midwest renewable energy association

Financial Modeling of Residential PV Systems

Solar Powering Michigan Conference
Traverse City, Michigan
September 12, 2014

The Challenge:

- Develop a course that teaches solar energy professionals concepts associated with financing a PV system, that includes having them use a software model to accurately determine PV system costs and benefits.

Which financial software models would meet this challenge?

The Choices Available:

- Sophisticated financial modeling software
- Websites that quickly calculate PV financial results
- Excel Spreadsheet

The Choices Available: Sophisticated Financial Modeling Software

A number of companies and organizations provide PV financial modeling software to PV professionals and their customers can access online (ex. *Energy Periscope*)

Advantages

- Sophisticated modeling of finances
- Results reporting may be included
- Some software models the finances of solar thermal and small wind systems
- Model itself is protected from being changed or altered
- Many come with technical support services

Limitations

- Can take time to see results
- Often can't see how financial calculations are done
- Don't always know what assumptions are used in the model
- Can't customize the models for your own purposes
- Some online financial modeling software requires a fee (after a free trial) before it can be used

The Choices Available:
Websites that Quickly Calculate PV Financial Results

Advantages

- Requires only a few essential inputs: utility rates, electricity usage, etc.
- Easy to use, and don't require sophisticated knowledge of financing
- Results are quickly reported
- Websites are protected from being changed or altered

Limitations

- Limited in terms of sophistication and detail
- "Black box-like": can't see how financial calculations are done
- Don't always know what assumptions are used in the model
- Can't customize the models for your own purposes

The Choices Available: Excel Spreadsheet Models

Advantages

- Financial modeling can range from simple to sophisticated
- Results are quickly reported
- Programming is transparent – can see what assumptions have been made
- Easy to customize for the user's own purpose
- Good choice for teaching financial concepts

Limitations

- Need to have some Excel background to develop, work with, and revise the model
- There may be little to no technical support or model updates for some users

The MREA used an Excel spreadsheet to Develop a PV Finance Model for its PV 203: *PV Sales and Finance* course.

The MREA PV Finance Model

Features

- Excel spreadsheet that models residential PV systems using PVWatts production data.
- Incorporates residential utility rates, net metering production credits, and feed-in tariffs.
- Can enter PV system, O&M, and equipment costs; and grants, rebates, and other benefits.
- Produces a PV System Cumulative Cash Flow chart alongside reported cost and benefit results. The Cash Flow chart changes immediately upon entering new input data, so the user can quickly see the effects of revised inputs on cumulative cash flow.
- Reports environmental benefits of electricity produced by a PV system.
- Can be customized to add features and calculate additional results.

MREA PV Finance Model – Entering Data and Calculating Results

- Data are entered into the *White cells* of the PV Finance Model.
- Calculations, results, and other functions are shown in the *Green cells*
- **Costs** are entered as negative numbers and shown as red: **-$100.00** (exceptions: PV system costs and Utility rates)
- **Income and benefits** are entered as positive numbers and shown as black: **$4,800.00**
- To enter the same number many times in the same row or column, highlight the cell and grab it at the lower right corner square [■] with the cursor showing a [**+**] sign, then drag over or down. You can also use the **Edit > Fill > Right** function from the menu.

Source: MREA.

MREA PV Finance Model – PV System Inputs

PV System Cost ($/Watt) and Size (kW).

- Enter the PV system cost/Watt and the desired PV system size.
- Calculates annual energy production using PVWatts production data.

PV System Location.

- Enter a location from a list of 26 midwest cities and towns, or enter "Custom" to get PVWatts data for a specified location.
- Model returns PV system characteristics corresponding to the specified location.

PV System Lifetime and PV Module Degradation Rate.

- Can model a PV system with up to a 30 year lifetime.

PV SYSTEM INPUTS:

PV System Costs in $/Watt	$4.00	/Watt
PV System Size	9.00	kW DC
PV System Location	Traverse City	Michigan
PV System - Custom Location	------	------
DC to AC Derate Factor	0.800	
Array Type	Fixed (roof mount)	
Array Tilt	36.0	degrees
Array Azimuth	180	degrees
PV System Lifetime	30	years
PV Module Degradation Rate	0.50%	per year

Source: MREA., NREL PVWatts Calculator. http://pvwatts.nrel.gov/index.php

MREA PV Finance Model – Custom PVWatts Data Input

- Enter data from PVWatts into the spreadsheet in the *PVWatts System Data-Custom* tab.

