PV PLANNER
A DESIGN AND ANALYSIS TOOL FOR BUILDING INTEGRATED SOLAR ELECTRIC SYSTEMS

FINAL REPORT

A Renewable Energy Applications for Delaware Yearly (READY) Project

Center for Energy and Environmental Policy
University of Delaware

December 2006

PV PLANNER
A DESIGN AND ANALYSIS TOOL FOR BUILDING INTEGRATED SOLAR ELECTRIC SYSTEMS

Final Report

A Renewable Energy Applications for Delaware Yearly (READY) Project

Project Advisors
John Byrne, Director, CEEP
Gerard Alleng, Policy Fellow, CEEP
Aiming Zhou, Policy Fellow, CEEP
Steve Hegedus, Associate Scientist, Institute of Energy Conversion
Ralph Nigro, Applied Energy Group

Project Team
Lado Kurdgelashvili, Research Assistant, CEEP
Jackson Schreiber, Research Assistant, CEEP
Aly Sanoh, Research Assistant, CEEP
Xilin Zhang, Research Assistant, CEEP

READY Program Support
Delaware Public Service Commission
Delaware Division of the Public Advocate
Conectiv Power Delivery
Delaware Energy Office
University of Delaware

Center for Energy and Environmental Policy
University of Delaware

December 2006

TABLE OF CONTENTS

1. INTRODUCTION 1

1.1 READY Project Mission 1

1.2 PV Planner: An Overview 1

1.3 Background 1

2. *PV PLANNER* DATA INPUT WORKSHEETS 7

2.1 Project Information 7

2.2 Application Type 9

2.3 System Configuration 10

2.4 System Costs 12

2.5 O&M Costs 13

2.6 Financial Inputs 14

2.7 Policy 15

2.8 Load Data 17

2.9 Rate Data 19

2.10 Results 21

2.11 Cash Flow/Payback Yr 22

2.12 Power Dispatch 26

3. ILLUSTRATIVE OUTPUTS FROM *PV PLANNER* FOR A BUILDING INTEGRATED (BIPV) PV APPLICATION 29

SELECTED CEEP PUBLICATIONS ON BUILDING INTEGRATED PV (BIPV) APPLICATIONS & SOLAR ELECTRICITY POLICY: 1983 – 2006 59

1. INTRODUCTION

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 approaches to encourage renewable energy suppliers to enter Delaware markets; developing creative and effective education and consumer outreach regarding renewable energy technologies." In reviewing the mission of the READY project, it was determined that the development of the software program, *PV Planner*, would be an ideal opportunity to showcase the benefits of photovoltaic technologies within the context of the financial assessments of residential and commercial applications.

1.2 PV Planner: An Overview

CEEP has worked with the U.S. National Renewable Energy Laboratory (NREL) and others for 12 years on the development of *PV Planner* to analyze the benefits of PV technology beyond its conventional of energy-supply value. *PV Planner* utilizes a vast quantity of data to model the physical, economic, financial and policy contexts specific to the area where the PV system is being installed. The software simulates the performance of a PV system operating in an energy supply-only mode (sometimes referred to as a non-dispatchable system as the energy produced by the device must be used immediately) or in a dispatchable mode (where because of the addition of storage, solar energy can be released when needed).

The software uses financial, economic and policy data from the area where the PV system is to be installed in order to analyze its financial feasibility. The performance of the system is reported using several metrics including present value, payback period, benefit-cost ratio, cash flows and levelized costs.[1] Because the policy environment is constantly developing (particularly with the addition of new incentives to promote renewables), *PV Planner* is regularly upgraded to reflect new measures (e.g., recent changes track the new renewable energy credits or RECs and GHG emission markets).

1.3 Background

For 20 years, the Center for Energy and Environmental Policy (CEEP) has investigated the technical and economic feasibility of using solar electric power (provided by commonly termed 'photovoltaic' (PV) technology or 'solar cells'). Its analysis has emphasized multi-service configurations for residential and commercial buildings. These configurations offer a combination of benefits that include the energy-only value (i.e., the system's ability to reduce grid-energy demand), capacity value (in the form of peak demand reduction through peak shaving – see Byrne and Hadjilambrinos, 1994; and Byrne et al, 1992, 1993a-c, 1994a-f, 1995, 1996a-d, 1997b, 1998, 2000, 2001b and 2004), service value (for example, through the provision

[1] Levelized cost equals the present value of the capital and operating costs of an electric power plant over its projected economic life, converted to equal annual payments per unit of electricity generated during that lifetime (e.g., per kWh). Normally, levelized costs are calculated in a manner that removes inflation (see, http://www.eia.doe.gov/glossary/).

of emergency power during electrical outages – see Byrne et al, 1997a-b, 1998, 2000 and 2001b) and material replacement value (displacing building material – see Byrne et al, 2000 and 2001b). Additionally, CEEP has modeled social and environmental co-benefits from the use of solar-generated electricity (e.g., reduced air pollution and diminished vulnerability to fossil fuel price spikes – see Byrne and Kurdgelashvili, 2003; Byrne and Rich, 1983; Byrne et al, 1996, 1997a, 1999, 2001a, 2004 and 2005a; Letendre et al, 1998; and Rickerson et al, 2005), including analyses of policy options to capture these co-benefits.

The basic configuration of a grid-connected, building integrated PV system (or BIPV) consists of a PV array connected via power conditioning equipment to a building's distribution panel (Figure 1).

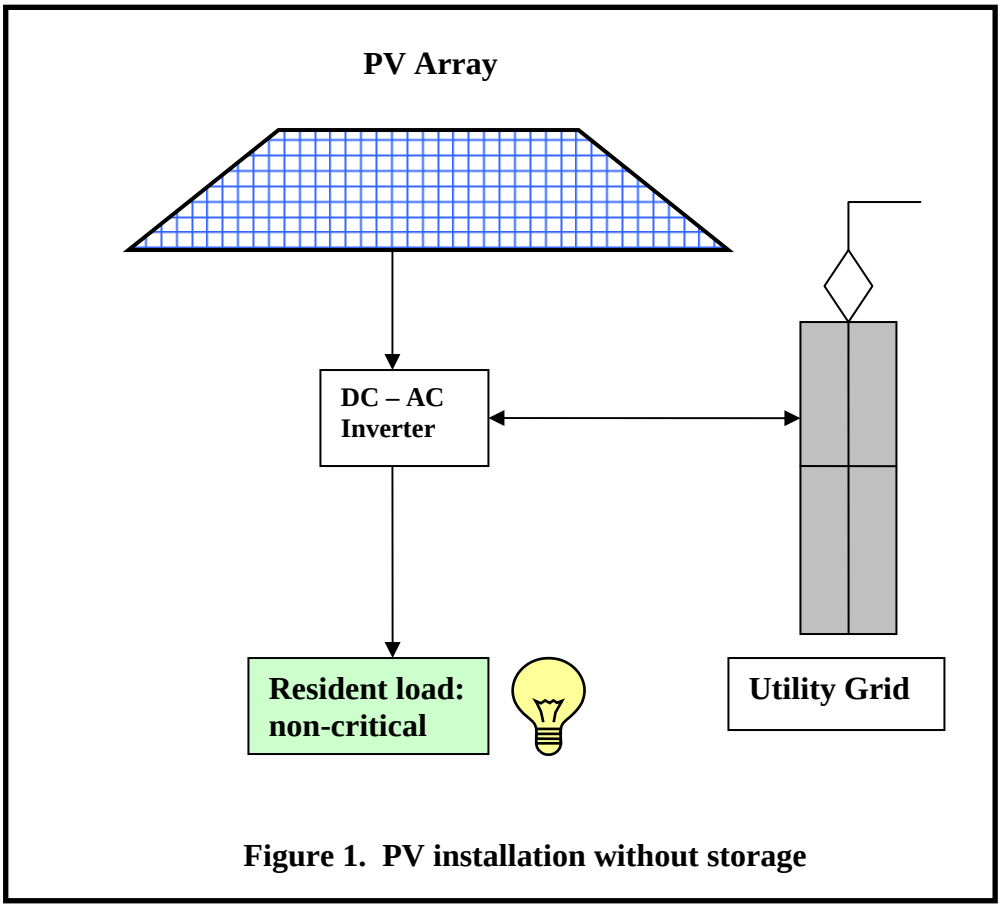


Figure 1. PV installation without storage

Under this configuration, PV operates as a conventional electricity technology, complementing the energy obtained from the grid. The net value from this configuration can be estimated using the following equation (Byrne et al, 1998, 2000 and 2001a):

$$V_E = [O_{PV} * P_E] - C_{PV}$$ [Equation 1]

where,

V_E	=	Value of PV system
O_{PV}	=	Building PV output (kWh)
P_E	=	Utility energy charge (cents/kWh)
C_{PV}	=	Capital and operating costs of the PV energy supply system.

P_E and C_{PV} are discounted to reflect the time value of the benefits and costs of the system. Under this configuration, most PV systems tend not to be economically feasible as compared to conventional electricity supply options as the average cost of electricity can be in the range of 2.5–4.5¢ per kWh (coal plants and combined cycle gas plants)[2], whereas PV systems are about 25 cents/kWh.

In order to improve the economics of the PV system, its configuration can be changed to provide additional services. One of these is building electricity demand management, which requires the addition of modest amounts of storage to the PV array, allowing the system to operate as a dispatchable peak-shaving technology (Figure 2).

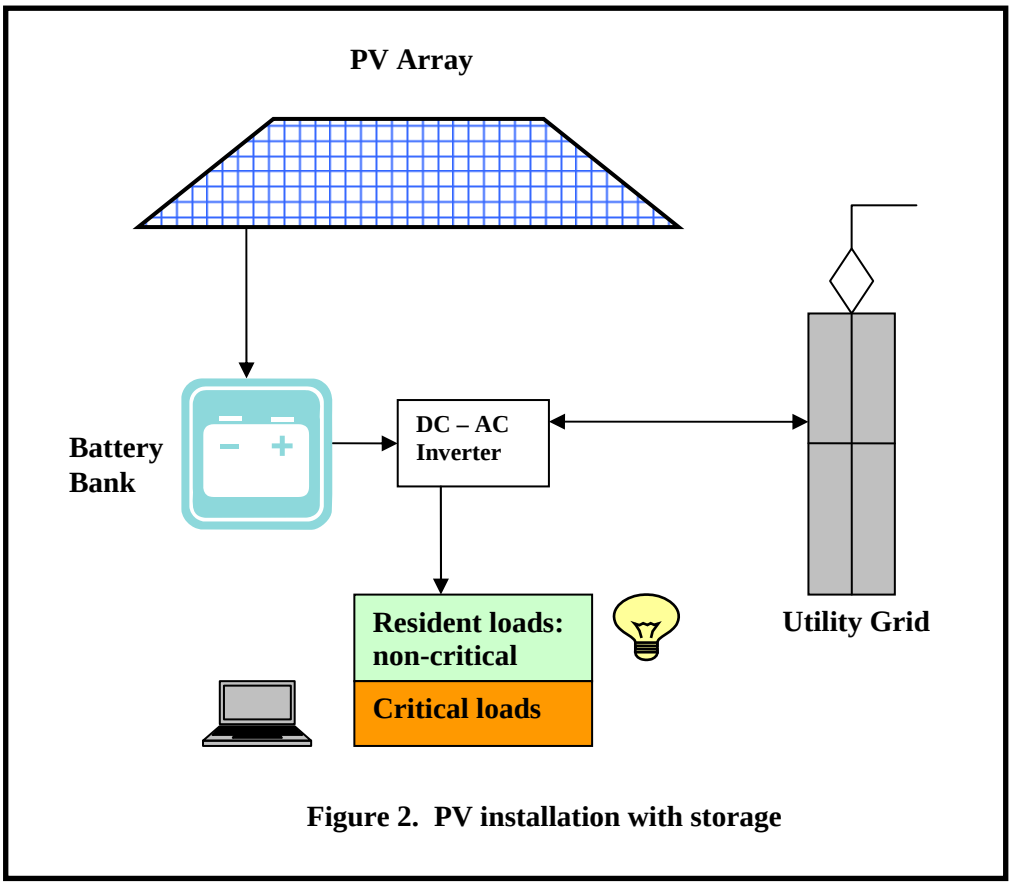


Figure 2. PV installation with storage

[2] http://www.energyfinder.org/renewable/solar/resources.asp

The addition of the storage facility provides benefits from the perspectives of both the PV user and electric utility (Byrne et al, 1996a-d, 1997b, 1998, 2000, 2001b and 2004; and Hoff et al, 2004).

Under this configuration, the following equation applies (Byrne et al, 2000):

$$\mathbf{V_M = [P_D(O_{PV} + O_{BAT}) + V_E] - C_{PV}} \qquad \text{[Equation 2]}$$

where,

$\mathbf{V_M}$	=	Demand management value of a PV peak-shaving system
$\mathbf{O_{PV}}$	=	PV output at time of building peak demand (kW)
$\mathbf{O_{bat}}$	=	Battery bank output (net of round trip losses) at time of building peak demand (kW)
$\mathbf{P_D}$	=	Utility demand (capacity) charge
$\mathbf{V_E}$	=	Value as defined in Equation [1] above
$\mathbf{C_{PV}}$	=	Capital and operating costs of the PV demand management system.

The O_{bat} term represents the output of the battery bank at the time the building is experiencing its peak demand. It is a function of battery bank size and the number of peak-shaving hours needed to maximize the reduction in the peak load of the building for a given PV array size.

The addition of storage to the PV system also provides the system with the capability to offer emergency power (EP) to a building (Byrne et al, 1996). EP could be used for emergency lighting or as backup power for computers. This addition of EP enhances the overall value of a PV system as its economic benefit can be expressed as the "avoided cost" associated with the purchase and operation of a conventional EP system. The EP system is usually in the form of an uninterrupted power supply (UPS) and the major assumption is that the user would have already identified the need for EP and purchased the necessary requirements such as an inverter and battery storage or the balance of system components similar for a peak shaving PV system. The only additional cost of using a PV system for EP would be the capital costs associated with the PV array (cost of modules and installation).

Accordingly a new equation can be derived that demonstrates the dual function of peak shaving with emergency power (Byrne et al, 1998, 2000 and 2001b):

$$V_S = [(B_{EP} - C_{EP}) + V_M] - \Delta C_{PV} \quad \text{[Equation 3]}$$

where,

V_S	=	Energy services value of a PV- peak shaving and EP system
B_{EP}	=	Customer designated benefits of EP
C_{EP}	=	EP system cost (equivalent to BOS cost of a dispatchable PV system)
V_M	=	Demand management value of a PV peak shaving and EP system, as defined in Equation [2] above
ΔC_{PV}	=	Additional PV system cost

An additional purpose can be added to the PV system when it displaces conventional construction materials (hereinafter materials displacement benefit). In this case, the PV array serves as an architectural element containing both functional (electricity production) and aesthetic (part of the rooftop or façade of the building) value (Byrne et al, 2001). The economic benefit of using PV to displace architectural materials can be expressed as the "avoided cost" of the material displaced by the area of the array. Thus, the effective capital cost of the PV system amounts to its cost minus the value of the displaced material. The underlying assumption for this purpose to be beneficial is that the material being displaced (e.g., polished stone, marble, aluminum) is more costly than the PV system (measured in area costs such as m^2 of roofing material. To determine the material displacement benefit requires adjusting PV system cost in Equation 3 (ΔC_{PV}) by an amount equal to the avoided cost of the displaced material.

Another contribution of a PV system as an energy service technology is the provision of environmental services through the avoided emissions of greenhouse gases (GHGs) in electricity generation. Growing concern about the effects of increasing levels of GHGs in the atmosphere has led to market-based and policy initiatives aimed at reducing their emissions from electricity generation. PV as a clean energy technology can play a role in mitigating GHG emissions by displacing some amount of electricity generation and also through its attribute as a renewable energy fuel source (see, e.g., Byrne et al, 1999, 2003, 2004 and 2005a). Policies can create markets for selling and buying avoided CO_2, SO_x and NO_x emissions and other renewable energy benefits through, for example, what are called renewable energy credits (RECs).[3] Additional revenue streams from RECs and other policies can be accounted for in the financial analysis of PV system benefits, which in most cases will greatly improve the economic feasibility of a PV investment. In particular, the emergence of RECs into the economics of renewable energy technologies can have a significant impact in the utilization of PV technology.

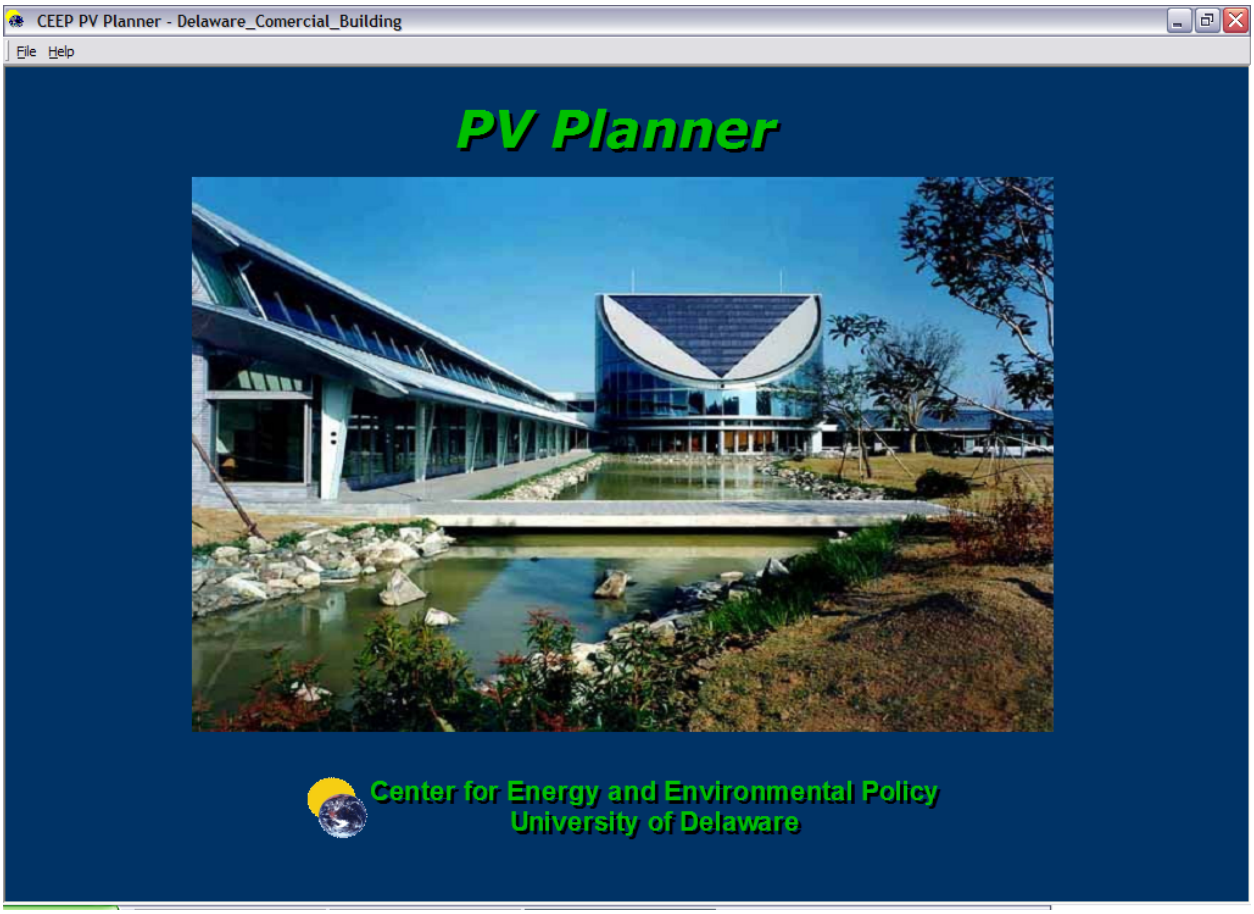
CEEP has been able to demonstrate these potential savings/benefits of PV systems under different configurations and policy options in several case studies, both within the US (including Delaware) and internationally (see Byrne et al, 1999, 2003, 2004, 2005a & b and 2006; Letendre et al, 1998; and Rickerson et al, 2005).

[3] RECs allow a buyer the right to claim associated social and environmental benefits of renewables from the generation of electricity; or what it called the 'attribute value' of renewables that is being purchased separate from the electricity itself (Kotas, 2001; CEEP, 2005). Additional policy options such as tax credits, rebates and accelerated depreciation rates can further monetize favorable economic outcomes of PV systems.

2. *PV PLANNER* DATA INPUT WORKSHEETS

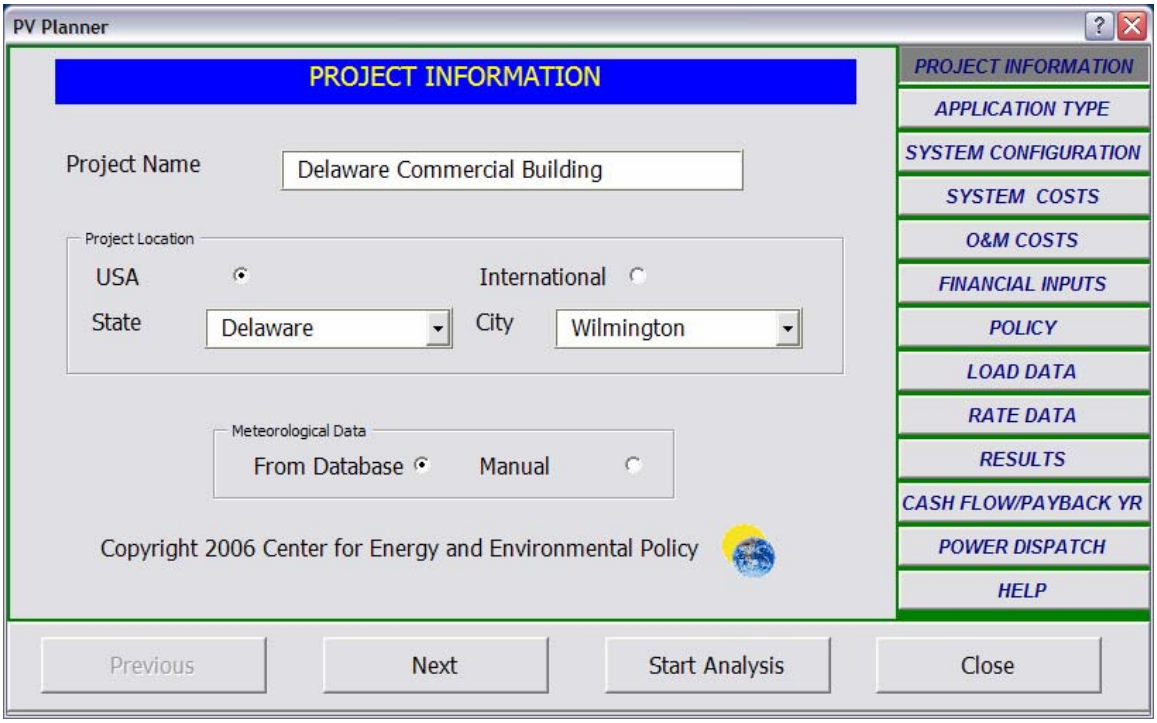
The following provides an overview of the various worksheets in *PV Planner* that a user will use to enter data in order to perform analyses of PV building-integrated applications.

At this interface, users click on the BIPV image to start the program.



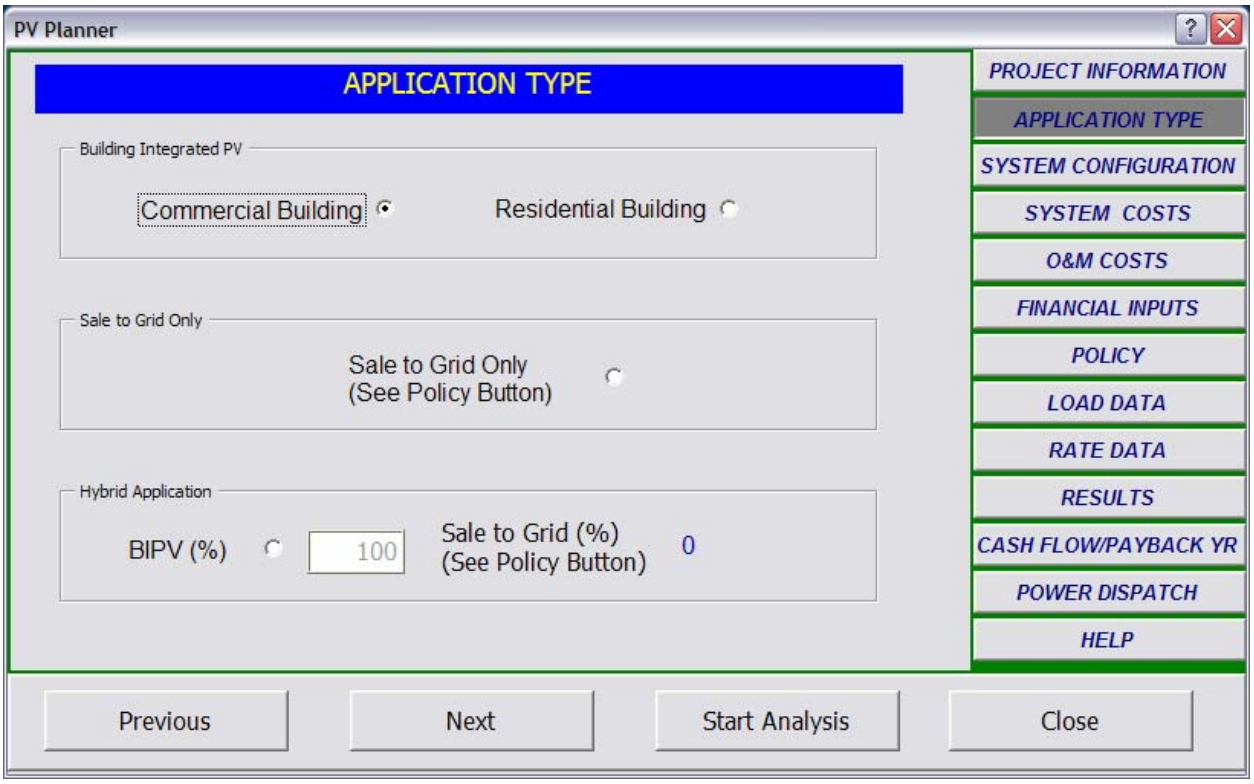
2.1 Project Information

The **Project Information** interface is used to enter basic information on the project to be analyzed by *PV Planner*, including a user-defined project name and the project's location. The program has a database of solar radiation data for most cities within the United States and many countries around the world from which the user can choose. If users have their own solar radiation records, they can enter this data instead. The program's database uses the format for Typical Meteorological Year (TMY) weather data developed by the National Renewable Energy Laboratory (U.S.).


