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QUARTERLY TECHNICAL REPORT

First Quarter 1996

By
PVUSA Project Staff

Pacific Gas & Electric Company
Research and Development Department
San Ramon, CA 94583

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PHASE II -- PHOTOVOLTAICS FOR UTILITY SCALE APPLICATIONS (PVUSA)

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PVUSA Project Staff

**Pacific Gas & Electric Company
Research and Development Department
San Ramon, CA 94583**

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I. SUMMARY

This is the first of three planned quarterly Technical Reports of 1996 system performance and major project activities. The final quarter will be discussed in the 1996 Progress Report.

Activity for the PVUSA project was curtailed considerably, pending resolution of the transfer of management to the California Energy Commission (CEC) and the Sacramento Municipal Utility District (SMUD). Principal activities during the first quarter of 1996 included:

- Continued negotiations regarding the transfer of project management from PG&E to the joint CEC/SMUD team. Primary remaining hurdle is obtaining approval from the California Public Utilities Commission.
- Provided training to CEC and SMUD project team members on January 8, 9, and 11. Training covered site operations including data acquisition.
- Completed the draft of the 1995 Progress Report.
- Supported the contractor in their efforts for enhancing the performance and reliability of the Amonix EMT-3 array at Davis.
- Reviewed the PSCo installation drawings, and started activities to provide the PVUSA DAS equipment.
- Operation and maintenance of existing systems, including data collection and reporting.

Data were collected for 19 completed systems with a combined capacity of 1,800 kW. Combined, these systems generated nearly 1.1 million kWh during January through March. The project's cumulative generation now stands at 8.2 million kWh. Key cumulative 1996 results are listed in the following table. The locations of systems other than Davis are noted alongside the supplier's name.

Emerging Module Technologies 1995 average = []	Efficiency %	Capacity Factor %	Performance Index ¹ %
Amonix	n/a	n/a	n/a
AstroPower	5.6 [5.5] dc	17 [20]	97 [94]
ENTECH	10.0 [10.1] dc	15 [19]	87 [75]
Solarex	7.7 [7.1] dc	13 [16]	84 [83]
Sovonics	2.1 [2.5] dc	13 [17]	90 [91]
Sovonics (Maui, HI)	3.3 [3.3] dc	15 [20]	100 [97]
SCI	6.5 [6.5] dc	17 [14]	100 [99]
SSI	9.9 [9.7] dc	13 [17]	88 [92]
UPG	2.9 [2.9] dc	15 [17]	100 [91]
Utility Scale Systems 1995 average = []			
APS	3.4 [2.8] ac	10 [13]	68 [73]
ENTECH (Fort Davis, TX)	9.1 [n/a] ac	5 [14]	16 [n/a]
IPC	7.9 [7.2] ac	14 [11]	76 [40]
IPC (Austin, TX)	7.9 [7.6] ac	8 [16]	45 [77]
IPC (Farmingdale, NY)	n/a [7.8] ac	n/a [7]	n/a [38]
IPC (Maspeth, NY)	2.4 [3.0] ac	2 [10]	21 [84]
SSI	8.4 [9.7] ac	12 [15]	67 [57]
SSI (Kerman, CA)	7.4 [8.1] ac	7 [13]	45 [51]
UPG (Fort Davis, TX)	10.6 [8.5] ac	est. 25 [18]	98* [63]
UPG (Sacramento, CA)	8.4 [10.1] ac	13 [21]	70 [81]

* Based on March 1996 data only

II. PROJECT MANAGEMENT

1. Schedule Analysis and Transition Activities

The Amonix EMT-3 system has been accepted by PVUSA using a provisional rating. Final rating is on hold until weather conditions are appropriate and all necessary repairs/improvements have been completed.

The New World Power (NWP) host system for Public Service Company of Colorado schedule has been delayed from the end of April until June due to delays in delivery of structural components.

Systems to be installed:	Original Estimated Completion Date	Current Forecast Completion Date
PSCo (NWP)	December 1994	June 1996
DOD (UPG)	October 1995	August 1996

The transition of PVUSA to the CEC continued working its way through the many necessary steps. Many questions were raised at the January 17 CEC Business meeting concerning the assumption of responsibility for PVUSA. Commissioner Sharpless questioned the availability of net metering and was also strongly against the CEC looking like or becoming an actual qualifying facility. Changes to the contracts, and in particular the power

¹ Defined as the percentage of actual to expected generation. The expected generation adjusts for ordinary differences between actual and rated output caused by variations in insolation and temperature, as well as shortfalls related to scheduled outages, long-term degradation, and BOS limitations.

purchase agreement, were eventually made to eliminate all references to a qualifying facility. Direct payments for power were eliminated in favor of an annual membership contribution based on the net value of the power.

PVUSA was again brought before the commissioners at the February 14 meeting. The seven agreements (all but one involve PG&E) were approved with an added stipulation, requested by Commissioner Rohy, that additional soil analysis be made to further establish baseline conditions prior to CEC assumption of liabilities.

The CEC approval was a major milestone which allowed the transition to move forward. However, on February 8, the CPUC informed PG&E that they expect PG&E to file an application for the contribution of the assets to the CEC (Code section 851). Filing of the application is expected mid-June. CEC has preferred to wait for CPUC approval rather than enter into a licensing agreement which would allow operation by them to begin sooner.

The Utility PhotoVoltaic Group (UPVG) issued an RFP for software, collection and analysis of data for their sponsored systems. PVUSA has some of the best expertise in this area. The Executive Committee discussed the resources, expertise, etc. and endorsed PVUSA responding with a proposal. No one in the TRC or SC responded with any concerns or votes against PVUSA involvement. PVUSA then prepared and submitted a bid on March 22. PG&E signed the proposal on behalf of PVUSA, but clearly indicated that if awarded, a contract would need to be signed with the new management. This activity would be wholly funded by UPVG. (In April, PVUSA was notified that we were not the selected bidder.)

2. Cost Analysis and Funding Activities

At the end of the quarter DOE approved and released another \$83,000 per a request for extension. The extension allows the project to continue at the current reduced level through June. Public Service Company of Colorado fulfilled their requirements for obtaining a refund of membership dues. (TRC found merit and value in their host system in March. This was the final requirement.)

Expenses for 1996 under PG&E are forecast at \$600,000 assuming project transition to CEC/SMUD by June 30, 1996 with cleanup and audit support by PG&E thereafter. (Last year's expenses were approximately \$2.6 M.) This includes final payments made to both Amonix and SCI (for EMT-3 systems, total \$70,000) and final payments to Bechtel, which completed its contract at the end of March. Presently, PG&E and DOE are the only sources of funding.

3. Principal Activities

Principal activities over the January-March 1996 period are detailed below for the Davis, Kerman, and host sites, and for general project activities. The focus for this section is on procurement, engineering, construction, and planning activities. Maintenance activities for operating systems are discussed in Sections III (Davis systems) and IV (Kerman and hosts).

