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An Analysis of the Real World Output and Present Value of a Solar Photovoltaic System

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Abstract

A 2.4 kW solar voltaic system installed on the campus of SUNY Ulster County Community College has produced about 6,000 kWhr of electricity in two years of operation (3,000 kWhr/year). This output corresponds to 1250 kWhr per year per kW of installed capacity. At an average New York State electricity cost of $0.20/kWhr, this electrical output would have a present value of $3153 (20 year life, 5% discount rate). That is, solar electrical systems would be cost effective in our area (the middle Hudson River Valley region of New York State) if their installed price per watt is approximately $3.15 or less.

Introduction

The use of “solar cells” (“solar PV” - solar photovoltaic electrical power generation) has been practiced since the latter half of the twentieth century. The first solar cells for space flight applications were produced by Bell Labs in 1954, and the first solar powered calculator debuted in 1978 (Wikipedia). Originally, the high cost of solar PV units restricted their use to applications where alternative electrical power would be either too expensive or unobtainable. Such applications included off-grid electrical power in remote locations or power for Earth-orbiting or outer space vehicles.

More recently, however, the cost of solar PV systems has decreased considerably. Solar PV modules can be purchased for about $1.30 per watt ($1.30/W). However, the cost of integrating the solar module into an electrical system (including ancillary equipment – inverter, batteries, charge controller, and wiring – design and installation) currently amounts to about $4.90/W, inflating the total cost to about $6.10/W. More recently, the advent of “grid-tie” inverters that interface the solar PV module directly with the power utility’s electrical grid have eliminated the need for batteries and a charge control system. The decreased component requirement can decrease the total installed cost, thus making solar PV systems more competitive.

As a result of a recent grant, a solar PV system was installed on the Stone Ridge, NY campus of SUNY Ulster County Community College in May of 2011. The system consists of twelve 200 W solar modules (total 2,400 W) arranged into two arrays, and connected to a grid-tie inverter that feeds the electricity produced by the solar PV system back into the College’s electrical system. The unit thus decreases the amount of electricity purchased by the College, resulting in a cost saving. The inverter has the capability (through a “data logger”) to track power production by the day and over the life of the system, and the data logger can display that information over a website that is readily accessible (http://datalogger.sunyulster.edu/).

We were curious regarding the amount of the electricity produced by the system and the cost that would be justified using a "present value" calculation based on the value of the electricity. In other words, we wanted to calculate the system cost that would be justified by the electricity produced. We thought that such a calculation might help provide a cost target for suppliers of solar PV systems. At or below the present value, solar PV would compete effectively against commercially supplied power, and thus be a viable alternative power source.

Method

System Power Output

At the end of the first year (May, 2012) the system had produced about 3000 kWhr of electricity, according to the data logger in the inverter. At the end of the second year (May, 2013), the system power output read about 6,000 kWhr, corresponding to an annual output of 3,000 kWhr. This actual output compares favorably with an estimated 2780kWhr/year for this area (Albany, NY – NREL PV Watt Energy Calculator). Any shortfall in production could be explained by the low tilt of the system as installed (about 15º from the horizontal – a 30º to 50º tilt angle would be more productive; a 43º tilt was used by the NREL solar energy calculator). The tilt angle is restricted by clearance issues at higher angles of tilt.

Value Calculation

The annual output of 1,250 kWhr (for a 1 kW solar system) was converted into an annual electrical cost saving of $250, using an electrical cost factor of $0.20/kWhr (given as an average cost for New York State by the Bureau of Labor Statistics).

The annual power saving was entered for each year of a 20 year lifetime into a "present value" function in Microsoft EXCEL®. The discount rate was arbitrarily chosen to be 5%, and the present value was calculated. With a total investment equal to the present value, the electrical power savings barely justify the capital cost of the system. <u>Note: this cost does not include any tax credits that may be available for solar energy installations. Tax credits vary by location and by time, but they can be substantial.</u>

Results

"Present Value" calculation

Project size – 1 kW solar PV system, complete and installed.
Present Value – calculated value.
Electrical production – 1,250 kWhr/year.
Cost of electricity - $0.20/kWhr.
Electrical cost savings - $250/year.
Project lifetime - 20 years.
Discount – 5%

At an electrical cost of $0.20/kWhr, a 1 kW system would yield $250 in annual electrical cost savings. Based on a 20 year lifetime and a discount rate of 5%, these savings would justify an up-front investment ("present value") of $3,153, or $3.15 per installed watt (including all costs – system, design, and installation). This value is easily scaled for different electricity costs – for example, if a customer paid only $0.10/kWhr, the justified investment cost would be only half as great - $1.58/W. The justified cost is lower than a typical installed cost of about $6.10 per watt (LBNL-5919E, for small residential systems installed in 2011); this difference explains why solar power has not been widely implemented.