PV Watts (beta) Input Data

Station ID:	Custom	Location
Enter Location:	**Houghton**	
Enter State:	**Michigan**	
Latitude:	**47.17**	Degrees N
Longitude:	**88.5**	Degrees W
Elevation:		meters

PV System Specifications

DC Rating:	**1.0**	kW
DC to AC Derate Factor:	**0.800**	
AC Rating:	**0.8**	kW
Array Type:	Fixed (Roof Mount)	
Array Tilt:	**36.0**	degrees
Array Azimuth:	**180**	degrees

Energy Value

Cost of Electricity:	0.0000	$/kWh

PV Watts Results

AC Energy Production 1 kW DC of System Size

Month	Solar Radiation (kWh/m2/day)	Unshaded AC Energy Production (kWh)	Energy Value ($)
January	1.92	50	0.00
February	3.03	71	0.00
March	4.29	105	0.00
April	5.51	127	0.00
May	6.26	144	0.00
June	5.50	120	0.00
July	5.39	119	0.00
August	5.67	127	0.00
September	4.49	97	0.00
October	2.11	47	0.00
November	1.30	26	0.00
December	1.34	32	0.00
YEAR		**1065**	**0.00**

Yearly Average Solar Radiation: **3.90** peak sun hours / day

= (kWh/m2/day) / (1kW/m2 basis)

- Then enter "Custom" in the cell for *PV System Location*

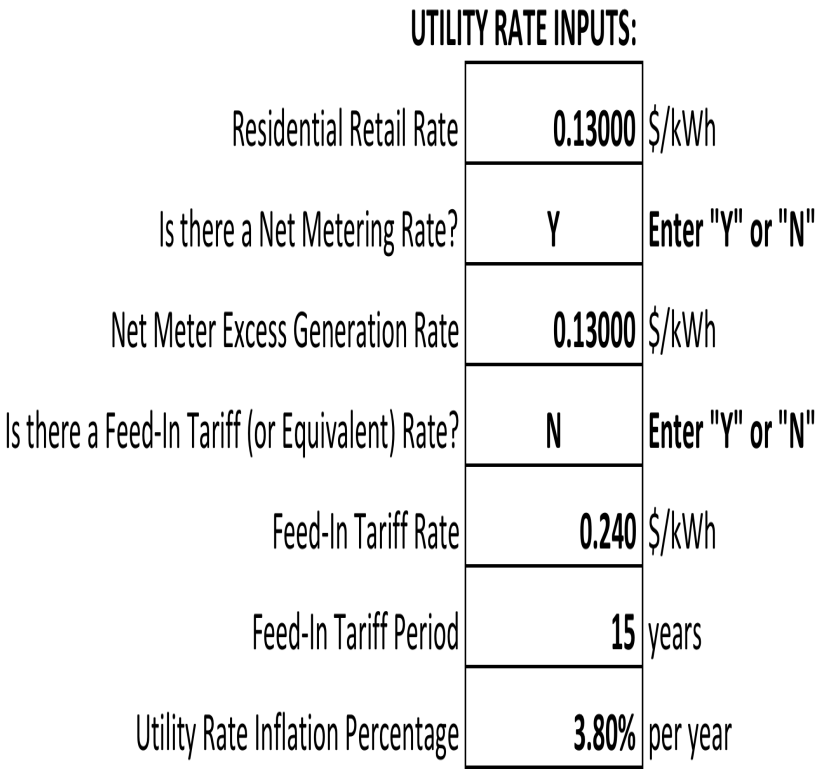
PV System Location	**Custom**	---------
PV System - Custom Location	**Houghton**	**Michigan**

Source: MREA.