Davis

Starting January 19, PVUSA began a period of reduced operation pending transfer to the CEC. Bechtel relinquished site custodial responsibility to PG&E, who in turn assigned it to Endecon Engineering. Minimal site operations have been carried out since then. There were no engineering or construction activities this quarter, other than supporting Amonix contractors in January and March. Bechtel closed out open subcontracts and purchases and ended procurement and engineering support at the end of the quarter. Documents, such as drawings, specifications, and correspondence relating to site operations and maintenance were transferred to the

Davis site. Bechtel archived all other documents, which may be retrieved if necessary, with a two-day turnaround time.

Site personnel completed the first draft of the 1995 Progress Report, begun in the fourth quarter of 1995. Minimum site maintenance was conducted. The site continued to give tours, although the number and size of tour groups have decreased. Testing of fire extinguishers and hot sticks was completed during the quarter. First aid and CPR training for site personnel will be done this coming quarter.

The Amonix array received significant attention this quarter. Two basic activities were carried out. First, Amonix tried to systematically determine the root cause of and fix the lower-than-expected power output. The second task was geared to resolving tracker operational problems.

The Amonix array was accepted as construction-complete on October 12, 1995. Amonix was allowed, as were other PVUSA PV contractors, to work on their system with the intent to improve system performance. The work performed by Amonix late last year uncovered a misalignment of the array at its north-west corner. Structural deformation was suspected; corrective measures were done, but had minor impact on the power output. Winter weather hampered diagnostic efforts by Amonix.

In early January, Scientific Engineering, a subcontractor to Amonix, was on-site and continued to monitor the performance of the array. The final rating was postponed until the spring, after Amonix has had an opportunity to improve their array performance. PVUSA required them to vacate the site after Bechtel management terminated on January 19, but established an agreement which allowed them to return in March. Amonix still is not pleased with the overall performance of the array, and hopes to perform more work in the spring before a research rating is determined.

At the end of January, the tracker developed a problem. As the array moved down in elevation, it did not come to an immediate stop, but continued to coast. On one occasion, the array hit the dc disconnect switch located at the base of the array pedestal.

On February 28, Amonix proposed to upgrade the controller board to incorporate an "electric brake circuit" which turns the dc motor into an electric brake if it overshoots a predestined position. After the tracker was put back in service, Amonix planned to obtain IV curves to assist them in identifying the cause of low output performance. PVUSA accepted the proposed upgrade and Amonix was on-site from March 11 through March 19. Amonix upgraded the tracker controller with an electric brake circuit, and obtained IV curves. During this same period, Amonix replaced several suspect receiver plates.

The Amonix array was operational between March 19 and March 25. During this time some data were collected. The raw data are a small sample, but Amonix has detected an anomaly in array power that may be related, in part, to the inverter's peak power operation. PVUSA will re-investigate the PCU's peak power function after the system is back in service.

On March 26, the tracker failed to wake up. The problem has not yet been resolved. Amonix is committed to determine the cause of the system's low performance and address the tracker problems that the system is encountering.

The Kenetech PCU for the IPC US-1 array operated without incident from January 1 until March 27, when an IGBT failed. Repairs are scheduled for early April. The Dickerson inverter for the SSI US-1 array operated satisfactorily with minor interruptions, two caused by utility transients and three shutdowns which required a manual reset. The APS System operated satisfactorily with minor interruptions -- four manual shutdowns for storms and three instances of not automatically waking up, one caused by a utility transient.

Except for Amonix, the other seven EMT systems operated satisfactorily with minor interruptions, mostly due to resettable PCU synchronization errors in the mornings.

Kerman

The Kerman system saw significant downtime this quarter, generating only 45% of the energy that was expected over the past three months. PCU # 2 operated with 6 (out of 8) source circuits during this quarter, and PCU # 1 has been shutdown and left shut down for half of January and the entire months of February and March. Accordingly, many of the activities reported over the past three months were maintenance-related issues. These are discussed in Section IV.2. A voltage imbalance in the dc source circuits of inverter #2 was eliminated by opening the associated source circuits. Investigation by a Fresno electrical technician showed shorted movistors and cleared movistor fuses.

Austin

The Austin PCU has been tripping on "Reg/Crowbar Fault." These inverter problems resulted in a 25 to 30 percent loss of energy for January. Due to problems with the telephone line, about 6 percent of the quarter's data was lost. Data problems continued in February, including a period of four days when the datalogger was inadvertently collecting data at five-second intervals rather than calculating 10-minute averages.

The Austin host system was mostly unattended this quarter, as the engineer normally assigned to maintain it (Leslie Libby) was on maternity leave for most of February and March.

Farmingdale

The site's PCU, tracking system, and DAS have each been down since September 1995. NYSERDA has enlisted AWS Scientific to assess the situation and develop recommendations. IPC/Omnion have agreed to modify the PCU controls. Other issues remain to be addressed.

Ft. Davis

In order to help Central and South West (CSW) catch up on O&M and reporting tasks, Tim Townsend took a leave of absence from his work at the PVUSA Davis site to assist Brian Champion from late February through May.

The ENTECH system was returned to full power operation on March 15 after a dc combiner box was rebuilt and replaced. The combiner box failed in November, with smoke and fire damage originating at a fuse block wire terminal. The array had been operating at half power while the box was being rebuilt.

On the UPG system, a problem with unreasonably high ac power data that had persisted since September 1995 was resolved in late February after a degraded burden resistor was identified and replaced.

Maui

Communications were lost on February 26 when telephone lines were moved during unrelated nearby construction. Data collection resumed on March 26, at which time data from March 20 onward were collected.

NREL/NYPA

Through January, system efficiency continued to fall, indicating a gross array problem. Data communications were interrupted briefly in February, but no data were lost. The system stopped functioning on February 12. Few

details on the failure have been communicated to PVUSA, but USSC has been tasked with fixing the system, and has scheduled work to begin in mid-May.

General

The abstract intended for the May 1996 IEEE PV Specialists Conference covering regression-based PV models was postponed indefinitely due to insufficient resources.

4. Technology Transfer Activities

Publications, Conferences, and Meetings

Chuck Whitaker attended Soltech '96 in Palm Springs in April.

An paper titled "PVUSA -- The First Decade of Experience," was submitted in March for the upcoming May 1996 IEEE Photovoltaic Specialists Conference.

The draft of the 1995 PVUSA Progress Report was completed, reviewed by the project team and TRC, and was in final editing by the end of the quarter.

Site Tours

During the first quarter of 1996, PVUSA hosted 7 tours of the Davis site for a total of 35 visitors.

III. TECHNICAL ANALYSIS - DAVIS SITE

1. System Performance

General

Performance data are listed in Table III.1 for eleven Davis systems, including eight EMT arrays and three US systems. DC efficiencies are listed for the EMT arrays and ac efficiencies are listed for the US systems. The insolation totals differ in this table, even for arrays of the same orientation. They differ primarily because this quantity is integrated only when the PCU is on, and the hours of PCU operation vary between arrays. In addition to the instrument uncertainty (typically $\pm 3\%$), there are also small differences in the field of view from each array. Background data for the performance index calculations are listed in Appendix A.

While the months of January and February had somewhat lower than average 30° tilted surface insolation, March had 19% more than average. The high March insolation, coupled with an energy capture of nearly 100% for each system but Amonix, resulted in a record site energy output of almost 112 MWh for March (as much as was produced in August 1995!).

