DOE/CH/10569--T1

Development of a Dispatchable PV Peak Shaving System

Final Report on PV:BONUS Phase 2 Activities

William D. Ferguson, Conectiv, Inc.
Ralph M. Nigro, Applied Energy Group, Inc.

Submitted by:
Conectiv, Inc.
(formerly Delmarva Power & Light Company)

January 20, 1999

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY
Under Cooperative Agreement
No. DE-FC36-93CH10569

DISCLAIMER

Table of Contents

1 Introduction....1
2 Dispatchable PV Peak Shaving System Development and Deployment....3
2.1 System Enhancements Since Phase 1....3
2.1.1 Self-Dispatch....3
2.1.2 AC Battery Module Packaging....4
2.1.3 PV Array Configuration and Packaging....4
2.1.4 Thin Film Arrays....5
2.2 System Configurations in Phase 2....6
2.2.1 Wisconsin Public Service Corporation/ShopKo....6
2.2.2 Delmarva Power & Light Company Conowingo District Office....8
2.2.3 Delaware Division of Facilities Management Carvel State Office Building....10
2.2.4 INTEK Corporation....11
2.3 Dispatchable PV Peak Shaving System Performance....12
2.3.1 Monitoring and Data Collection....12
2.3.2 PV Array Performance....14
2.3.3 Mounting Systems....14
2.3.4 PV-31 Battery/Inverter/Control System....15
3 Grid-Independent System Development....20
3.1 System Design Specifications and Applications....20
3.2 Prototype System Construction and Performance....22
4 Development of Modeling Tool....23
4.1 Overview....23
5 Progress Towards Commercialization....24
5.1 Commercialization Summary....24
5.2 Market Research Summary....25

APPENDICES

Appendix A – Sample Reports of Dispatchable Peak Shaving System Performance
Appendix B - CEEP Study
Appendix C - Survey of Utility Energy Managers
Appendix D - Survey of Buildings Specialists
Appendix E - Distribution Feeder Analysis

1 Introduction

In July 1993, the Delmarva Power & Light Company was awarded a contract for the development of a Dispatchable Photovoltaic Peak Shaving System under the U.S. Department of Energy PV:BONUS Program. The rationale for the dispatchable PV peak shaving system is based on the coincidence between the solar resource and the electrical load in question. Where poor coincidence exists, a PV array by itself does little to offset peak demands. However, with the addition of a relatively small amount of energy storage, the energy from the PV array can be "managed" and the value of the PV system increases substantially. Furthermore, the design and manufacturing approaches represented in the Phase 1 system were significantly different. Instead of custom designed systems tailored for specific sites, the design of the Phase 1 dispatchable PV peak shaving systems was based on modular, factory assembled components that increased quality and reduced field assembly time.

A proof-of-concept system was installed on a Delmarva office facility in Newark, Delaware. The experience gained during the installation and operation of the Phase 1 system helped to direct the course of additional development work in Phase 2. The performance of the Phase 1 system and associated analytical and business development efforts are documented in a separate report.

In Phase 2, Delmarva Power continued the refinement of the system deployed in Phase 1. Four additional dispatchable PV peak shaving systems were installed for extended testing and evaluation at sites in Delaware, Maryland, Wisconsin and North Carolina. A second type of system that can be used to provide back-up power as well as peak shaving was also developed in Phase 2. This "PV-UPS" system used a packaging approach nearly identical to the PV peak shaving system, although there were significant differences in the design of the power electronics and control systems. Conceptually, the PV-UPS system builds upon the idea of adding value to PV systems by increasing functionality. A prototype of the PV-UPS system was installed in Delaware for evaluation near the end of the contract period.

Finally, a large amount of market research and analysis were undertaken to help understand the characteristics of the potential market for PV systems in the commercial buildings sector. This report summarizes the work performed by Delmarva Power and its subcontractors during its Phase 2 contract. Subcontractors participating in the Phase 2 work were:

- Applied Energy Group, Inc.
- AC Battery Corporation
- Advanced Energy Systems
- Ascension Technology, Inc.
- Solarex
- University of Delaware, Center for Energy and Environmental Policy

2 Dispatchable PV Peak Shaving System Development and Deployment

2.1 System Enhancements Since Phase 1

At the end of Phase 1, several significant enhancements were made to the basic dispatchable PV peak shaving system configuration. These included substantial improvements in system control and efficiency. A block diagram of the dispatchable PV peak shaving system is shown in Figure 1.

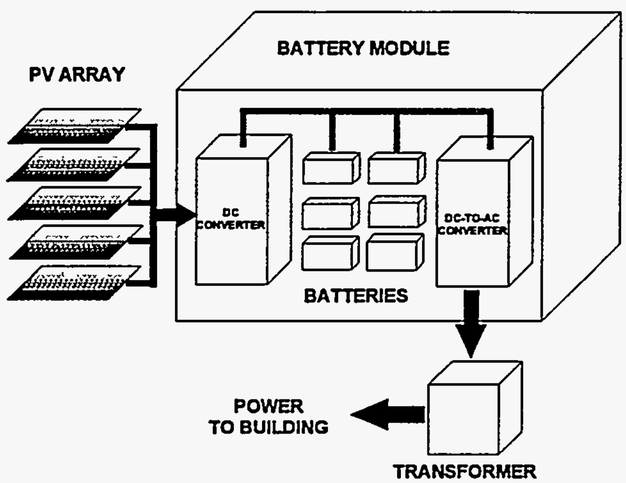


Figure 1. Dispatchable PV Peak Shaving System Block Diagram

In Phase 2, these refinements were incorporated into the four units produced for this stage of product development. These are described below.

2.1.1 Self-Dispatch

At the end of Phase 1, the battery/inverter module was capable of being dispatched by a remote utility SCADA system or a local energy management system (EMS). In many cases, remote control by a utility or automatic control by an EMS is not possible. A self-dispatch feature was added to allow the unit to operate during peak demand periods without the need for SCADA or EMS input. The data acquisition system is utilized for this purpose. By monitoring building load levels, the DAS can "see" a building peak and automatically dispatch the unit when a pre-set load level is reached. This feature can be optimized in future units to allow greater flexibility in programming set points and dispatch output levels.

2.1.2 AC Battery Module Packaging

AC Battery Corporation invested considerable time in improving the battery/inverter module packaging to reduce size, improve cooling airflow and to optimize assembly. As a result of these improvements, unit height was reduced by six inches, and airflow distribution has been improved. The changes in packaging helped to eliminate battery string temperature gradients, which can cause degraded performance and reduce battery life. The battery "rack-and-stack" assembly was also completely re-designed to eliminate a considerable amount of miscellaneous hardware previously required for the assembly of the older rack-and-stack unit. The module's outer skin also makes use of high-strength plastics, which are easier to form and cut than the original sheet metal material.

2.1.3 PV Array Configuration and Packaging

Working with Solarex, a standard PV panel assembly was developed based on the MSX-60 module. The panel consists of six MSX-60 frameless modules connected in series. The modules are assembled onto steel channels using high-strength adhesive tape. Pre-fabricated plug connectors are used at the end of each panel section for interconnection to adjoining panels. The panels are designed for use in either ballasted roof jack support systems (horizontal orientation) or in the structural steel support system designed for this program (vertical orientation). Because the panels are based on the MSX-60 module, other modules such as the MSX-64 and MSX-120 can be used with no design modifications. Modules produced by other manufacturers can also be used with little modification required to the panel design.

Source circuit strings are assembled using four panelized sections connected in series. This provides the required input voltage for the battery/inverter module. One source circuit string utilizing MSX-60 or MSX-120 modules is rated at 1,440 Watts (STC). Open circuit voltage is approximately 480 Volts DC. Nine to ten parallel strings (12 to 14 kW at STC, depending on the modules selected) can be connected to the AC Battery Module. The 14 kW DC-to-DC input converter is currently the limiting component.

2.1.4 Thin Film Arrays

In addition to the MSX-60 polycrystalline modules, Solarex's new thin film amorphous silicon (a-Si) PV modules were used in the design of the PV-UPS system. The new modules were produced in Solarex's new manufacturing plant in Toano, Virginia, and represent one of the earliest installations of the product. The modules used in the PV-UPS systems were MST-43MV (medium voltage) frameless modules. The medium voltage a-Si modules had significantly different electrical and physical characteristics than the polycrystalline modules used in the dispatchable PV peak shaving units. Only five modules connected in series were necessary to achieve the same open circuit voltage level as the polycrystalline modules. The modules were also much heavier, and required a different panel design to allow handling by two people.

The design process resulted in a string configuration consisting of two panel sections. One panel was constructed of two modules, and another panel was constructed of three modules. Aluminum channel sections were used to support the modules. Modules were attached in the field using RTV silicon adhesive and high strength adhesive tape. Module and panel wiring were also done in the field, using pre-cut wires and plug connectors to facilitate final termination.

The design and installation of the a-Si panels highlighted the two most important drawbacks of the thin film modules. First, the area-related costs of installation are higher than for polycrystalline or single crystal silicon cell modules. This is a direct result of a-Si modules' lower efficiency. Second, they are nearly four times heavier per Watt, mainly because two layers of glass are used in module construction. The weight of the modules required a two-section string design in order to allow two people to handle the assembled panels.

2.2 System Configurations in Phase 2

The basic components of the four dispatchable PV systems installed in Phase 2 are nearly identical. Solarex MSX-60 frameless modules make up the PV arrays in source-circuit strings of 1,440 Watts each (at STC rating) in three of the four systems. Due to delivery problems, one of the systems utilized ASE Americas PV modules. In all cases, Ascension Technology provided PV source circuit protectors. The battery/inverter module is an AC Battery Corporation PV-31 unit with integral controls. The PV-31 consists of 48 Delco 200 batteries connected in a single series string, a 32 kVA, three phase inverter, and a DC-to-DC converter used to increase the array input voltage to battery bus voltage (nominally 600 Volts DC). The DC-to-DC converter is also used as a maximum power point tracker.

Some changes in the standard equipment package were required to accomodate each of the sites, although none of the changes required any fundamental re-design of the system. These are explained below.

2.2.1 Wisconsin Public Service Corporation/ShopKo

The first system was installed in July 1996 on a ShopKo retail store in Green Bay, Wisconsin. ShopKo is a large discount retailer based in Green Bay, with over 120 stores in the upper midwestern and northwestern regions of the United States. Wisconsin Public Service Corporation

(WPS) funded the installation of the system, and has agreed to monitor and support the system for 15 years.

The ShopKo system consists of a PV array of eight source circuit strings. The total STC output rating is 11.5 kW. The array is roof mounted using Ascension Technology's ballasted roof jack mounting system and is tilted 25° above horizontal. The rooftop array is shown in Figure 2.

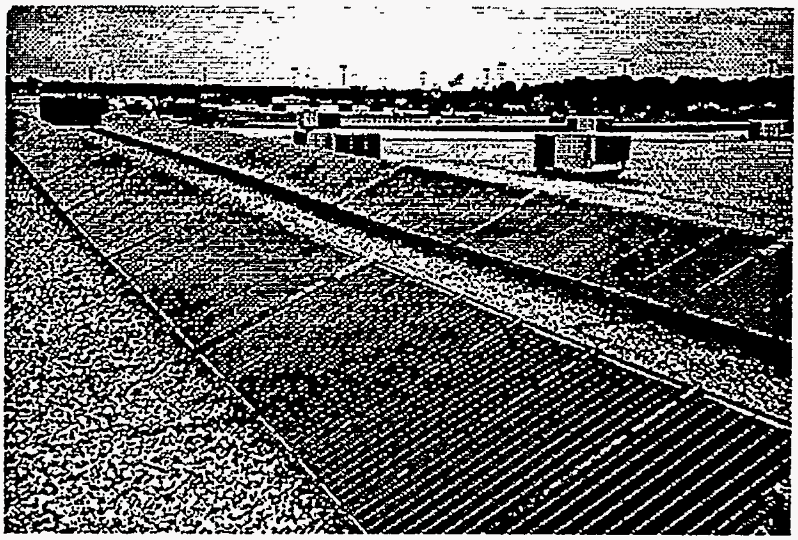


Figure 2. PV Array at ShopKo/WPS Site

The PV-31 battery/inverter module is located inside the building in the warehouse area. Originally, the maximum power tracker (MPT) unit was mounted on the side of the PV-31 module in the standard factory configuration. In order to reduce noise, the MPT was moved to an electrical switchboard room nearby. Baffles were also added to reduce noise from the inverter magnetics. The PV-31 module used at ShopKo is shown in Figure 3.

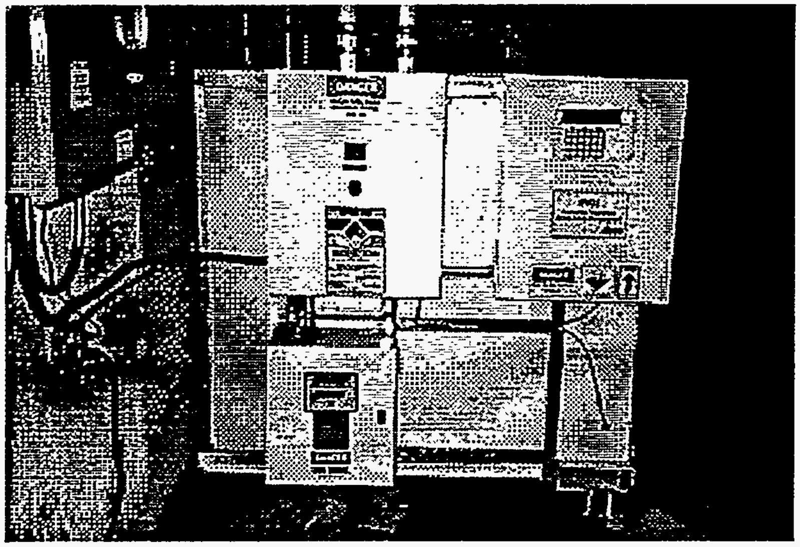


Figure 3. PV-31 Module at ShopKo/WPS

2.2.2 Delmarva Power & Light Company Conowingo District Office

The second system was installed at Delmarva Power's new Conowingo District Office, located near North East, Maryland. The building was constructed to house customer service, distribution construction and maintenance personnel for Delmarva's Conowingo District. The total floor area for offices is approximately 10,000 square feet. The building also houses a storeroom and garage of approximately 4,000 square feet.

The array at the Conowingo District Office is electrically identical to the ShopKo/WPS array. Instead of a roof installation, the PV array was installed on a ground-mounted structure. The array and structure are shown in Figure 4. The structure installed at Conowingo is designed for use on either roof- or ground-mounted PV arrays. If installed on a roof, the vertical support legs are designed to be located directly over building columns.

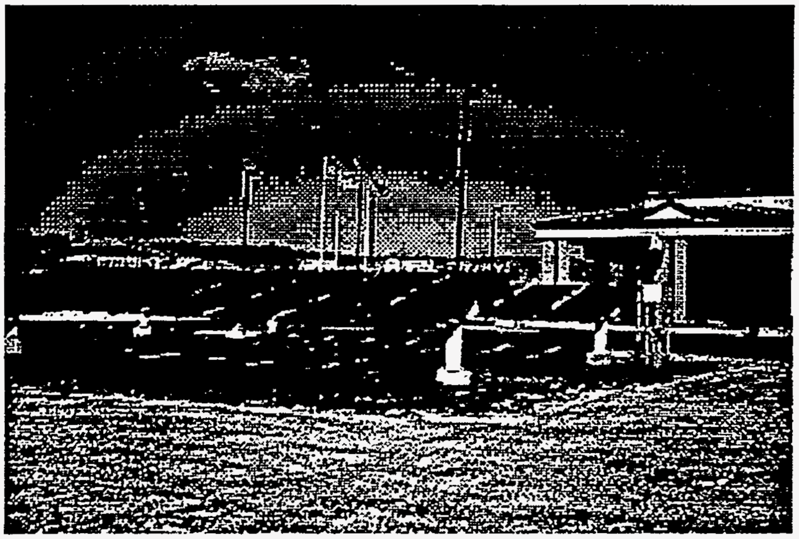


Figure 4. PV Array and Support Structure at the DP&L Conowingo District Office

The PV-31 module is located inside the store room and garage area at the building. Because the building is used to house vehicles, the National Electric Code requires that potential ignition sources be elevated at least 18 inches above the floor level. As shown in Figure 5, a steel auxiliary support stand was installed to meet this requirement.

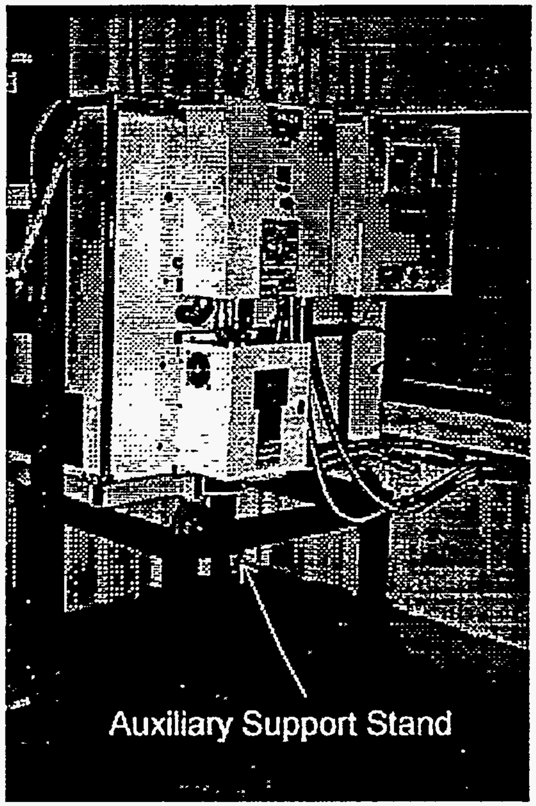


Figure 5. PV-31 Module at DP&L's Conowingo District Office

The Conowingo District Office is provided with 120/208 VAC wye-connected electrical service from a pad mounted transformer located at the site. The PV-31 modules used in the PV:BONUS Program provide 480 VAC delta-connected output through the output transformer. Because of this difference, a second step-down transformer was installed to permit connection with the building electrical distribution system. This is not expected to be a standard configuration for future 120/208 wye-connected systems.

2.2.3 Delaware Division of Facilities Management Carvel State Office Building

The Carvel State Office Building is located in downtown Wilmington, Delaware. The Carvel Building is a large office facility maintained by the Delaware Division of Facilities Management.

The building houses many of the state's administrative offices, and an office for the Governor. The building is 12 stories, with approximately 500,000 square feet of office space.

The PV array consists of six source circuit strings. The STC rated output of the array is 8.6 kW. Like the ShopKo/WPS array, it is mounted using a ballasted roof jack system tilted at 25° above horizontal.

The PV-31 module is installed on the mechanical equipment mezzanine level between the eleventh and twelfth floors of the building. Electrical service to the building is provided at 13.8 kV, but is reduced to 480 VAC for distribution throughout the building.

2.2.4 INTEK Corporation

INTEK Corporation is a manufacturer of interior fabrics for modular office furniture located in Aberdeen, North Carolina. The system installed at INTEK was part of an overall facility expansion completed in April 1997. The PV array consists of 32 ASE Americas large area modules rated at 285 Watts each. The modules are mounted on ballasted roof jacks. There are eight 1,140 Watt source circuit strings. The total array capacity is 9,120 Watts. The INTEK array is shown in Figure 6.

Figure 6. PV Array at INTEK, Inc.

The PV-31 unit is located in the new Electrical Equipment Room on the main floor of the INTEK facility. The unit is connected the building's 480 Volt electrical distribution system

2.3 Dispatchable PV Peak Shaving System Performance

2.3.1 Monitoring and Data Collection

Data acquisition systems (DAS) were installed at each site. The data acquisition system equipment and software were designed and installed by Ascension Technology.

The systems included the following equipment and instruments:

1. Campbell Scientific CR10-X data logger and telephone modem
2. Ascension Technology rotating shadow band pyranometer (RSP)
3. Plane of array pyranometer
4. Ambient temperature sensor

5. PV array voltage and current transducers
6. System output AC Watt transducer
7. Building load input sensor (pulse initiating demand meter installed by utility or customer)

An auxiliary relay was also installed at each site to automatically control the dispatch function based on building load. The Campbell Scientific data logger and software were used to control the relay.

Although generally reliable, a few problems with the DAS equipment emerged. These were:

1. Ascension Technology has a generic problem with the rotating shadow band pyranometer. A potentiometer used to measure shadow band position failed at all of the sites. Symptoms of the problem were with erratic operation and eventually failure of the shadow band. All of the RSP units were replaced by Ascension.

2. Ascension originally selected an AC Watt transducer for each site that utilized an ungrounded signal input. The transducer initially produced small but increasing measurement errors at three of the four sites. The problem was indicated by abnormally high tare losses. Replacing the transducers at the ShopKo, Conowingo and Carvel sites solved the problem.

3. Moisture inside the main DAS equipment box at the Carvel site caused the failure of the dispatch relay and CR10-X wiring panel. The failure caused the relay to send a constant dispatch signal to the battery/inverter unit for approximately three weeks, preventing battery system recharge. Although the batteries were prevented from dispatching by a low voltage cutoff, they remained at a very low state of charge for a long period. This condition may have affected battery performance towards the end of the evaluation period.

Monitoring was performed on a three to four day cycle with particular attention paid to dispatch set points and battery charging. Monthly progress reports were issued to each of the four test sites from initial system installation through August 1998. Typical monthly reports for each site are included in Appendix A.

2.3.2 PV Array Performance

PV array performance throughout the installation and testing of the four dispatchable PV peak shaving systems was good. In all cases, the arrays performed at or slightly above guaranteed STC rating. Array performance was tracked on a monthly basis, and helped to identify two problems:

1. In November 1997, a broken module caused reduced output at the ShopKo site in Green Bay. Although the cause of the breakage was not identified, the system returned to normal after replacement.
2. In February 1998, a broken module at the INTEK site in Aberdeen, North Carolina caused erratic output. Again, the cause of the breakage was not identified, but the array returned to normal after replacement of the broken module.

2.3.3 Mounting Systems

One significant problem occurred with the ballasted roof jack mounting system used in three of the four dispatchable PV arrays. In February 1998, a storm with very high northerly winds crossed over the northern Delaware region. The storm damaged the PV array at the Carvel State Office Building in Wilmington, Delaware by causing one section of the rear row of the array to move forward approximately three feet. An analysis discovered the following problems:

1. The ballast trays were installed on asphalt composite roof pads. The pads were installed by a contractor during the replacement of the building's roof in July 1997. Although the

installation team advised the contractor to use rubber membrane material between the trays and the pads to increase friction and reduce the possibility of sliding, they were not installed. The contractor also failed to install sufficient ballast material.

2. The location of the building and array contributed to the problem. The roof of the building is one of the highest points in Wilmington, and there are no obstructions to the north. High winds are frequent on the roof. The array was installed in front of two penthouse structures on top of the twelve-story building. A "wind tunnel" effect was created by the two structures that significantly accelerated the winds coming from the north. Wind speeds at the local airport during the storm were measured in excess of 60 MPH, and the speed at rear of the array was probably significantly higher.

As a result of the problems, two modules were broken, and two roof jacks were damaged. Minor damage also occurred to the electrical conduit and wiring between several modules. Repairs included the addition of roofing adhesive between the roof pads and the affected ballast trays. Under a separate PV:BONUS contract, Ascension Technoogy, which provided the roof jacks and trays, is performing wind tunnel testing of the ballasted roof jack design. To date, however, there have been few problems with the basic design. In this case, the contractor's failure to follow instructions was the primary cause of the problem.

2.3.4 PV-31 Battery/Inverter/Control System

The PV-31 unit is a factory-integrated system that is intended to reduce field labor costs, improve quality and provide enhanced functionality. The PV-31 unit is adapted from the AC Battery module, which was intended for use in reducing local electric demand during peak periods.

The primary focus of the test program was the performance of the Delco 2000 batteries. The Delco 2000 is flooded cell, sealed lead-acid battery. The Delco 2000 has been used in other PV applications. Typically, the battery has been applied in small, off-grid power systems using off-the-shelf charge controllers. The design of the unit assumes that peak demand is relatively infrequent, and that regular, deep cycling is not necessary. Under this assumption, an inexpensive battery should provide a favorable trade off between cost and performance.

The test program had three main goals, which are explained below:

1. Evaluation of the reliability of the PV-31 hardware;
2. Measurement of inverter efficiency and round-trip battery efficiency;
3. Evaluation of the Delco 2000 for use in a PV peak shaving system in terms of cycle life and depth of discharge.

The long-term performance of the units is described below in relationship to these goals.

Throughout the testing phase of the program, the PV-31 hardware generally performed reliably. However, a few minor problems emerged with the control system:

1. An improperly sized capacitor on the PCS master control board caused the Carvel unit to trip frequently for a "DC injection" fault." The problem was difficult to diagnose, causing the Carvel system to be down for an extended period while control boards were tested at the manufacturer's. Eventually, a circuit board component was replaced in the field to remedy the properly.

2. An operational amplifier on the PCS master control board caused problems at the ShopKo and Conowingo sites. The symptoms of the problem were somewhat different at the two sites. At the ShopKo site, the PV-31 unit would trip on an "AC over current" fault. Test data from the site indicated that the unit would also occasionally dispatch itself at output levels higher than the established dispatch set point. At the Conowingo site, only the self-dispatch

problem emerged. In both cases, the problem was erratic and emerged only after months of successful operation. Several months of shop testing at Omnion Power Engineering were required to isolate the problem. The solution involved installing two Zener diodes on operational amplifier's output. This prevented saturating the input of the PCS gate driver control.

3. Unexplained nuisance trips were experienced at all four sites, although they were very infrequent. In at least two cases, inadvertent operation and resetting of the Emergency Stop pushbutton was the most likely cause.

Only one significant power train problem occurred during the test program. An IGBT failed on one phase of the Conowingo inverter. The failed IGBT and its associated snubber were replaced with no problems.

DC to AC conversion efficiency was calculated using measurements of PV array input and total AC output. Energy contributions from the batteries were not included during these measurements since they could not be directly measured. AC output was measured on the high voltage side of the step up transformer, and therefore included transformer losses. In all cases, inverter efficiency was predictable. Up to DC input of 1 kW, AC output was zero. Above 1 kW, efficiency increased rapidly to 85% at approximately 5 kW DC input. Above 5 kW, efficiency increased slowly to a maximum of 87%. The Conowingo system measurements also included the losses caused by the second transformer, which reduced the system's output from 480 VAC delta to 120/208 wye. The Conowingo system consistently displayed conversion efficiencies approximately 3% below the efficiencies measured on the other units.

Evaluation of the Delco 2000 batteries was based on the premise that peak shaving would be required for continuous periods of one or more hours several times a month. Dispatches were automatically initiated when building load exceeded a pre-set level. The peak would then be reduced by pre-set kW amounts for as long as the peak occurred, or until the batteries were exhausted. Based on the original set of operating assumptions, it was expected that dispatches would last up to several hours. Under these circumstances, the frequency and depth of individual discharges are very important.

Once monitoring commenced, it soon became evident that peak loads for individual buildings did not behave this way. Load duration curves and load profiles based on 15-minute load data revealed that peak loads tended to be brief, often only a few seconds up to 20 or 30 minutes. In some cases, continuous periods of high loads occurred, but these were the exceptions. Peak loads at all of the sites are very difficult to predict. While ambient temperature plays a significant role in overall load trends, there is a large amount of variance. Load diversity, building size and type have important impacts on determining peak load. The INTEK site in Aberdeen, North Carolina proved to be the most difficult for predicting peak loads. As a manufacturing facility, ambient temperature played a less important role than production schedules.

The vast majority of discharges were scattered throughout the day at all of the sites, depending on where the original threshold value was set. Qualitatively, it became apparent that peak shaving would require numerous relatively shallow discharges (less than 20 percent depth of discharge) rather than a few deep discharges. Based on the Delco 2000 characteristics, the battery is very capable of operating for hundreds of shallow discharges. Original projections, based on the earlier assumptions, determined that the batteries would be capable of providing between 200 and 300 discharges of up to 80% depth of discharge. To date, all of the systems have exceeded this number of discharges, although at much shallower depth of discharge, with no signs of problems. Although there was uncertainty about the application of this battery for peak shaving, it now appears to be suitable. Depending on the application, a three to five year life should be easily obtainable.

A more difficult problem is the development of an automatic control algorithm to predict peak loads. A simple threshold set point was used in the test units, but this is not suitable for widespread commercial applications due to the large amount of variance in peaks and the need to maximize the value of the peak shaving function provided by limited storage. Such a system would necessarily monitor temperatures, but would also track historical trends and relationships on order to prevent unnecessary discharges.

3 Grid-Independent System Development

The development of a grid-independent system based on the PV-31 unit was also part of the Phase 2 work. This system is intended to improve the functionality and value of the original modular design by adding power conditioning, UPS, emergency back-up and/or remote power capabilities.

Because of the unique requirements of this unit, Advanced Energy Systems of Wilton, New Hampshire and AC Battery Corporation cooperated in its development.

3.1 System Design Specifications and Applications

The grid-independent unit is designated "PV-GI." The PV-GI unit makes use of the basic AC Battery rack-and-stack configuration and mechanical chassis. Power conversion and control equipment are mounted in the same location as the PV-31 power conversion system.

Overall, the unit is capable of providing 12.5 kVA, 120 VAC single phase output for approximately 2.5 hours with 25 kWh of energy storage. The unit also employs an inductor for power conditioning to limit the impacts of utility or generator surges and sags.

The prototype PV-GI unit includes a PV array consisting of 75 Solarex MST-43-MV amorphous silicon, thin-film modules. Total array capacity is 3.2 kW at STC conditions. A schematic overview of the PV-GI system is shown in Figure 7. Operating modes and functions are described below

Grid-Interactive, Line Conditioning Mode: During normal operation, with the batteries fully charged, the PV modules will operate in a grid interactive mode, and will displace utility power.

In this mode, the PV-GI unit will also provide line conditioning through an inductor, helping to minimize transient sags and surges which can harm electrical and electronic systems in the building. In this mode, the inverter will actively compensate for the phase shift introduced by the inductor.

Uninterruptible Power Supply (UPS) Mode: In this mode, the batteries will discharge energy to the building distribution system in the even of a utility outage. In the UPS mode, a properly sized system can provide all or a portion of the electricity required by a facility for a finite period of time. At the full rated inverter output (12 kVA), the system can provide power from the batteries for approximately 2.5 hours, depending on the amount of solar energy available at the time.

Stand-Alone Mode: In the stand-alone mode, the PV-GI unit can operate independently of the utility grid indefinitely at lower power levels, utilizing energy available from the PV array to recharge the batteries. This operating mode is useful for extended outages when critical equipment must keep running, or in areas where long-duration power outages are a chronic problem.

Battery Charging Mode: In the charge mode, the PV-GI unit will draw power from the utility grid, generator and/or PV array to recharge the on-board batteries.

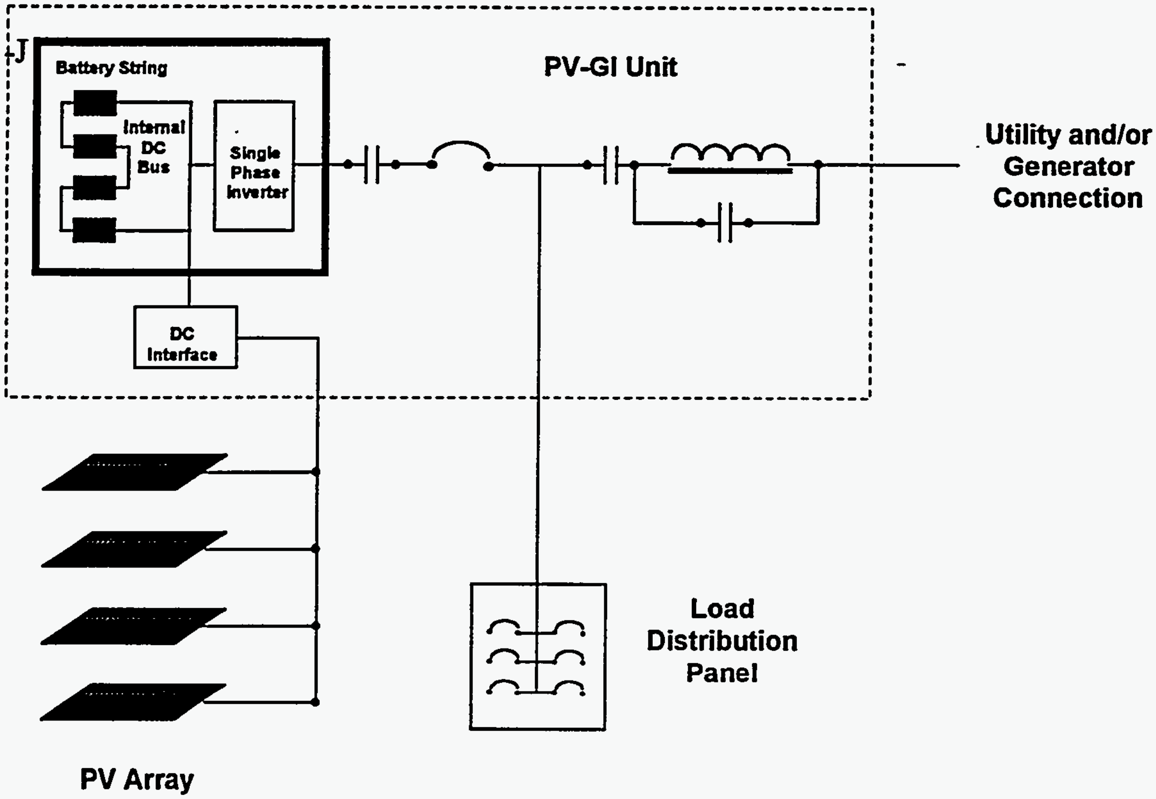


Figure 7. Block Diagram of PV-GI Unit

3.2 Prototype System Construction and Performance

The prototype system was installed at the Delaware Division of Facilities Management Office in Dover, Delaware in August 1998. Since the original installation, the unit has been functionally tested to verify its ability to provide power during a utility outage. No problems have been observed, and the system has performed reliably. Due to the limited data collection since original installation, long term PV array performance and inverter performance have not been established, although early site tests indicate that both components are performing within specifications.

4 Development of Modeling Tool

Part of the work in Phase 2 involved the development of analytical tools capable of accurately predicting the economic and energy impacts of dispatchable PV peak shaving systems. A spreadsheet-based tool called "PV-Planner" was developed and used extensively in market research analysis and in providing prototype system customers with estimates of impacts on electric bills. The model has also been used in several studies by the University of Delaware Center for Energy and Environmental Policy (CEEP) to compare conventional grid-connected PV systems with dispatchable PV peak shaving systems. CEEP worked closely with Delmarva and its subcontractors to create the analytical framework and methodology for examining dispatchable PV systems.

4.1 Overview

PV-Planner is a multi-level Excel spreadsheet with calculation algorithms designed to perform the following tasks:

- Analyze insolation and other weather variables to develop typical insolation and temperature profiles;
- Analyze electrical demand and consumption data to determine typical load patterns;
- Analyze electric rates;
- Analyze cost and financial variables.

Once basic data is processed and entered into the spreadsheet, the model can be used to compare the following:

- Compare dispatchable and non-dispatchable PV systems for a given site
- Determine the energy and demand impacts of the PV systems on the building, feeder or utility being analyzed
- Determine the impacts of different dispatch strategies
- Determine the economic and energy impacts of system component costs and performance
- Determine the economic impacts of tax credits and other policy measures on PV system economics.

The PV-Planner model was used extensively in the market analysis in Appendix B, "Building Load Analysis of Dispatchable Peak-Shaving Photovoltaic Systems: A Regional Analysis of Technical and Economic Potential."

The PV:BONUS Program was not intended to develop "marketable" software, and the analytical model developed under the program was solely intended to make it more convenient to analyze dispatchable, grid-connected PV systems for specific sites, and to compare them to conventional grid-connected systems. However, the model in its current form is usable for further analytical studies by others with sufficient explanation. It is also possible to enhance the model to create a more "user friendly" version if such a need exists.

5 Progress Towards Commercialization

5.1 Commercialization Summary

The original intent of all of the participants in this effort was to develop and fully commercialize the Dispatchable PV Peak Shaving System and the PV-GI system based on a partnership business model. In 1995, Delmarva Power, Applied Energy Group, Inc. and AC Battery Corporation agreed to work together towards the development of a separate business entity responsible for manufacturing, marketing, distributing and servicing fully integrated systems including PV arrays. In late 1997, Delmarva Power decided to reduce its commitment to the commercialization of the systems due to restructuring pressures. In January 1998, Omnion Power Engineering purchased AC Battery Corporation from the Delphi Division of General Motors. At this point, discussions concerning the development of a separate business entity for commercialization ceased. Omnion Power Engineering is currently marketing the PV-31 unit as a balance-of-system component, and Advanced Energy Systems is using the PV-GI unit as the basis for future product development efforts.

5.2 Market Research Summary

Although the commercialization effort ceased, market research done as part of Phase 2 can contribute to other commercialization efforts. Four individual studies were done under the PV:BONUS Program, each providing insight into the potential applications of dispatchable PV peak shaving systems. The reports are listed below with a brief description of their contents:

- *Appendix B - CEEP Study (Building Load Analysis of Dispatchable Peak-Shaving Photovoltaic Systems)*: This study analyzes the technical and economic potential for dispatchable PV peak shaving systems taking into account regional variation in electricity prices and insolation. For each major region, different types of commercial occupancies (offices, hotels, schools, restaurants, etc.) are compared using typical load shape information for each type of occupant.

- *Appendix C - Survey of Utility Energy Managers*: This survey analyzed the attitudes of utility account and energy management personnel about potential applications of dispatchable PV peak shaving for utility customers. The survey provides information primarily about the attitudes of the utility managers towards the technology.

- *Appendix D - Survey of Buildings Specialists*: This survey sampled a large number of commercial property owners to directly assess their attitudes towards PV technology, and to guide future product development. The survey covered a wide range of commercial building types and ownership.

- *Appendix E - Distribution Feeder Analysis*: Delmarva Power commissioned a study of it own distribution system to analyze the potential for using PV peak shaving systems to defer distribution system investment. The study analyzed over 400 distribution feeders and substations.

Although each study and survey contains considerable detail, several overall conclusions can be reached as a result of the work:

- The CEEP study indicated that there are areas in the country where PV can be more cost effective due to high base electric rates, favorable tax credits and incentives, or a combination of both. The most powerful factors influencing system economics are policies, like tax credits, that encourage individual end users to purchase PV systems. Load shape is also a significant factor. Since the dispatchable PV peak shaving system is designed to minimize demand charges, its economics are especially sensitive to the time and duration of peak loads. The most favorable economics occur when high demand charges are combined with pronounced but relatively brief peaks. Overall, dispatchable PV peak shaving is more cost effective than simple, grid-connected PV systems for commercial applications because theses systems can take advantage of the demand charge component of commercial electric rates.

- Utility account managers are generally pessimistic about their customers' willingness to employ dispatchable PV. This perception about customer attitudes among utility managers appears to be based on current costs rather than any systematic inquiry about the use of PV among commercial accounts. As a result of restructuring, and in an effort to focus on "core" businesses and competencies, renewable energy has generally become less attractive to utilities, although most of the utility managers indicated a willingness to provide PV technology if requested by their customers. Utilities have assumed a passive role in promoting and marketing PV to commercial customers in the current business environment.

- Building specialists appear to be more open-minded when asked directly about their interest in PV. Although their prime concern is the cost-effectiveness of any energy technology, they are usually willing to try new technologies if it provides significant benefits. From the survey of building specialists, it became clear that a multi-function system, like the PV-GI, would be preferred over a system that was capable of peak shaving only.

- Finally, it is very clear that distribution system feeders and substations could be better utilized, and that technologies like dispatchable PV peak shaving systems could help to manage distribution system peak loads, and defer distribution system investments. However, the number of feeders that could benefit from either dispatchable or non-dispatchable PV systems is small, and there is an overall reluctance to invest in renewable technologies when the benefits to the utility could be difficult to quantify.

As a whole, the market research indicates that technology and policy development efforts should focus on multi-function PV systems for retail users. Utilities are unlikely to employ or promote PV systems in substantial numbers due to uncertainty arising from restructuring and competition. This naturally favors "status quo" technologies, especially on the distribution system. End-users, on the other hand, appear to be quite willing to try new technologies if there are significant economic, convenience and/or reliability benefits.

Appendix A – Sample Reports of Dispatchable Peak Shaving System Performance

Key to Monthly Performance Report Charts (WPS/ShopKo)

Monthly performance reports for the Dispatchable PV Peak Shaving units installed under the PV:BONUS Program consist of a series of graphical profiles and charts, along with a brief written summary of system performance. The following information is presented to help clarify the meaning of the attached charts and graphs.

Monthly Profiles

Four monthly profiles are provided with each report. The monthly profiles show 15 minute, time-series data for the following measured variables:

- PV system AC input (during battery charging) and AC output (during PV array operation and/or battery discharge)
- Global horizontal and direct normal solar radiation
- PV array DC output
- Building load

Monthly profiles provide a quick overview of PV system operation, solar resource availability and building operation over the reporting period.

Building Load Characteristics

Four graphs are provided to indicate the response of the building to temperature and solar radiation. A fifth graph is provided to show the building's load-duration characteristics. These are explained below:

- *Weekday Building Load vs. Temperature*: This graph plots the sensitivity of the building's load to outside air temperature using 15-minute data. Electrical loads tend to increase during seasonal extremes. In hot weather, air conditioning runs more frequently, resulting in higher electrical demand. Likewise, during periods of very cold weather, equipment used in the operation of heating systems (fans, pumps, etc.) also run more frequently. In buildings that use electric heating systems, such as heat pumps, demand can be significantly higher during the winter than in the summer. Peak summer loads tend to occur in the early to late afternoon when temperatures are highest. Peak winter loads tend to occur during the early morning and early evening when high heating and lighting loads coincide. For most commercial and industrial buildings, loads also tend to be higher during weekdays when occupancy and usage levels are higher.

- *Weekday Building Load vs. Global Horizontal Irradiance*: This graph plots the sensitivity of the building's load to global horizontal irradiance using 15-minute data. During the summer months, building loads tend to be higher during periods of high irradiance. This is because high summer temperatures are partially correlated to high sunlight levels. In climates where haze and humidity accompany hot weather, solar radiation levels may actually be somewhat lower than cool, clear days when solar radiation approach ideal maximums. A strong positive correlation between building load and global horizontal irradiance indicates that the output of a PV array is also strongly correlated with building load, and can therefore provide relatively reliable demand reduction. In these cases, the benefit of battery energy storage is lower. It is much more common to have moderate or poor correlation. In these cases, battery energy storage provides higher benefits by assuring reliable peak shaving.

- ***Building Daily Peak Load vs. Daily Average Temperature***: This graph is similar to the graph of Weekday Building Load versus Temperature. However, data used in this graph are derived from the raw 15-minute data. The data is processed to calculate average daily temperatures and to find corresponding peak building loads. Peak building loads are likely to be higher on days when the average daily temperatures approach seasonal extremes.

- ***Building Daily Peak Load vs. Daily Global Horizontal Irradiance***: This graph is similar to the graph of Weekday Building Load versus Global Horizontal Irradiance. Like the graph above, the data used to generate this graph are derived from the raw 15-minute data. Global horizontal irradiance is summed for an entire day to determine the total availability of solar energy and plotted against the corresponding daily peak load. A positive correlation indicates that peak loads occur on days when the availability of solar energy is high. This graph should be interpreted in conjunction with the graph of Weekday Building Load versus Global Horizontal Irradiance. It is possible to have poor correlation between building load and 15 minute readings of solar radiation while having good correlation between daily peak load and total daily solar radiation. This implies that the building's peak load is not instantaneously coincident with solar radiation, i.e., peak loads occur either before or after the solar resource peaks. A good positive correlation in this graph indicates that battery energy storage is of high value in managing the energy output of the PV array, because it allows peak shaving independent of PV array output.

