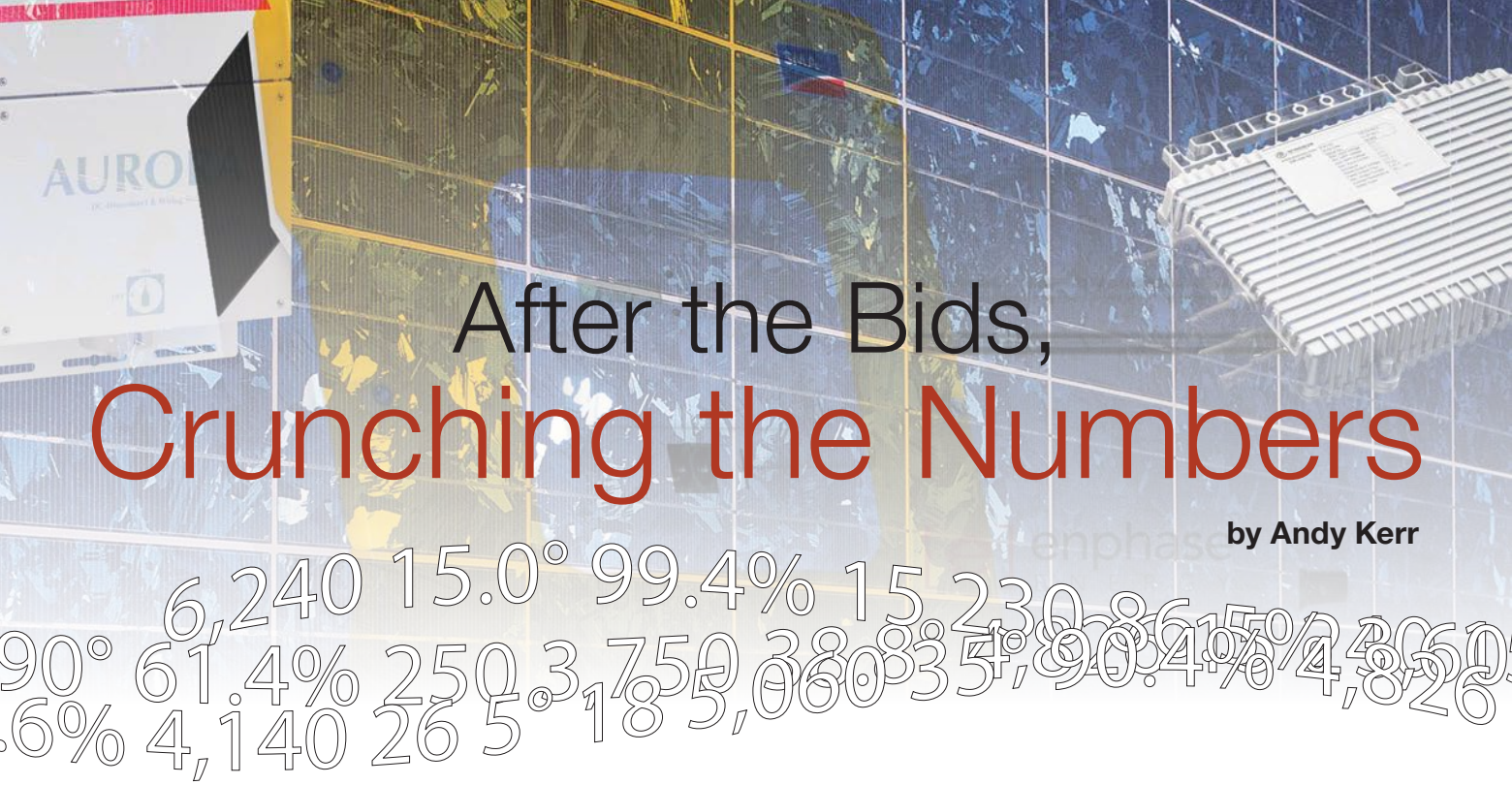


After the Bids, Crunching the Numbers

by Andy Kerr

The bids are in, but then what? Andy Kerr examines how you can fairly compare different PV system bids to optimize your investment.

