Residential PV Systems Cost Report

Cost Analysis for TEAM-UP Residential PV Installations

Solar Electric Power Association

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Summary of 2001 TEAM-UP Final Reports

Final Summary Report

The final summary report is a comprehensive view of TEAM-UP, with documented data, information, and experiences that SEPA has collected throughout the program, including lessons learned by participating ventures, and sections covering costs and other information on both large and small systems. This report also covers the barriers that TEAM-UP faced to PV commercialization at the beginning of the program, barriers the project was able to remove or reduce, and what barriers remain on the road ahead.

Creating a Successful PV Program

This is a brief report that provides energy service providers with eight essential "What Every Energy Service Provider Needs to Know" items to help develop and implement a PV program. The report is based on the lessons learned by the ventures funded under the TEAM-UP program.

Large System Cost Report

This report analyzes cost data collected from 23 TEAM-UP systems ranging in size from 70kW to over 400kW. Systems in this range were examined because they are believed to be the most cost effective use of PV. The analysis consists of cost trends based on installation size, project leader experience, components, and declining costs of components over time. The report concludes that costs for large scale systems are decreasing over the years, the most recent being installed for only $5.50/W.

Residential PV Systems Cost Report

This report examines the costs of over 600 residential PV systems installed as part of the TEAM-UP program. Most of the systems used in this analysis are less than 5 kW, and are roof-mounted. The data was examined to determine trends for the residential PV market. The report shows that there has been little change in the final cost of residential systems since the beginning of TEAM-UP. However, the PV industry has changed the approach to installing residential systems, originally larger systems were favored, but by the end of the program more ventures were installing PV systems under 1.5 kW.

PV Performance Data Report

This report overviews the results of the TEAM-UP performance monitoring efforts on over 100 of the TEAM-UP PV system installations. Selected installations funded under the program had a data collection system installed to collect site weather and PV system output data. The report describes the monitoring strategy; the results obtained from an analysis of this data; and describes the trends identified.

Business Models Report

This report looks carefully at seven business models used by TEAM-UP ventures and describes the results of several interviews with venture teams to document the business concepts and plans of the ventures, the challenges faced by the teams, solutions identified, venture achievements, lessons learned, and prospects for the future. The report includes case studies of several ventures providing information that can be used to replicate these business models.

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Executive Summary

Since 1995, the Solar Electric Power Association has managed TEAM-UP, a cost-sharing program funded by the U.S. Department of Energy and designed to promote the commercialization of photovoltaic equipment for connection to the electric grid. Cost-share funding was available through three competitively selected Rounds beginning in 1995.

The technical variety and number of participants expanded as the program evolved, with a total of 35 ventures installing more than 7.2 megawatts of PV. Of that 7.2 megawatts, 1.2 megawatts of PV were installed in residential applications. Eleven ventures installed a total of 644 residential PV systems,[1] which generate more than 1,200 kilowatts of alternating current (AC) electrical capacity.

Only three ventures installed residential systems in Round One, using modules from two manufacturers. By Round Three, seven ventures had installed modules from nine different PV companies on residential rooftops.

The majority of installations were made as retrofits on existing rooftops, but at least 89 installations were made on new construction, and at least four were ground-mounted. All types of silicon cell technologies were used, including PV shingles, standing seam metal roofs, and AC modules. Seventy-three of the systems included storage batteries.

The PV system sizes included in this residential analysis ranged from less than 0.3 kilowatts to more than eight kilowatts (PTC)[2]. Most residential systems were less than two kilowatts in size, and only a few were larger than five kilowatts. Overall, there were only a few distinct trends in costs associated with residential PV systems. One notable trend was that the TEAM-UP ventures that installed the most residential PV systems and the greatest number of kilowatts had the lowest costs. Costs decreased for systems from 0.3 kilowatts to 1.5 kilowatts, and then leveled out for all systems larger than 1.5 kilowatts.

The ventures changed their approach to residential systems from Rounds One to Three. Round One ventures installed mostly larger residential systems, over two kilowatts, but by Round Three many ventures were installing systems less than one kilowatt, despite the higher cost per watt. Additionally, a few Round Three ventures began to work with homebuilders to install PV systems on new homes, rather than installing rooftop retrofit PV systems.

There are still many variables involved that make predicting the cost of residential PV systems difficult. Costs are influenced by the project leader's experience, system size, type of system, local incentives, utility interconnection requirements, and installation

[1] Not all residential systems were used in the analysis; some systems were excluded due to a lack of sufficient data.
[2] PVUSA Test Conditions

process, just to name a few. Until the PV market has grown, each of these factors will impart an element of uncertainty when planning a project.

About the Association

The Solar Electric Power Association (SEPA) is a nonprofit association of more than 150 energy service providers, PV industry, and PV stakeholders in the United States, Canada, Europe, Australia, and the Caribbean, cooperating to accelerate the commercial use of solar electricity. SEPA's objectives are to stimulate the development of viable PV business opportunities, serve as a bridge between government and industry, and provide timely information to industry and the general public.

SEPA is composed of a broad spectrum of the electricity industry, including investor-owned utilities and their subsidiaries, public power systems, and rural electric cooperatives. SEPA members account for nearly 50 percent of total U.S. electricity sales (1.5 billion megawatt-hours in 1998) and have some 40 million customers.

TEAM-UP Overview

Beginning in 1994, the Utility PhotoVoltaic Group (UPVG) and its successor, the Solar Electric Power Association (SEPA), have managed TEAM-UP (**T**echnology **E**xperience to **A**ccelerate **M**arkets in **U**tility **P**hotovoltaics), a partnership of the electric utility industry and the PV industry. TEAM-UP provided cost sharing for selected solar electric (photovoltaic, or PV) business ventures throughout the U.S.

The intent of the TEAM-UP program is to demonstrate and validate PV system hardware installations and to build confidence among utilities, energy service providers, industry, and customers. Data and information produced by TEAM-UP installations and venture experiences are shared with SEPA members and the public.

Cost sharing between the ventures and SEPA was carried out through three separate Rounds of funding, in which a total of 35 ventures were awarded funding, including 11 that installed residential projects. SEPA chose ventures for cost sharing based on competitive proposals provided in response to a formal request-for-proposal process. Some ventures received funding in multiple Rounds. Each Round of TEAM-UP began with a request for proposal; competitive awards were made based on the recommendations of an independent proposal evaluation committee. Round One began in 1995, Round Two in 1996, and Round Three in 1998. All TEAM-UP installations were completed by the end of October 2000.