- ***Building Load-Duration Curve***: The final graph related to building loads is a Load Duration Curve. The load duration curve depicts 15 minute building load intervals in order of highest to lowest for the monitoring period. The graph included in this report shows only the highest 400 15 minute intervals. Load-duration curves are typically used to show the relationship between peak and base building loads. Buildings with sharp "spikes" at the left of the curve are usually good candidates for peak shaving, especially if demand charges are a significant portion of the overall electric bill.

Dispatchable PV System Performance

Six graphs are used to show overall PV system performance and to provide diagnostic information during the monitoring period. These are explained below:

- ***Inverter Efficiency vs. DC Input***: A three-phase, solid state inverter is used to convert the DC output of the PV array and battery string to AC power compatible with the building's electric power system. Like all conversion devices, losses are inherent in its operation. For the 32 kVA inverter installed in the PV-31 battery/inverter modules, efficiency is nearly flat at 90% for DC input levels above approximately 4 kW. For DC inputs between approximately 1 and 4 kW, efficiency increases rapidly from nearly 0 to about 90%. Below approximately 1 kW, conversion losses and parasitic loads usually prevent generation of significant AC power.

- ***DC Conversion Efficiency vs. Plane of Array Insolation***: In order to monitor PV array performance, a graph of sunlight to DC power conversion efficiency is plotted. For the polycrystalline silicon PV modules used in the dispatchable PV systems, sunlight conversion efficiencies are typically between 10 and 12%. Conversion efficiency between 100 and 200 Watts/m^2 varies in a nearly linear fashion from approximately 6 to 12%. Efficiency peaks at 10 to 12% between about 200 and 700 Watts/m^2. Above 700 Watts/m^2, temperature effects tend to reduce efficiency somewhat.

- ***Temperature Corrected DC Output vs. Plane of Array Insolation***: A second graph of PV array performance shows the PV array output in kW versus insolation. For each data point a temperature correction factor is applied since PV output varies inversely with solar cell temperature. The corrected performance reflects PV array output at Standard Test Conditions, i.e., a cell temperature of 25°C. Performance curves should be nearly identical from month to month when plotted in this way. At 1,000 Watts/m^2, the temperature corrected output should be within several percentage points of the PV array rating at STC.

- ***Daily PV Array Output***: A vertical bar chart shows the daily PV array output in DC kWh. This chart provides a quick summary of PV array operation, and an approximate indication of the amount of energy generated by the system.

- ***PV Array Performance***: A second vertical bar chart presents PV array performance as a percentage of theoretical output at 10% conversion efficiency. Values will typically vary between 80 and 110%, depending on site conditions and daily insolation. Values that are significantly lower indicate that the array may have been out of service for at least a portion of the day.

- ***Daily Plane of Array Insolation***: A third vertical bar chart shows the total amount of solar energy available to the array for each day. This chart, in combination with the other bar charts, is used to quickly identify outages and other array problems.

Tabular Summaries

There are two tabular summaries included in the monthly reports:

The first tabular summary of daily performance provides more detailed information about system performance and solar resource availability. The last column in the tabular summary also indicates the amount of time, in seconds, that the PV-31 unit was dispatched during the day.

WPS/ShopKo Dispatchable PV Peak Shaving System
Monthly Performance Summary
August 1998

Overall PV System Operation

The PV system operated normally throughout August with no interruptions or problems observed. Unit dispatches occurred routinely throughout the month at building load levels in excess of 400 kW.

Building Load Characteristics

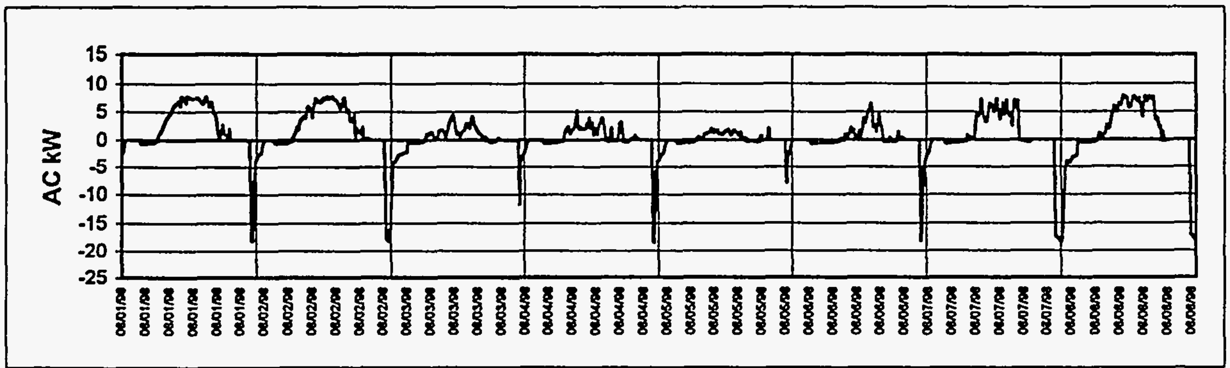
Daily building load shapes in August were very similar to load shapes observed in July. Peak daily loads varied from less than 350 to slightly more than 400 kW. Typically, loads peaked at about 3:00 PM (CDT). Due to the use of air conditioning, a very strong correlation was observed between building loads and ambient temperature. A slight positive correlation was observed between building load and global horizontal irradiance.

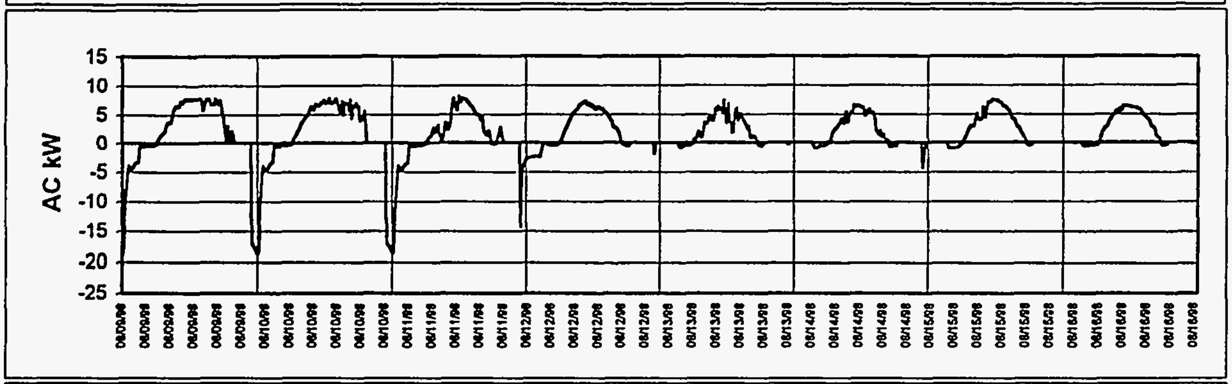
Peak 15-minute load for the period was 418 kW, approximately 33 kW lower than the July peak load.

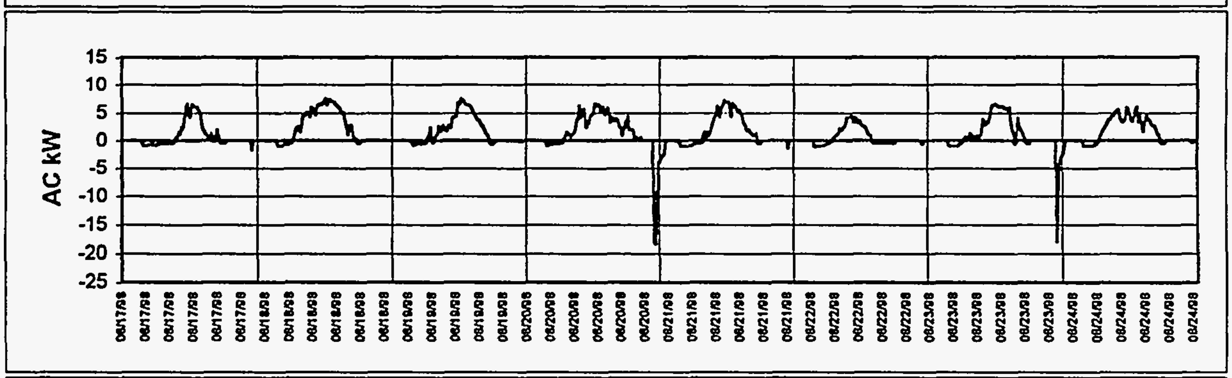
Dispatchable PV System Performance

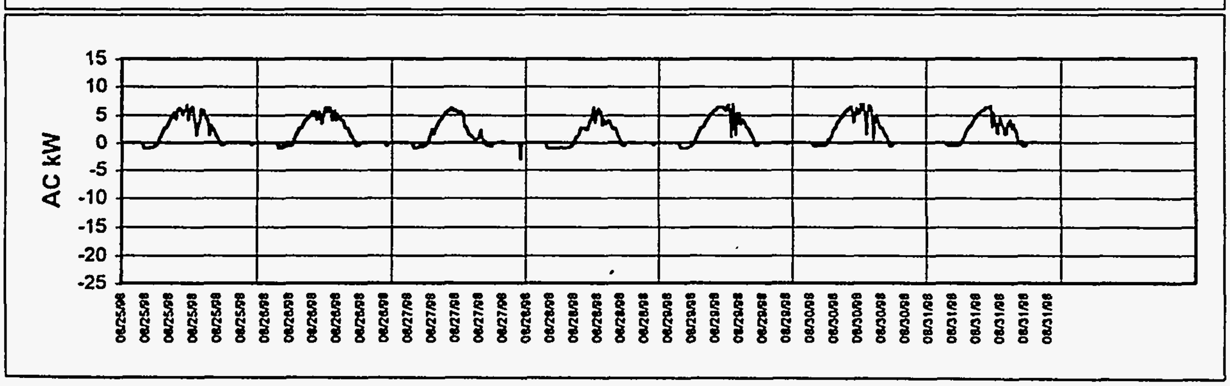
108 separate dispatch events were recorded during the period, on 27 separate days. Dispatch duration ranged from 15 seconds to 7 ½ hours. During the longest dispatches, significant storage shortfalls resulted, due to the high peak loads and extended durations of the peaks. The dispatch set point will remain at 400 kW in September, in anticipation of cooler weather and lower peaks.

WPS/ShopKo Dispatchable PV Peak Shaving System
AC Output and Charging Profiles

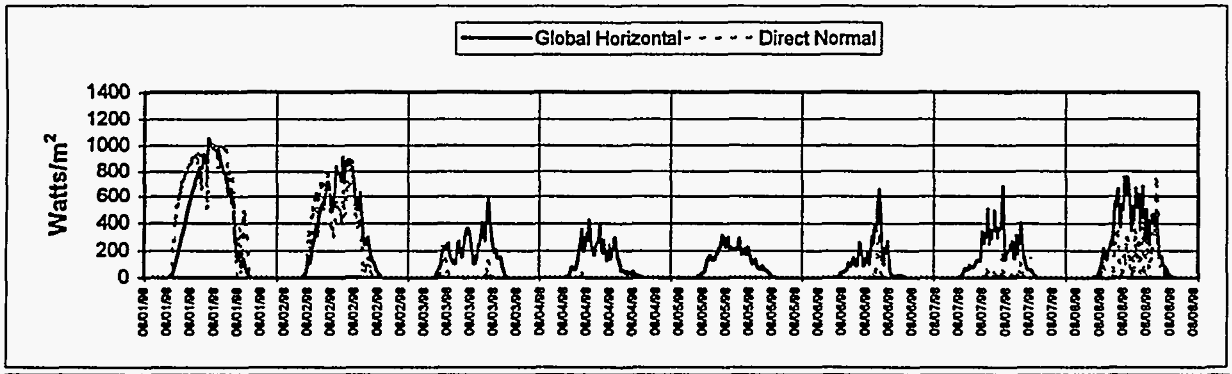


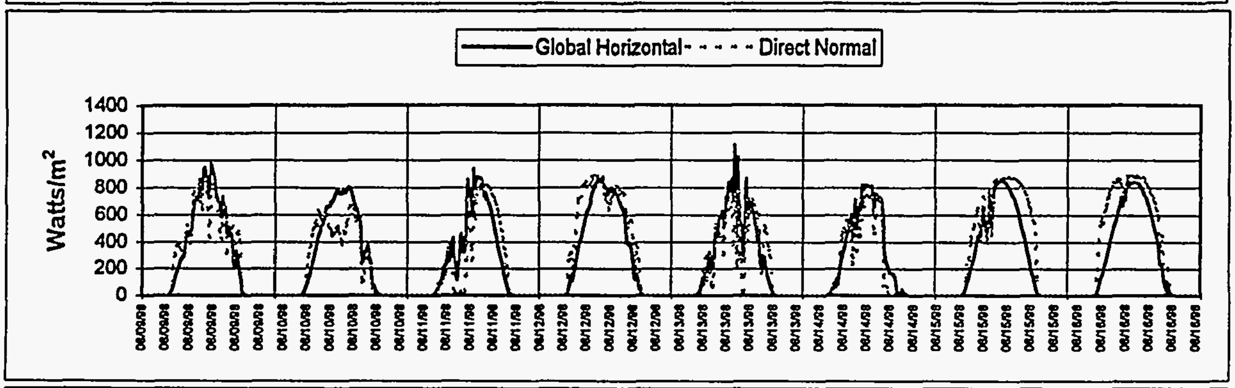


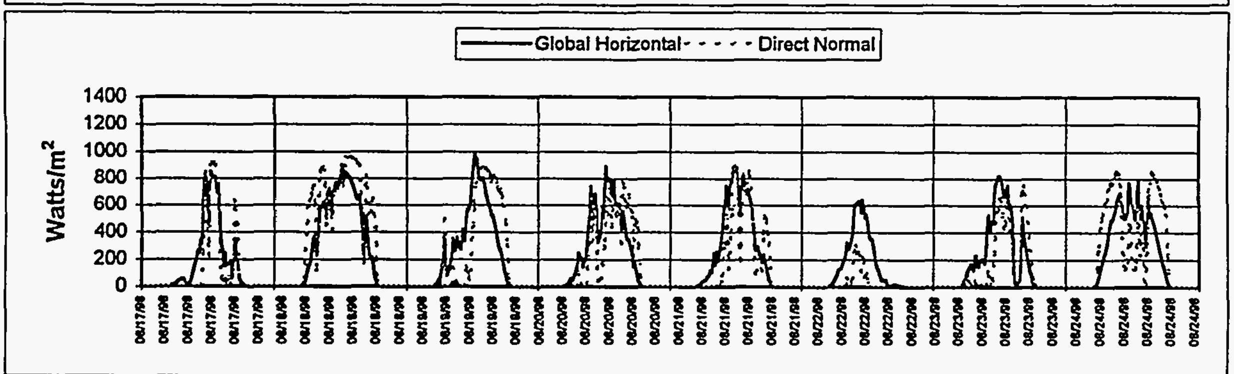


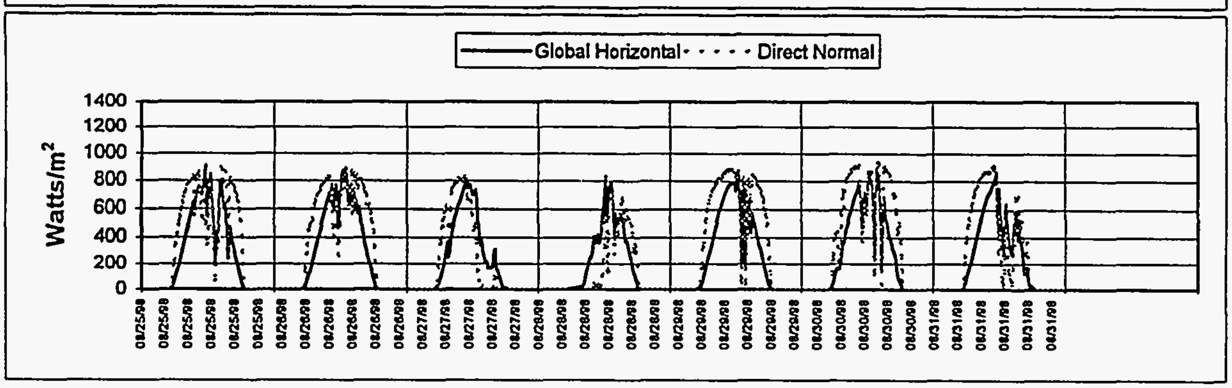


WPS/ShopKo Dispatchable PV Peak Shaving System Aug-98
Solar Resource Profiles



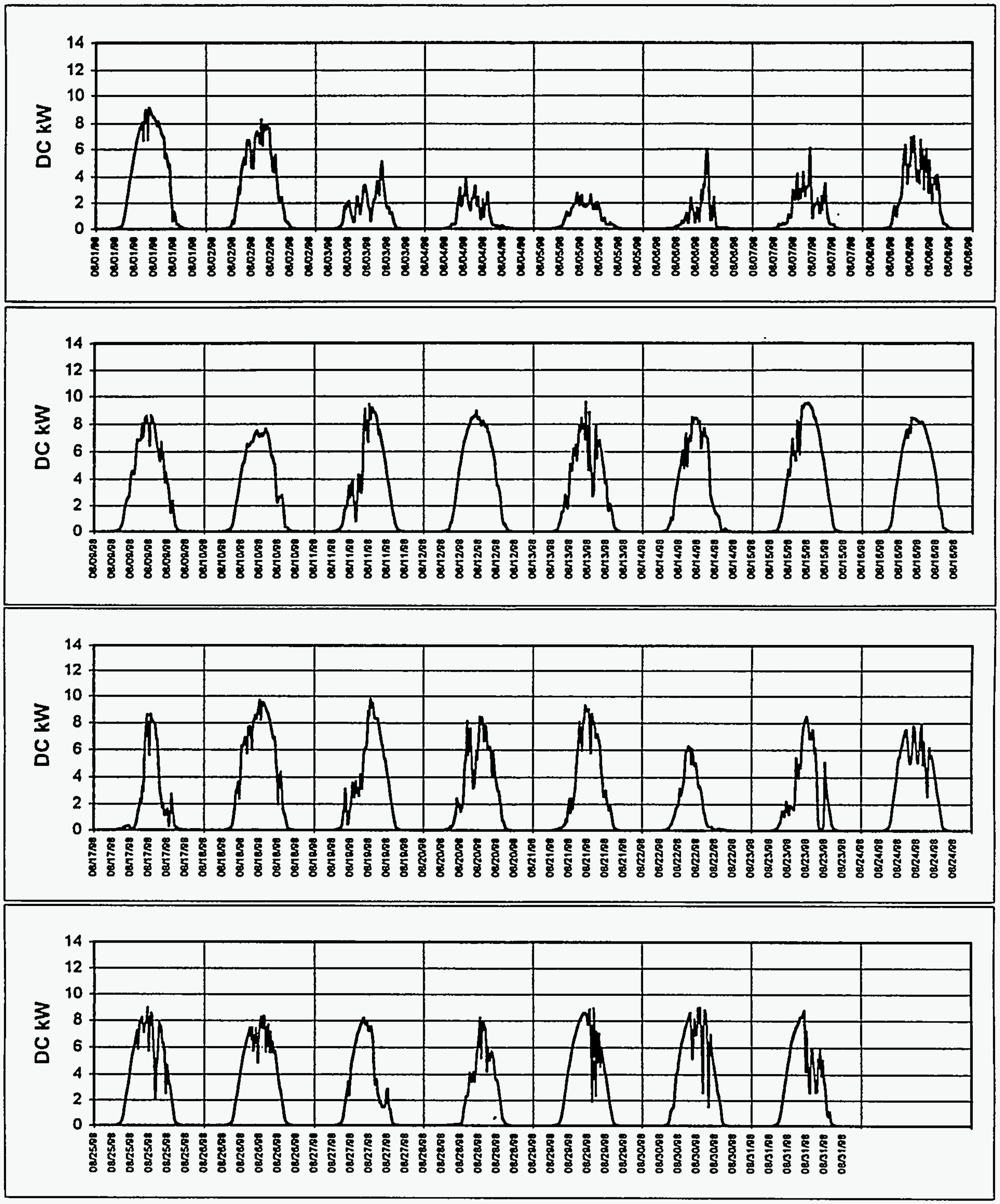




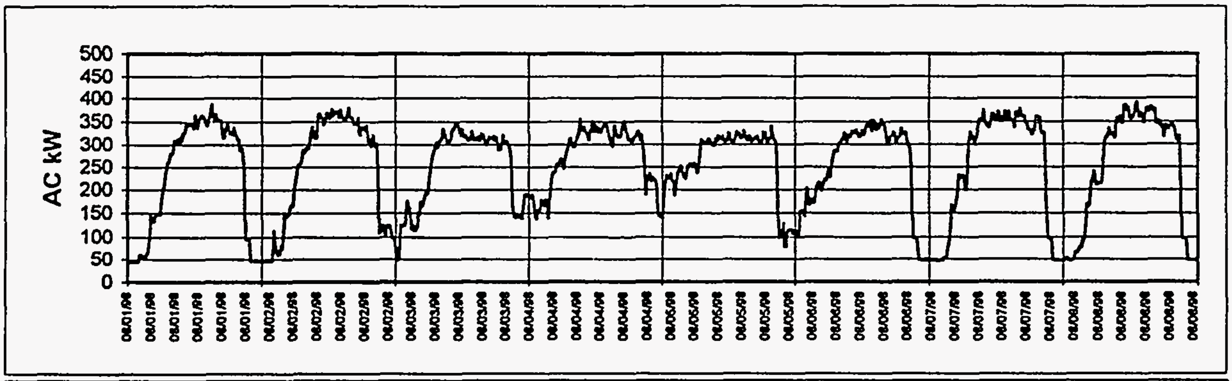


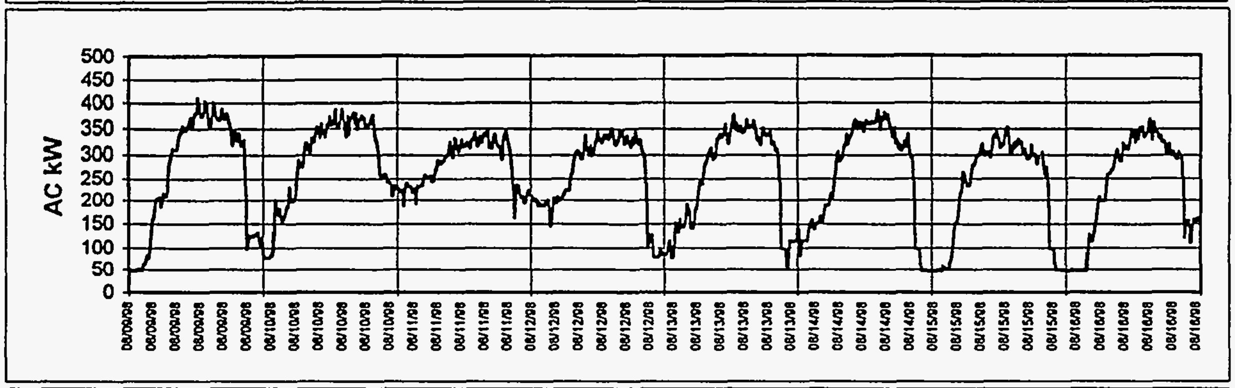
WPS/ShopKo Dispatchable PV Peak Shaving System
DC Output Profile

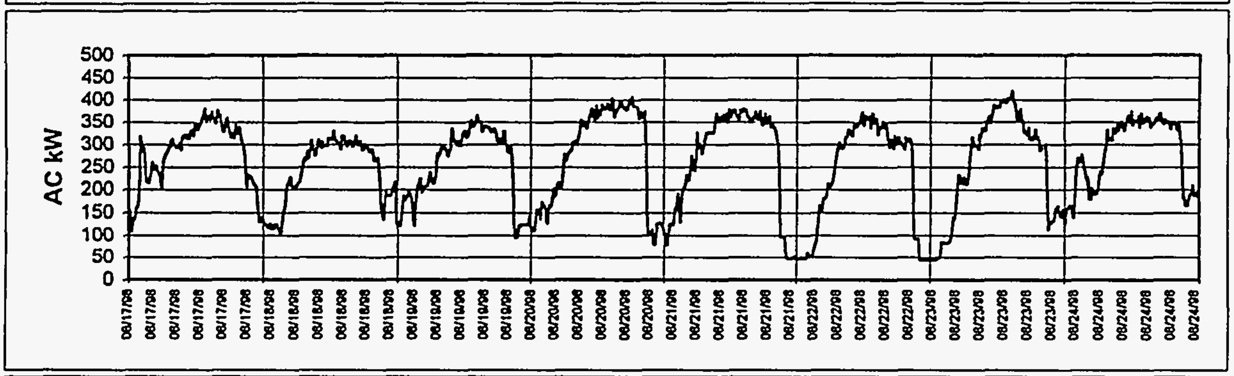
Aug-98

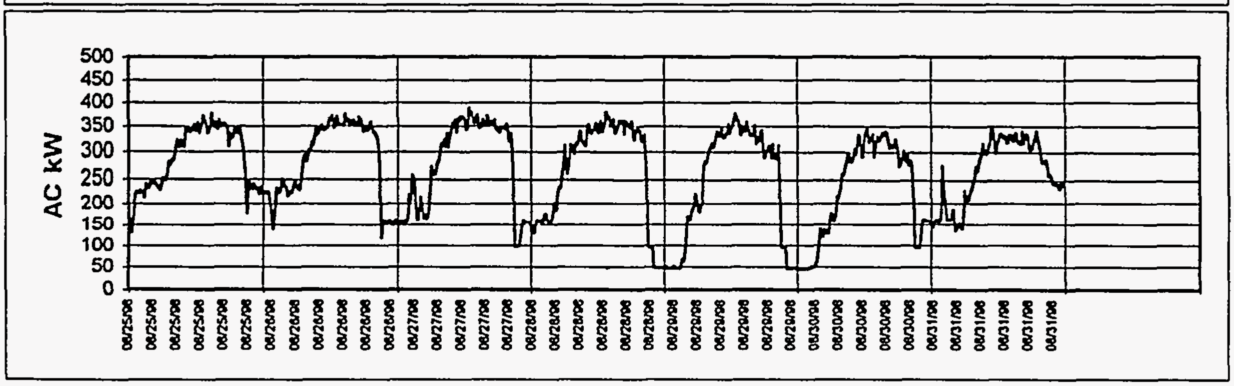


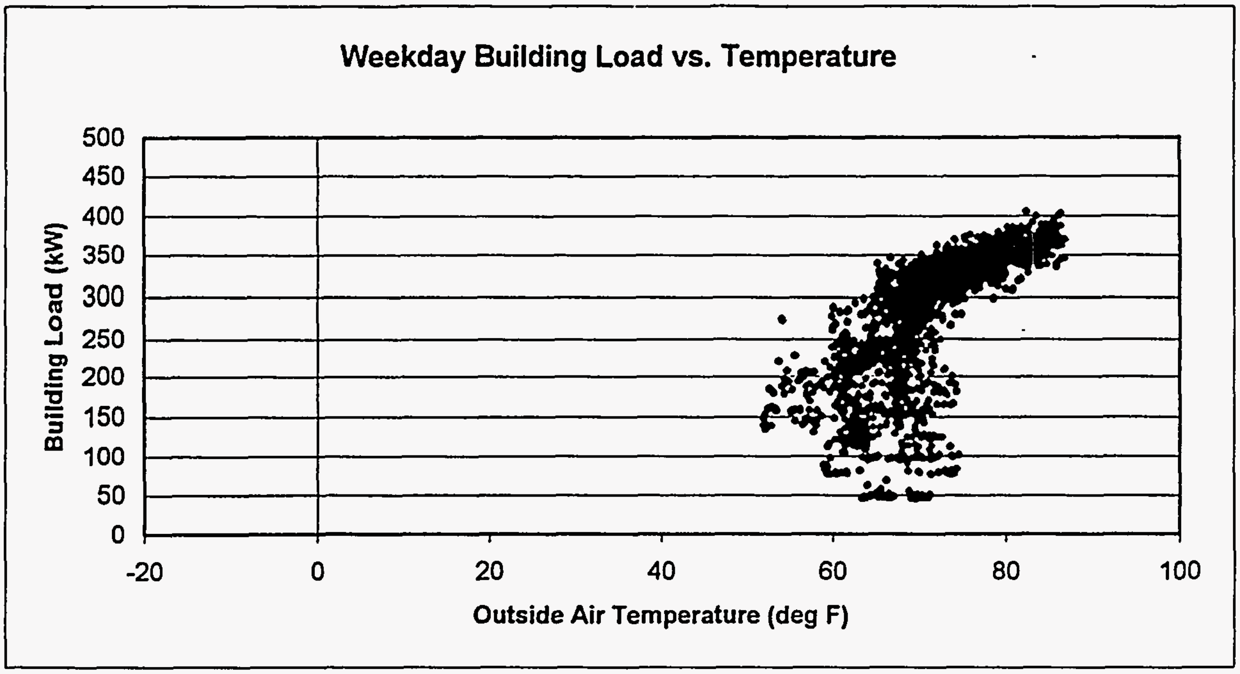
WPS/ShopKo Dispatchable PV Peak Shaving System	Aug-98
Building Load Profiles

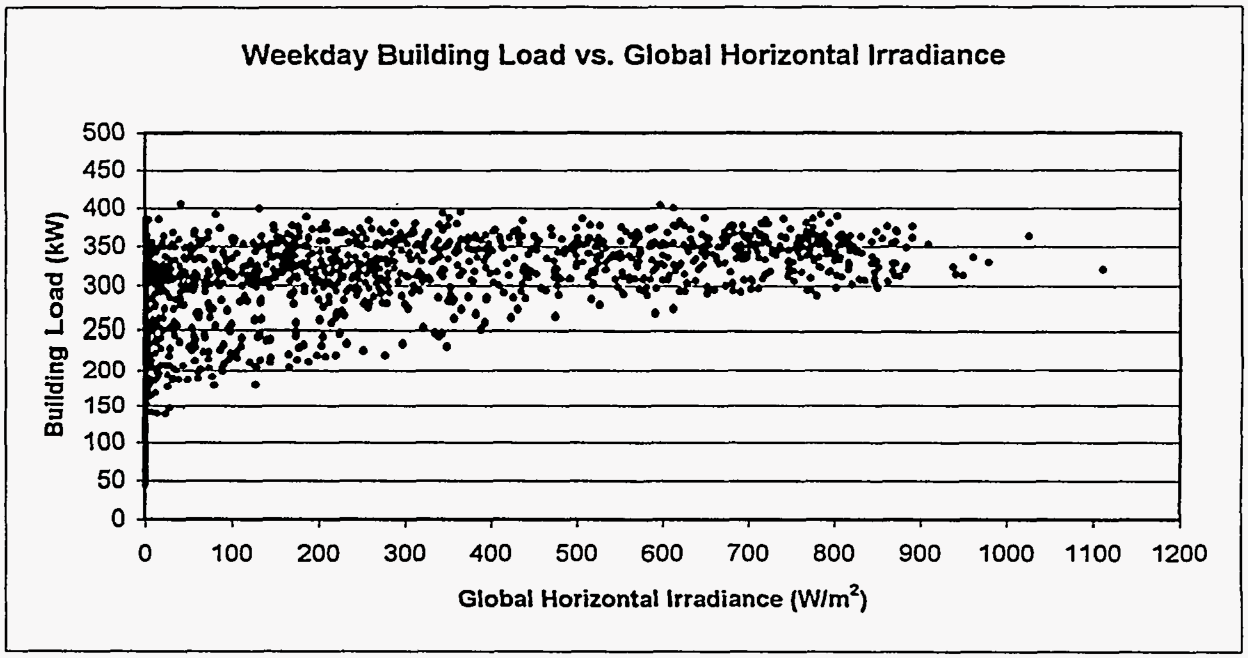


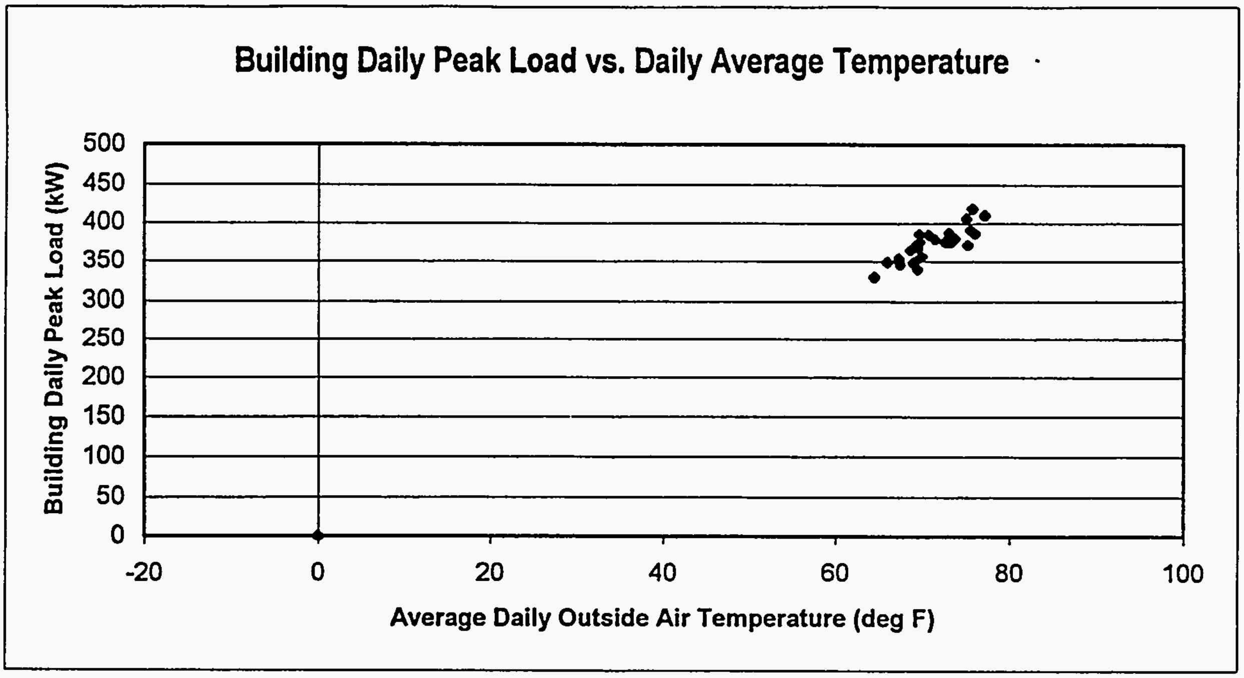


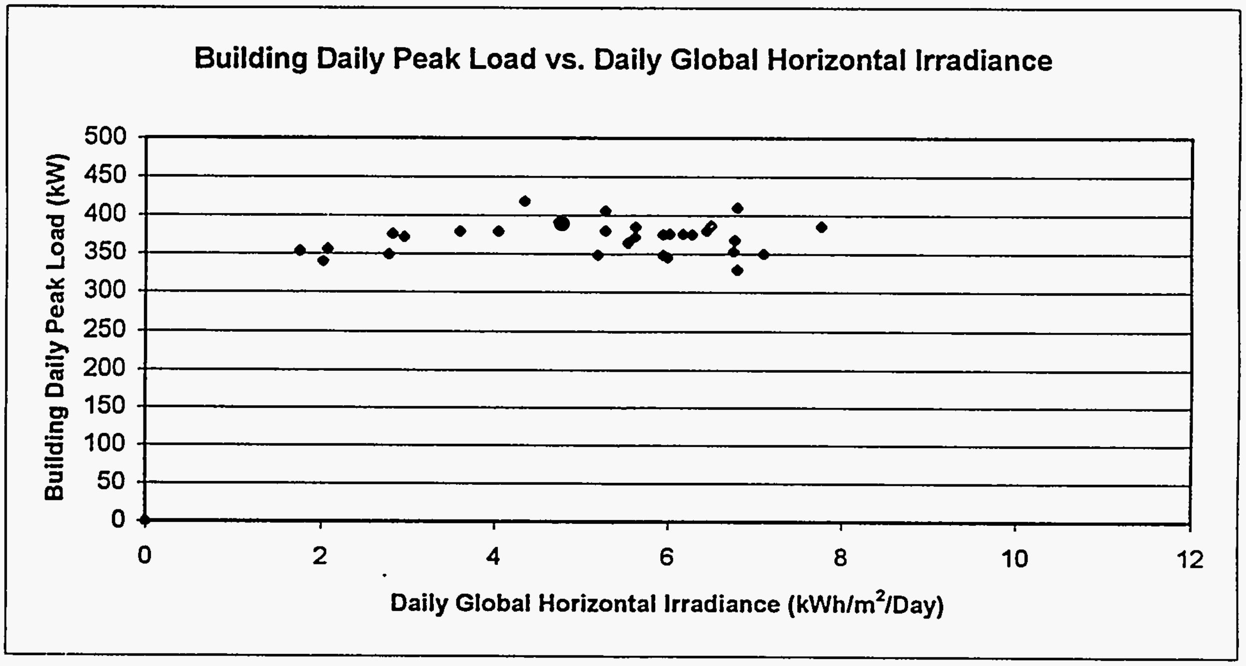


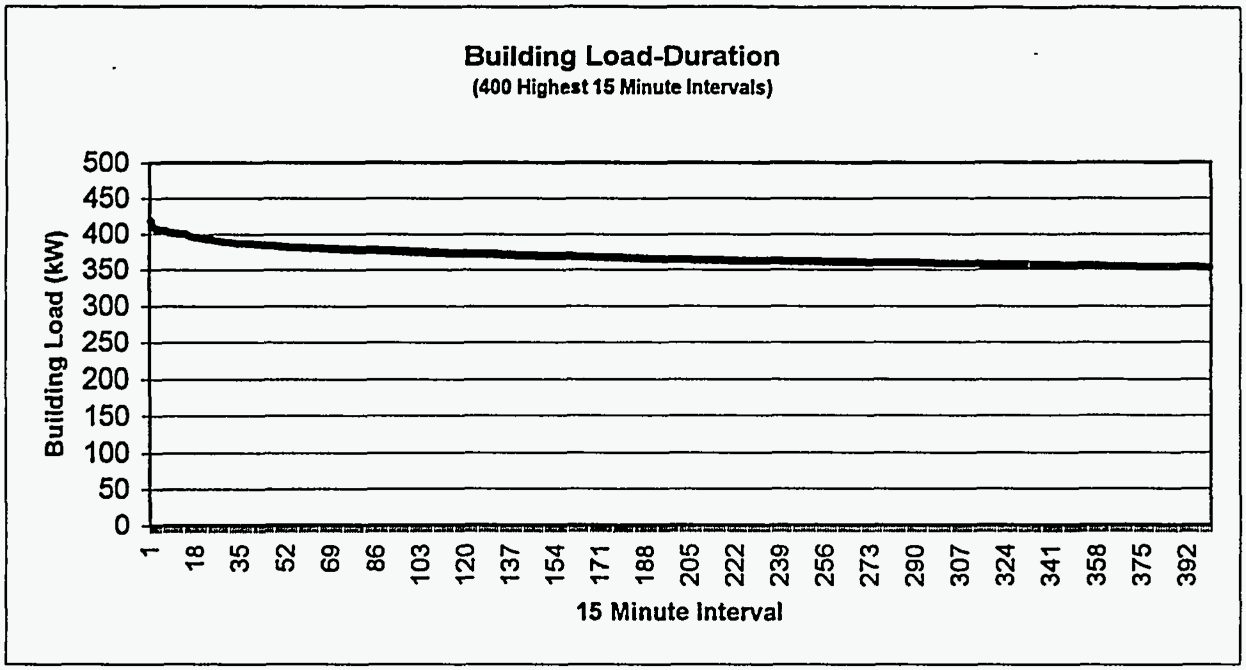


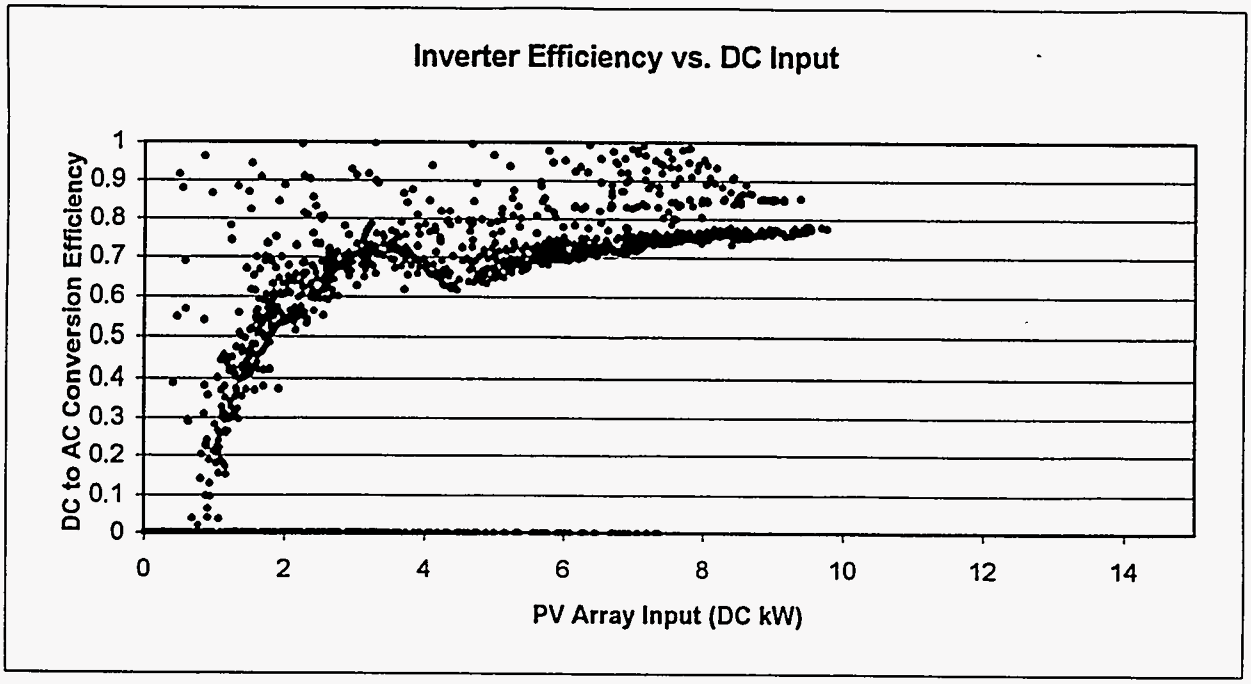

Weekday Building Load vs. Temperature
Building Load (kW)
500
450
400
350
300
250
200
150
100
50
0
-20
0
20
40
60
80
100
Outside Air Temperature (deg F)