PV Planner
PROJECT INFORMATION
Project Name
Delaware Commercial Building
Project Location
USA
International
State
Delaware
City
Wilmington
Meteorological Data
From Database
Manual
Copyright 2006 Center for Energy and Environmental Policy
PROJECT INFORMATION
APPLICATION TYPE
SYSTEM CONFIGURATION
SYSTEM COSTS
O&M COSTS
FINANCIAL INPUTS
POLICY
LOAD DATA
RATE DATA
RESULTS
CASH FLOW/PAYBACK YR
POWER DISPATCH
HELP
Previous
Next
Start Analysis
Close

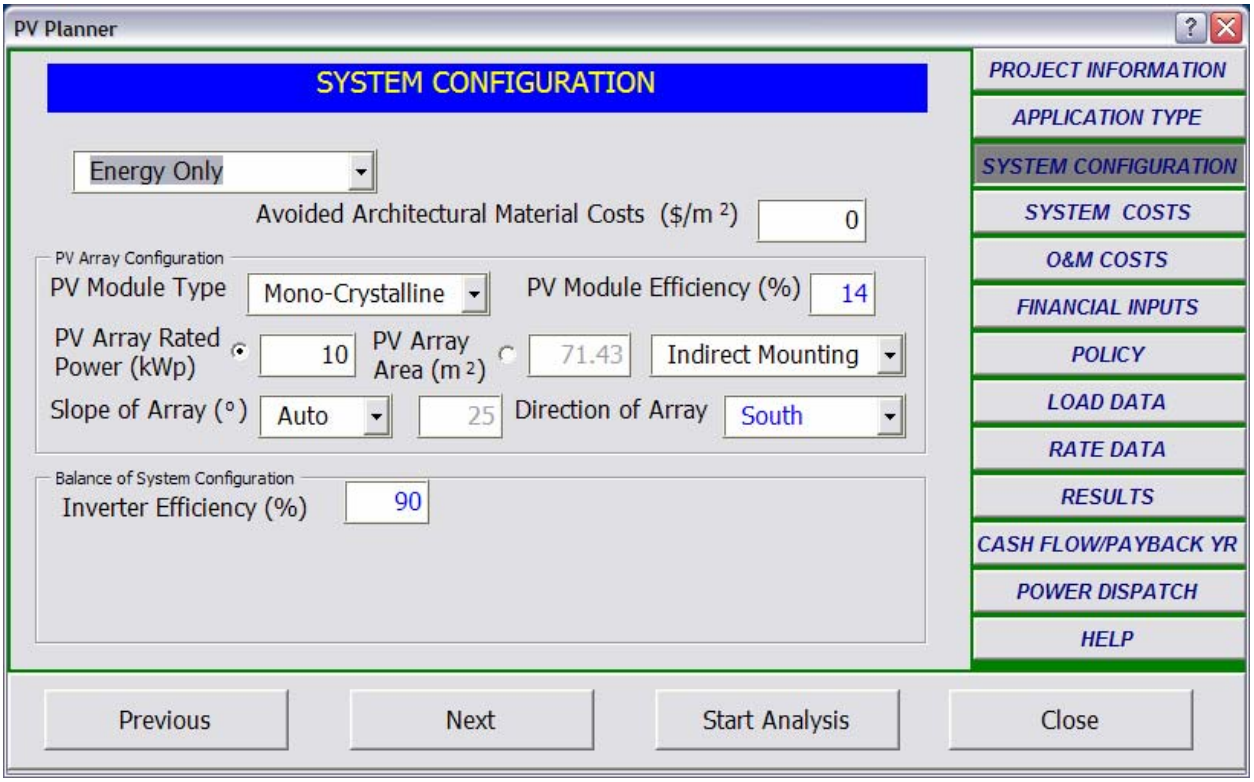
2.2 Application Type

At this interface, the user enters information on the type of project being analyzed. The initial option available is a building integrated PV (or BIPV) system installed either on a commercial or residential building. Alternatively, a project may exclusively involve a "Sale to Grid Only" format in which the electricity generated from the PV system is sold directly to a utility (pricing for this application is set in the **Policy Interface** – see p. 15 for details). A third option is the Hybrid application, which is a combination of the BIPV and Sale to the Grid options.



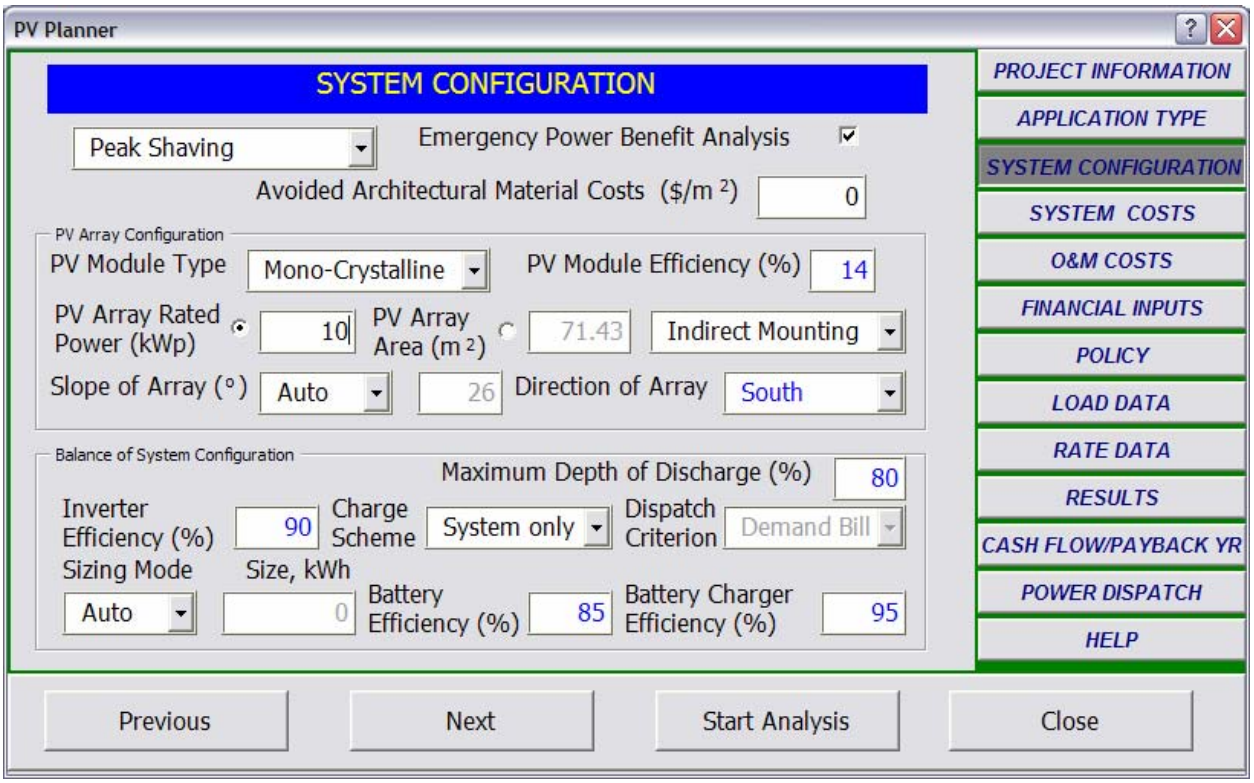
2.3 System Configuration

At the **System Configuration** interface, the user chooses the size, basic purpose and other technical features of the PV system. Users begin by choosing whether they want a system that is configured to provide energy only (no storage and the electricity produced is used immediately) or whether the system will provide dispatchable peak shaving (battery storage allows for the dispatching of energy when needed – see p. 11). The "Energy Only" configuration is illustrated below.



For either an "Energy Only" (see above) or "Peak Shaving" (see p. 11) configuration, the user also decides which type of PV module to use, the size of the array (in either area – m^2 – or electrical peak capacity – Wp), the method used to mount the array, and whether it is a rooftop or wall-mounted system (the user-indicated slope of the array determines this).

The user can also decide if PV panels can be mounted in a manner that reduces the need for roofing or other building materials (in this case, architectural material displacement costs are calculated).

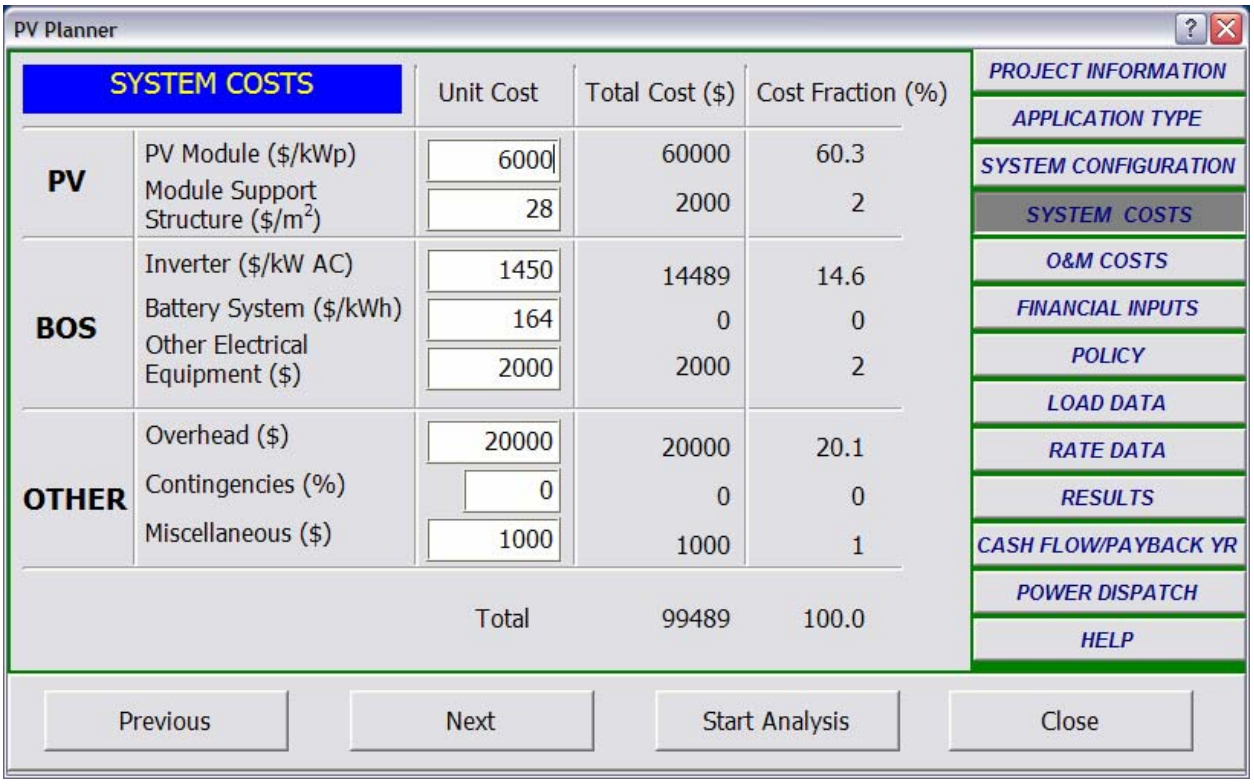


If the user wishes to have reliable peak-shaving capability built into the system, battery storage should be added. This "dispatchable" (i.e., "Peak Shaving") configuration allows the PV system to accumulate solar energy and release it as the building approaches its peak demand for electricity. ***PV Planner*** has an algorithm included in the software to determine the battery size that will maximize peak-shaving based on maximum daily solar energy available in each month. The size and efficiency of the battery storage system are set by the user (which includes an "Auto" choice for battery size that uses ***PV Planner's*** calculator). The battery bank can be charged in one of two ways: via the PV array only (click "Charge Scheme: System only"); or electric energy can be drawn from the grid during off-peak hours (click "Charge Scheme: Off Peak"). The user also decides whether to dispatch the solar energy in order to maximize bill savings from demand or energy charges (see the Rate Data interface on pp. 19-20). Utility demand charges are typically assessed only for commercial buildings.

If battery storage is included in the configuration of the PV system, the user can withdraw energy during electrical grid outages or 'blackouts.' The user can request ***PV Planner*** to calculate emergency power benefits. In this scenario, the program calculates benefits equal to the initial costs of inverters and batteries included in the configuration.

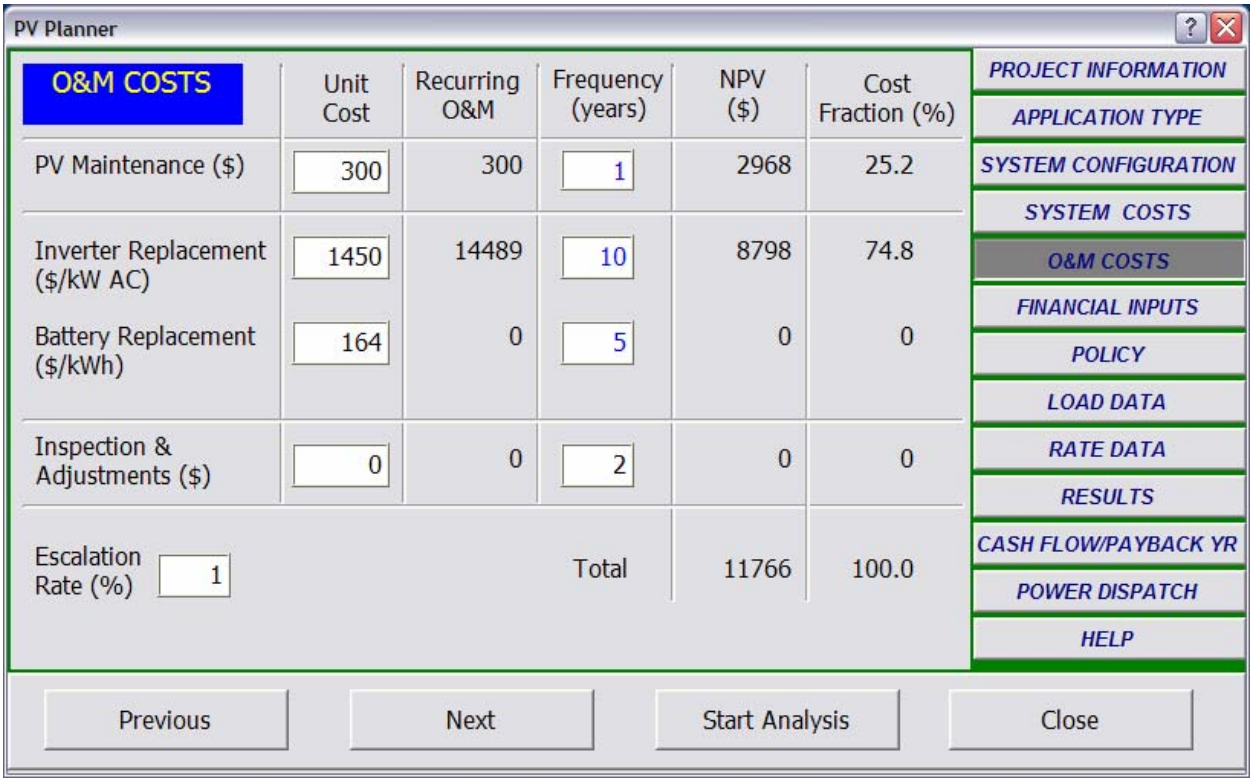
2.4 System Costs

At the **System Costs** interface, the user enters the system's capital costs. These are divided into three types: (i) the cost of the photovoltaic array (modules plus supporting structure); (ii) the balance of system (BOS) costs, which are associated with the inverters, batteries and any other electrical equipment used; and (iii) other costs such as overhead (e.g., transportation), contingencies and miscellaneous expenses.



2.5 O&M Costs

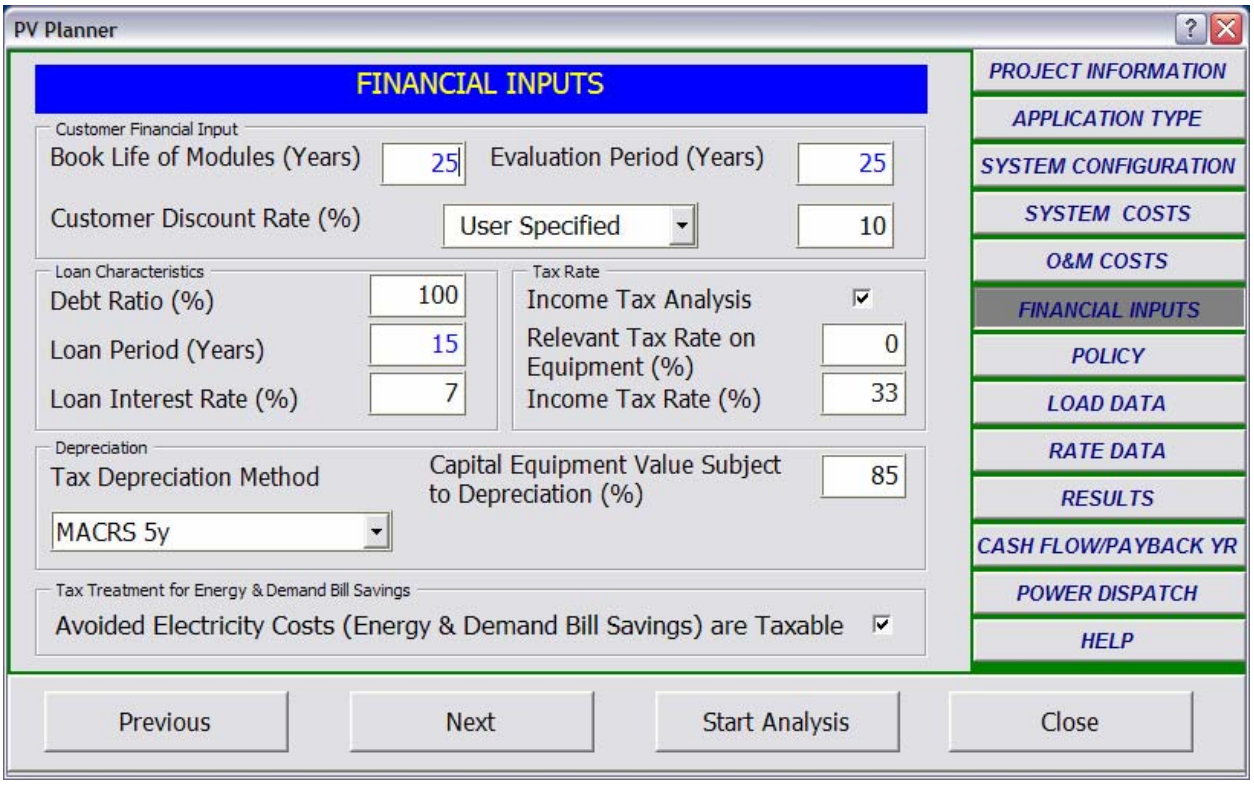
At the **O&M Costs** interface, the user decides the frequency of replacement of components, and maintenance costs associated with the PV system, as well as escalation rates for these items. O&M costs are divided into those associated with the maintenance of the PV array, and those associated with the replacement of inverters and batteries. Costs are also assigned to the inspection of and periodic adjustments to the system. The user is expected to enter the frequency (in years) of maintenance tasks. The Recurring O&M Cost, the Net Present Value (NPV) and Cost Fractions of the various cost items are calculated for the user.



2.6 Financial Inputs

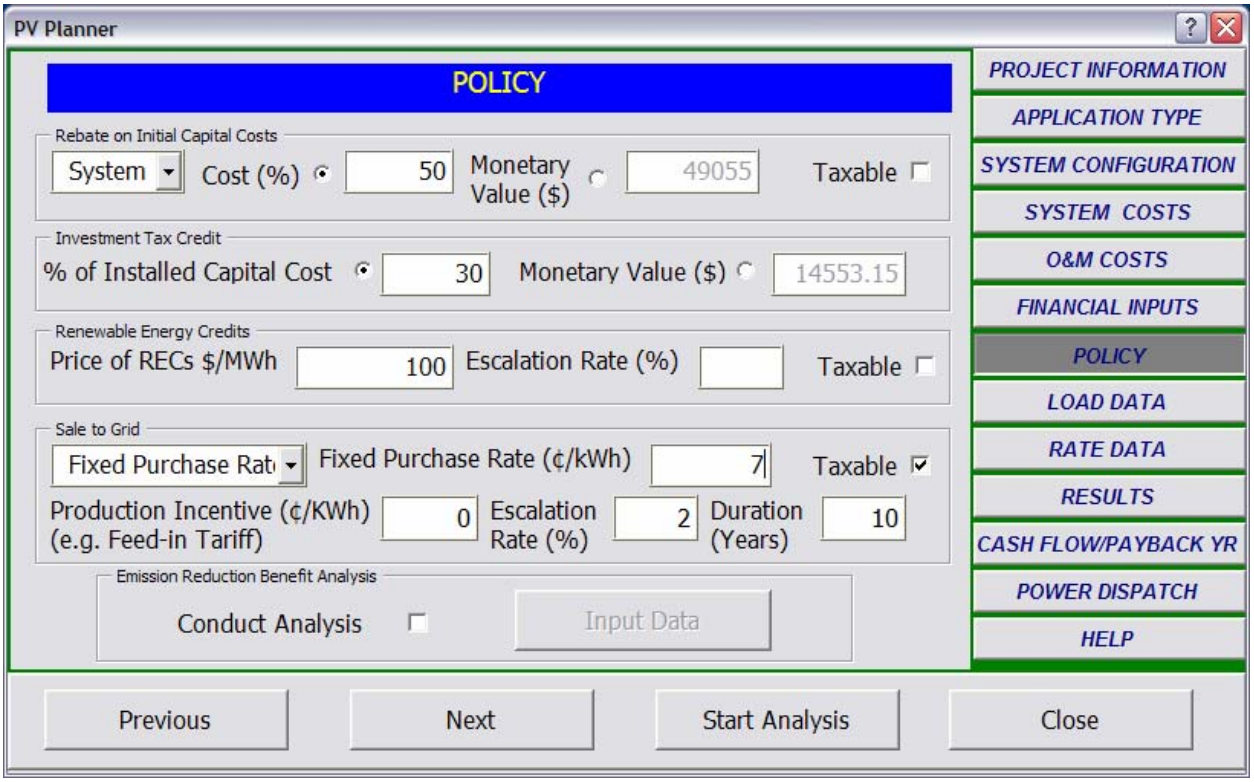
The **Financial Inputs** interface asks users to decide how the PV system will be financed and how its purchase will affect income. At this interface, the user also determines the length of the evaluation period and module lifetime.

The user is required to enter information related to the book life of the modules and the period of evaluation of the project. Discount rates are set by the user (with discount rate) defaults suggested for commercial, governmental and socially-oriented projects). Information is requested on the characteristics of the loan being used to finance the project (if necessary), as well as tax information (income tax rate, tax depreciation, etc.). The user chooses a depreciation method (e.g., Straight line, Double Declining Balance, MACRS 5y, etc.) and the level of depreciation that is applied to the capital equipment. The user also indicates if bill savings generated by a PV system are taxable. (Usually, bill savings for PV systems on commercial buildings are subject to income tax; while savings from residential systems ordinarily are not taxable).

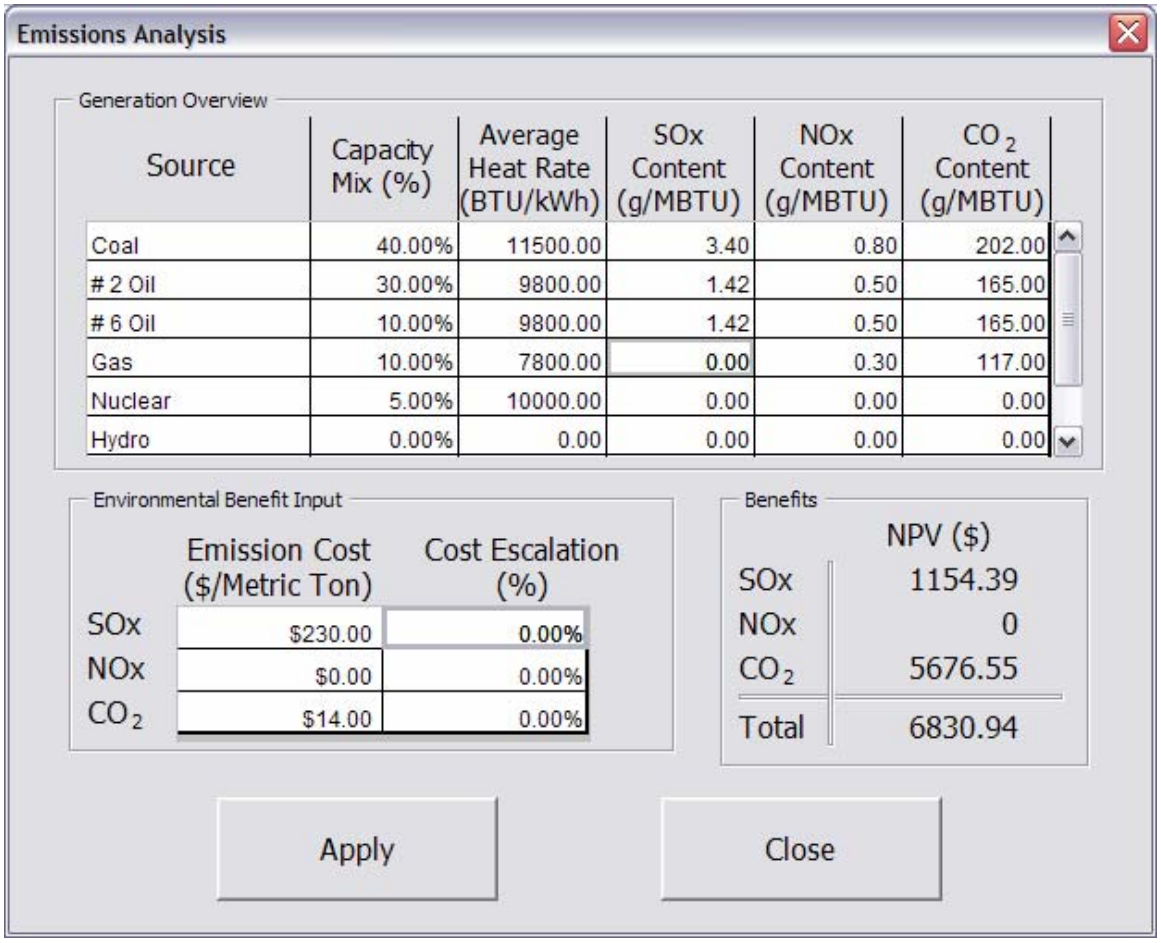


2.7 Policy

The **Policy** interface is built to address many of the incentives and benefits offered by government policy for the installation of PV systems. The user inputs data that reflects the existing or projected energy policies within the project service territory. Policies can include rebates, investment tax credits, renewable energy credits (RECs), and special prices for the sale of PV-generated electricity to the grid (including net metering and production incentives such as feed-in tariffs). For all government-based incentives and benefits, the user is asked to indicate if they are subject to tax.