A Few Caveats

All costs cited are nominal; no adjustments were made for inflation. All system ratings, unless otherwise noted, are in units of AC power at PVUSA Test Conditions (see page 7 for a description of the "PTC" rating). Costs cited throughout are in U.S. dollars per watt ($/W); they are, thus, nominal costs based on an AC rating at PTC.

Numerous judgments had to be made in order to group dissimilar cost data into distinct categories and compare cost on a per-watt basis. There are some dangers associated with this process. Residential PV systems are individualized installations and, though each venture may use a somewhat standardized system for their projects, each venture's systems will be different. The systems discussed in this report represent a wide range of utilities, locations, and array types. Furthermore, as with any industry in the beginning stages of commercialization, residential PV systems are experimental to some degree. Thus, it is exceedingly difficult to accurately compare costs between such dissimilar projects.

Another danger is that, in order to compare costs on a per-watt basis, costs must be divided by the system rating. While these per-watt comparisons are useful, they can also distort component cost distinctions. For example, a low system rating will increase the cost per watt of all of the system components, even though the low rating may be the direct result of a specific problem with one component, such as the modules.

Documenting costs and value and providing strategic advice are key TEAM-UP goals. Much of the cost information reported in TEAM-UP deliverables is confidential and could disclose trade secrets of participating utilities, systems integrators, and manufacturers. Therefore, cost information studied in this report is displayed in aggregated form to prevent the reader from linking cost information to specific projects. Hopefully, the steps we have taken to preserve confidential information have not diminished the usefulness of this report.

In sum, the usefulness of this report is limited by the inherent variability of the data. The accuracy of the costs discussed has a healthy range of uncertainty, which we do not attempt to quantify here. It is important to keep this in mind when reading the report. Although some of the figures are presented with several significant digits, we do not mean to imply such a high level of certainty. Moreover, none of the trends discussed in this paper can be considered statistically significant, as there are too many variables to ensure a reasonable level of confidence.

System Ratings and Performance

AC RATINGS FOR TEAM-UP SYSTEMS

Rooftop PV system at Village Green Homes in Sylmar, CA installed by BP Solar

In the final analysis, what customers most want to know is the level of energy production they can expect, which, in turn, depends not only on the system characteristics but also on the weather at the specific site, a variable which can be enormously inconsistent. The focus of the TEAM-UP project was grid-connected systems, generating power for the utility electric grid. As was required by TEAM-UP, many of the TEAM-UP ventures reported their information in AC figures based on PTC (PVUSA Test Conditions) testing standards. Unfortunately, a few reported their costs on STC (Standard Test Conditions) standards.

The only way to be sure of actual AC ratings is to measure the output under real operating conditions (which vary with time) and then to use that data to calculate a rating for each system. Data acquisition systems were installed on a small portion of the installations, providing measured data points for AC output, plane-of-array irradiance, ambient temperature, and wind speed, over a 30-day period. These data points were used to estimate the rating, using a mathematical regression with the following equation:

$$\mathbf{X = A{*}Irr + B{*}Irr^2 + C{*}Irr{*}T_{amb} + D{*}\ Irr{*}WS}$$

where: **X** = system output power, kWac;
Irr = irradiance, W/m^2;
$\mathbf{T_{amb}}$ = ambient air temperature, degrees C;
WS = wind speed, m/s.

A, B, C, D are regression coefficients that are estimated statistically from a regression of the actual data. A system rating can then be calculated by substituting the PVUSA standard conditions of 1,000 W/m^2 irradiance, 20 degrees C for T_{amb}, and one m/s for WS.

Having estimated the coefficients A, B, C, and D for a given installation, the power output X can be calculated for that particular system, not only for PTC but for any conditions.

AC ratings, in theory, were estimated by the procedure described above, with extensions to those similar systems on which measurements were not made. Venture conversion ratios from DC (STC) to AC (PTC) varied widely, when battery systems and AC modules are excluded. The shortfall of output of the comparison gave an unexpectedly large range, from four percent to 45 percent.

TEAM-UP required one of every ten PV systems installed to include a data acquisition system (DAS). Some participants of the program followed that requirement, but several did not. For those residential systems on which data acquisition systems are operating, measured DC to AC conversion ratios are summarized in Table 1. Measured conversion ratios are lower than the values estimated by the ventures. Based on these empirical data, the shortfall between STC and actual output ranges from 15 percent to 54 percent, calculated as one minus the values in Table 1's fourth column.

Measured energy production for the same sites, on both a monthly and daily basis, is presented on the SEPA web site (www.solarelectricpower.org). The data are noted, along with a performance index (PI), using measured hourly site conditions. These PI values measure how well each site meets the energy production that theoretically should be generated. They should average 1.0, but these PI values, which do vary from day to day, are consistently less than 1.0. This suggests that either:

- Systems are producing less energy than they should,
- Measurements are faulty, or
- The equation used to estimate power is inaccurate.

Table 1: Measured DC (STC) to AC (PTC) Conversion Ratios

Location	AC (PTC) Rating (kW)	DC (STC) Rating (kW)	DC to AC Conversion Ratio	Modules
Sylmar CA	1.2	1.53	0.784	18 BP585
Sylmar CA	1.3	1.53	0.850	18 BP585
Vacaville CA	2.9	4.60	0.630	40 AP1206
Belmont CA	2.8	4.80	0.580	64 APX75
Sacramento CA	3.3	5.76	0.573	90 MSX64
Davis CA	3.0	4.61	0.651	72 MSX64
Sacramento CA	2.9	5.38	0.539	84 MSX64
Sacramento CA	2.1	4.61	0.456	72 MSX64
Sacramento CA	4.3	6.14	0.700	96 MSX96
Truckee CA	1.3	2.16	0.602	180 AP-G
Carmichael CA	0.7	5.60	0.130	128 MST43MV
Denver CO	1.7	2.40	0.710	32 SP75
Pueblo CO	2.0	3.84	0.521	60 MSX64
Minnetonka MN	2.1	2.85	0.737	10 ASE300-DG50-285
Rosemont MN	1.8	2.28	0.789	8 ASE300-DG50-285
White Bear	2.1	2.85	0.737	10 ASE300-

Lake MN				DG50-285
Las Vegas NV	2.8	4.22	0.664	66 MSX 64
Lakewood CA	1.6	2.56	0.625	32 AP8225
Austin TX	1.3	1.80	0.720	24 SP75

Source: SEPA web site: www.SolarElectricPower.org

Data Used for this Analysis

Data have been collected for more than 600 residential PV projects installed by the 11 different TEAM-UP ventures listed in Table 2. These installations total approximately 1,200 kilowatts of alternating current (AC) generating capacity. Not all systems are used for all of the analysis because data were insufficient, missing, or lacking in some areas.

