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Economics of Solar Photovoltaic Systems

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Solar photovoltaic systems vary greatly in size and cost. Calculating the economics of a solar system is key to knowing whether a solar system is right for your home, business, or farm.

Solar photovoltaic (PV) systems convert sunlight directly into electricity (*Figure 1*). Systems can be any size from a single panel about 200 Watts to hundreds of panels totaling tens of thousands of Watts. Calculating the economics of a solar system is key to understanding whether an investment in solar is right for your home, business, or farm.

1. Determine if you have a viable site (facing south with little shade).
2. Determine the total installed cost of a system from your local solar installer.
   - Work with the installer to estimate annual production from solar array.
3. Determine your cost of electricity (check your most recent electricity bill).
   - Check state net metering laws.
   - Check your local utility's net metering policy (in some cases local utilities have a more generous policy than state law).
4. Calculate simple payback.
5. Determine eligibility for local, state, and federal grants and tax credits.
6. Calculate payback with incentives.
7. Include inflation estimate in your calculations.
8. Calculate internal rate of return and net present value using a spreadsheet or an online calculator.

Figure 1. Solar panels are installed in groups that make up a solar array. Mounts can be placed on the ground, on roofs, or other structures. Panels face south and are tilted at an angle equal to their latitude. For Nebraska, solar panels should be tilted to an angle between 40 and 43 degrees.

The price of solar panels has declined in recent years, improving the economics of solar installations. The Lawrence Berkley National Laboratory reported a reduction of solar installed costs of $9.70 per Watt in 2000 to $6.20 per Watt in 2010. The declines have continued with installed costs closer to $4 to $5 in 2012. Excess electricity also may be sold back to the grid (local power company) or in the case of net metering can flow to the grid with the sum used to offset electricity used during other times. Understanding the economics of solar PV systems will be one of the most important considerations when deciding on solar energy.

You should view your solar PV system as an investment. This decision should be made after determining the feasibility of installing a solar system at a specific site. This publication focuses on grid-tied PV systems, but the economic calculations will be similar for off-grid or battery-backup systems. Grid-tied systems are connected to the electric grid so that electricity can flow out to the grid when the system is producing more than the load.

To find the total installed cost of a system, consult a solar array installer who can provide the total cost of solar panels, mounting system, inverters, and installation (*Figure 2*). Make sure you determine total installed costs. All solar systems have many small components beyond the panels that make up the balance of the system and can add to total costs. System components will differ depending on the goals and configuration of the system.

Grid-tied systems are the most common when a load is connected to both the solar PV system and the utility electric grid. Off-grid systems are not connected to the utility electric grid and will need batteries to provide on-demand power. Batteries can be added to a grid-connected system to give backup power during an outage. Note that the addition of batteries is uncommon due to the added cost of batteries and the associated parts. Contact your local utility company first to establish an

Figure 2. Installation of a solar PV system requires careful preparation to ensure a safe, long-lasting operation. This solar array is installed near Concord, Nebraska. For live data from this solar array, visit *http://bioenergy.unl.edu.*

understanding of its specific policies and protocols for safe installation. You should not assume all utilities follow the same guidelines. Policy and protocol will vary depending whether a company is a cooperative, public utility, or investor-owned utility. Check your electrical provider's cost per kilowatt-hour consumed; this can usually be found on your monthly statement.

After you know all this information, it is best to determine the payback period. A payback period is the length of time required to cover the cost of an investment. Here is an equation that can be used to help determine the payback period for your specific solar system:

Simple Payback Period

$$= \frac{\textit{Total installed cost of project – tax credits, grants, and subsidies}}{\textit{(Estimate of annual produced kilowatt hours)} \times \textit{(grid price per kilowatt hour)}}$$

The grid price of electricity refers to the retail rate for electricity. Solar electricity produced is credited at the retail rate if the total is under monthly use. See Net Metering for more details.

Simple payback period is only a simplistic measure and gives the number of years needed for a system to pay itself off. Consider that modern, high quality solar panels have an expected life of approximately 30 years. Refer to the manufacturer's specifications for the exact lifespan. In some cases the simple payback calculation is not enough because it does not take into account the time value of money and does not measure profitability. Nor does it include price inflation.

For these reasons, it is also important to compute the net present value and internal rate of return for your investment. Net present value compares the difference between present cash outflows and present cash inflows, essentially comparing the value of the dollar today with that in the future. Internal rate of return is the rate of growth a project is supposed to generate. These can be calculated with Microsoft Excel® or with online financial calculators. The mathematical equations are not shown in this document because a key factor in the equations changes based on time and interest rates.