An important policy component is related to the reduction in air pollution (e.g., SO_x and NO_x emissions) and greenhouse gas (GHG) emissions through the use of solar energy. The user can choose to conduct an Emission Reduction Benefit Analysis, which determines the environmental benefits from displacing a part of the energy mix (e.g., use of coal, oil, natural gas, etc.) and associated air emissions. When the user selects this option, a new screen appears (see p. 16) in which relevant pollution information is entered.

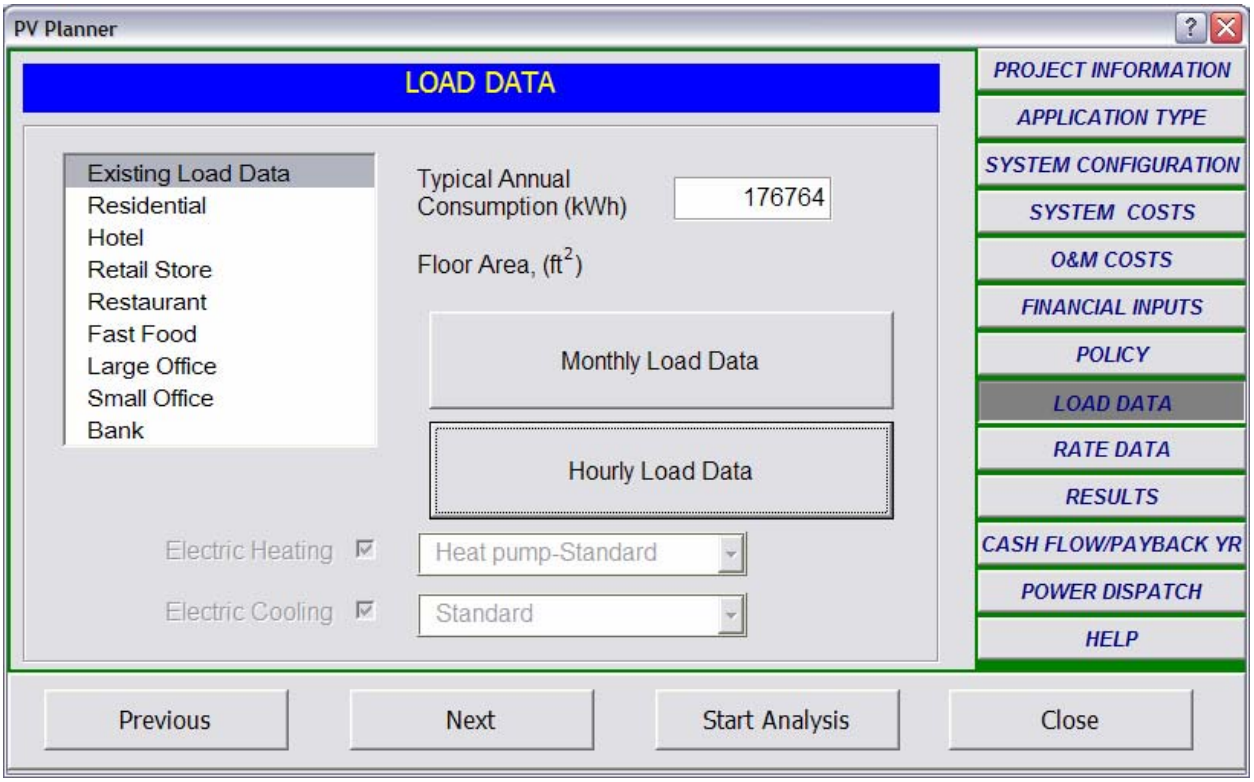


Users provide information related to the generation mix of their service area, the average heat rate of the fuels used by power plants in their area (default values are suggested), and their respective SO_x, NO_x and CO_2 (again, default values are suggested). An emission cost for each pollutant is entered, which can be obtained from current market prices for tradeable emission permits. The value of reduced emissions is then calculated for the user by ***PV Planner***.

2.8 Load Data

The **Load Data** interface allows the user to enter electricity load information for the type of building that will receive energy services from the PV system. Many options are available to the user with typical building load profiles already loaded into ***PV Planner*** for homes, office buildings, restaurants, stores, etc. The user adjusts these profiles by entering the typical annual consumption or floor area of a specific building. Users can also choose to enter their own hourly load data if available or monthly energy demand (in kW) and usage levels (in kWh) from billing statements. In the latter case, ***PV Planner*** will populate the building load matrix for the user based on the monthly information it is provided.

In addition, the user indicates if the building utilizes electricity for heating. In this instance, the user selects the relevant electric heating technology (standard heat pump, high efficiency heat pump and ground-coupled heat pump and resistance heating). Similarly, the user chooses the "Electric Cooling" option, if it is appropriate.



Load Data

		January	February	March	April	May	June	July	August	September	October	November	December
Usage (kWh)	1	14400	13520	11920	11880	13880	16080	18800	17920	16960	13280	12520	12480
Maximum Demand (kW)	2	30.8	31.2	30.8	32.8	33.2	43.2	47.2	47.2	42	36.8	32	31.2

Modify Close

Load Data

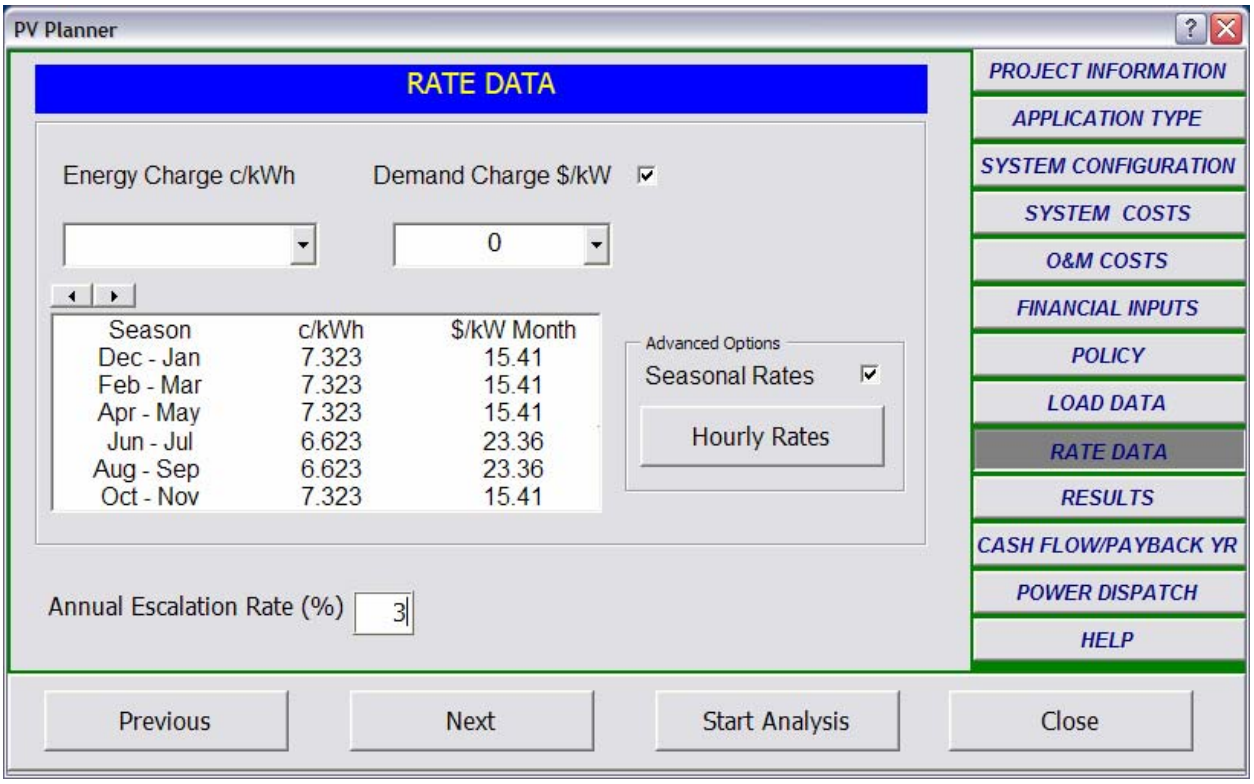
	January	February	March	April	May	June	July	August	September	October	November	December
1	12.52	12.95	8.71	8.51	9.52	10.07	11.54	10.42	11.55	8.93	9.72	9.71
2	12.29	12.79	8.39	8.02	9.07	9.59	11.31	10.13	11.17	8.24	9.18	9.34
3	12.15	12.69	8.21	7.79	8.88	9.76	11.04	9.83	11.02	7.85	9.06	9.00
4	12.14	12.65	8.09	7.66	8.78	9.68	11.14	9.94	11.00	7.69	8.90	8.82
5	12.37	12.76	8.93	8.18	8.82	9.93	12.31	11.11	11.41	8.05	9.38	9.20
6	14.17	14.34	10.72	9.97	10.62	12.37	16.04	14.51	13.25	9.41	10.85	10.87
7	17.81	18.24	14.40	13.98	15.26	18.40	22.53	21.19	19.16	13.61	14.58	14.30
8	21.39	22.24	17.85	18.02	19.86	24.48	28.87	27.92	25.45	18.57	18.63	17.86
9	24.92	25.80	22.29	22.73	24.64	30.33	34.98	33.58	30.82	24.02	23.47	22.44
10	26.80	27.34	25.58	26.07	27.46	34.01	38.79	37.46	34.39	27.82	26.29	25.70
11	26.99	27.36	26.99	27.33	28.38	35.52	40.02	39.05	35.75	29.21	27.70	26.98
12	26.88	27.34	26.59	28.75	29.03	36.32	40.74	40.60	36.42	31.24	28.05	27.34
13	26.71	27.27	25.21	27.76	28.88	36.67	40.43	40.22	36.42	30.76	27.41	26.55
14	26.71	27.40	25.96	28.26	29.10	37.44	41.37	41.00	36.74	32.25	27.08	26.12
15	26.43	27.33	24.70	26.89	28.81	37.86	41.12	41.37	36.81	31.72	26.62	25.25
16	25.99	27.01	23.79	25.61	28.56	37.10	39.73	39.49	36.45	29.87	25.65	24.44
17	24.69	25.69	21.78	24.04	27.28	34.37	37.36	36.49	34.93	27.23	24.05	23.07
18	21.24	22.19	18.34	19.87	22.96	28.53	31.13	30.09	29.11	22.03	20.35	19.41
19	18.31	19.29	15.40	16.11	18.51	21.66	23.87	22.51	22.62	17.49	16.93	16.30
20	17.07	17.88	13.88	14.68	16.41	18.88	20.85	19.61	20.09	15.82	15.51	15.05
21	15.82	16.60	12.46	12.77	14.35	16.30	18.21	17.01	17.64	13.97	13.84	13.42
22	14.25	14.85	11.02	11.22	12.54	14.05	15.42	14.38	15.22	11.91	12.17	11.93
23	13.24	13.85	9.82	9.73	11.08	12.20	13.75	12.83	13.80	10.46	10.98	10.68
24	12.87	13.41	9.33	9.06	10.37	11.34	12.80	11.89	12.99	9.95	10.22	10.20

Modify Close

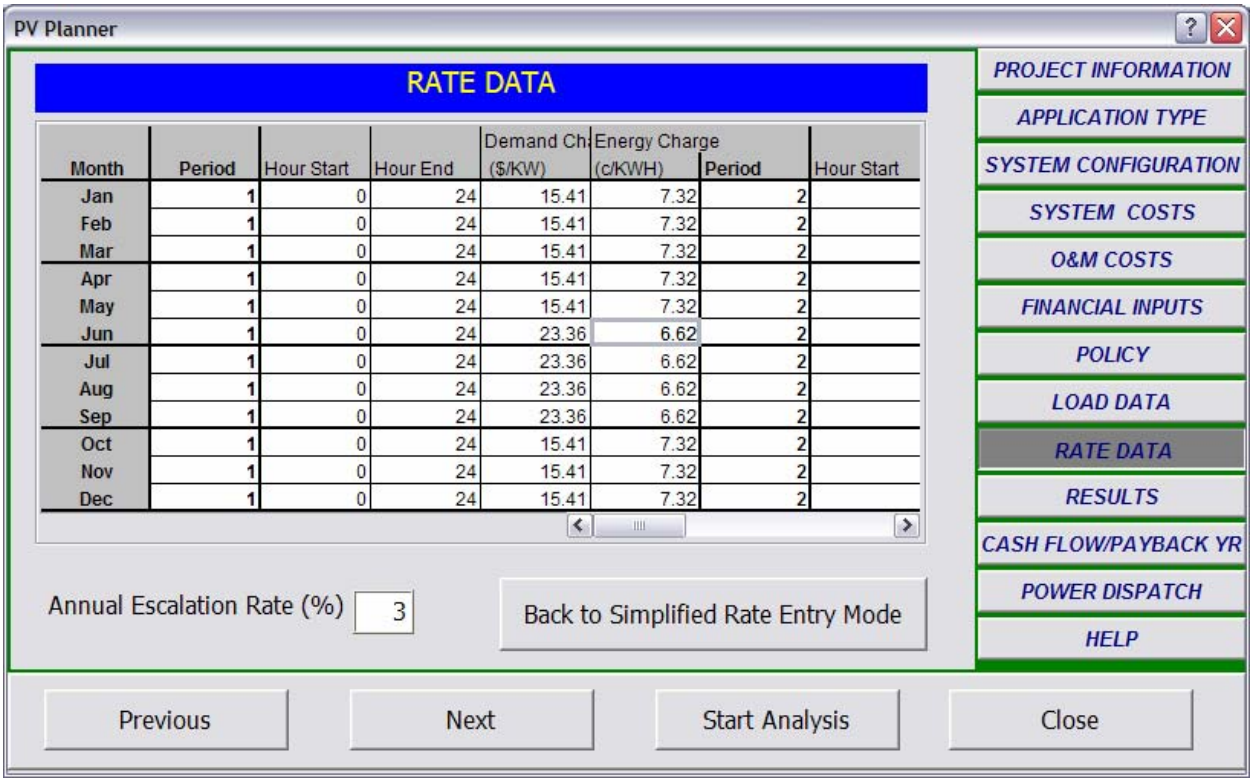
If a new user decides to enter specific building load data, the above table must be completed. It is possible to copy and paste data from an Excel data sheet to ***PV Planner***.

2.9 Rate Data

The **Rate Data** interface is used to input prices for electricity. Electricity rate charges usually have two components for commercial and industrial users: a demand charge, based on monthly pulse readings of the kW connected loads; and an energy charge which sets the price kWh used each month. Residential ratepayers usually pay an energy charge only. The demand charge (or power charge) is based on maximum monthly kilowatt (kW) load; whereas the energy charge prices electricity consumption per kilowatt hour (kWh) used.



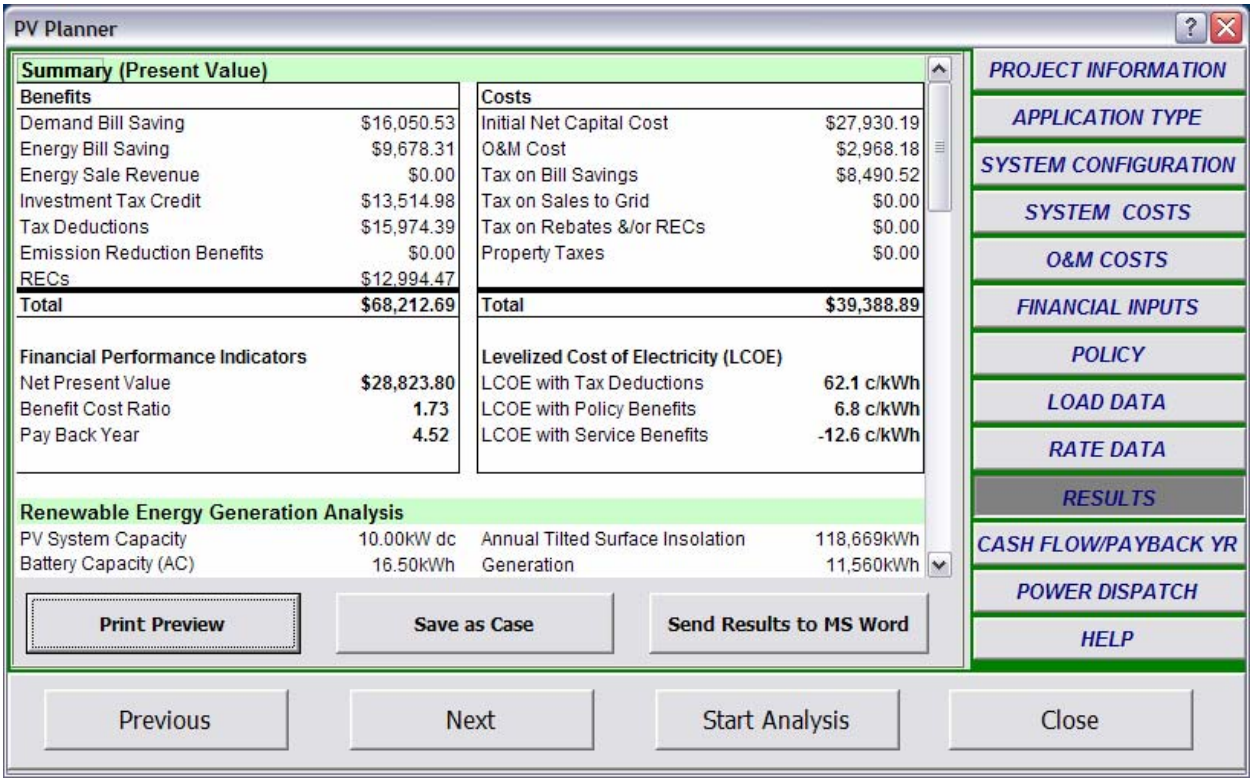
In some instances, energy and demand charges may vary during the year, with higher seasonal rates (e.g., for summer consumption) being applied. If this situation applies, the user is taken to a screen where hourly electricity rates are entered by time of day and month (see p. 20).



The user also decides the likely annual rate of increase in electricity prices (Annual Escalation Rate).

2.10 Results

The **Results** interface reports findings for the project entered by the user into ***PV Planner*** via a scrollable window. Users are given summaries related to the technical aspects of the PV system such as the amount of electricity that is generated, the capacity of the PV array, battery and inverter and the efficiency of the system. A summary is given of the financial inputs (e.g., initial capital costs and rebates) together with the financial performance of the system. Net Present Value, Benefit Cost Ratio, Payback Year and the Levelized Cost of Electricity for the system are given as measures of financial performance. Users can print, save or have the results sent to an MS Word file.



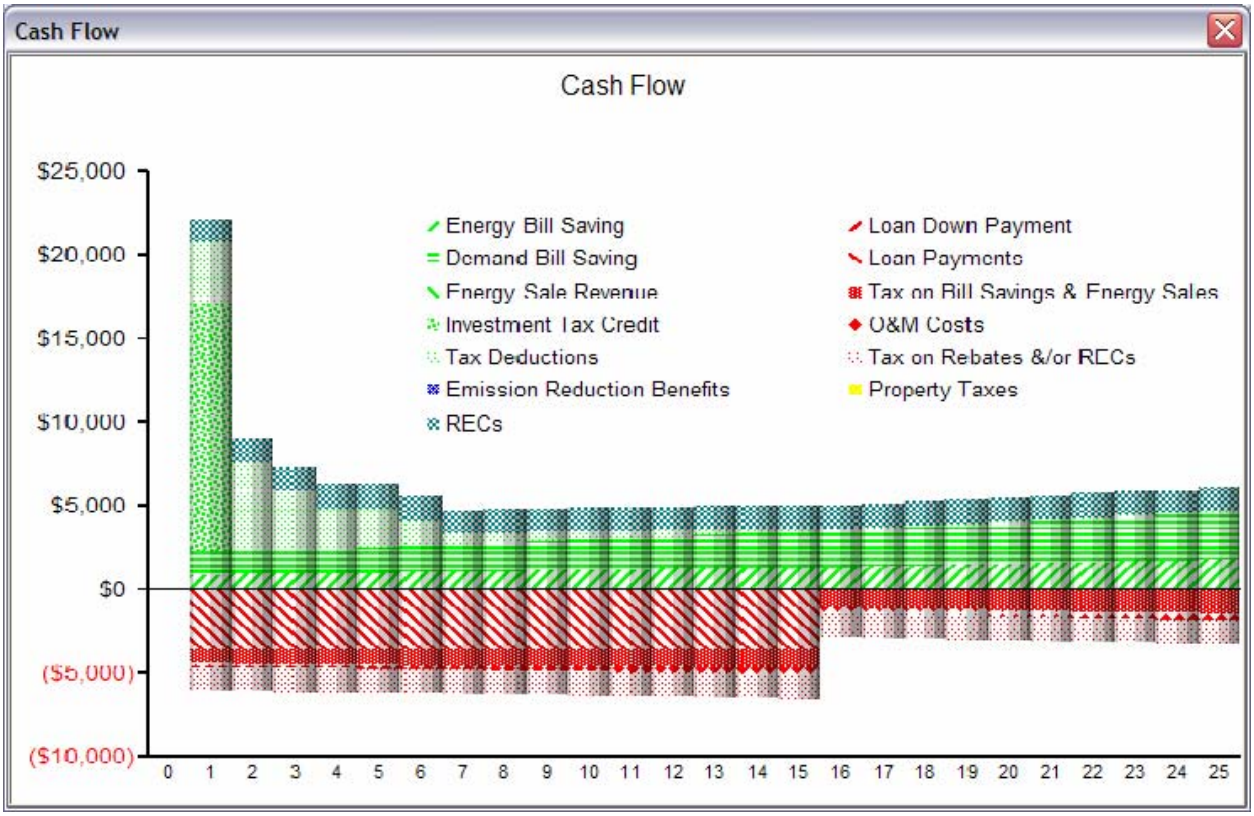
The user can also learn the levelized cost per kWh generated by the PV system over its lifetime. Those not familiar with levelized cost methodology should consult the following urls: http://www.eia.doe.gov/glossary/ (select "L" and scroll to levelized cost) and http://www.rio02.de/proceedings/pdf/293_stavy.pdf

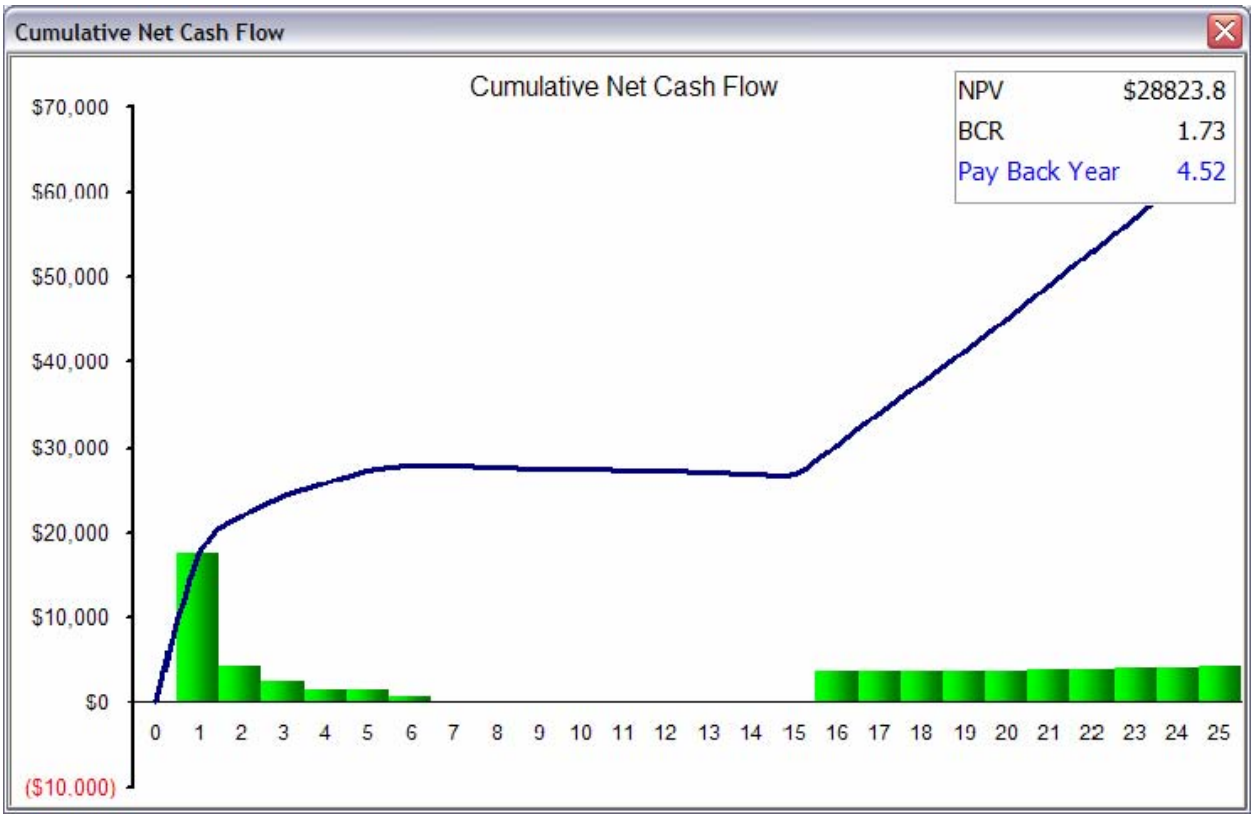
The user can scroll to additional reports on the energy performance of the analyzed PV system, including its annual generation and energy on peak-shaving services and amounts sold to the grid by month.

