Photovoltaic Systems Performance and Reliability Database [1]

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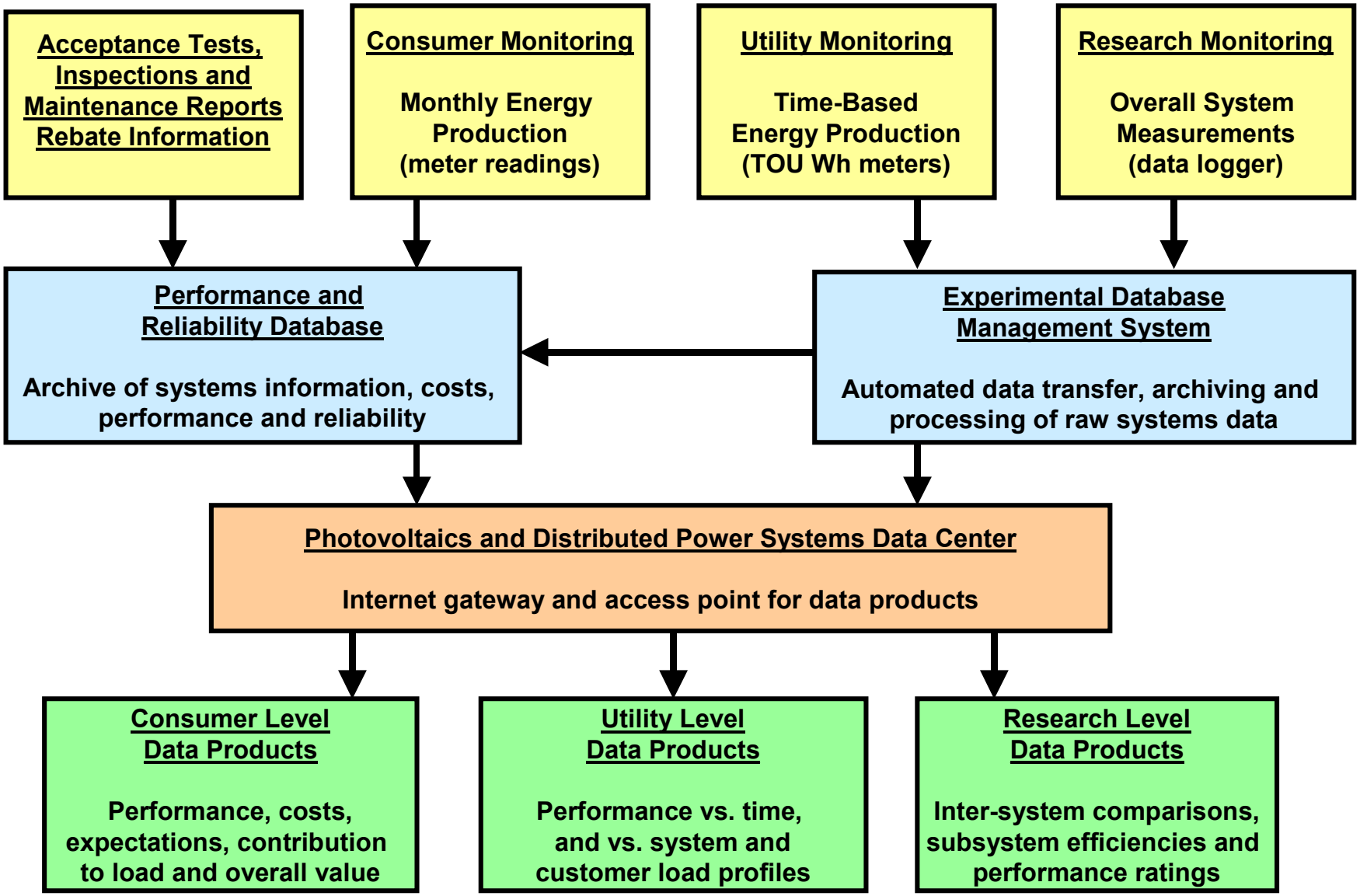
Photovoltaic Systems Performance and Reliability Database

Monitoring and Data Acquisition Processes



Objectives:

- Identify reliability and performance issues for PV systems and components.
- Validate overall system designs.
- Document costs for hardware, installation, operation and maintenance.

Target Audience:

- System manufacturers, integrators, installers, utilities and consumers.

Scope:

- Over 100 grid-connected PV systems in Florida are currently being monitored, some with information dating back to 1998.

Database Components:

Performance information includes monthly total and time-based energy production data, on-site test results, and research-level data acquisition.

Reliability information is collected through system evaluations, acceptance testing and operator record keeping.