MREA PV Finance Model – Utility Rate Inputs

Utility Rate Inputs Include:

- Residential retail rate
- Net meter excess generation rate
  - Retail rate
  - Utility avoided cost rate
  - Other rates
- Feed-in Tariff (or equivalent) rate and period
  - Standard Feed-in Tariff
  - Value of Solar Tariff (VOST)
- Utility rate inflation percentage per year



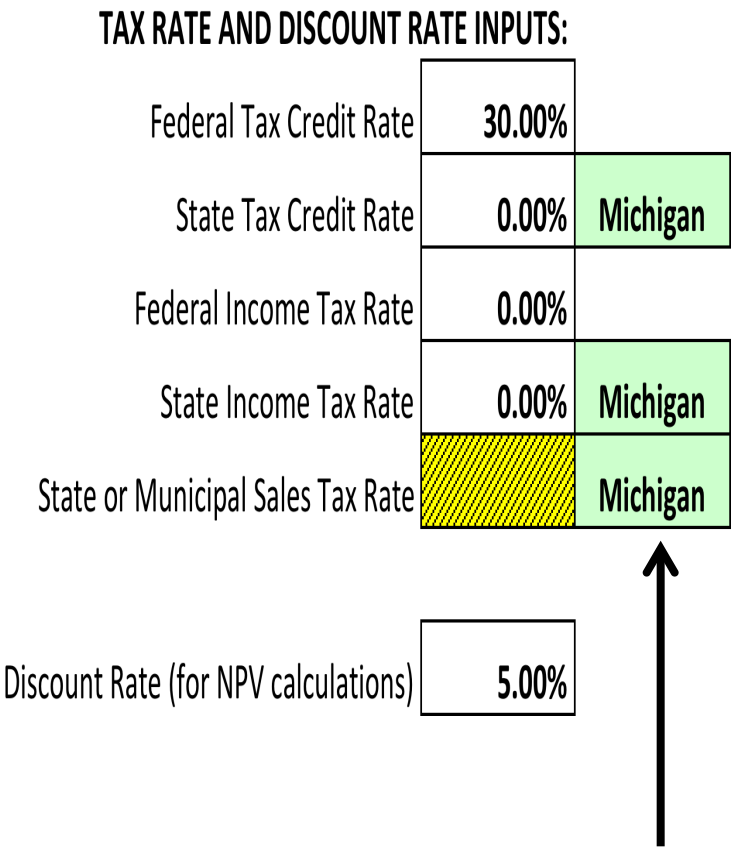
UTILITY RATE INPUTS:		
Residential Retail Rate	0.13000	$/kWh
Is there a Net Metering Rate?	Y	Enter "Y" or "N"
Net Meter Excess Generation Rate	0.13000	$/kWh
Is there a Feed-In Tariff (or Equivalent) Rate?	N	Enter "Y" or "N"
Feed-In Tariff Rate	0.240	$/kWh
Feed-In Tariff Period	15	years
Utility Rate Inflation Percentage	3.80%	per year

Source: MREA.

MREA PV Finance Model – Tax Rate and Discount Rate Inputs

Tax Rate and Discount Rate Inputs Include:

- Federal tax credit rate for installing PV systems
- State tax credit rate for installing PV systems, if applicable
- Federal and state income tax rates for calculating pre-tax benefits of energy savings from the PV system
- State or municipal sales tax rate (under construction)
- Discount rate for calculating net present values (NPV) of future cash flows



- Label with state name alerts user to enter corresponding state tax information, if applicable.

Source: MREA.

MREA PV Finance Model – PV System Costs

- *Calculates the Initial Cost of the PV System:*
  - Equals $/Watt x 1,000 W/kW x PV system size (kW)
- *Enter Grants, Rebates, and Cash Down Payment*
- *Calculates Federal Tax Credit (ITC) and State Tax Credits (fi available)*
- *Calculates Net Cost of the PV system after grants, rebates, federal and state tax credits, and cash down payment*

PV SYSTEM COSTS:

Initial Cost of PV System	-$36,000.00
Grants	$0.00
Rebates	$0.00
PV System Cost after Grants/Rebates	-$36,000.00
Federal Tax Credit	$10,800.00
State Tax Credit	$0.00
Cash Down Payment	$0.00
Net Cost of PV System	-$25,200.00

Source: MREA.