Factors such as the price of electricity per kilowatt-hour and its inflation rate will play a large role in the payback period of a solar PV system. One key example of this is the system size with regard to net metering. When building a system, you should consider sizing it according to how many kilowatt-hours of electricity it can produce. Based on the net metering laws in your location, an undersized system can usually have all electricity produced by the system either used or credited at "retail rate," while an oversized system will likely have some of its production purchased by the utility at an avoided cost rate, which is usually less than half of the retail rate.

Net Metering

Federal law ensures small renewable systems are allowed to connect to the grid. But states and electrical utilities can have different policies on how the excess power is bought and sold. Net metering is a policy in which the "net" electricity usage is used to calculate a bill at the end of the billing period. In the case of net metering, electricity put on the grid offsets electricity used from the grid at other times during the same billing period. For example, the solar electricity will flow to the grid while you are not home (and thus using less power), and the solar electricity will be used first when you return and use electricity. Your bill at the end of the month will represent the "net" amount, referring to how much you used minus how much you produced.

The method of calculation for the net amount will differ with each utility's individual policy. In the case of Nebraska's Net Metering Law (LB 436 passed in 2009), the bill is totaled at the end of each month. Other small-scale renewables qualify for net metering in Nebraska, including wind, micro-hydro, methane, etc. There is a 25 kW limit in the size of systems that automatically qualify under state law. If the renewable system produced more than was used in that month, the excess energy is purchased by the utility at the avoided cost rate (usually much lower than retail). Each Nebraska utility sets its own rate for purchasing the excess.

Other states have net metering laws that allow the excess to roll over each month, only totaling at the end of each year. This annual system allows for balance between a solar PV system's high production in the summer and lower production in winter. Allowing any kind of net metering is a benefit to renewable energy system owners. However, the annual type can be of greater value to the system owner due to the seasonal differences in production and electricity usage, and the ability to bank credits from times of the year when more energy is produced to times when more energy is used. In Nebraska's system of monthly net metering, it is of greater benefit to undersize a system with respect to the load. Undersized systems generally will have most or all of the energy they produce used or offsetting retail-priced electricity.

Incentives

State and national economic incentives also can play a large role in the feasibility of installing a solar system. Federal incentives available to all solar PV installations (and many other renewable systems) include a 30 percent tax credit. In Nebraska, incentives such as net metering and low interest loans are also available. Qualifying farms and rural businesses, but not residences, also may have grants and guaranteed loans available through USDA Rural Development's REAP program. To learn more specifics or gain knowledge of other states' incentive programs, visit *www.dsireusa.org*.

NOTE: In the USDA Rural Development's Renewable Energy for America Program, applicants must be farmers, ranchers, or owners of rural small businesses. USDA Rural Development defines a rural area as any location beyond the urbanized periphery surrounding a city of 50,000 or more — in essence, areas not located in a Metropolitan Statistical Area (MSA).

Solar System Examples:

10 kW Solar Array

A 10 kW solar PV system is installed for $4 per Watt. The figures below show an estimated energy output, simple payback period, internal rate of return, and net present value for the 30 years of the project life.

Assumptions:

- Price of electricity: $.0931/kWh.
- Monthly net metering applies (based on LB 436).
- The electric load exceeds the system-size load (if the load is greater than production, most or all of the electricity produced by solar systems gets used or credited at full retail rate).
- Electricity production is estimated at 15,000 kWh per year. (Use solar estimates or from the panel manufacturer to calculate estimated production. Online tools also can be used.)
  - o One simple method that works for many Midwest sites: (Multiply solar array rating (kW) × 6 hours a day × 365 days a year × 70 percent). The 70 percent takes into account system efficiencies. In this example, this would give 15,330 kWh per year.

10,000 W × $4 / Watt = $40,000
Annual Offset Electrical Cost: $.0931/kWh × 15,000 kWh = $1,396

Simple Payback Period Without Incentives:

$40,000 / $1,396 = 28.6 years
Internal Rate of Return: 0.2%
Net Present Value: minus $15,851 (rate = 4%)

Payback Including Incentives:

- USDA Renewable Energy for America Program 25 percent grant
  (must be farm, ranch, or rural business to qualify; renewable system must be attached to farm, ranch, or rural business meter — no house meters)
- Federal Tax Credit 30 percent
  $40,000 × 25 percent = $10,000, leaving $30,000
  $30,000 × 30 percent = $9,000, leaving $21,000

  $21,000 / $1,396 = 15-year payback

Payback Including Incentives and Inflation:

Assuming a 4 percent annual increase in electricity costs.

Yields a payback of just over 11 years.

Internal Rate of Return: 9.0%
Net Present Value: $19,283 (rate = 4%)

100 kW Array

A 100 kW solar PV system is installed for $4 per Watt. The figures below show an estimated energy output, simple payback period, internal rate of return, and net present value for the 30 years of the project life.