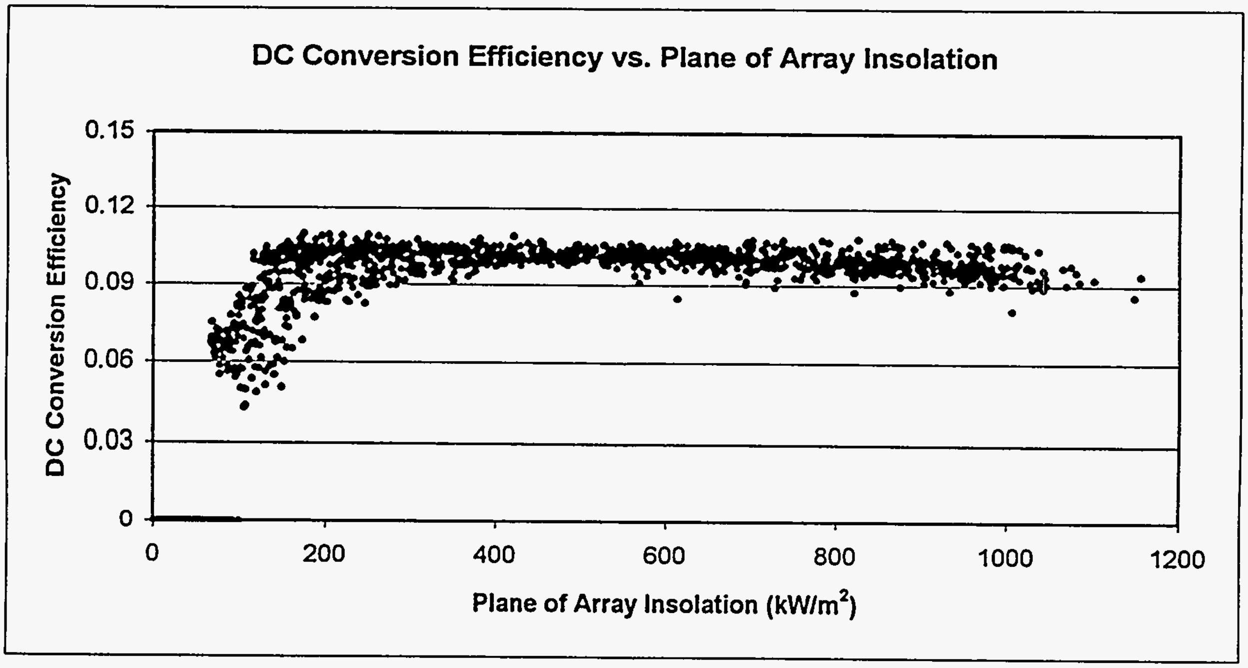

Weekday Building Load vs. Global Horizontal Irradiance
Building Load (kW)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Global Horizontal Irradiance (W/m²)

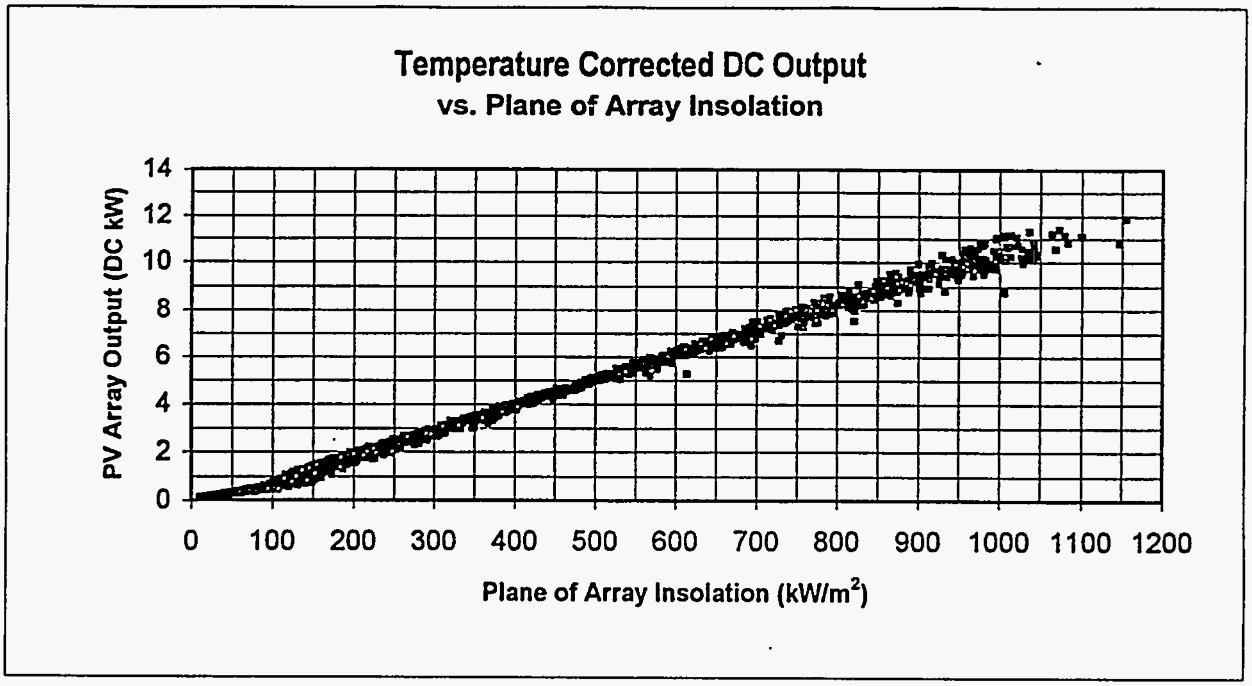

Building Daily Peak Load vs. Daily Average Temperature
Building Daily Peak Load (kW)
500
450
400
350
300
250
200
150
100
50
0
-20
0
20
40
60
80
100
Average Daily Outside Air Temperature (deg F)

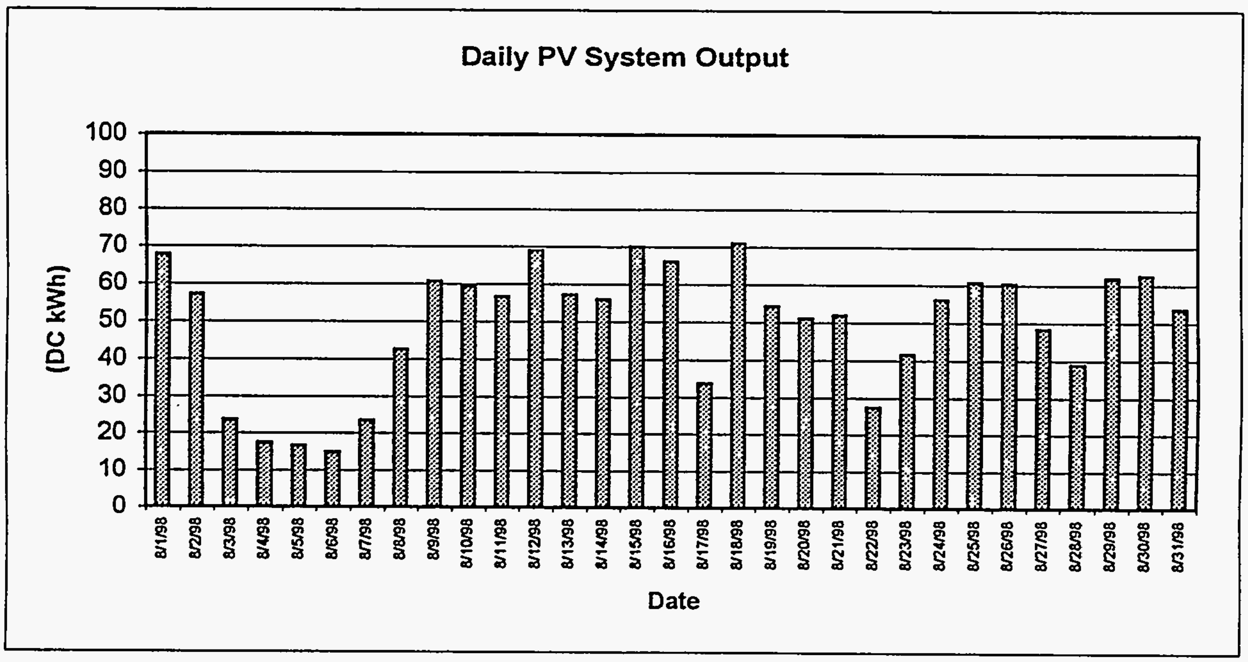

Building Daily Peak Load vs. Daily Global Horizontal Irradiance
Building Daily Peak Load (kW)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Daily Global Horizontal Irradiance (kWh/m2/Day)

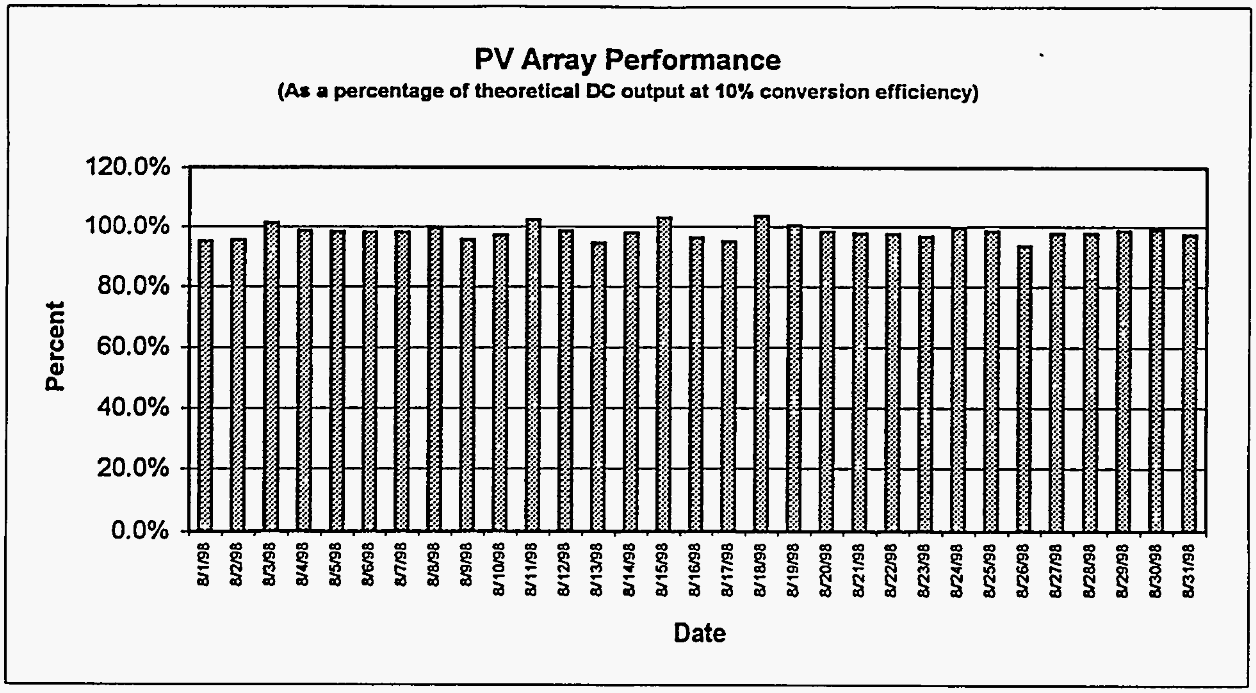

Building Load-Duration
(400 Highest 15 Minute Intervals)
Building Load (kW)
500
450
400
350
300
250
200
150
100
50
0
1
18
35
52
69
86
103
120
137
154
171
188
205
222
239
256
273
290
307
324
341
358
375
392
15 Minute Interval

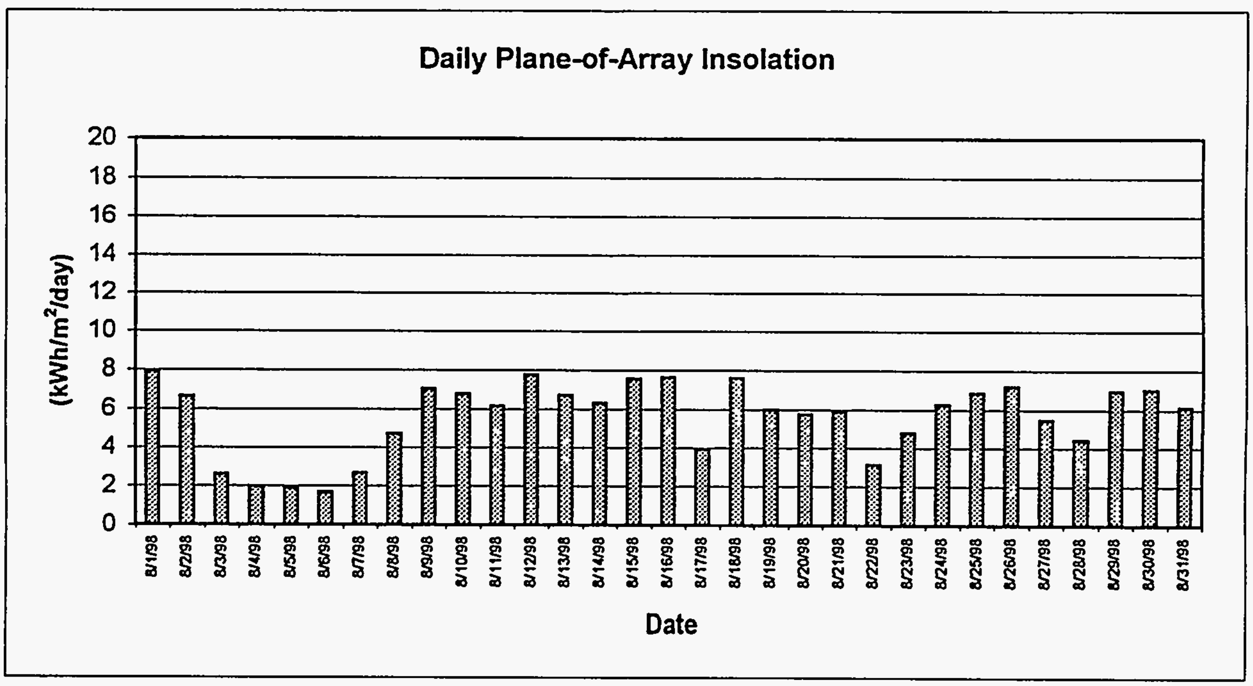

Inverter Efficiency vs. DC Input
DC to AC Conversion Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
PV Array Input (DC kW)


DC Conversion Efficiency vs. Plane of Array Insolation
DC Conversion Efficiency
0.15
0.12
0.09
0.06
0.03
0
0
200
400
600
800
1000
1200
Plane of Array Insolation (kW/m2)


Temperature Corrected DC Output
vs. Plane of Array Insolation
PV Array Output (DC kW)
0
2
4
6
8
10
12
14
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Plane of Array Insolation (kW/m2)


Daily PV System Output
(DC kWh)
0
10
20
30
40
50
60
70
80
90
100
8/1/98 8/2/98 8/3/98 8/4/98 8/5/98 8/6/98 8/7/98 8/8/98 8/9/98 8/10/98 8/11/98 8/12/98 8/13/98 8/14/98 8/15/98 8/16/98 8/17/98 8/18/98 8/19/98 8/20/98 8/21/98 8/22/98 8/23/98 8/24/98 8/25/98 8/26/98 8/27/98 8/28/98 8/29/98 8/30/98 8/31/98
Date


PV Array Performance
(As a percentage of theoretical DC output at 10% conversion efficiency)
Percent
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
8/1/98 8/2/98 8/3/98 8/4/98 8/5/98 8/6/98 8/7/98 8/8/98 8/9/98 8/10/98 8/11/98 8/12/98 8/13/98 8/14/98 8/15/98 8/16/98 8/17/98 8/18/98 8/19/98 8/20/98 8/21/98 8/22/98 8/23/98 8/24/98 8/25/98 8/26/98 8/27/98 8/28/98 8/29/98 8/30/98 8/31/98
Date


Daily Plane-of-Array Insolation
(kWh/m²/day)
20
18
16
14
12
10
8
6
4
2
0
8/1/98 8/2/98 8/3/98 8/4/98 8/5/98 8/6/98 8/7/98 8/8/98 8/9/98 8/10/98 8/11/98 8/12/98 8/13/98 8/14/98 8/15/98 8/16/98 8/17/98 8/18/98 8/19/98 8/20/98 8/21/98 8/22/98 8/23/98 8/24/98 8/25/98 8/26/98 8/27/98 8/28/98 8/29/98 8/30/98 8/31/98
Date

WPS/ShopKo Dispatchable PV Peak Shaving System
Monthly Summary Data
Aug-98

Date	Julian Day	Global Horizontal (kWh/m2/day)	Direct Normal (kWh/m2/day)	Diffuse Horizontal (kWh/m2/day)	Plane of Array (kWh/m2/day)	Average Daily Temperature (Deg F)	Total System Output (AC kWh/day)	Total System Input (kWh/m2/day)	PV Array Output (DC kWh/day)	Average Inverter Efficiency	Average PV Array Conversion Efficiency	Peak Building Load (kW)	Daily Building Electricity Consumption (kWh/day)	System Dispatch Time (seconds)	% of Nominal Theoretical Output
8/1/98	213	7.77	9.80	1.28	7.96	69.71	64.33	-15.33	67.93	0.80	0.093	386.32	5498.60	13581	95.0%
8/2/98	214	6.44	5.58	2 55	6.67	73.64	62.52	-22.85	57.12	0.79	0.092	380.04	5873.90	19188	95.4%
8/3/98	215	2.78	0 22	2.68	2.60	69.02	18.55	-18.29	23.68	0.64	0.100	349.12	5939.20	2613	101.4%
8/4/98	216	2.07	0 02	2.06	1.96	69.99	20.43	-16.29	17.44	0.74	0.099	355.94	6546.90	6675	98.9%
8/5/98	217	2.03	0 01	2.02	1.89	69.49	10.32	-9.98	16.66	0.56	0.098	339.86	6285.80	1398	98.4%
8/6/98	218	1.76	0 21	1.58	1.69	69.60	17.14	-14.99	14.89	0.70	0.093	353.87	5996.50	6129	98.3%
8/7/98	219	2.82	0 16	2.70	2.66	73.43	40.59	-22.57	23.48	0.31	0.095	376.38	5850.50	23217	98.1%
8/8/98	220	4.73	1 82	3.55	4.73	75.61	57.79	-39.86	42.50	0.65	0.098	391.97	5950.00	23970	100.0%
8/9/98	221	6.79	6 74	2.28	7.07	77.21	73.77	-39.48	60.69	0.84	0.094	410.06	6120.60	26887	95.6%
8/10/98	222	6.49	5 59	2 81	6.79	76.07	73.01	-40.02	59.30	0.84	0.095	386.49	6804.40	24729	97.2%
8/11/98	223	5.94	5.33	2 51	6.16	68.94	48.65	-30.13	56.64	0.76	0.099	348.20	6670.50	3645	102.4%
8/12/98	224	7.10	8.59	1.57	7.77	67.27	51.85	-9.29	68.99	0.74	0.096	350.54	6099.00	60	98.8%
8/13/98	225	6.17	5.34	2.77	6.74	69.73	39.60	-2.01	57.22	0.66	0.094	375.77	5954.20	270	94.5%
8/14/98	226	5.62	4.77	2.18	6.35	70.76	39.91	-4.18	55.95	0.66	0.097	384.90	6059.80	1035	98.1%
8/15/98	227	6.75	8 74	1.30	7.58	67.27	50.39	-2.63	70.13	0.69	0.100	353.64	5336.80	0	103.0%
8/16/98	228	6.77	9.07	1.02	7.65	69.57	47.13	-2.04	66.18	0.69	0.095	367.82	5556.40	27	96.3%
8/17/98	229	3.60	2 67	1.63	3.95	71.45	22.61	-4.86	33.71	0.62	0.095	379.66	6754.10	513	95.0%
8/18/98	230	6.80	9.02	1.40	7.62	64.47	51.68	-2.21	71.01	0.69	0.100	329.74	5781.00	0	103.7%
8/19/98	231	5.54	5 32	2.46	6.02	68.62	37.85	-2.25	54.33	0.66	0.098	364.32	6058.50	15	100.5%
8/20/98	232	5.28	4.52	2.55	5.78	75.16	44.79	-14.63	51.11	0.73	0.097	405.90	6677.90	8256	98.4%
8/21/98	233	5.28	4.18	2.46	5.92	73.78	36.86	-7.12	51.95	0.68	0.096	380.01	6449.70	993	97.8%
8/22/98	234	2.96	0 57	2.51	3.13	69.33	17.48	-5.17	27.40	0.65	0.095	371.63	5525.80	330	97.6%
8/23/98	235	4.34	2.99	2.48	4.78	75.78	32.98	-11.84	41.49	0.62	0.094	418.19	6096.20	6618	96.7%
8/24/98	236	5.62	6 70	2.19	6.27	75.24	38.43	-3.98	56.08	0.67	0.096	371.87	6801.10	234	99.6%
8/25/98	237	6.02	7.97	1.54	6.86	72.56	43.13	-2.56	60.79	0.69	0.096	376.43	6920.80	138	98.7%
8/26/98	238	6.28	8.36	1.52	7.19	72.88	42.88	-2.23	60.44	0.68	0.092	374.97	6798.50	336	93.5%
8/27/98	239	4.79	4 56	1.97	5.49	73.12	33.92	-3.30	48.25	0.67	0.096	387.67	6584.60	864	97.8%
8/28/98	240	4.04	3 10	2.29	4.44	72.92	26.73	-4.99	38.94	0.67	0.098	379.57	6291.80	258	97.7%
8/29/98	241	5.94	8 62	1.05	6.98	73.32	44.01	-2.55	61.94	0.69	0.096	375.02	5494.80	69	98.8%
8/30/98	242	5.99	8 41	1.26	7.02	67.46	44.48	-1.69	62.52	0.67	0.097	345.37	5224.50	0	99.1%
8/31/98	243	5.19	6.32	1.54	6.13	65.97	37.31	-1.84	53.57	0.67	0.095	348.76	6267.00	0	97.3%
Monthly Total		159.69	155 31	63.73	173.86		1271.10	-361.17	1532.30			418.19	190269.40	172048.00	
Monthly Average		5.15	5.01	2.06	5.61	71.27	41.00	-11.65	49.43			371.61	6137.72		

WPS/ShopKo Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-98

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
213	1000	213	1945	13581	51.53	47.43	37.73	20.33	17.40	0.00	17.40
214	900	214	930	267	4.20	4.57	0.74	0.45	0.29	0.00	0.29
214	1000	214	1915	18861	50.48	38.41	52.39	24.71	25.77	-22.80	26.06
214	1945	214	2015	60	0.09	0.00	0.17	0.00	0.09	0.07	26.16
215	815	215	930	453	1.76	1.92	1.26	0.10	1.16	0.00	1.16
215	1015	215	1200	1548	5.53	4.65	4.30	1.13	3.17	0.00	4.32
215	1215	215	1230	189	0.45	0.43	0.53	0.03	0.42	0.04	4.74
215	1245	215	1300	30	0.69	0.93	0.08	0.01	0.07	0.00	4.81
215	1400	215	1445	156	3.15	3.49	0.43	0.12	0.31	0.00	5.13
215	1500	215	1515	45	1.40	1.61	0.13	0.04	0.08	0.00	5.21
215	1530	215	1615	87	1.30	1.76	0.24	0.05	0.20	0.00	5.40
215	1715	215	1730	15	0.02	0.29	0.04	0.00	0.01	0.02	5.42
215	1930	215	1945	45	0.07	0.00	0.13	0.00	0.07	0.06	5.48
216	730	216	800	129	1.50	1.79	0.36	0.08	0.28	0.00	0.28
216	900	216	1100	1311	5.61	5.03	3.64	0.81	2.84	0.00	3.12
216	1115	216	1500	3069	8.71	6.36	8.53	1.47	7.05	0.00	10.17
216	1530	216	1800	1911	2.73	0.58	5.31	0.12	2.60	2.46	12.77
216	1930	216	2045	240	0.39	0.00	0.67	0.00	0.39	0.27	13.17
217	830	217	845	27	0.46	0.76	0.08	0.01	0.06	0.00	0.06
217	1015	217	1030	15	0.72	1.01	0.04	0.01	0.03	0.00	0.10
217	1200	217	1230	87	1.07	1.40	0.24	0.04	0.20	0.00	0.30
217	1330	217	1415	207	1.41	1.71	0.58	0.09	0.48	0.00	0.78
217	1500	217	1530	204	0.42	0.54	0.57	0.04	0.37	0.11	1.15
217	1545	217	1615	102	0.09	0.38	0.28	0.02	0.08	0.18	1.22
217	1830	217	1900	312	0.34	0.06	0.87	0.01	0.33	0.52	1.55
217	1945	217	2015	360	0.58	0.00	1.00	0.00	0.58	0.42	2.14
218	900	218	915	69	0.06	0.26	0.19	0.01	0.05	0.13	0.05
218	945	218	1145	633	2.11	2.43	1.76	0.21	1.55	0.00	1.60
218	1200	218	1645	4869	14.13	10.13	13.53	3.27	10.26	0.00	11.86
218	1900	218	2015	345	0.55	0.02	0.96	0.00	0.55	0.40	12.41
219	730	219	745	141	0.17	0.24	0.39	0.02	0.15	0.20	0.15

WPS/ShopKo Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-98

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
219	800	219	815	15	0.17	0.46	0.04	0.00	0.04	0.00	0.19
219	845	219	2100	23061	39.63	20.29	64.06	12.14	27.49	12.29	27.68
220	800	220	845	234	2.05	2.32	0.65	0.13	0.52	0.00	0.52
220	900	220	915	15	2.30	2.58	0.04	0.02	0.02	0.00	0.54
220	930	220	2030	23706	52.44	32.67	65.85	23.11	29.33	-9.70	29.87
221	900	221	2100	26887	68.30	49.02	74.69	35.29	33.01	-28.90	33.01
222	745	222	815	45	2.50	2.94	0.13	0.05	0.08	0.00	0.08
222	845	222	2100	24684	67.85	48.22	68.57	24.91	42.93	-24.19	43.01
223	945	223	1000	15	1.72	2.01	0.04	0.02	0.02	0.00	0.02
223	1030	223	1100	210	3.09	3.31	0.58	0.18	0.41	0.00	0.43
223	1115	223	1130	15	3.61	3.96	0.04	0.04	0.01	0.00	0.44
223	1145	223	1200	15	2.86	3.19	0.04	0.03	0.01	0.00	0.45
223	1245	223	1315	87	5.76	6.28	0.24	0.21	0.04	0.00	0.49
223	1330	223	1445	402	10.11	11.00	1.12	0.79	0.32	0.00	0.81
223	1500	223	1700	1236	9.35	9.60	3.43	1.46	1.98	0.00	2.79
223	1715	223	1830	630	1.31	1.18	1.75	0.16	1.15	0.27	3.94
223	1915	223	2030	1035	1.58	0.02	2.88	0.00	1.57	1.29	5.51
224	945	224	1015	60	4.96	5.45	0.17	0.12	0.05	0.00	0.05
225	1115	225	1130	15	2.80	3.45	0.04	0.03	0.01	0.00	0.01
225	1245	225	1300	81	1.79	2.23	0.23	0.10	0.13	0.00	0.14
225	1445	225	1515	144	3.44	4.39	0.40	0.24	0.16	0.00	0.30
225	1615	225	1630	30	0.97	1.39	0.08	0.03	0.05	0.00	0.35
226	1030	226	1045	15	2.62	3.24	0.04	0.03	0.01	0.00	0.01
226	1115	226	1130	15	3.14	3.84	0.04	0.03	0.01	0.00	0.02
226	1245	226	1300	15	2.70	3.35	0.04	0.03	0.01	0.00	0.03
226	1330	226	1345	15	2.90	3.57	0.04	0.03	0.01	0.00	0.05
226	1430	226	1700	975	5.19	6.63	2.71	0.89	1.82	0.00	1.86
228	1445	228	1500	15	2.24	2.95	0.04	0.03	0.02	0.00	0.02
228	1515	228	1530	12	1.96	2.61	0.03	0.02	0.02	0.00	0.03
229	1330	229	1400	243	4.10	5.02	0.68	0.46	0.21	0.00	0.21
229	1430	229	1445	15	0.90	1.30	0.04	0.01	0.03	0.00	0.24

WPS/ShopKo Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-98

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
229	1500	229	1515	75	0.58	0.88	0.21	0.03	0.17	0.00	0.42
229	1530	229	1545	15	0.14	0.54	0.04	0.00	0.04	0.00	0.46
229	1600	229	1645	165	0.51	1.06	0.46	0.05	0.41	0.00	0.86
231	1515	231	1530	15	2.00	2.66	0.04	0.02	0.02	0.00	0.02
232	1100	232	1215	543	5.62	6.58	1.51	0.61	0.90	0.00	0.90
232	1230	232	1245	96	3.13	3.81	0.27	0.21	0.06	0.00	0.95
232	1300	232	1945	7407	25.26	22.57	20.58	5.83	14.74	0.00	15.70
232	2000	232	2030	120	0.17	0.00	0.33	0.00	0.17	0.16	15.87
232	2045	232	2100	90	0.13	0.00	0.25	0.00	0.13	0.12	16.00
233	945	233	1000	15	1.93	2.43	0.04	0.02	0.02	0.00	0.02
233	1130	233	1145	57	3.38	4.08	0.16	0.12	0.04	0.00	0.06
233	1200	233	1315	282	9.25	11.27	0.78	0.54	0.25	0.00	0.31
233	1400	233	1600	432	8.66	11.02	1.20	0.70	0.50	0.00	0.81
233	1630	233	1700	69	0.85	1.32	0.19	0.04	0.16	0.00	0.97
233	1730	233	1745	114	0.24	0.46	0.32	0.04	0.20	0.04	1.17
234	1145	234	1215	87	2.43	3.31	0.24	0.11	0.13	0.00	0.13
234	1230	234	1300	87	1.91	2.34	0.24	0.08	0.17	0.00	0.30
234	1345	234	1415	156	0.46	0.81	0.43	0.05	0.38	0.00	0.68
235	1115	235	1545	6477	23.69	23.39	17.99	8.10	9.89	0.00	9.89
235	1600	235	1630	141	1.55	2.16	0.39	0.17	0.22	0.00	10.12
236	1115	236	1130	15	2.48	3.17	0.04	0.02	0.02	0.00	0.02
236	1200	236	1215	45	2.05	2.69	0.13	0.07	0.05	0.00	0.07
236	1345	236	1400	15	2.17	2.83	0.04	0.03	0.02	0.00	0.09
236	1615	236	1645	60	1.77	2.31	0.17	0.05	0.11	0.00	0.20
236	1715	236	1745	84	0.23	0.70	0.23	0.03	0.20	-0.03	0.40
236	2000	236	2015	15	0.02	0.00	0.04	0.00	0.02	0.03	0.41
237	1330	237	1345	66	1.17	1.53	0.18	0.04	0.15	0.00	0.15
237	1500	237	1515	57	2.30	2.93	0.16	0.09	0.07	0.00	0.21
237	1715	237	1730	15	0.27	0.62	0.04	0.01	0.04	0.00	0.25
238	1200	238	1215	12	2.83	3.50	0.03	0.02	0.01	0.00	0.01
238	1230	238	1245	60	2.97	3.63	0.17	0.13	0.04	0.00	0.05

WPS/ShopKo Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-98

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
238	1445	238	1500	96	2.22	2.79	0.27	0.14	0.13	0.00	0.18
238	1515	238	1530	45	2.01	2.62	0.13	0.06	0.06	0.00	0.24
238	1615	238	1630	15	1.25	1.61	0.04	0.01	0.03	0.00	0.27
238	1715	238	1745	93	0.19	0.66	0.26	0.03	0.16	0.04	0.42
238	1915	238	1930	15	0.02	0.00	0.04	0.00	0.02	0.02	0.44
239	1030	239	1045	12	3.00	3.71	0.03	0.02	0.01	0.00	0.01
239	1100	239	1115	15	3.01	3.69	0.04	0.03	0.01	0.00	0.02
239	1130	239	1215	84	5.66	7.03	0.23	0.17	0.07	0.00	0.09
239	1300	239	1500	633	4.98	6.36	1.76	0.73	1.03	0.00	1.12
239	1615	239	1630	60	0.69	0.97	0.17	0.04	0.12	0.00	1.24
239	1945	239	2015	45	0.06	0.00	0.13	0.00	0.06	0.07	1.30
240	1030	240	1045	15	1.31	1.67	0.04	0.01	0.03	0.00	0.03
240	1345	240	1430	183	4.17	5.28	0.51	0.30	0.21	0.00	0.23
240	1715	240	1730	30	0.08	0.44	0.08	0.01	0.07	-0.01	0.30
241	1245	241	1330	69	4.90	6.05	0.19	0.11	0.08	0.00	0.08

Key to Monthly Performance Report Charts (Carvel Revised 9/97)

Monthly performance reports for the Dispatchable PV Peak Shaving units installed under the PV:BONUS Program consist of a series of graphical profiles and charts, along with a brief written summary of system performance. The following information is presented to help clarify the meaning of the attached charts and graphs.

Monthly Profiles

Four monthly profiles are provided with each report. The monthly profiles show 15 minute, time-series data for the following measured variables:

- PV system AC input (during battery charging) and AC output (during PV array operation and/or battery discharge)
- Global horizontal and direct normal solar radiation
- PV array DC output
- Building load

Monthly profiles provide a quick overview of PV system operation, solar resource availability and building operation over the reporting period.

Building Load Characteristics

Four graphs are provided to indicate the response of the building to temperature and solar radiation. A fifth graph is provided to show the building's load-duration characteristics. These are explained below:

- *Weekday Building Load vs. Temperature*: This graph plots the sensitivity of the building's load to outside air temperature using 15-minute data. Electrical loads tend to increase during seasonal extremes. In hot weather, air conditioning runs more frequently, resulting in higher electrical demand. Likewise, during periods of very cold weather, equipment used in the operation of heating systems (fans, pumps, etc.) also run more frequently. In buildings that use electric heating systems, such as heat pumps, demand can be significantly higher during the winter than in the summer. Peak summer loads tend to occur in the early to late afternoon when temperatures are highest. Peak winter loads tend to occur during the early morning and early evening when high heating and lighting loads coincide. For most commercial and industrial buildings, loads also tend to be higher during weekdays when occupancy and usage levels are higher.
- *Weekday Building Load vs. Global Horizontal Irradiance*: This graph plots the sensitivity of the building's load to global horizontal irradiance using 15-minute data. During the summer months, building loads tend to be higher during periods of high irradiance. This is

because high summer temperatures are partially correlated to high sunlight levels. In climates where haze and humidity accompany hot weather, solar radiation levels may actually be somewhat lower than cool, clear days when solar radiation approach ideal maximums. A strong positive correlation between building load and global horizontal irradiance indicates that the output of a PV array is also strongly correlated with building load, and can therefore provide relatively reliable demand reduction. In these cases, the benefit of battery energy storage is lower. It is much more common to have moderate or poor correlation. In these cases, battery energy storage provides higher benefits by assuring reliable peak shaving.

- *Building Daily Peak Load vs. Daily Average Temperature*: This graph is similar to the graph of Weekday Building Load versus Temperature. However, data used in this graph are derived from the raw 15-minute data. The data is processed to calculate average daily temperatures and to find corresponding peak building loads. Peak building loads are likely to be higher on days when the average daily temperatures approach seasonal extremes.

- *Building Daily Peak Load vs. Daily Global Horizontal Irradiance*: This graph is similar to the graph of Weekday Building Load versus Global Horizontal Irradiance. Like the graph above, the data used to generate this graph are derived from the raw 15-minute data. Global horizontal irradiance is summed for an entire day to determine the total availability of solar energy and plotted against the corresponding daily peak load. A positive correlation indicates that peak loads occur on days when the availability of solar energy is high. This graph should be interpreted in conjunction with the graph of Weekday Building Load versus Global Horizontal Irradiance. It is possible to have poor correlation between building load and 15 minute readings of solar radiation while having good correlation between daily peak load and total daily solar radiation. This implies that the building's peak load is not instantaneously coincident with solar radiation, i.e., peak loads occur either before or after the solar resource peaks. A good positive correlation in this graph indicates that battery energy storage is of high value in managing the energy output of the PV array, because it allows peak shaving independent of PV array output.

- *Building Load-Duration Curve*: The final graph related to building loads is a Load Duration Curve. The load duration curve depicts 15 minute building load intervals in order of highest to lowest for the monitoring period. The graph included in this report shows only the highest 400 15 minute intervals. Load-duration curves are typically used to show the relationship between peak and base building loads. Buildings with sharp "spikes" at the left of the curve are usually good candidates for peak shaving, especially if demand charges are a significant portion of the overall electric bill.

Dispatchable PV System Performance

Six graphs are used to show overall PV system performance and to provide diagnostic information during the monitoring period. These are explained below:

- ***Inverter Efficiency vs. DC Input***: A three-phase, solid state inverter is used to convert the DC output of the PV array and battery string to AC power compatible with the building's electric power system. Like all conversion devices, losses are inherent in its operation. For the 32 kVA inverter installed in the PV-31 battery/inverter modules, efficiency is nearly flat at 90% for DC input levels above approximately 4 kW. For DC inputs between approximately 1 and 4 kW, efficiency increases rapidly from nearly 0 to about 90%. Below approximately 1 kW, conversion losses and parasitic loads usually prevent generation of significant AC power.

- ***DC Conversion Efficiency vs. Plane of Array Insolation***: In order to monitor PV array performance, a graph of sunlight to DC power conversion efficiency is plotted. For the polycrystalline silicon PV modules used in the dispatchable PV systems, sunlight conversion efficiencies are typically between 10 and 12%. Conversion efficiency between 100 and 200 Watts/m^2 varies in a nearly linear fashion from approximately 6 to 12%. Efficiency peaks at 10 to 12% between about 200 and 700 Watts/m^2. Above 700 Watts/m^2, temperature effects tend to reduce efficiency somewhat.

- ***Temperature Corrected DC Output vs. Plane of Array Insolation***: A second graph of PV array performance shows the PV array output in kW versus insolation. For each data point a temperature correction factor is applied since PV output varies inversely with solar cell temperature. The corrected performance reflects PV array output at Standard Test Conditions, i.e., a cell temperature of 25°C. Performance curves should be nearly identical from month to month when plotted in this way. At 1,000 Watts/m^2, the temperature corrected output should be within several percentage points of the PV array rating at STC.

- ***Daily PV Array Output***: A vertical bar chart shows the daily PV array output in DC kWh. This chart provides a quick summary of PV array operation, and an approximate indication of the amount of energy generated by the system.

- ***PV Array Performance***: A second vertical bar chart presents PV array performance as a percentage of theoretical output at 10% conversion efficiency. Values will typically vary between 80 and 110%, depending on site conditions and daily insolation. Values that are significantly lower indicate that the array may have been out of service for at least a portion of the day.

- ***Daily Plane of Array Insolation***: A third vertical bar chart shows the total amount of solar energy available to the array for each day. This chart, in combination with the other bar charts, is used to quickly identify outages and other array problems.

Tabular Summaries

There are two tabular summaries included in the monthly reports:

The first tabular summary of daily performance provides more detailed information about system performance and solar resource availability. The last column in the tabular summary also indicates the amount of time, in seconds, that the PV-31 unit was dispatched during the day.

The second tabular summary is a dispatch event log. The log provides detailed information for each period when the unit is called to automatically dispatch including: start and stop intervals; the amount of time (in seconds) that the unit was required to dispatch; the amount of energy required for peak shaving during the interval; and the contributions from storage and the PV array. The amount of energy storage shortfall (if any) is also recorded, along with the cumulative amount of energy drawn from storage during a daily period. Energy storage shortfalls indicate that the duration of the peak period was too long for the available storage. The daily cumulative amount of energy drawn from storage indicates the depth of discharge. On a daily basis, the total amount of energy that can be provided from storage will range from approximately 20 to 30 kWh, depending on the amount of solar energy available and the dispatch output level.

Carvel Dispatchable PV Peak Shaving System
Monthly Performance Summary
May 1998

Overall PV System Operation

The system was completely repaired and restarted in early May, and operated continuously throughout the rest of May, with no outages or problems. The system was dispatched automatically to help reduce building peak load.

Building Load Characteristics

Building loads in May were virtually identical to loads in April. Peak daytime loads were approximately 800 kW. Towards the end of May, peak loads were somewhat higher and were attributable to warmer weather and higher demand for air conditioning during the period. Nighttime and weekend loads were approximately 500 kW. There was a significant positive correlation between building load and ambient temperature, due to warmer weather. A slight positive correlation between global horizontal irradiance and building load was also noted.

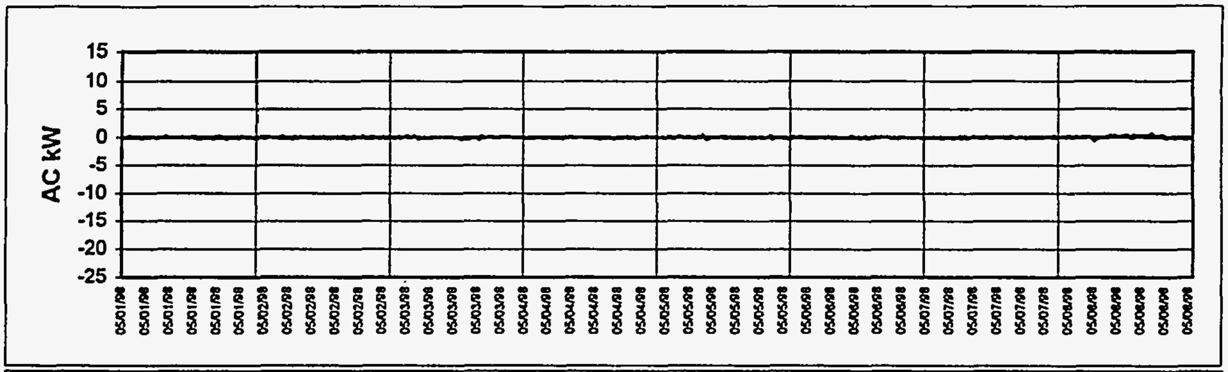
Peak 15-minute load for the period was 924 kW, approximately 60 kW higher than the April peak load.

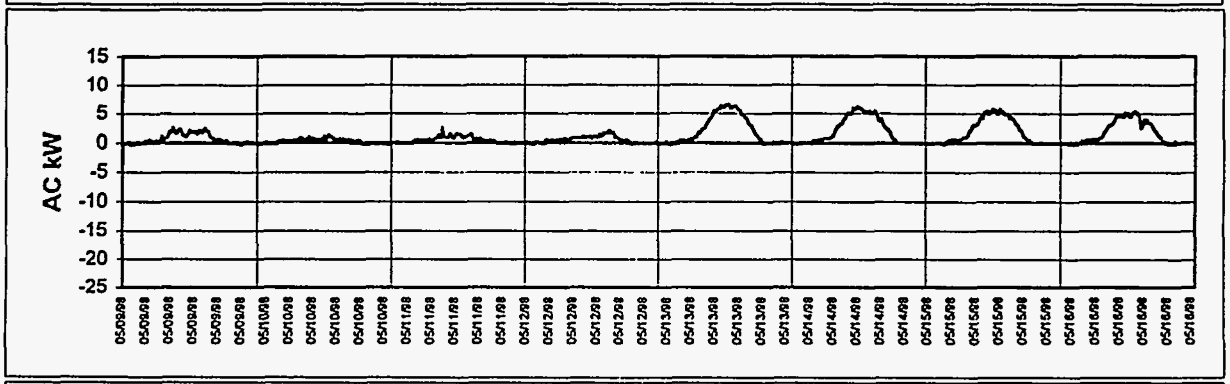
Dispatchable PV System Performance

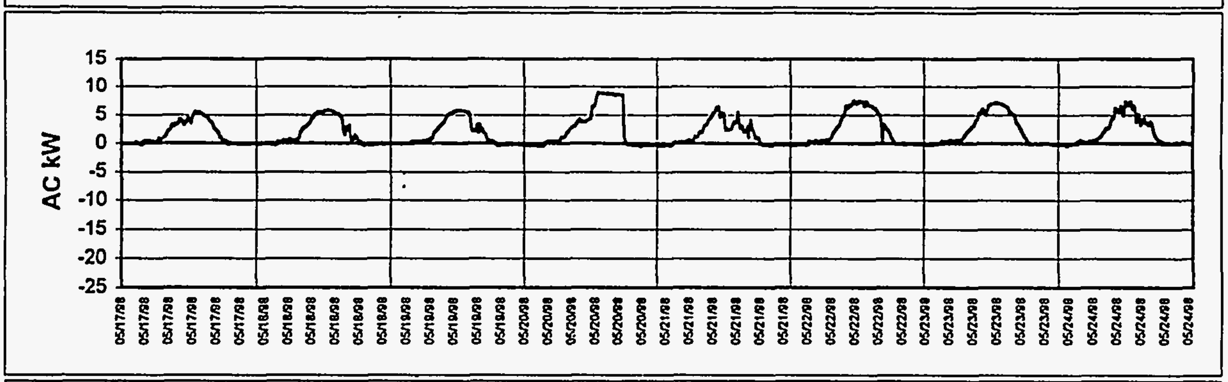
The system was automatically dispatched after May 21 at a building load of 880 kW. Some storage shortfalls occurred, indicating that it may be necessary to adjust the dispatch set point in the upcoming month.