Energy

Figure III.1 tracks the monthly energy supplied by seven of the eight Davis site EMT systems over the past 15 months. Figure III.2 shows the same information for three US-1 systems, including start-up and testing energy delivered during the IPC PCU replacement. The right scales refer to insolation measured at the site weather station (integrated over all hours). On both plots, the 30° tilt insolation is shown as a reference trend for the fixed tilt systems. On Figure III.1, the 1989-95 monthly average 30° tilt insolation is also included, and on Figure III.2, the horizontal N-S 1-axis insolation is included as a reference trend for the IPC and SSI 1-axis tracking systems.

The monthly energy production patterns generally follow the insolation trends, except that the array energy production also reflects outages, limited operation during installation and startup, and seasonal efficiency variations. EMT1 SSI did not follow the overall trend in energy production during March because of a blown dc source circuit fuse that virtually eliminated half of the array.

The Utility Scale systems' generation trends on Figure III.2 are generally less distinct than those of the EMT arrays, partly because these systems use different orientations and also because their capacities differ widely. The regular failures that have marked the operation of these systems were much less pronounced this quarter. Familiarity with the APS PCU's propensity to blow fuses when utility outage events occur, for example, has led to the intentional shutdown of the system during storms. This has resulted in more predictable operation, though PVUSA still does not consider these outages to be "scheduled," as the conditions inducing them (storms) are random.

The SSI system's one active Dickerson PCU, Unit "B," has been in its seasonal "reliable" phase this quarter. During the late spring through fall period, this inverter has difficulty starting in the morning. This quarter, there were only three trouble events. The other notable item for this system is that the data showed an unusually high system and dc efficiencies, an anomaly which we attribute to range-of-motion problems on the row on which the plane-of-array irradiance is measured. At least two of the four rows move more freely than the reference row. Consequently, more insolation was received than indicated, resulting in inappropriately high efficiency. Poor tracker performance is believed to be largely responsible for the system's low performance index of 67%.

The 75% performance index for the IPC system was lower than expected. The dc efficiency was in the expected range, and the Kenetech PCU efficiency is only a few percent lower than expected. The PCU was quite reliable until one of its IGBTs failed catastrophically on March 27. The problem with the low PI appears to be related to a combination of factors: the plane-of-array insolation was 15% below the reference measurement, and the PCU's conservative start/stop threshold limited its operation to just 80% of the daytime hours. Energy losses due to non-ideal tracking are not expected to exceed 5% for the IPC system.. . As the dc efficiency was reasonable and the plane-of-array insolation was probably accurate, there appears to have been tracking problems. The system was down for 7 full days during the quarter. The remaining downtime was attributable to partial day outages and sunrise/sunset PCU idling.

Table III.1
PVUSA Davis Systems: Performance Summary

Characteristics	EMT (dc ratings)								US1 (ac ratings)		
	SSI	Sovonics	UPG	Solarex	ENTECH	Astro-Power	SCI	Amonix	APS	IPC	SSI US-1
Orientation (fixed flat plate, tracking)	30° ffp	30° ffp	30° ffp	30° ffp	2-ax trk.	30° ffp	30° ffp	2-ax trk.	30° ffp	1-ax trk.	1-ax trk.
Initial rating, kW	18.7	17.3	15.7	15.7	16.5	17.1	12.0	n/a	479	196	67
Installation date	1/89	6/89	12/89	10/90	3/91	11/94	9/95	10/95	9/92	6/93	5/94
Module area, m ²	169	497	477	182	172	292	190	159	11520	2443	845

System	Quantity	1994	1995	Jan-Mar '96
SSI	AC kWh	30,141	27,119	5,231
	Performance Index %	88	92	88
	DC eff. %	10.0	9.7	9.9
	AC cap.fac. %	19.1	17.2	13.3
	Insol. kWh/m ²	2,016	1,961	361
Sovonics	AC kWh	24,350	22,489	4,417
	Performance Index %	88	91	90
	DC eff. %	2.6	2.5	2.1
	AC cap.fac. %	17.7	16.2	12.7
	Insol. kWh/m ²	2,076	1,961	364
UPG	AC kWh	26,537	22,464	4,904
	Performance Index %	95	91	100
	DC eff. %	2.8	2.9	2.9
	AC cap.fac. %	20.1	17.0	14.9
	Insol. kWh/m ²	2,083	1,956	354
Solarex	AC kWh	25,915	21,002	4,305
	Performance Index %	90	83	84
	DC eff. %	7.8	7.1	7.7
	AC cap.fac. %	19.6	15.9	13.1
	Insol. kWh/m ²	2,055	1,958	363
ENTECH	AC kWh	27,258	25,745	5,019
	Performance Index %	67	75	87
	DC eff. %	10.7	10.1	10
	AC cap.fac. %	19.9	18.8	14.1
	Insol. kWh/m ²	1,523	1,956	287
AstroPower	AC kWh	1,803	28,785	5,917
	Performance Index %	81	94	97
	DC eff. %	6.0	5.5	5.6
	AC cap.fac. %	10.6	20.4	16.8
	Insol. kWh/m ²	112	1,969	367
Solar Cells, Inc.	AC kWh	n/i	4,519	3,977
	Performance Index %	n/i	n/r	100
	DC eff. %	n/i	6.5	6.5
	AC cap.fac. %	n/i	14.1	16.9
	Insol. kWh/m ²	n/i	378	372
Amonix	AC kWh	n/i	5,341	1,305
	Performance Index %	n/i	n/r	n/r
	DC eff. %	n/i	n/r	n/r
	AC cap.fac. %	n/i	n/r	n/r
	Insol. kWh/m ²	n/i	333	116
APS	AC kWh	650,555	535,129	100,516
	Performance Index %	83	73	68
	AC eff. %	3.2	2.8	3.4
	AC cap.fac. %	15.5	12.8	9.6
	Insol. kWh/m ²	1,757	1,838	312
IPC	AC kWh	168,742	187,335	58,634
	Performance Index %	31	40	76
	AC eff. %	7.8	7.2	7.9
	AC cap.fac. %	9.8	10.9	13.7
	Insol. kWh/m ²	843	1,774	346
SSI	AC kWh	98,995	90,514	17,663
	Performance Index %	60	57	67
	AC eff. %	7.5	6.9	8.4
	AC cap.fac. %	16.3	15.4	12.1
	Insol. kWh/m ²	1,022	2,036	265

(Quantities reflect intermittent pre-June -94 start-up power)

PVUSA DAVIS EMT SYSTEMS RECENT OUTPUT and INSOLATION

Figure III.1

PVUSA UTILITY SCALE SYSTEMS RECENT OUTPUT and INSOLATION

Figure III.2

Efficiency

Figures III.3 and III.4 show monthly average efficiency histories for the EMT arrays and US systems, respectively. DC efficiencies are reported for the eight EMT arrays, and ac efficiencies are reported for the three US systems. Except for the ENTECH array, the efficiencies are calculated as the ratio of monthly energy produced to monthly plane-of-array insolation during hours when the PCU was operating. The ENTECH array, which uses a 22X concentrating lens and two-axis tracking structure, shades portions of itself and its pyrheliometer during the early and late hours of the day. Therefore, its efficiency calculations are based on the hours between 9 a.m. and 3 p.m. PST, when shading does not occur at any time of the year.