MREA PV Finance Model – PV Cost and Benefit Inputs Over Time

CASH FLOW INPUTS AND CALCULATIONS:

Year	0	1	2	3	4	5	6	7	8	9
Total PV System Cost	-$36,000.00									
Grants	$0.00									
Rebates	$0.00									
Federal Tax Credit	$10,800.00									
State Tax Credit	$0.00									
Net Cost of PV System	-$25,200.00									
O & M Costs		-$50.00	-$50.00	-$50.00	-$50.00	-$50.00	-$50.00	-$50.00	-$50.00	-$50.00
Equipment Costs									-$2,500.00	
Utility Bill Savings (Pre Tax / Post Tax)		$1,354.60	$1,399.05	$1,444.95	$1,492.36	$1,541.32	$1,591.89	$1,644.12	$1,698.07	$1,753.78
Cash Payment	$0.00									
Total Returns / Cash Flow	-$25,200.00	$1,304.60	$1,349.05	$1,394.95	$1,442.36	$1,491.32	$1,541.89	$1,594.12	-$851.93	$1,703.78
Cumulative Returns / Cash Flow	-$25,200.00	-$23,895.40	-$22,546.35	-$21,151.40	-$19,709.04	-$18,217.72	-$16,675.83	-$15,081.70	-$15,933.63	-$14,229.85
Year	0	1	2	3	4	5	6	7	8	9

- Enter rebates, performance-based incentives, other credits, O&M, and equipment costs that occur over time in the *Cash Flow Inputs and Calculations* section of the model.

Source: MREA.

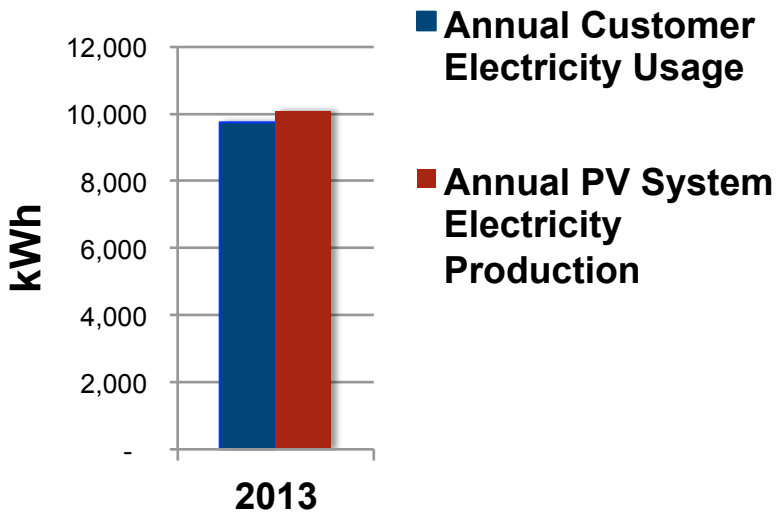
MREA PV Finance Model – PV System Electricity Production Results

PV System Electricity Production Results Include:

- Customer's annual electricity usage (kWh)
- Annual electricity production of PV System (installed kWh)
- Percentage of annual electricity usage supplied by the PV system
- Lifetime electricity production of the PV system (kWh)
  - Accounts for module degradation over the specified PV system lifetime.

PV SYSTEM ELECTRICITY PRODUCTION RESULTS:

Customer's Annual Electricity Usage	9,746	kWh/year
Annual Electricity Production of PV System	10,089	kWh/year
% of Annual Electricity Usage	104%	
Lifetime Electricity Production of PV System	290,397	kWh



Source: MREA.