TEAM-UP ventures were led by a variety of organizations, including PV installers, equipment suppliers, system integrators, utilities, and PV manufacturers. Ventures that installed residential systems are shown in the Table 2, organized by the Rounds in which they received funding. All ventures consisted of collaborative groups, most with utilities involved.

Table 2: Venture Leaders Participating by Round

Round 1	Round 2	Round 3
Ascension Technology (now Schott Applied Power) CUPV – Sacramento Municipal Utility District UtiliCorp United	Ascension Technology (now Schott Applied Power) CUPV – Sacramento Municipal Utility District Evergreen GPU Solar Solarex Uni-Solar	Altair Applied Power Corporation (now Schott Applied Power) Ascension Technology (now Schott Applied Power) BP Solar GPU Solar Tucson Coalition for Solar

Half (50 percent) of all the residential projects were installed in California, 10 percent in Colorado, and the remainder in other states. Chart 1 illustrates the distribution of the residential systems by state. The seven states with the most residential TEAM-UP installations are shown, the remaining are grouped in the “Other” category. Residential systems tended to be installed in areas that offer financial incentive, as seen by the large number of systems in California.

Chart 1: Distribution of Residential Installations Throughout the U.S.

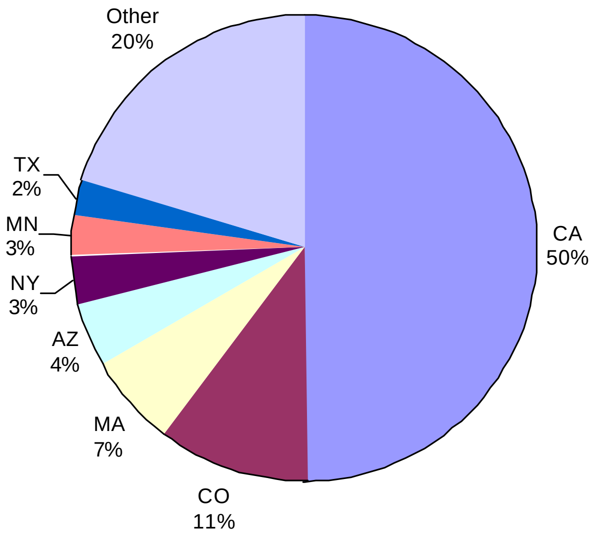


Table 3 lists all of the states with TEAM-UP installations, plus the number of systems and amount of kilowatts generated. Most regions of the U.S. are well represented, the notable exception being the Midwest, where few systems were installed.

Table 3: Installations by State

State	Number of Installations	Kilowatts
Alabama	1	0.72
Arizona	28	36.68
California	319	881.73
Colorado	69	91.16
Connecticut	1	1.42
D.C.	1	2.78
Delaware	6	10.95
Florida	5	9.5
Idaho	1	4.6
Indiana	1	0.82
Maryland	5	7.64
Massachusetts	42	27.03
Minnesota	17	4.36
Nevada	5	11.75
New Hampshire	8	17.48
New Jersey	1	1.90
New Mexico	3	2.78
New York	22	16.60
Ohio	3	3.38
Pennsylvania	2	0.76

Rhode Island	2	2.28
Texas	16	29.5
Utah	3	5.6
Vermont	7	12.54
Washington	1	1.23
West Virginia	1	0.82
Unknown	74	46.4
Total	**644**	**1,232.44**

Ventures participated in various Rounds from 1995[3] to 2000. Some ventures installed systems only in one Round, whereas one (Ascension, now part of Schott Applied Power) installed systems in all Rounds and all years. Tables 4 and 5 show the number of installations and kilowatts installed by Round and by year.

Table 4: Installations by Round

Round	Number of Installations	Kilowatts
1	94	358
2	248	536
3	302	338
Total	644	1,232

Table 5: Installations by Year

Year	Number of Installations	Kilowatts
1996	91	350.93
1997	83	309.08
1998	65	83.05
1999	201	296.30
2000	199	183.14
Unknown	5	11.00
Total	644	1,232.00

The TEAM-UP program funded 644 residential systems, totaling 1,232 kilowatts. Of those systems, 73 included energy storage batteries. Most installations were made on the roofs of existing houses (443 known roof retrofits), but four were ground-mounted and at least 89 were installed in new residential construction. Three were installed on patios or

[3] Although Round One began in 1995, no systems were installed until 1996.

arbors, at least one was made with PV shingles, and several were made on standing seam metal roofs.

All major silicon module technologies were represented in the mix of installations. Conventional modules from seven different manufacturers were used, along with equipment from three inverter manufacturers and three models of AC modules. AC modules are standard PV modules with inverters mounted directly on the back of the module, which eliminates the need for DC wiring and reduces the labor cost of installing a system. AC modules utilize module-size inverters, which are smaller than more conventional inverters. Four installations with Evergreen modules were equipped with module-sized AES inverters (two each) and module-sized Trace Micro-Sine inverters (also two each); Ascension installed 24 module-mounted SunSine inverters.