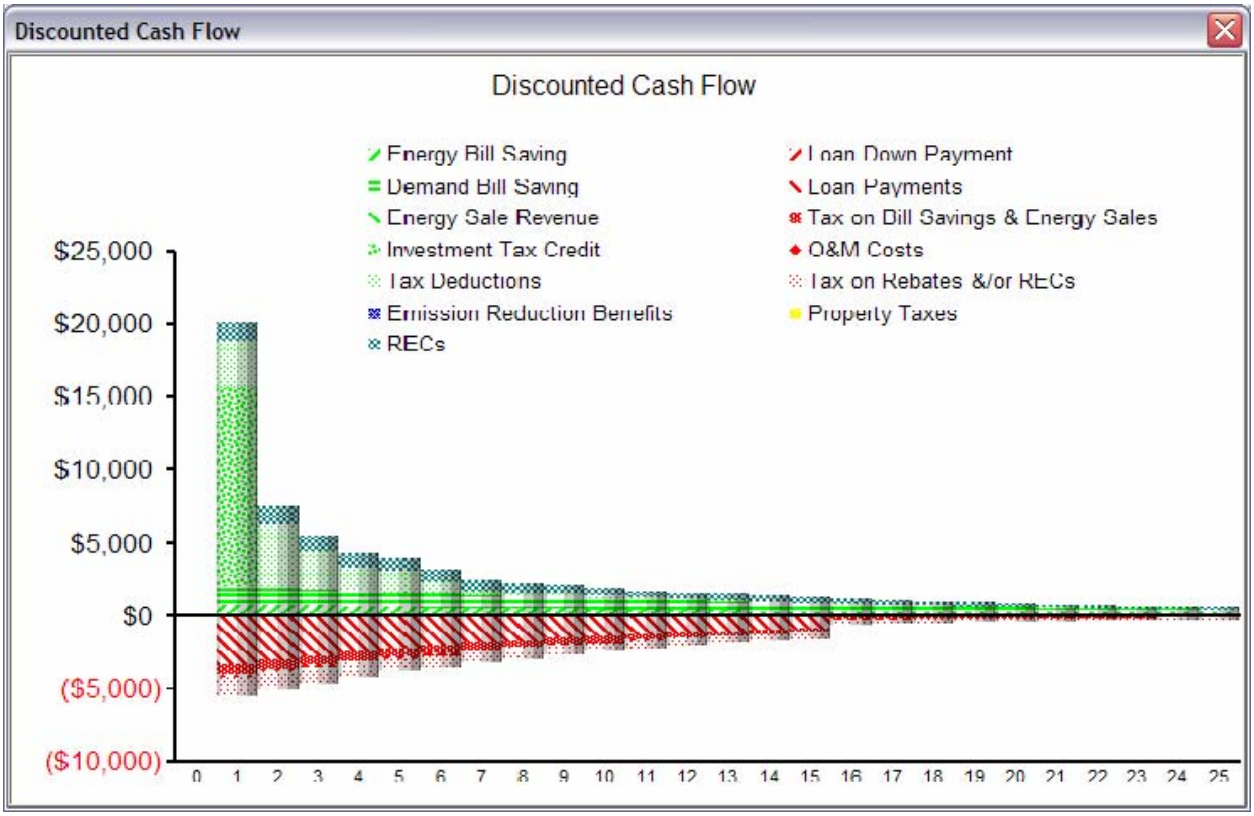
2.11 Cash Flow/Payback Yr

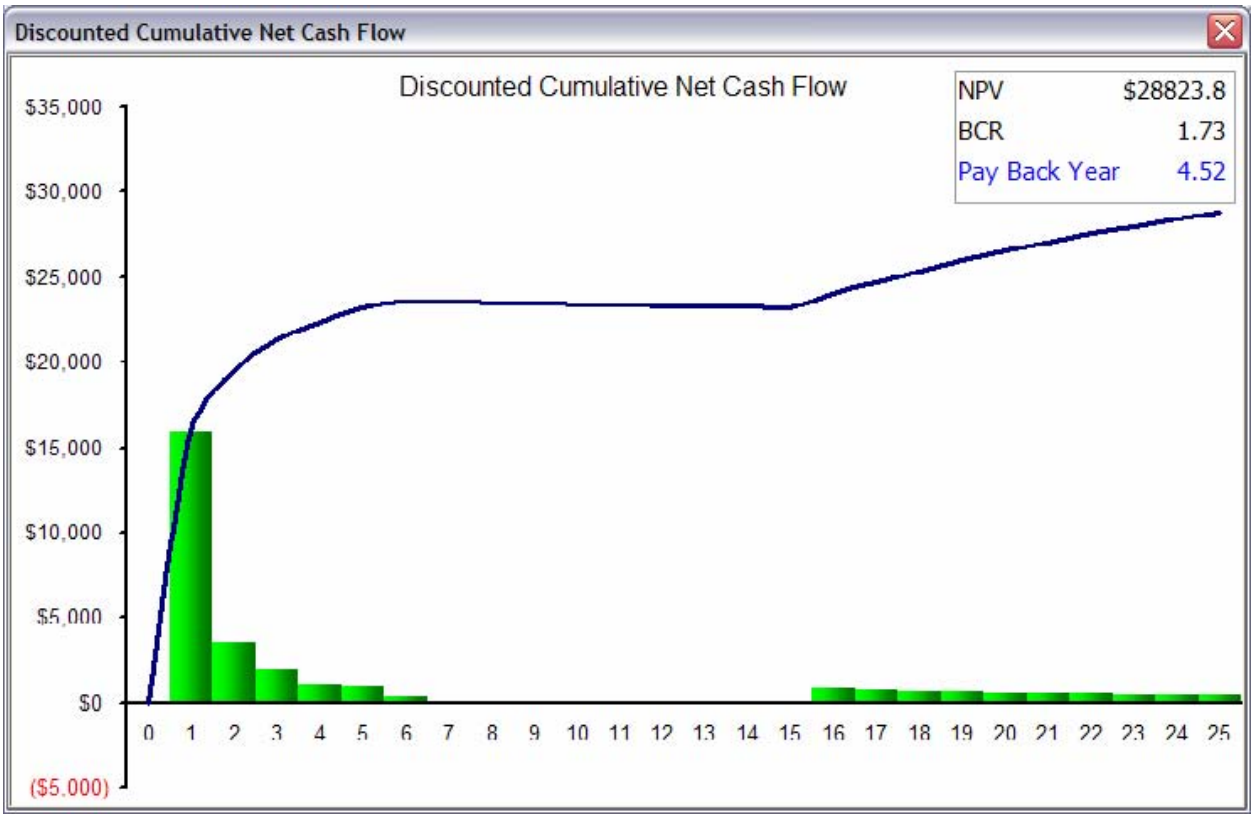
The **Cash Flow/Payback Yr** interface graphically displays the cash inflows and outflows during the life of the project, and presents these flows in four formats: nominal cash flow, discounted cash flow, cumulative cash flow and cumulative discounted cash flow. The user can click on individual graphs to obtain an enlarged version, which will also display the net preset value (NPV), benefit-cost ratio (BCR) and payback year.

Bar graphs of Cash Flow details are also provided (see below). From them, the user can visually inspect the relative effects of such ordinarily positive sources of cash flows as bill savings, sales revenues (when some or all of the PV system's output is sold to the grid), tax incentives, emission reduction benefits and RECs (renewable energy credits – tradable market permits associated with state RPS, or Renewable Portfolio Standards legislation – see Kotas, 2001; and CEEP, 2005). Likewise, negative effects on cash flow can be understood for such things as loan down payment, loan payments, taxes and O&M (operations and maintenance) costs. Results are presented in nominal and discounted dollars.

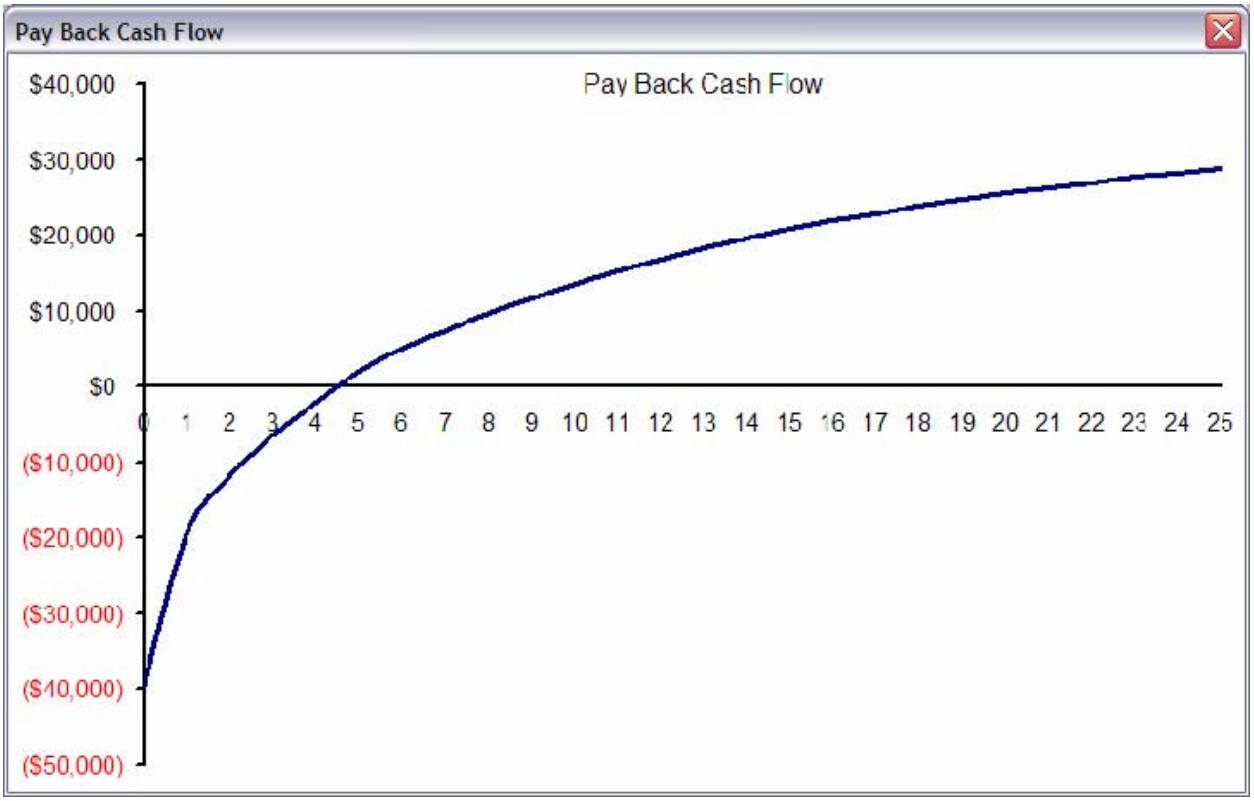

Cash Flow
Cash Flow
$25,000
$20,000
$15,000
$10,000
$5,000
$0
($5,000)
($10,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Energy Bill Saving
Demand Bill Saving
Energy Sale Revenue
Investment Tax Credit
Tax Deductions
Emission Reduction Benefits
RECs
Loan Down Payment
Loan Payments
Tax on Bill Savings & Energy Sales
O&M Costs
Tax on Rebates &/or RECs
Property Taxes


Cumulative Net Cash Flow
Cumulative Net Cash Flow
NPV $28823.8
BCR 1.73
Pay Back Year 4.52
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
($10,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Discounted Cash Flow
Discounted Cash Flow
Energy Bill Saving
Demand Bill Saving
Energy Sale Revenue
Investment Tax Credit
Tax Deductions
Emission Reduction Benefits
RECs
Loan Down Payment
Loan Payments
Tax on Bill Savings & Energy Sales
O&M Costs
Tax on Rebates &/or RECs
Property Taxes
$25,000
$20,000
$15,000
$10,000
$5,000
$0
($5,000)
($10,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Discounted Cumulative Net Cash Flow
Discounted Cumulative Net Cash Flow
NPV $28823.8
BCR 1.73
Pay Back Year 4.52
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
($5,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

By clicking on the phrase "**Pay Back Year**" in the Results box of the two Cumulative Cash Flow graphics, the user can map the PV system's payback performance by year to the end of the useful lifetime of the device.

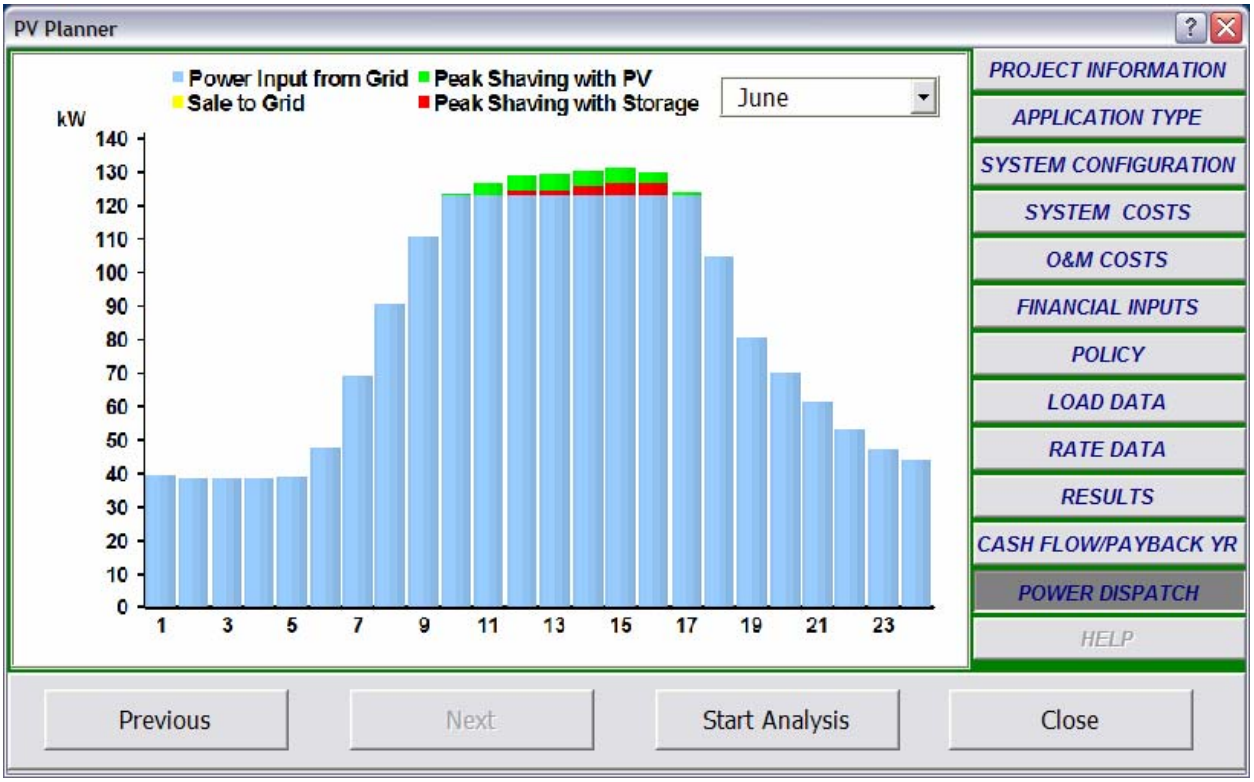


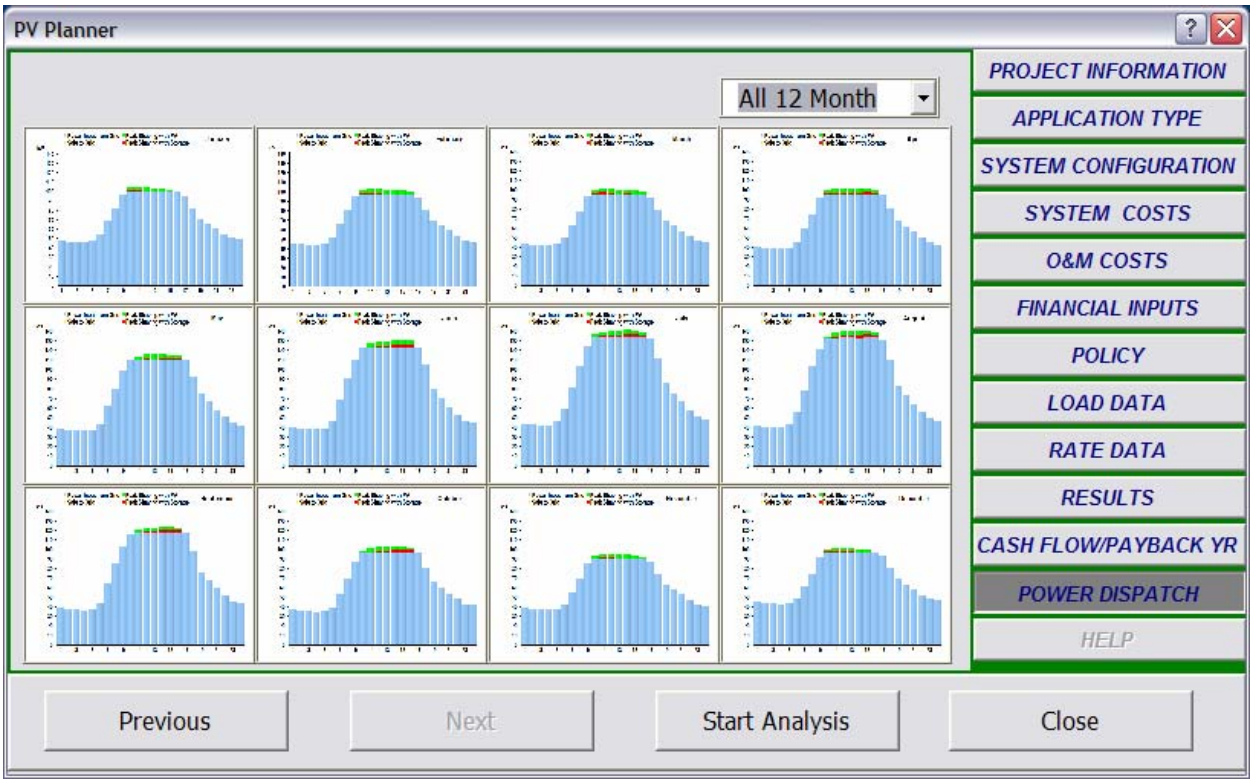
2.12 Power Dispatch

The **Power Dispatch** interface graphically displays the energy services of the PV system for each month. The graph is divided into areas that indicate periods where:

- Power input from the grid - Blue
- Peak shaving from coincident output of the PV array only - Green
- Peak shaving using battery storage - Red
- Solar energy sold to the grid (if any) - Yellow

Power Dispatches can be displayed separately for each month or for all twelve months (see next page).




PV Planner
All 12 Month
PROJECT INFORMATION
APPLICATION TYPE
SYSTEM CONFIGURATION
SYSTEM COSTS
O&M COSTS
FINANCIAL INPUTS
POLICY
LOAD DATA
RATE DATA
RESULTS
CASH FLOW/PAYBACK YR
POWER DISPATCH
HELP
Previous
Next
Start Analysis
Close

3. ILLUSTRATIVE OUTPUTS FROM *PV PLANNER* FOR BUILDING INTEGRATED PV (BIPV) APPLICATIONS

EXAMPLE 1: 10 kW Rooftop PV installation
No battery storage resulting in modest peak-shaving
All sales to grid at $0.06/kWh

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $0
Energy Bill Saving: $0
Energy Sale Revenue: $12408.94
Investment Tax Credit: $11063.08
Tax Deductions: $16611.68
Emission Reduction Benefits: $0
RECs: $0
Total: $40083.7

Costs
Initial Net Capital Cost: $38843.53
O&M Cost: $2449.70
Tax on Bill Savings: $0
Tax on Sales to Grid: $4094.95
Tax on Rebates &/or RECs: $0
Property Taxes: $0

Total: $45388.18

Financial Performance Indicators
Net Present Value: $-5304.47
Benefit Cost Ratio: .88
Payback Year: N/A

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 54.81c/KWh
LCOE with Policy Benefits: 15.64c/KWh[i]
LCOE with Service Benefits: NA
LCOE with Avoided Fuel Cost Volatility: 11.96c/KWh[ii]

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): NA
Maximum Depth of Discharge: NA
Inverter Capacity: 9.17kW dc
System Efficiency (w temp. effects): 12.06%
Capacity Factor: 16.34%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 14315.76kWh
Average Daily PV Generation: 39.22kWh
Peak Generation: NA
Generation per Wp: 1431.58kWh
Specific Yield: 200.42kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $9171.69
Battery Bank: $0
Other Electrical Equipment: $13757.54
Capital Cost: $22929.23
Rebate: $11464.62

[i] Includes state-provided 50% rebate.

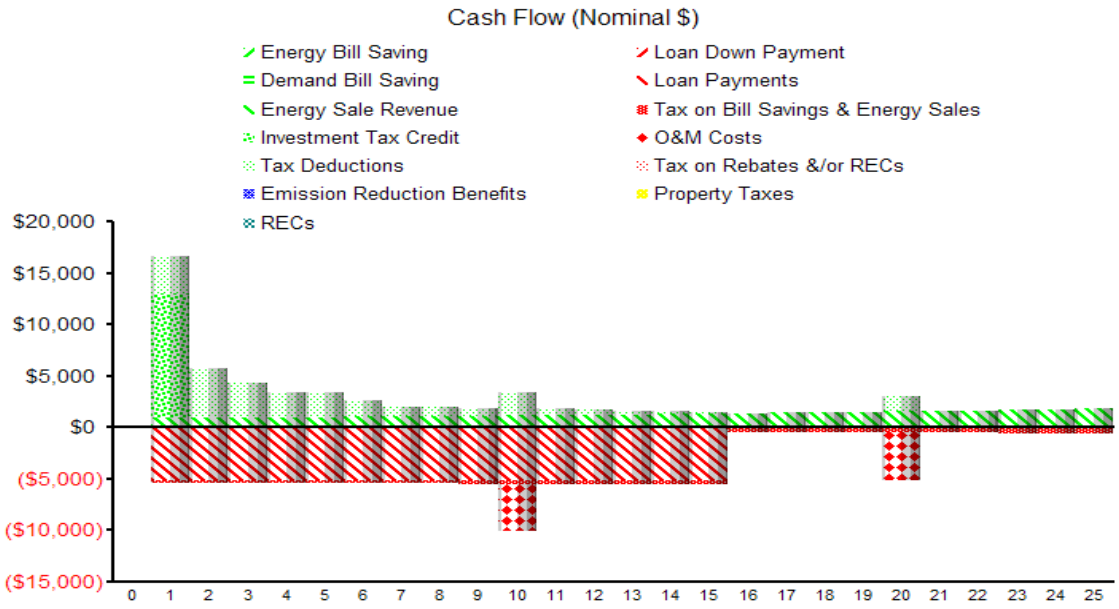
[ii] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year.