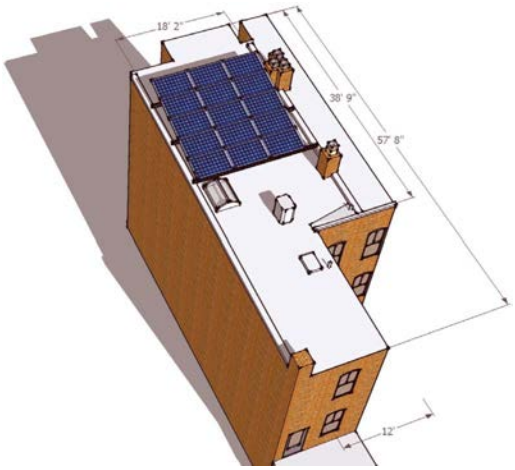
You should no more buy a PV system for your house based only on the lowest installed cost than you should buy a water heater or refrigerator in such a manner. For energy-consuming appliances, it's critical to consider ongoing operating costs. But for energy-producing equipment—like a PV system—once you are satisfied with the qualifications of your potential installers, considering operating efficiency of the presented systems is crucial.

As a way to provide comparative information on the cost-effectiveness of batteryless, grid-tied PV systems, DC Solar United Neighborhoods (DC SUN), a coalition of solar cooperatives, solicited bids from four installers for a rooftop system in the Capitol Hill neighborhood of Washington, DC. The results shown are specific to one homeowner and rooftop scenario, but DC residents can use the customizable spreadsheet (at homepower.com/webextras) to assess the finances of installing your own PV system. (The worksheet can also be modified for the circumstances in any location.)

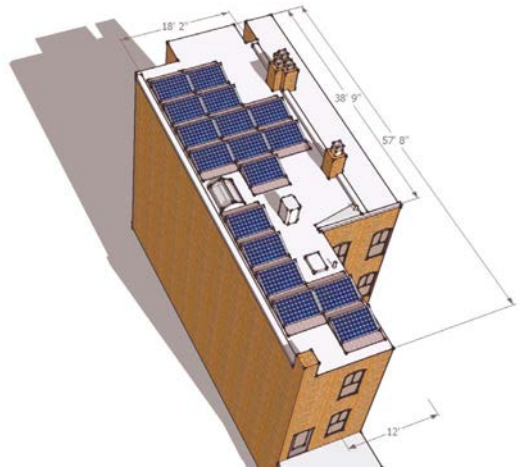
In this comparison, the constant is the slope and size of the roof, which in this case is the flat roof of a row house, found commonly in many DC neighborhoods. The variables are the installers and their bids, some of whom offered more than one equipment and/or financing option. The proposal analyses included:

There's no prescriptive path for solar-electric systems, since each site is different. Several configurations were proposed for this row house's rooftop (see illustrations, opposite page).

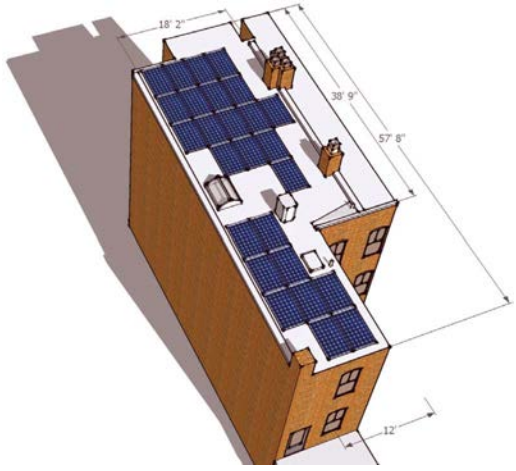
Vendor D Options



Purchased I-Beam Array
Tilt = 14.5°; 15, 240 W modules with microinverters
for 3.6 kW total; Est. production = 4,477 kWh per year



Purchased Tilted, Ballasted Array
Tilt = 15°; 17, 240 W modules with microinverters
for 4.08 kW total; Est. production = 5,086 kWh per year



Purchased Flat-Ballast Array
Tilt = flat; 26, 240 W modules with microinverters
for 6.24 kW total; Est. production = 6,983 kWh per year

Module Tilt & Impacts on Production

Washington, DC, is known for its row houses—two- or three-story structures that are narrow and deep. Roof space is sparse, and fitting enough PV modules on a rooftop to zero out a household's annual electricity usage can be challenging.