Assumptions:

- Price of electricity: $.0931/kWh
- Monthly net metering applies (based on LB 436).
- Solar system load exceeds electric load.
- Electricity production is estimated at 150,000 kWh per year. (Use solar estimates or from the panel manufacturer to calculate estimated production. Online tools also can be used.)
  - o One simple method that works for many Midwest sites: (Multiply solar array rating (kW) × 6 hours a day × 365 days a year × 70 percent). The 70 percent takes into account system efficiencies. In this example, the system would produce 153,300 kWh per year.

100,000 W × $4/Watt = $400,000
Annual Offset Electrical Cost: $.05/kWh × 150,000 kWh = $7,500
(**Note:** due to the fact that the system is over 25 kW, it does not qualify under Nebraska's net metering law, and, thus, a negotiated rate of less than retail will likely be paid for excess.)

Simple Payback Period Without Incentives:

$400,000 / $7,500 = 53 years
Internal Rate of Return: minus 3.4%
Net Present Value: minus $270,000 (rate = 4%)

Payback Including Incentives:

- USDA Renewable Energy for America Program 25 percent grant
  (must be farm, ranch, or rural business to qualify; renewable system must be attached to farm, ranch, or rural business meter — no house meters)
- Federal Tax Credit 30 percent
  $400,000 × 25 percent = $100,000, leaving $300,000
  $300,000 × 30 percent = $90,000, leaving $210,000

  $210,000 / $7,500 = 28 year payback

Payback Including Incentives and Inflation:

Assuming a 4 percent annual increase in electricity costs.

Yields a payback of just over 19 years.

Internal Rate of Return: 4.2%
Net Present Value: $6,346 (rate = 4%)

Solar PV System for Irrigation

The following irrigation example is hypothetical; currently no large scale systems such as this exist in Nebraska.

Solar PV systems can be used for many different applications. Most common are small systems where intermittent power or battery charging is required. The irrigation example that follows is only meant to show the large scale potential of such a system. This example is a grid-connected system in which the system is not meant to run independently of the grid-powered electricity. An off-grid system can be constructed. It would be designed for a specific motor and pumping depth and would either be intermittent or need batteries.

The average irrigation pump uses 57 kWh per hour. (*http://www.ksre.ksu.edu/irrigate/OOW/P10/Kranz10.pdf*)

If we assume a solar system has an overall system efficiency of 70 percent of DC rating for six hours a day, operating a pivot would require approximately 80 kW of solar panels to run an irrigation system averaging 6 hours a day.

80 kW = 80,000 Watts = ~400 (200 Watt panels) (2.8 ft × 4.3 ft each) covering ~5,000 sq ft

At $4 per installed Watt = $320,000

Incentives:

USDA REAP grant
$320,000 × 25% = $80,000, leaving $240,000

Federal tax credit of 30 percent
$240,000 × 30% = $72,000, leaving $168,000

Using an online solar estimation tool, an 80 kW system in West Central Nebraska could produce approximately 165,000 kWh/year (*http://www.wunderground.com/calculators/solar.html*)

~45,000 kWh during the June, July, and August growing season
~123,000 kWh during the rest of the year

If the electricity is immediately used, it offsets grid electricity at (~$0.08) per kWh, and if it is put back on the grid, the rate paid would be negotiated and would likely be between $0.015 and $0.05 per kWh.
Using the costs of electricity above:

45,000 kWh × $0.08 = $3,600 per year
123,000 kWh × $0.03 = $3,690 per year

Total = $7,290 per year

Simple Payback:

$320,000 / $7,290 = 43 years

Payback Including Incentives:

Simple payback of $168,000 / $7,290 = 23 years

Payback Including Incentives and Inflation:

If the average value of electricity is $0.05 per kWh and the inflation rate is 4 percent, the system yields a payback of 15 years:

Internal Rate of Return: 6.5%
Net Present Value: $69,980

Other Considerations:

Solar systems run during peak times of year (hot summer days). Electric utilities are receptive to systems that help them with peak load, and in some cases have offered incentives for such systems. Contact your local utility provider. Solar systems also may work for irrigation during load management times.

How to Calculate Net Present Value and Internal Rate of Return in Excel:

http://academic.brooklyn.cuny.edu/economic/friedman/npvirr.htm

The National Renewable Energy Laboratory offers a useful online, map-based, interface tool to estimate electrical generation by a PV array called "In My Back Yard" or IMBY. This tool is able to look at specific locations across the U.S. and calculate payback periods according to initial costs, rebates, tax credits, and other incentives by various sizes of PV units. The tool may be accessed online at *http://www.nrel.gov/eis/imby/*.

Websites with financial calculators:

http://www.fdic.gov/consumers/loans/prevention/NPVCalculator.html
http://www.bergey.com/technical
http://www.investopedia.com/calculator/NetPresentValue

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