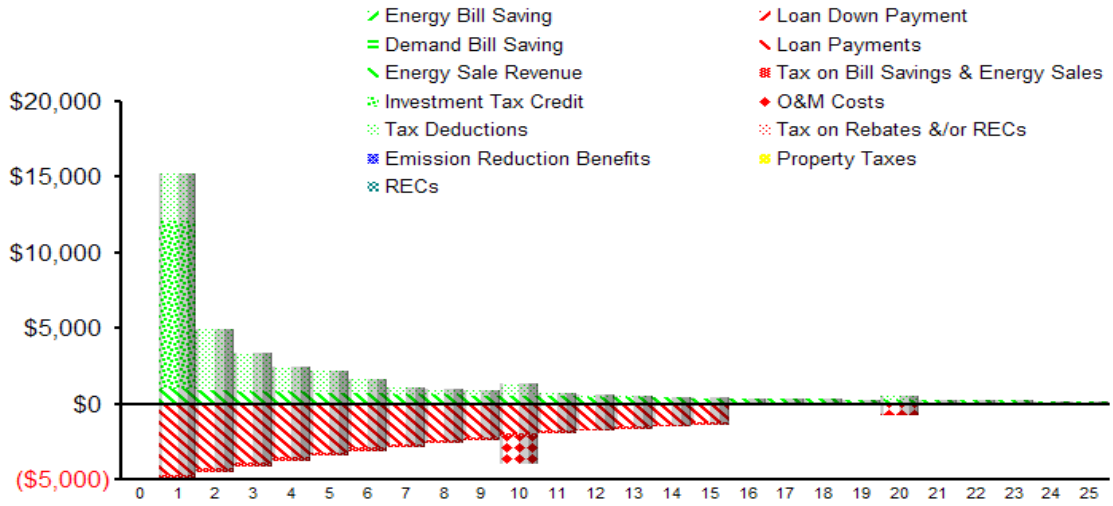
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

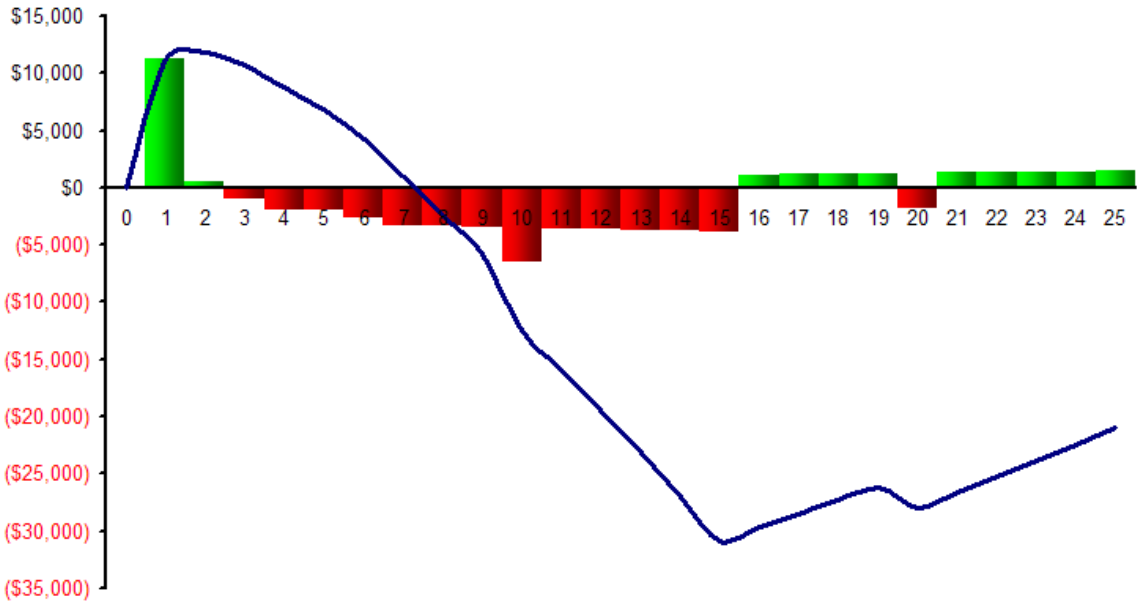
Policy Summary
Sale to grid: Production Incentive – none
RECs: 0$/MWh
System Rebate: 50%
InvestmentTtax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $81129.23
Total Rebate (one-time, 0th year): $40564.62
Initial Net Capital Cost: $40564.62

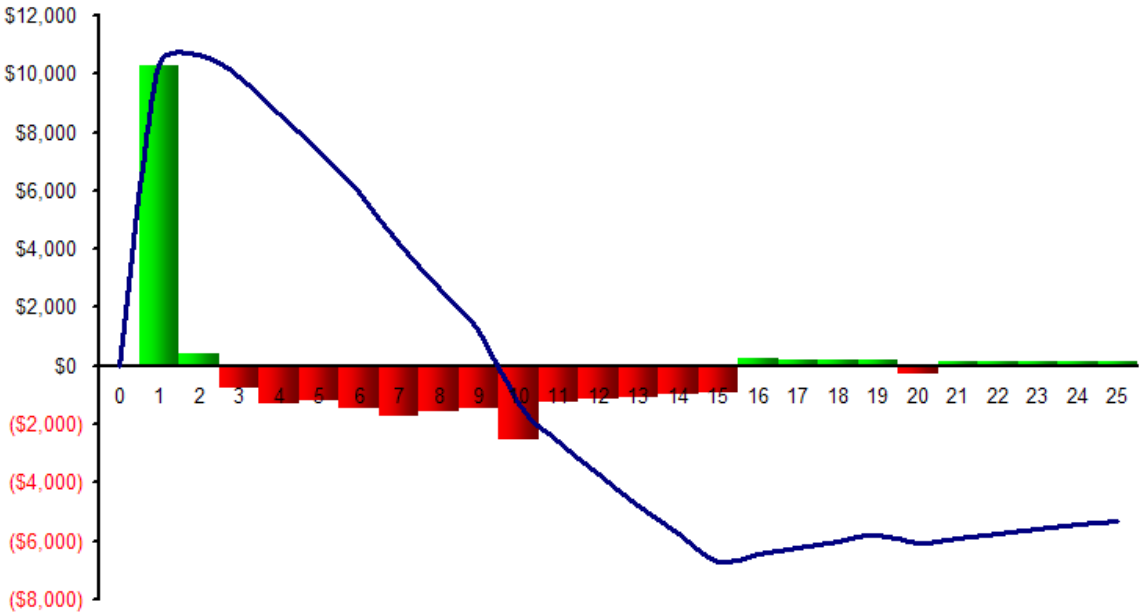


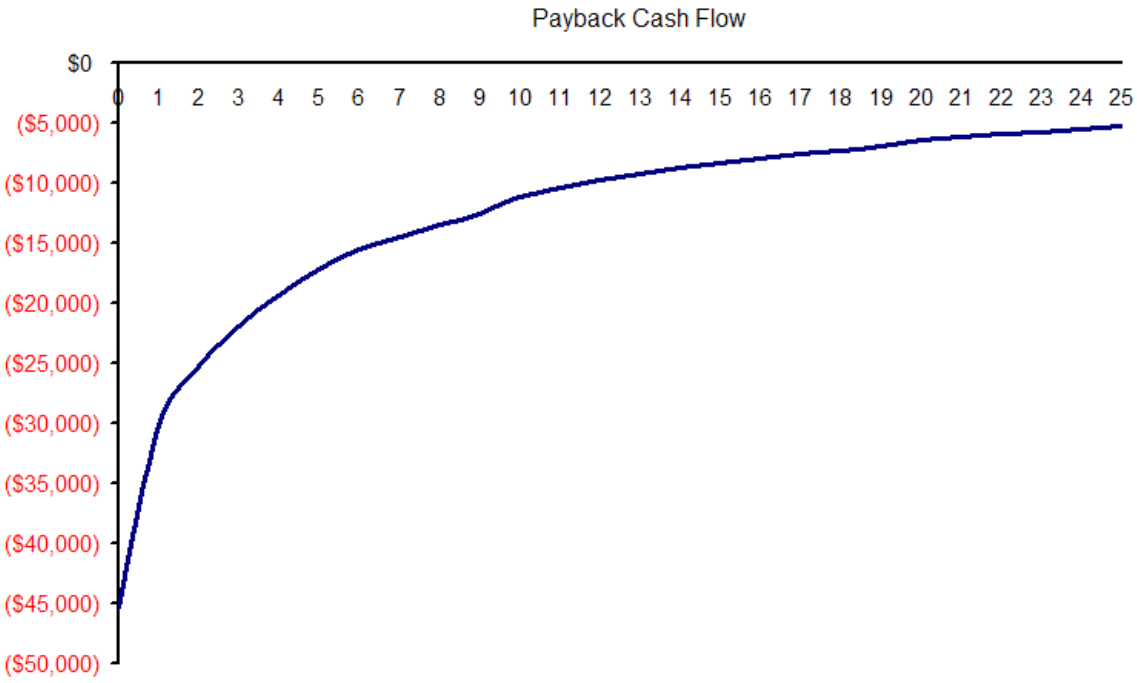


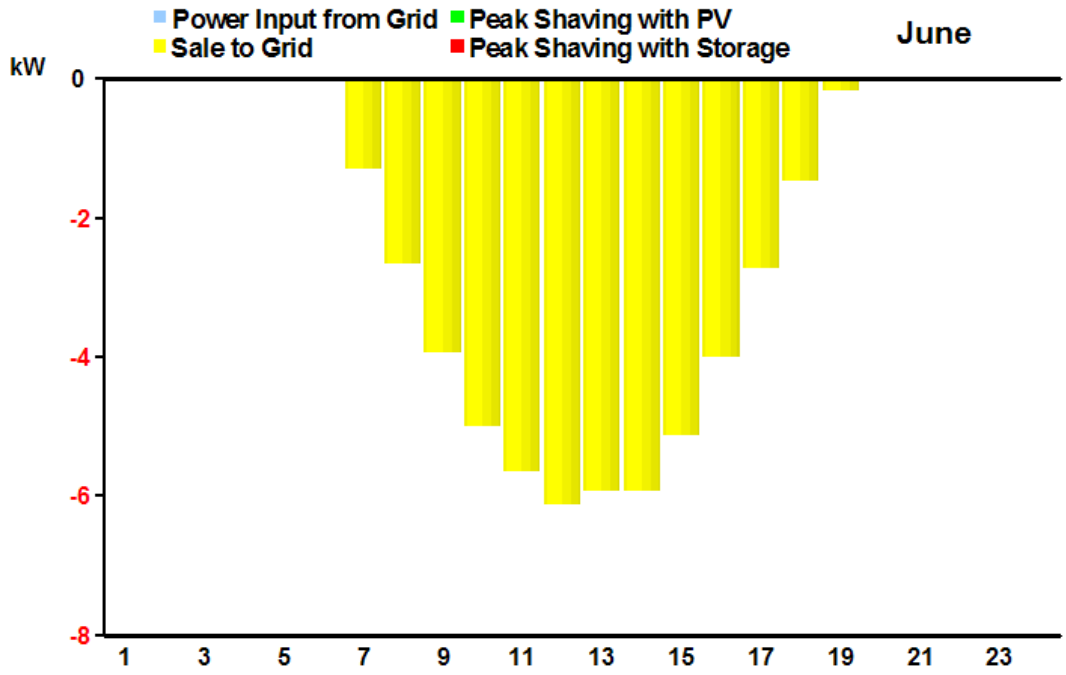
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$0
($5,000)
($10,000)
($15,000)
($20,000)
($25,000)
($30,000)
($35,000)
($40,000)
($45,000)
($50,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
June
kW
0
-2
-4
-6
-8
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	0	0	0.00	0	846	846	0	0	63
February	0	0	0.00	0	1,032	1,032	0	0	77
March	0	0	0.00	0	1,278	1,278	0	0	96
April	0	0	0.00	0	1,366	1,366	0	0	102
May	0	0	0.00	0	1,459	1,459	0	0	109
June	0	0	0.00	0	1,499	1,499	0	0	105
July	0	0	0.00	0	1,485	1,485	0	0	104
August	0	0	0.00	0	1,449	1,449	0	0	101
September	0	0	0.00	0	1,236	1,236	0	0	86
October	0	0	0.00	0	1,162	1,162	0	0	87
November	0	0	0.00	0	817	817	0	0	61
December	0	0	0.00	0	686	686	0	0	51
Total		0		0	14,316	14,316	0	0	1,045

EXAMPLE 2: 10 kW Rooftop PV installation
No battery storage resulting in modest peak-shaving
All sales to grid at $0.06/kWh
Renewable Energy Credits sold at $0.20/kWh in New Jersey Solar RECs Market

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $0
Energy Bill Saving: $0
Energy Sale Revenue: $12408.94
Investment Tax Credit: $11063.08
Tax Deductions: $16611.68
Emission Reduction Benefits: $0
RECs: $25988.94
Total: $63860.06

Costs
Initial Net Capital Cost: $38843.53
O&M Cost: $2449.70
Tax on Bill Savings: $0
Tax on Sales to Grid: $4094.95
Tax on Rebates &/or RECs: $0
Property Taxes: $0

Total: $44658.02

Financial Performance Indicators
Net Present Value: $19202.04
Benefit Cost Ratio: 1.43
Payback Year: 7.35

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 54.81c/KWh
LCOE with Policy Benefits: -14.21c/KWh[i]
LCOE with Service Benefits: NA
LCOE with Avoided Fuel Cost Volatility: -10.86c/KWh[ii]

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): NA
Maximum Depth of Discharge: NA
Inverter Capacity: 9.17kW dc
System Efficiency (w temp. effects): 12.06%
Capacity Factor: 16.34%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 14315.76kWh
Average Daily PV Generation: 39.22kWh
Peak Generation: NA
Generation per Wp: 1431.58kWh
Specific Yield: 200.42kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $9171.69
Battery Bank: $0
Other Electrical Equipment: $13757.54
Capital Cost: $22929.23
Rebate: $11464.62

[i] Indicates that policy benefits (including state-provided rebate and REC sales) are greater than system costs.

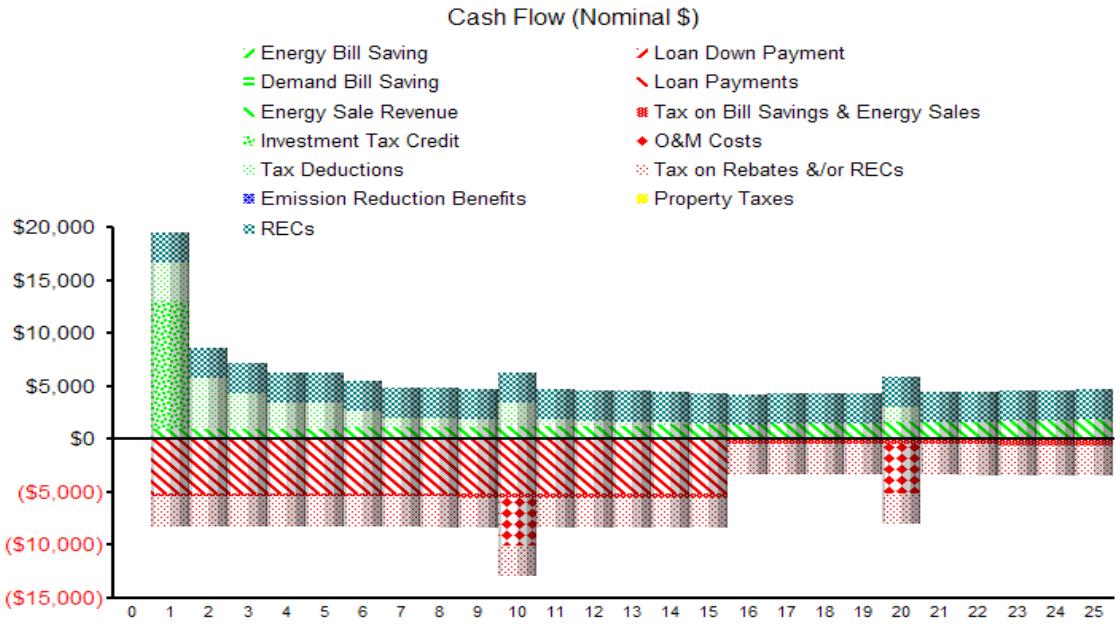
[ii] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year. The benefit is calculated as additional to applicable policy and service benefits.

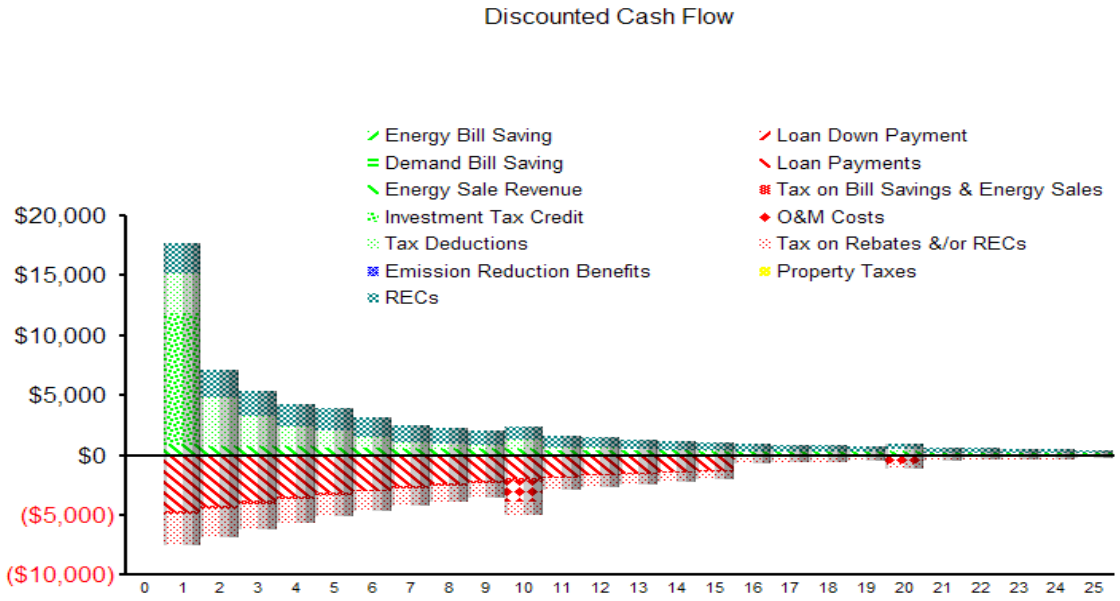
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

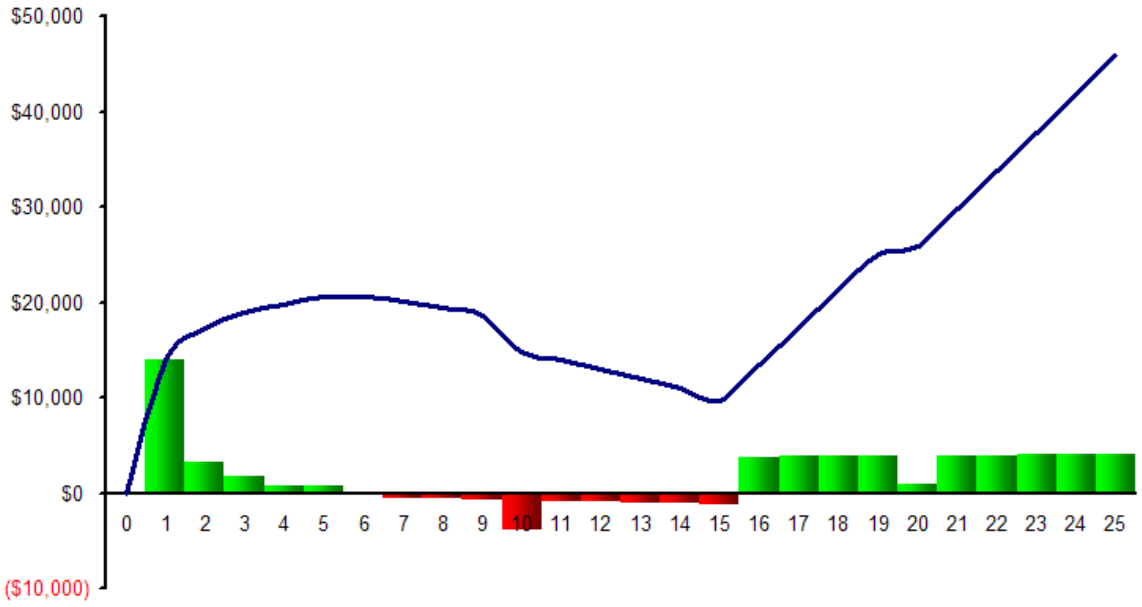
Policy Summary
Sale to grid: Production Incentive – none
RECs: 200$/MWh
System Rebate: 50%
Investment Tax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $81129.23
Total Rebate (one-time, 0th year): $40564.62
Initial Net Capital Cost: $40564.62

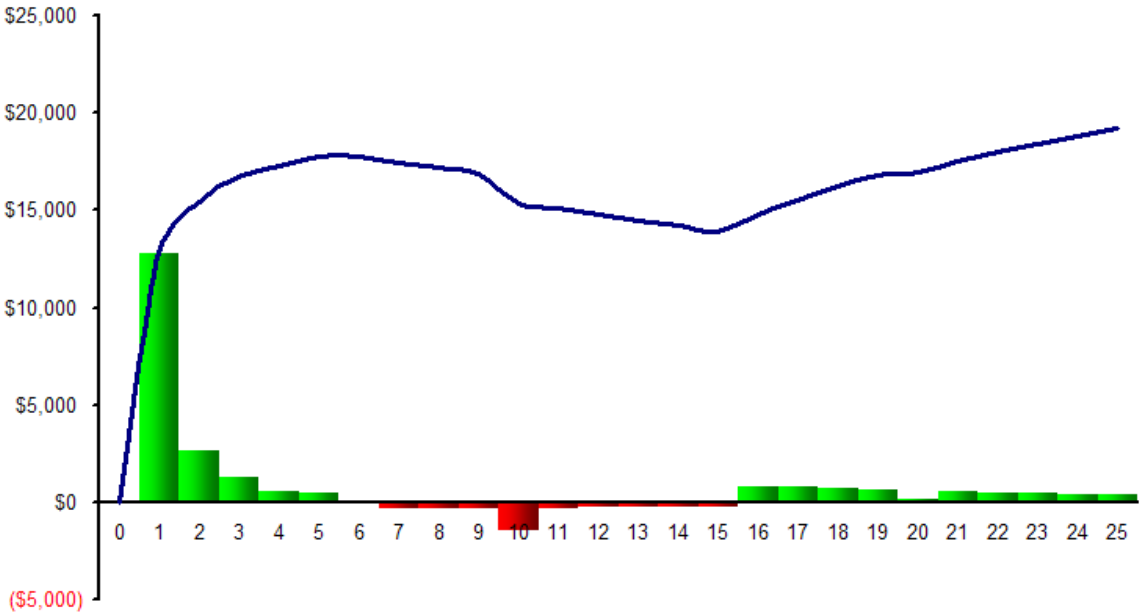


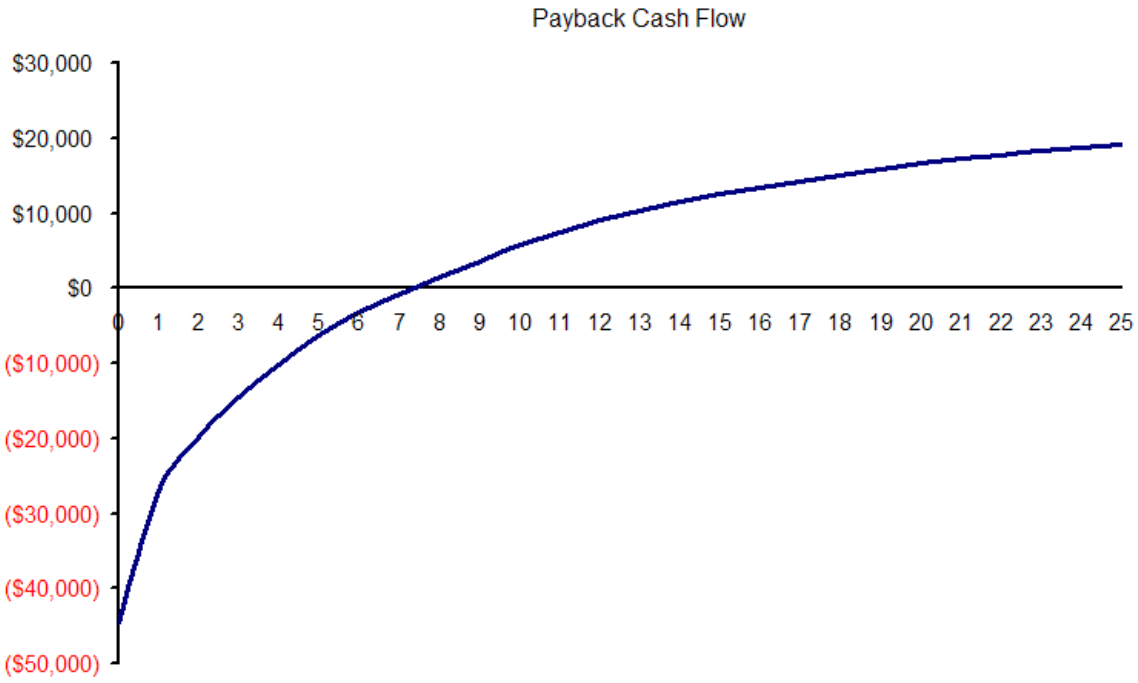


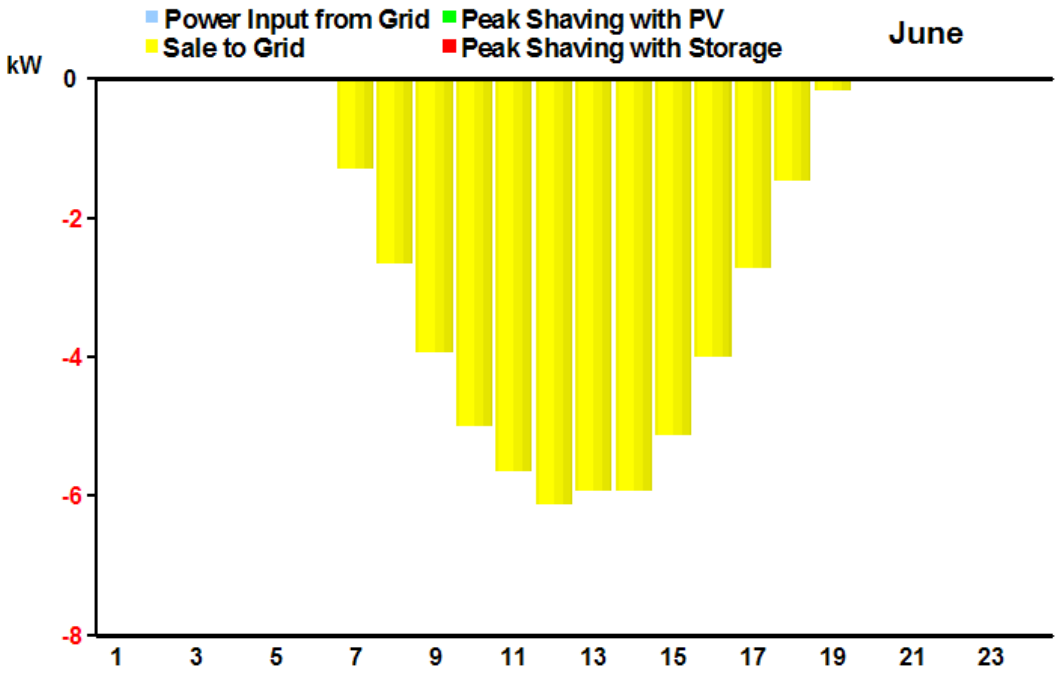
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$30,000
$20,000
$10,000
$0
($10,000)
($20,000)
($30,000)
($40,000)
($50,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
June
kW
0
-2
-4
-6
-8
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	0	0	0.00	0	846	846	0	0	51
February	0	0	0.00	0	1,032	1,032	0	0	62
March	0	0	0.00	0	1,278	1,278	0	0	77
April	0	0	0.00	0	1,366	1,366	0	0	82
May	0	0	0.00	0	1,459	1,459	0	0	88
June	0	0	0.00	0	1,499	1,499	0	0	90
July	0	0	0.00	0	1,485	1,485	0	0	89
August	0	0	0.00	0	1,449	1,449	0	0	87
September	0	0	0.00	0	1,236	1,236	0	0	74
October	0	0	0.00	0	1,162	1,162	0	0	70
November	0	0	0.00	0	817	817	0	0	49
December	0	0	0.00	0	686	686	0	0	41
Total		0		0	14,316	14,316	0	0	859

EXAMPLE 3: 10 kW Rooftop PV installation
No battery storage resulting in modest peak-shaving
PV energy output used to reduce monthly customer electric bills

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $11964.68
Energy Bill Saving: $12408.94
Energy Sale Revenue: $0
Investment Tax Credit: $11063.08
Tax Deductions: $16611.68
Emission Reduction Benefits: $0
RECs: $0
Total: $52048.38

Costs
Initial Net Capital Cost: $38843.53
O&M Cost: $2449.70
Tax on Bill Savings: $8043.3
Tax on Sales to Grid: $0
Tax on Rebates &/or RECs: $0
Property Taxes: $0

Total: $49336.52

Financial Performance Indicators
Net Present Value: $2711.86
Benefit Cost Ratio: 1.05
Payback Year: 19.43

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 54.81c/KWh
LCOE with Policy Benefits: 15.64c/KWh
LCOE with Service Benefits: NA
LCOE with Avoided Fuel Cost Volatility: 11.96c/KWh

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): NA
Maximum Depth of Discharge: NA
Inverter Capacity: 9.17kW dc
System Efficiency (w temp. effects): 12.06%
Capacity Factor: 16.34%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 14315.76kWh
Average Daily PV Generation: 39.22kWh
Peak Generation: NA
Generation per Wp: 1431.58kWh
Specific Yield: 200.42kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $9171.69
Battery Bank: $0
Other Electrical Equipment: $13757.54
Capital Cost: $22929.23
Rebate: $11464.62

[i] Policy benefit is state-provided rebate.