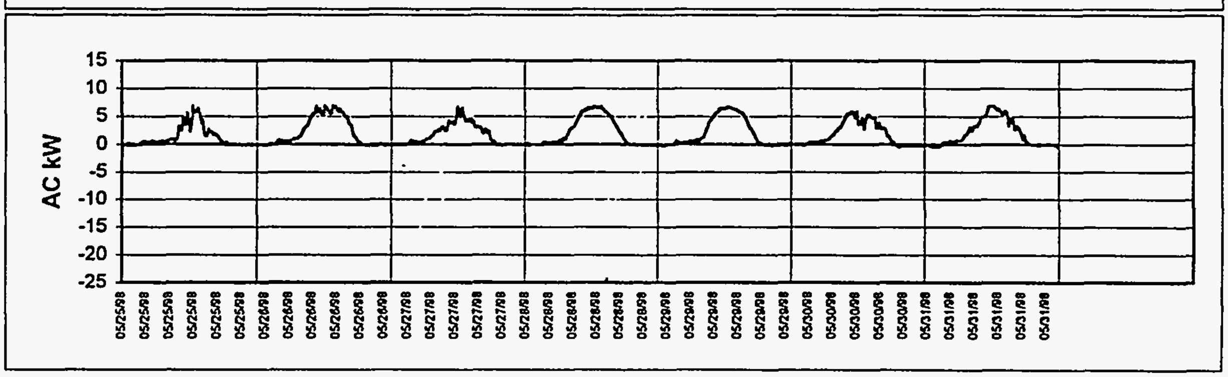
Carvel Dispatchable PV Peak Shaving System
AC Output and Charging Profiles

May-98



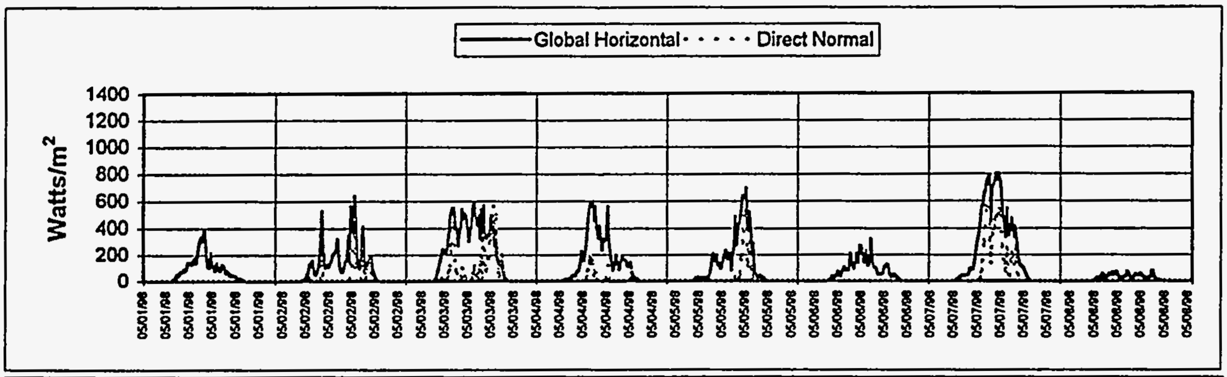


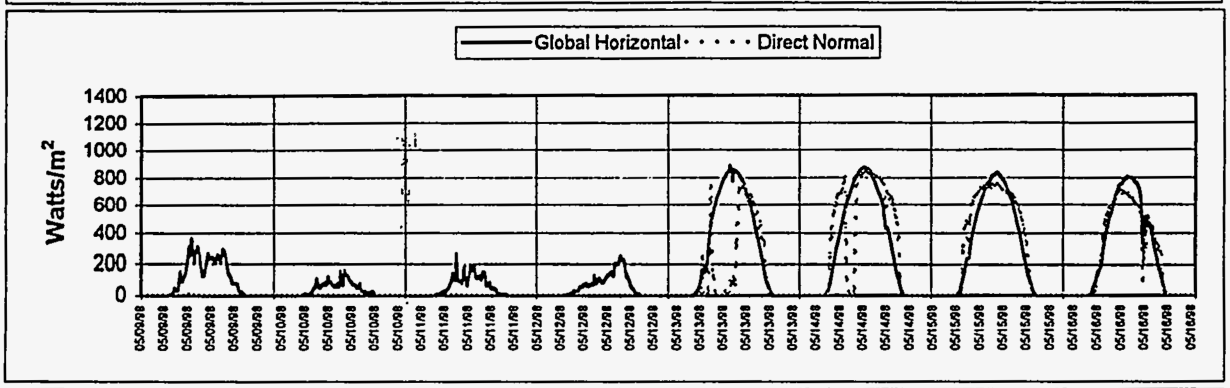


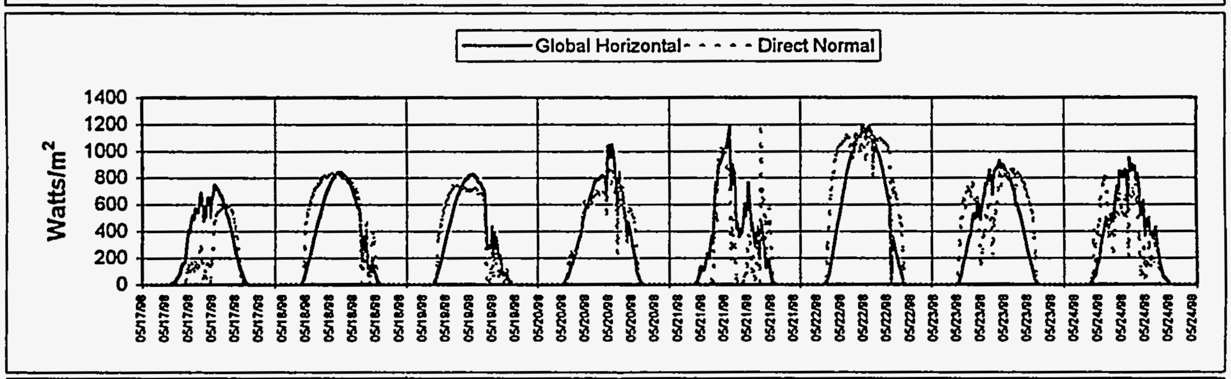


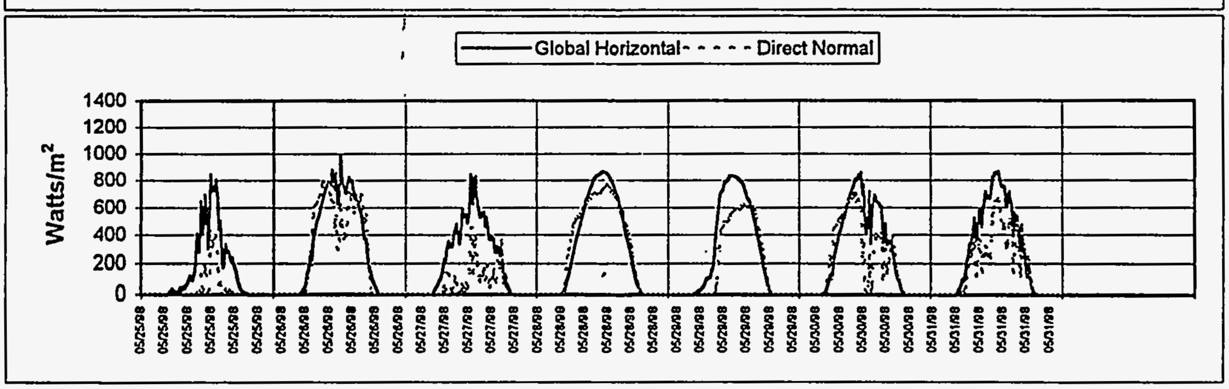
Carvel Dispatchable PV Peak Shaving System
Solar Resource Profiles

May-98



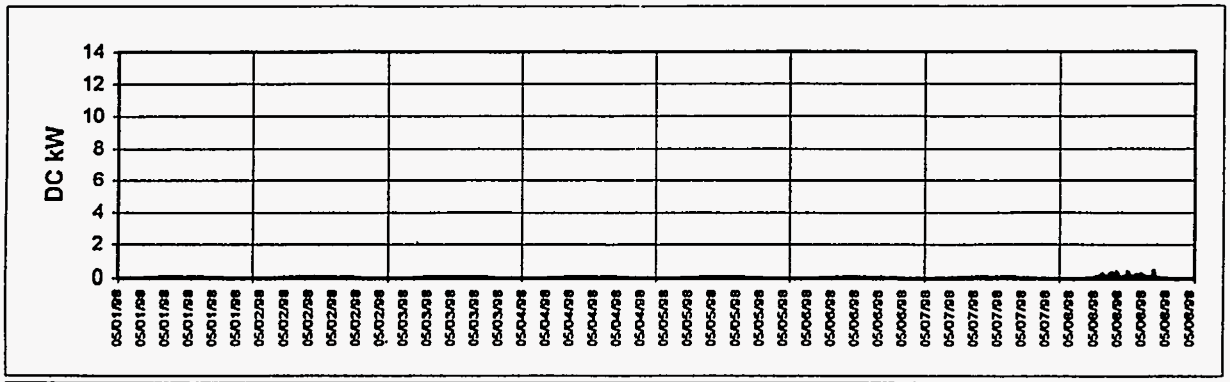


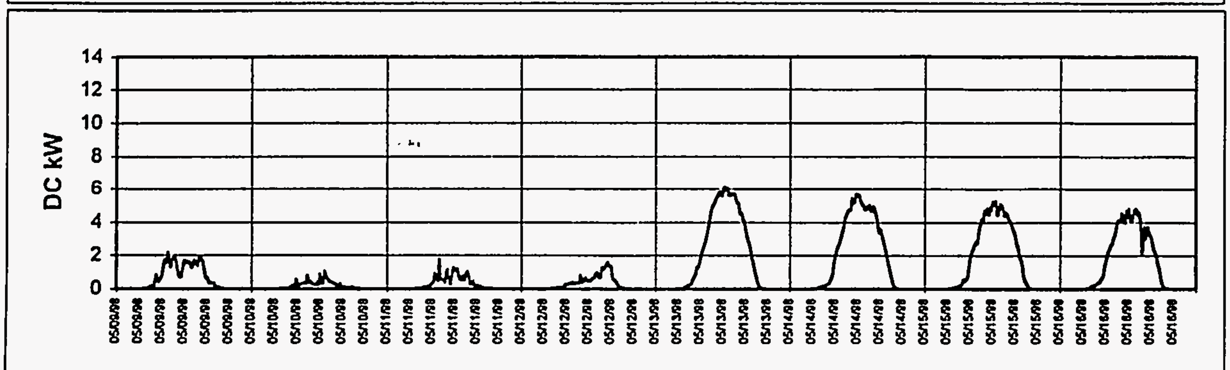


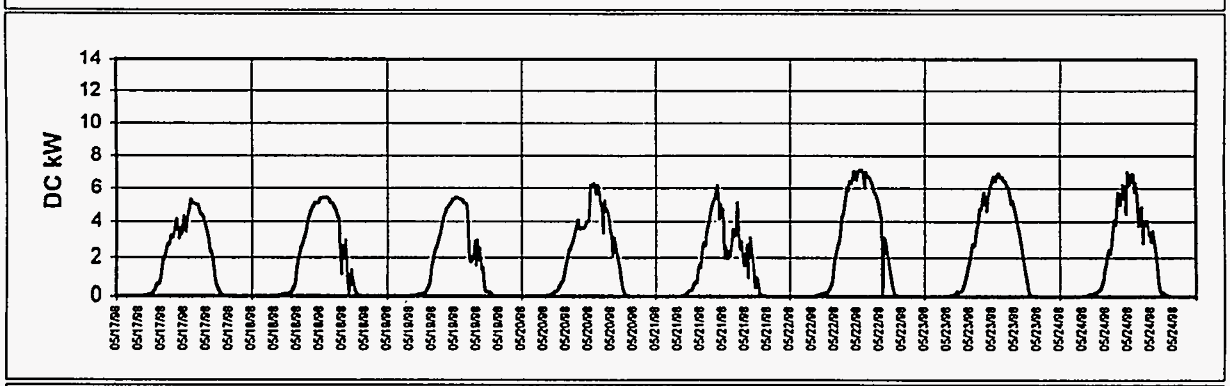


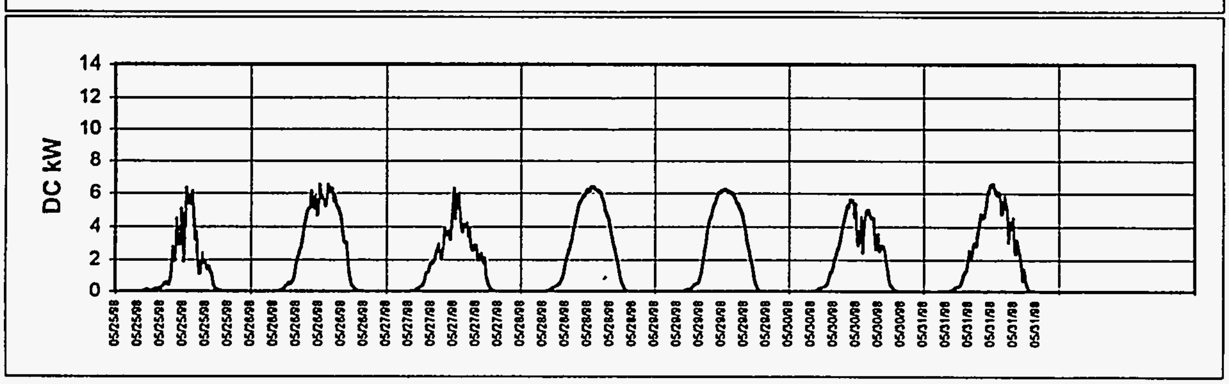
Carvel Dispatchable PV Peak Shaving System
DC Output Profile

May-98



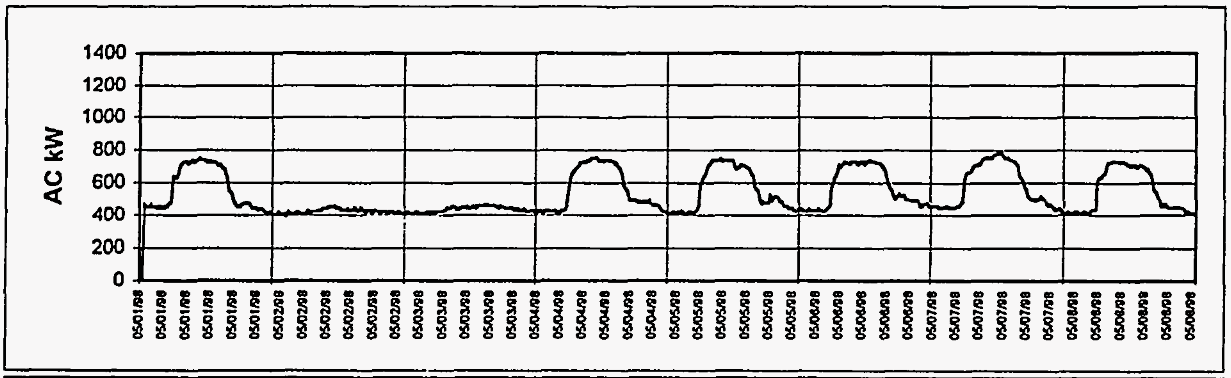


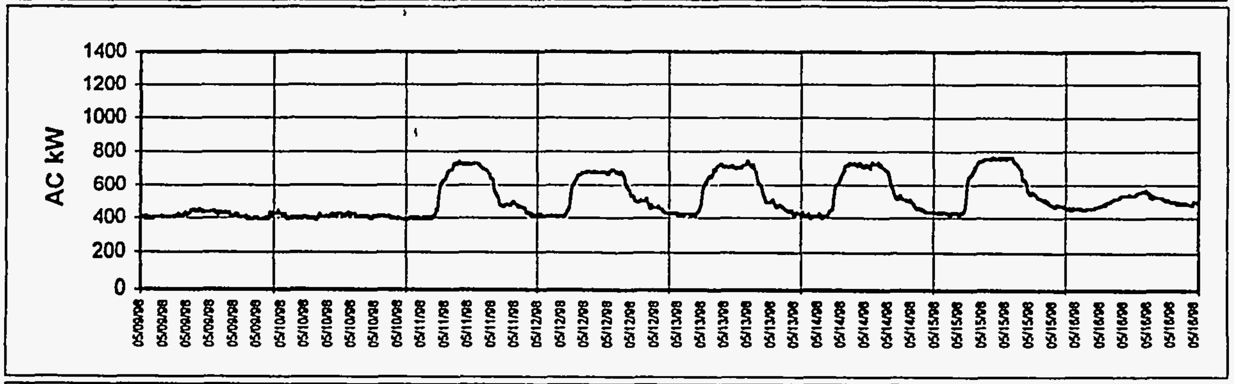


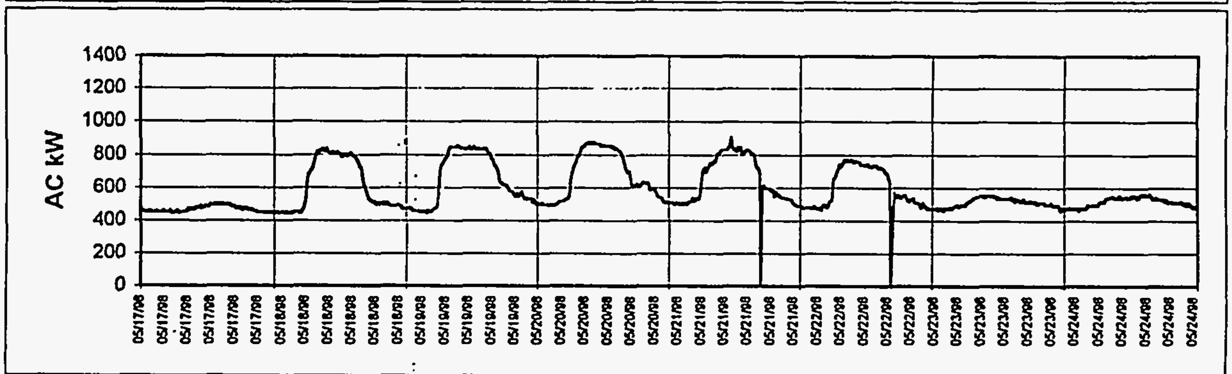


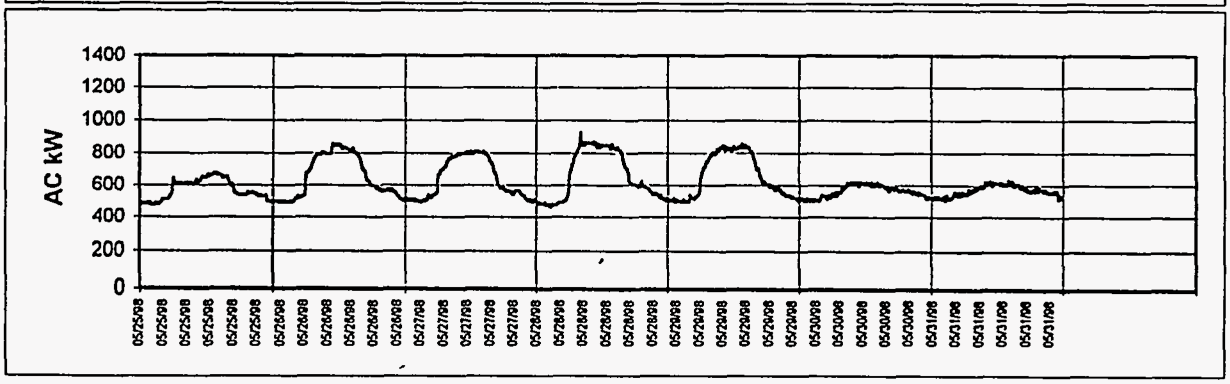
Carvel Dispatchable PV Peak Shaving System
Building Load Profiles

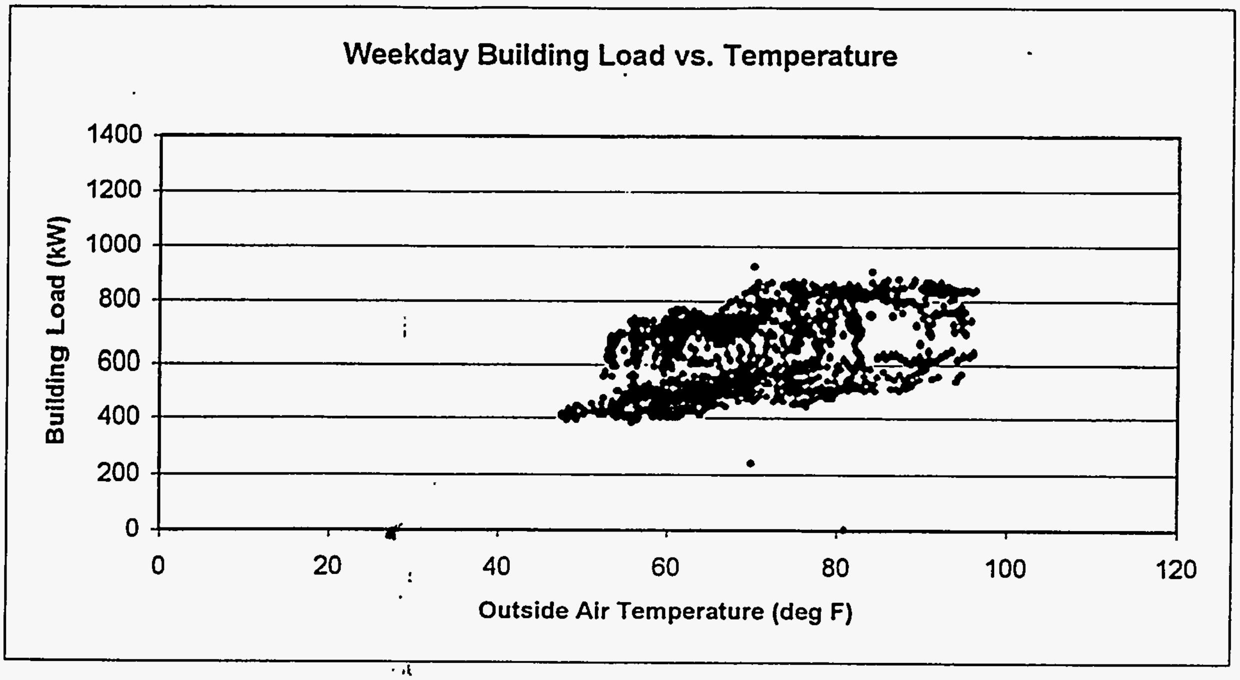
May-98

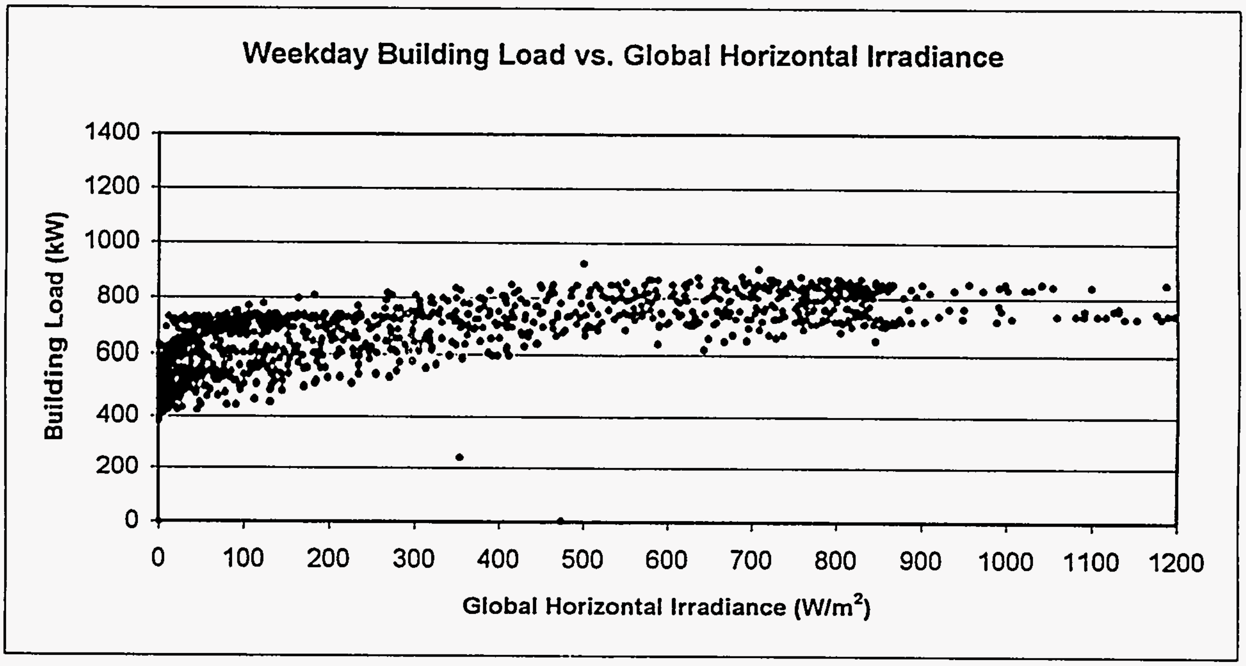


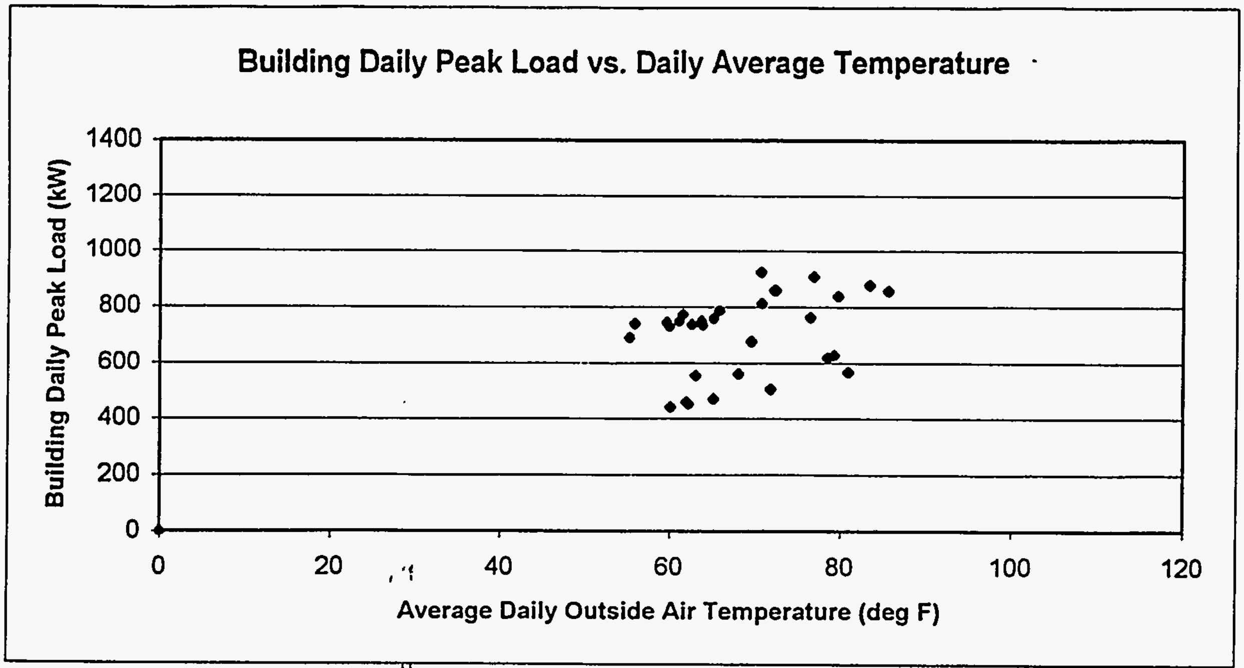


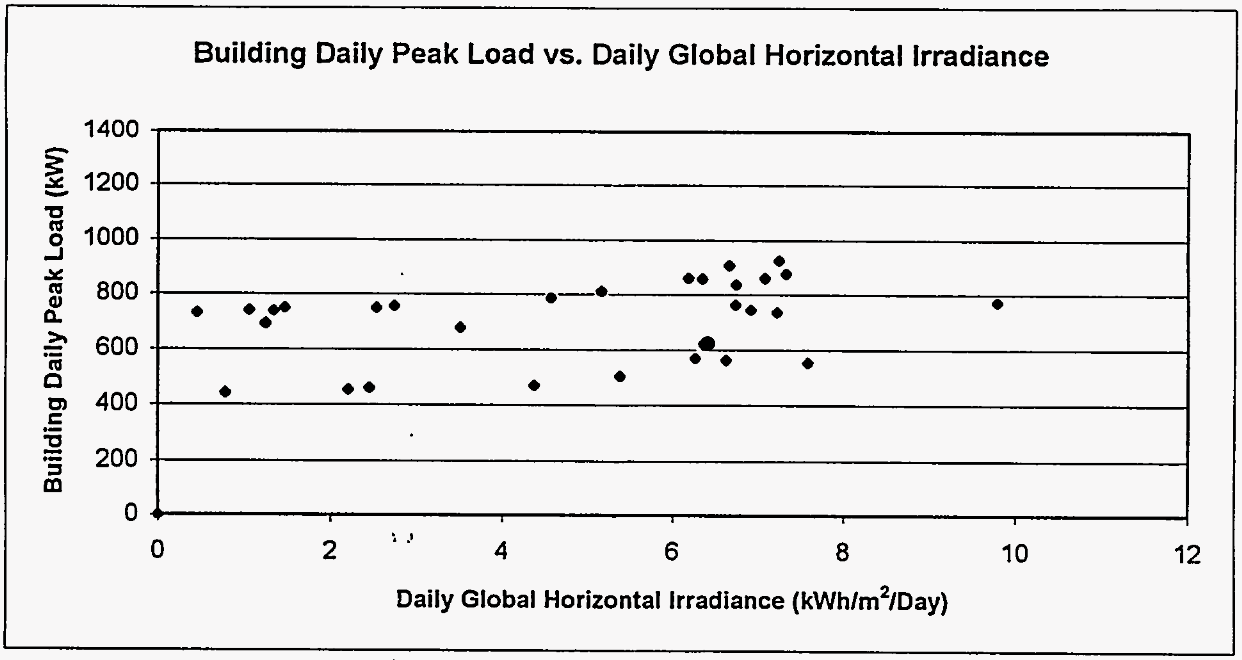


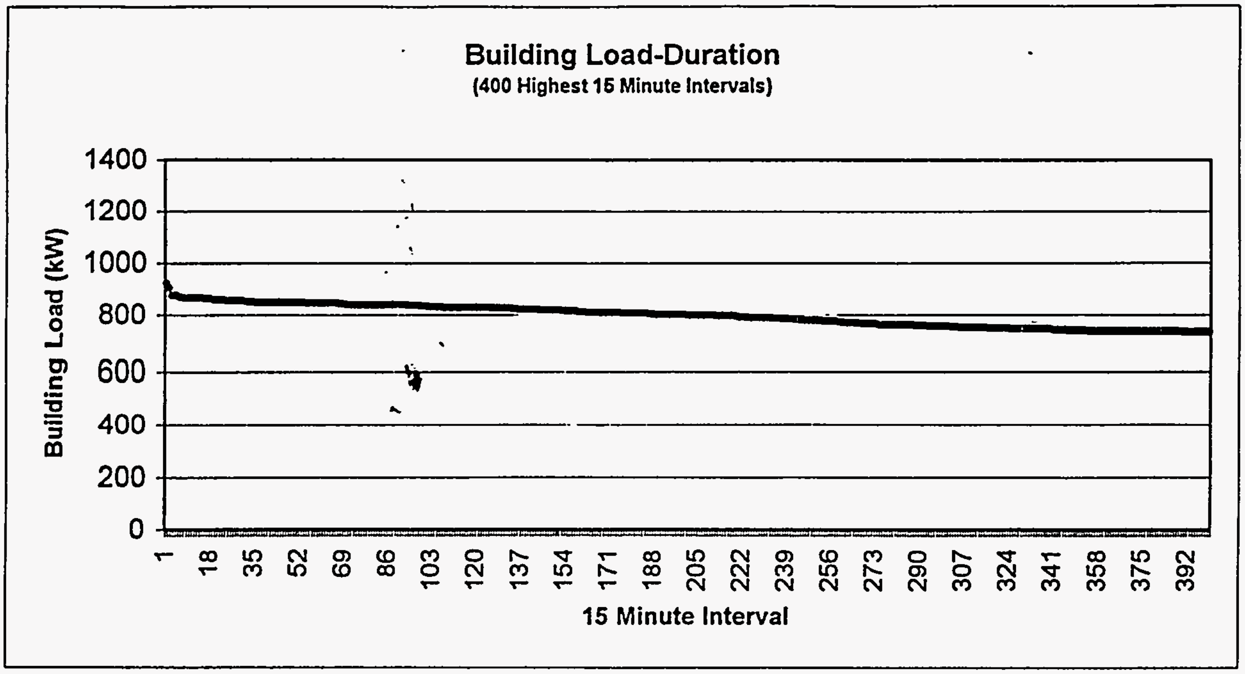


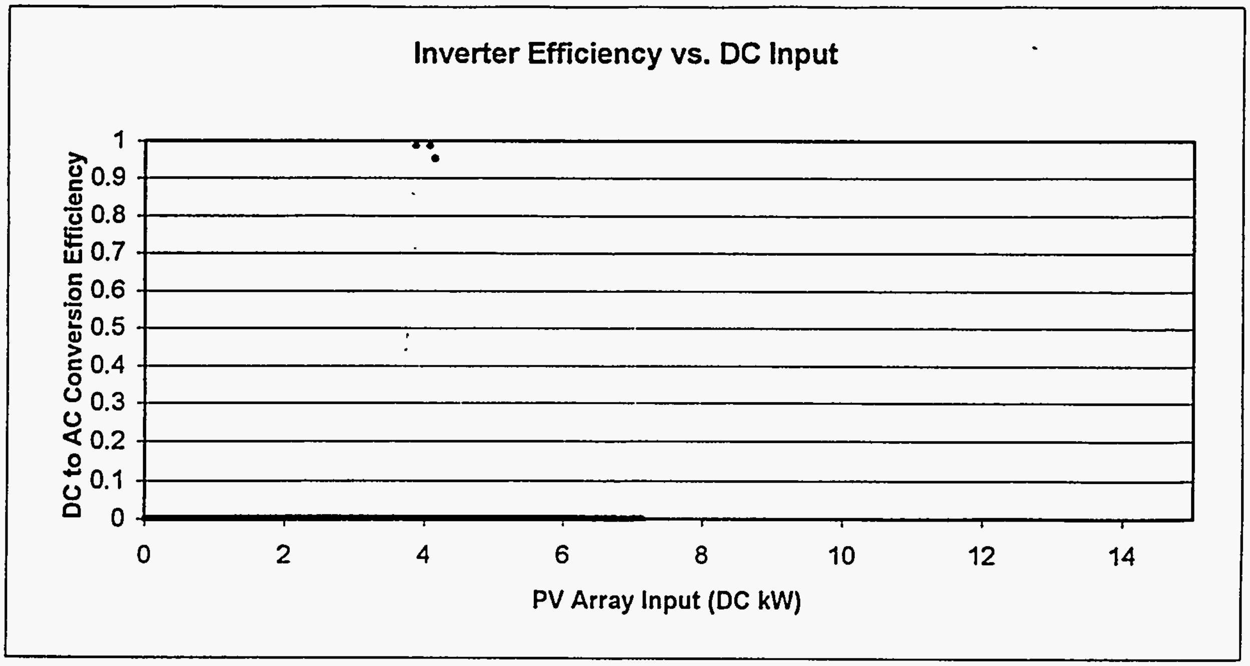

Weekday Building Load vs. Temperature
Building Load (kW)
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
Outside Air Temperature (deg F)

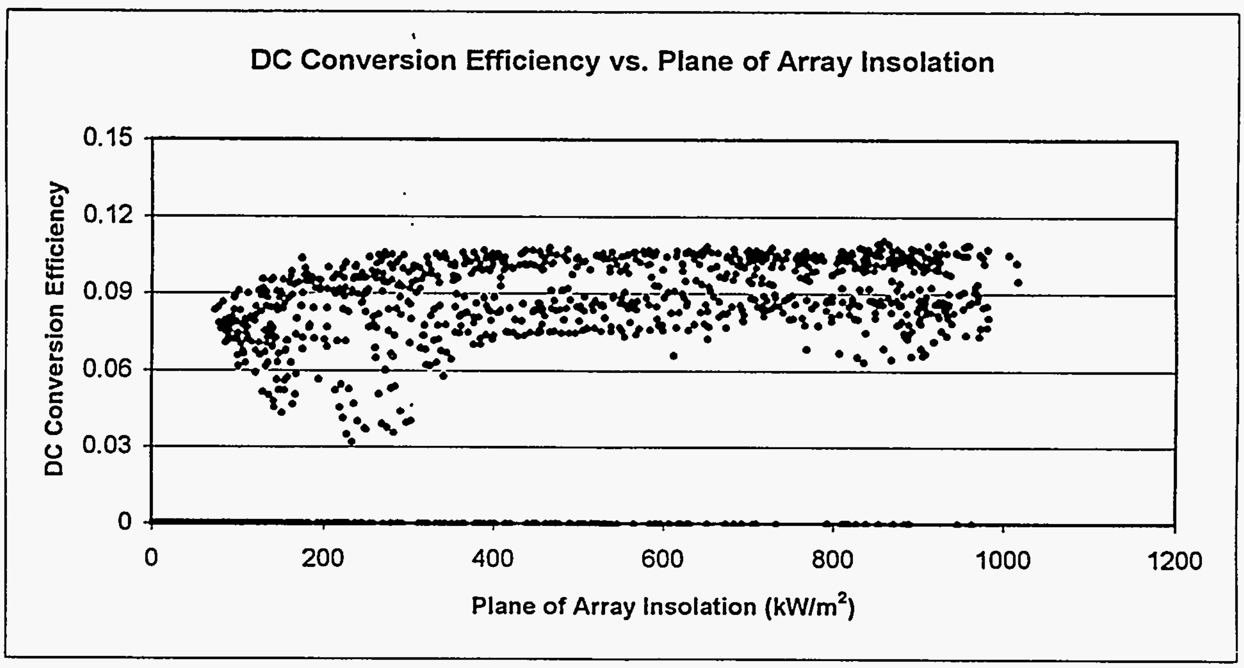

Weekday Building Load vs. Global Horizontal Irradiance
Building Load (kW)
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Global Horizontal Irradiance (W/m2)

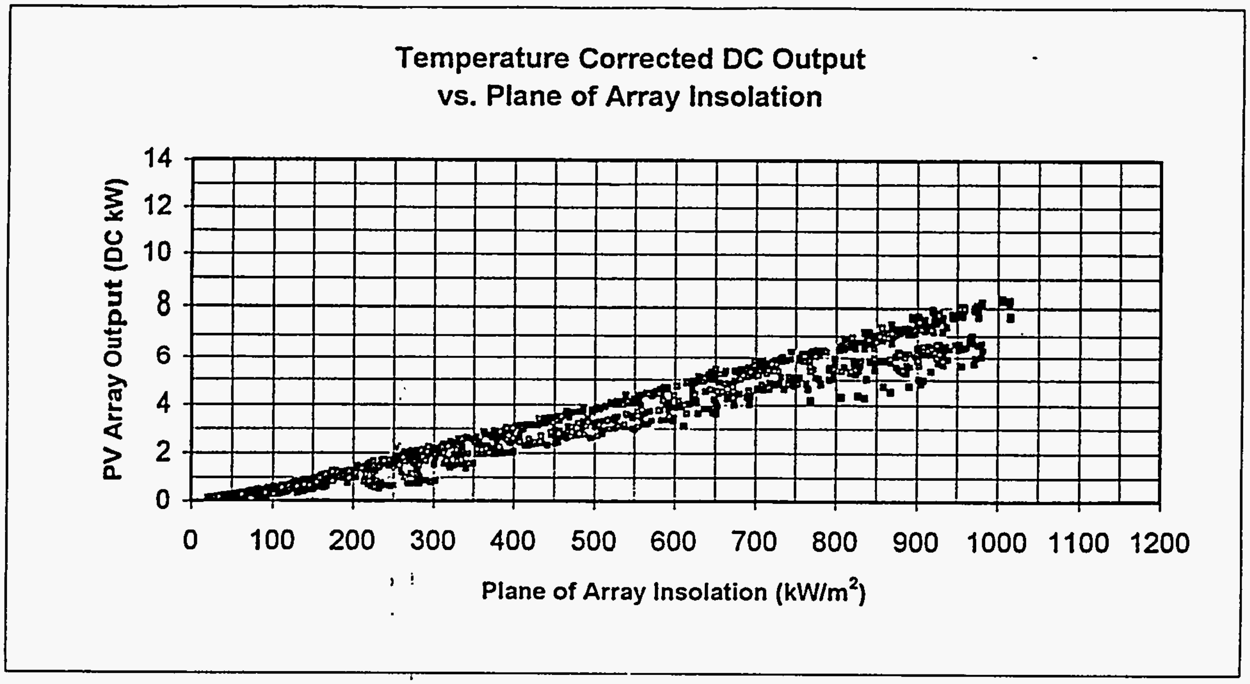

Building Daily Peak Load vs. Daily Average Temperature
Building Daily Peak Load (kW)
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
Average Daily Outside Air Temperature (deg F)