While most of the EMT arrays performed consistently with last year's performance, the SSI and ENTECH arrays did not. SSI efficiency dropped more than usual in March because a dc fuse blew and went unnoticed for about a week. ENTECH tracking accuracy drifted in February, requiring a recalibration to bring efficiency back up. Amonix was only operational for a few hours in February due to tracking problems, and Amonix continued to diagnose and determine the cause of the low array output.

Figure III.4 shows the US system efficiencies. The performance of two of the three systems is consistent with their performance over the same period last year, but the IPC system did not experience the same drop in efficiency. The efficiency patterns of the IPC system prior to the installation of the Kenetech inverter were marked by off-performance dominated by the Omnion inverter's mechanism of throttling back the system to avoid overpowering (heating) during peak hours (by switching off source circuits). The Kenetech utilizes the full array at all times and adjusts the operating current to avoid overpower conditions and thus operates more consistently. The efficiency in January and February may actually be lower than expected due to limitations of the peak power tracking algorithm in use by the inverter. This algorithm will be upgraded in the second quarter of 1996.

Figure III.3

Figure III.4

2. Solar/Weather Data

Table III.2 lists several solar radiation, temperature, and wind speed statistics for this quarter, along with data from 1994 and 1995. The global horizontal insolation over this quarter was just 1% below the long-term seasonal average. The average ambient temperature of 11°C, while higher than the seasonal average of 9 ± 3 °C, was not unusually high. The 13" of rain was about the normal amount for the same period. The average wind speed of 3.4 m/s was only slightly higher than the site's six-year seasonal average of 3.1 ± 0.6 m/s ($\pm$ is one standard deviation of the quarterly averages).

Table III.2
Solar/Weather Summary

Insolation, kWh/m ² ; Peak Irradiance, W/m ²	1994	1995	Jan-Mar '96
LT-Avg. global horizontal insolation	1,838	1,838	285
Global horizontal insolation	1,872	1,773	281
Peak 10-min. avg. irradiance	1,156	1,186	1,081
Global 30° tilt insolation	2,122	1,989	382
Peak 10-min. avg. irradiance	1,297	1,209	1,268
Global normal insolation	3,052	2,823	492
Peak 10-min. avg. irradiance	1,321	1,267	1,310
Horizontal 1-axis tracking insolation	2,748	2,603	406
Peak 10-min. avg. irradiance	1,233	1,236	1,080
Direct normal insolation	2,289	2,123	336
Peak 10-min. avg. irradiance	983	1,007	1,004
Minimum T _{ambient} , °C	-2.5	-1.3	-1
LT-Avg. T _{ambient} , °C	15	15	9
Avg. T _{ambient} , °C	15	16	11
Maximum T _{ambient} , °C	41	42	28
Avg. wind speed, m/s	2.9	3.1	3.4
Max. wind speed, m/s (sustained 10-min.)	14.2	17.8	13.8

3. Operation and Maintenance

Table III.3 summarizes PVUSA's Davis O&M activities. This summary does not include Data Acquisition System (DAS) O&M activities. Host system activities are described along with host system performance in the following section of the report. The activities are identified as either preventive maintenance (including planned outages), or failure-related (including forced outages) activities.

Table III.3
January - March 1996 O&M Summary

O&M Type	Event	Date; Force x Time (default is 1 person)
Preventive	<p><u>Site-BOS:</u> Read meters and report to PG&E Control Dept. Check fire extinguisher, water wagon, Lift, Fourtrax, and sump pump Check field safety boxes and perimeter fence Reset azimuth of reference NIP Grease sump pumps Check rain gage Replaced I&C bldg. smoke alarm battery</p> <p><u>US-1 APS:</u> Clean PCU filters, test emergency lights. Manually shutdown system to prevent damage due to utility outage during high windy, and stormy conditions.</p> <p><u>US-1 IPC:</u> Clean PCU filters, set tracker clock Inspect array, interconnections, switches</p> <p><u>US-1 SSI:</u> Inspect array, interconnections, switches Inspect array, actuators, lubricate bearings</p> <p><u>EMT-1 ENTECH:</u> Inspect array, check tracker alignment, check battery Check tracker gear oil, lubricate bearings Obtain IV curves</p> <p><u>EMT-1 SOLAREX:</u> Inspect array, interconnections, switches, dc collection box Obtain IV curves</p> <p><u>EMT-1 SOVONICS:</u> Inspect array, interconnections, switches, dc collection box Obtain IV curves</p> <p><u>EMT-1 SSI:</u> Inspect array, interconnections, switches, dc collection box Obtain IV curves</p> <p><u>EMT-1 UPG:</u> Inspect array, interconnections, switches, dc collection box Obtain IV curves</p> <p><u>EMT-3 AMONIX:</u> Inspect array, check tracker alignment, check UPS Check tracker controller, UPS, array, lubricate bearings Obtain IV curves</p> <p><u>EMT-3 SCI:</u> Obtain IV curves</p>	<p>Monthly; 0.5 hr Monthly; 1.0 hr Quarterly; 1.5 hr 1/18; 0.5 hr 3/7; 0.5 hr 3/14; 0.1 hr 3/26; 0.1 hr</p> <p>Monthly; 0.75 hr 1/16; 0.25 hr 3/4, 3/5; 0.2 hr 3/14; 0.25 hr 3/28; 0.2 hr</p> <p>Monthly; 1.0 hr Semi-annual; 1.0 hr</p> <p>Monthly; 1.0 hr Semi-annual; 8.5 hr +\$20.0</p> <p>Monthly; 1.5 hr Quarterly; 0.5 hr 2/12; 0.25 hr</p> <p>Semi-annual; 1.0 hr 2/12 0.5 hr</p> <p>Semi-annual; 0.5 hr 2/12 0.5 hr</p> <p>Semi-annual; 0.5 hr 2/12 0.5 hr</p> <p>Semi-annual; 0.5 hr 2/12 0.5 hr</p> <p>Monthly; 0.6 hr Semi-annual; 0.5 hr 2/12 0.5 hr</p> <p>2/12 0.5 hr</p>

Table III.3
January - March 1996 O&M Summary

O&M Type	Event	Date; Force x Time (default is 1 person)
Failure-related	<u>Site-BOS: (1.0 hr total)</u> Reset plant after utility outage. Reset plant after utility disturbance.	2/25; 0.5 hr 3/22; 0.5 hr
	<u>US-1 APS: (1.6 hr total)</u> Reset PCU, failed to automatically wake up Replace blown REC fuse on PCU #2 Reset, unit shutdown for unknown reason	1/2, 2/12; 0.6 2/27; 0.5 hr 3/25; 0.5 hr
	<u>US-1 IPC: (0.1 hr total)</u> Reset PCU, gate fault "2026"	3/25/96; 0.1 hr
	<u>US-1 SSI: (0.75 hr total)</u> Reset PCU, various reasons for shutdown	2/20, 2/22, 2/26; 0.75 hr
	<u>EMT-1 ENTECH: (1.15 hr. total)</u> Adjust tracker, roll position not on sun Synch error	4 occurrences; 0.9 hr 3/13/96; 0.25
	<u>EMT-1 SOLAREX: (1.95 hr total)</u> Synch error Shutdown on excessive reverse power, troubleshoot and reset	2/26/96; 0.25 hr 3 occurrences; 1.7 hr
	<u>EMT-1 SOVONICS: (2.8 hr. total)</u> Synch error Shutdown on dc overvoltage, troubleshoot and reset	2 occurrences; 0.2 hr 4 occurrences; 2.6 hr
	<u>EMT-1 SSI: (0.1 hr. total)</u> Synch error	2/26/96; 0.1 hr
	<u>EMT-3 AMONIX: (5.95 hr total)</u> A2J5 adjusted, to fix grid out of range problem Troubleshoot tracker failure	1/19/96; 0.75 hr 1/30, 3/26, 3/28; 5.2 hr
	<u>EMT-3 SCI: (0.25 hr total)</u> Fix burned capacitor connector in PCU	1/2/96; 0.25 hr