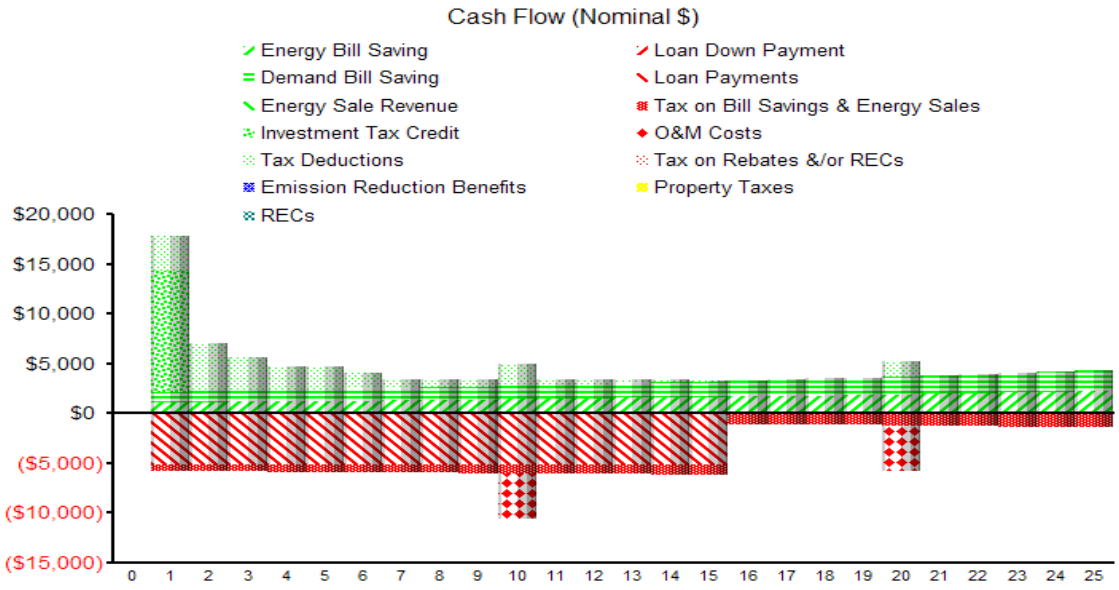
[ii] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year. The benefit is calculated as additional to applicable policy and service benefits.

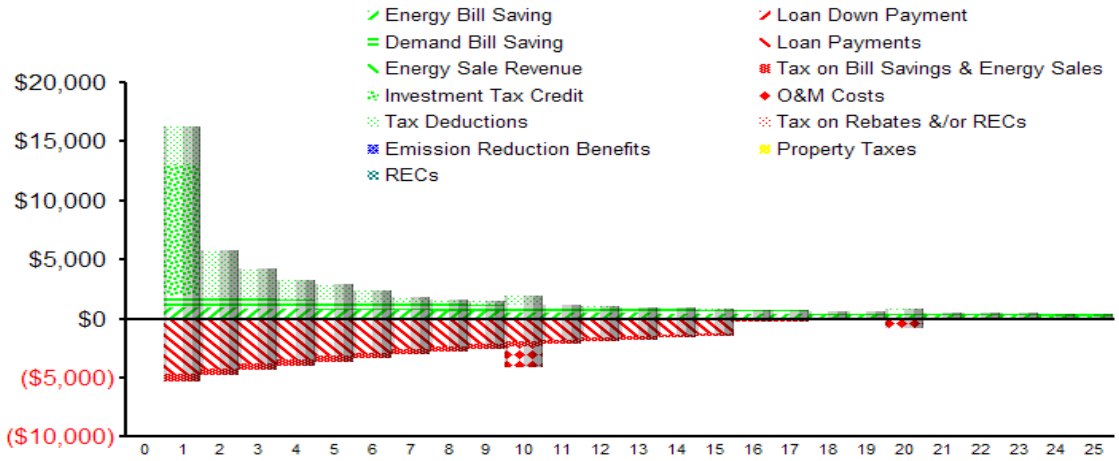
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

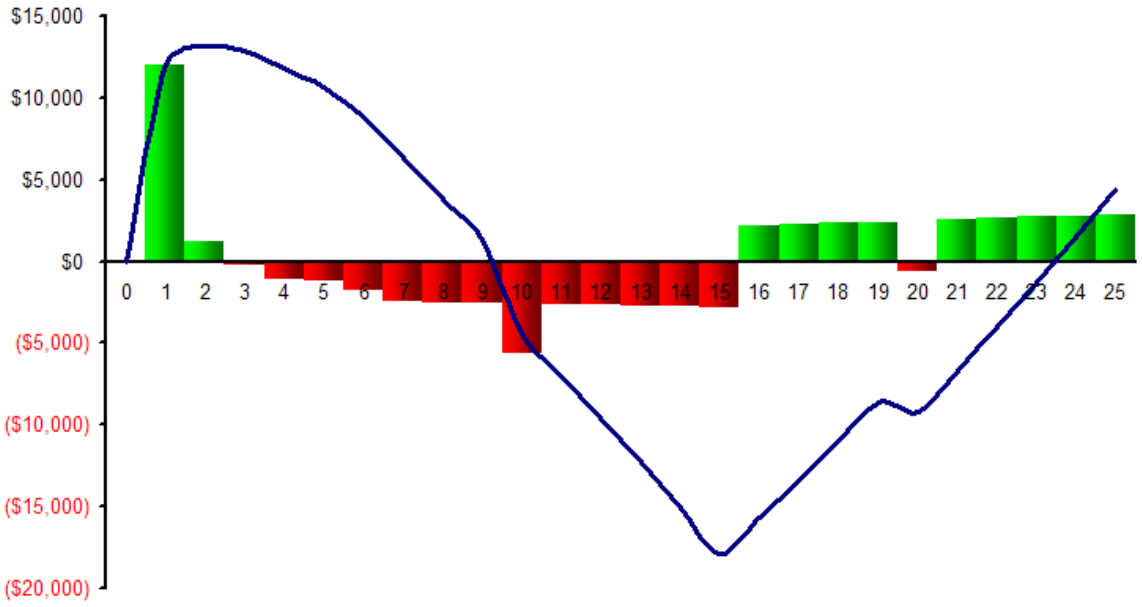
Policy Summary
Sale to grid: Production Incentive – none
RECs: 0$/MWh
System Rebate: 50%
Investment Tax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $81129.23
Total Rebate (one-time, 0th year): $40564.62
Initial Net Capital Cost: $40564.62

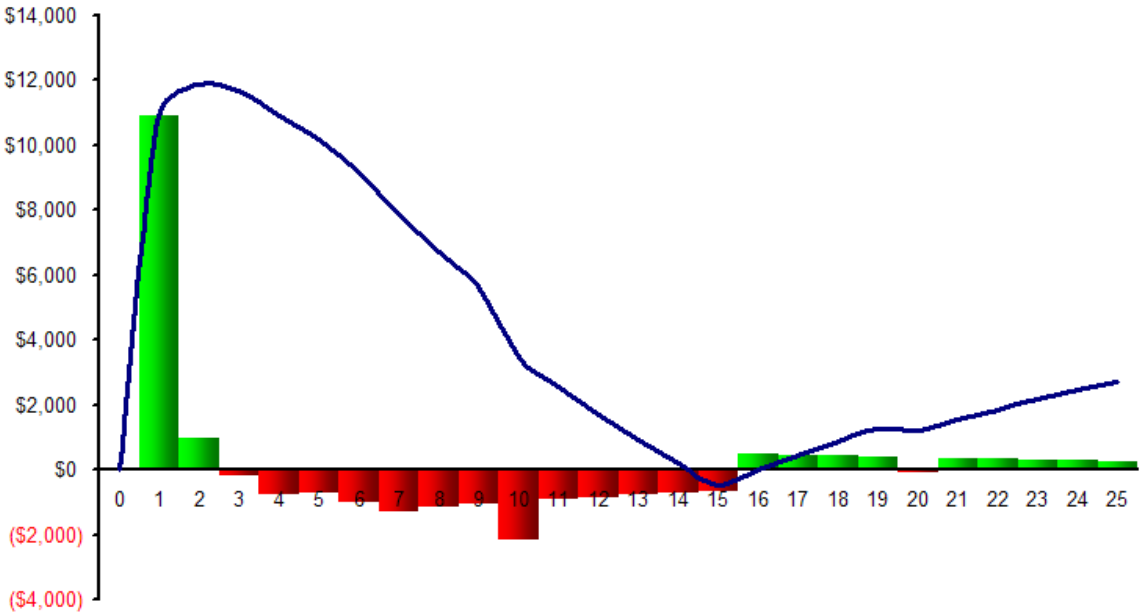


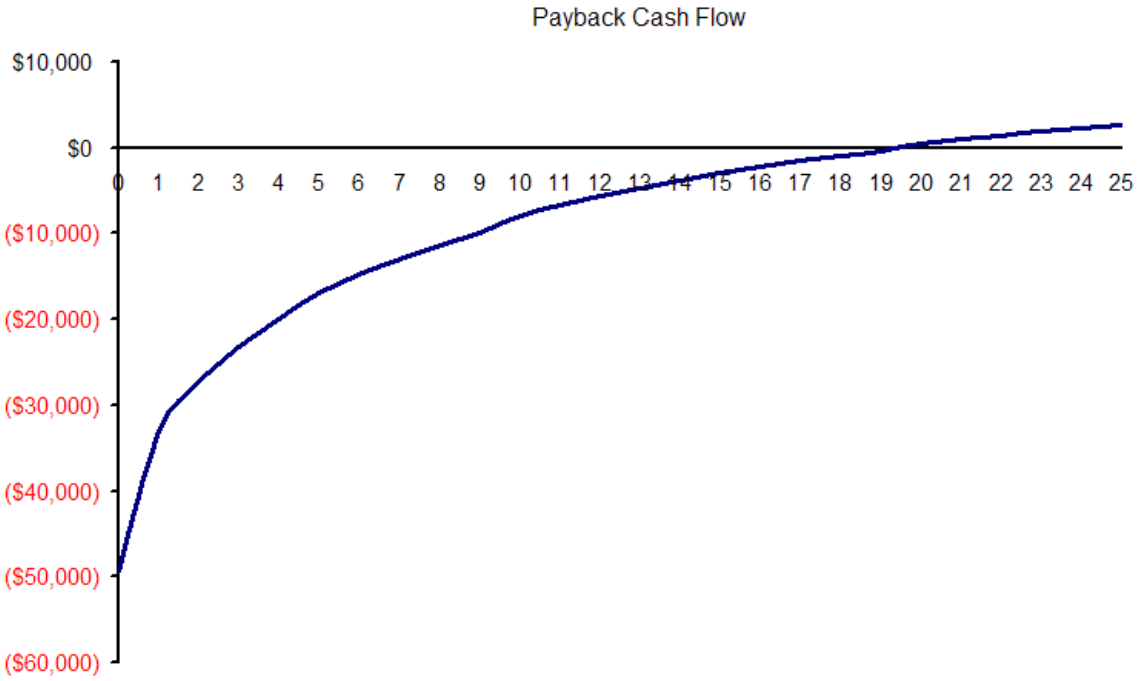


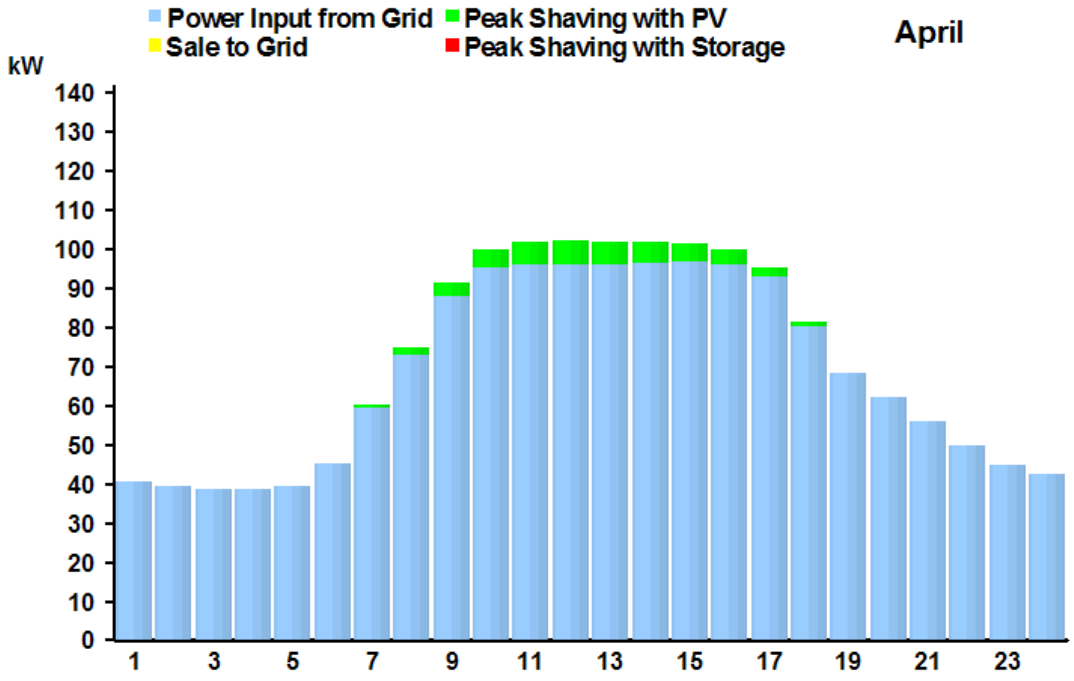
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$10,000
$0
($10,000)
($20,000)
($30,000)
($40,000)
($50,000)
($60,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
April
kW
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	105	55,434	3.62	846	846	0	56	63	0
February	103	48,808	4.90	1,032	1,032	0	75	77	0
March	102	52,879	4.99	1,278	1,278	0	77	96	0
April	102	50,310	5.42	1,366	1,366	0	83	102	0
May	116	56,224	5.17	1,459	1,459	0	80	109	0
June	131	59,906	4.93	1,499	1,499	0	115	105	0
July	141	67,874	5.21	1,485	1,485	0	122	104	0
August	141	66,721	4.86	1,449	1,449	0	114	101	0
September	124	56,899	4.23	1,236	1,236	0	99	86	0
October	103	50,677	4.25	1,162	1,162	0	65	87	0
November	95	46,911	4.27	817	817	0	66	61	0
December	102	52,891	3.61	686	686	0	56	51	0
Total		665,535		14,316	14,316	0	1,008	1,045	0

EXAMPLE 4: 10 kW Rooftop PV installation
No battery storage resulting in modest peak-shaving
PV energy output used to reduce monthly customer electric bills
Renewable Energy Credits sold at $0.20/kWh in New Jersey Solar RECs Market

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $11964.68
Energy Bill Saving: $12408.94
Energy Sale Revenue: $0
Investment Tax Credit: $11063.08
Tax Deductions: $16611.68
Emission Reduction Benefits: $0
RECs: $25988.94
Total: $78037.32

Costs
Initial Net Capital Cost: $38843.53
O&M Cost: $2449.70
Tax on Bill Savings: $8043.3
Tax on Sales to Grid: $0
Tax on Rebates &/or RECs: $0
Property Taxes: $0

Total: $49336.52

Financial Performance Indicators
Net Present Value: $28700.8
Benefit Cost Ratio: 1.58
Payback Year: 6.68

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 54.81c/KWh
LCOE with Policy Benefits: -14.21c/KWh[i]
LCOE with Service Benefits: NA
LCOE with Avoided Fuel Cost Volatility: -10.86c/KWh[ii]

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): NA
Maximum Depth of Discharge: NA
Inverter Capacity: 9.17kW dc
System Efficiency (w temp. effects): 12.06%
Capacity Factor: 16.34%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 14315.76kWh
Average Daily PV Generation: 39.22kWh
Peak Generation: NA
Generation per Wp: 1431.58kWh
Specific Yield: 200.42kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $9171.69
Battery Bank: $0
Other Electrical Equipment: $13757.54
Capital Cost: $22929.23
Rebate: $11464.62

[i] Indicates that policy benefits (including state-provided rebate and REC sales) are greater than system costs.

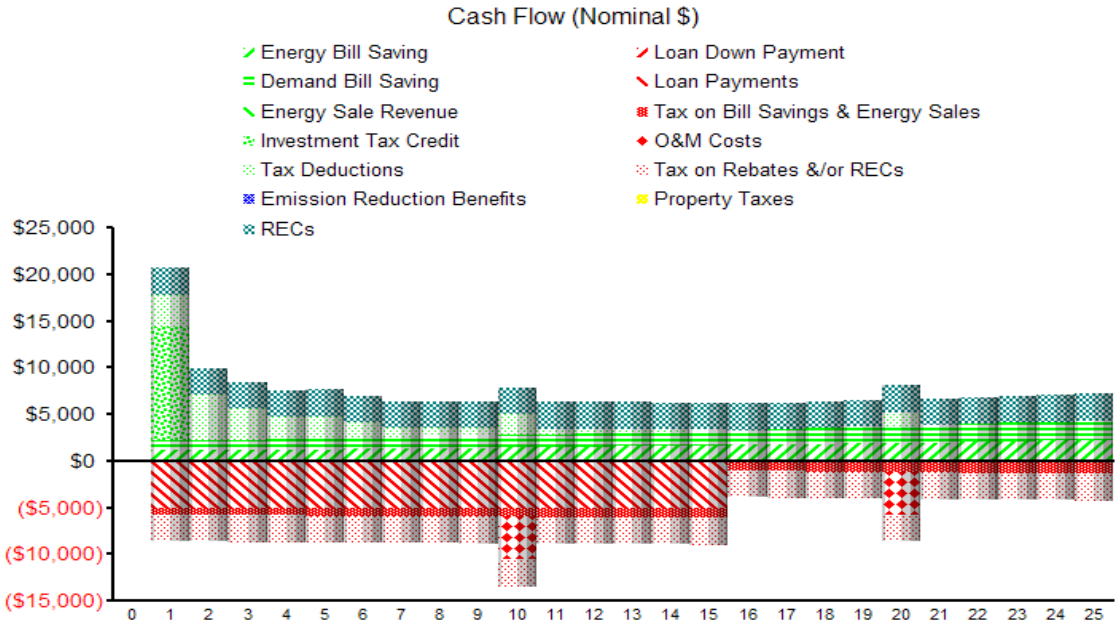
[ii] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year. The benefit is calculated as additional to applicable policy and service benefits.

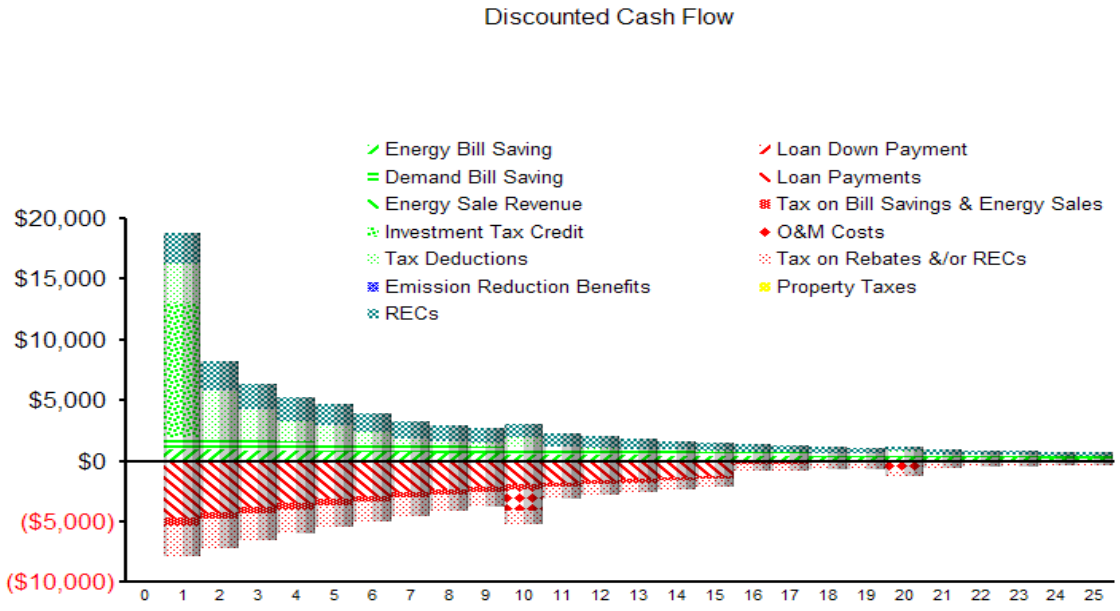
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

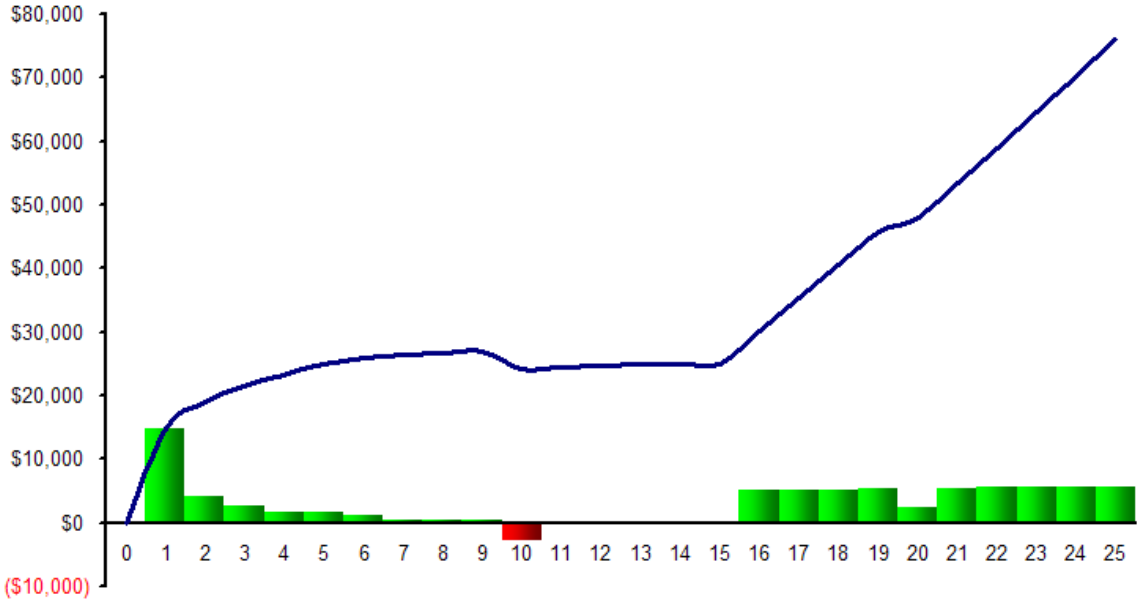
Policy Summary
Sale to grid: Production Incentive – none
RECs: 200$/MWh
System Rebate: 50%
Investment Tax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $81129.23
Total Rebate (one-time, 0th year): $40564.62
Initial Net Capital Cost: $40564.62