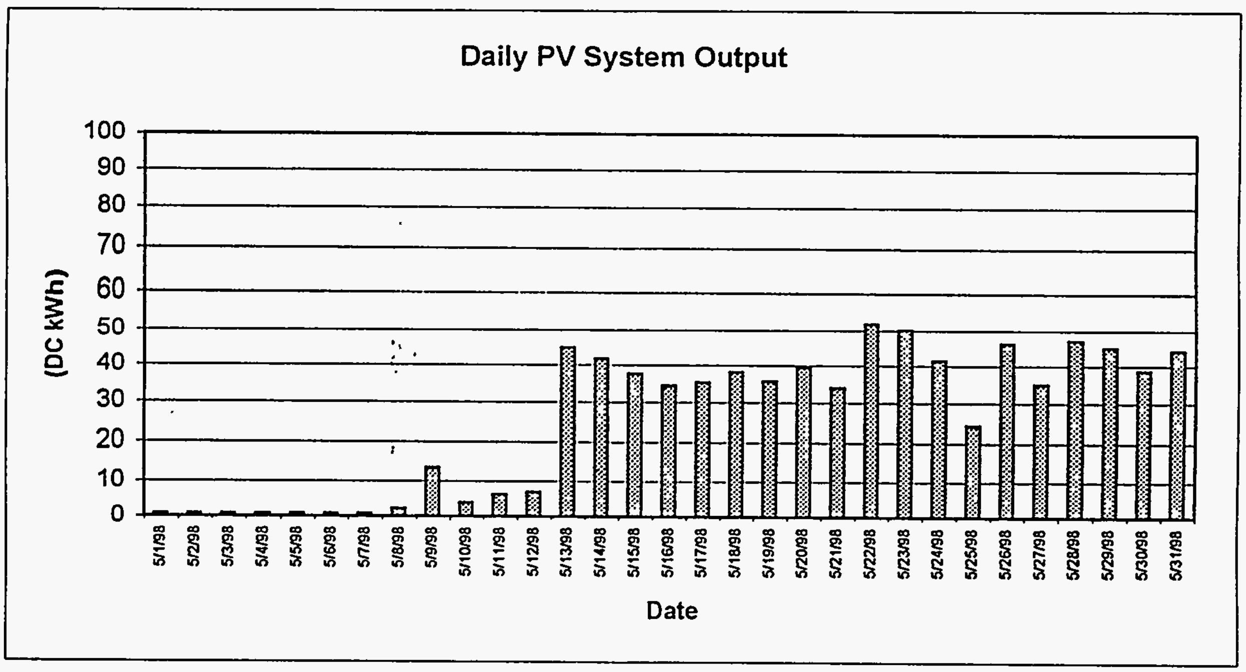

Building Daily Peak Load vs. Daily Global Horizontal Irradiance
Building Daily Peak Load (kW)
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
Daily Global Horizontal Irradiance (kWh/m²/Day)

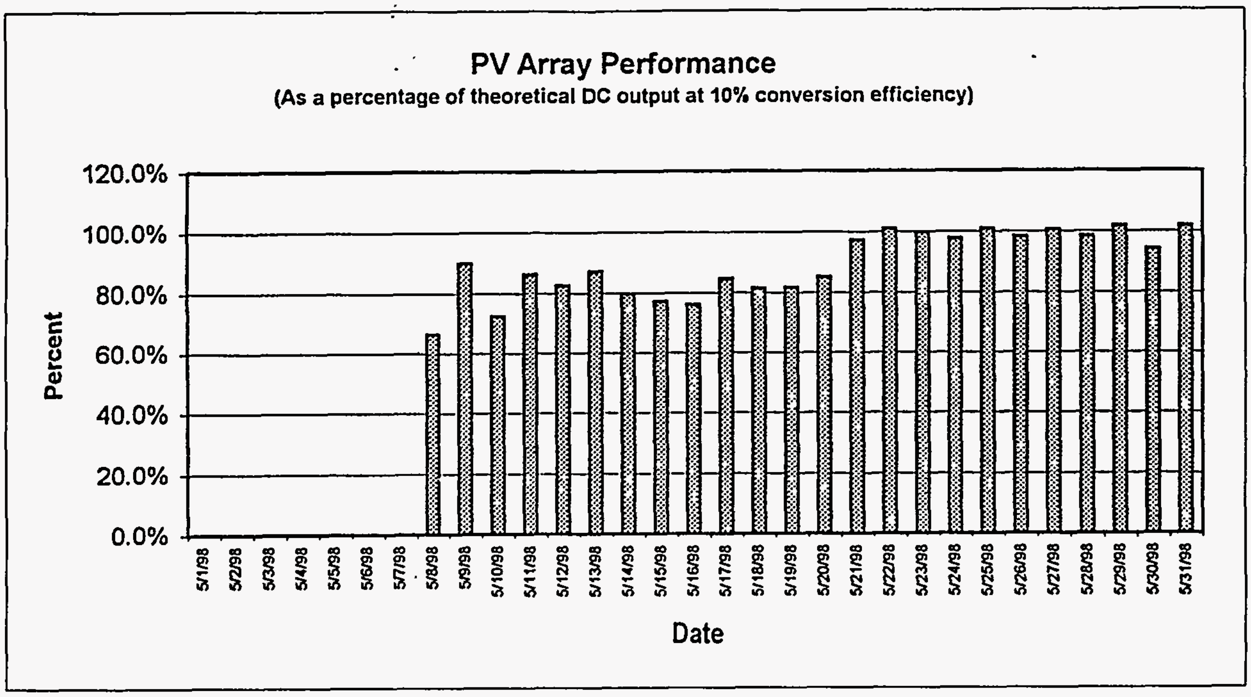

Building Load-Duration
(400 Highest 15 Minute Intervals)
Building Load (kW)
1400
1200
1000
800
600
400
200
0
1
18
35
52
69
86
103
120
137
154
171
188
205
222
239
256
273
290
307
324
341
358
375
392
15 Minute Interval

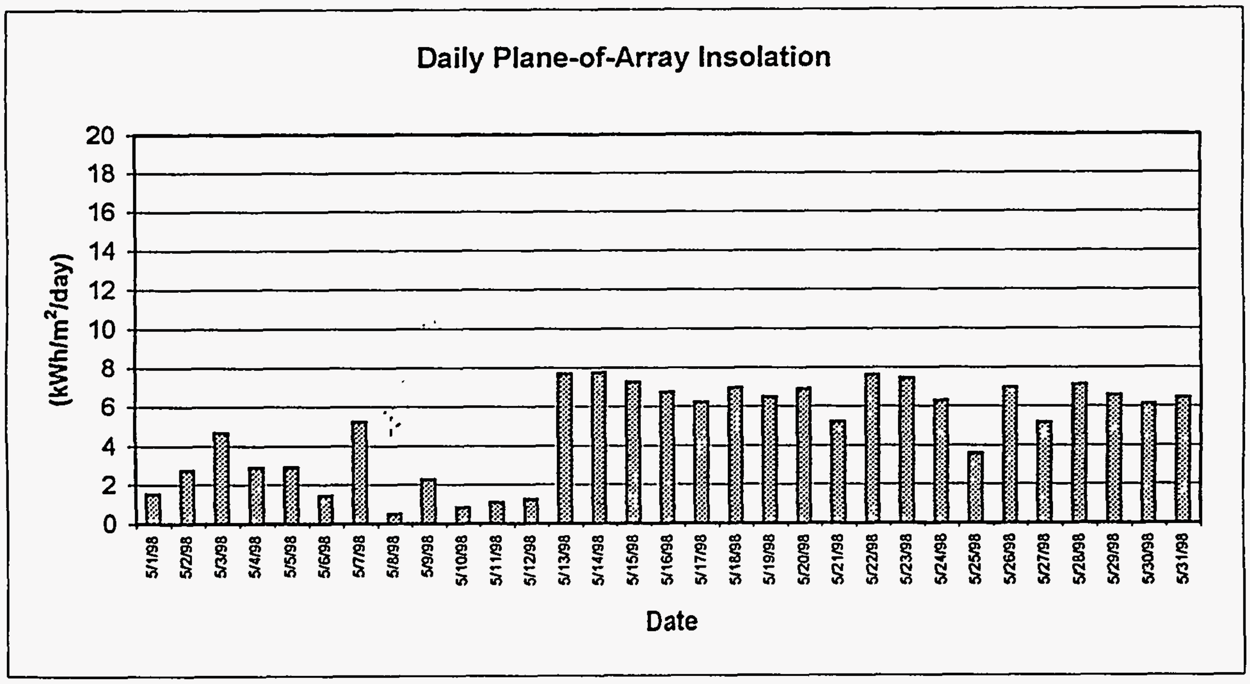

Inverter Efficiency vs. DC Input
DC to AC Conversion Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
PV Array Input (DC kW)


DC Conversion Efficiency vs. Plane of Array Insolation
DC Conversion Efficiency
0.15
0.12
0.09
0.06
0.03
0
0
200
400
600
800
1000
1200
Plane of Array Insolation (kW/m2)


Temperature Corrected DC Output
vs. Plane of Array Insolation
PV Array Output (DC kW)
0
2
4
6
8
10
12
14
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Plane of Array Insolation (kW/m2)


Daily PV System Output
(DC kWh)
0
10
20
30
40
50
60
70
80
90
100
5/1/98 5/2/98 5/3/98 5/4/98 5/5/98 5/6/98 5/7/98 5/8/98 5/9/98 5/10/98 5/11/98 5/12/98 5/13/98 5/14/98 5/15/98 5/16/98 5/17/98 5/18/98 5/19/98 5/20/98 5/21/98 5/22/98 5/23/98 5/24/98 5/25/98 5/26/98 5/27/98 5/28/98 5/29/98 5/30/98 5/31/98
Date


PV Array Performance
(As a percentage of theoretical DC output at 10% conversion efficiency)
Percent
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
5/1/98
5/2/98
5/3/98
5/4/98
5/5/98
5/6/98
5/7/98
5/8/98
5/9/98
5/10/98
5/11/98
5/12/98
5/13/98
5/14/98
5/15/98
5/16/98
5/17/98
5/18/98
5/19/98
5/20/98
5/21/98
5/22/98
5/23/98
5/24/98
5/25/98
5/26/98
5/27/98
5/28/98
5/29/98
5/30/98
5/31/98
Date


Daily Plane-of-Array Insolation
(kWh/m2/day)
20
18
16
14
12
10
8
6
4
2
0
5/1/98
5/2/98
5/3/98
5/4/98
5/5/98
5/6/98
5/7/98
5/8/98
5/9/98
5/10/98
5/11/98
5/12/98
5/13/98
5/14/98
5/15/98
5/16/98
5/17/98
5/18/98
5/19/98
5/20/98
5/21/98
5/22/98
5/23/98
5/24/98
5/25/98
5/26/98
5/27/98
5/28/98
5/29/98
5/30/98
5/31/98
Date

Carvel Dispatchable PV Peak Shaving System
Monthly Summary Data
May-98

Date	Julian Day	Global Horizontal (kWh/m2/day)	Direct Normal (kWh/m2/day)	Diffuse Horizontal (kWh/m2/day)	Plane of Array (kWh/m2/day)	Average Daily Temperature (Deg F)	Total System Output (AC kWh/day)	Total System Input (kWh/m2/day)	PV Array Output (DC kWh/day)	Average Inverter Efficiency	Average PV Array Conversion Efficiency	Peak Building Load (kW)	Daily Building Electricity Consumption (kWh/day)	System Dispatch Time (seconds)	% of Nominal Theoretical Output
5/1/98	121	1.47	0.01	1.46	1.51	61.02	0 33	-2.20	0.77	0.00	0.000	748.97	13174.00	1512	0.0%
5/2/98	122	2.46	0.60	2.10	2.73	61.93	0.43	-2.76	0.82	0.00	0.000	460.82	10188.00	0	0.0%
5/3/98	123	4.38	1.48	3.48	4.67	65.06	0.38	-2.46	0.84	0.00	0.000	470.33	10493.00	0	0.0%
5/4/98	124	2.75	0.28	2.53	2.87	65.05	0.42	-2.38	0.81	0.00	0.000	757.82	13578.00	2484	0.0%
5/5/98	125	2.54	0.68	2.02	2.89	63.67	0.45	-2.38	0.79	0.00	0.000	748.87	13419.00	1674	0.0%
5/6/98	126	1.34	0.01	1.33	1.41	62.54	0.37	-2.45	0.79	0.00	0.000	738.98	13736.00	1134	0.0%
5/7/98	127	4.58	1.98	2.90	5.23	65.78	0.28	-2.29	0.81	0.00	0.000	786.92	14014.00	5076	0.0%
5/8/98	128	0.46	0.01	0.45	0.48	59.88	2.06	-1.80	2.15	0.00	0.078	730.25	13115.00	594	68.4%
5/9/98	129	2.21	0.02	2.19	2.24	62.12	17.62	-0.93	13.51	0 00	0.089	453.15	9974.20	0	89.5%
5/10/98	130	0.79	0.01	0.78	0.81	60.05	7.88	-1.13	3.96	0.00	0.079	441.50	9805.90	0	72.4%
5/11/98	131	1.07	0.02	1.05	1.09	55.82	11.51	-0.71	6.29	0.00	0.088	740.03	13108.00	864	88.1%
5/12/98	132	1.25	0.01	1.23	1.25	55 24	13.19	-0.86	6.98	0.00	0.085	692.66	13085.00	0	82.6%
5/13/98	133	6.92	3.68	4 36	7.67	59.58	50.00	-0.94	44.96	0.00	0.084	744.70	13349.00	432	87.0%
5/14/98	134	7 23	7.77	2.06	7.76	63.77	47.04	-0.74	41 68	0.00	0.077	735.41	13441.00	648	79.8%
5/15/98	135	6.74	7.54	1.40	7.24	76.45	43.40	-0.74	37.71	0.99	0.075	763.69	14053.00	4698	77.3%
5/16/98	136	6.27	5.93	1.94	6.73	80.93	39.54	-0.87	34.54	0.00	0.075	568.83	11921.00	0	76.2%
5/17/98	137	5.39	3.12	3.19	6.20	71.84	39.55	-0.89	35.39	0.00	0.083	504.62	11247.00	0	84.7%
5/18/98	138	6.75	8.13	1.06	6.95	79.71	42.70	-1.52	38.18	0.00	0.079	838.64	14720.00	15120	81.5%
5/19/98	139	6.35	6.28	1.81	6.46	85.63	40.11	-1.73	35.56	0.00	0.081	857.44	15660.00	22194	81.7%
5/20/98	140	7.33	6.97	2.37	6.91	83.44	66.54	-2.75	39.60	0.00	0.084	877.92	16151.00	23329	85.1%
5/21/98	141	6 67	4.56	3.63	5.20	76.87	38.32	-2.61	33.99	0 00	0.095	907.45	15490.00	17600	97.1%
5/22/98	142	9.79	12.85	1.32	7.60	61.51	56 81	-1.66	51.82	0 95	0 096	772.62	14270.00	0	101.2%
5/23/98	143	7.59	8.82	2.15	7.45	62.95	55 29	-0.93	50.10	0 00	0.095	553.29	12285.00	0	99.8%
5/24/98	144	6 63	5.31	2.97	6.28	68.07	46 26	-0.96	41.33	0 00	0.096	561.21	12396.00	0	97.7%
5/25/98	145	3.51	0.74	2.85	3 56	69.51	29.53	-0.90	24.27	0 00	0.099	678.36	13696.00	51	101.2%
5/26/98	146	7.08	6.41	2.39	6.98	72.23	52.66	-0.82	46.24	0 00	0.094	860.13	15676.00	0	98.4%
5/27/98	147	5.17	1.48	4.13	5.15	70.72	39.90	-0.67	34.97	0 00	0.099	812.65	15315.00	0	100.7%
5/28/98	148	7.25	7.29	2.01	7.11	70.64	51.85	-0.65	47.21	0.00	0.094	924.60	15904.00	1454	98.5%
5/29/98	149	6.19	4.54	2.66	6.57	72.42	49.60	-0.92	45.06	0.00	0.099	860.28	15764.00	918	101.8%
5/30/98	150	6.37	4.92	3.06	6.11	78.49	42.79	-1.80	38.65	0.00	0.093	620.23	13495.00	0	93.9%
5/31/98	151	6.41	4.01	3.40	6.44	79.28	48.77	-1.38	44.21	0.99	0.099	629.54	13622.00	0	101.9%
Monthly Total		150.90	115.48	70.29	151.56		935.57	-45.82	803.99			924.60	416145.10	99782.00	
Monthly Average		4.87	3.73	2.27	4.89	68.46	30.18	-1.48	25.94			704.58	13424.04		

Carvel Dispatchable PV Peak Shaving System
Dispatch Event Record
May-98

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
124	815	124	845	108	0.00	0.04	0.30	0.00	0.00	0.29	0.00
128	900	128	1030	324	0.23	0.45	0.90	0.02	0.21	0.65	0.21
128	1230	128	1245	54	0.12	0.10	0.15	0.00	0.12	0.02	0.33
131	900	131	915	108	0.47	0.29	0.30	0.02	0.28	0.00	0.28
131	930	131	945	54	0.85	0.54	0.15	0.02	0.13	0.00	0.40
131	1000	131	1045	216	1.00	0.60	0.60	0.03	0.57	0.00	0.98
131	1100	131	1130	108	0.78	0.46	0.30	0.02	0.28	0.00	1.25
131	1145	131	1200	54	0.72	0.50	0.15	0.01	0.14	0.00	1.39
131	1230	131	1345	324	1.67	1.17	0.90	0.07	0.83	0.00	2.22
133	900	133	915	54	1.64	1.40	0.15	0.04	0.11	0.00	0.11
133	945	133	1015	108	3.57	3.11	0.30	0.12	0.18	0.00	0.29
133	1030	133	1045	54	2.68	2.39	0.15	0.07	0.08	0.00	0.37
133	1345	133	1400	54	3.10	2.65	0.15	0.08	0.07	0.00	0.44
133	1430	133	1500	162	4.18	3.65	0.45	0.22	0.23	0.00	0.67
134	830	134	845	108	1.42	1.13	0.30	0.06	0.24	0.00	0.24
134	900	134	930	108	2.54	2.18	0.30	0.08	0.22	0.00	0.45
134	945	134	1015	108	3.35	2.90	0.30	0.11	0.19	0.00	0.64
134	1045	134	1115	108	3.92	3.46	0.30	0.13	0.17	0.00	0.81
134	1145	134	1200	54	3.01	2.58	0.15	0.08	0.07	0.00	0.89
134	1315	134	1330	108	2.62	2.29	0.30	0.14	0.16	0.00	1.05
134	1415	134	1430	54	2.61	2.28	0.15	0.07	0.08	0.00	1.12
135	815	135	1530	4698	33.61	28.71	13.05	5.23	7.82	0.00	7.82
138	700	138	1615	15120	38.52	33.04	42.00	15.59	22.93	-12.10	22.93
139	630	139	1645	22194	37.63	31.86	61.65	21.14	16.49	2.88	16.49
140	700	140	1630	23329	52.22	33.46	64.80	23.57	28.65	-10.99	28.65
141	715	141	1645	17600	33.32	28.38	48.89	16.53	16.79	-0.97	16.79
145	900	145	915	51	0.48	0.27	0.14	0.01	0.13	0.00	0.13
148	815	148	900	914	2.85	2.25	2.54	0.51	2.03	0.00	2.03
148	945	148	1015	540	3.69	3.14	1.50	0.62	0.88	0.00	2.91
149	1345	149	1415	918	4.65	4.17	2.55	1.43	1.12	0.00	1.12

Key to Monthly Performance Report Charts (Conowingo Revised 9/97)

Monthly performance reports for the Dispatchable PV Peak Shaving units installed under the PV:BONUS Program consist of a series of graphical profiles and charts, along with a brief written summary of system performance. The following information is presented to help clarify the meaning of the attached charts and graphs.

Monthly Profiles

Four monthly profiles are provided with each report. The monthly profiles show 15 minute, time-series data for the following measured variables:

- PV system AC input (during battery charging) and AC output (during PV array operation and/or battery discharge)
- Global horizontal and direct normal solar radiation
- PV array DC output
- Building load

Monthly profiles provide a quick overview of PV system operation, solar resource availability and building operation over the reporting period.

Building Load Characteristics

Four graphs are provided to indicate the response of the building to temperature and solar radiation. A fifth graph is provided to show the building's load-duration characteristics. These are explained below:

- ***Weekday Building Load vs. Temperature***: This graph plots the sensitivity of the building's load to outside air temperature using 15-minute data. Electrical loads tend to increase during seasonal extremes. In hot weather, air conditioning runs more frequently, resulting in higher electrical demand. Likewise, during periods of very cold weather, equipment used in the operation of heating systems (fans, pumps, etc.) also run more frequently. In buildings that use electric heating systems, such as heat pumps, demand can be significantly higher during the winter than in the summer. Peak summer loads tend to occur in the early to late afternoon when temperatures are highest. Peak winter loads tend to occur during the early morning and early evening when high heating and lighting loads coincide. For most commercial and industrial buildings, loads also tend to be higher during weekdays when occupancy and usage levels are higher.

- ***Weekday Building Load vs. Global Horizontal Irradiance***: This graph plots the sensitivity of the building's load to global horizontal irradiance using 15-minute data. During the summer months, building loads tend to be higher during periods of high irradiance. This is

because high summer temperatures are partially correlated to high sunlight levels. In climates where haze and humidity accompany hot weather, solar radiation levels may actually be somewhat lower than cool, clear days when solar radiation approach ideal maximums. A strong positive correlation between building load and global horizontal irradiance indicates that the output of a PV array is also strongly correlated with building load, and can therefore provide relatively reliable demand reduction. In these cases, the benefit of battery energy storage is lower. It is much more common to have moderate or poor correlation. In these cases, battery energy storage provides higher benefits by assuring reliable peak shaving.

- ***Building Daily Peak Load vs. Daily Average Temperature***: This graph is similar to the graph of Weekday Building Load versus Temperature. However, data used in this graph are derived from the raw 15-minute data. The data is processed to calculate average daily temperatures and to find corresponding peak building loads. Peak building loads are likely to be higher on days when the average daily temperatures approach seasonal extremes.

- ***Building Daily Peak Load vs. Daily Global Horizontal Irradiance***: This graph is similar to the graph of Weekday Building Load versus Global Horizontal Irradiance. Like the graph above, the data used to generate this graph are derived from the raw 15-minute data. Global horizontal irradiance is summed for an entire day to determine the total availability of solar energy and plotted against the corresponding daily peak load. A positive correlation indicates that peak loads occur on days when the availability of solar energy is high. This graph should be interpreted in conjunction with the graph of Weekday Building Load versus Global Horizontal Irradiance. It is possible to have poor correlation between building load and 15 minute readings of solar radiation while having good correlation between daily peak load and total daily solar radiation. This implies that the building's peak load is not instantaneously coincident with solar radiation, i.e., peak loads occur either before or after the solar resource peaks. A good positive correlation in this graph indicates that battery energy storage is of high value in managing the energy output of the PV array, because it allows peak shaving independent of PV array output.

- ***Building Load-Duration Curve***: The final graph related to building loads is a Load Duration Curve. The load duration curve depicts 15 minute building load intervals in order of highest to lowest for the monitoring period. The graph included in this report shows only the highest 400 15 minute intervals. Load-duration curves are typically used to show the relationship between peak and base building loads. Buildings with sharp "spikes" at the left of the curve are usually good candidates for peak shaving, especially if demand charges are a significant portion of the overall electric bill.

Dispatchable PV System Performance

Six graphs are used to show overall PV system performance and to provide diagnostic information during the monitoring period. These are explained below:

- ***Inverter Efficiency vs. DC Input***: A three-phase, solid state inverter is used to convert the DC output of the PV array and battery string to AC power compatible with the building's electric power system. Like all conversion devices, losses are inherent in its operation. For the 32 kVA inverter installed in the PV-31 battery/inverter modules, efficiency is nearly flat at 90% for DC input levels above approximately 4 kW. For DC inputs between approximately 1 and 4 kW, efficiency increases rapidly from nearly 0 to about 90%. Below approximately 1 kW, conversion losses and parasitic loads usually prevent generation of significant AC power.

- ***DC Conversion Efficiency vs. Plane of Array Insolation***: In order to monitor PV array performance, a graph of sunlight to DC power conversion efficiency is plotted. For the polycrystalline silicon PV modules used in the dispatchable PV systems, sunlight conversion efficiencies are typically between 10 and 12%. Conversion efficiency between 100 and 200 Watts/m^2 varies in a nearly linear fashion from approximately 6 to 12%. Efficiency peaks at 10 to 12% between about 200 and 700 Watts/m^2. Above 700 Watts/m^2, temperature effects tend to reduce efficiency somewhat.

- ***Temperature Corrected DC Output vs. Plane of Array Insolation***: A second graph of PV array performance shows the PV array output in kW versus insolation. For each data point a temperature correction factor is applied since PV output varies inversely with solar cell temperature. The corrected performance reflects PV array output at Standard Test Conditions, i.e., a cell temperature of 25°C. Performance curves should be nearly identical from month to month when plotted in this way. At 1,000 Watts/m^2, the temperature corrected output should be within several percentage points of the PV array rating at STC.

- ***Daily PV Array Output***: A vertical bar chart shows the daily PV array output in DC kWh. This chart provides a quick summary of PV array operation, and an approximate indication of the amount of energy generated by the system.

- ***PV Array Performance***: A second vertical bar chart presents PV array performance as a percentage of theoretical output at 10% conversion efficiency. Values will typically vary between 80 and 110%, depending on site conditions and daily insolation. Values that are significantly lower indicate that the array may have been out of service for at least a portion of the day.

- ***Daily Plane of Array Insolation***: A third vertical bar chart shows the total amount of solar energy available to the array for each day. This chart, in combination with the other bar charts, is used to quickly identify outages and other array problems.

Tabular Summary

There are two tabular summaries included in the monthly reports:

The first tabular summary of daily performance provides more detailed information about system performance and solar resource availability. The last column in the tabular summary also indicates the amount of time, in seconds, that the PV-31 unit was dispatched during the day.

The second tabular summary is a dispatch event log. The log provides detailed information for each period when the unit is called to automatically dispatch including: start and stop intervals; the amount of time (in seconds) that the unit was required to dispatch; the amount of energy required for peak shaving during the interval; and the contributions from storage and the PV array. The amount of energy storage shortfall (if any) is also recorded, along with the cumulative amount of energy drawn from storage during a daily period. Energy storage shortfalls indicate that the duration of the peak period was too long for the available storage. The daily cumulative amount of energy drawn from storage indicates the depth of discharge. On a daily basis, the total amount of energy that can be provided from storage will range from approximately 20 to 30 kWh, depending on the amount of solar energy available and the dispatch output level.

Conowingo Dispatchable PV Peak Shaving System
Monthly Performance Summary
August 1997

Overall PV System Operation

The system operated normally through the month of August, with no outages. The unit was also automatically dispatched throughout the month as needed to shave peak loads in excess of 65kW.

Building Load Characteristics

Building loads in August were nearly identical to loads during July, although temperatures were somewhat lower. The relationship between ambient temperature and 15-minute building load shows a positive correlation, while the relationship between 15-minute building load and global horizontal irradiance became slightly flatter in comparison to July.

Building peak load during the period was 67 kW, the same as July.

Dispatchable PV System Performance

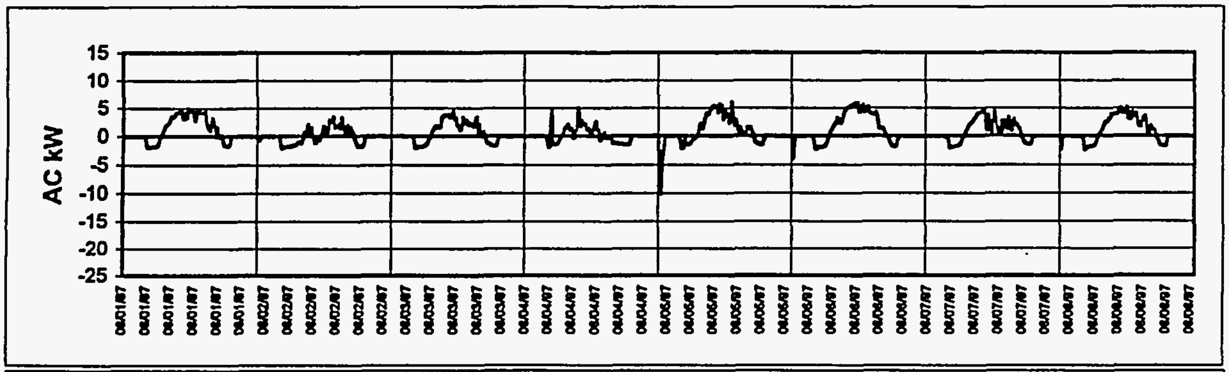
The system performed normally during the monitoring period as shown on the graphs of inverter performance and DC conversion efficiency.

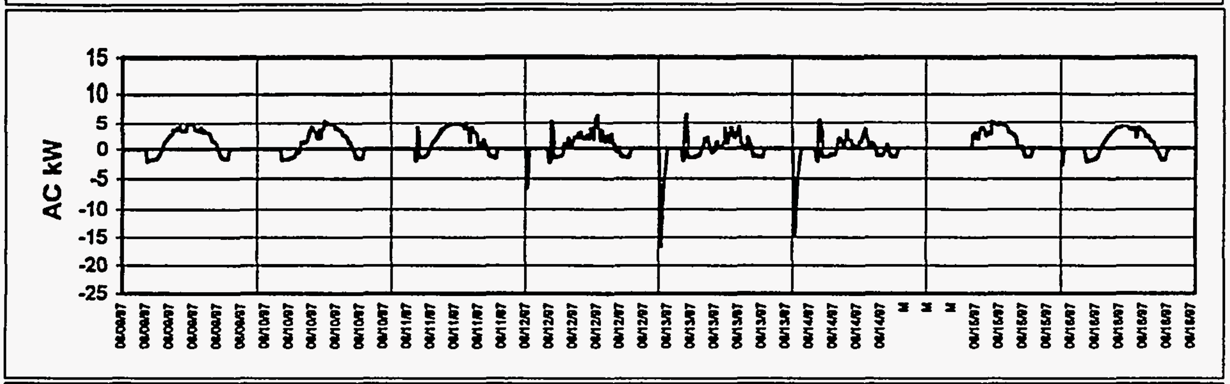
The system automatically dispatched 20 separate times for peak shaving on nine different days. The unit is set to provide a 10 kW reduction in building load. Dispatch events ranged in duration from less than one minute to as long as 37 minutes. Although the dispatch event table shows small energy shortfalls, this is inaccurate due to instrument error. A persistent offset in the system's AC output measurement understates the actual output by up to 2 kW. No more than 25% of the available stored energy was used on any single day, precluding the possibility a shortfall.

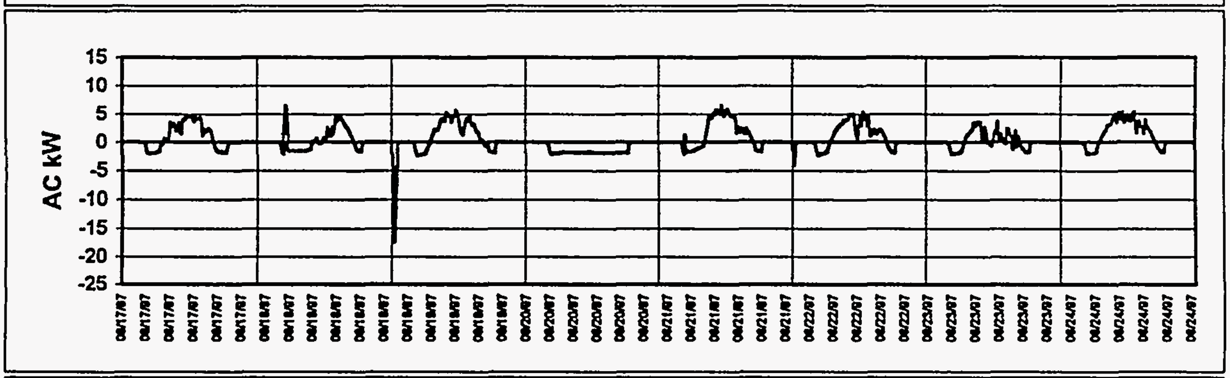
Based on the building load data the set point for starting a dispatch will remain at 65 kW building load. With the arrival of cooler weather in September, and the need for heating, peak loads are expected to increase in duration and frequency, and will require somewhat more energy from the batteries.

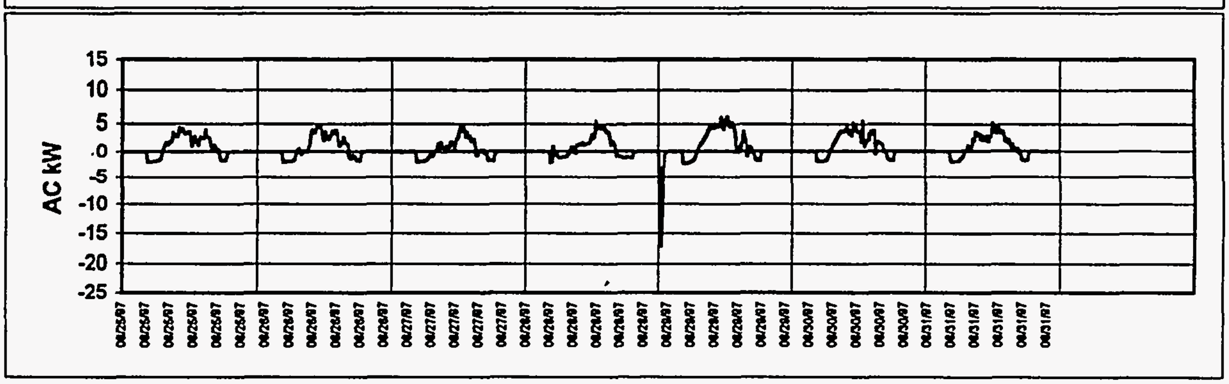
Conowingo Dispatchable PV Peak Shaving System
AC Output and Charging Profiles

Aug-97



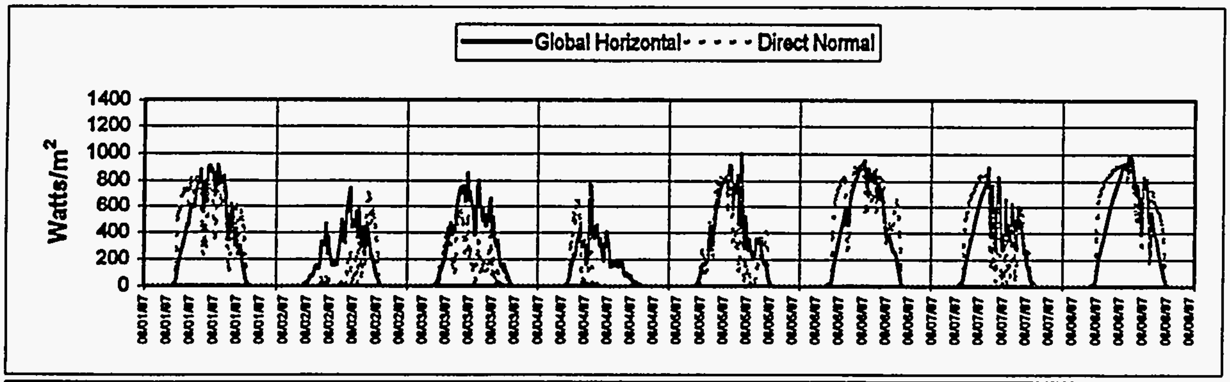


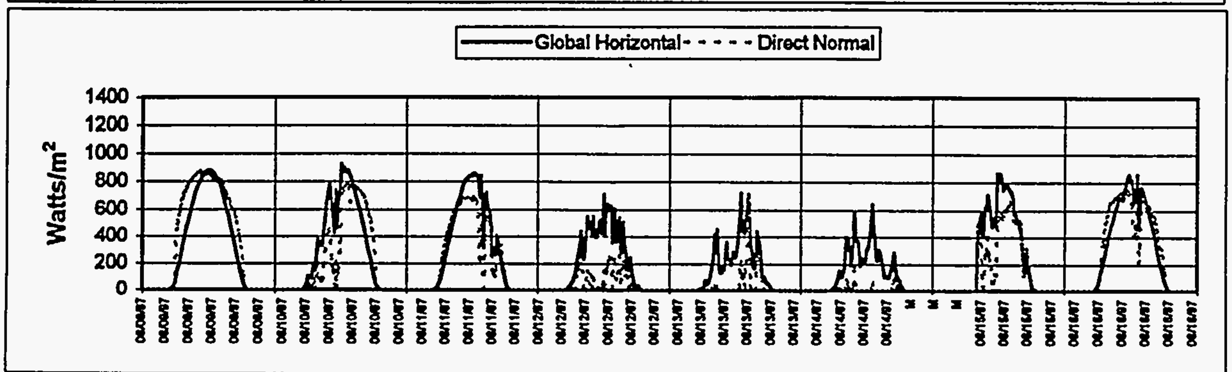


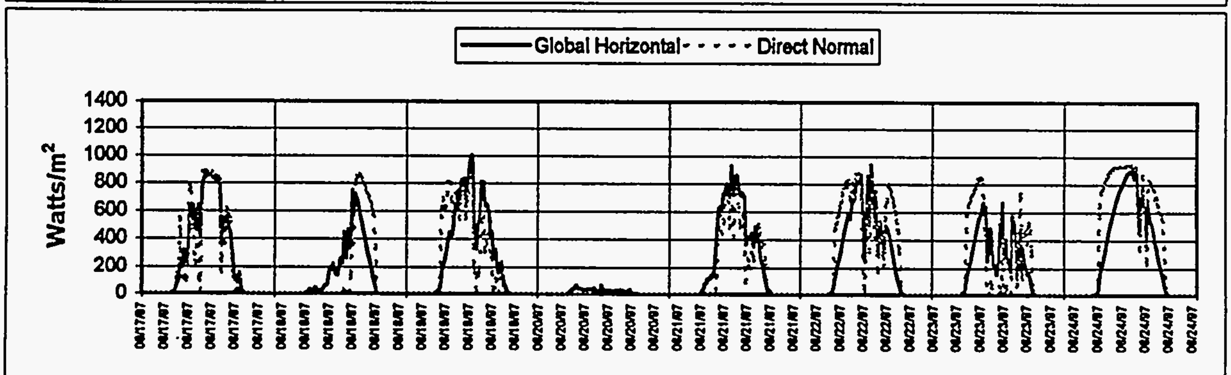


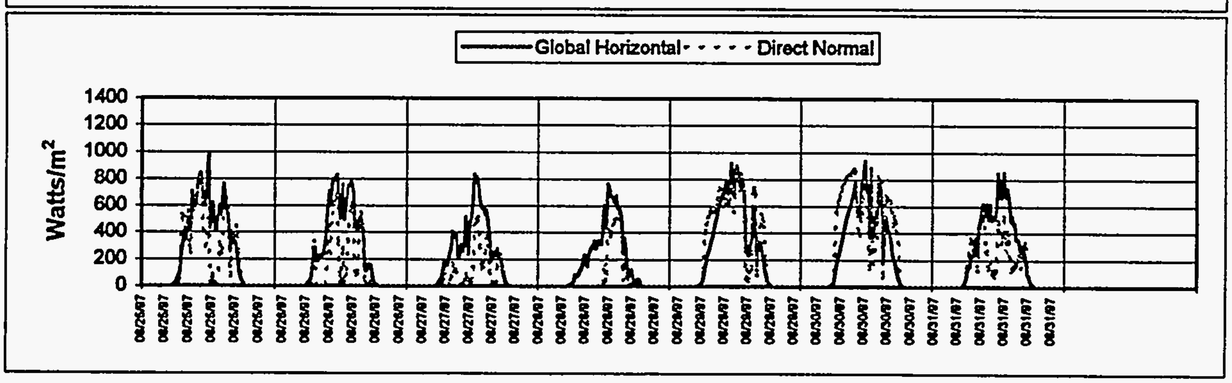
Conowingo Dispatchable PV Peak Shaving System
Solar Resource Profiles

Aug-97



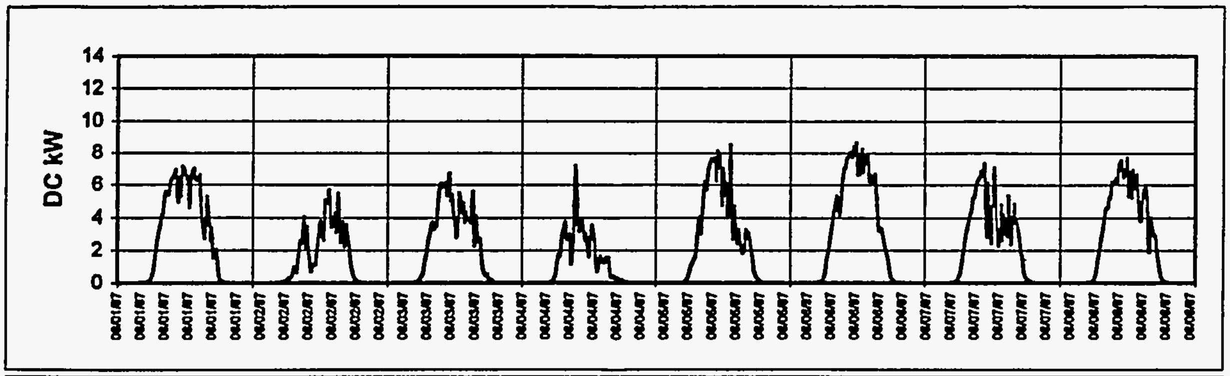


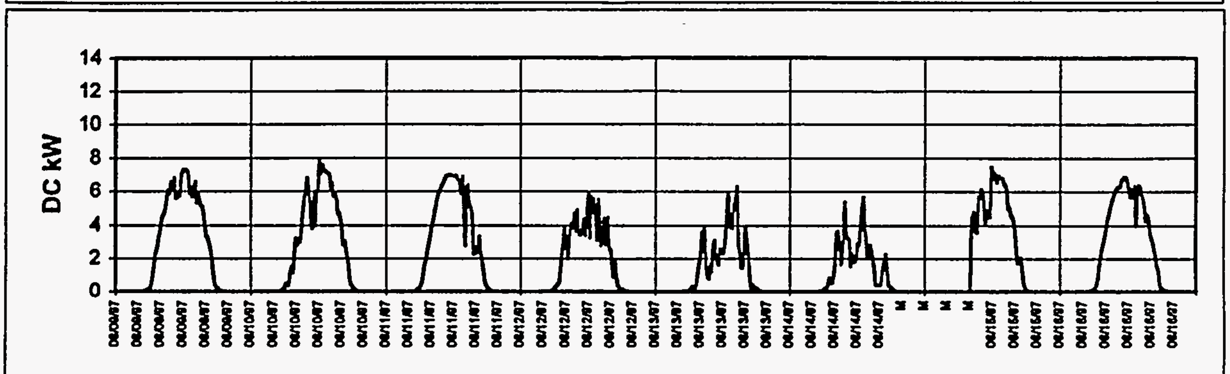


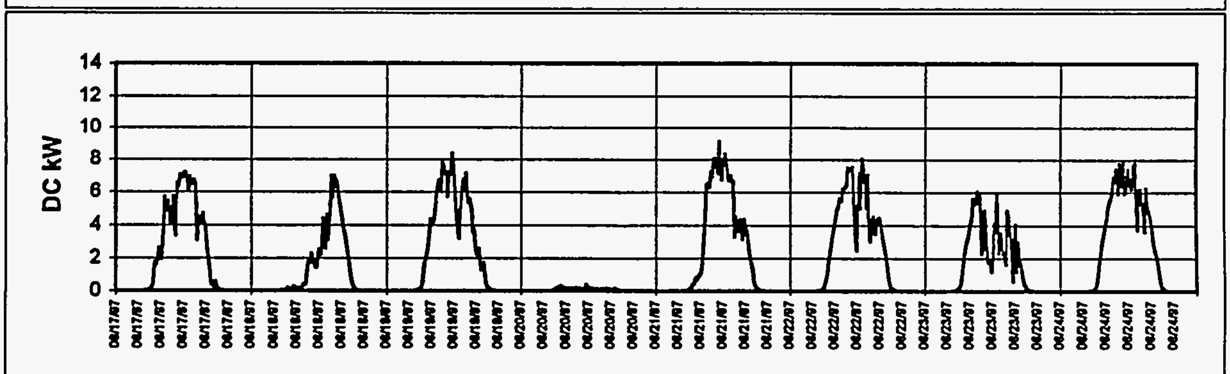


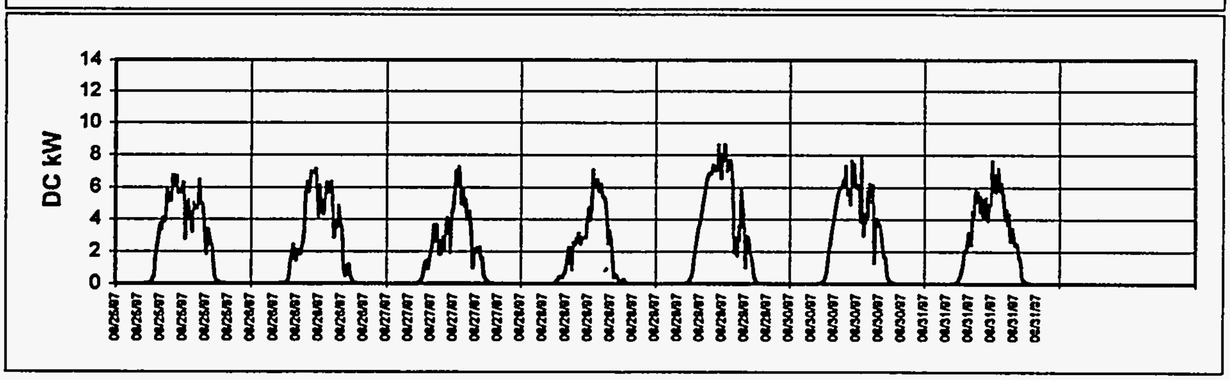
Conowingo Dispatchable PV Peak Shaving System
DC Output Profile