If modules are mounted at a tilt optimized for annual production—which is usually somewhat close to the degree of latitude—the rows of modules on flat roofs have to be widely spaced to avoid shading each other.

Reducing the tilt somewhat decreases output, but allows more modules in a given space. In this case, deviating from what is generally considered the optimal tilt can provide more net production since more modules can be placed on the roof—as long as interrow shading is avoided (see "Methods: Interrow Shading" in *HP151*).

Vendor D offered three options (see illustrations at left): tilting the PV modules on I-beams that would lay across the "party" walls to avoid any weight on the roof; a tilted, ballasted array; and an array that was mounted flat on the roof, resulting in an estimated 4,477, 5,086, and 6,983 kWh per year production, respectively. Each option was progressively more expensive initially, but progressively more profitable in terms of net present value and internal rate of return. If you can afford to make the larger investment, the payoff will also be larger.

Production vs. Array Tilt for Washington, DC

Tilt	% of Max. Production	Notes
90°	61.4%	Vertical
45°	98.8%	12:12 pitch roof is 45°
40°	99.4%	10:12 pitch roof is 39.8°
38.8°	99.6%	Latitude of Washington, DC
35°	100.0%	Accounts for climate & annual changes in the sun's position
25°	99.4%	6:12 roof pitch is 26.6°
20°	98.1%	4:12 roof pitch is 18.4°
15°	96.2%	3:12 roof pitch is 14.0°
10°	93.6%	2:12 roof pitch is 9.7°
5°	90.4%	1:12 roof pitch is 4.8°
0°	86.5%	Horizontal

Source: PVWatts

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Example Results (With District of Columbia Grant)

Initial Costs	How To Generally Interpret
Acquisition method: configuration	—
Gross system cost	—
Net cost (after subsidies) for purchase, or initial cost for lease	Generally, lower is better, but SP, IRR & NPV are better metrics
Annual lease payment	NPV & IRR are better metrics to consider
Annual increase in lease payment	NPV & IRR are better metrics to consider
Cost per watt	Lower is better; cost per kWh is better, as it includes system efficiency
Cost per kWh per year	Lower is better

Production Results

Nameplate Rating (DC Watts)	Size of array
Portion of consumption offset	Close to 100% is better unless anticipated loads are higher (electric car) or lower (improved efficiency)

Financial Results

Simple payback (SP), years	Year cash flow turns positive
Internal rate of return (IRR)	Higher is better
Net present value (NPV)	Higher is better

Residential Property Value Increase

Estimated increased property value ($6.00 per nameplate watt)	Higher is better
Estimated increased property value ($7.60 per nameplate watt)	Higher is better
Estimated price premium (low; 21x foregone electricity cost)	Higher is better
Estimated price premium (high; 26X foregone electricity cost)	Higher is better

- **Financial return.** Simple payback (SPB), net present value (NPV) and internal rate of return (IRR) were all calculated. NPV and IRR are sophisticated financial metrics that consider the time value of money and are therefore more useful.

- **Production.** Estimated annual production is a function of local seasonal climatic conditions, PV array size, and DC-to-AC derate values (wiring losses, module soiling, inverter efficiency, etc).

- **Energy Cost.** Both dollars per nameplate watt and dollars per kilowatt-hour per year were calculated. The latter is more useful, as it factors in overall PV system efficiency.

Methodology

So as not to prejudice the evaluation by having an adequately informed consumer, no direction was given to the vendors as to the goal of the PV system, be it to just offset annual household electricity consumption or to maximize energy production given the available space. Nor was a preference expressed for buying or leasing a system. While the competing vendors saw the same roof, each proposed different configurations. Though most all PV bid packages came with their own presentations of the financial benefits the homeowner would receive, each made different enough assumptions as to make any across-the-board comparisons useless without further analysis.