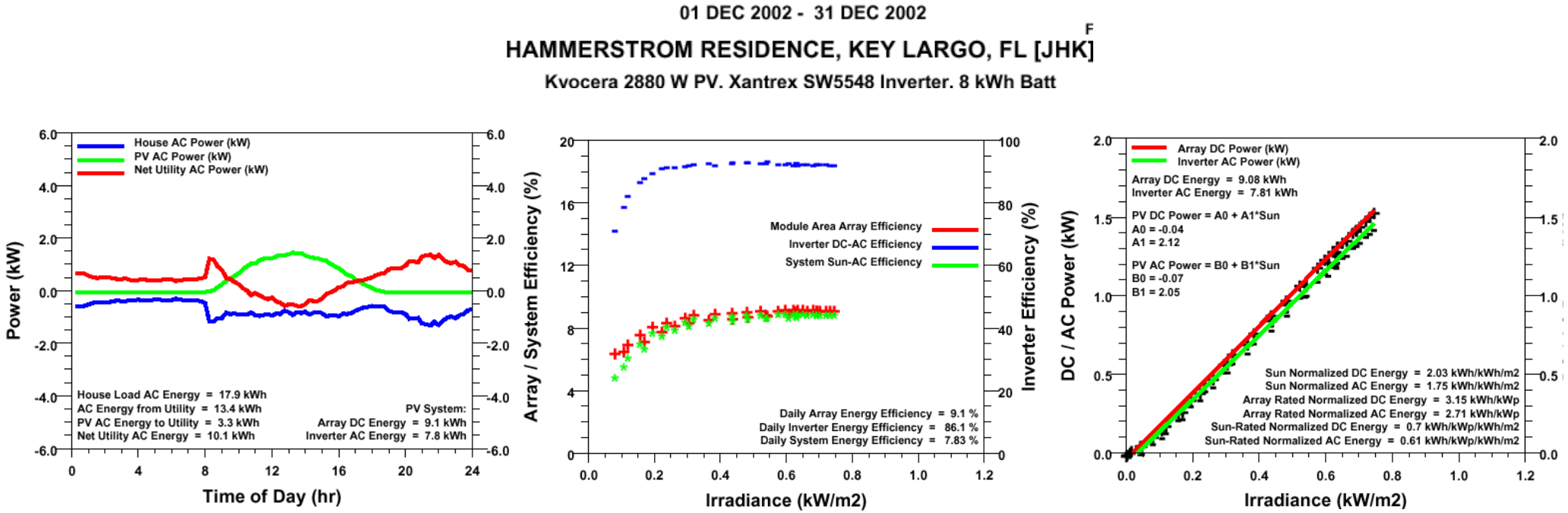
Cost information is collected through rebate program reporting requirements by contractors and consumers, and by operation and maintenance data.

Performance Data

- Research-level data acquisition systems are installed on over 20 of the 103 systems tracked in the database.
- Data helps validate designs and identify specific subsystem performance and reliability issues.
- Data collection fully automated with on-line data accessibility.
- Normalized parameters are key to comparing performance of similar and dissimilar systems in different climates.
- Determines coincidence and contribution of PV output to building and utility loads.
- In most cases, PV system output does not correspond well with building or utility loads in Florida, suggesting opportunities for energy storage and load management practices.