Aug-97



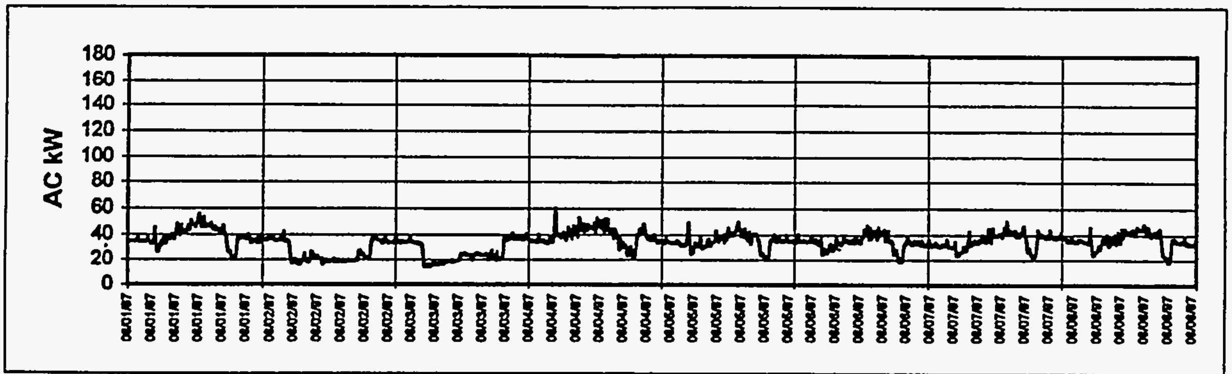


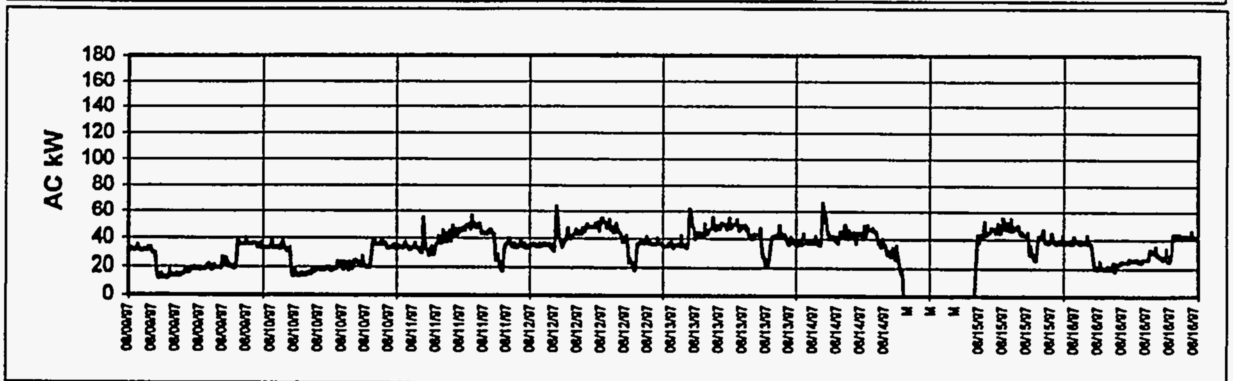


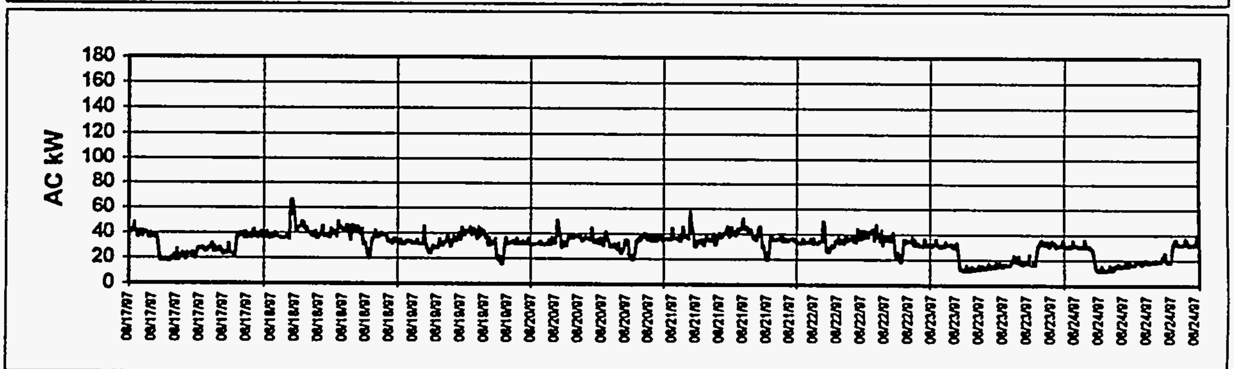


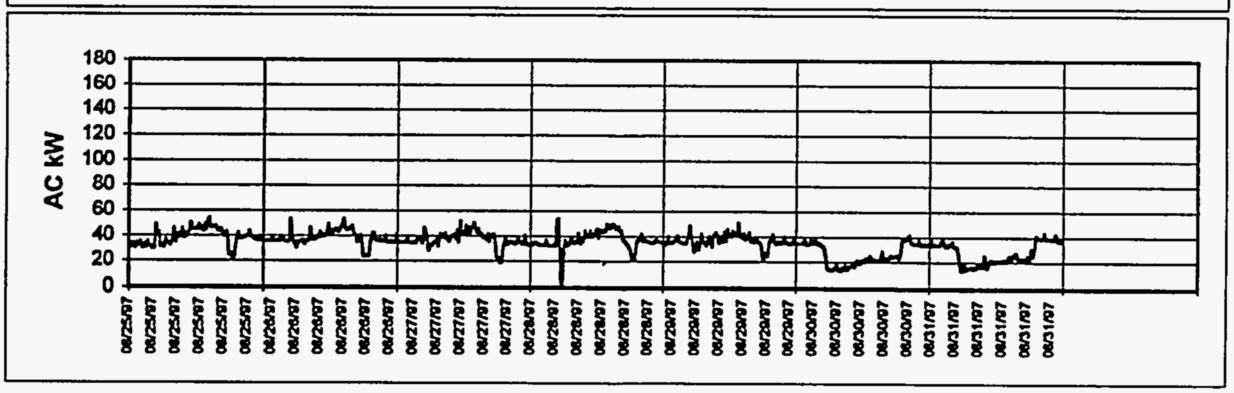
Conowingo Dispatchable PV Peak Shaving System
Building Load Profiles

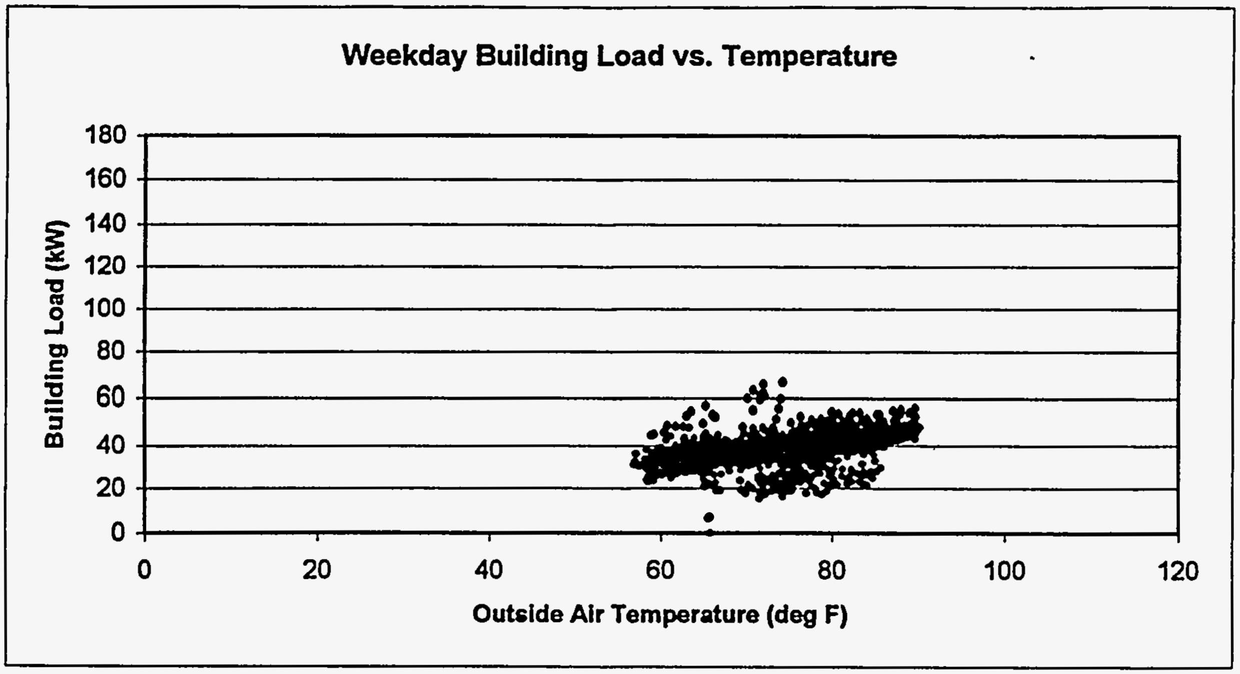
Aug-97

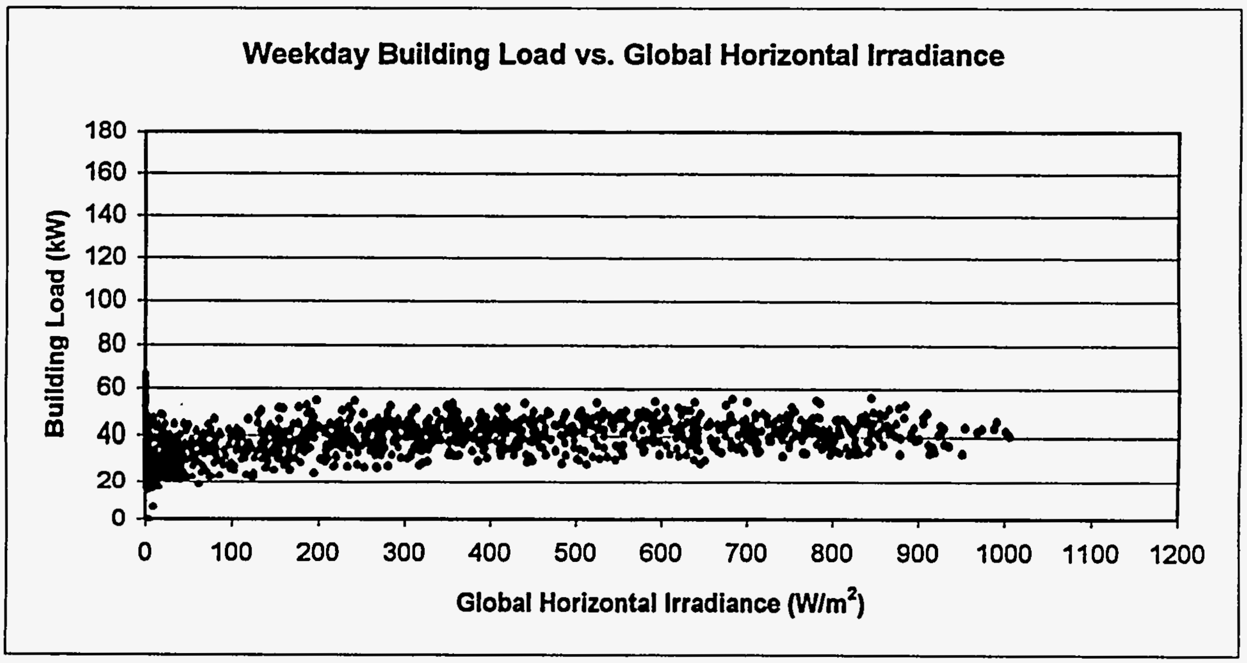


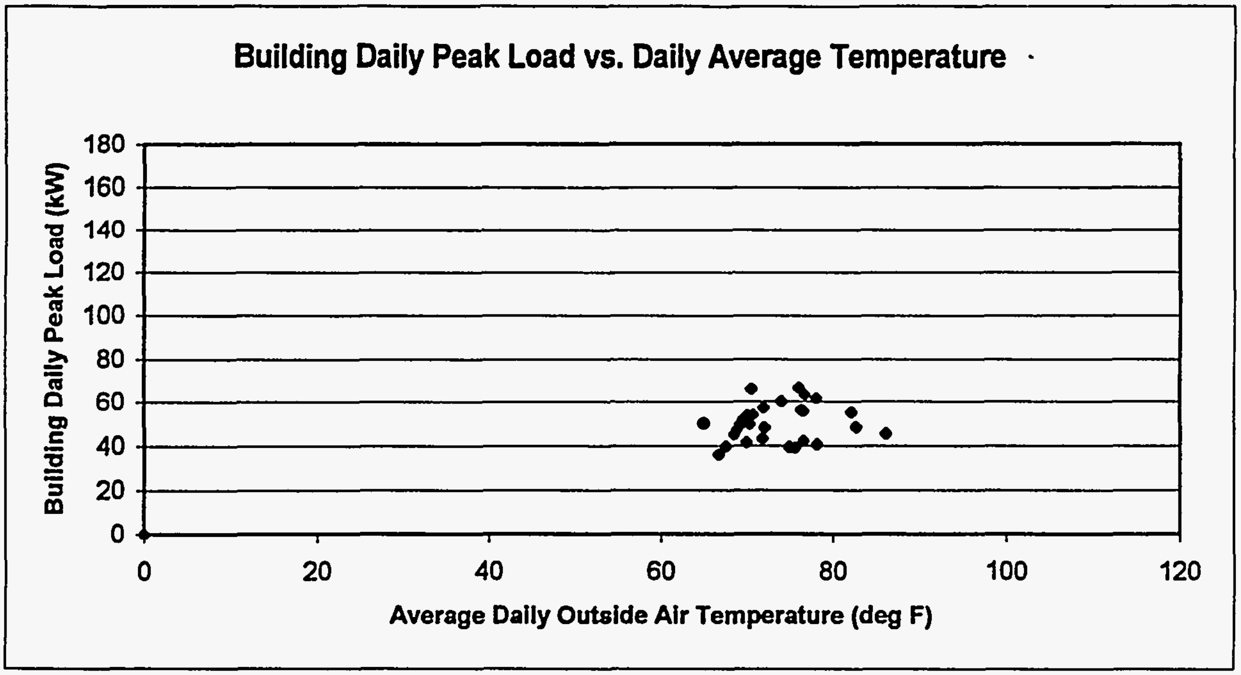


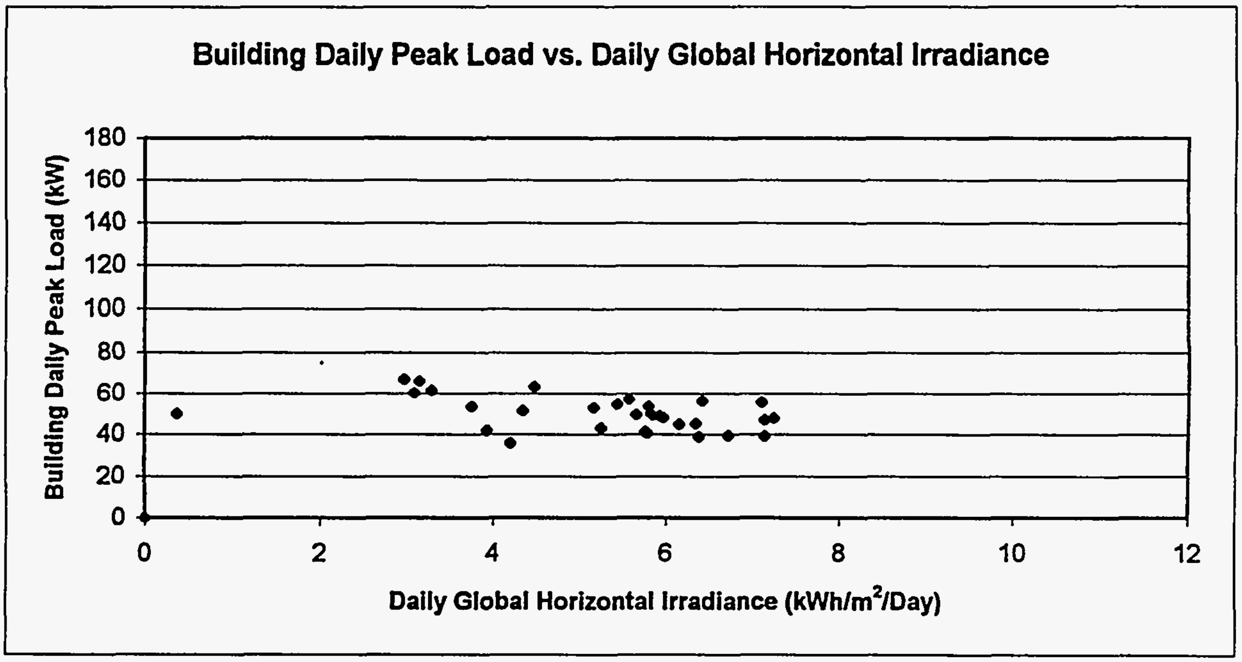


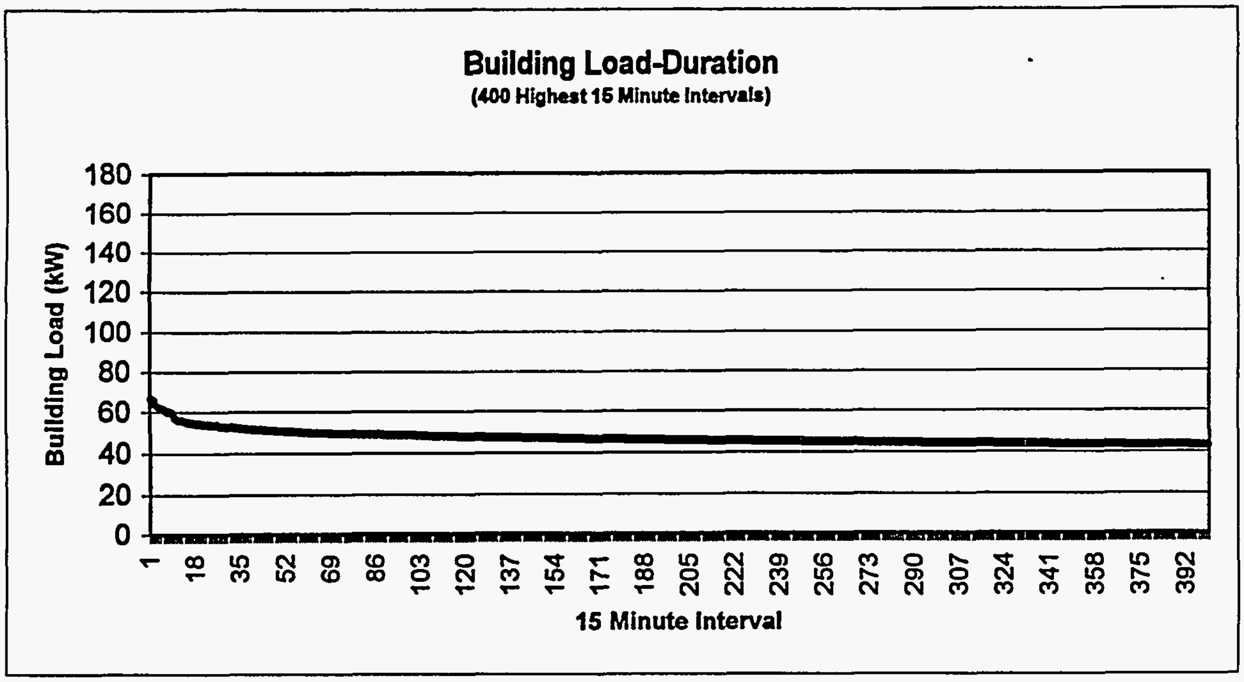


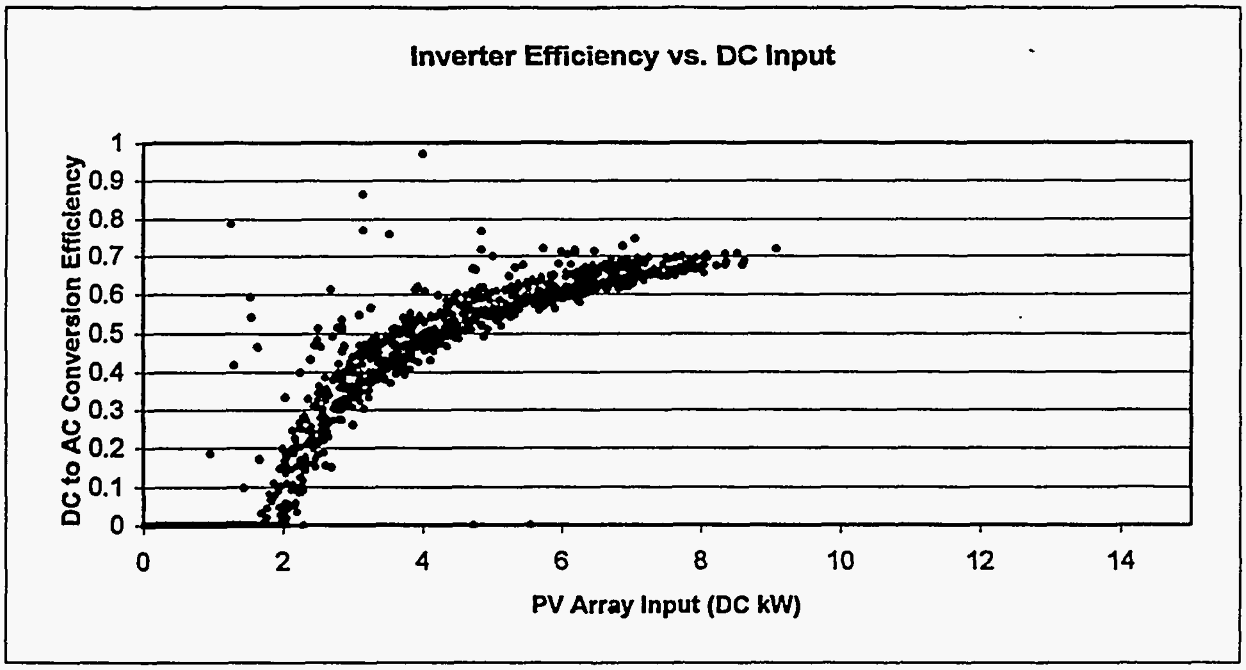

Weekday Building Load vs. Temperature
Building Load (kW)
0
20
40
60
80
100
120
140
160
180
0
20
40
60
80
100
120
Outside Air Temperature (deg F)

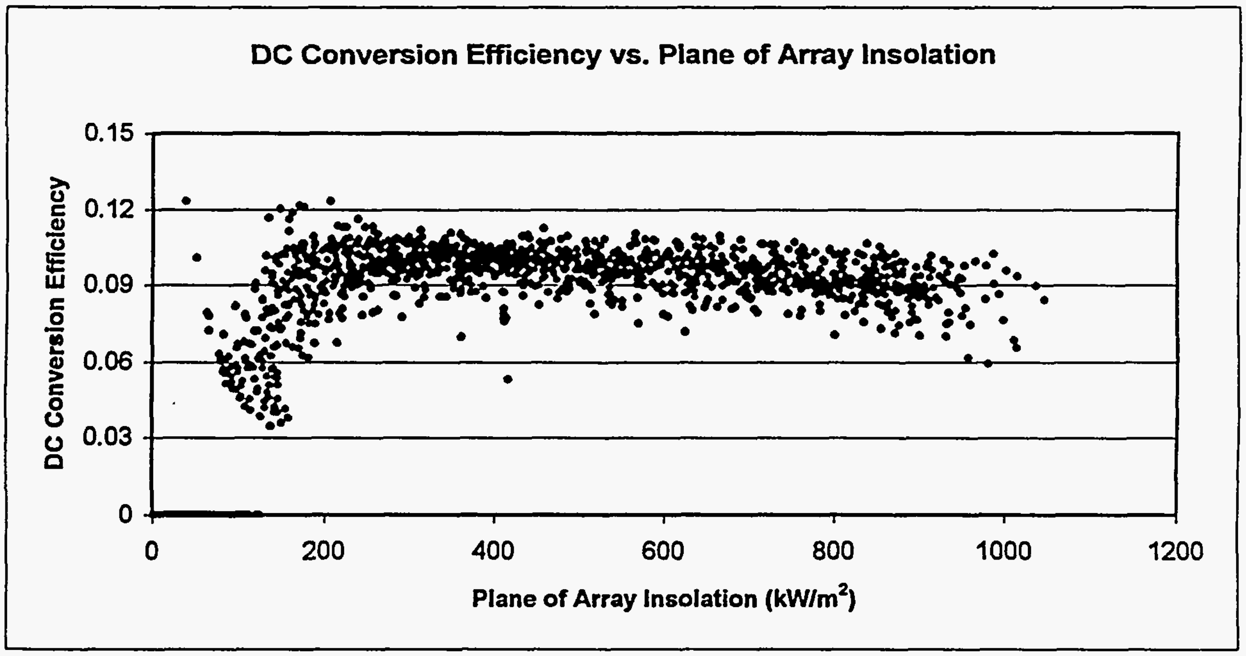

Weekday Building Load vs. Global Horizontal Irradiance
Building Load (kW)
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Global Horizontal Irradiance (W/m2)

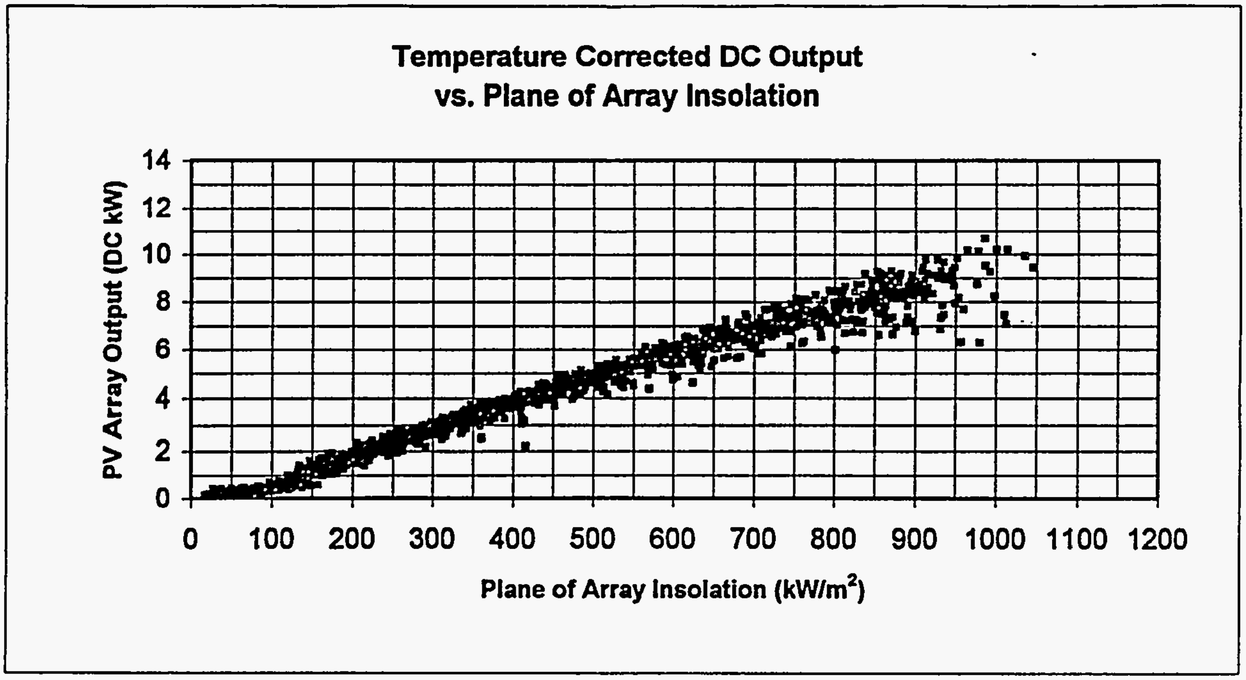

Building Daily Peak Load vs. Daily Average Temperature
Building Daily Peak Load (kW)
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
Average Daily Outside Air Temperature (deg F)

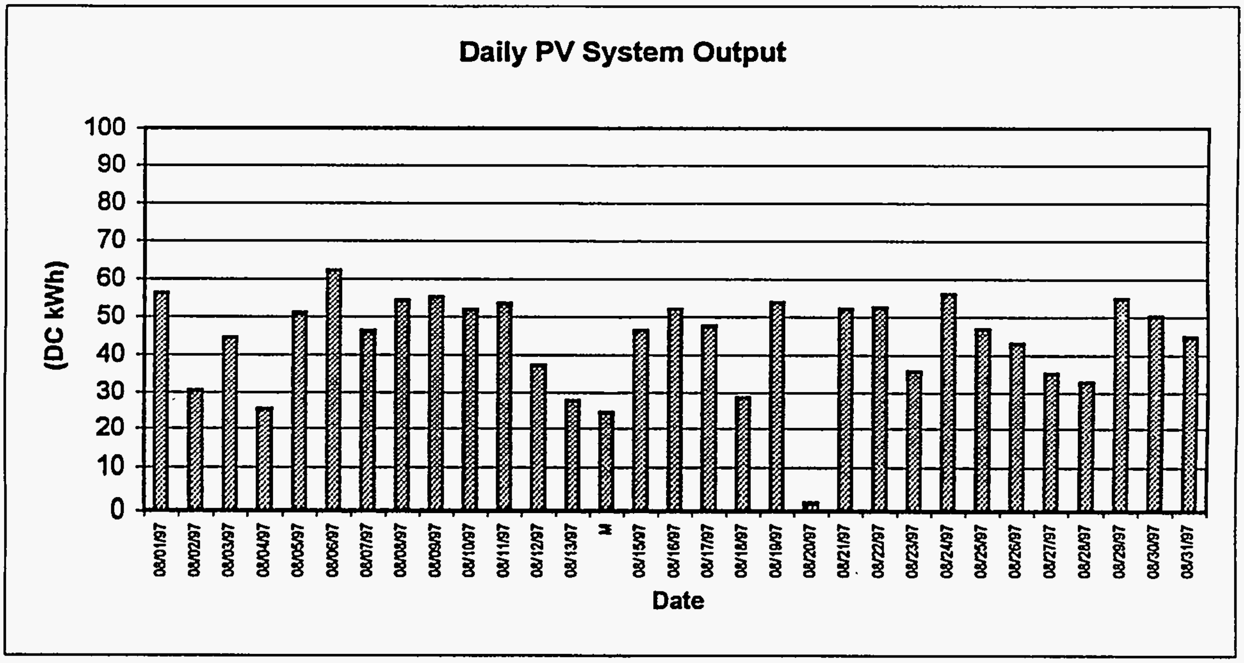

Building Daily Peak Load vs. Daily Global Horizontal Irradiance
Building Daily Peak Load (kW)
180
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
Daily Global Horizontal Irradiance (kWh/m2/Day)

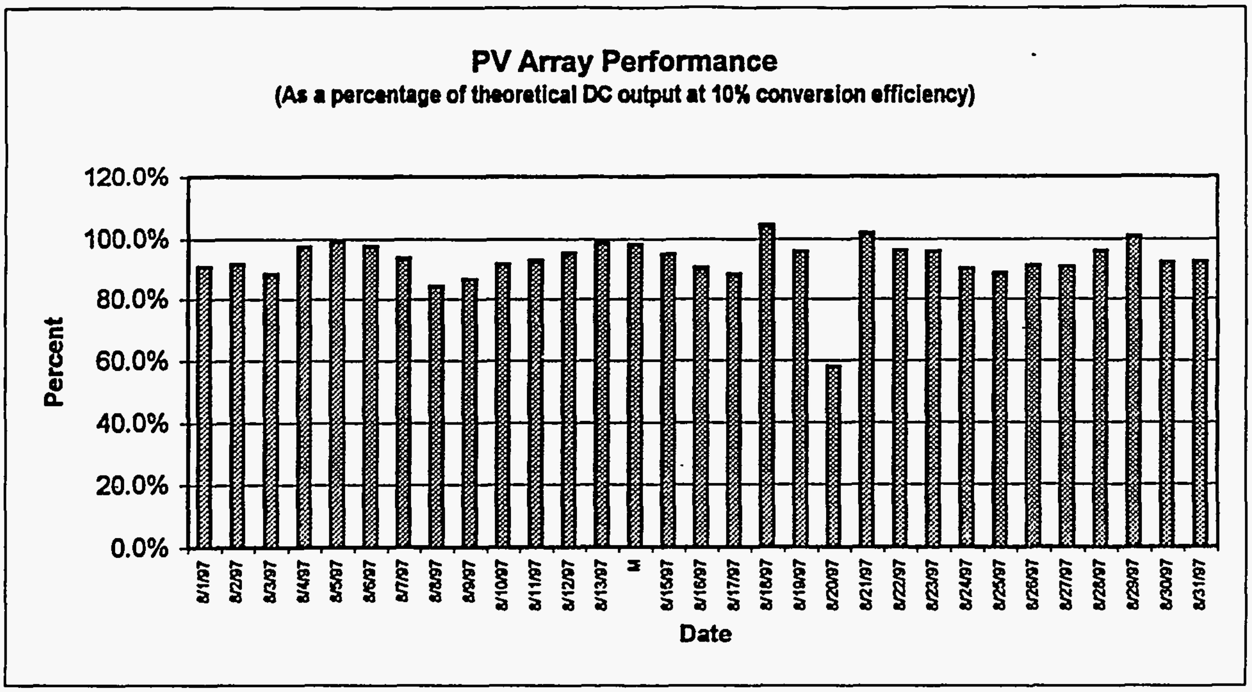

Building Load-Duration
(400 Highest 15 Minute Intervals)
Building Load (kW)
0
20
40
60
80
100
120
140
160
180
1
18
35
52
69
86
103
120
137
154
171
188
205
222
239
256
273
290
307
324
341
358
375
392
15 Minute Interval

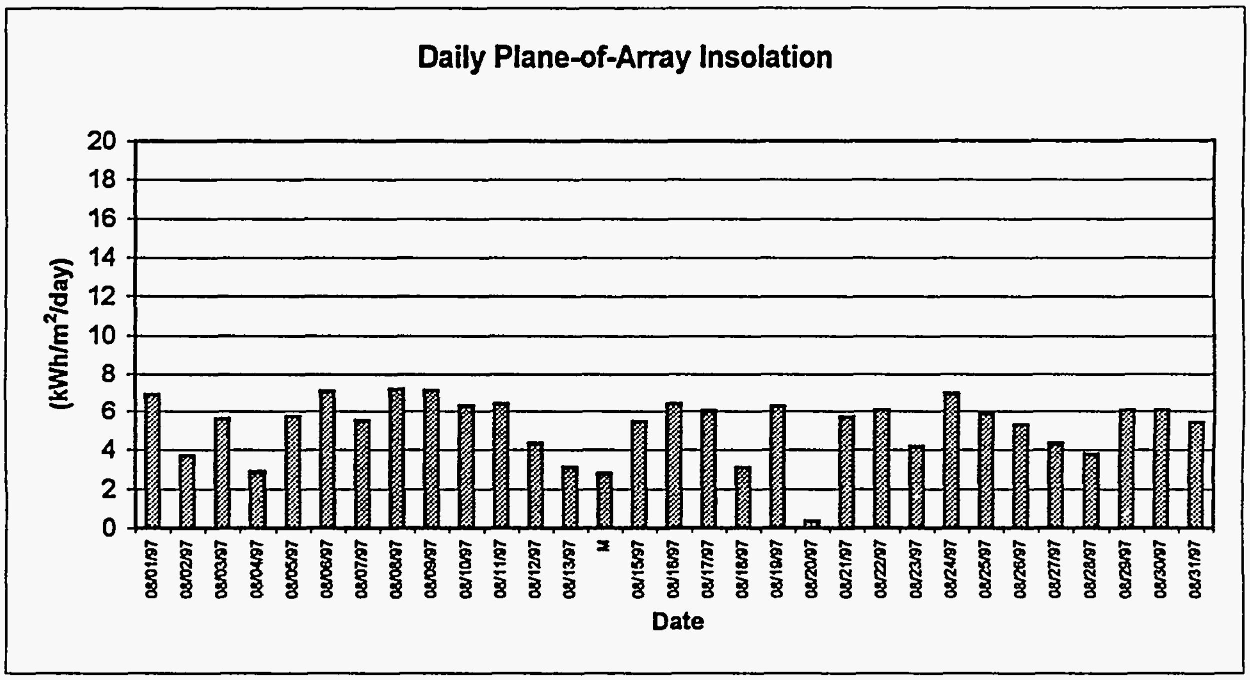

Inverter Efficiency vs. DC Input
DC to AC Conversion Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
PV Array Input (DC kW)


DC Conversion Efficiency vs. Plane of Array Insolation
DC Conversion Efficiency
0.15
0.12
0.09
0.06
0.03
0
0
200
400
600
800
1000
1200
Plane of Array Insolation (kW/m²)


Temperature Corrected DC Output
vs. Plane of Array Insolation
PV Array Output (DC kW)
Plane of Array Insolation (kW/m²)
0
2
4
6
8
10
12
14
0 100 200 300 400 500 600 700 800 900 1000 1100 1200


Daily PV System Output
(DC kWh)
Date
0
10
20
30
40
50
60
70
80
90
100


PV Array Performance
(As a percentage of theoretical DC output at 10% conversion efficiency)
Percent
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Date


Daily Plane-of-Array Insolation
(kWh/m2/day)
20
18
16
14
12
10
8
6
4
2
0
Date

Conowingo Dispatchable PV Peak Shaving System
Monthly Summary Data
Aug-97

Date	Julian Day	Global Horizontal (kWh/m2/day)	Direct Normal (kWh/m2/day)	Diffuse Horizontal (kWh/m2/day)	Plane of Array (kWh/m2/day)	Average Daily Temperature (Deg F)	Total System Output (AC kWh/day)	Total System Input (kWh/m2/day)	PV Array Output (DC kWh/day)	Average Inverter Efficiency	Average PV Array Conversion Efficiency	Peak Building Load (kW)	Daily Building Electricity Consumption (kWh/day)	System Dispatch Time (seconds)	% of Nominal Theoretical Output
8/1/97	213	7.11	7.33	2.35	6.90	76.54	32.56	-7.54	56.21	0.56	0.092	55.66	927.10	54	90.7%
8/2/97	214	3.93	1.81	3.06	3.70	76.55	10.78	-11.51	30.43	0.37	0.090	41.82	632.12	0	91.5%
8/3/97	215	5.79	2.82	3.85	5.60	78.18	21.23	-8.78	44.36	0.48	0.086	40.59	637.21	0	88.1%
8/4/97	216	3.09	1.35	2.48	2.89	74.05	11.23	-9.62	25.27	0.48	0.097	60.11	943.68	1551	97.4%
8/5/97	217	5.84	4.65	2.57	5.74	70.34	28.68	-13.33	51.09	0.52	0.099	49.45	844.69	279	99.1%
8/6/97	218	7.15	8.41	1.60	7.09	68.82	38.12	-9.48	62.23	0.54	0.096	47.00	825.32	0	97.7%
8/7/97	219	5.66	5.55	2.20	5.50	70.40	23.25	-7.74	46.27	0.48	0.093	49.76	855.36	216	93.6%
8/8/97	220	7.25	8.93	1.41	7.20	72.00	28.92	-8.80	54.38	0.51	0.084	47.62	860.94	0	84.1%
8/9/97	221	7.14	8.80	1.15	7.13	74.92	30.67	-8.25	55.31	0.55	0.086	39.29	581.35	0	86.3%
8/10/97	222	6.38	5.25	2.78	6.31	75.58	28.03	-8.68	51.91	0.52	0.090	38.94	603.18	0	91.5%
8/11/97	223	6.42	5.53	2.52	6.42	76.34	32.64	-6.61	53.49	0.56	0.093	56.26	914.56	1221	92.8%
8/12/97	224	4.48	1.16	3.68	4.34	76.76	22.57	-10.31	37.23	0.48	0.094	63.32	966.08	2832	95.4%
8/13/97	225	3.28	0.71	2.79	3.13	78.10	15.33	-18.83	27.69	0.43	0.098	61.47	1009.70	2622	98.6%
M	M	2.97	0.24	2.84	2.78	76.03	12.17	-18.69	24.55	0.36	0.094	66.68	762.78	2280	98.3%
8/15/97	227	5.44	3.69	2.75	5.45	82.13	27.78	-2.58	46.49	0.58	0.095	54.90	666.01	0	95.0%
8/16/97	228	6.35	6.51	1.95	6.41	86.10	27.84	-9.49	52.04	0.53	0.091	45.24	748.27	0	90.4%
8/17/97	229	5.97	5.46	1.95	6.03	82.66	24.84	-9.39	47.64	0.51	0.088	46.13	722.88	0	88.0%
8/18/97	230	3.15	3.14	1.56	3.07	70.57	17.29	-10.27	28.82	0.46	0.107	65.91	945.67	2223	104.4%
8/19/97	231	6.16	5.52	2.56	6.26	68.50	29.08	-16.10	53.86	0.53	0.096	44.93	798.59	0	95.8%
8/20/97	232	0.37	0.01	0.37	0.35	65.05	0.00	-27.95	1.80	0.00	0.000	49.97	808.06	0	58.0%
8/21/97	233	5.57	4.28	2.48	5.71	71.95	31.76	-7.66	52.20	0.57	0.097	57.10	895.81	342	101.7%
8/22/97	234	5.93	7.29	1.53	6.07	69.20	27.65	-9.38	52.47	0.50	0.096	49.16	828.00	0	96.2%
8/23/97	235	4.21	4.33	2.11	4.16	66.77	14.04	-8.64	35.80	0.38	0.095	36.02	540.03	0	95.8%
8/24/97	236	6.72	9.26	0.95	6.96	67.57	30.62	-7.50	56.18	0.52	0.092	39.57	552.11	0	89.9%
8/25/97	237	5.80	4.31	3.07	5.89	70.76	23.51	-8.00	46.74	0.49	0.089	53.71	921.10	0	88.4%
8/26/97	238	5.17	2.68	3.25	5.27	70.02	21.23	-9.08	43.07	0.48	0.090	53.00	915.56	0	90.9%
8/27/97	239	4.34	1.48	3.33	4.34	69.59	13.94	-8.86	35.28	0.40	0.091	51.60	890.33	0	90.4%
8/28/97	240	3.76	1.46	2.69	3.80	70.09	19.12	-8.00	32.79	0.56	0.094	53.47	880.74	285	96.0%
8/29/97	241	5.83	6.20	1.87	6.08	69.96	30.51	-15.64	55.01	0.53	0.099	50.19	882.51	0	100.8%
8/30/97	242	5.76	7.06	1.59	6.07	69.95	26.39	-7.61	50.14	0.51	0.092	41.26	636.53	0	91.9%
8/31/97	243	5.25	3.12	3.34	5.41	71.79	22.06	-7.61	44.76	0.46	0.092	43.07	653.60	0	92.2%
Monthly Total		162.26	138.34	72.62	162.08		721.84	-322.32	1355.48			66.68	24650.07	13905.00	
Monthly Average		5.41	4.61	2.42	5.40	75.58	24.06	-10.74	45.18			51.85	821.67		

Conowingo Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-97

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
213	645	213	700	54	0.04	0.81	0.15	0.02	0.02	0.09	0.02
216	500	216	530	741	0.48	0.02	2.06	0.00	0.48	1.57	0.48
216	915	216	930	162	0.48	0.99	0.45	0.06	0.39	0.00	0.87
216	1030	216	1045	216	1.16	1.60	0.60	0.18	0.42	0.00	1.29
216	1300	216	1315	162	0.82	1.31	0.45	0.13	0.32	0.00	1.61
216	1430	216	1445	108	0.11	0.64	0.30	0.04	0.07	0.16	1.68
217	1400	217	1415	108	1.11	1.71	0.30	0.07	0.23	0.00	0.23
219	1415	219	1445	216	1.56	2.46	0.60	0.22	0.38	0.00	0.38
223	500	223	515	627	0.61	0.01	1.74	0.00	0.61	1.13	0.61
223	1345	223	1415	486	2.41	3.37	1.35	0.72	0.63	0.00	1.24
223	1430	223	1445	108	2.09	2.90	0.30	0.17	0.13	0.00	1.37
224	500	224	530	1425	2.10	0.01	3.96	0.00	2.10	1.85	2.10
224	715	224	730	108	0.35	0.88	0.30	0.04	0.26	0.00	2.35
224	1200	224	1215	216	1.88	2.49	0.60	0.27	0.33	0.00	2.68
224	1300	224	1330	1026	3.64	3.50	2.85	1.38	1.47	0.00	4.15
225	500	225	530	1539	2.40	0.01	4.28	0.00	2.40	1.87	2.40
225	1215	225	1230	432	1.17	1.12	1.20	0.26	0.92	-0.23	3.31
225	1315	225	1345	378	2.50	3.21	1.05	0.42	0.63	0.00	3.95
226	500	226	545	2109	3.32	0.01	5.86	0.01	3.31	2.53	3.31
230	500	230	545	2223	3.56	0.02	6.18	0.01	3.55	2.61	3.55

Key to Monthly Performance Report Charts (INTEK Revised 9/97)

Monthly performance reports for the Dispatchable PV Peak Shaving units installed under the PV:BONUS Program consist of a series of graphical profiles and charts, along with a brief written summary of system performance. The following information is presented to help clarify the meaning of the attached charts and graphs.