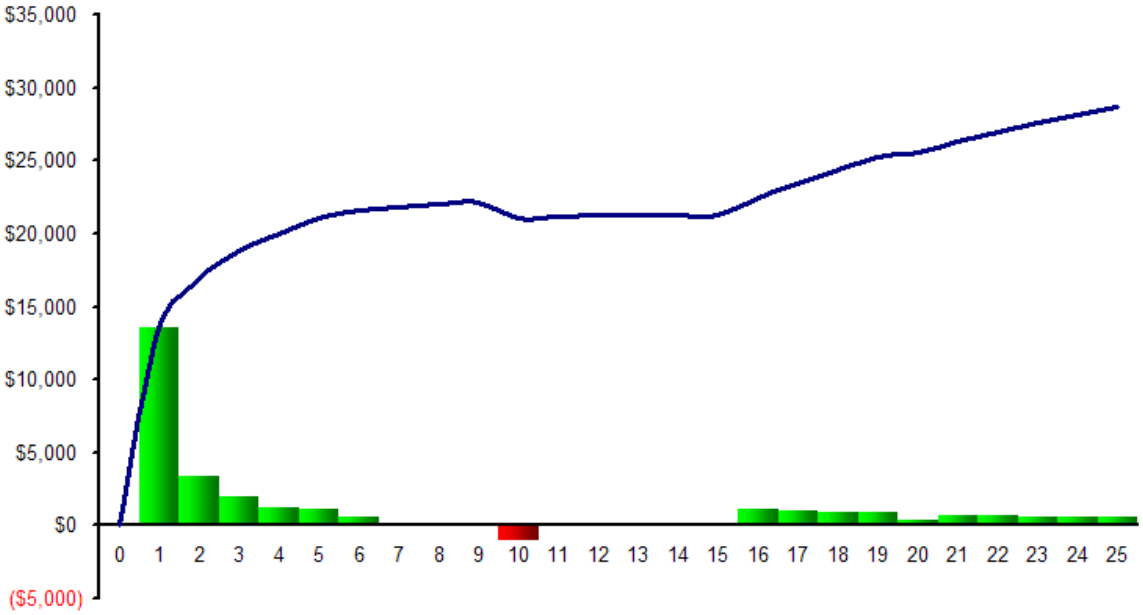


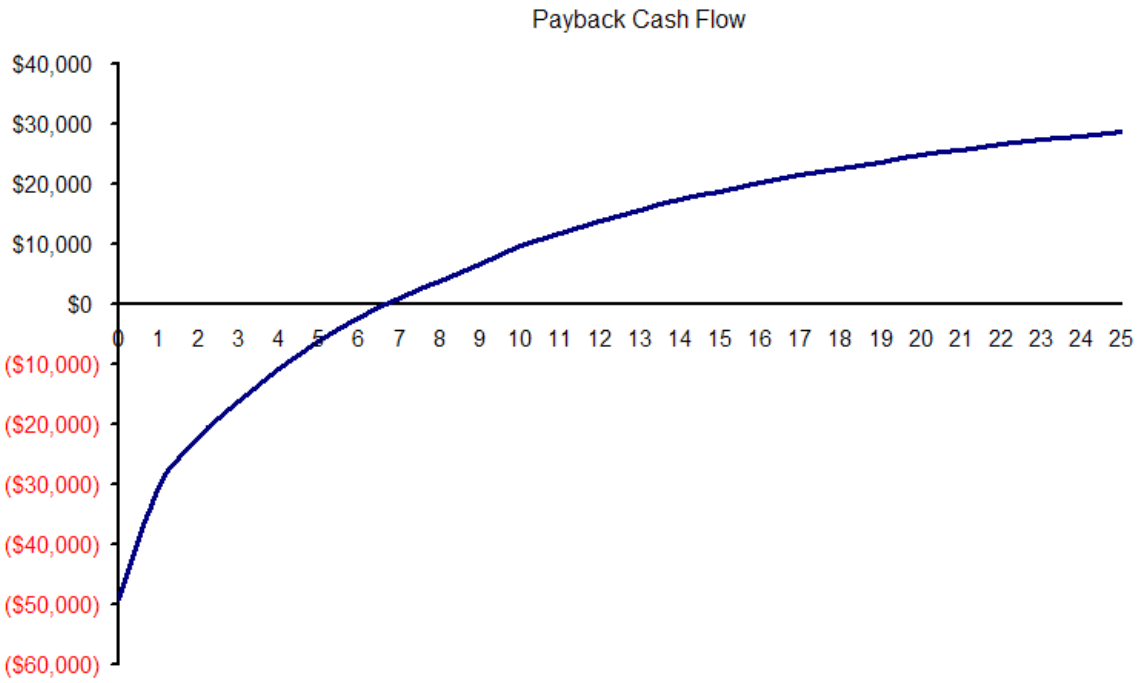


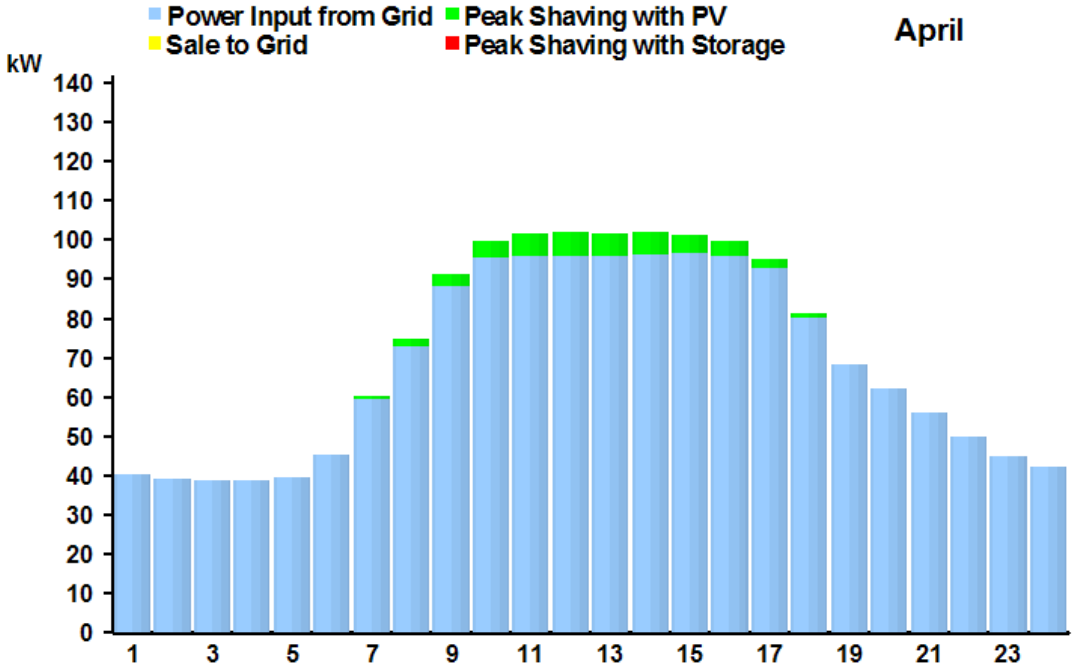
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$40,000
$30,000
$20,000
$10,000
$0
($10,000)
($20,000)
($30,000)
($40,000)
($50,000)
($60,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
April
kW
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	105	55,434	3.62	846	846	0	56	63	0
February	103	48,808	4.90	1,032	1,032	0	75	77	0
March	102	52,879	4.99	1,278	1,278	0	77	96	0
April	102	50,310	5.42	1,366	1,366	0	83	102	0
May	116	56,224	5.17	1,459	1,459	0	80	109	0
June	131	59,906	4.93	1,499	1,499	0	115	105	0
July	141	67,874	5.21	1,485	1,485	0	122	104	0
August	141	66,721	4.86	1,449	1,449	0	114	101	0
September	124	56,899	4.23	1,236	1,236	0	99	86	0
October	103	50,677	4.25	1,162	1,162	0	65	87	0
November	95	46,911	4.27	817	817	0	66	61	0
December	102	52,891	3.61	686	686	0	56	51	0
Total		665,535		14,316	14,316	0	1,008	1,045	0

EXAMPLE 5: 10 kW Rooftop PV installation
With battery storage to allow significant peak-shaving
Renewable Energy Credits sold at $0.20/kWh in New Jersey Solar RECs Market

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $16059.19
Energy Bill Saving: $10030.25
Energy Sale Revenue: $0
Investment Tax Credit: $10139.50
Tax Deductions: $15805.01
Emission Reduction Benefits: $0
RECs: $25988.94
Total: $78022.88

Costs
Initial Net Capital Cost: $35600.74 (after rebate)
O&M Cost: $4003.12
Tax on Bill Savings: $8609.51
Tax on Sales to Grid: $0
Tax on Rebates &/or RECs: $0
Property Taxes: $0

Total: $48213.38

Financial Performance Indicators
Net Present Value: $29809.5
Benefit Cost Ratio: 1.62
Payback Year: 6.65

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 63.89c/KWh
LCOE with Policy Benefits: -17.54c/KWh[i]
LCOE with Service Benefits: NA
LCOE with Avoided Fuel Cost Volatility: -13.41c/KWh[ii]

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): 16.5kWh
Maximum Depth of Discharge: 80%
Inverter Capacity: 5.8kW dc
System Efficiency (w temp. effects): 9.74%
Capacity Factor: 13.2%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 11559.97kWh
Average Daily PV Generation: 31.67kWh
Peak Generation: 4.94 kW
Generation per Wp: 1156kWh
Specific Yield: 161.84kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $5802.50
Battery Bank: $1650.07
Other Electrical Equipment: $8703.74
Capital Cost: $16156.31
Rebate: $8078.15

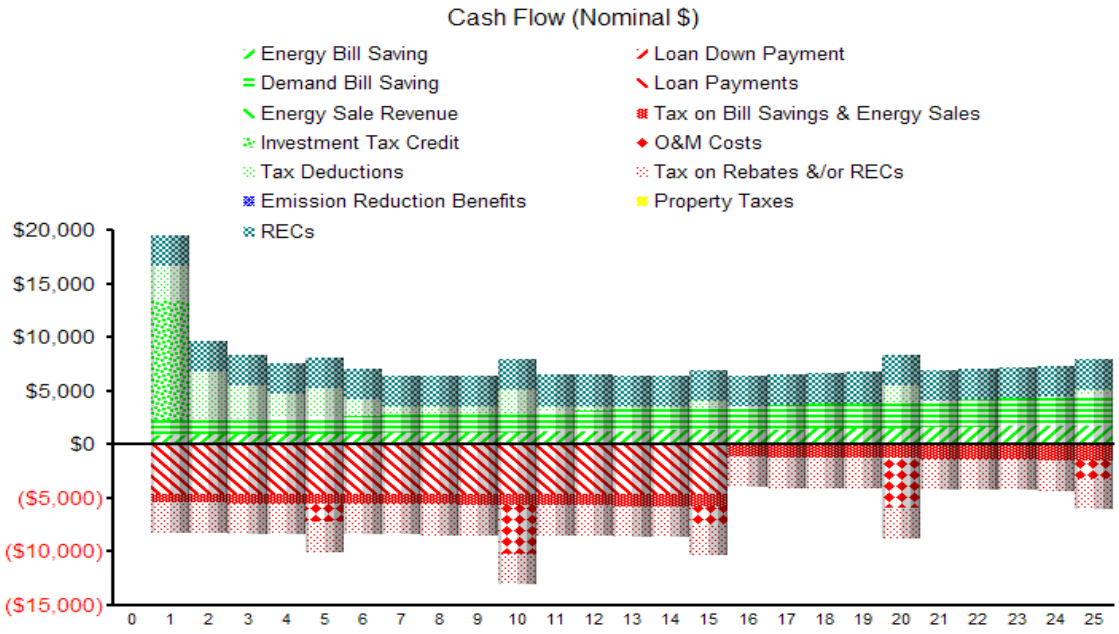
[i] Indicates that policy benefits (including state-provided rebate and REC sales) are greater than system costs.
[ii] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year. The benefit is calculated as additional to applicable policy and service benefits.

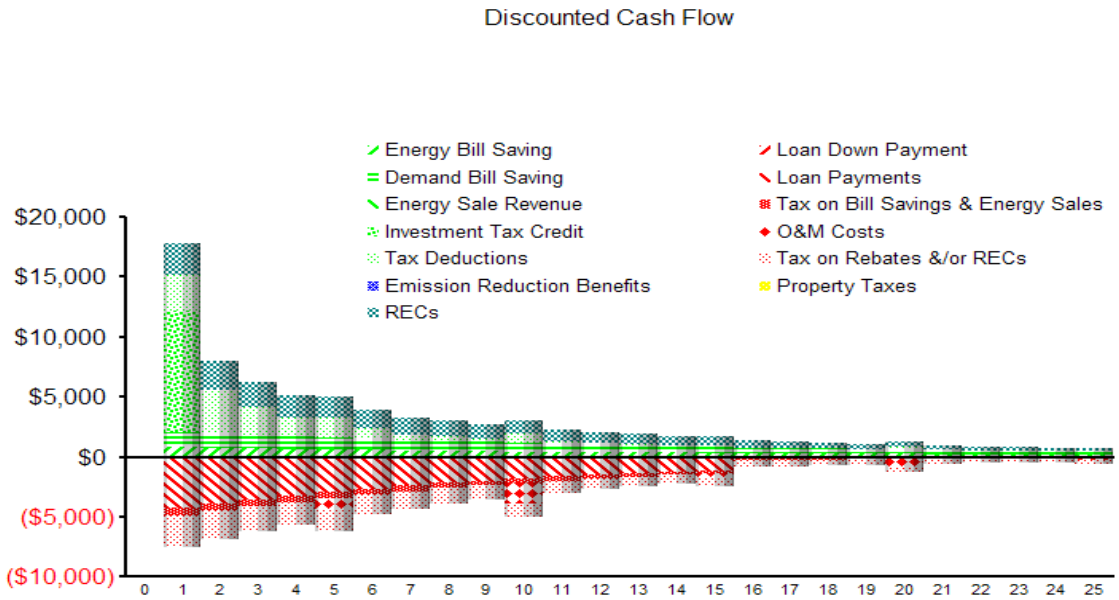
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

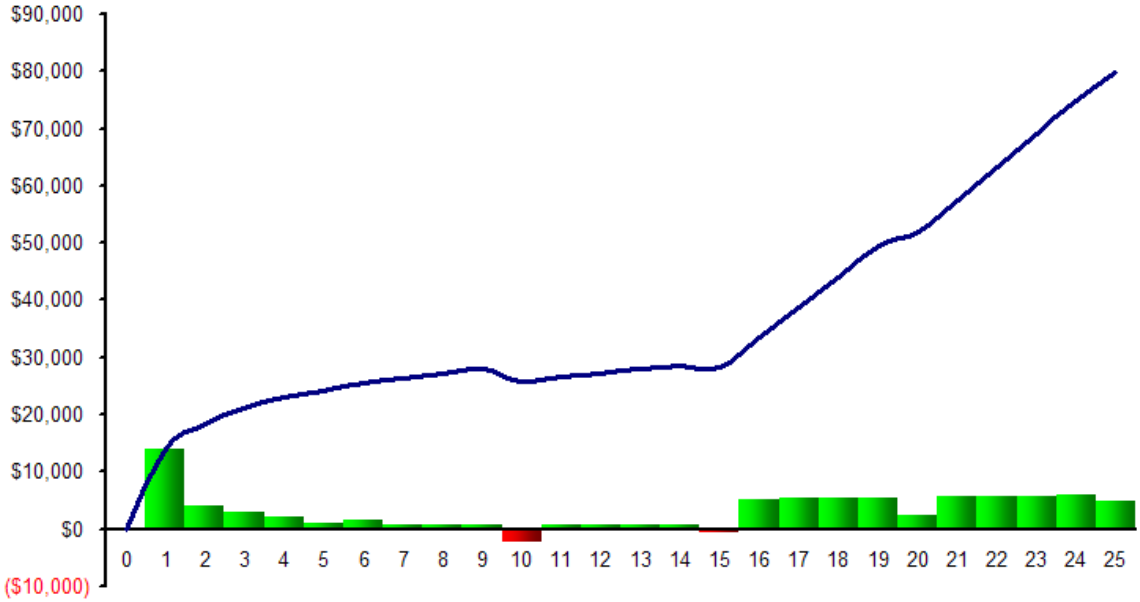
Policy Summary
Sale to grid: Not Permitted
RECs: 200$/MWh
System Rebate: 50%
Investment Tax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $74356.31
Total Rebate (one-time, 0th year): $37178.15
Initial Net Capital Cost: $37178.15

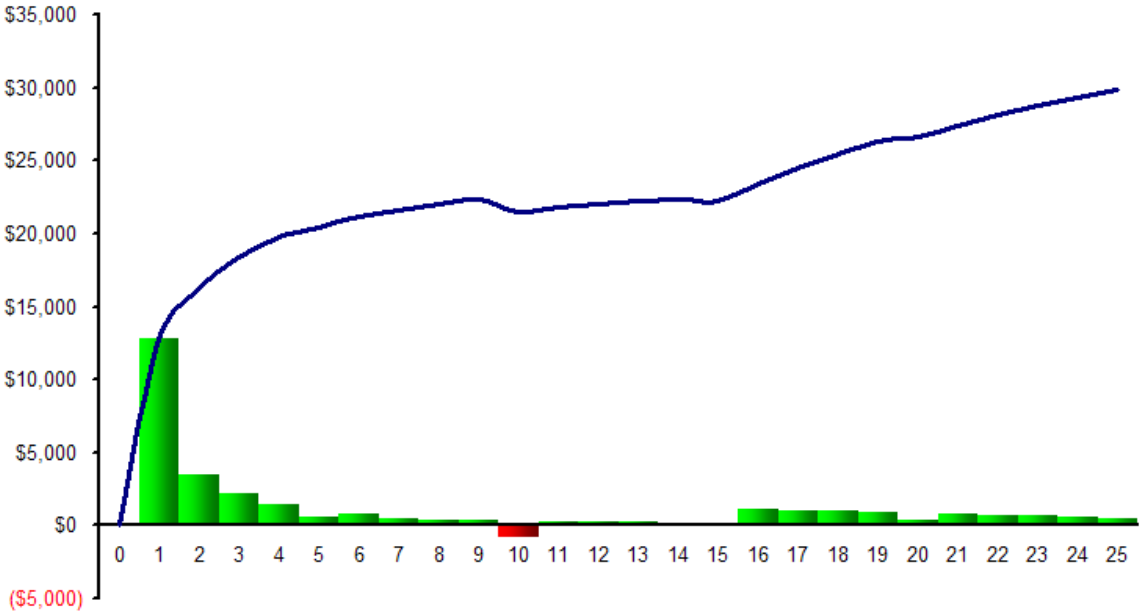


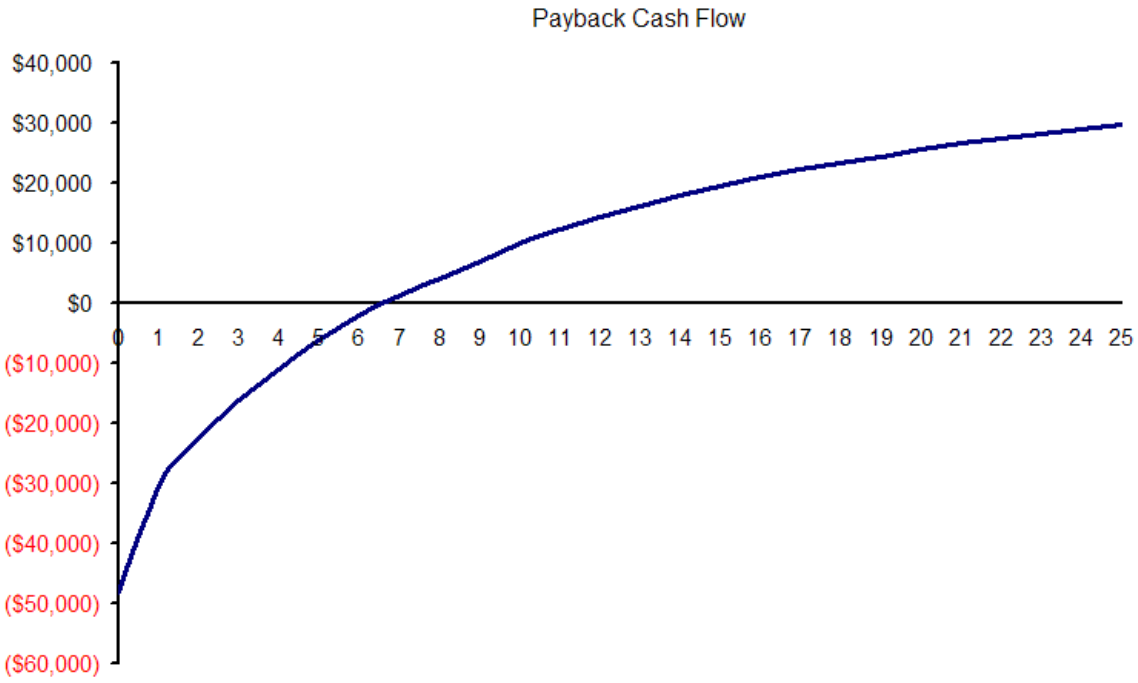


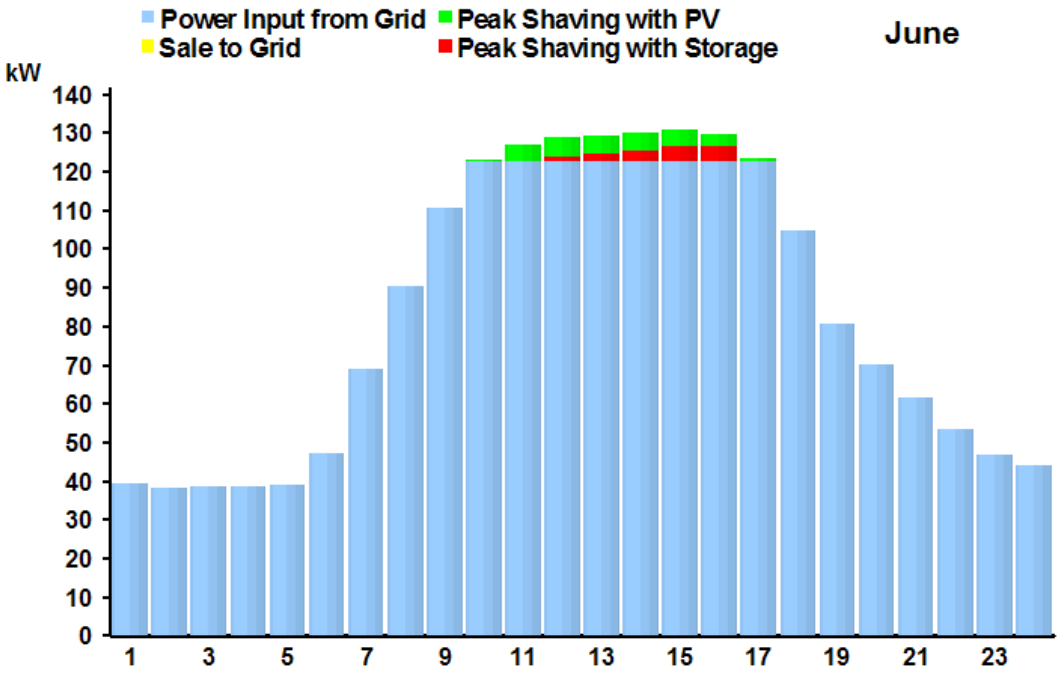
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$40,000
$30,000
$20,000
$10,000
$0
($10,000)
($20,000)
($30,000)
($40,000)
($50,000)
($60,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
June
kW
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	105	55,434	4.73	683	683	0	73	51	0
February	103	48,808	5.60	833	833	0	86	63	0
March	102	52,879	6.13	1,032	1,032	0	94	78	0
April	102	50,310	6.18	1,103	1,103	0	95	83	0
May	116	56,224	6.89	1,178	1,178	0	106	88	0
June	131	59,906	7.99	1,211	1,211	0	187	85	0
July	141	67,874	7.03	1,199	1,199	0	164	84	0
August	141	66,721	7.11	1,170	1,170	0	166	82	0
September	124	56,899	6.99	998	998	0	164	70	0
October	103	50,677	5.81	939	939	0	89	70	0
November	95	46,911	4.35	659	659	0	67	50	0
December	102	52,891	3.93	554	554	0	61	42	0
Total		665,535		11,560	11,560	0	1,353	845	0

EXAMPLE 6: 10 kW Rooftop PV installation
With battery storage to allow significant peak-shaving
Battery storage sized to permit emergency back-up power
Renewable Energy Credits sold at $0.20/kWh in New Jersey Solar RECs Market

Evaluation Period: 25 years

Country: US
State: Delaware
City: Wilmington

Summary (Present Value)

Benefits
Demand Bill Saving: $16059.19
Energy Bill Saving: $10030.25
Energy Sale Revenue: $0
Investment Tax Credit: $10139.50
Tax Deductions: $11694.05
Emission Reduction Benefits: $0
REC revenues: $25988.94
Total: $73911.92

Costs
Initial Net Capital Cost: $20129.92
O&M Cost: $0.00[i]
Tax on Bill Savings: $8609.51
Tax on Sales to Grid: $0
Tax on Rebates &/or RECs: $0
Property Taxes: $0
Total: $28739.44

Financial Performance Indicators
Net Present Value: $45172.48
Benefit Cost Ratio: 2.57
Payback Year: 2.66

Levelized Cost of Electricity (LCOE)
LCOE with Tax Deductions: 63.89c/KWh
LCOE with Policy Benefits: -17.54c/KWh[ii]
LCOE with Service Benefits: -39.39c/KWh[iii]
LCOE with Avoided Fuel Cost Volatility: -30.12c/KWh [iv]

Renewable Energy Generation Analysis

PV System Capacity: 10kW dc
Battery Capacity (AC): 16.5kWh
Maximum Depth of Discharge: 80%
Inverter Capacity: 5.8kW dc
System Efficiency (w temp. effects): 9.74%
Capacity Factor: 13.2%

Annual Tilted Surface Insolation: 118669.04kWh
Generation: 11559.97kWh
Average Daily PV Generation: 31.67kWh
Peak Generation: 4.94kW
Generation per Wp: 1156kWh
Specific Yield: 161.84kWh/m^2
Average Cell Temperature: 18.24 C

Financial & Tax Inputs
Avg. Income Tax Rate: 33%
Avg. Property Tax Rate (% of capital investment): 0
Income Tax Analysis: Yes
Tax Depreciation Method: MACRS 5 Years
Depreciation Duration: 5 years
Cap. Equip. Value Subject to Depreciation: 85%
Equipment Book Life (years): 25 years
Customer Discount Rate: 10%

PV Array & Support Structure
Capital Cost: $44200
Rebate: $22100

Balance of System (BOS)
Inverter: $5802.50
Battery Bank: $1650.07
Other Electrical Equipment: $8703.74
Capital Cost: $16156.31
Rebate: $8078.15

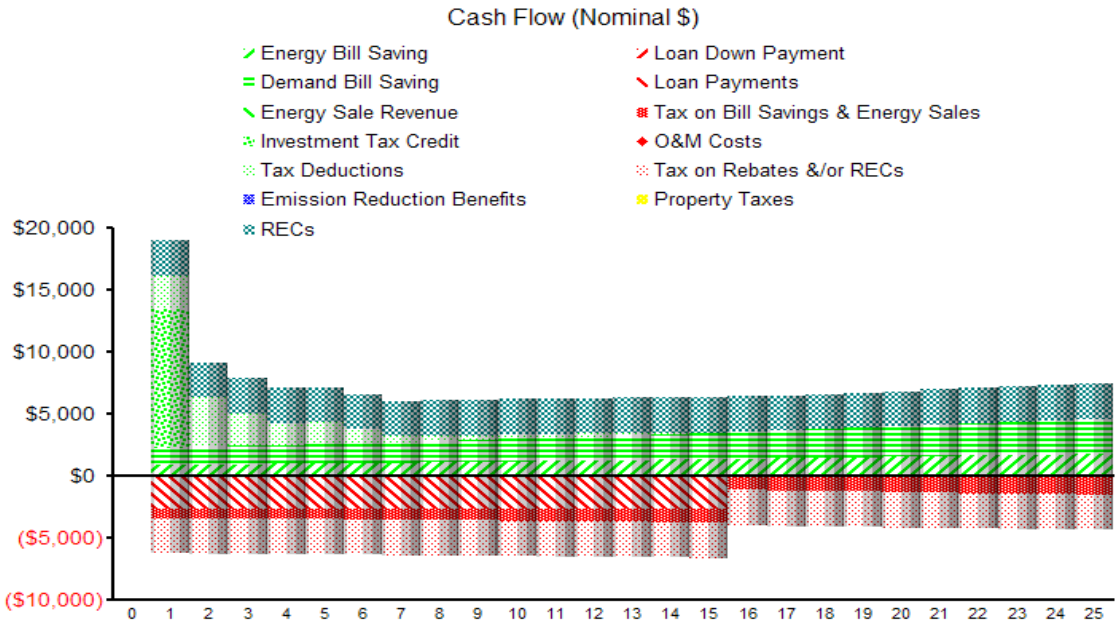
[i] Emergency power benefit assumed to equal cost of battery storage and inverter (defined as O&M costs).
[ii] Indicates that policy benefits (including state-provided rebate and REC sales) are greater than system costs.
[iii] Indicates emergency power benefit is greater than system cost.
[iv] Computed as the avoided cost of fuel price increases associated with fossil and other non-renewable energy sources. For this analysis, non-renewable energy fuel costs are assumed to grow on average 3% per year. The benefit is calculated as additional to applicable policy and service benefits.