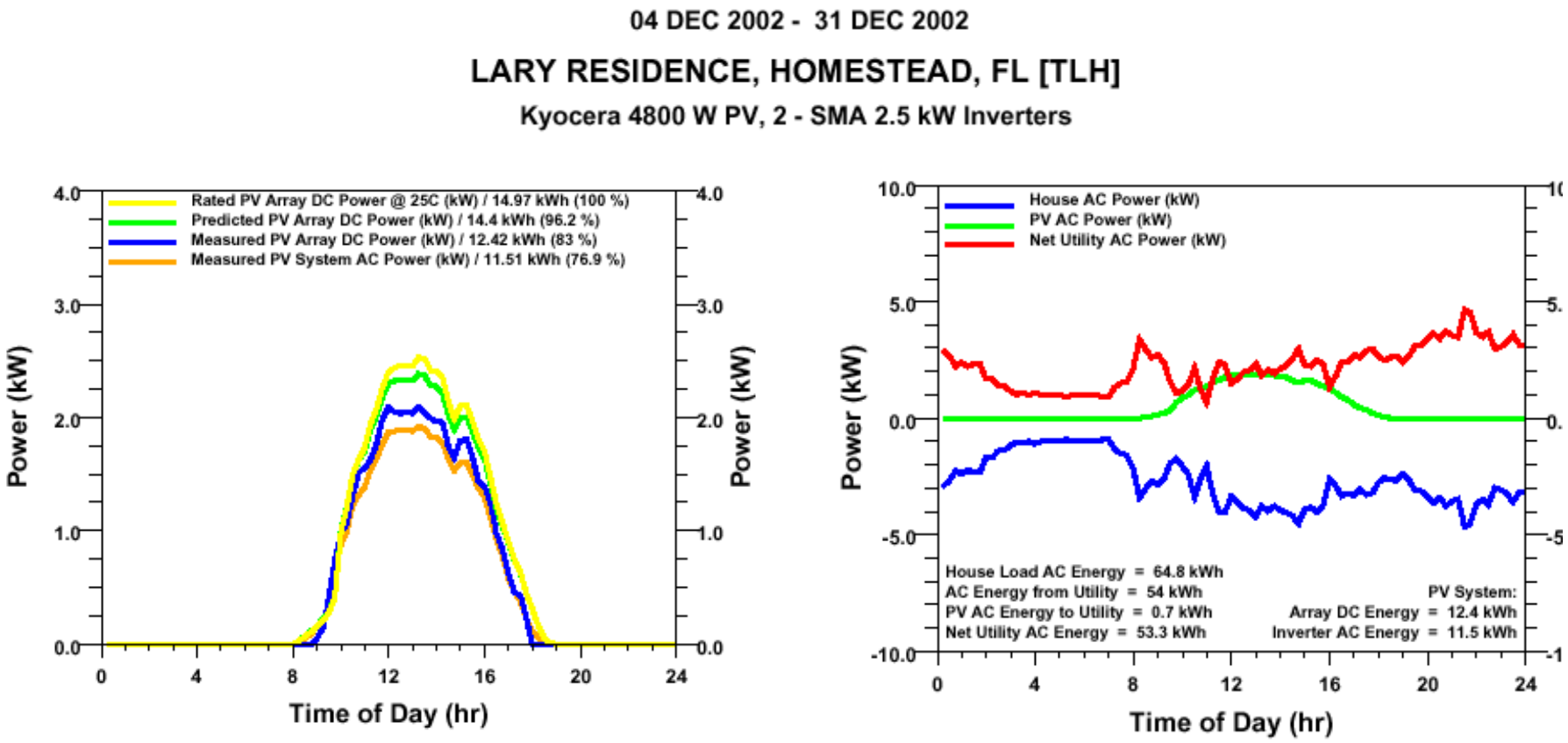
Performance Data Example #1

- Building load averages 18 kWh/day, net utility usage is about 10 kWh/day – but little A/C required.
- PV contributes 44% of overall energy needed, but 42% of PV energy sent back to grid.
- Application is net metered by utility - customer receives full retail value for excess PV energy.
- Actual PV system AC energy is 61% of array STC-rated DC power x PSH – could be significantly improved with MPPT controller and higher inverter efficiency.
- PV system AC output at peak sun is approx. 2 kW for 2.88 kW STC-rated array.



Performance Data Example #2

- This system achieves high utilization of PV array energy – actual AC output is 77% of array DC rated output x PSH - due to high inverter and MPPT efficiency, and accurate module ratings.
- PV supplies 18% of building load, but very little PV energy sent to grid due to customer load profile – preferable in this dual-metered application.



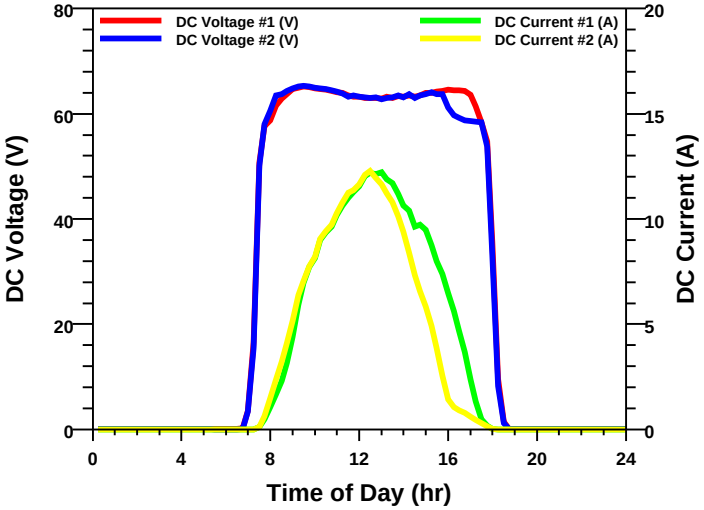
Florida Solar Energy Center
PVDG Division