The actual time spent conducting routine maintenance during the first quarter of 1996 was 27 hours. The actual time spent for conducting non-routine maintenance during the first quarter of 1996 was 20 hours. Actual time spent for conducting maintenance work does not include the time spent reviewing vendor documents, consulting with vendors, planning, preparation and documentation activities. The maintenance hours reported herein only includes hours by PVUSA on-site personnel. The hours spent by vendors or equipment manufacturers are not included in the maintenance hours above.

About one-third of the failure related maintenance hours were spent for Amonix. PVUSA personnel provided assistance to Amonix personnel in an effort to restore the system on-line. The Amonix system was placed in a shutdown mode for most of the quarter, while Amonix decided on a course of action and an agreement allowing on-site work could be made. Overall, the EMT PCUs and US-1 PCUs operated satisfactorily during the quarter, requiring occasional resets, usually in the morning. There were intermittent excessive reverse power and dc overvoltage shutdowns for the Solarex and Sovonics PCUs. Troubleshooting activities did not reveal any problems; however, cleaning logic card contacts may have fixed the problems.

IV. OTHER PVUSA SITES

1. Summary

Figure IV.1.a shows the location and lists basic information about PVUSA's various sites. In addition to the Davis and Kerman sites within PG&E's service territory, host systems are operating in Kihei, HI, Austin, TX, Farmingdale, NY, Maspeth, NY, Sacramento, CA, and Fort Davis, TX. There are presently 19 systems totaling 1.8 MW in the PVUSA network. Two more host systems are planned, including a 375-kW system at the DOD's site in Yuma and a 22.5 kW system in Colorado to be installed by PSCo.

At a glance, Figure IV.1.b compares how much insolation the various sites have been receiving—and how well their systems have been using it. Two key statistics are presented: this year's cumulative global horizontal insolation, expressed as an average daily quantity; and this year's cumulative performance index.

Through March, the Maui and Fort Davis sites received, as usual, a higher average global horizontal insolation than the other sites. Note that due to 29 days of lost data, the total recorded insolation for Maui is roughly 32% lower than it should have been. The average presented here was computed only for those days on which data were available. The average insolation may be interpreted as hours of rated irradiance, or peak hours: Maui and Fort Davis averaged about 5 peak hours equivalent per day, while the Davis, Kerman, Austin, and Sacramento sites averaged closer to 3 peak hours per day, and the Maspeth site averaged just over two peak hours per day. Farmingdale data were not available this quarter.

Three of PVUSA's 17 systems with data available generated at least 100% of the energy expected from them this quarter. This is unusual, since the rating procedure is biased toward conditions that are more ideal than typical. Three systems generated between 90 and 100% of their expected amounts, including the UPG system at Fort Davis (for which only March data were valid). Five of the remaining eleven systems generated from 70% to 90% of their expected amounts, four operated in the range of 40% to 70%, and two systems produced less than 30% of their expected energy. Data used for the performance index computations are listed in Appendix A.

The following subsections include detailed performance information for operating sites.

Figure IV.1.a

PERFORMANCE INDEX and INSOLATION
January - March 1996

Figure IV.1.b

2. Kerman

Tables IV.2.a and IV.2.b summarize 1994, 1995, and 1996 PV system, solar insolation, and weather data for the Kerman site. The plant's poor performance index of 45% was principally due to recurring PCU #1 (often flagged as "regulator or crowbar faults") problems. In many instances, a remote reset command was sufficient to get the system going again for a day or two. In addition, two of eight source circuits feeding PCU #2 were disabled when their protective movistors failed, limiting that PCU to 3/4 of its expected power.

Table IV.2.a
Kerman Performance Summary

SSI system characteristics	
Rating:	498 kW ac
Installation date:	6/93
Total module area:	5210 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	1995	Jan-Mar '96
Performance Index %	85 (89 [*])	51	45
AC kWh (incl. '93 start-up)	1,016,118	586,570	78,515
AC eff. %	9.0	8.1	7.4
Cap. fac. %	23.3	13.4	7.2
Max. ac kW	533	498	364
Wtd. avg. T _{module} °C	43	40	34
POA insol. (PCU on) kWh/m ²	2,162	1,279	192

^{*} updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.2.b
Kerman Solar/Weather Summary

Quantity	1994	1995	Jan-Mar '96
1-axis insol. kWh/m ²	est. 2,534	est. 2,513	est. 374
Horiz. insol. kWh/m ²	1,835	1,781	284
LT-Avg. horiz. insol. kWh/m ²	1,899	1,899	307
Peak 1-axis irradi. W/m ²	1,221	1,238	1,004
Peak horiz. insol. W/m ²	1,205	1,158	1,098
Min. T _{amb} °C	-2	2	0
Avg. T _{amb} °C	18	19	14
LT-Avg. T _{amb} °C	17	17	12
Max. T _{amb} °C	42	43	29
Avg. wind speed m/s	2.6	2.6	2.4
Max. wind speed m/s	11.4	12.7	10.9

3. Maui

Table IV.3.a summarizes 1994, 1995 and first quarter 1996 performance for the Maui Sovonics array. Table IV.3.b summarizes solar/weather data. The system's performance index over the first quarter of 1996 was nearly 100% (rounded). As in previous reports, this result is suspect, since reduced performance was noted after the resumption of data communications. An April report from Maui Electric indicated that corroded connections in the array caused the reduced performance.

Additional failures have occurred through the data loss period of February 24 through March 20. Maui Electric was contacted about the failures and will address these as time permits.

