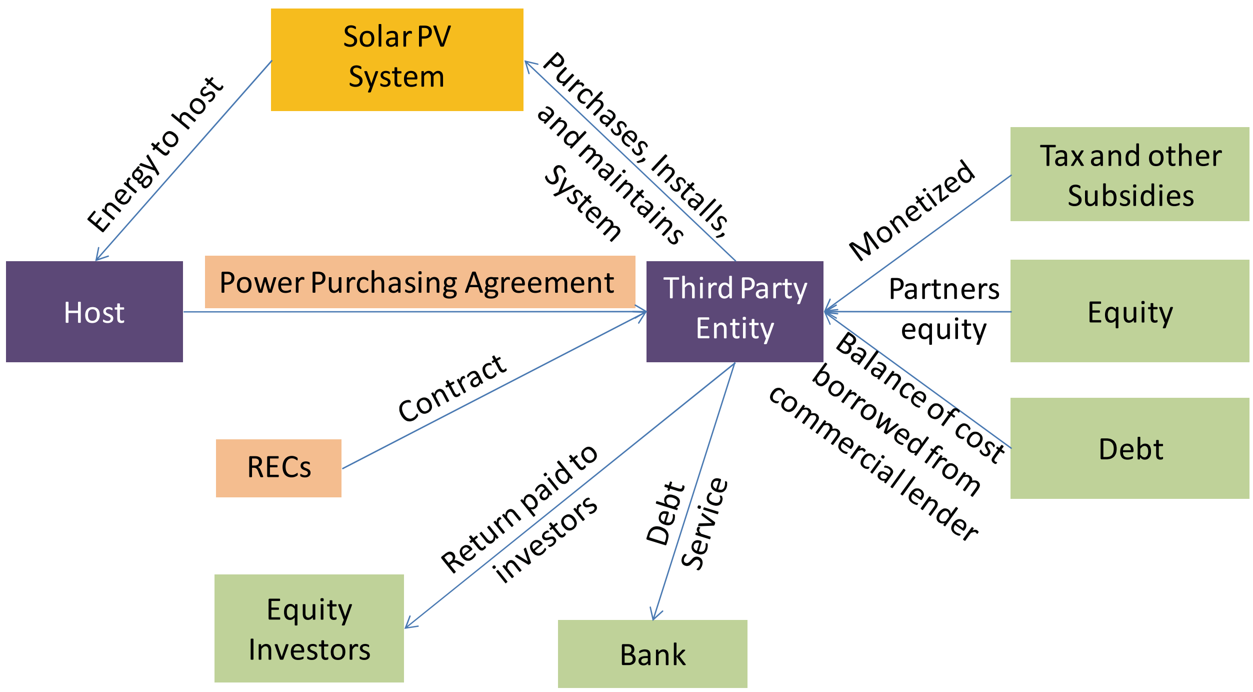


**Figure 4. Third Party Finance Model of a PV System with a PPA**

### 5.2.3 Solar City Newark

Capturing the City's full solar potential requires a common effort of its residents, businesses and government. Building a distributed solar plant on the scale of 100MWp would need to be planned over several years. Options would need to be considered. Would the assembly of the solar plant proceed through a plan that offered incentives to individual building owners? Would a Solar Energy Utility be created which planned the assembly of the plant on behalf of participants?[27]

[27] This option is what this report terms a "solar share" program. Participants could contribute real estate (roof area or land area) as host site for the distributed solar plant. Or host sites can be "rented" by the third party owner. Regardless of whether a participant contributed host sites, participation in the "solar share" program would occur through their monthly purchase of solar electricity. In this respect, participation can be by all members of the community, regardless of their roof orientation or land ownership. In this model, the City of Newark would create the Solar Energy utility, earning it the status of solar city.

While this research has focused on roof area to host the distributed solar plant, it is possible to consider ground-mounted solar systems which provide shading for the City's many parking lots. Moreover, non-forest, non-park land in the city's border that is currently unoccupied may, in some instances, be suitable for solar electric development. A rough estimate of the area provided by parking lots and unoccupied, non-forest, non-park land suggests that it could equal more than the carefully measured solar-suitable roof area. Ground locations could be considered as a substitute for roof-mounted systems in appropriate circumstances. The aggregate of installations of both kinds could furnish the City's electricity needs during daylight hours, enabling it to sell the surplus to the grid.