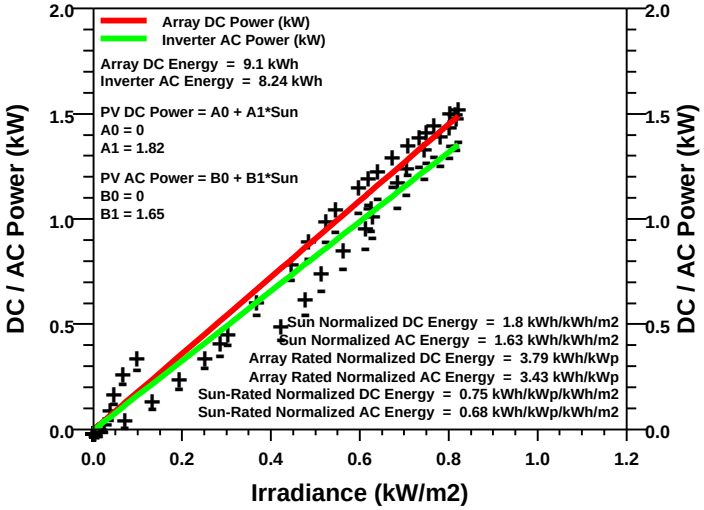
01 JAN 2003 - 31 JAN 2003

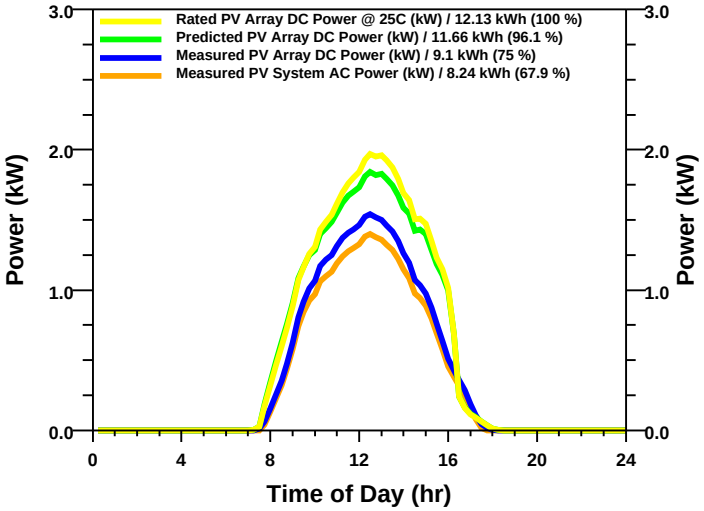
Florida Power & Light

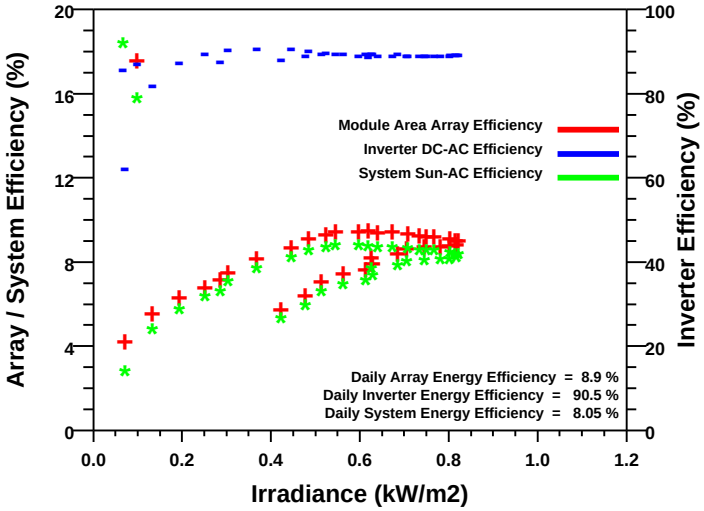
LYNN RESIDENCE, ROCKLEDGE, FL [KEV]

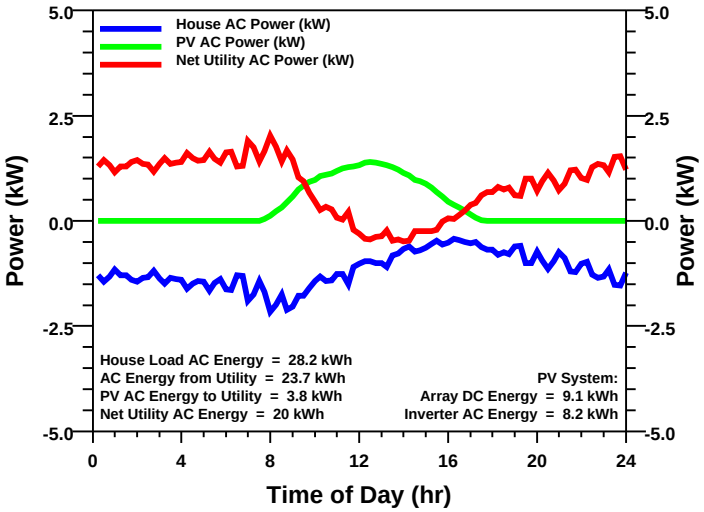
Siemens SP75 2400 W PV, 2 AEI GC1000 Inverters

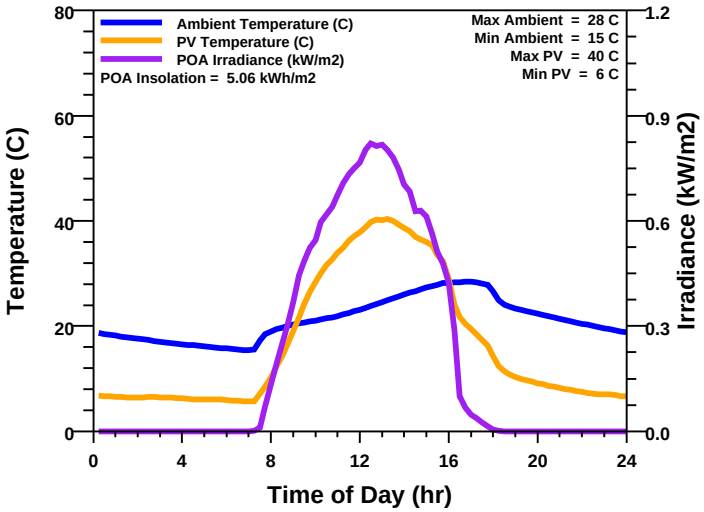












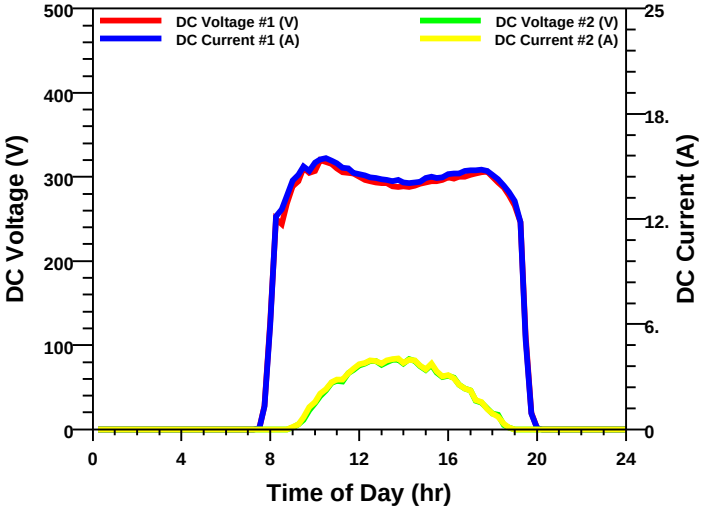
Florida Solar Energy Center
PVDG Division