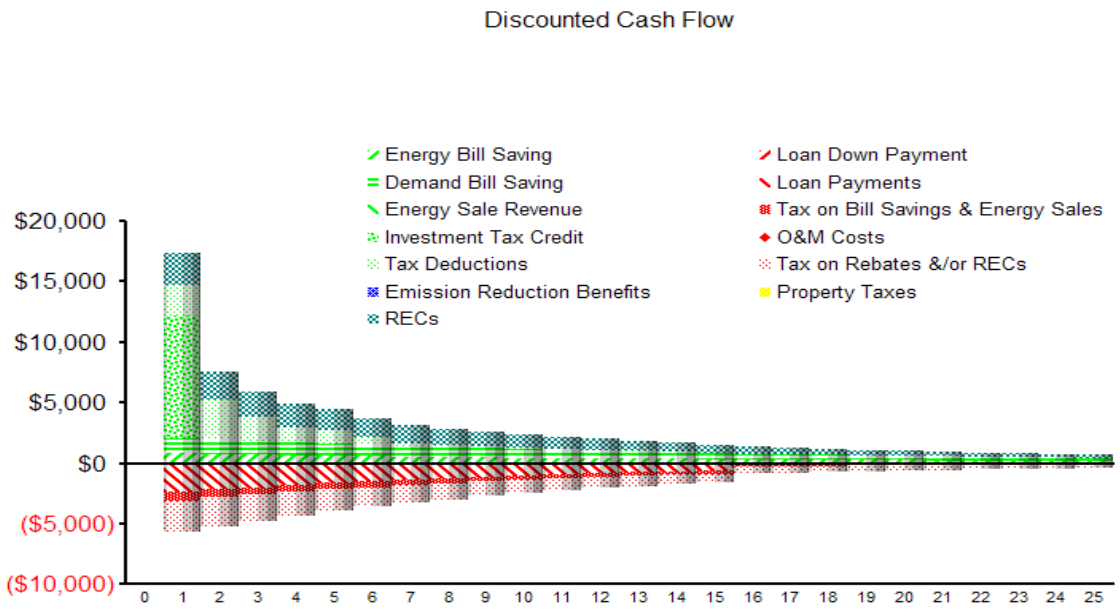
Loan
Debt Ratio: 100%
Loan Interest Rate: 9.25%
Loan Period: 15 years

Project Administration
Overhead: $14000
Rebate: $7000

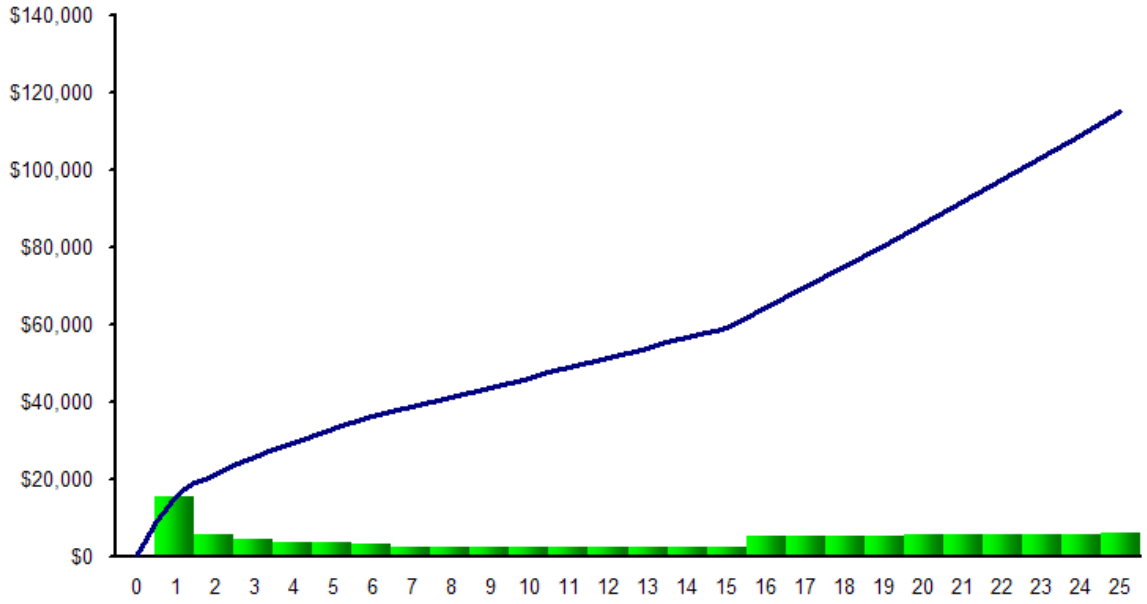
Policy Summary
Sale to grid: Not Permitted
RECs: 200$/MWh
System Rebate: 50%
Investment Tax Credit: 30%

Capital Cost Summary (Nominal $)
Estimated Initial Project Cost: $74356.31
Total Rebate (one-time, 0th year): $37178.15
Emergency Power Avoidance: $16156.31 (see note 1 below)
Initial Net Capital Cost: $21021.85

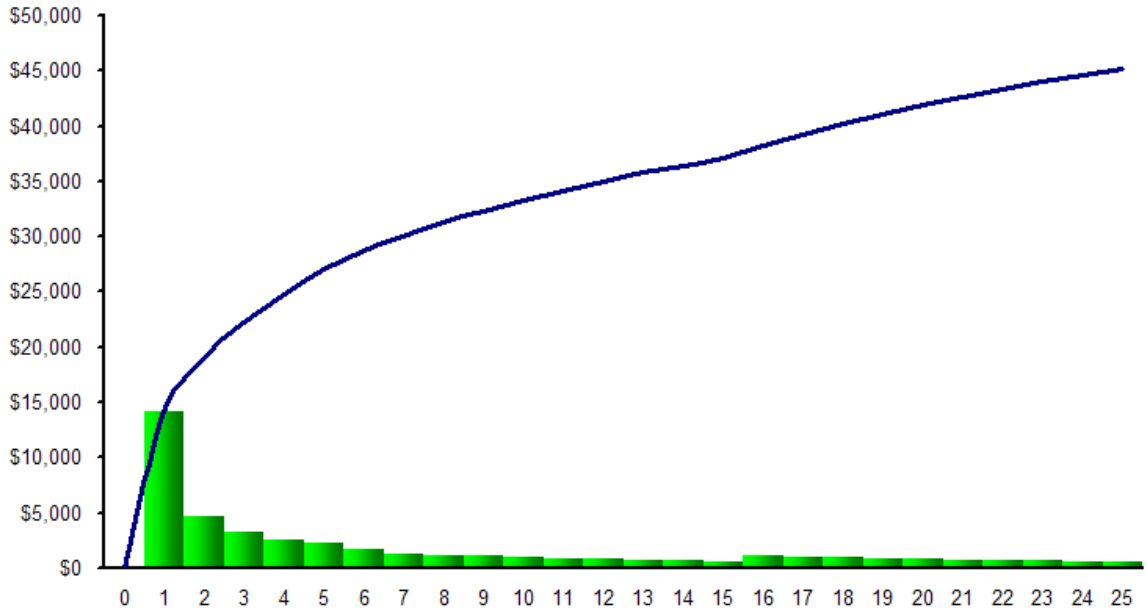


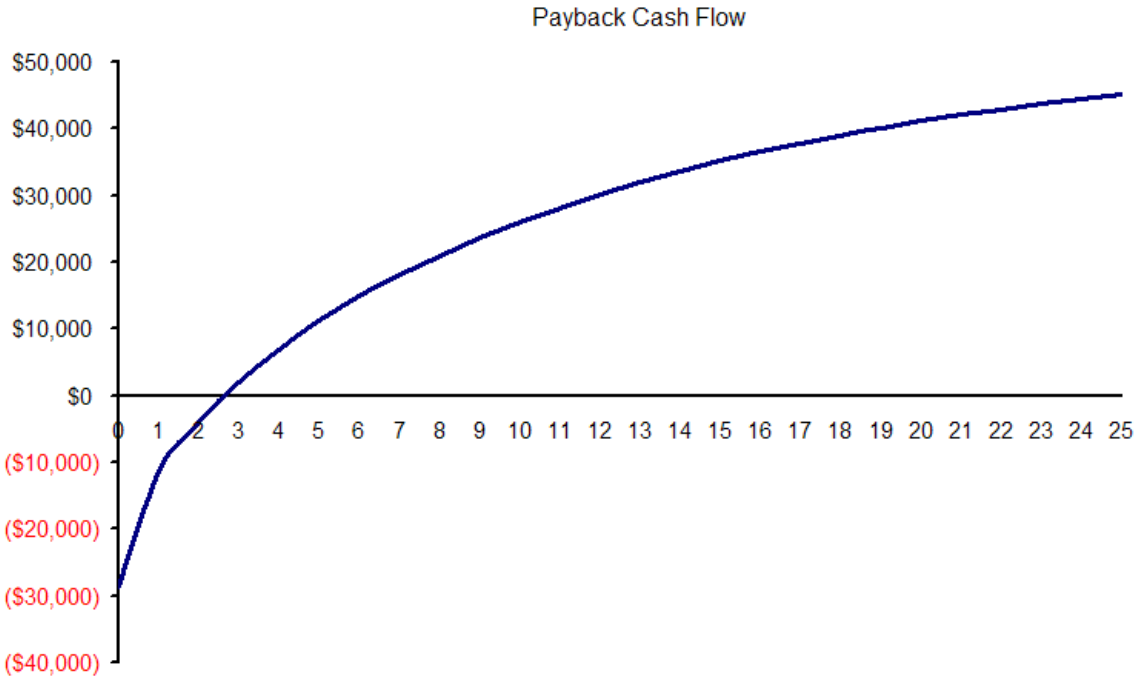


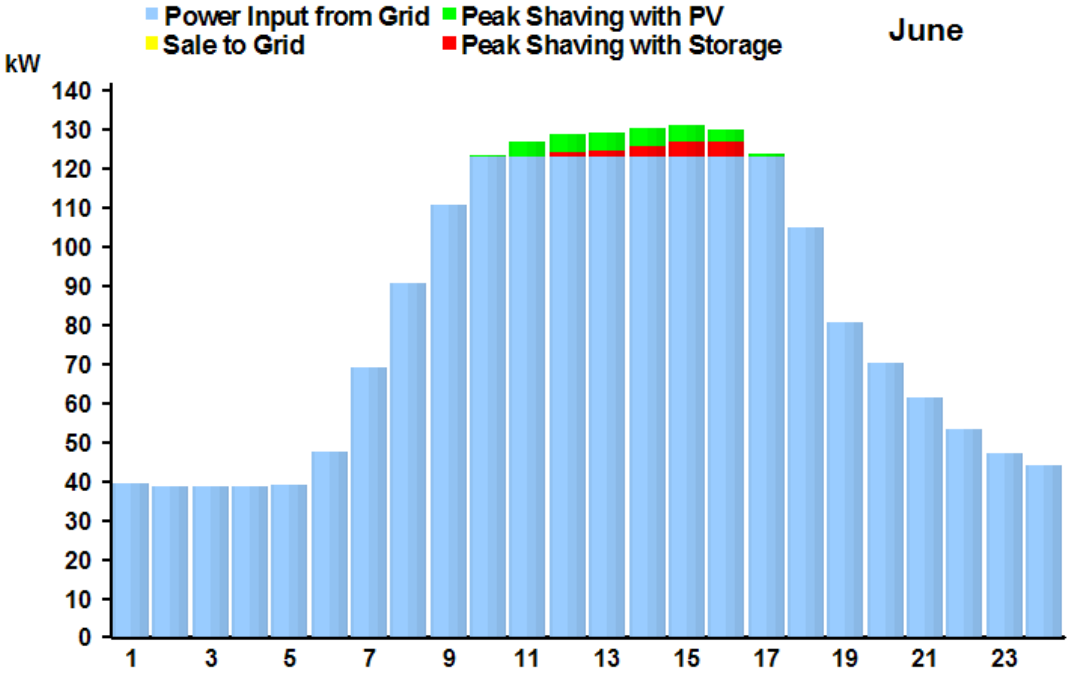
Annual and Cumulative Net Cash Flow



Discounted Annual and Cumulative Net Cash Flow




Payback Cash Flow
$50,000
$40,000
$30,000
$20,000
$10,000
$0
($10,000)
($20,000)
($30,000)
($40,000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Power Input from Grid
Peak Shaving with PV
Sale to Grid
Peak Shaving with Storage
June
kW
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23

First Year Result

Month	Original Demand (kW)	Original Energy (kWh)	Peak Shaving (kW)	Energy Savings (kWh)	PV Energy Generation (kWh)	Reverse Energy Flow(kWh)	Demand Bill Savings($)	Energy Bill Savings($)	Sales to Grid($)
January	105	55,434	4.73	683	683	0	73	51	0
February	103	48,808	5.60	833	833	0	86	63	0
March	102	52,879	6.13	1,032	1,032	0	94	78	0
April	102	50,310	6.18	1,103	1,103	0	95	83	0
May	116	56,224	6.89	1,178	1,178	0	106	88	0
June	131	59,906	7.99	1,211	1,211	0	187	85	0
July	141	67,874	7.03	1,199	1,199	0	164	84	0
August	141	66,721	7.11	1,170	1,170	0	166	82	0
September	124	56,899	6.99	998	998	0	164	70	0
October	103	50,677	5.81	939	939	0	89	70	0
November	95	46,911	4.35	659	659	0	67	50	0
December	102	52,891	3.93	554	554	0	61	42	0
Total		665,535		11,560	11,560	0	1,353	845	0

SELECTED CEEP PUBLICATIONS ON
BUILDING INTEGRATED PV (BIPV) APPLICATIONS &
SOLAR ELECTRICITY POLICY: 1983 – 2006

Byrne, J., W. Rickerson, J. Tian and A. Borchers. 2006. *Integrating Photovoltaic Systems into Public Sector Performance Contracts*. Newark, DE: Center for Energy and Environmental Policy (CEEP), University of Delaware. (Available online at http://ceep.udel.edu/energy/publications/2006_es_READY_PV_Public%20Bldgs_Delaware.pdf)

Byrne, J., L. Kurdgelashvili, A. Barnett, K. Hughes, and A. Thurlow. 2005a. "Beyond Oil: A Comparison of Projections of PV Generation and European and U.S. Domestic Oil Production." In D. Y. Goswami and K. Boer, eds., *Advances in Solar Energy*, Vol. 16. Pp. 35-70. Boulder, CO: American Solar Energy Society.

Byrne, J., L. Glover, S. Hegedus, G. Van Wicklen, M. Weitz. 2005b. *The Potential for Solar Electric Applications for Poultry Farms*. Newark, DE: CEEP, University of Delaware. (Available online at http://ceep.udel.edu/energy/publications/READY_2005_PV%20Poultry_report_04-12-05_paginated.pdf)

CEEP (Center for Energy and Environmental Policy). 2005. "The Potential Economic Impacts of a Renewable Portfolio Standard in Delaware." Briefing Paper. 26 pp. Newark, DE: CEEP, University of Delaware. (Available online at http://ceep.udel.edu/energy/publications/2005_es_Delaware%20Senate_RPS%20briefing%20paper.pdf)

Rickerson, W., H. Wong, J. Byrne, Y-D. Wang and S. Sasser. 2005. "Bracing for an Uncertain Energy Future: Renewable Energy and the US Electricity Industry." *Risk Management Matters.* Vol. 3, No. 1: 46-61. (Available online at http://ceep.udel.edu/publications/energysustainability/2005_es_renewables&risk.pdf)

Byrne, J., L. Kurdgelashvili, D. Poponi and A. Barnett. 2004. "The potential of solar electric power for meeting future US energy needs: A comparison of projections of solar electric energy generation and Arctic National Wildlife Refuge oil production." *Energy Policy.* Vol. 32, No. 2: 289-297.

Byrne, J. and L. Kurdgelashvili. 2003. "The Potential of Solar Electric Power for Meeting Future European and U.S. Energy Needs: A Comparison of Projections of PV Generation and European and U.S. Domestic Oil Production." *Proceedings of the ISES Solar World Congress 2003.* Vol. 1 (Solar Energy and Society), paper O1 9.

Byrne,, J., G. Alleng, A. Zhou. 2001a. "Using Economic Incentives to Accelerate Development of Green Technologies." 2001. With Gerard Alleng and Aiming Zhou. *Proceedings of the Green Buildings Workshop*. Shanghai, China. Environmental Market Solutions, Inc. (Washington, D.C.) and Pacific Energy Research Center, Tongji University (Shangahi, China) (July).

Byrne, J., A. Zhou and G. Alleng. 2001b."Economics of Building Integrated PV In China." *Proceedings of the Green Buildings Workshop*. Shanghai, China. Environmental Market Solutions, Inc.

(Washington, D.C.) and Pacific Energy Research Center, Tongji University (Shanghai, China) (July). (Available online at http://ceep.udel.edu/publications/energy/publications/2001_energy_bipv_econ_china.pdf)

Byrne, J., L. Agbemabiese, K-J. Boo, Y-D. Wang and G. Alleng. 2000. "An International Comparison of the Economics of Building Integrated PV in Different Resource, Pricing and Policy Environments: The Cases of the U.S., Japan and South Korea." *Proceedings of the American Solar Energy Society Solar 2000 Conference,* Madison, WI (June): 81-85. (Available online at http://ceep.udel.edu/publications/energy/publications/2000_energy_bipv_international_comparison.pdf)

Byrne, J., L. Agbemabiese, J. Kliesch, C. Hadjilambrinos, P. Eiffert and R. Nigro. 1999. "Environmental Impacts of Building Integrated PV Applications in the State Public Buildings Sector." *Proceedings of the American Solar Energy Society Solar 99 Conference,* Portland, Maine (June): 425-429.

Byrne, J., S. Letendre, L. Agbemabiese, D. Bouton, J. Kliesch and D. Aitken. 1998. "Photovoltaics as an Energy Services Technology: A Case Study of PV Sited at the Union of Concerned Scientists Headquarters." *Proceedings of the American Solar Energy Society Solar 98 Conference*, Albuquerque, NM (June 15-17): 131-136. (Available online at http://ceep.udel.edu/publications/energy/publications/1998_energy_pv_energy_service_technology_ucs.pdf)

Letendre, S., J. Byrne, C. Weinberg and Y-D. Wang. 1998. "Commercializing Photovoltaics: The Importance of Capturing Distributed Benefits." *Proceedings of the American Solar Energy Society Solar 98 Conference*, Albuquerque, NM (June 15-17):231-237. (Available online at http://ceep.udel.edu/publications/energy/publications/1998_energy_distributed_benefits.pdf)

Byrne, J., S. Letendre, L. Agbemabiese, D. Redlin and R. Nigro. 1997a. "Commercial Building Integrated Photovoltaics: Market and Policy Implications." *Proceedings of the 26th IEEE Photovoltaic Specialists Conference*, Anaheim, CA (October): 1301-1304. (Available online at http://ceep.udel.edu/publications/energy/publications/1997_energy_bipv_market_policy.pdf)

Byrne, J., S. Letendre, Y-D. Wang, R. Nigro and W. Ferguson. 1997b. "Building Load Analysis of Dispatchable Peak-Shaving Photovoltaic Systems: A Regional Analysis of Technical and Economic Potential." *Proceedings of the of the American Solar Energy Society Solar 97 Conference*, Washington, D.C. (April 25-30): 147-152.

Byrne, J., S. Letendre and Y-D. Wang. 1996a. "The Distributed Utility Concept: Toward a Sustainable Electric Utility Sector." 1996. With *Proceedings of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings*. Vol. 7: 7.1-7.8.

Byrne, J. S. Letendre, C. Govindarajalu, R. Nigro and Y-D. Wang. 1996b. "Evaluating the Economics of Photovoltaics in a Demand-Side Management Role." *Energy Policy*. Vol. 24, No.2 (February): 177-185. (Available online at

http://ceep.udel.edu/publications/energy/publications/1996_epolicy_economics%20of%20pv-dsm_byrne_letendre_chandra_ydw_nigro.pdf)

Byrne, J., R. Nigro and W. Ferguson. 1996c. "The Performance and Economics of Dispatchable PV Peak Shaving Systems in Isolated Electric Utility Systems." *Proceedings of the World Renewable Energy Congress* (June).

Byrne, J., R. Nigro and W. Ferguson. 1996d. "The Development of a Dispatchable PV Peak Shaving System." *Proceedings of the First International Conference on Solar Electric Buildings* (March).

Byrne, J., Y-D. Wang and R. Nigro. 1995. "Photovoltaic Technology as a Dispatchable, Peak-Shaving Option." 1995. With Ralph Nigro and Young-Doo Wang. *Public Utilities Fortnightly* (Sept. 1). (Available online at http://ceep.udel.edu/publications/energy/publications/1995_energy_pv_peakshaving.pdf)

Byrne, J. and C. Hadjilambrinos. 1994. "Photovoltaics for Demand-Side Management." *Progress in Solar Energy Technologies and Applications: An Authoritative Review*. Boulder CO: American Solar Energy Society. Pp. 22-23.

Byrne, J., S. Letendre, R. Nigro, C. Govindarajalu, W. Wallace and Y-D. Wang. 1994a. "Photovoltaics for Demand-Side Management Utility Markets: A Utility/Customer Partnership Approach." *IEEE Proceedings of the First World Conference on Photovoltaic Energy Conversion*.

Byrne, J., Y-D. Wang, S. Letendre, C. Govindarajalu, R. Nigro and W. Bottenberg. 1994b. "Deployment of a Dispatchable Photovoltaic System: Technical and Economic Results." *IEEE Proceedings of the First World Conference on Photovoltaic Energy Conversion*: 1200-1203.

Byrne, J., Y-D. Wang and S. Hegedus. 1994c. "Photovoltaics as a Demand-Side Management Technology: An Analysis of Peak-Shaving and Direct Load Control Options." 1994. With *Progress in Photovoltaics* Vol. 2: 235-48.

Byrne, J., S. Letendre, R. Nigro, and Y-D. Wang. 1994d. "PV-DSM as a Green Investment Strategy." *Proceedings of the 5th NARUC-DOE National Conference on Integrated Resource Planning*: 272-285.

Byrne, J., S. Letendre and R. Nigro, 1994e. "Photovoltaics in High-Value, Utility Markets: A Demand-Side Management Strategy." *Proceedings of the American Solar Energy Society Solar '94 Conference*: 44-48.

Byrne, J., Y-D. Wang, R. Nigro and S. Letendre. 1994f. "Photovoltaics in a Demand-Side Management Role." *Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings*. Vol. 2: 2.43-2.49.

Byrne, J., Y-D. Wang, R. Nigro and C. Hadjilambrinos. 1993a. "Valuing Photovoltaic Technology as a Utility Demand-Side Management Application: Regulatory Issues." *Proceedings of the NARUC-DOE Conference on Renewable Energy*: 258-269.

Byrne, J., Y-D. Wang, R. Nigro, and W. Bottenberg. 1993b. “Commercial Building Demand-Side Management Tools: Requirements for Dispatchable Photovoltaic Systems.” *Proceedings of the 23rd IEEE Photovoltaics Specialists Conference*: 1140-1145.

Byrne, J., Y-D. Wang, I. Han and K. Ham. 1993c. “Photovoltaic Technology as a Utility Demand-Side Management Option.” *Energex '93: Proceedings of the 5th International Energy Conference* Vol. III: 119-133.

Byrne, J. and R. Nigro. 1992. “Applying Photovoltaics as a Demand-Side Management Tool.” *Proceedings of the Delmarva Photovoltaics Conference*. Wilmington, DE: Delmarva Power.

Byrne, J., Y-D. Wang and R. Nigro. 1992. “The Role of Photovoltaics in Demand-Side Management: Policy and Industry Challenges.” *Proceedings of the 11th Photovoltaics Advanced Research and Development Project Review*. Golden, CO: National Renewable Energy Laboratory.

Byrne, J. and D. Rich. 1983. “The Solar Energy Transition as a Problem of Political Economy.” 1983. In D. Rich et al (eds.), *The Solar Energy Transition: Implementation and Policy Implications*. Pp. 163-186.

ADDITIONAL REFERENCES

Hoff, T., Perez, R. and Margolis, R., 2004. *Increasing the Value of Customer-Owned PV Systems using Batteries*. NREL Contract AAD-2-31904-03 Deliverable 2H and Contract NAD-1-318904-01 (3G).

Kotas, J., 2001. *Renewable Energy Credits: Another Option in your Renewable Energy Portfolio*. Paper presented at Sixth National Green Power Marketing Conference: Opportunity in the Midst of Uncertainty, July 30 - August 1, 2001, Portland, Oregon.