Prodigy Homes in Sacramento, CA using Atlantis Solar roof tiles under the SMUD venture

Table 6: Module Manufacturers

Ascension AC Modules
ASE
AstroPower
Atlantis
BP
Evergreen
Siemens
Solarex
Uni-Solar

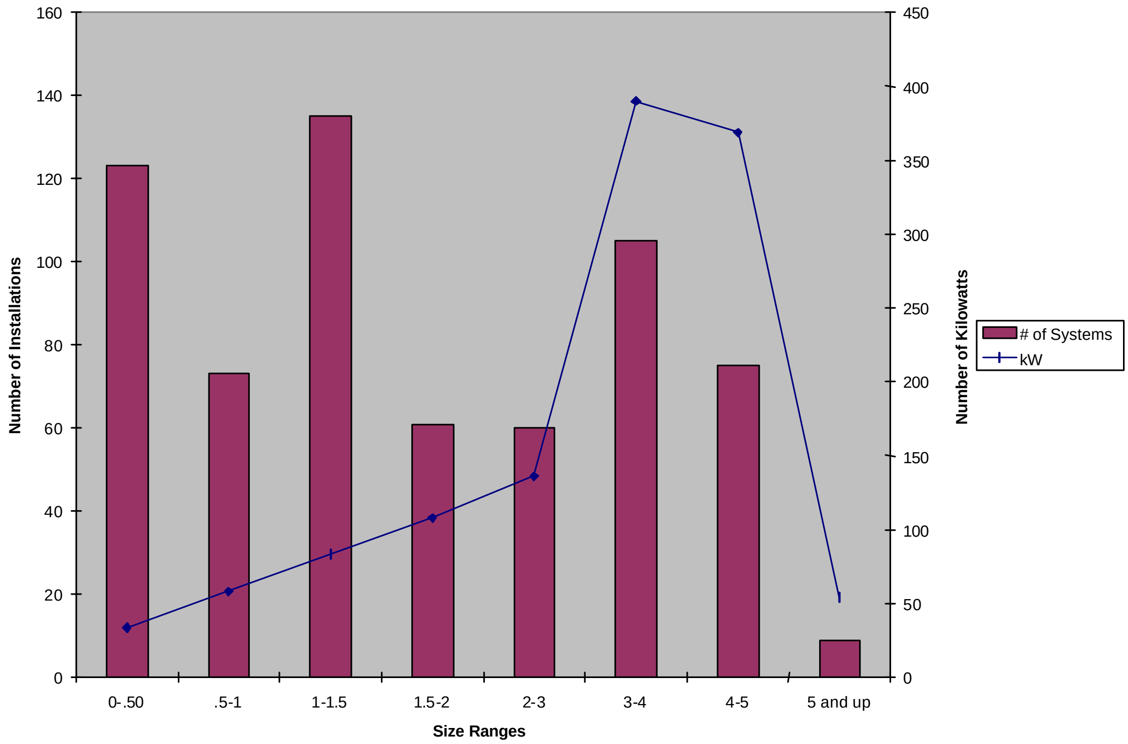
Important components of the TEAM-UP program are demonstration and validation of hardware, and building confidence in this new hardware. Confirming the industry's expansion from one Round to the next, a wider technological variety of equipment was employed. By Round Three, nine module manufacturers provided equipment, and the number of AC module suppliers had increased from zero in Round One to three in Round Three. Tables 6 and 7 show both the module and inverter manufacturers used for the residential systems installed under TEAM-UP.

Table 7: Inverter Manufacturers

ASE
Omnion
Trace

System sizes, as measured by their PTC ratings, ranged from 300 watts to more than eight kilowatts. The majority of these residential projects were smaller than five kilowatts, which corresponds to the average residential roof areas available for PV systems.

Chart 2: Number of Installations and Kilowatts by Installation Size

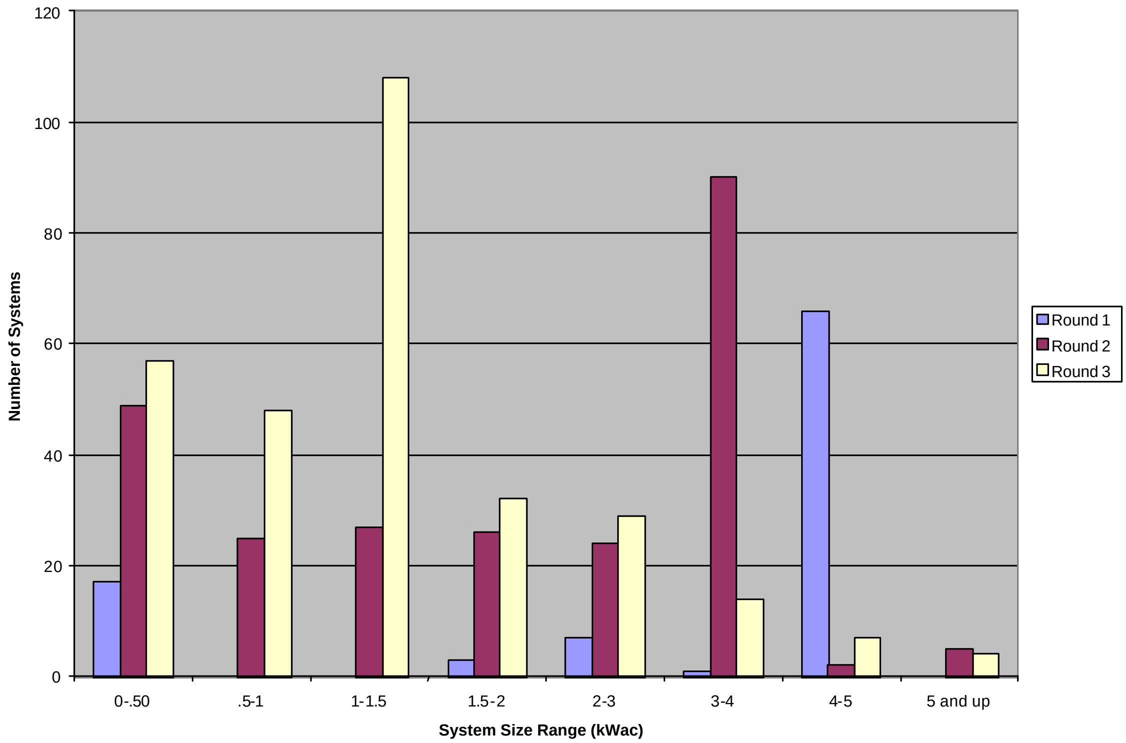


In terms of number of systems installed, Chart 2 shows that the majority of systems were less than two kilowatts. Relatively few systems were larger than four kilowatts. Installations greater than three kilowatts comprised the bulk of the kilowatts installed.

Installed capacity showed an interesting pattern when examined by both TEAM-UP Round and Installation year. As shown in Chart 3, the majority of Round One installations were in the four- to five-kilowatt range. Round Two installations are more evenly distributed over the size ranges, but most fell in the three- to four-kilowatt range. However, Round Three systems were mostly less than 1.5 kilowatts. Chart 3 shows that each Round is dominated by one particular size category, and this decreases for each Round. Tables 4 and 5 show that, while the number of systems installed increased by Round and by year, the total kilowatts installed decreased. By Round Three, ventures were installing many small systems, often less than one kilowatt, for an installation total of 302 systems and 338 kilowatts. It appears that the ventures evolved from customized, larger, residential systems in Round One, to smaller, standardized systems in Round

Three. Many of these Round Three systems were AC modules that were 500 watts or less.