To compare the competitors, the bids were analyzed using PVWatts (see Access). The same key variables were extracted from the bids: number of PV modules and module rating to determine DC nameplate rating; inverter type (string or microinverters) to determine inverter efficiency; and module tilt to determine array efficiency. Except for the case of microinverter efficiency, all the PVWatts default derates were used. The PVWatts results were used in the financial calculations.

Interpreting the Results

As you review the "Results" table, keep in mind:

- With net metering, sizing your system to get as close as possible to producing 100% of your annual electricity consumption is the most cost-effective plan. Both your PV system's production and your energy consumption vary each year, so "close" is the best you can do. (And as appliances are replaced or added, consumption will change.)

- The negative net present value (NPV) for most options is a result of the owner's savings investment rate, which

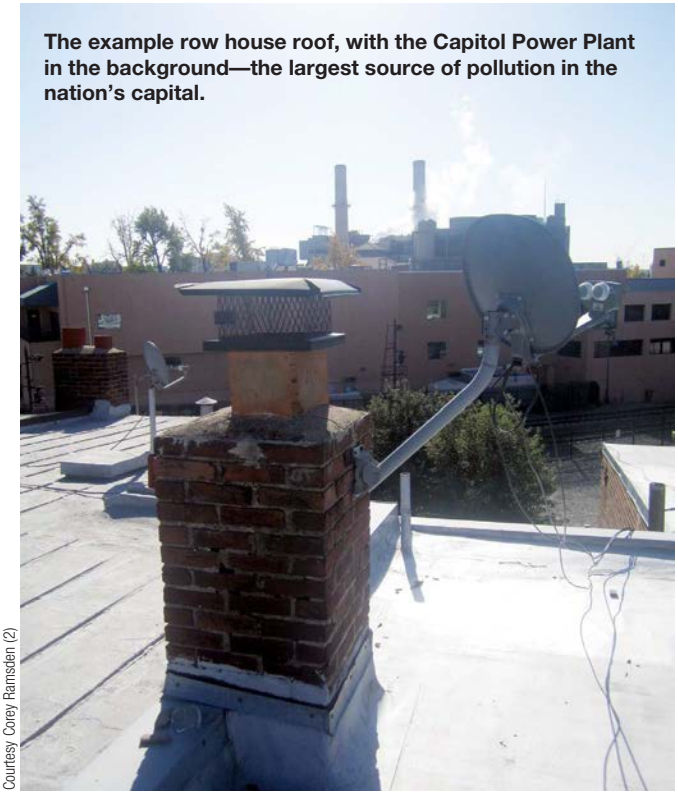
Vendor A	Vendor B				Vendor C	Vendor D			Averages	
Purchase	Purchase	Lease: 0% down plan	Lease: initial payment plan	Lease: prepay plan	Purchase	Purchase: I-beam	Purchase: tilt ballast	Purchase: flat ballast	Purchase options	Lease options
$19,382	$23,196	N/A	N/A	N/A	$22,995	$24,975	$25,500	$34,320	$25,061	N/A
$4,672	$8,110	$0	$3,639	$7,278	$4,677	$7,747	$7,005	$9,004	$6,876	$3,639
N/A	N/A	$816	$516	$0	N/A	N/A	N/A	N/A	N/A	$444
N/A	N/A	3.9%	0.0%	0.0%	N/A	N/A	N/A	N/A	N/A	1.3%
$1.25	$1.96	N/A	N/A	N/A	$0.92	$2.15	$1.72	$1.45	$1.57	N/A
$1.06	$1.66	N/A	N/A	N/A	$0.80	$1.73	$1.38	$1.29	$1.27	N/A
3,750	4,140	4,140	4,140	4,140	5,060	3,600	4,080	6,240	4,478	N/A
92%	99%	99%	99%	99%	117%	102%	115%	159%	111%	N/A
7	10	Never	12	10	6	10	8	8	8	11
16.23%	9.46%	#DIV/0!	29.20%	10.83%	20.35%	10.35%	13.46%	14.39%	14.04%	10.02%
$7,431	$5,024	-$2,130	$2,579	$5,823	$10,571	$5,701	$8,199	$11,842	$8,128	$2,091
$22,500	$24,840	N/A	N/A	N/A	$30,360	$31,600	$24,480	$37,440	$26,870	N/A
$28,500	$31,464	N/A	N/A	N/A	$38,456	$27,360	$31,008	$47,424	$34,035	N/A
$13,296	$14,297	N/A	N/A	N/A	$16,802	$14,663	$16,653	$22,901	$16,435	N/A
$16,462	$17,701	N/A	N/A	N/A	$20,802	$1,815	$20,618	$28,354	$20,349	N/A