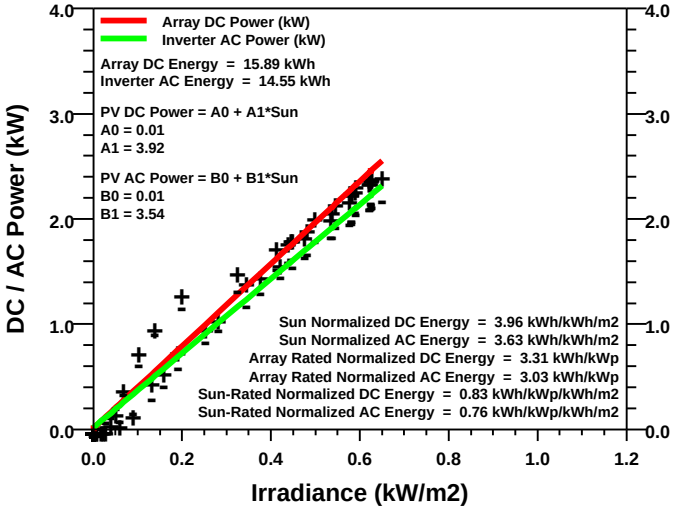
01 FEB 2003 - 28 FEB 2003

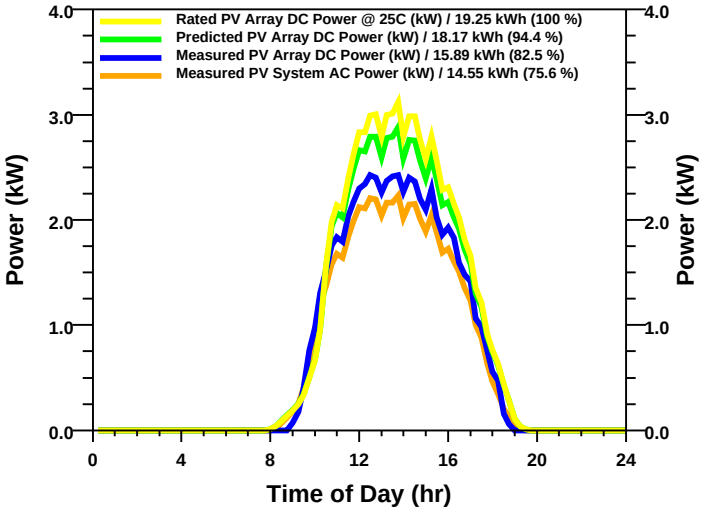
Florida Power & Light

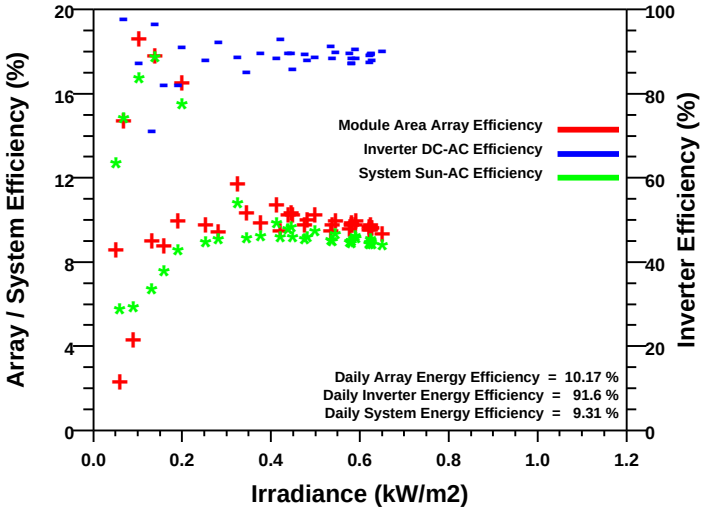
LARY RESIDENCE, HOMESTEAD, FL [TLH]

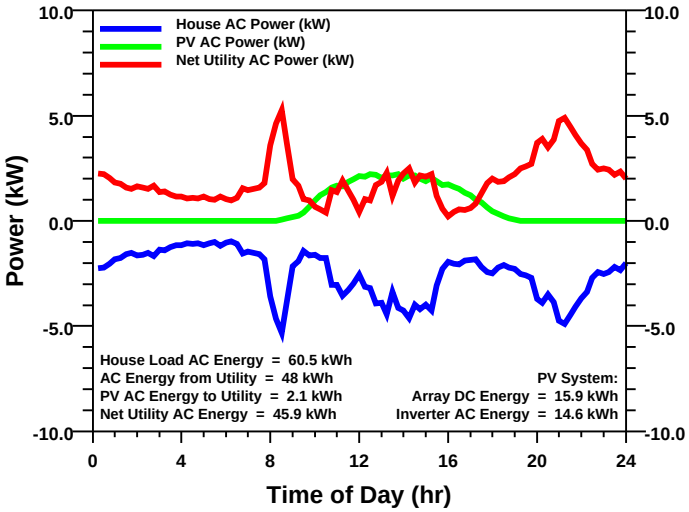
Kyocera 4800 W PV, 2 - SMA 2.5 kW Inverters