Discussion

The cost of solar power modules has declined about 70%, from about $4.80/W in 1998 to about $1.30/W in 2011 (LBNL). However, the custom design and custom installation costs are substantial, and they have declined by only about 30%, from about $6.90/W in 1998 to about $4.80/W in 2011 (LBNL). In effect, we are living in the "pre-Model T" era of solar power, where custom design and custom installation costs have impeded the decline of solar PV installation prices to economic levels.

What we envision is a mass-production approach to solar power installation, where a standardized design 200 W solar system (consisting of a single panel and an attached micro-grid-tie inverter) literally plugs into a customer's electrical outlet, rolling design and installation costs into a single charge for a standardized system that is amortized over numerous installations, thus decreasing the cost per system.

Such a system is much closer to fruition with the advent of "micro-grid-tie inverters" that attach to the back side of a single solar panel and convert the output of that solar panel (about 200 W peak) into 120 V ac power that is synchronized with electrical grid power. The wiring from the inverter terminates in a standard electrical plug that inserts directly into a residential electrical outlet. Installation then becomes "plug and play" – as easy as just plugging it in. Such a system could be acquired by the customer as a pre-assembled package. The customer would then site the solar array and plug into an available exterior electrical outlet. Without the extra charges for system design and installation, the total cost would come much closer to the justified capital cost calculated above, and solar power might be implemented much more widely than it is today.

Moreover, there may be a significant cost driver that is not being utilized today. With the installation of numerous solar power systems in many homes, power generation would become more distributed and less centralized, with the benefit of removing a significant load from the power distribution grid. This load decrease would in turn decrease the strain on the electrical grid and decrease the cost of maintaining and expanding the distribution system. As a consequence, distributed power generation afforded by solar panels could improve the reliability of the electrical grid while decreasing its maintenance cost.

Since the majority of this benefit would accrue to the power supplier, the solar system cost might be borne most efficiently by the same power supplier. In one potential scenario, the electrical supplier would buy and install 200 W single panel "plug and play" solar systems in customer homes without charge. The supplier would keep any tax credit, and it would also benefit from mass purchase of system components, including panels, inverters, wiring, etc. The supplier would own the unit and its output during the payback period (perhaps 10 to 20 years). At the end of that period, ownership of the solar system and its output would revert to the homeowner. The homeowner would eventually gain a free solar power system and an electrical cost saving. The power supplier would gain a lower grid distribution maintenance and upgrade cost, and the public relations benefit of promoting sustainable ("green") energy production.

A "plug and play" solar system described above would be aimed at a different demographic compared with current solar PV systems. Current solar customers are trend-setters with disposable income who want to lead the world into renewable energy production. The customer for the "plug and play" system would be someone who values renewable energy but who does not have the resources to justify an uncompetitive power system. Thus, a "plug and play" system would not compete directly with current solar PV installations, rather it would open a new demographic to the world of economically advantageous renewable power, and increase public acceptance of solar power.

Calculation of Present Value

Input Table		
hWhr/yr	1250	
Cost per kWhr	0.2	20 cents per kWhr
Investment rate	0.05	5% interest
life of system (years)	20	
future value	0	
Electric value (year)	250	calculated field
Electric value (bi-monthly billing period)	41.66667	calculated field
Present value	3152.965	Justified Investment
Target Solar PV total installed cost per W	$3.15	Investment $/W
Target cost for a 1kW system	$3,152.97	

References

Solar PV timeline:
http://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf

http://en.wikipedia.org/wiki/Timeline_of_solar_cells

NREL solar energy calculator:
http://rredc.nrel.gov/solar/calculators/pvwatts/version1/

Cost of electricity:
http://www.bls.gov/ro2/avgengny.pdf

Solar PV cost:
http://emp.lbl.gov/sites/all/files/lbnl-5919e.pdf

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