we assumed to be 4%. In all cases, NPV is more than $0, so one would be that much "richer" today for having made the investment. In the case of 0%-down leasing, one would be that much "poorer" for making such an investment. If you don't have the cash or can't get a loan, then get a $0-down lease, as you will lose less money on such an investment than paying the "noninvestment" of your monthly electric bill.

- The highest NPV and/or IRR—or shortest simple payback (SP)—should not be the only factors you consider when choosing a vendor. Also make sure to consider the quality of equipment and warranties offered, and the installer's experience and follow-up service capabilities. These factors must be qualitatively evaluated and they are not easily quantified for a NPV or IRR analysis.

- In the IRR for Vendor B, "DIV/0!" is a Microsoft Excel error code for division by zero. Excel's IRR function requires at least one negative number (more cash out than in) during one investment year. The 0% down leasing option is cash-flow positive from the start (compare SP and NPV instead).

- Because it accounts for overall system efficiency, the metric of $/kWh/year is more useful than $/nameplate watt.



The example row house roof, with the Capitol Power Plant in the background—the largest source of pollution in the nation's capital.

Courtesy Corey Ramsden (2)

Unfortunately, when the air-conditioning compressor was placed, no thought was given to the placement of future PV modules.

Courtesy Corey Ramsden (2)

Configuration Options

Company	No. of Modules	Module Rating (W)	Array Size (W)	Tilt	PVWatts Est. Production (kWh/Yr.)*	Inverter Type
A	15	250	3,750	14.0°	4,413	Aurora string inverter
B	18	230	4,140	14.0°	4,872	Not specified
C	22	230	5,060	10.0°	5,819	SMA string inverter
D1	15	240	3,600	14.5°	4,477	Enphase microinverters
D2	17	240	4,080	15.0°	5,086	Enphase microinverters
D3	26	240	6,240	Flat	6,983	Enphase microinverters

*Based on PVWatts data for Sterling, VA, and using the default derate values (DC-to-AC derate of 0.77). In systems using microinverters (which improve system availability, and negate the module mismatch and DC wiring derates), a DC-to-AC derate of 0.81 was applied.

Leasing

From purely a financial standpoint, our results show that a prepaid lease of a PV system might be the most financially advantageous. However, leases are a relatively new option and have not been well-tested in the marketplace. Make sure you understand all the ins and outs of a lease—such as liability, performance guarantees, and access for maintenance—before you sign. There is also some risk that the leasing company might go out of business (which doesn't necessarily mean you end up with a free system). Leasing may be a preferred option if you cannot immediately absorb incentives in the form of tax credits (they may be carried over to future years).

The leasing company will contract another party to install the system, and will receive all of the incentives. Depending upon which state you live in, a solar leasing company may either "lease" you the PV equipment on your roof, in which you receive the benefits of its production, or sign a power purchase agreement (PPA) with you, where you contract to pay for the electricity at a set rate, usually below, or at least at the current utility retail rate. In either case, you don't own the system or have to maintain it. At the end of the lease term, you sometimes are able to buy the system at a "salvage value" cost or it will be removed by the hardware owner.

There are two other major financial benefits to leasing or purchase beyond IRR and NPV:

- Electricity prices are locked in. You no longer are affected by utility rate increases. In fact, if rates rise, your actual NPV and IRR will improve.

- In most locations, a PV system increases the home's resale value (probably more if you own, rather than lease, the system), possibly enough to offset most or all of your initial capital outlay for the system.

Access

Andy Kerr (andykerr@andykerr.net) spends part of his year living in the Capitol Hill neighborhood of Washington, DC, where he advocates for nature and writes about energy efficiency and renewable energy.

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