Whichever path is chosen by the City's citizens, the realization of a *Solar City* Newark would require significant financial resources. For the reasons noted in the previous section on third-party ownership, it is worthwhile to consider the establishment of a Solar Energy Utility that could take advantage of the financing and tax benefits of a third-party model (see Figure 4). The utility could be chartered by the City and operated by an oversight board appointed by city government. Federal tax and other benefits would allow an 8-year planning horizon for the creation of *Solar City* Newark. If the goal was to capture the 97 MWp solar potential identified by this research, more than 50-60% of the capital requirements would be secured through existing federal tax and other benefits assuming the REC and power purchase prices in Table 26. Additional funds might come from carbon allowances (if a national market is created)[28] and/or other environmental adders. Environmental adders involve some risk: Will the legislation that creates them remain in force and support at least the effective price noted here? Will market demand for these adders support 10-year or longer contracts? Will pricing in adder markets be stable or volatile? The remainder of the capital requirement could be secured largely through a Power Purchase Agreement.

Experts from two energy investment companies were contacted to obtain their evaluations of the *Solar City* Newark project described here. [29] Common assumptions were given to these experts (see Table 26). Both concluded that under the assumptions detailed in Table 26, a *Solar City* Newark project, owned and operated by a third-party investor is

[28] The U.S. House of Representatives recently passed the American Clean Energy and Security Act (HR 2454), which proposes to create a national carbon allowance trading market.
[29] Communications with AERCA Advisors and Becker Capital and Finance (August 2009).

financeable. Their evaluations should not be interpreted as contractual commitments since additional details beyond the scope of this research would need to be addressed with the host.

**Table 26. *Solar City* Newark Financeability Test: Common Assumptions**

| | |
|---|---|
| Price-to-beat | $0.14 per kWh escalating at 2.5% per year |
| Contract Term | 20 years (with extensions possible) |
| REC Price/Contract Term | $220 per MWh opening sale price, with each sale as part of a 10-year contract term and an annual REC price de-escalation rate of 3%; all RECs owned by the third-party investor |
| REC Market | No barrier to the sale of 10 years of RECs at the stated terms |
| Other Environmental Adders | Owned by the third-party investor |
| ITC/MACRS Benefits | No barrier to monetizing these benefits at their maximum allowable value |
| Operation and Maintenance | Third-party investor is responsible for O&M with guarantee of minimum annual electricity supply |
| Rooftop/Land Acquisition | Annual rental payment structure established by third party investor |

As with any large-scale initiative, *Solar City* Newark would involve risk and uncertainties. Yet, the conclusion by energy investors consulted for this report that the project is financeable should encourage its careful consideration. A summary of the advantages of a *Solar City* Newark would include:

- The distinction of Newark as a leading community in pioneering a renewable energy transition;
- Significant reductions in Newark's carbon footprint, enabling the city to contribute to cleaner air and water, and healthier soil;
- Affordable electricity to citizens and businesses at predictable prices that are equal to those currently paid in the City;
- Lower risks of energy price spikes and supply availability vulnerabilities associated with the existing electricity supply system;
- Major progress in the creation of a green energy economy with green jobs anchoring the city's future; [30]

[30] The benefit of *Solar City* Newark and other locally-based initiatives is that an important share of employment and economic multiplier effects can be locally focused. National and state plans, by comparison, can disburse such benefits. Of course, national and state plans can be scaled to produce larger aggregate benefits.

- The advantage of enlisting technological expertise of the University of Delaware in PV[31] and the solar manufacturing facilities of General Electric near the City to better control the City's economic destiny;
- Participation by <u>all</u> residents, businesses and the university community without regard to their roof orientation, land holdings or income – in this respect, it is an inclusive, community model inviting everyone to contribute to and enjoy the benefits of the transition to a low-carbon future.

### 5.3 Barriers to Solar City Newark

The development of this potential requires significant financial resources. Utilization of all available incentives and grants, including federal and state subsidies, is essential to obtain the services of rooftop solar systems at lowest possible cost. Additionally, full development of Newark's solar potential will require selling RECs each year for approximately 125,000 MWh. Selling such a high volume of RECs will not be easy. Based on Delaware's solar carve-out, the State is expected to need 175 MWp (see Table 27) by 2019. Although this amount is higher than Newark's solar potential, it means that the City could generate more than one-half of the solar RECs needed to meet the State's requirement. RECs from a *Solar City* Newark project can be sold in any jurisdiction of the PJM Interconnection (which serves 13 states and Washington, DC). But, it would remain a challenge to sell such a large volume for 10 or more years. Since other cities and larger jurisdictions could consider the *Solar City* option, REC markets nationwide could quickly be over-supplied.

An additional difficulty would be the ability of investors to find partners with 'tax appetites' to absorb the ITC and MACRS tax benefits. If Newark alone sought to realize its full PV potential, this would not be a problem. However, if many *Solar City* projects emerge, it is evident that these policy benefits could overwhelm federal capacities.