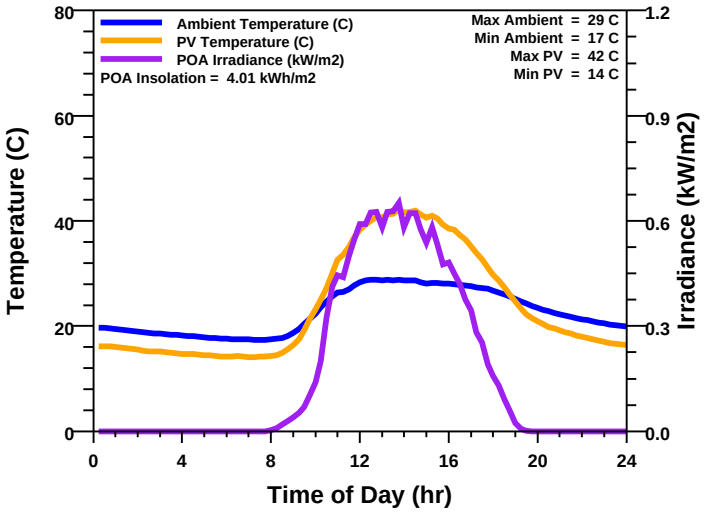






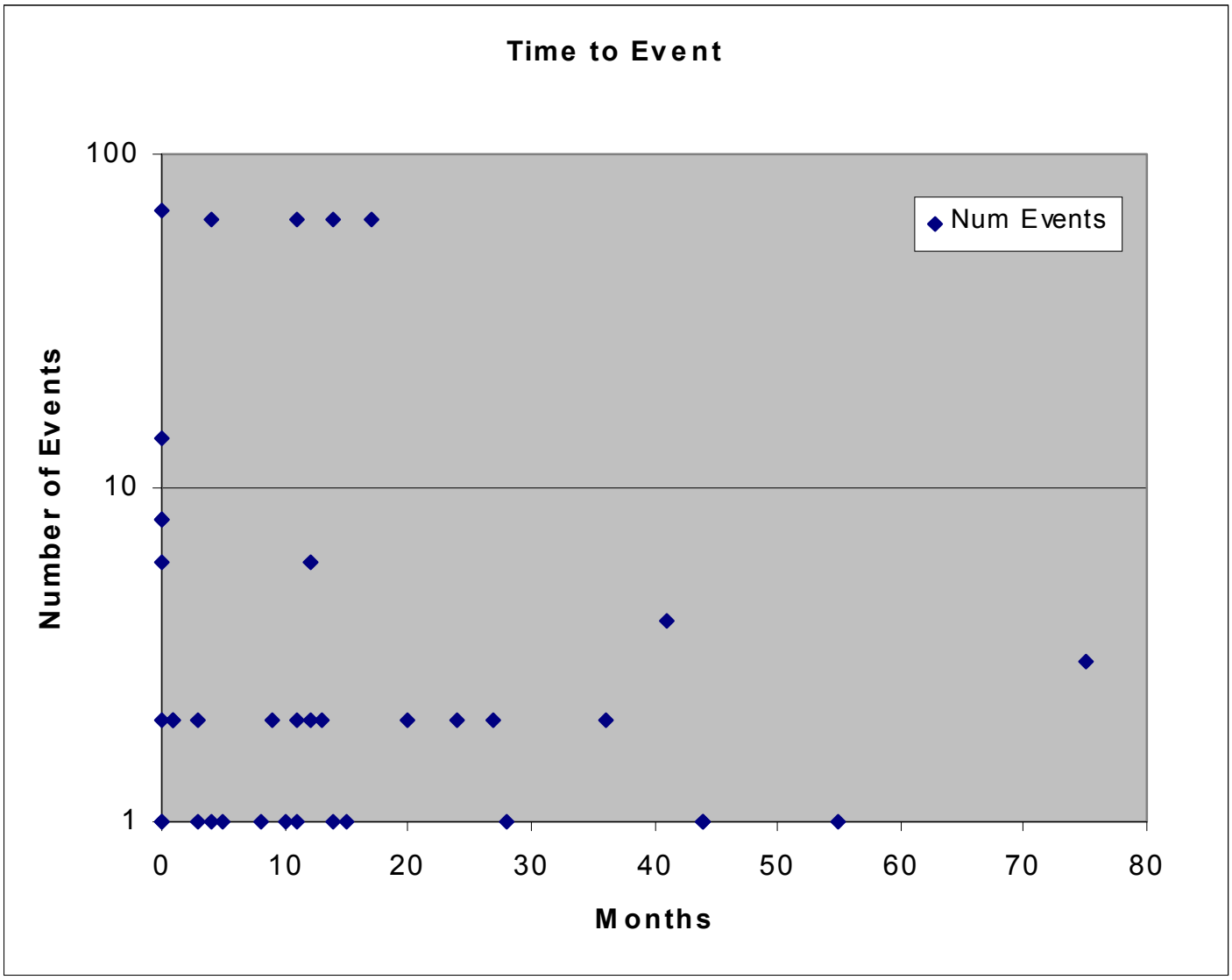


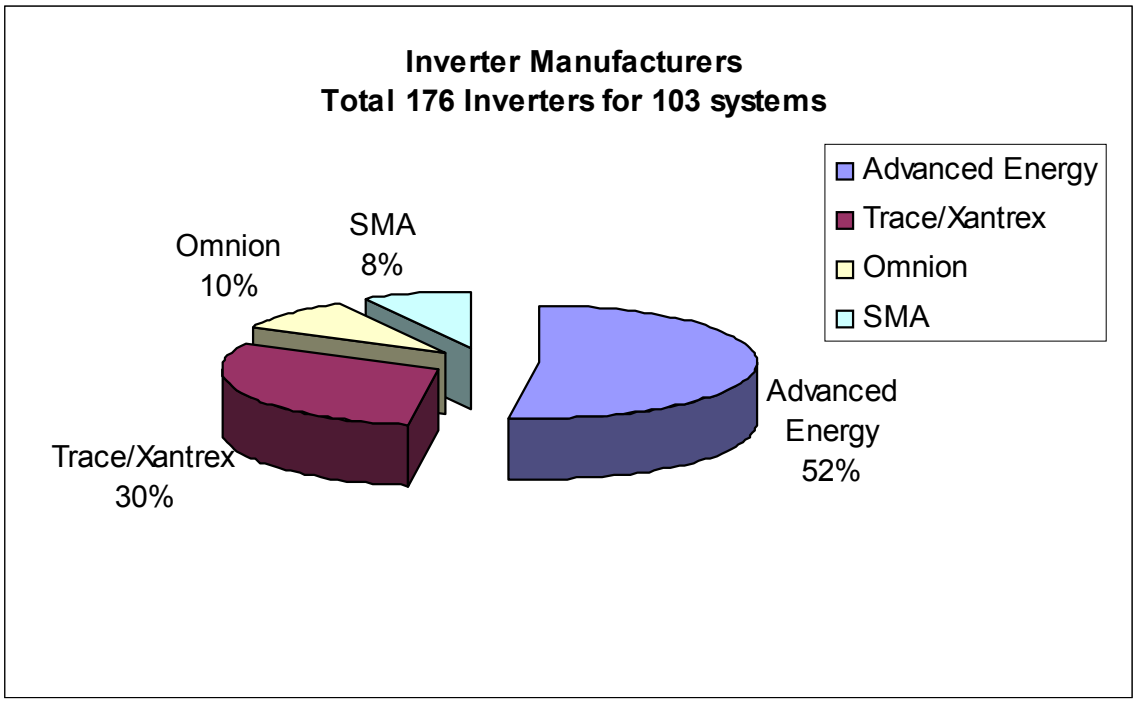




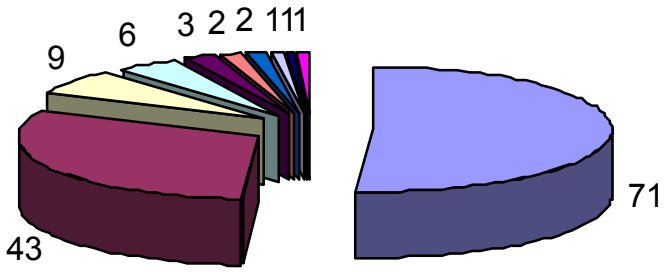
Reliability Data

- Reliability data includes information on 103 grid-connected PV systems using 176 inverters
- Database includes systems using PV arrays from 9 manufacturers, and inverters from 4 manufacturers.
- In the past four years, 213 events have been recorded on these 103 systems, with 139 events (65 percent) attributed to inverters. Most events were recorded during the first year of system operation.
- Most inverter events were attributed to poor maximum power tracking function and ability to maintain grid connection, requiring either software upgrades or replacement/repair of inverter by manufacturer.