Chart 3: System Size Compared to Round



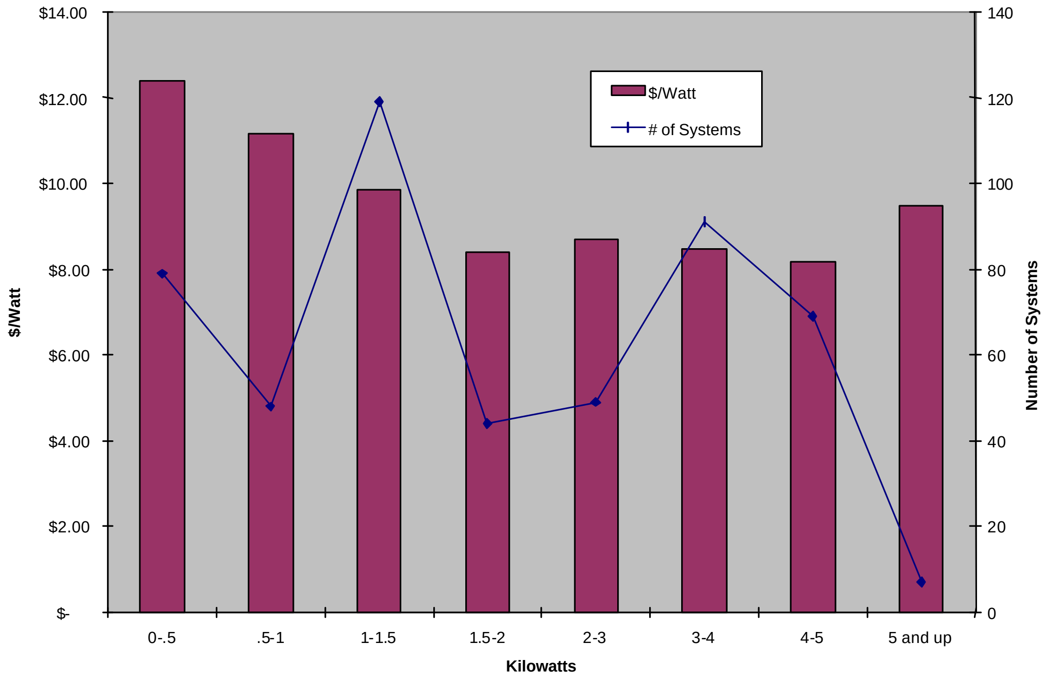
Trends and Comparisons

This report examines the costs from the 644 residential systems installed as part of TEAM-UP, and attempts to establish trends in these costs. There is a great deal of variation between the costs of residential systems, due to system location, module manufacturer, module type, installation, use of batteries, and other factors.

SYSTEM COST COMPARED TO KW RATING

Chart 4 illustrates the cost per watt for the residential systems when organized by size. As is expected, system costs are notably higher per kilowatt for systems less than 1.5 kilowatts (AC) in size. The total cost for systems larger than 1.5 kilowatts are relatively level. Smaller systems must incorporate installation and overhead costs, making the cost per watt higher. Also, many of the smaller systems are AC modules, which usually cost more, as shown in Chart 6.

Chart 4: Average $/Watt by Installation Size



As Chart 4 illustrates, there are only a few systems that were larger than five kilowatts. Because of these few data points, the slight increase in cost for systems larger than five kilowatts is most likely due to insufficient data.

COSTS OVER TIME AND BY ROUND

As noted previously, cost-share funding was supplied to the ventures in a series of three Rounds, beginning in 1995 and continuing through 2000. The three Rounds overlapped; therefore, looking at data by Rounds may not show as clear a trend as examining the data by year.

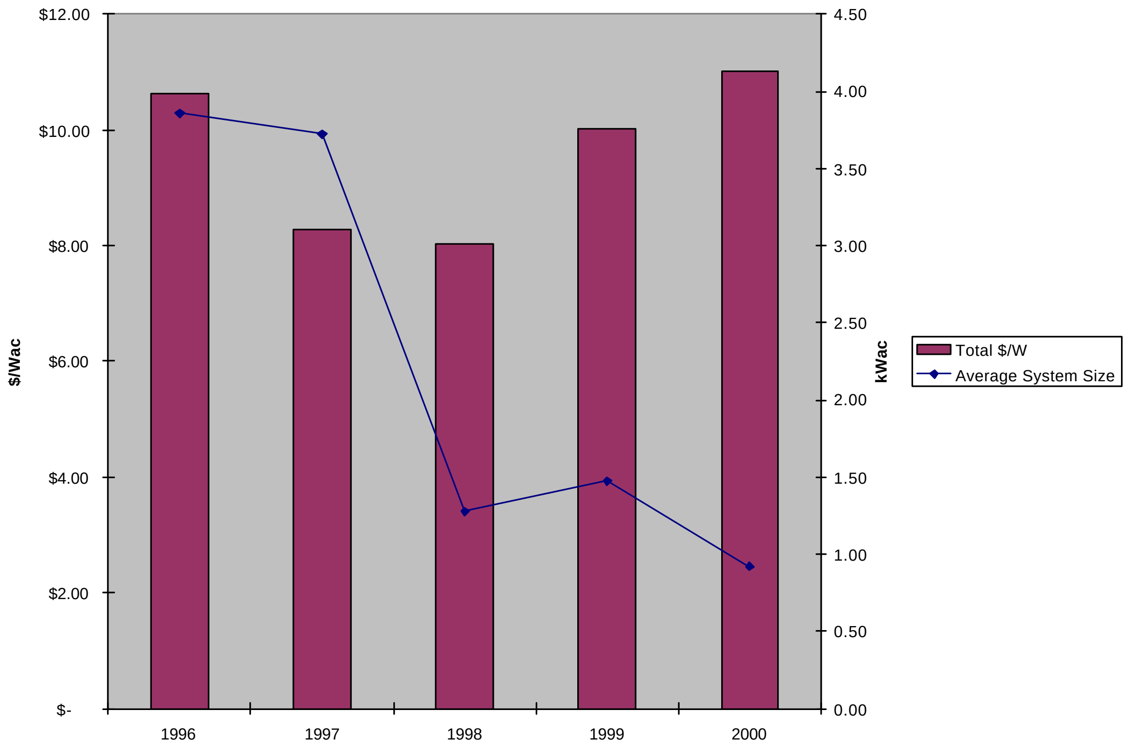
Table 8: System Costs by Year and Round

	Total $/W
1996	$ 10.63
1997	$ 8.27
1998	$ 8.02
1999	$ 10.02
2000	$ 11.00
Round 1	$ 10.63
Round 2	$ 9.23
Round 3	$ 10.62