Both barriers underscore the lack of scalability of the existing national and state/local policy infrastructure. Only by significantly increasing RPS requirements throughout the country and obtaining federal assurances to guarantee support for the ITC and MACRS at significantly

[31] The U.S. Department of Energy has designated the University of Delaware as the nation's "center of excellence" in PV technology.

greater scales than present experience, can a scalable *Solar City* program attract the needed capital investment.[32]

**Table 27. Delaware RPS Schedule for PV**

| Compliance Year | Percentage from Solar Photovoltaic Energy Resources | Cumulative Installed PV Capacity (kW) |
|---|---|---|
| 2008 | 0.011% | 700 |
| 2009 | 0.014% | 878 |
| 2010 | 0.018% | 1,193 |
| 2011 | 0.048% | 3,320 |
| 2012 | 0.099% | 7,061 |
| 2013 | 0.201% | 14,678 |
| 2014 | 0.354% | 26,670 |
| 2015 | 0.559% | 43,354 |
| 2016 | 0.803% | 64,131 |
| 2017 | 1.112% | 91,463 |
| 2018 | 1.547% | 131,143 |
| 2019 | 2.005% | 175,039 |

Source: Sustainable Energy Utility Task Force, 2008

Scalability of the policy infrastructure that currently incentivizes solar energy is perhaps the most important barrier to a *Solar City*. The current menu of federal and state policies appears to be sufficient to support a *Solar City* Newark project if, and only if, few other communities join in pursuing this option. The positive assessment of the financeability of the *Solar City* Newark reported above considers the project in isolation. It may be an entirely different matter if many jurisdictions in Delaware and in all states, sought to build *Solar Cities*. This problem is in no sense unique to solar energy. The recent decision to downsize the world's largest wind farm proposal (the so called "Pickens Plan" – see MarketWatch, 2009) is due to scalability issues in both the policy and technology infrastructure (the latter concerns, especially, the country's electricity transmission and distribution system).

## 5.4 Getting Started: A Practical First Step

Scalability of the policy environment needs to be examined. Certainly, federal actions will be required to address this barrier. At the same time, it is important to continue support for

[32] It should be noted that initiatives to significantly scale up the use of wind and other renewable energy options face the identical policy problem.

local leadership efforts to build sustainable communities. In this view, the city might consider a multi-step strategy in building a *Solar City* in its future. The first step could be to scale the initial size of the distributed solar power plant to a capacity that would represent a population-based share of the State RPS requirement for solar power purchases.[33]

Assuming that state electricity consumption grows at approximately 1.0% per year (EIA, 2009), Newark – on a population basis – might be expected to supply at least 10 MW of solar power in order to satisfy the State's RPS requirement. As the first step in building a *Solar City*, this capacity of PV electricity installed over the next 5 years or so would avoid scalability and other barriers discussed above. Obviously, the green economy benefit associated with this goal would be smaller than if the city exploited all of its existing rooftop solar potential. Still, barriers and employment opportunities could be expected to be sizeable. Building a 10 MW distributed solar power plant could encompass and complement the announced 6 MW PV goal of the University of Delaware for its Newark Campus (UDaily, April 22, 2009).

The City of Newark should also consider a concerted effort to improve the energy performance of existing and new buildings. The University of Delaware has targeted a 20% reduction in carbon emissions by 2020 for its building stock and transportation (UDaily, April 22, 2009). Recently passed state legislation calls for a decrease of 15% in Delaware per capita electricity use by 2015 (Delaware Senate Bill 106). If city planning embraced such goals for its own building stock, a 10 MW distributed solar power plant would serve nearly 10% of the community's daylight hours electricity needs.

Combining energy efficiency, conservation and community solar power would enable Newark to pursue *Solar City* and *Sustainable Community* goals in a coordinated, synergistic manner. It is an opportunity well within the ability of its citizens, business sector, and university community. The CEEP research team recommends its thoughtful consideration.

[33] Currently, the City of Newark voluntarily participates in the State RPS, including the 2% solar carve-out by 2019. State law does not require municipalities like Newark to participate in its RPS policy and the Newark government has passed no ordinance obligating its citizens and businesses to comply with the State RPS.

## 6. SUMMARY

The initial assessment of the PV rooftop solar potential presented here offers a useful tool for an assessment of solar energy contributions to localities in Delaware. There are considerable educational and public awareness benefits that can derive from the application of this tool throughout the State. The ability to demonstrate the potential of PV for individual buildings and communities will help to advance its wider consideration. It is also useful to show the effects of changes to system parameters and policy initiatives that impact the technical and economic evaluation of PV's use. Techniques developed under this READY project can be applied to other communities in the State. This type of assessment can also help in the planning process so that when new buildings are being considered for construction, the issue of solar access can be incorporated into planning decisions.