Table IV.3.a
Maui Performance Summary

Sovonics array characteristics	
Rating:	18.5 kW dc, 17.6 kW ac
Installation date:	10/89
Total module area:	497 m ²
Orientation:	22° tilt, south facing

Quantity	1994	1995	Jan-Mar '96
Performance Index %	92 (97 [*])	97	100
AC kWh	30,760	31,006	5,605
DC eff. %	3.3	3.3	3.3
Cap. fac. %	20.0	20.1	14.6
Max. ac kW	18.9	18.9	18.8
Wtd. avg. T _{module} °C	45	44	42
POA insol.(PCU on) kWh/m ²	2,008	2,037	361

* updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.3.b
Maui Solar/Weather Summary

Quantity	1994	1995	Jan-Mar '96
POA insol. kWh/m ²	2,146	2,139	376
Horiz. insol. kWh/m ²	2,065	2,057	316
LT-Avg. horiz. insol. kWh/m ²	2,008	2,009	600
Peak POA irradi. W/m ²	1,226	1,218	1,221
Peak horiz. irradi. W/m ²	1,257	1,291	1,184
Min. T _{amb} °C (Jun-Jul '93 n/a)	13	15	14
Avg. T _{amb} °C (Jun-Jul '93 n/a)	27	28	25
LT-Avg. T _{amb} °C	24	24	23
Max. T _{amb} °C (Jun-Jul '93 n/a)	43	42	45
Avg. wind speed m/s	3.2	3.6	4.1
Max. wind speed m/s	14.4	12.4	13.8

4. Austin

Table IV.4.a summarizes 1994, 1995 and first quarter 1996 performance for the Austin IPC system. Table IV.4.b summarizes solar/weather data. The Austin site's performance index over the first three months of the year was 45%. Aside from communications with Leslie Libby early in the quarter concerning unusual PCU shutdown problems, very little information about the operational status of the system has been available to explain this.

PVUSA contacted John Hoffner of City of Austin to get some comparative measurements of the array and ambient temperatures. Both readings appear to be high by a few degrees. Leslie Libby, who normally oversees this system, is off on maternity leave. Since John has to cover both his and Leslie's duties, we don't expect rapid action.

Table IV.4.a
Austin Performance Summary

IPC system characteristics	
PTC Rating:	17.9 kW ac
Installation date:	7/92
Total module area:	212 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	1995	Jan-Mar '96
Performance Index %	84 (88 [*])	77	45
AC kWh	26,209	25,732	2,973
AC eff. %	8.2	7.6	7.9
Cap. fac. %	16.7	16.4	7.6
Max. ac kW	19.8	17.6	16.8
Wtd. avg. T _{module} °C	40	43	33
POA insol. (PCU on) kWh/m ²	1,522	1,614	180

^{*} updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.4.b
Austin Solar/Weather Summary

Quantity	1994	1995	Jan-Mar '96
POA insol. kWh/m ²	1,847	1,855	391
Horiz. insol. kWh/m ²	1,525	1,599	304
LT-Avg. horiz. insol. kWh/m ²	1,700	1,700	349
Peak POA irradi. W/m ²	1,171	1,096	1,102
Peak horiz. irradi. W/m ²	1,181	1,129	1,006
Min. T _{amb} °C	-2	-8	-6
Avg. T _{amb} °C	21	23	15
LT-Avg. T _{amb} °C	20	20	12
Max. T _{amb} °C	43	45	42
Avg. wind speed m/s	1.8	1.7	2.2
Max. wind speed m/s	9.2	10.6	8.8

5. NYSERDA

Table IV.5.a summarizes the system's 1994 and 1995 performance. Table IV.5.b summarizes solar/weather data. Although it began operating in mid-1993, NYSERDA has yet to accept the system from IPC, as it has been limited by PCU, tracker, and DAS problems from its first days of operation. The system integrator, IPC, has built four systems using the same components in different array configurations. Problems with the dc to ac inverter have occurred in all four systems. A site survey by contractor AWS Scientific indicated many minor system problems which required changes before reliable operation might be expected. IPC responded to the items in the AWS report, maintaining that most of the deficiencies are actually within design guidelines. IPC, along with Omnion, agreed to modify the inverter control software to attempt three resets automatically, after which it will "strike out," hence the label "baseball fault" has been coined for the new control configuration. Yet to be resolved is who will pay for the inverter modification and when NYSERDA will accept the system as complete. Ancillary issues of who is responsible for operation and maintenance of the system have also not been resolved.

Table IV.5.a
NYSERDA Performance Summary

IPC system characteristics	
Temporary rating:	17.9 kW ac
Installation date:	8/93
Total module area:	212 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	1995	Jan-Mar '96
Performance Index %	66 (69*)	38	n/a
AC kWh	19,270	11,084	n/a
AC eff. %	8.4	7.8	n/a
Cap. fac. %	12.3	7.1	n/a
Max. ac kW	23.4	20.9	n/a
Wtd. avg. T _{module} °C	30	38	n/a
POA insol. (PCU on) kWh/m ²	1,079	674	n/a

* updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.5.b
NYSERDA Solar/Weather Summary

Quantity	1994	1995	Jan-Mar '96
POA insol. kWh/m ²	1,505	est. 1,723	n/a
Horiz. insol. kWh/m ²	1,366	est. 1,340	n/a
LT-Avg. horiz. insol. kWh/m ²	1,460	1,460	255
Peak POA irradi. W/m ²	1,310	1,080	n/a
Peak horiz. irradi. W/m ²	1,246	1,267	n/a
Min. T _{amb} °C	n/a	n/a	n/a
Avg. T _{amb} °C	n/a	n/a	n/a
LT-Avg. T _{amb} °C	13	13	2
Max. T _{amb} °C	n/a	n/a	n/a
Avg. wind speed m/s	1.6	1.7	n/a
Max. wind speed m/s	12.4	10.4	n/a

6. NREL/NYPA

Table IV.6.a summarizes the system's 1994, 1995, and 1996 performance to date. Table IV.6.b summarizes solar/weather data.

No maintenance activities were reported by NYPA or the New York Transit Authority. A ground fault on February 12, 1996 caused the system to be turned off until array wiring repairs are performed by USSC. USSC has been given the performance data for the system from 1995 through the end of March. A USSC representative will be on site next quarter (end of May or early June) to troubleshoot the array and determine if the array is causing the system shutdown.

Table IV.6.a
NREL/NYPA Performance Summary

IPC/Uni-Solar system characteristics	
NREL Rating:	17.0 kW ac
Installation date:	7/93
Total module area:	413 m ²
Orientation:	Fixed 10° tilt, south-facing

Quantity	1994	1995	Jan-Mar '96
Performance Index %	83 (87 [*])	84	21
AC kWh	19,478	14,559	659
AC eff. %	3.3	3.0	2.4
Cap. fac. %	13.1	9.8	1.8
Max. ac kW	17.7	16.2	9.9
Wtd. avg. T _{module} °C	35	36	11
POA insol. (PCU on) kWh/m ²	1,420	1,226	71

* updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.6.b
NREL/NYPA Solar/Weather Summary

Quantity	1994	1995	Jan-Mar '96
POA insol. kWh/m ²	1,448	1,391	252
Horiz. insol. kWh/m ²	1,298	1,223	207
LT-Avg. horiz. insol. kWh/m ²	1,460	1,460	255
Peak POA irradi. W/m ²	1,163	1,174	1,028
Peak horiz. irradi. W/m ²	1,050	1,071	907
Min. T _{amb} °C	-17	-13	-10
Avg. T _{amb} °C	14	15	3
LT-Avg. T _{amb} °C	13	13	2
Max. T _{amb} °C	39	44	20
Avg. wind speed m/s	3.2	2.6	3.5
Max. wind speed m/s	10.9	20.3	11.7

7. SMUD

Table IV.7.a summarizes the system's 1994, 1995 and first quarter 1996 performance. Table IV.7.b summarizes solar/weather data.