PV costs are assumed to decrease over time, and this is often the case. However, the data on the TEAM-UP residential systems actually shows an increase over time, as seen in

Chart 5. Chart 5 also shows the average system size installed each year, which decreased steadily, with a slight exception for 1999. Systems smaller than one kilowatt were shown to cost more on a dollar-per-watt basis, which may somewhat explain why costs increased significantly in 2000, and to some extent in 1999. Additionally, many of the systems installed in 1999 and 2000 were AC modules, which have a higher cost. One venture that installed very low cost systems in both Rounds One and Two did not install any in Round Three. This venture's systems may have artificially lowered the cost per watt averages in 1997 and 1998, which is when the bulk of their systems were installed. Most likely, costs per watt are not increasing, but are staying relatively stable.

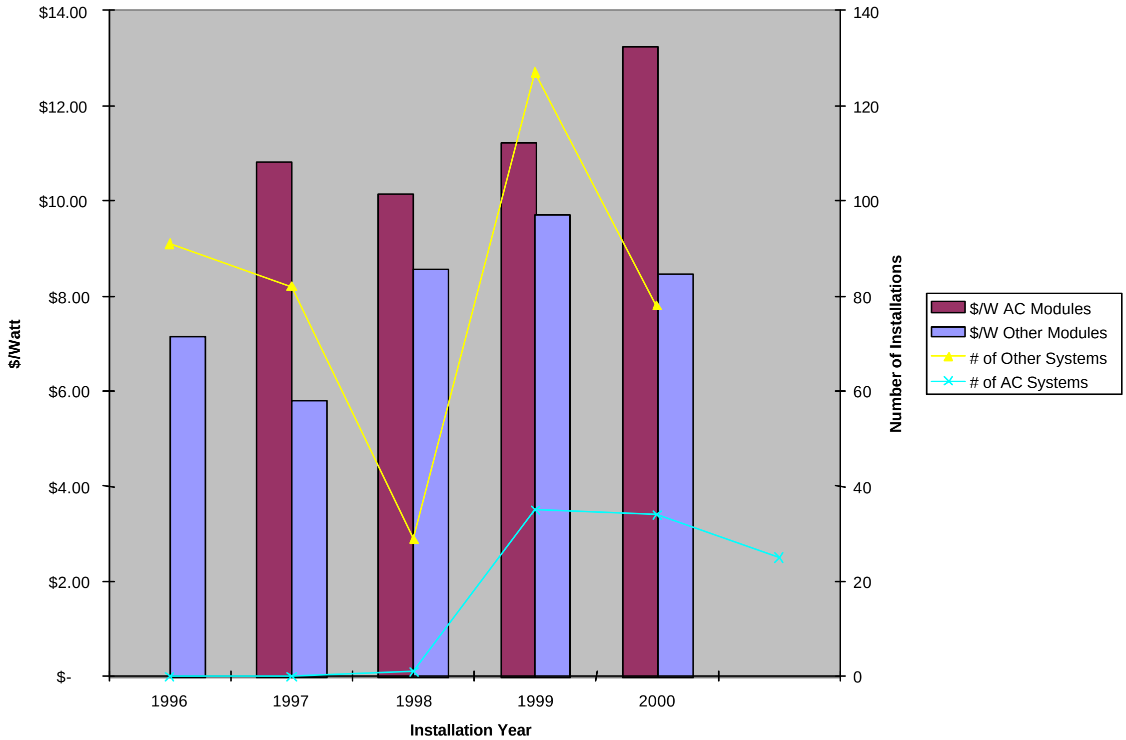
Chart 5: System Size and Cost per Watt Over Time



AC MODULES

Several ventures developed AC modules for use in their TEAM-UP projects. These AC module systems were more expensive than standard systems, as illustrated in Chart 6. Most of the AC modules used in TEAM-UP were relatively new products, which contributed to their higher cost. Additionally, systems using AC modules were usually small, less than one kilowatt. The cost analysis in this report includes the AC modules and, when examining the data, this must be noted to understand the trends.