Monthly Profiles

Four monthly profiles are provided with each report. The monthly profiles show 15 minute, time-series data for the following measured variables:

- PV system AC input (during battery charging) and AC output (during PV array operation and/or battery discharge)
- Global horizontal and direct normal solar radiation
- PV array DC output
- Building load

Monthly profiles provide a quick overview of PV system operation, solar resource availability and building operation over the reporting period.

Building Load Characteristics

Four graphs are provided to indicate the response of the building to temperature and solar radiation. A fifth graph is provided to show the building's load-duration characteristics. These are explained below:

- ***Weekday Building Load vs. Temperature***: This graph plots the sensitivity of the building's load to outside air temperature using 15-minute data. Electrical loads tend to increase during seasonal extremes. In hot weather, air conditioning runs more frequently, resulting in higher electrical demand. Likewise, during periods of very cold weather, equipment used in the operation of heating systems (fans, pumps, etc.) also run more frequently. In buildings that use electric heating systems, such as heat pumps, demand can be significantly higher during the winter than in the summer. Peak summer loads tend to occur in the early to late afternoon when temperatures are highest. Peak winter loads tend to occur during the early morning and early evening when high heating and lighting loads coincide. For most commercial and industrial buildings, loads also tend to be higher during weekdays when occupancy and usage levels are higher.

- ***Weekday Building Load vs. Global Horizontal Irradiance***: This graph plots the sensitivity of the building's load to global horizontal irradiance using 15-minute data. During the summer months, building loads tend to be higher during periods of high irradiance. This is

because high summer temperatures are partially correlated to high sunlight levels. In climates where haze and humidity accompany hot weather, solar radiation levels may actually be somewhat lower than cool, clear days when solar radiation approach ideal maximums. A strong positive correlation between building load and global horizontal irradiance indicates that the output of a PV array is also strongly correlated with building load, and can therefore provide relatively reliable demand reduction. In these cases, the benefit of battery energy storage is lower. It is much more common to have moderate or poor correlation. In these cases, battery energy storage provides higher benefits by assuring reliable peak shaving.

- ***Building Daily Peak Load vs. Daily Average Temperature***: This graph is similar to the graph of Weekday Building Load versus Temperature. However, data used in this graph are derived from the raw 15-minute data. The data is processed to calculate average daily temperatures and to find corresponding peak building loads. Peak building loads are likely to be higher on days when the average daily temperatures approach seasonal extremes.

- ***Building Daily Peak Load vs. Daily Global Horizontal Irradiance***: This graph is similar to the graph of Weekday Building Load versus Global Horizontal Irradiance. Like the graph above, the data used to generate this graph are derived from the raw 15-minute data. Global horizontal irradiance is summed for an entire day to determine the total availability of solar energy and plotted against the corresponding daily peak load. A positive correlation indicates that peak loads occur on days when the availability of solar energy is high. This graph should be interpreted in conjunction with the graph of Weekday Building Load versus Global Horizontal Irradiance. It is possible to have poor correlation between building load and 15 minute readings of solar radiation while having good correlation between daily peak load and total daily solar radiation. This implies that the building's peak load is not instantaneously coincident with solar radiation, i.e., peak loads occur either before or after the solar resource peaks. A good positive correlation in this graph indicates that battery energy storage is of high value in managing the energy output of the PV array, because it allows peak shaving independent of PV array output.

- ***Building Load-Duration Curve***: The final graph related to building loads is a Load Duration Curve. The load duration curve depicts 15 minute building load intervals in order of highest to lowest for the monitoring period. The graph included in this report shows only the highest 400 15 minute intervals. Load-duration curves are typically used to show the relationship between peak and base building loads. Buildings with sharp "spikes" at the left of the curve are usually good candidates for peak shaving, especially if demand charges are a significant portion of the overall electric bill.

Dispatchable PV System Performance

Six graphs are used to show overall PV system performance and to provide diagnostic information during the monitoring period. These are explained below:

- *Inverter Efficiency vs. DC Input*: A three-phase, solid state inverter is used to convert the DC output of the PV array and battery string to AC power compatible with the building's electric power system. Like all conversion devices, losses are inherent in its operation. For the 32 kVA inverter installed in the PV-31 battery/inverter modules, efficiency is nearly flat at 90% for DC input levels above approximately 4 kW. For DC inputs between approximately 1 and 4 kW, efficiency increases rapidly from nearly 0 to about 90%. Below approximately 1 kW, conversion losses and parasitic loads usually prevent generation of significant AC power.

- *DC Conversion Efficiency vs. Plane of Array Insolation*: In order to monitor PV array performance, a graph of sunlight to DC power conversion efficiency is plotted. For the polycrystalline silicon PV modules used in the dispatchable PV systems, sunlight conversion efficiencies are typically between 10 and 12%. Conversion efficiency between 100 and 200 Watts/m^2 varies in a nearly linear fashion from approximately 6 to 12%. Efficiency peaks at 10 to 12% between about 200 and 700 Watts/m^2. Above 700 Watts/m^2, temperature effects tend to reduce efficiency somewhat.

- *Temperature Corrected DC Output vs. Plane of Array Insolation*: A second graph of PV array performance shows the PV array output in kW versus insolation. For each data point a temperature correction factor is applied since PV output varies inversely with solar cell temperature. The corrected performance reflects PV array output at Standard Test Conditions, i.e., a cell temperature of 25°C. Performance curves should be nearly identical from month to month when plotted in this way. At 1,000 Watts/m^2, the temperature corrected output should be within several percentage points of the PV array rating at STC.

- *Daily PV Array Output*: A vertical bar chart shows the daily PV array output in DC kWh. This chart provides a quick summary of PV array operation, and an approximate indication of the amount of energy generated by the system.

- *PV Array Performance*: A second vertical bar chart presents PV array performance as a percentage of theoretical output at 10% conversion efficiency. Values will typically vary between 80 and 110%, depending on site conditions and daily insolation. Values that are significantly lower indicate that the array may have been out of service for at least a portion of the day.

- *Daily Plane of Array Insolation*: A third vertical bar chart shows the total amount of solar energy available to the array for each day. This chart, in combination with the other bar charts, is used to quickly identify outages and other array problems.

Tabular Summary

There are two tabular summaries included in the monthly reports:

The first tabular summary of daily performance provides more detailed information about system performance and solar resource availability. The last column in the tabular summary also indicates the amount of time, in seconds, that the PV-31 unit was dispatched during the day.

The second tabular summary is a dispatch event log. The log provides detailed information for each period when the unit is called to automatically dispatch including: start and stop intervals; the amount of time (in seconds) that the unit was required to dispatch; the amount of energy required for peak shaving during the interval; and the contributions from storage and the PV array. The amount of energy storage shortfall (if any) is also recorded, along with the cumulative amount of energy drawn from storage during a daily period. Energy storage shortfalls indicate that the duration of the peak period was too long for the available storage. The daily cumulative amount of energy drawn from storage indicates the depth of discharge. On a daily basis, the total amount of energy that can be provided from storage will range from approximately 20 to 30 kWh, depending on the amount of solar energy available and the dispatch output level.

INTEK Dispatchable PV Peak Shaving System
Monthly Performance Summary
August 1997

Overall PV System Operation

The dispatchable PV system operated continuously from the beginning of August through the morning of August 28th when the unit was taken out of service during the Labor Day weekend. Throughout the period, the unit was automatically dispatched to help shave building peak loads.

A new rotating shadow band pyranometer (RSB) was ordered by Ascension Technology and should be to the site in late September to replace the defective RSB.

Building Load Characteristics

Plant operations during August were more consistent in August than in July, as characterized by long, continuous periods of high, flat electrical demand. Weekday loads were frequently higher than 800 kW, with average loads of 750 to 800 kW. Loads during weekends were usually less than 400 kW. As in July, a positive correlation between building load and ambient temperature can be seen in the 15-minute load data, and, also like previous months, there is no correlation between global horizontal irradiance and load. Peak 15-minute electrical demand during the monitoring period was 834 kW, approximately 60 kW less than the July peak load.

Although the peak loads and temperatures in August were less than in July, overall energy consumption increased. This indicates that the plant's load factor is higher, probably due to increased equipment utilization.

Dispatchable PV System Performance

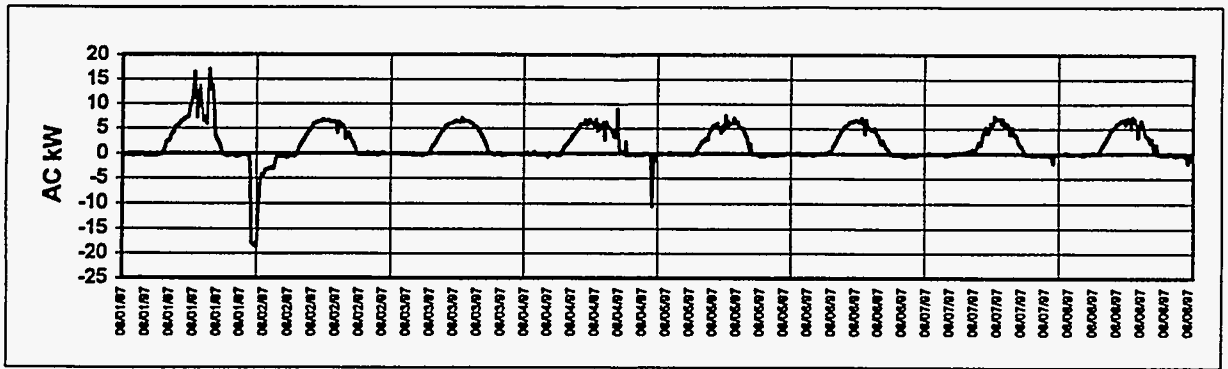
Equipment performance during the period was normal, as shown on the graphs of inverter efficiency, DC conversion efficiency and temperature corrected DC array output.

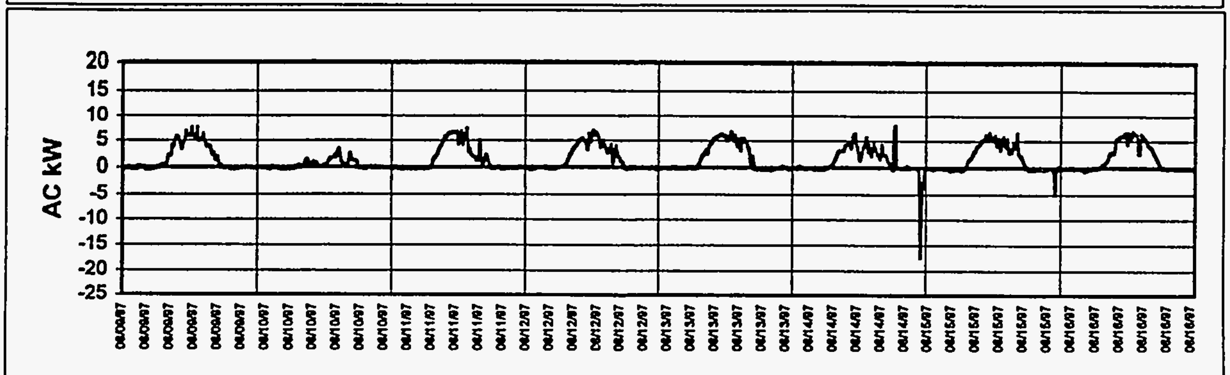
The system dispatched automatically 37 times on 14 separate days. The output level during dispatch is 20 kW. The dispatch durations ranged from less than one minute to nearly 4 ½ hours. On August 1st, the building set its peak demand for the month, although it was not the hottest day of the period. The longest peak period on August 1st occurred from 4:30 PM to 9:00 PM. The unit did not have sufficient storage to meet the need for peak shaving throughout the period, resulting in a storage shortfall of approximately 59 kWh. An analysis of the collected data indicated that sufficient storage would have been available if the building load dispatch set point had been set at 830 kW, or if the dispatch level had been set between 10 and 15 kW. A large shortfall shown in the Dispatch Event Log at the end of the month was caused by the system being shut down for the Labor Day holiday. Building loads following the shut down were high enough to have required peak shaving for approximately two hours.

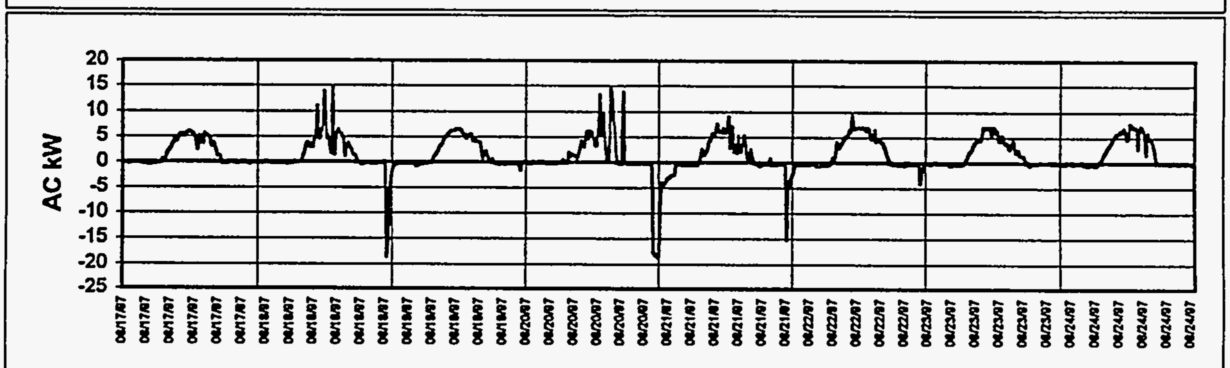
Because higher load factors and overall electricity consumption were observed in August, the unit will be set to dispatch at 830 kW to reduce deep cycling of the batteries. The output during dispatch will remain at 20 kW.

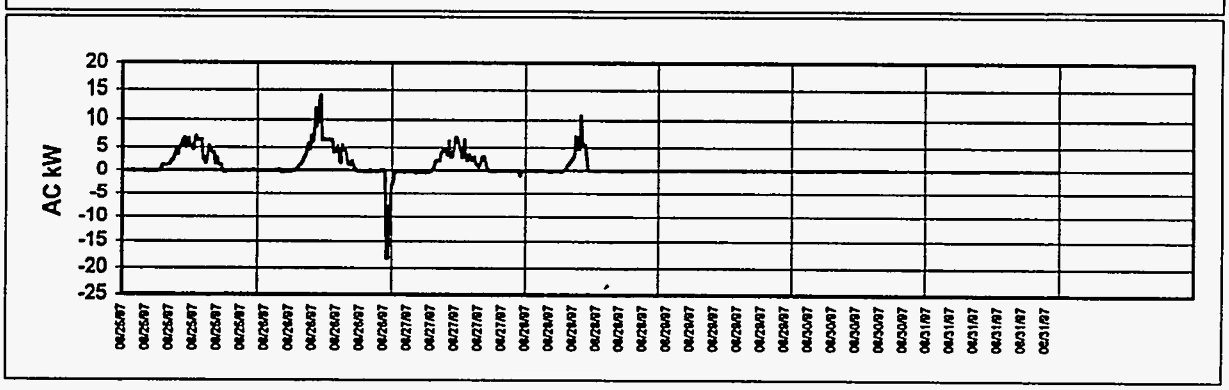
INTEK Dispatchable PV Peak Shaving System
AC Output and Charging Profiles

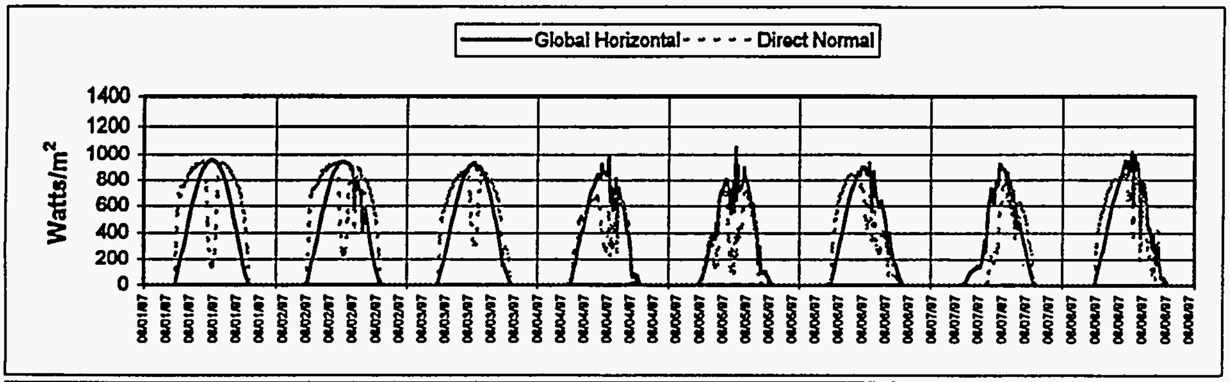
Aug-97

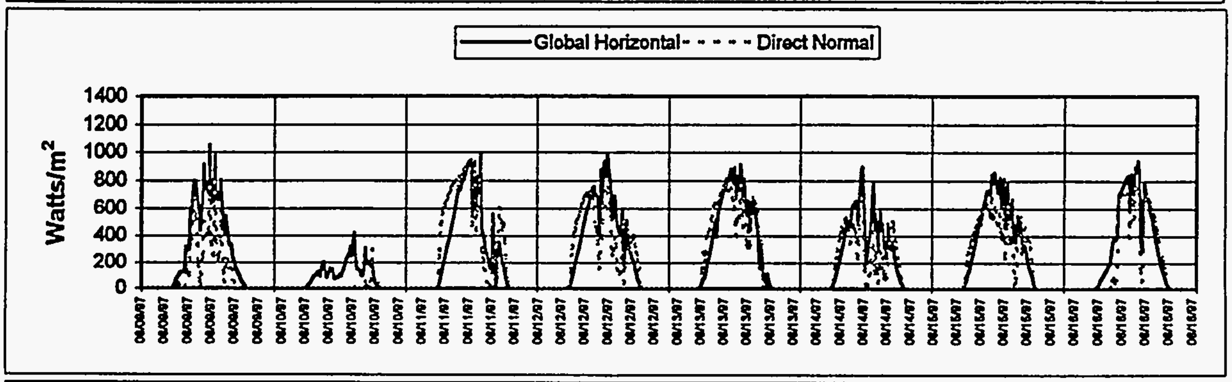


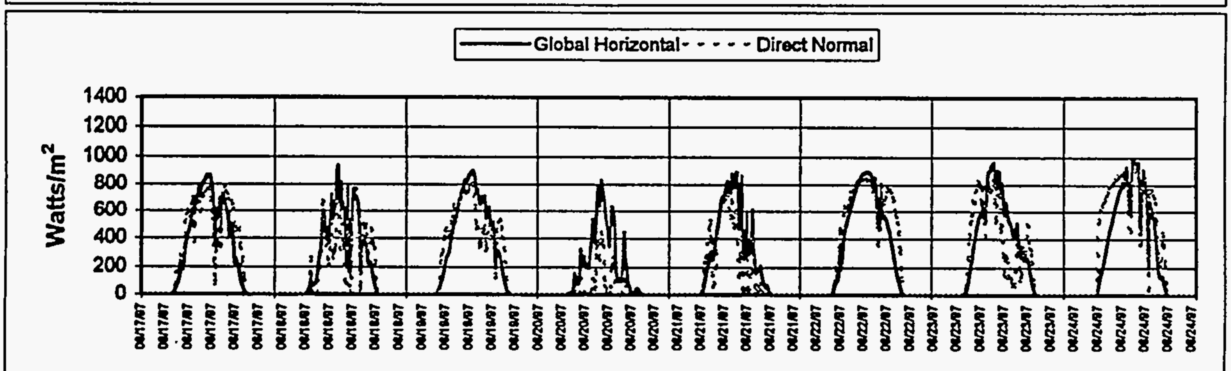


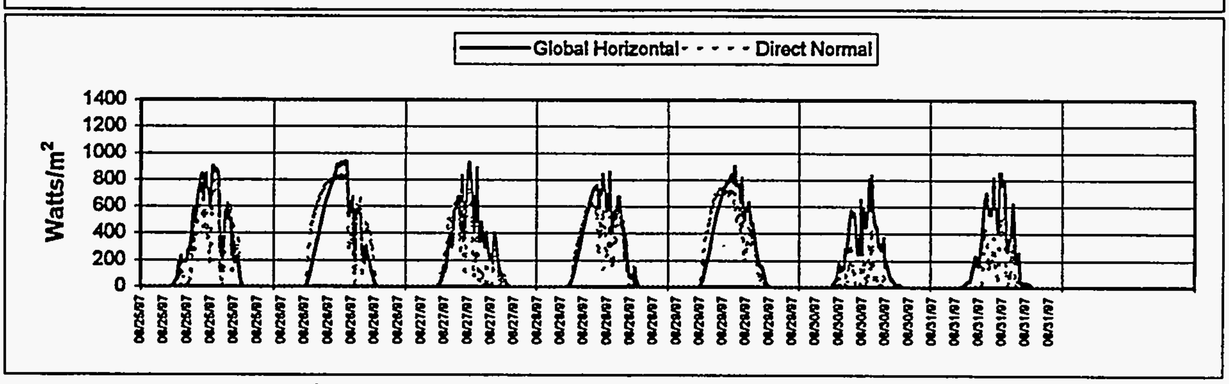





Global Horizontal - - - - Direct Normal
Watts/m2
1400
1200
1000
800
600
400
200
0

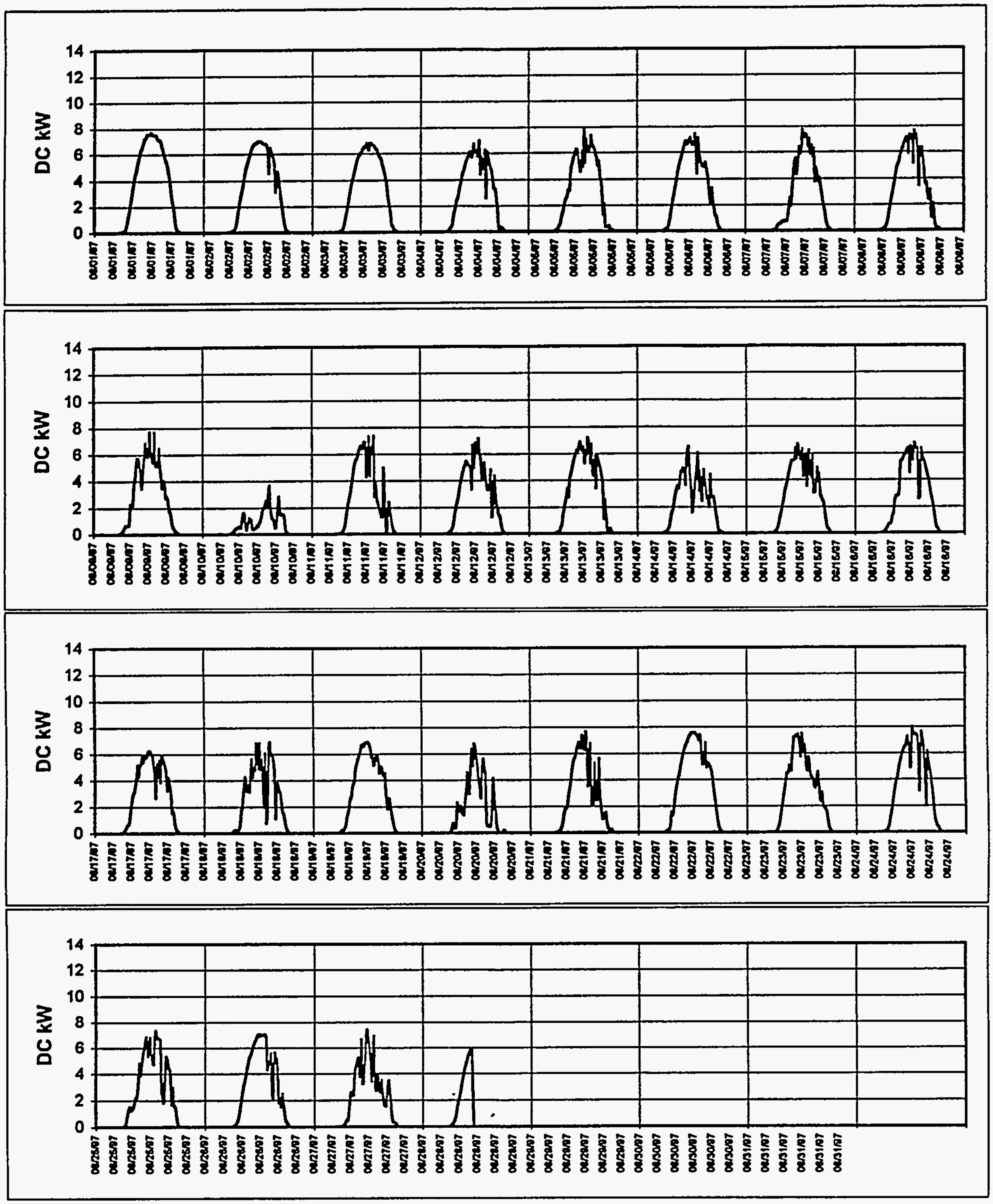

Global Horizontal - - - - Direct Normal
Watts/m2
1400
1200
1000
800
600
400
200
0


Global Horizontal - - - - Direct Normal
Watts/m2
1400
1200
1000
800
600
400
200
0


Global Horizontal - - - - Direct Normal
Watts/m2
1400
1200
1000
800
600
400
200
0

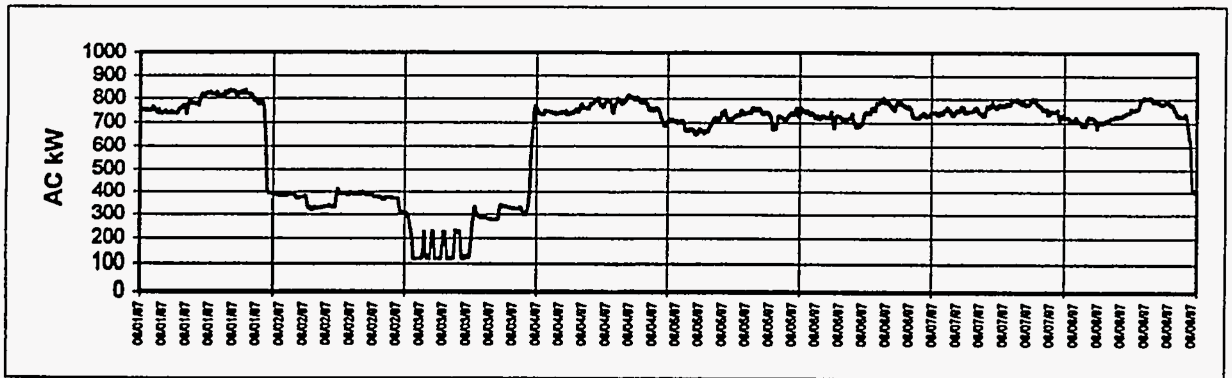
INTEK Dispatchable PV Peak Shaving System
DC Output Profile

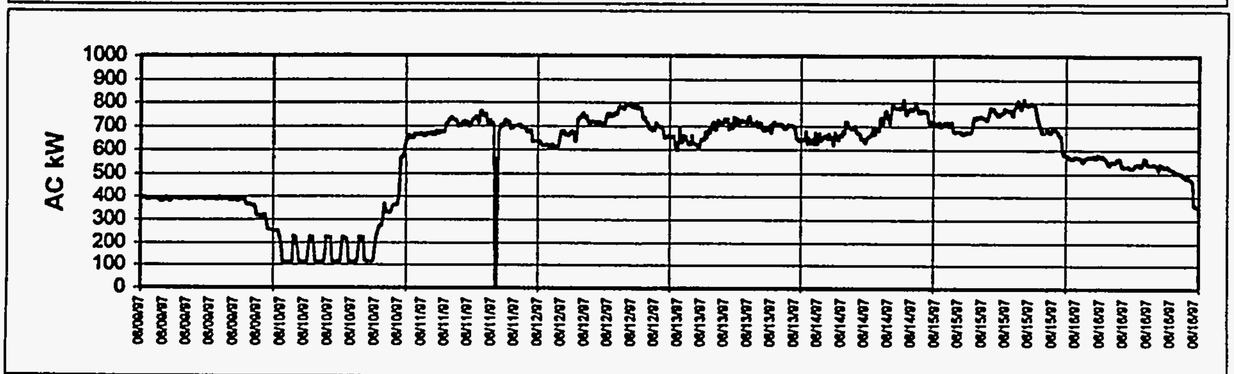
Aug-97

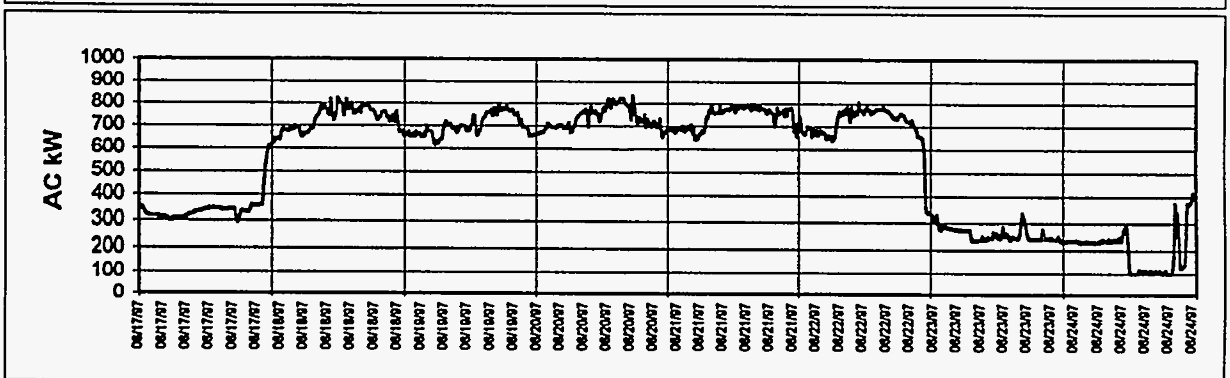


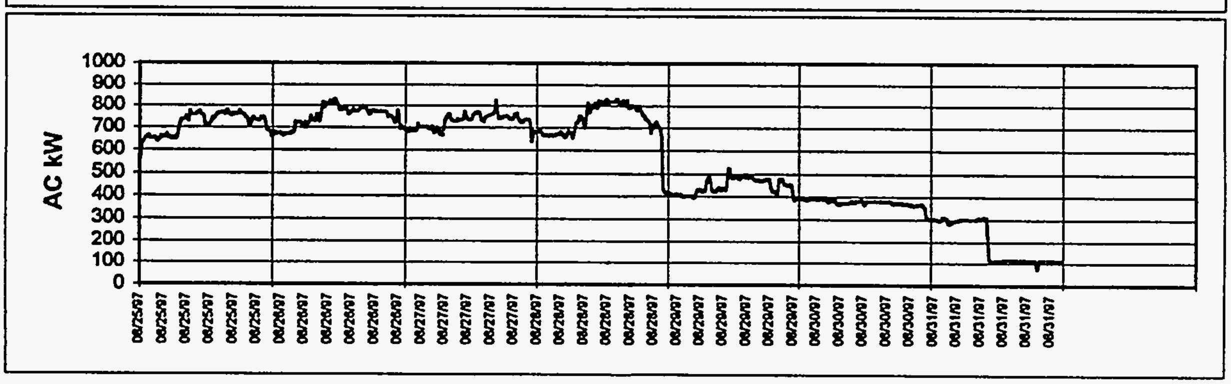
INTEK Dispatchable PV Peak Shaving System
Building Load Profiles