The system's performance index for the first quarter was 70%. While this is low enough to warrant an explanation, no fully satisfactory one has been deciphered from the data. One factor could be that the system efficiency is down by 17% from last year, and had been low since last November. Efficiency did jump back to 10% in the last week of March, so it would appear that some repairs were performed at that time. Since calibration of the dc measurements has not been verified, it is not possible to distinguish whether the source of the problem was in the array or in the PCU. A factor tending to artificially raise the performance index is the plane-of-array instrument, which appears to be reading about 18% lower than the comparable figure at Davis, less than 20 miles away. Since the system availability is 90% and the percentage of insolation received while the PCU was on is 97%, it does not appear that downtime is a significant cause, either. No one from SMUD, UPG or Omnion has been able to answer queries about O&M activities on this system.

Table IV.7.a
SMUD Performance Summary

UPG/SSI system characteristics	
PTC Rating:	207 kW ac
Installation date:	4/94
Total module area:	2043 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	8/16-12/31 94	1995	Jan-Mar '96
Performance Index %	66 (69*)	81	70
AC kWh	99,399	384,380	56,537
AC eff. %	9.4	10.1	8.4
Cap. fac. %	14.5	21.2	12.5
Max. ac kW	196	240	217
Wtd. avg. T _{module} °C	40	40	30
POA insol. (PCU on) kWh/m ²	515	1,856	326

* updated 1994 value, consistent with present calculation that includes a 5% PCU low-load loss allowance.

Table IV.7.b
SMUD Solar/Weather Summary

Quantity	8/16-12/31 94	1995	Jan-Mar '96
POA insol. kWh/m ² [1-axis insol. est. from Davis]	657	2,184 [2,473]	336 [406]
Horiz. insol. kWh/m ²	513	1,668	265
LT-Avg. horiz. insol. kWh/m ²	532	1,788	279
Peak POA irradi. W/m ²	1048	1,143	988
Peak horiz. irradi. W/m ²	1018	1,135	1,008
Min. T _{amb} °C	-1	1	1
Avg. T _{amb} °C	16	18	12
LT-Avg. T _{amb} °C	16	16	10
Max. T _{amb} °C	41	44	28
Avg. wind speed m/s	2.0	2.6	2.4
Max. wind speed m/s	12.7	19.0	16.4

8. Central and South West Services (CSW)

Telephone line interference on several lines to the Fort Davis site has continued to be a problem, and has in fact worsened. Data are currently being collected through telephone lines originally dedicated to other purposes. In spite of these difficulties, PVUSA has managed not to lose any data over this quarter through close cooperation with Fort Davis personnel.

Another limitation in the Fort Davis system is the absence of a reference one-axis-tracking pyranometer or normal incidence pyrliometer. While a NIP was included in the original weather station instrumentation, its tracker has proven to be unreliable, so no valid data is collected from that instrument. The weather station includes a Licor shadowband reference instrument that suffers from spectral bandwidth limitations and does not accurately distinguish diffuse and direct components of irradiance. The Licor has been observed to report about 6% too much direct normal insolation, so 94% of the measured Licor value is used as a reference for the ENTECH performance index calculation.

UPG

Performance data are summarized in Table IV.8.a. Although it rarely tripped off line, the system's PCU often shed one of the array's five source circuits to avoid overpowering the unit, reducing system generation. However, its ac power data were invalid as site personnel determined that the burden resistor for the ac power transducer was out of specification. On February 28, 1996 the burden resistor on the ac power transducer was replaced with one of the correct value, correcting the power reading. The original burden resistor may have been damaged in connection with the transducer failure last fall.

For the P.I. calculations, the 1-axis insolation has been estimated by multiplying the measured global horizontal insolation by the ratio of the El Paso long-term-average ratio of global 1-axis insolation to global horizontal insolation (from NREL's Solar Radiation Data Manual).

ENTECH

Performance for ENTECH was down for the first two months of the quarter. The ENTECH system had residual damage to a dc collection box which prevented full system operation. Site personnel working with ENTECH repaired the dc junction box, restoring the array to full power on March 15. Performance data are summarized in Table IV.8.b

The ENTECH tracker still has aiming deficiencies even after a retrofit of the tracking motors intended to improve tracker performance. The tracker roll drive tends to lose the sun under winds greater than about 15 mph.

Table IV.8.a
CSW UPG Performance Summary

UPG/SSI system characteristics	
PTC Rating:	98 kW ac
Installation date:	11/94
Total module area:	1021.5 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1995	Jan-Mar '96
Performance Index %	63	98**
AC kWh	160,341*	53,160*
AC eff. %	8.5	10.6
Cap. fac. %	18.7	24.8
Max. ac kW	105	106
Wtd. avg. T _{module} °C	38	31
POA insol. (PCU on) kWh/m ²	1,613	512

* Adjusted estimate to compensate for out of tolerance burden resistor on power transducer

** March data only

Table IV.8.b
CSW ENTECH Performance Summary

ENTECH system characteristics	
PTC Rating:	83 kW ac
Installation date:	2/95
Total module area:	907 m ²
Orientation:	2-axis trk. concentrator

Quantity	1995	Jan-Mar '96
Performance Index %	n/a	16
AC kWh	91,602	9,729
AC eff. %	n/a	9.1
Cap. fac. %	13.8	4.8
Max. ac kW	97	93
Wtd. avg. T _{module} °C	n/a	26
POA insol. (PCU on) kWh/m ²	n/a	73

Table IV.8.c
Fort Davis Solar/Weather Summary

Quantity	1995	Jan-Mar '96
UPG POA insol. kWh/m ² [Estimated available 1-axis insol. using El Paso]	incomplete 2,272 [2,762]	610 [625]
Direct normal insol. kWh/m ²	2,518	665
LT-Avg. dir. nrml. insol. kWh/m ²	2,445	570
Horiz. insol. kWh/m ²	1,968	434
LT-Avg. horiz. insol. kWh/m ²	2,082	417
Peak 1-axis irradi. W/m ²	1,349	1,128
Peak dir. nrml. irradi. W/m ²	1,087	1,086
Peak horiz. irradi. W/m ²	1,232	1,022
Min. T _{amb} °C	-8	-10
Avg. T _{amb} °C	16	10
El Paso LT-Avg. T _{amb} °C	17	9
Max. T _{amb} °C	37	25
Avg. wind speed m/s	3.1	3.4
Max. wind speed m/s	18.0	18.0