- A fair number of system reliability events were due to BOS, including dc breakers tripping and source circuit overcurrent devices failing, as well as ac overcurrent devices, requiring manual resets or replacement of the components.
- Approximately 6 inverter failures were due to lightning strikes at or near the PV arrays.


Time to Event
100
10
1
Number of Events
Num Events
0
10
20
30
40
50
60
70
80
Months

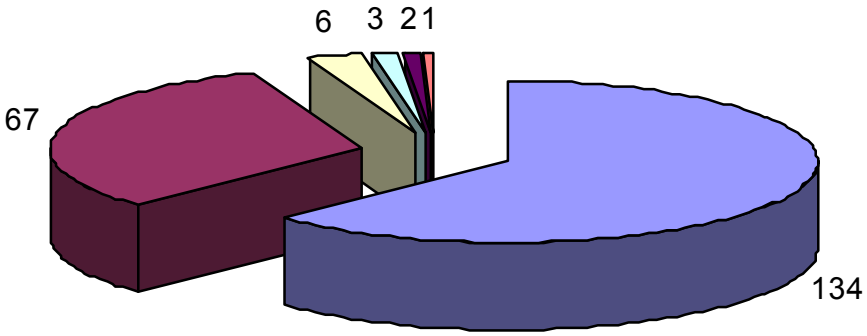

Inverter Manufacturers
Total 176 Inverters for 103 systems
Advanced Energy
Trace/Xantrex
Omnion
SMA
Omnion
10%
SMA
8%
Trace/Xantrex
30%
Advanced
Energy
52%

Inverter Reliability Events by Type



- Inverter-Tracking
- Inverter-Unknown
- Inverter-Fuse Failure-Unknown Cause
- Inverter-Internal
- Inverter-DC Circuit Breaker
- Inverter-DCBCB-Open
- Inverter-Sizing
- Inverter-ACBCB-Open
- Inverter-ACD-Open