Limitations to the use of GIS should be taken into consideration when applying this tool. For example, remote sensing data available for use in GIS mapping may not be recently acquired information and therefore may not adequately reflect the current building inventory of an area. A substantial change that may have occurred between the time the imagery was acquired and the analysis is undertaken could affect the accuracy of the assessment. Changes affecting the assessment include the construction of new buildings or housing developments as well as building demolitions or renovations. In the Newark project case study, there were major changes after the aerial photo survey was undertaken. For example, a hotel and new university student dormitories were constructed in the northern section of the City after our acquisition of the remote sensing data. The rooftops of these buildings could not be included in the assessment and as a result, cause an underestimation in the solar potential of the commercial and university sectors. An additional source of underestimation of the solar potential arises from the fact that building walls were not considered in this study for BIPV use.[34] Possible uses of BIPV to shade uncovered areas (for example, open spaces or parking lots) also were not assessed.

Nevertheless, the assessment tool described here provides a platform for communities in Delaware to prepare for wider adoption of renewable energy technologies. It is envisioned that as the development and use of the tool expands, new capabilities can be added such as the incorporation of a web-based interface to ease the assessment process.

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[34] Researchers in New York noted the difficulty of estimating building façade use of PV using remotely sensed and GIS data - Columbia University, 2006. See Ettenson, L. (Ed.). (2006). *Powering forward: Incorporating renewable energy into New York City's energy future*. New York, NY: Columbia University, School of International and Public Affairs, Center for Energy, Marine Transportation and Public Policy.

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**APPENDIX I**

**Parameters Used to Run PV Planner**

| **Inputs for Residential Case Studies** | |
|---|---|
| **SYSTEM CONFIGURATION** | |
| PV module type | Monocrystalline |
| PV module efficiency | 18% |
| Size of Array | 5 kW; 3 kW |
| Slope of array | 25° |
| Inverter efficiency | 92% |
| **SYSTEM COSTS** | |
| PV System ($/kWp) | $7,000/kW for 3 kW and $6,800/kW for 5 kW systems (includes cost of installation, electrical equipment and module support structure – information obtained from installers) |
| Cost of inverter ($/kW AC) | $700/kW |
| **O & M COSTS** | |
| Inverter Replacement - Cost<br>Frequency | $700/kW<br>10 years |
| **FINANCIAL INPUTS** | |
| Evaluation period | 25 years |
| Customer discount rate | 6% |
| Debt Ratio | 0 % |
| Tax Depreciation Method | NA |
| Avoided electricity costs are taxable | No |
| **POLICY** | |
| Rebate on initial capital costs | 25% of system cost |
| Tax credit | 30% of installed capital cost |
| Price of RECS | $150/MWh (NREL value)<br><br>$250/MWh (based on DE amended RPS legislation) |
| Escalation rate | -3% |
| Duration | 10 years |
| Sale to grid | Net metering |
| Tax on sale to grid | No |
| **LOAD DATA** | |
| | Provided by City of Newark |
| **RATE DATA** | |
| | Provided by City of Newark |

| Inputs for Commercial/Industrial and University Case Studies | |
|---|---|
| **SYSTEM CONFIGURATION** | |
| PV module type | Monocrystalline |
| PV module efficiency | 18% |
| Slope of array | 25° |
| Inverter efficiency | 92% |
| **SYSTEM COSTS** | |
| PV System ($/kWp) | $6,600/kW for 6 kW, $6,400 for 7 kW, $6,000 for 15-45 kW, $5,000 for 100-250 kW systems (includes cost of installation, electrical equipment and module support structure – information obtained from installers) |
| Cost of inverter ($/kW AC) | $700/kW |
| **O & M COSTS** | |
| Inverter Replacement<br>Cost<br>Frequency | <br>$700/kW<br>10 years |
| **FINANCIAL INPUTS** | |
| Evaluation period | 25 years |
| Customer discount rate | 10% |
| Debt Ratio | 50% (10 yrs loan with 6% interest rate) |
| Tax Depreciation Method | MACRS 5 yr |
| Capital Equipment Value Subject to Depreciation | 85% |
| Avoided electricity costs are taxable | Yes |
| Tax Rate | 35% Federal and 9% State |
| **POLICY** | |
| Rebate on initial capital costs | 25% of system cost |
| Tax credit | 30% of capital cost |
| Price of RECS | $150/MWh (NREL value)<br>$250/MWh (based on DE's amended RPS legislation) |
| Escalation rate | -3% |
| Duration | 10 years |
| Sale to grid | Net metering |
| Tax on sale to grid | Yes |
| **LOAD DATA** | |
| | Provided by City of Newark and Facilities Department, University of Delaware |
| **RATE DATA** | |
| | Provided by City of Newark |