APPENDIX A

1996 Performance Index Worksheet

PERIOD	SYSTEM	KWH	TOTAL INSOL	SCH.OUTG INSOL	Tmod pwr-wtd-av	Tmod PTC	Beta	ORIGINAL AC RATING	RATING IRR kW/m2	DA	TA	BOSA	SA	P.I.
Jan-Mar	SSI- Davis EMT	5231	382.2		31	47	-0.0045	18.1	1.000	0.864	1.0720	0.93	1.00	87.9
						47	-0.0045	18.1	1.000	0.864		0.93	1.00	0.0
						47	-0.0045	18.1	1.000	0.864		0.93	1.00	0.0
						47	-0.0045	18.1	1.000	0.864		0.93	1.00	0.0
Jan-Mar	Sovonics- Davis	4417	382.2		31	44	-0.0027	15.9	1.000	0.836	1.0351	0.93	1.00	90.2
						44	-0.0027	15.9	1.000	0.836		0.93	1.00	0.0
						44	-0.0027	15.9	1.000	0.836		0.93	1.00	0.0
						44	-0.0027	15.9	1.000	0.836		0.93	1.00	0.0
Jan-Mar	UPG- Davis EMT	4904	382.2		33	51	-0.0010	15.1	1.000	0.881	1.0180	0.93	1.00	101.8
						51	-0.0010	15.1	1.000	0.881		0.93	1.00	0.0
						51	-0.0010	15.1	1.000	0.881		0.93	1.00	0.0
						51	-0.0010	15.1	1.000	0.881		0.93	1.00	0.0
Jan-Mar	Solarex	4305	382.2		31	43	-0.0045	15.1	1.000	0.907	1.0540	0.93	1.00	83.8
						43	-0.0045	15.1	1.000	0.907		0.93	1.00	0.0
						43	-0.0045	15.1	1.000	0.907		0.93	1.00	0.0
						43	-0.0045	15.1	1.000	0.907		0.93	1.00	0.0
Jan-Mar	ENTECH- Davis EMT	5019	336.0		40	61	-0.0045	15.6	0.850	1.000	1.0945	0.86	1.00	87.0
						61	-0.0045	15.6	0.850	1.000		0.86	1.00	0.0
						61	-0.0045	15.6	0.850	1.000		0.86	1.00	0.0
						61	-0.0045	15.6	0.850	1.000		0.86	1.00	0.0
Jan-Mar	AstroPower- Davis	5917	382.2		29	44	-0.0045	16.1	1.000	1.000	1.0675	0.93	1.00	96.8
						44	-0.0045	16.1	1.000	1.000		0.93	1.00	0.0
						44	-0.0045	16.1	1.000	1.000		0.93	1.00	0.0
						44	-0.0045	16.1	1.000	1.000		0.93	1.00	0.0
Jan-Mar	APS	100516	382.2		34	49	-0.0027	479.0	1.000	0.835	1.0405	0.93	1.00	67.9
						49	-0.0027	479.0	1.000	0.835		0.93	1.00	0.0
						49	-0.0027	479.0	1.000	0.835		0.93	1.00	0.0
						49	-0.0027	479.0	1.000	0.835		0.93	1.00	0.0
Jan-Mar	IPC- Davis US	58634	406.3		31	48	-0.0045	196.0	1.000	1.000	1.0765	0.90	1.00	75.8
						48	-0.0045	196.0	1.000	1.000		0.90	1.00	0.0
						48	-0.0045	196.0	1.000	1.000		0.90	1.00	0.0
						48	-0.0045	196.0	1.000	1.000		0.90	1.00	0.0
Jan-Mar	SSI- Davis US	17663	406.3		28	44	-0.0045	67.0	1.000	1.000	1.0720	0.90	1.00	67.1
						44	-0.0045	67.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	67.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	67.0	1.000	1.000		0.90	1.00	0.0
Jan-Mar	Sovonics- Maul	5605	375.8		42	44	-0.0027	17.6	1.000	0.892	1.0054	0.95	1.00	99.5
						44	-0.0027	17.6	1.000	0.892		0.95	1.00	0.0
						44	-0.0027	17.6	1.000	0.892		0.95	1.00	0.0
						44	-0.0027	17.6	1.000	0.892		0.95	1.00	0.0
Jan-Mar	IPC- Austin	2973	390.6		33	46	-0.0045	17.9	1.000	1.000	1.0585	0.90	1.00	44.5
						46	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
						46	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
						46	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
Jan-Mar	SSI- Kerman US	78515	374		34	44	-0.0045	498.0	1.000	1.000	1.0450	0.90	1.00	44.7
						44	-0.0045	498.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	498.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	498.0	1.000	1.000		0.90	1.00	0.0
Jan-Mar	IPC- Farmingdale	No data				48	-0.0045	17.9	1.000	1.000	1.2160	0.90	1.00	0.0
						48	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
						48	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
						48	-0.0045	17.9	1.000	1.000		0.90	1.00	0.0
Jan-Mar	IPC- Maspeth	659	252.0		11	53	-0.0010	17.0	1.000	0.759	1.0420	0.95	1.00	20.5
						53	-0.0010	17.0	1.000	0.759		0.95	1.00	0.0
						53	-0.0010	17.0	1.000	0.759		0.95	1.00	0.0
						53	-0.0010	17.0	1.000	0.759		0.95	1.00	0.0
Jan-Mar	UPG- Sacramento US (Davis tax Insol)	56537	406.3		30	44	-0.0045	207.0	1.000	1.000	1.0630	0.90	1.00	70.1
						44	-0.0045	207.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	207.0	1.000	1.000		0.90	1.00	0.0
						44	-0.0045	207.0	1.000	1.000		0.90	1.00	0.0
Mar	UPG- Ft. Davis US	23244	256.0		33	43	-0.0045	98.0	1.000	1.000	1.0450	0.90	1.00	98.2
						43	-0.0045	98.0	1.000	1.000		0.90	1.00	0.0
						43	-0.0045	98.0	1.000	1.000		0.90	1.00	0.0
						43	-0.0045	98.0	1.000	1.000		0.90	1.00	0.0
Jan-Mar	ENTECH- Ft. Davis US (est. dni)	9729	665.0		26	50	-0.0045	83.0	0.850	1.000	1.1080	0.86	1.00	15.8
						50	-0.0045	83.0	0.850	1.000		0.86	1.00	0.0
						50	-0.0045	83.0	0.850	1.000		0.86	1.00	0.0
						50	-0.0045	83.0	0.850	1.000		0.86	1.00	0.0
Jan-Mar	Solar Cells- Davis EMT	3977	382.2		32	47	0.0000	11.2	1.000	1.000	1.0000	0.93	1.00	99.8
						47	0.0000	11.2	1.000	1.000		0.93	1.00	0.0
						47	0.0000	11.2	1.000	1.000		0.93	1.00	0.0
						47	0.0000	11.2	1.000	1.000		0.93	1.00	0.0
Jan-Mar	Amonix- Davis EMT	1305	336.0		41	55	-0.0025	15.0	0.850	1.000	1.0000	0.95	1.00	n/r
						55	-0.0025	15.0	0.850	1.000		0.95	1.00	0.0
						55	-0.0025	15.0	0.850	1.000		0.95	1.00	0.0
						55	-0.0025	15.0	0.850	1.000		0.95	1.00	0.0

P.I. = [kWh x Rating Irrad.] / [(Total Insol. - Sched. Outage Insol.) x Orig. Rating x DA x TA x BOSA x SA]

note: Total Insol. based on appropriate reference for each system's fixed or tracking orientation.

TA = (1 + Beta x (Tmod - Tmod, rated))

DA = Present / Original ratings

BOSA = 0.86 (ENTECH), 0.90 (1-axis tracking), 0.93 (fixed tilt arrays at ≥30°), 0.95 (other arrays)

note: BOSA includes effects of non-ideal tracking, reduced PCU efficiency at low loads, and shading.