Chart 6: Systems with AC Modules Cost vs. Other Systems Costs

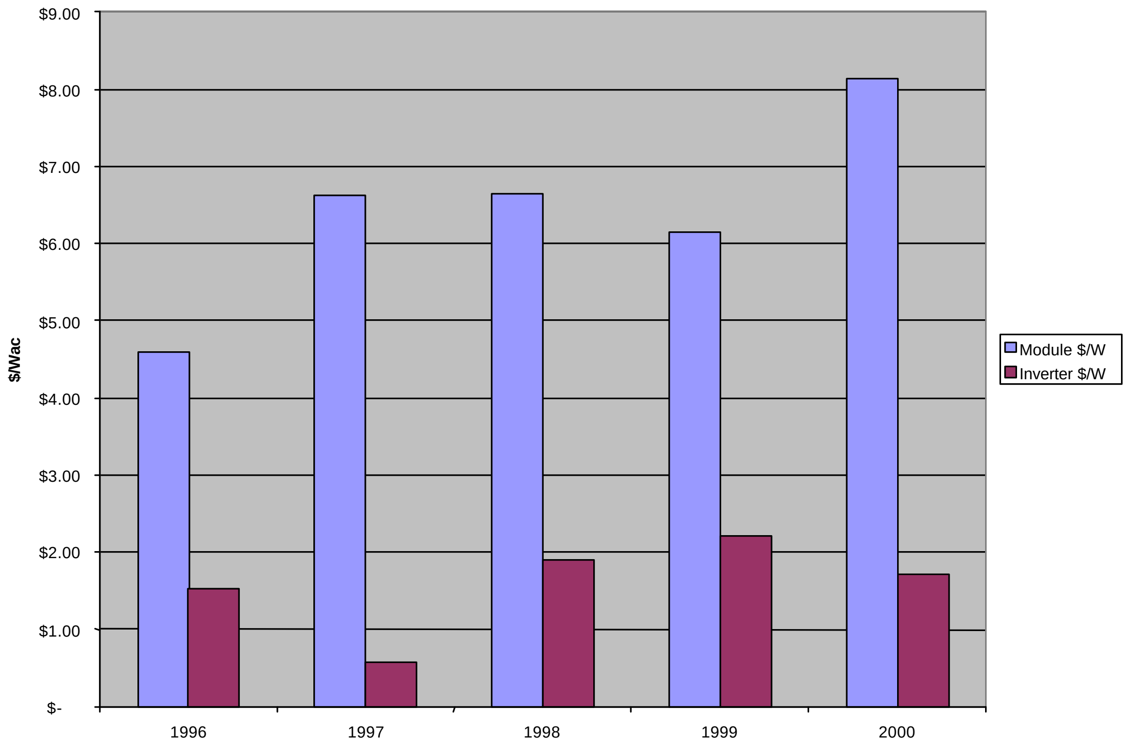


COMPONENT COSTS

It is difficult to get an accurate view of cost trends by a breakdown of components because there was a great deal of variation in the way the ventures reported component costs. Therefore, only the modules and inverter costs, which were the most accurately reported, are examined here.

Chart 7 shows fluctuation in both module costs and inverter costs. Much of this fluctuation can be attributed to factors mentioned previously in this report, including AC modules, venture participation, and system size. Module costs ranged from a low of $3.88/W to a high of $10.42/W (for AC modules) and inverter costs ranged from a low of $0.57/W to a high of $5.63/W. A possible explanation for the irregular component costs is that many of the systems were rated below expected performance, increasing the cost per watt.

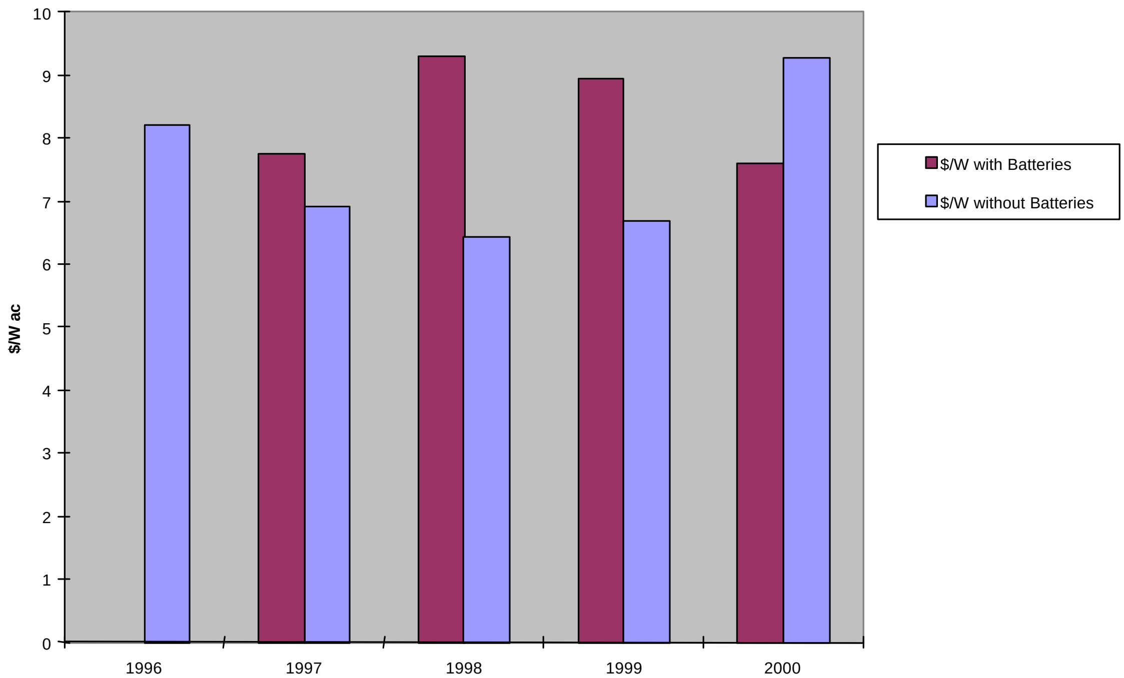
Chart 7: Component Costs Over Time[4]



Often residential systems include battery back up because the homeowner desires reliable energy. Of the 644 systems installed under TEAM-UP, 73 included batteries. Chart 8 shows that, in each year, the systems with batteries cost more than systems without. The exception is 2000. Many of the systems installed without batteries in 2000 were small systems, and many were AC modules, both of which, as shown in Charts 4 and 6, cost more on a per-watt basis. The systems installed with batteries in the year 2000 were, with the exception of one, all larger than one kilowatt (AC).

[4] Many ventures only reported turnkey costs; therefore, Chart 7 does not include as much data as most of the other analysis. Because of that, the trends in Chart 7 may not be as significant as other charts and tables included in this report.

Chart 8: Hardware Costs for Systems with Batteries Compared to Those Without



VENTURE EXPERIENCE COMPARED TO SYSTEM COST

Charts 9 and 10 examine the impact of the kilowatts and the number of systems installed per project on the average system cost per watt. Both charts show a decline in cost as either the kilowatts or the number of installations increases. (The one exception, which installed 77.12 kilowatts and 88 systems, used AC modules for the majority of its systems.) These ventures probably attained the lower cost by bulk purchasing and signing long-term contracts. Additionally, as ventures gain experience from installing many systems, those PV systems are more likely to be rated at or near the expected level, making the cost per watt easier to predict.