MREA PV Finance Model – PV System Financial Results

Measures of Financial Results Include:

- Simple Payback
- Return on Investment (ROI)

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Profitability Index (PI)

- Cumulative Cash Flow
  - Expressed in future values of $

- Number of Years to Cost Recovery
  - Usually < Simple Payback

- Sum of Returns
- NPV of Returns

PV SYSTEM FINANCIAL RESULTS:

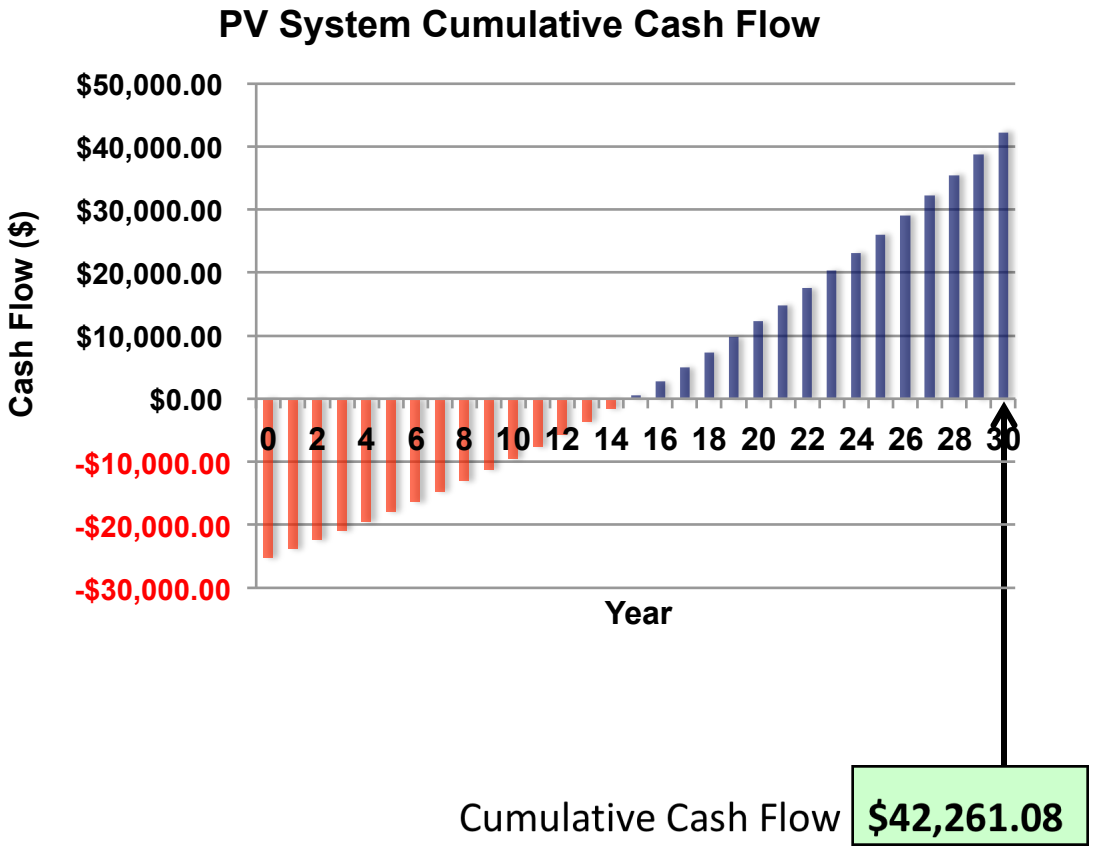
Simple Payback	18.6	years
Simple Return on Investment (ROI)	5.38%	
Net Present Value (NPV)	$5,576.48	
Internal Rate of Return (IRR)	6.54%	
Profitablity Index (PI)	1.22	
Cumulative Cash Flow	$42,261.08	
Number of Years to Cost Recovery	15.0	years
Sum of Returns	$67,461.08	
Net Present Value (NPV) of Returns	$30,776.48	

Source: MREA.

MREA PV Finance Model – Cumulative Cash Flow Chart

Cumulative Cash Flow Chart

- The cumulative cash flow chart is displayed to the right of the *Results* section of the spreadsheet.
- The chart changes immediately after new values are entered.
- Other charts can be easily produced as needed.



- The calculated cumulative cash flow is equal to the height of the last bar on the PV System Cumulative Cash Flow chart.

Source: MREA.