System Reliability Events
213 Total Events



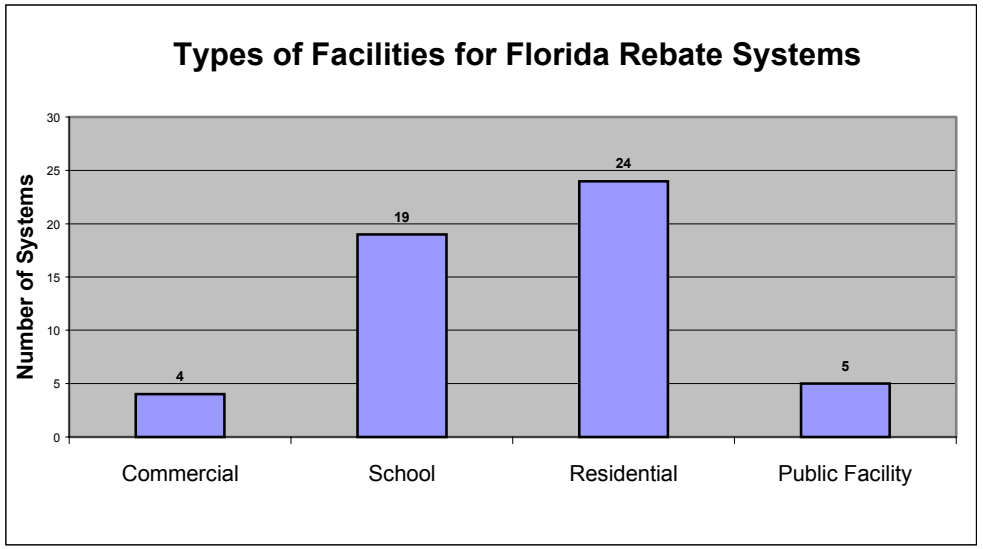
- Inverter
- System
- DataAcqSystem
- DCDisconnect
- ACDisconnect
- PVArray

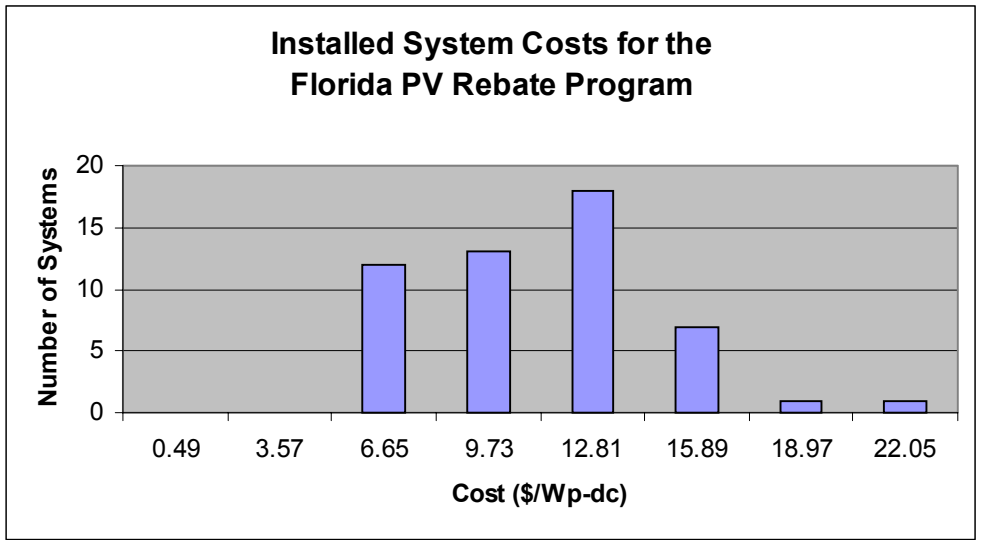
Cost Data

- Cost information obtained for 52 grid-connected PV systems installed under Florida rebate program through December 2002.
- Total installed PV capacity 170-kWp dc, total systems cost $1.73M.
- Rebate amounts totaled $516K, approximately 40 percent of total systems cost and average per installation.
- Equipment costs were approximately 75 percent of total system costs; installation labor was approximately 25 percent.
- Mean costs per system were $9.73/Wp and median costs were $9.91/Wp, suggesting bias toward more expensive systems and opportunities for cost reductions.
- Limited operation and maintenance costs were available, however the majority of installed systems required at least one site visit during the first year of operation, with costs largely offsetting value of energy produced.

Florida PV Rebate Program Cost Summary

Statistics	Array Size (Wp-dc)	Installed Cost	Equipment Cost	Labor Cost	Rebate Amount	Installed Cost ($/Wp)	Equipment Cost ($/Wp)	Labor Cost ($/Wp)
TOTALS	170,278	$ 1,727,948	$ 1,160,513	$ 366,511	$ 516,292			
MEAN	3,275	$ 33,230	$ 23,210	$ 7,330	$ 9,929	$ 9.73	$ 7.15	$ 2.38
MEDIAN	2,880	$ 29,900	$ 21,542	$ 5,376	$ 8,920	$ 9.91	$ 7.52	$ 1.96
STD. DEV.	1,679	$ 24,891	$ 12,458	$ 6,002	$ 4,972	$ 3.08	$ 2.01	$ 2.24





Summary

- System performance varied considerably for different array and inverter combinations. Average daily system utilization efficiencies ranged from less than 0.5 kWh/kWp/kWh/m^2 for problematic systems, to over 0.75 kWh/kWp/kWh/m^2 for well-performing systems.

- PV array performance appears to be 10-15 percent less than expected based on manufacturer's nameplate ratings and after temperature and other losses are considered.

- Inverter performance and reliability were by far the key issues identified during the past four years of this evaluation. Although inverter dc-ac conversion efficiencies are generally around 90 percent, many inverters are not tracking array maximum power properly, resulting in lower PV array utilization than expected.

- Improvements in the quality and completeness of system design packages, installer experience and improvements in inverters resulted in fewer performance and reliability problems in during past 6-9 month, but issues still remain.

- Rebate programs have stimulated markets, however incentives have artificially increased prices, suggesting further cost reductions are possible.

- Bulk competitive purchases by certain utilities have reduced equipment costs, in some cases to as low as 50 percent of the pricing for individual homeowner systems.

- Performance-based incentives and maintenance agreements offer opportunities to improve overall system performance and reliability.