Chart 9: Total Cost Compared to the Kilowatts Installed by Each Venture

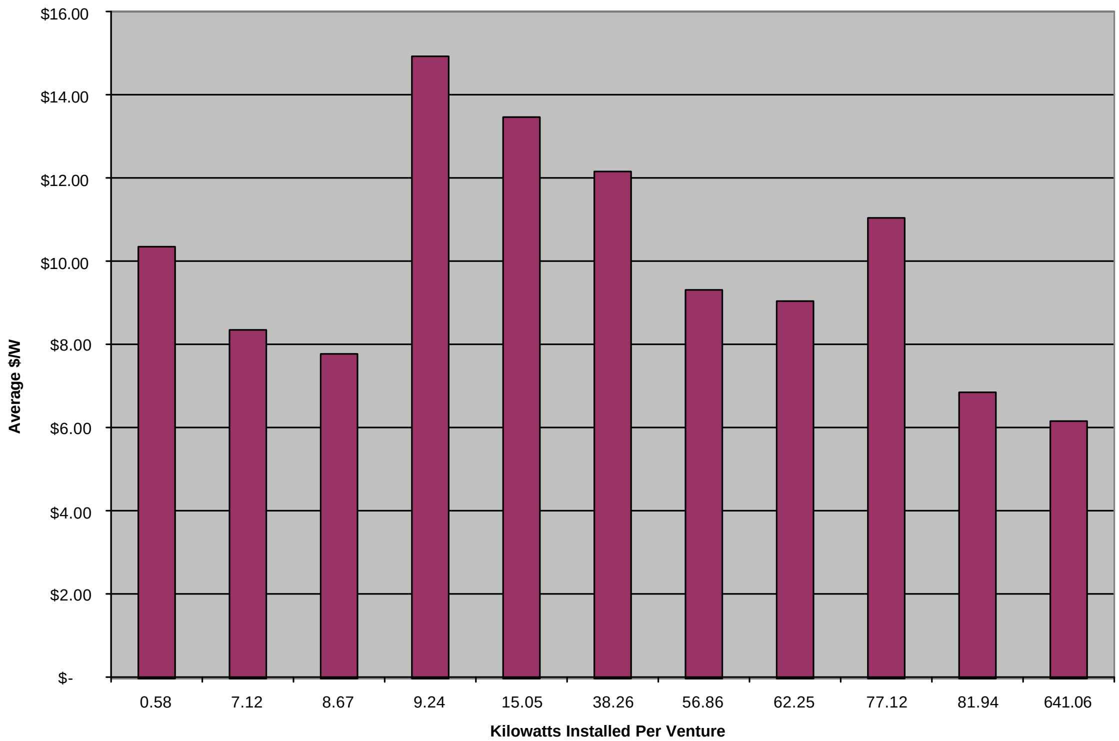
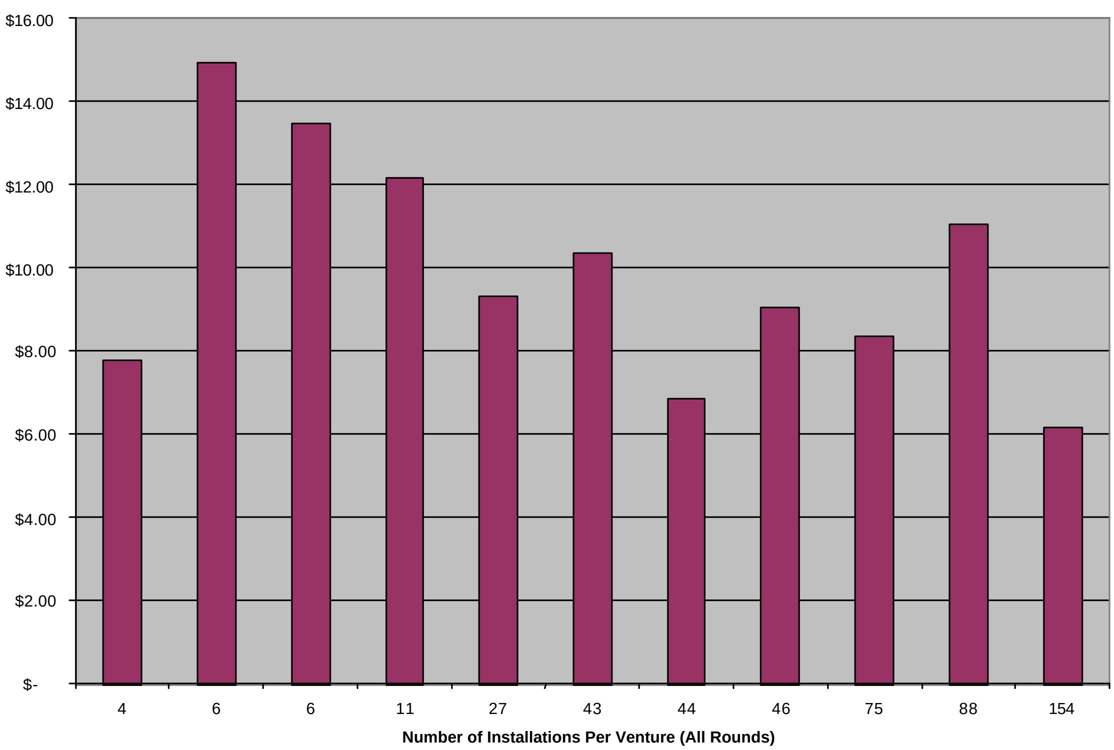


Chart 10: Total Cost Compared to the Number of Systems Installed by Each Venture



Conclusions

At first glance, much of the data indicate that costs are increasing for residential systems. The high degree of variation in installed PV system costs may indicate that residential systems differ in too many ways to accurately compare such systems. Additionally, the residential PV projects changed a great deal from Round One to Round Three, and it is difficult to compare costs over this time period without considering these changes.

Round One installed larger residential systems at a relatively low cost. The following two Rounds shifted from larger systems to smaller systems. As ventures became familiar with residential PV systems, they began to branch out into previously unexplored territory to find their niche market. A few ventures began using AC modules that are also higher priced but more easily installed and are well adapted for residential systems. By Round Three, several ventures had begun working with homebuilders to install PV systems on new homes.

Many ventures focused on areas where buy-down programs were available for residential customers. As these programs continue to expand, the demand for residential PV systems will increase. This will provide a prime opportunity for the PV industry to expand projects and help to bring the cost of residential PV down.

Currently, many ventures are trying out experimental approaches to residential PV. As utilities, installers, the PV industry, and the public gain experience with residential PV projects, costs will begin to stabilize and then to decrease. Until that time, project leaders who are new to PV may have difficulty minimizing costs, PV module and inverter prices may fluctuate for small purchases, and inexperienced installers may have dramatically higher labor costs. Finally, many projects received a lower than expected output rating, increasing the cost on a per-watt basis. It appears that all of these factors result from the relatively small role of PV in the U.S. electricity market. These problems should become less severe and less common as PV commercialization advances and utilities and installers gain more experience with PV technology.

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