MREA PV Finance Model - Environmental Benefits

Each Year, a PV system	**9.00**	**kW in size, producing**	**10,089**	**kWh/year:**
Avoids burning	**9,080**	lbs of coal		
and avoids emitting	**22,599**	lbs of CO2 by a coal-fired power plant		
Avoids emitting	**16,445**	lbs of CO2 by non-baseload electric generation		

If all the electricty produced each year by this PV system were used to charge an electric vehicle, it would:

Avoid burning	**275**	gallons of gasoline
produced from	**14.5**	barrels of crude oil
and avoid emitting	**5,398**	lbs of CO2 from burning gasoline
while driving	**6,477**	miles in a car with a U.S. average mileage of 23.5 mpg (2010)

The electricity produced each year by this PV system is equivalent to having:

8.4	acres of forest offset the CO2 emitted by a coal-fired power plant

Sources: MREA., Energy Periscope. www.energyperiscope.com, U.S. Environmental Protection Agency. www.epa.gov/cleanenergy/energy-resources/refs.html , U.S. Energy Information Administration. www.eia.gov

MREA PV Finance Model – Features Being Developed

- ✓ Full integration with PVWatts production data.
- ✓ Environmental benefits section.
- Additional charts showing ✓monthly PV output, ✓customer energy use, annual utility costs with and without a PV system, etc.
- Incorporate MREA PV Finance Model cost and benefit results with a report that can be given to a prospective customer.
- Calculations using time of Use (TOU) utility rates.
- Create version of MREA PV Finance Model for commercial customers.

MREA PV Finance Model – Comprehensive Example

Determine the costs and benefits for a PV system to be installed in Traverse City, Michigan with Consumers Energy as the utility, based on the following information:

PV SYSTEM INPUTS:

PV System Costs in $/Watt	$4.00	/Watt
PV System Size	9.00	kW DC
PV System Location	Traverse City	Michigan
PV System - Custom Location	------	------
DC to AC Derate Factor	0.800	
Array Type	Fixed (roof mount)	
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PV System Lifetime	30	years
PV Module Degradation Rate	0.50%	per year

UTILITY RATE INPUTS:

Residential Retail Rate	0.13000	$/kWh
Is there a Net Metering Rate?	Y	Enter "Y" or "N
Net Meter Excess Generation Rate	0.13000	$/kWh
Is there a Feed-In Tariff (or Equivalent) Rate?	N	Enter "Y" or "N
Feed-In Tariff Rate	0.240	$/kWh
Feed-In Tariff Period	15	years
Utility Inflation Rate Percentage	3.80%	per year

PV System cost = **$4.00/Watt**

Grants, Rebates, Cash Payments = **$0**

Federal Tax Credit rate = **30%**

O&M costs
= **-$50** from Year 1 to Year 30

Equipment Cost
= **-$2,500** for inverter replacement in Year 13

Assumptions:

- PV system lifetime = **30** years
- PV module degradation = **0.5%** / year
- Utility inflation rate = **3.80%** / year
- Discount rate = **5.00%**

Source: MREA.

To Learn More About the MREA PV Finance Model and the PV Sales and Finance Course:

PV 203.03 PV Sales and Finance

Saturday, September 13, 2014

8:30 AM – 4:30 PM

Aero Park Laboratories

Room APL 101

2525 Aero Park Drive, Traverse City, MI

Fees: Non-Member Price: $270.00, MREA Member price: $250.00

Course Materials:

Pencil & paper, laptop, calculator, lunch

Continuing Education Credits:

7.0 hours for NABCEP PV Technical Sales certification

Source: MREA.

Works Cited

- Energy Periscope™. http://www.energyperiscope.com/
- --- “Performance & Financial Analysis Report, September 18, 2013”. http://www.energyperiscope.com/
- Microsoft Office: Excel http://office.microsoft.com/en-us/excel-help/excel-functions-by-category-HP005204211.aspx
- Midwest Renewable Energy Association (MREA). www.midwestrenew.org.
- NREL PVWatts Calculator. http://pvwatts.nrel.gov/index.php.
- U.S. Energy Information Administration. www.eia.gov.
- U.S. Environmental Protection Agency. www.epa.gov/cleanenergy/energy-resources/refs.html.