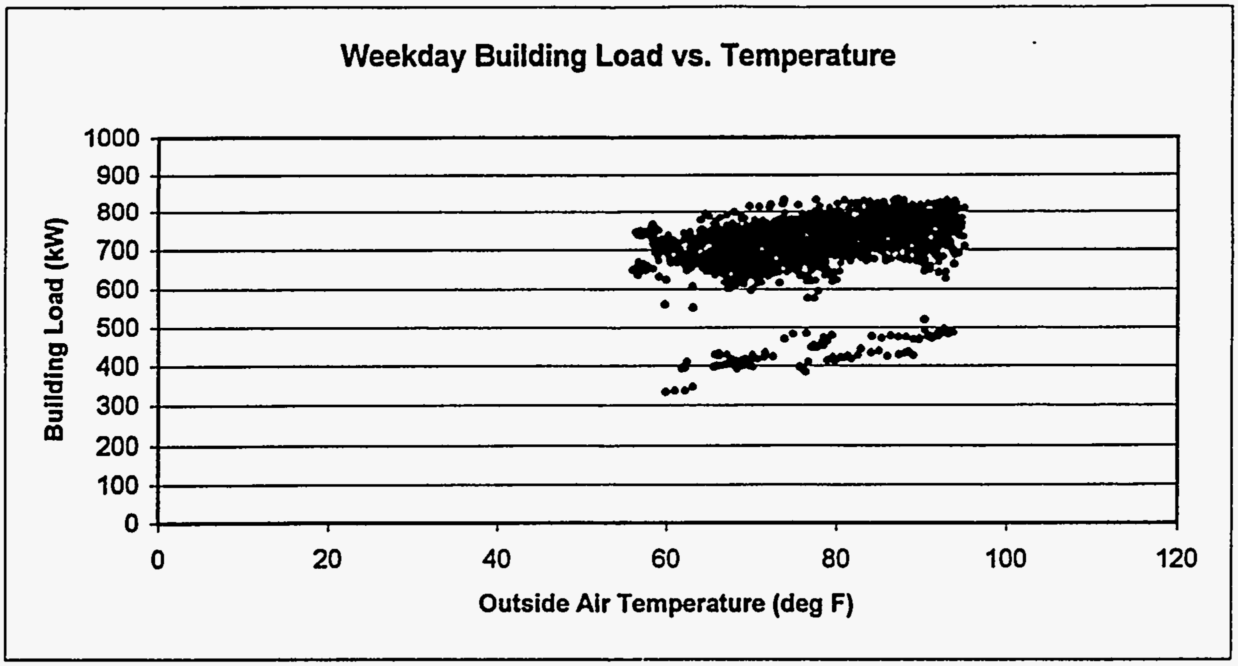
Aug-97

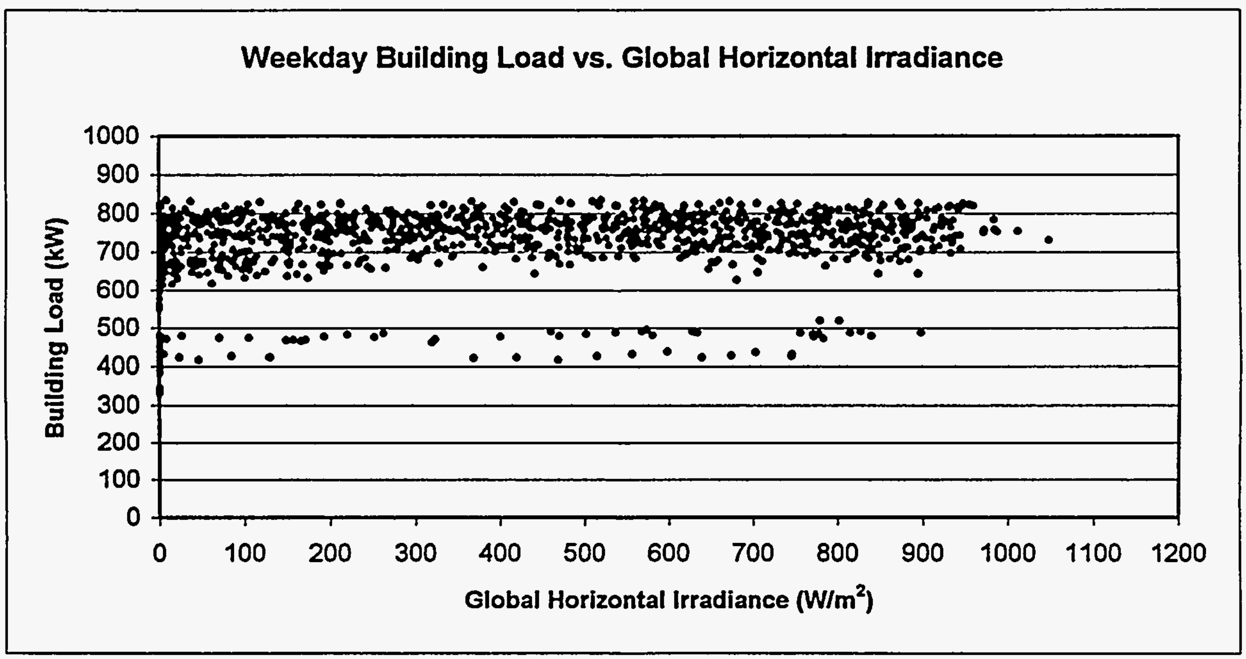


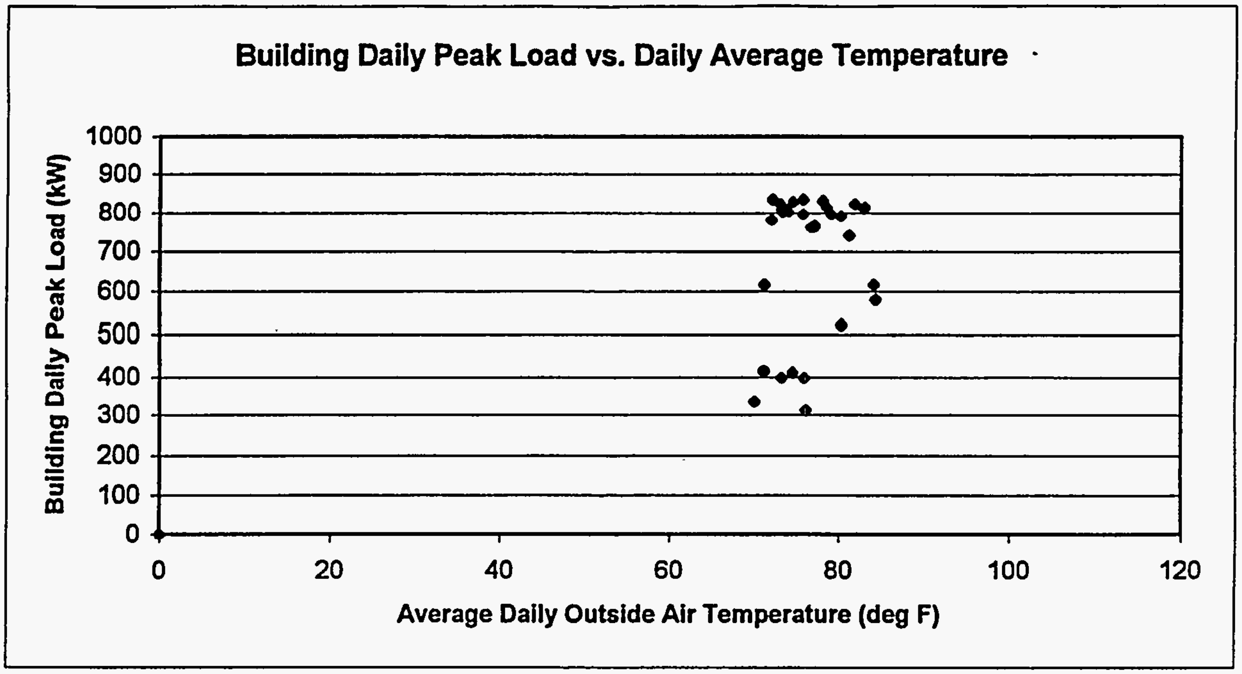


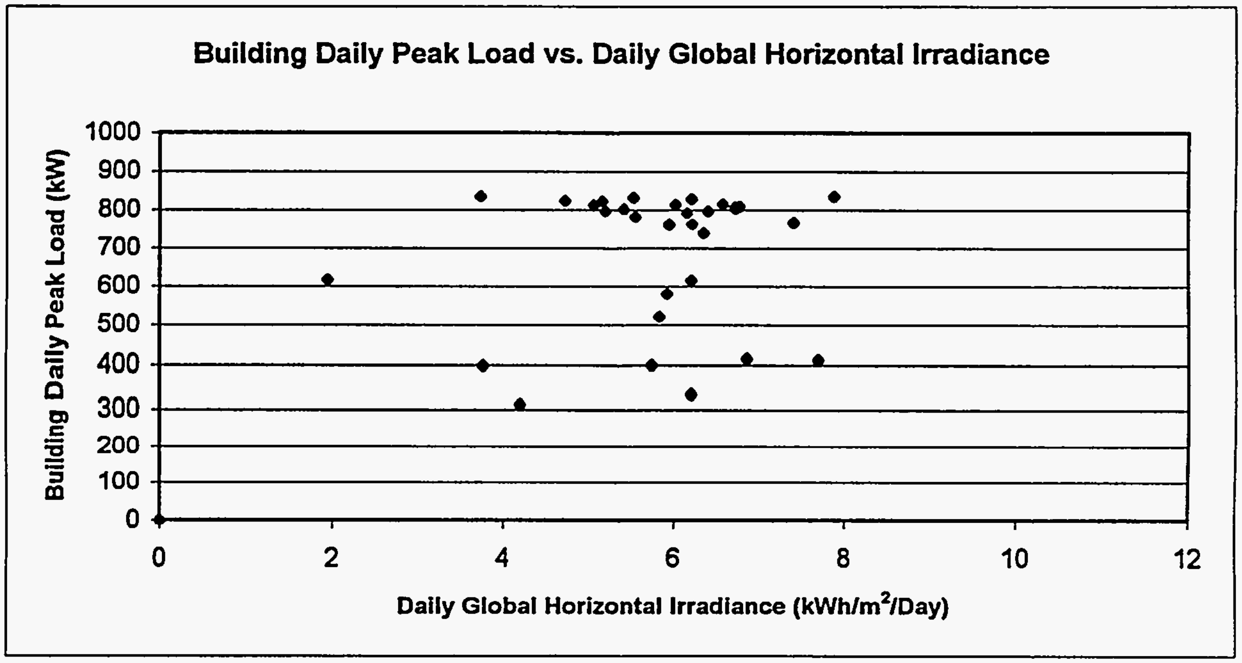


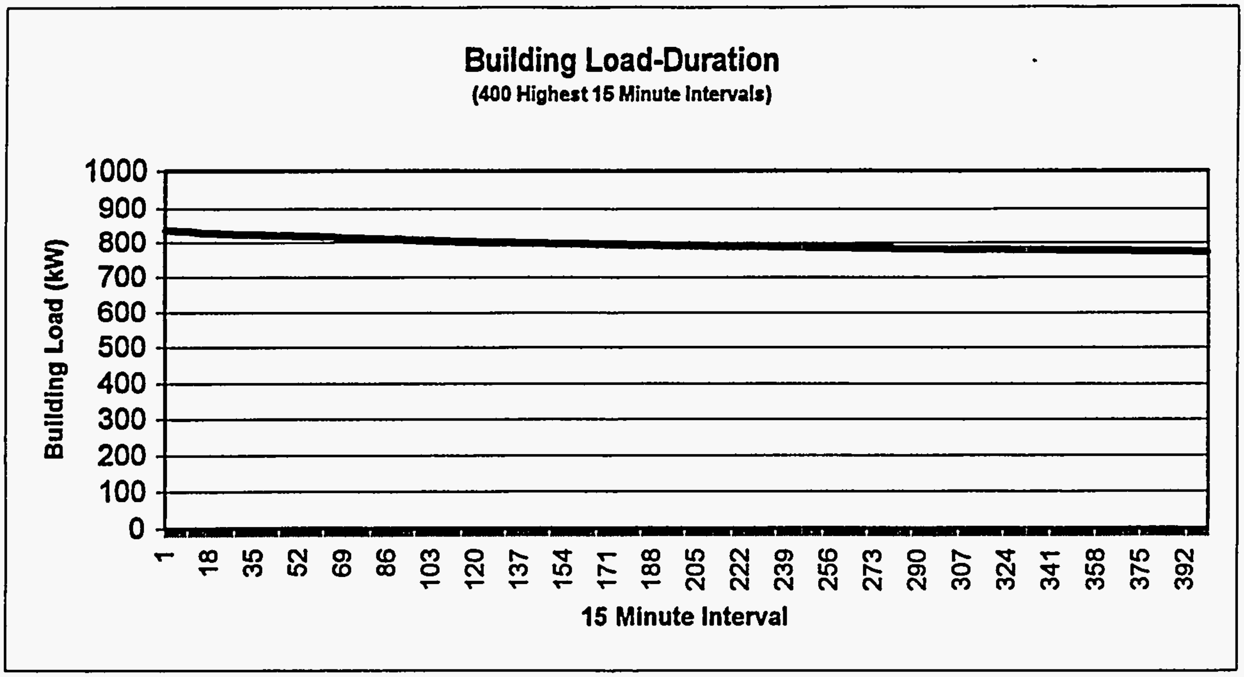


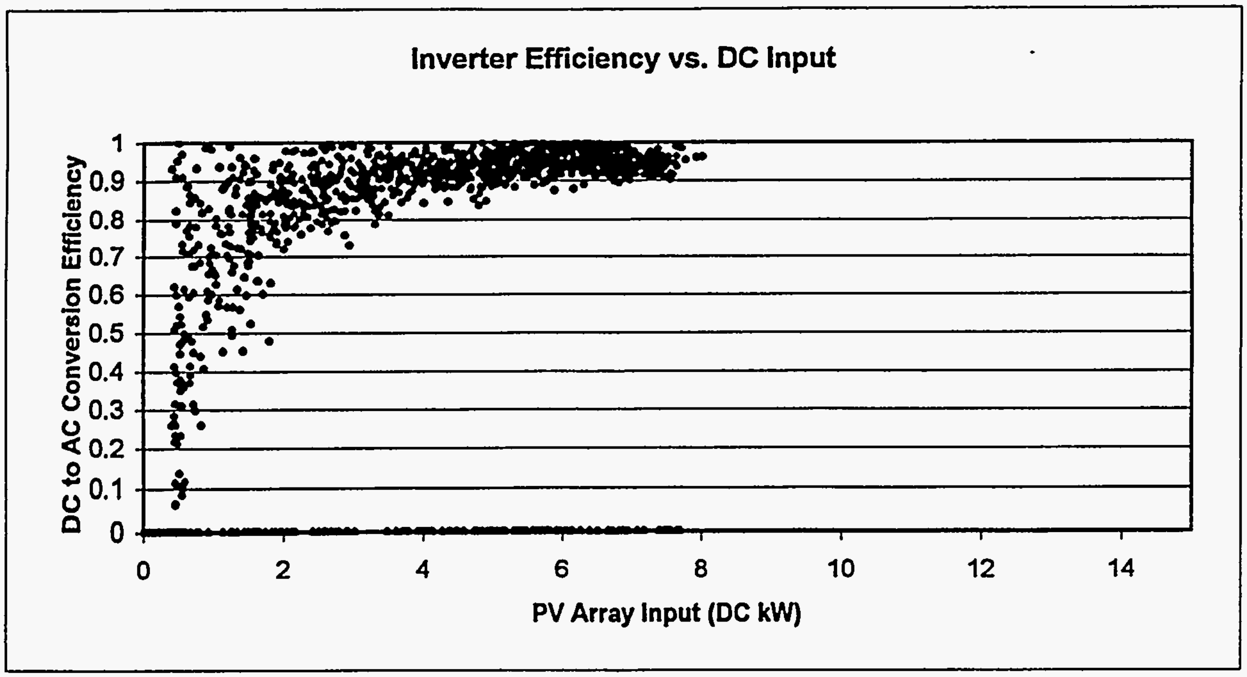

Weekday Building Load vs. Temperature
Building Load (kW)
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
Outside Air Temperature (deg F)

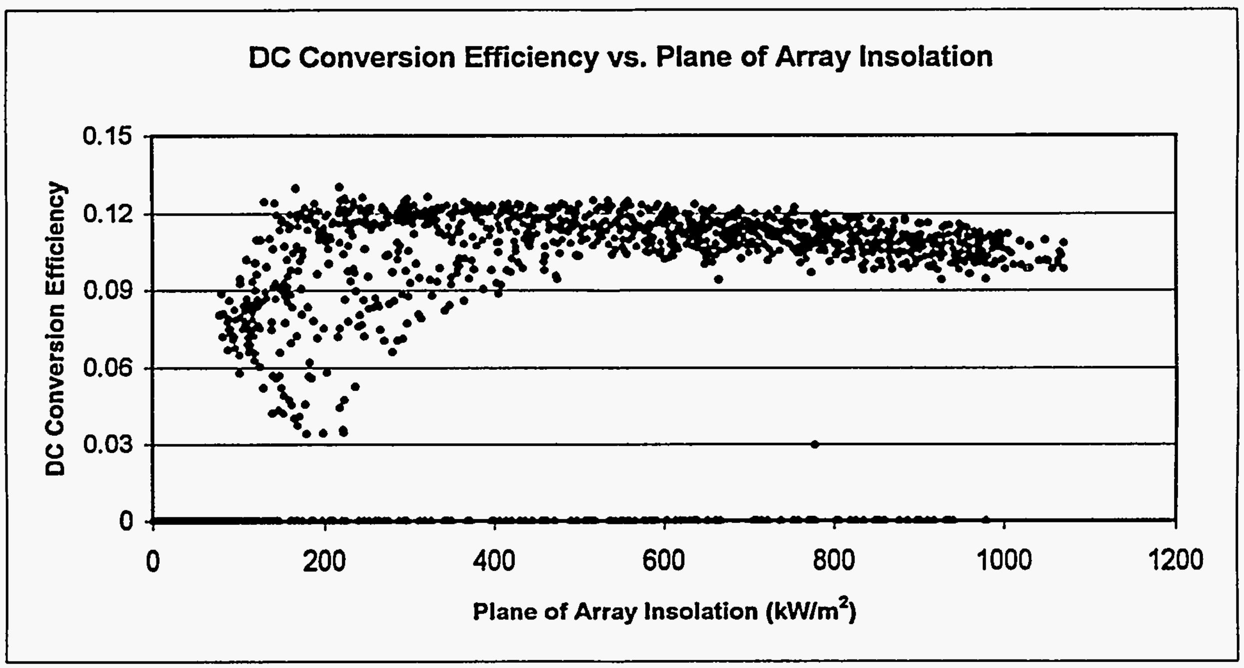

Weekday Building Load vs. Global Horizontal Irradiance
Building Load (kW)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Global Horizontal Irradiance (W/m²)

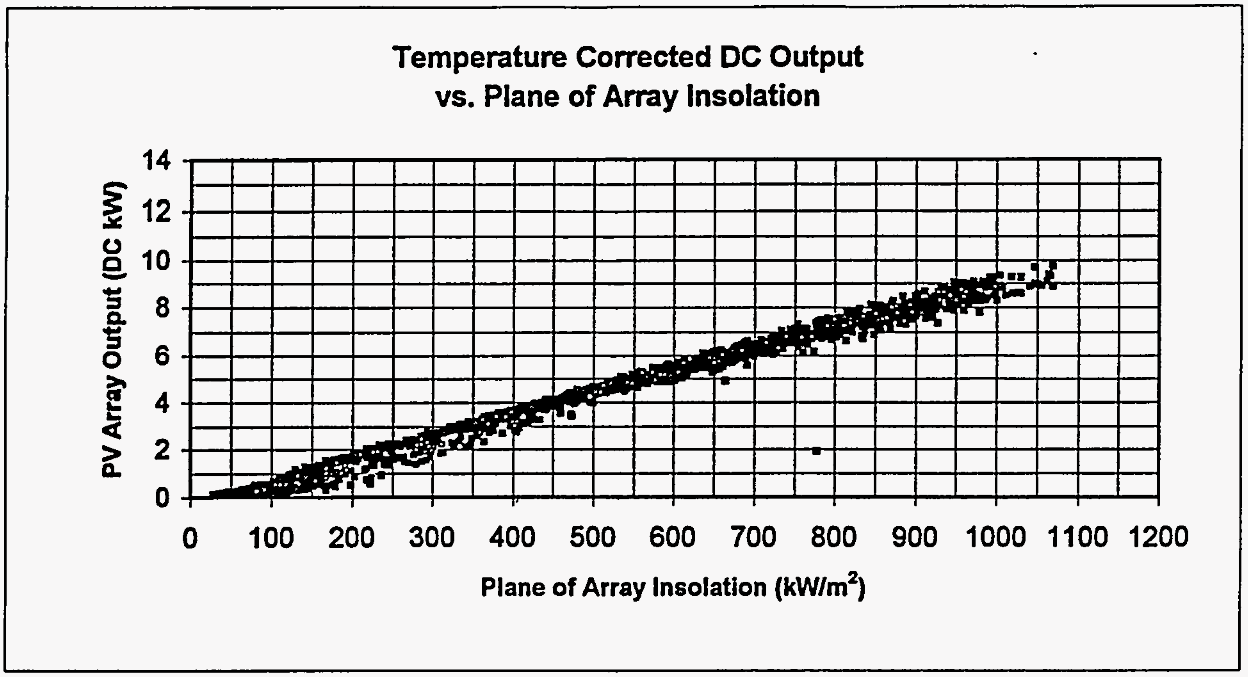

Building Daily Peak Load vs. Daily Average Temperature
Building Daily Peak Load (kW)
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
Average Daily Outside Air Temperature (deg F)

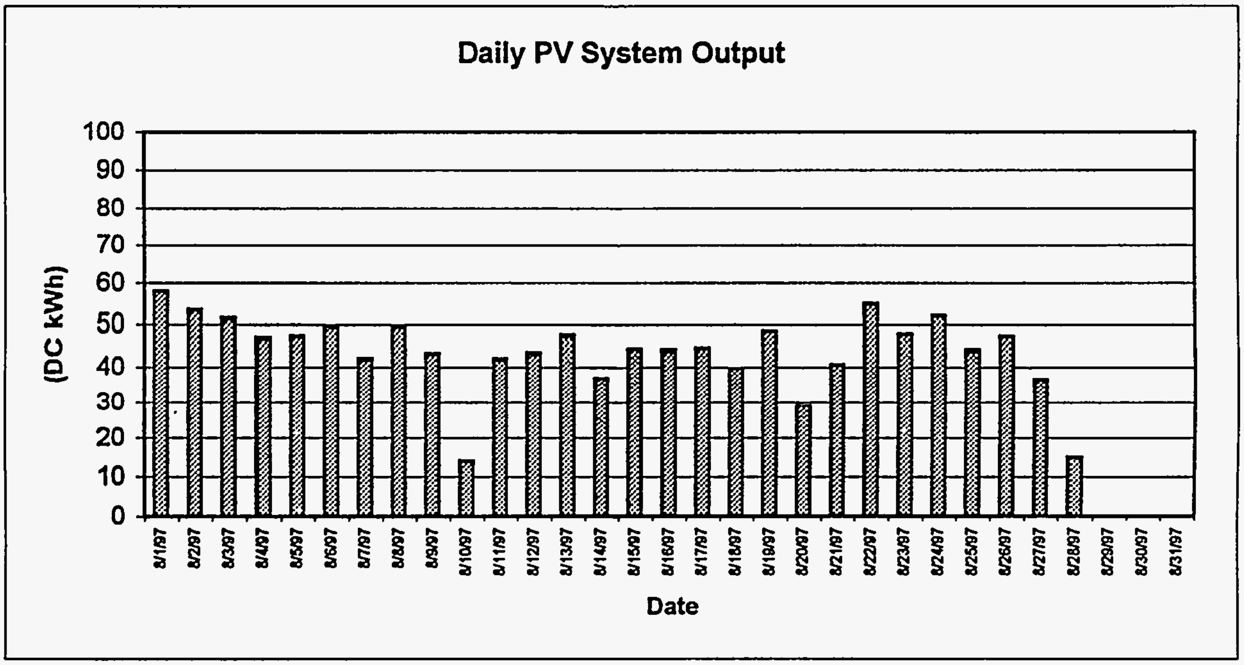

Building Daily Peak Load vs. Daily Global Horizontal Irradiance
Building Daily Peak Load (kW)
1000
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Daily Global Horizontal Irradiance (kWh/m²/Day)

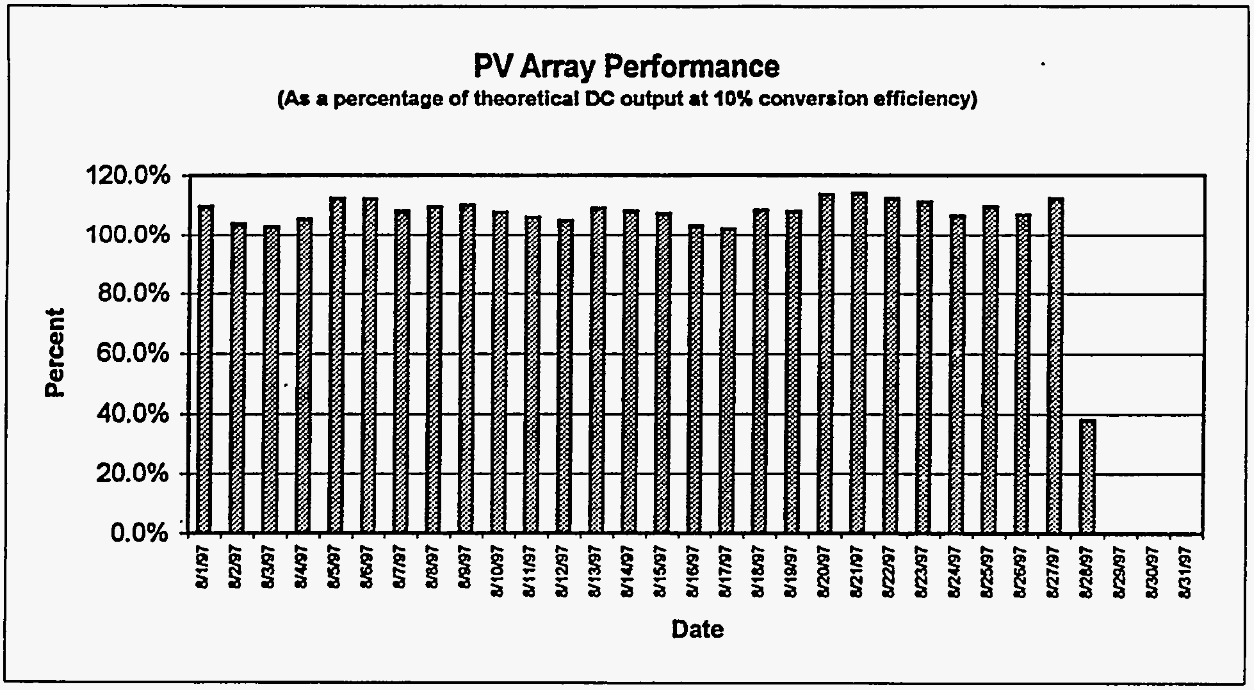

Building Load-Duration
(400 Highest 15 Minute Intervals)
Building Load (kW)
1000
900
800
700
600
500
400
300
200
100
0
1
18
35
52
69
86
103
120
137
154
171
188
205
222
239
256
273
290
307
324
341
358
375
392
15 Minute Interval

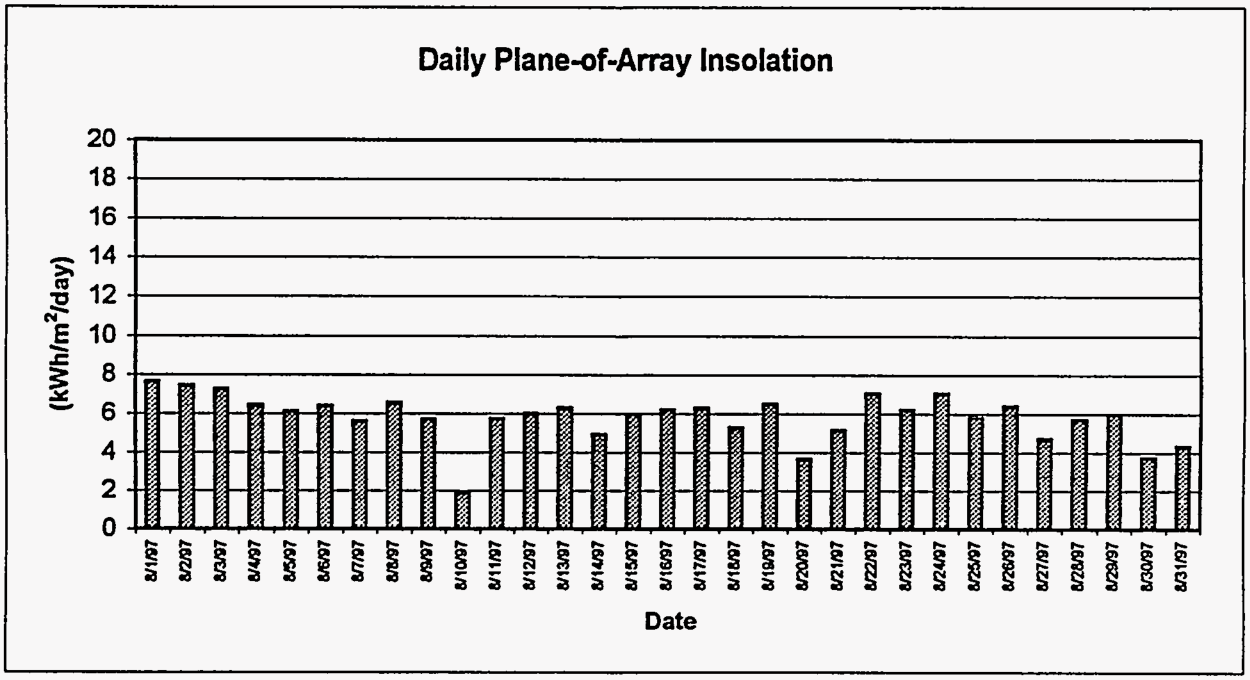

Inverter Efficiency vs. DC Input
DC to AC Conversion Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
PV Array Input (DC kW)


DC Conversion Efficiency vs. Plane of Array Insolation
DC Conversion Efficiency
0.15
0.12
0.09
0.06
0.03
0
0
200
400
600
800
1000
1200
Plane of Array Insolation (kW/m2)


Temperature Corrected DC Output
vs. Plane of Array Insolation
PV Array Output (DC kW)
0
2
4
6
8
10
12
14
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Plane of Array Insolation (kW/m2)


Daily PV System Output
(DC kWh)
0
10
20
30
40
50
60
70
80
90
100
8/1/97 8/2/97 8/3/97 8/4/97 8/5/97 8/6/97 8/7/97 8/8/97 8/9/97 8/10/97 8/11/97 8/12/97 8/13/97 8/14/97 8/15/97 8/16/97 8/17/97 8/18/97 8/19/97 8/20/97 8/21/97 8/22/97 8/23/97 8/24/97 8/25/97 8/26/97 8/27/97 8/28/97 8/29/97 8/30/97 8/31/97
Date


PV Array Performance
(As a percentage of theoretical DC output at 10% conversion efficiency)
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Percent
8/1/97
8/2/97
8/3/97
8/4/97
8/5/97
8/6/97
8/7/97
8/8/97
8/9/97
8/10/97
8/11/97
8/12/97
8/13/97
8/14/97
8/15/97
8/16/97
8/17/97
8/18/97
8/19/97
8/20/97
8/21/97
8/22/97
8/23/97
8/24/97
8/25/97
8/26/97
8/27/97
8/28/97
8/29/97
8/30/97
8/31/97
Date


Daily Plane-of-Array Insolation
20
18
16
14
12
10
8
6
4
2
0
(kWh/m2/day)
8/1/97
8/2/97
8/3/97
8/4/97
8/5/97
8/6/97
8/7/97
8/8/97
8/9/97
8/10/97
8/11/97
8/12/97
8/13/97
8/14/97
8/15/97
8/16/97
8/17/97
8/18/97
8/19/97
8/20/97
8/21/97
8/22/97
8/23/97
8/24/97
8/25/97
8/26/97
8/27/97
8/28/97
8/29/97
8/30/97
8/31/97
Date

INTEK Dispatchable PV Peak Shaving System
Monthly Summary Data
Aug-97

Date	Julian Day	Global Horizontal (kWh/m2/day)	Direct Normal (kWh/m2/day)	Diffuse Horizontal (kWh/m2/day)	Plane of Array (kWh/m2/day)	Average Daily Temperature (Deg F)	Total System Output (AC kWh/day)	Total System Input (kWh/m2/day)	PV Array Output (DC kWh/day)	Average Inverter Efficiency	Average PV Array Conversion Efficiency	Peak Building Load (kW)	Daily Building Electricity Consumption (kWh/day)	System Dispatch Time (seconds)	% of Nominal Theoretical Output
8/1/97	213	7.88	9.49	1.88	7.66	72.18	74.26	-21.80	58.05	0.86	0.108	834.92	18423.00	18399	109.7%
8/2/97	214	7.70	9.21	1.84	7.44	74.56	50.11	-20.10	53.45	0.91	0.103	411.66	8868.80	0	103.9%
8/3/97	215	7.41	8.31	1.79	7.26	77.13	50.03	-1.42	51.61	0.94	0.102	766.95	6024.20	0	102.9%
8/4/97	216	6.58	5.24	2.78	6.43	78.52	49.42	-5.49	46.92	0.98	0.106	815.00	18308.00	540	105.5%
8/5/97	217	6.22	4.36	2.92	6.10	77.07	44.14	-2.14	47.35	0.88	0.111	762.98	17127.00	0	112.2%
8/6/97	218	6.73	6.28	2.35	6.41	74.00	46.66	-1.97	49.70	0.90	0.111	803.41	17768.00	0	112.1%
8/7/97	219	5.41	3.86	2.65	5.63	73.36	38.95	-2.33	42.11	0.83	0.103	801.26	18252.00	108	106.2%
8/8/97	220	6.77	6.72	1.98	6.57	73.15	46.55	-2.46	49.69	0.89	0.109	808.00	17382.00	108	109.5%
8/9/97	221	5.74	2.78	3.49	5.71	73.24	42.45	-1.36	43.41	0.92	0.108	399.17	9026.80	0	110.1%
8/10/97	222	1.95	0.17	1.69	1.86	71.24	11.15	-1.51	13.89	0.72	0.106	616.87	4931.90	0	107.6%
8/11/97	223	5.95	6.85	1.40	5.75	76.69	40.56	-1.54	42.15	0.91	0.104	761.69	16315.00	0	106.0%
8/12/97	224	6.15	5.64	2.48	6.00	80.20	39.85	-1.53	43.55	0.86	0.105	792.21	16924.00	0	105.0%
8/13/97	225	6.35	6.15	1.96	6.31	81.19	43.63	-1.94	47.62	0.90	0.109	740.36	16422.00	0	109.2%
8/14/97	226	5.06	3.93	2.60	4.93	82.95	36.97	-7.55	36.87	0.87	0.109	811.94	16839.00	702	106.2%
8/15/97	227	6.02	5.28	2.46	5.99	82.98	41.66	-3.67	44.47	0.88	0.106	814.36	17381.00	213	107.5%
8/16/97	228	5.92	4.88	2.23	6.19	84.24	42.75	-1.58	44.13	0.93	0.102	580.90	12763.00	0	103.1%
8/17/97	229	6.21	6.34	1.90	6.32	84.02	41.33	-1.90	44.57	0.90	0.102	615.84	8278.70	0	102.0%
8/18/97	230	5.16	4.27	2.29	5.29	81.89	43.67	-11.93	39.70	0.90	0.108	822.76	17560.00	1890	106.5%
8/19/97	231	6.40	6.27	2.19	6.49	79.04	43.55	-4.24	48.42	0.85	0.108	797.43	16838.00	54	107.9%
8/20/97	232	3.74	0.98	2.92	3.69	75.76	44.04	-20.60	28.94	0.80	0.110	834.63	17640.00	4326	113.5%
8/21/97	233	5.20	3.66	2.55	5.17	75.77	39.80	-25.41	40.71	0.81	0.113	797.17	17795.00	1083	113.9%
8/22/97	234	6.72	7.89	1.38	7.08	73.84	50.35	-6.50	54.93	0.85	0.110	806.16	16986.00	324	112.3%
8/23/97	235	6.21	5.62	2.61	6.21	70.06	44.11	-2.15	47.79	0.89	0.109	333.80	6233.40	0	111.3%
8/24/97	236	6.86	8.38	1.42	7.05	71.13	48.62	-1.77	52.03	0.88	0.104	414.26	4861.30	0	106.7%
8/25/97	237	5.55	4.15	2.54	5.83	72.05	42.30	-1.32	44.15	0.92	0.110	782.18	17192.00	0	109.6%
8/26/97	238	6.21	6.86	1.67	6.40	74.51	52.11	-14.23	47.27	0.84	0.107	828.29	17975.00	2700	106.9%
8/27/97	239	4.73	3.10	2.66	4.72	73.09	31.92	-4.64	36.64	0.80	0.112	823.13	17461.00	54	112.2%
8/28/97	240	5.52	4.38	2.53	5.71	78.09	16.88	-1.01	15.00	0.78	0.107	831.99	17545.00	15336	38.0%
8/29/97	241	5.83	5.40	2.13	5.99	80.25	0.16	-0.39	0.00	0.00	0.000	520.00	10666.00	0	0.0%
8/30/97	242	3.76	0.60	3.14	3.74	75.88	0.16	-0.35	0.00	0.00	0.000	397.61	9009.60	0	0.0%
8/31/97	243	4.20	1.63	2.88	4.35	76.09	0.16	-0.33	0.00	0.00	0.000	310.40	4633.60	0	0.0%
Monthly Total		180.16	158.88	71.51	180.29		1198.29	-175.14	1215.13			834.92	433430.50	45837.00	
Monthly Average		5.81	5.13	2.31	5.82	76.59	38.65	-5.65	39.20			691.53	13981.63		

INTEK Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-97

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
213	1200	213	1330	1998	18.64	12.30	11.10	3.90	7.20	0.00	7.20
213	1345	213	1430	1134	10.46	6.71	6.30	2.11	4.19	0.00	11.39
213	1500	213	1515	108	3.32	2.96	0.60	0.18	0.42	0.00	11.81
213	1530	213	2100	15159	18.41	9.47	84.22	7.08	11.33	58.73	23.14
216	1115	216	1130	54	3.07	2.74	0.30	0.09	0.21	0.00	0.21
216	1700	216	1715	378	2.69	1.06	2.10	0.26	1.84	0.00	2.06
216	1830	216	1845	108	0.48	0.08	0.60	0.01	0.47	0.12	2.53
219	1600	219	1615	108	2.20	1.87	0.60	0.12	0.48	0.00	0.48
220	1445	220	1500	108	3.12	2.81	0.60	0.16	0.44	0.00	0.44
226	1830	226	1900	702	3.66	0.05	3.90	0.02	3.64	0.23	3.64
227	1630	227	1645	213	2.24	1.33	1.18	0.16	1.02	0.00	1.02
230	1045	230	1100	432	3.95	2.12	2.40	0.46	1.94	0.00	1.94
230	1200	230	1230	756	6.65	3.82	4.20	1.03	3.17	0.00	5.11
230	1330	230	1400	702	4.46	2.03	3.90	1.03	2.87	0.00	7.98
231	1815	231	1830	54	0.09	0.07	0.30	0.00	0.09	0.20	0.09
232	1315	232	1345	810	6.36	2.98	4.50	0.82	3.68	0.00	3.68
232	1400	232	1445	648	5.10	2.48	3.60	0.56	3.04	0.00	6.72
232	1515	232	1630	1944	11.23	2.55	10.80	0.96	9.84	0.00	16.57
232	1745	232	1815	924	3.44	0.05	5.13	0.00	3.44	1.69	20.01
233	800	233	815	54	1.00	0.87	0.30	0.03	0.27	0.00	0.27
233	915	233	930	54	2.17	2.07	0.30	0.06	0.24	0.00	0.52
233	945	233	1000	54	2.71	2.58	0.30	0.08	0.22	0.00	0.74
233	1030	233	1100	162	5.10	4.60	0.90	0.27	0.63	0.00	1.37
233	1245	233	1300	162	2.95	2.46	0.90	0.30	0.60	0.00	1.97
233	1315	233	1345	162	4.02	3.44	0.90	0.25	0.65	0.00	2.62
233	1400	233	1415	108	1.36	1.03	0.60	0.06	0.54	0.00	3.16
233	1445	233	1500	54	1.27	1.15	0.30	0.03	0.27	0.00	3.43
233	1545	233	1600	108	1.40	1.03	0.60	0.07	0.53	0.00	3.96
233	1645	233	1700	108	0.94	0.62	0.60	0.03	0.57	0.00	4.52
233	2015	233	2030	57	0.07	0.00	0.32	0.00	0.07	0.24	4.60
234	815	234	830	108	1.73	1.39	0.60	0.07	0.53	0.00	0.53

INTEK Dispatchable PV Peak Shaving System
Dispatch Event Record
Aug-97

Start Day	Start Time	Stop Day	Stop Time	Dispatch Seconds	Measured Output During Period (AC kWh)	Energy from PV Array During Period (AC kWh)	Total Peak Shaving Energy Required (AC kWh)	Energy from PV Array During Dispatch (AC kWh)	Net Energy From Storage (AC kWh)	Storage Shortfall (AC kWh)	Daily Cumulative Energy From Storage (AC kWh)
234	1100	234	1115	216	3.97	3.26	1.20	0.38	0.82	0.00	1.34
238	900	238	930	216	3.88	3.04	1.20	0.23	0.97	0.00	0.97
238	945	238	1145	2484	21.45	13.00	13.80	4.12	9.68	0.00	10.65
239	1645	239	1700	54	1.20	1.13	0.30	0.04	0.26	0.00	0.26
240	915	240	945	378	4.66	3.11	2.10	0.41	1.69	0.00	1.69
240	1015	240	1030	378	3.96	2.57	2.10	0.53	1.57	0.00	3.26
240	1115	240	1715	14580	0.77	0.37	81.00	0.02	0.75	80.20	4.01

Appendix B - CEEP Study

Building Load Analysis of Dispatchable Peak-Shaving Photovoltaic Systems: A Regional Analysis of Technical and Economic Potential

ceep

CENTER FOR ENERGY AND ENVIRONMENTAL POLICY

UNIVERSITY OF DELAWARE
NEWARK, DE 19716-7301

Project Directors:
John Byrne
Young-Doo Wang

Research Associates:
Steven Letendre
Arthur Babbott
Lawrence Agbemabiese

Submitted to:
Ralph Nigro
Applied Energy Group

In partial fulfillment of a subcontract for the
PV:BONUS Phase II Program
U.S. Department of Energy

May, 1996

TABLE OF CONTENTS

I. MAJOR FINDINGS 1

II. PROJECT OVERVIEW 3

III. ANALYSIS AND DATA 5

System Technical Analysis 6
Economic Analysis 7

IV. MAJOR FINDINGS AND RESULTS 9

Regional Analysis of Dispatchable Peak-Shaving PV Systems 10
Building Analysis of Dispatchable Peak-Shaving PV Systems 12
Statistical Analysis 15

V. CONCLUSIONS 16

REFERENCES 17

I. MAJOR FINDINGS

An analysis of dispatchable peak-shaving PV systems was performed for a variety of building types located in different regions across the United States. The analysis was conducted using a spreadsheet model developed by the University of Delaware's Center for Energy and Environmental Policy to perform a discounted cash-flow analysis for customer owned systems (CEEP, 1995). Region-specific building load data (northeast and southwest), region specific climate data, and utility-specific rate data, were used to identify cost-effective applications for dispatchable PV systems. This project is part of a marketing research effort in support of an initiative to develop a commercially viable modular grid-connected dispatchable PV system for the commercial buildings sector. The project is supported by a subcontract to Applied Energy Group under a U.S. Department of Energy PV:BONUS Phase III contract and involves the cooperative participation of the following organizations: Delmarva Power & Light, Applied Energy Group, Center for Energy and Environmental Policy, AC Battery Corporation, Ascension Technology, and Solarex.

The results of the study indicate that large state office buildings and fast food restaurants are particularly well suited for dispatchable peak-shaving PV systems. Office buildings and retail stores were also identified as potential candidates. These building types tend to experience peak demand during the day-light hours, thus only modest amounts of storage are required to shift the PV array's output to match the building's peak demand. Fast-food restaurants experience relatively sharp peaks and large state office buildings have relatively large variations in demand between afternoon hours both of which reduce the number of dispatch hours needed to achieve significant peak-shaving. These factors tend to make the economics of dispatchable peak-shaving

PV systems more attractive than building types with evening peaks and small hourly load variations.

The results of the analysis also indicate that the northeast and northern California appear to offer the greatest opportunity for future cost-effective dispatchable peak-shaving PV installations as system component prices drop. These regions of the country have relatively high electric rates which increases the value of the PV system to customer owners. In addition, North Carolina is a particularly attractive region for dispatchable peak-shaving PV systems, primarily due to the State's 35% renewable energy tax credit.

Table 1 lists the combinations of building types and regions with benefit-cost ratios greater than or equal to 1.00 indicating cost-effectiveness at current PV system prices (excluding storage) of $8.75 per Wp. This table supports the basic conclusions described above. Namely, that dispatchable peak-shaving PV systems are well suited for large state office buildings and fast food restaurants located in the northeast and North Carolina. This represents a near-term market for dispatchable peak-shaving PV systems in the commercial buildings sector.

Table 1
Summary of Runs With Benefit-Cost Ratios ≥ 1.00

Building Type	**Electric Utility (region)**	**Benefit-Cost Ratio**
Large State Office Building	Long-Island Lighting Company (NY)	1.02
Fast Food Restaurant (no electric heat)	Duke Power (NC)	1.02
Large State Office Building	Consolidated Edison (NY)	1.01
Fast Food Restaurant (with electric heat)	Duke Power (NC)	1.00
Fast Food Restaurant (with electric heat)	Crescent Electric Membership (NC)	1.00
Fast Food Restaurant (no electric heat)	Crescent Electric Membership (NC)	1.00

Source: Center for Energy and Environmental Policy

The remainder of this report describes the analysis in greater detail along with a description of the key input assumptions used in the model. In addition, a detailed discussion of the results from the analysis are presented.

II. PROJECT OVERVIEW

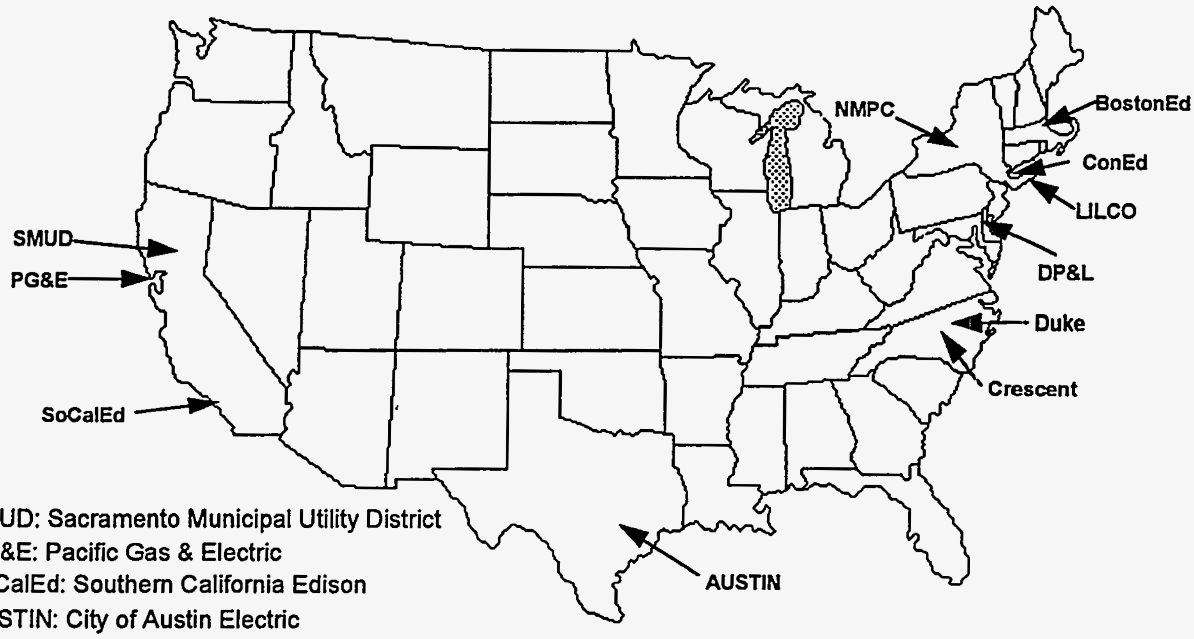
In recent years, several utilities across the U.S. have investigated the technical and economic feasibility of distributed photovoltaic (PV) systems. PV has been shown to be a technically sound and reliable peak-shaving technology for utilities and analyses indicate that it is closer to being cost-effective than when the technology is viewed as a supply-side resource. However, the technology's current high cost means that utility-owned PV peak-shaving systems still have benefit-cost ratios below 1.00 for most utility service territories in the U.S. This outcome is based on the use of avoided capacity and energy costs traditionally afforded demand-side management investments as the principal source of economic benefit.

A second potentially large market for PV technologies may be in the commercial buildings sector. Customer owned dispatchable peak-shaving PV systems can be used to effectively manage a building's load to reduce electricity bills. Traditional commercial tariffs, in which both demand and energy charges are applied to a customer's electricity usage, may make this application an attractive option for commercial building operators. To take advantage of these rate structures, a PV array is used in conjunction with modest amounts of battery storage to shave a building's peak demand. The University of Delaware's Center for Energy and Environmental Policy (CEEP) has developed a methodology and spreadsheet tool to assess the economic viability of customer-owned dispatchable peak-shaving PV systems.

The technical feasibility of this application has been established through a demonstration project . A dispatchable peak-shaving PV system has been operating for nearly two years on Delmarva Power & Light's northeast operations office located in Newark, Delaware. In addition, a limited number of case-study analyses conducted by CEEP in the Mid-Atlantic and other parts of the country illustrate that the economics for customer owned dispatchable peak-shaving systems are close to being cost-effective (Byrne et al., 1996; Byrne et al., 1995, Byrne et al., 1994)

The analysis presented in this report was designed to identify both the building types and regions of the country most favorable for customer investments in dispatchable peak-shaving PV applications. Twenty-one different building loads were analyzed in 11 different utility service territories (see Figure 1). Representative climate data was used in the CEEP spreadsheet model to simulate the performance of a PV array located in the service territory of each utility. The peak-shaving potential of the system was estimated based on a load-matching analysis between the dispatched PV system output and the building's load profile. This information was used, along with electric rate data, to estimate potential bill savings from the operation of the system. Discounted cash-flow analysis was conducted based on customer investments in dispatchable peak-shaving PV systems using a variety of financial information. Benefit-cost ratios and payback periods were estimated and are reported for each building type located in each utility's service territories.

Figure 1
Location of 11 Utility Service Territories



SMUD: Sacramento Municipal Utility District
PG&E: Pacific Gas & Electric
SoCalEd: Southern California Edison
AUSTIN: City of Austin Electric
BostonEd: Boston Edison
NMPC: Niagara Mohawk Power Corporation
ConEd: Consolidated Edison
LILCO: Long Island Lighting Company
DP&L: Delmarva Power & Light
Duke: Duke Power
Crescent: Crescent Electric Membership

III. ANALYSIS AND DATA

The analysis was conducted using a spreadsheet model developed by the University of Delaware's Center for Energy and Environmental Policy (CEEP) to assess the cost-effectiveness of dispatchable peak-shaving PV systems from a customer perspective. The model requires a variety of input data to simulate the performance of the PV array, determine the system's peak shaving ability, and conduct an economic analysis. This section describes the analysis in greater detail and identifies the key assumptions and data sources used in the analysis.

System Technical Analysis

Typical meteorological year (TMY2) data sets derived from the 1961-1990 National Radiation Data Base were used to obtain solar radiation and temperature data for each region under consideration. Specifically, weather data was obtained for the following U.S. cities:

Boston, MA; New York, NY; Syracuse, NY; Wilmington, DE; Los Angeles, CA; San Francisco, CA; Raleigh, NC; Sacramento, CA; Austin, TX. Global horizontal radiation and dry bulb temperature data were obtained from TMY2 files to construct a peak and average solar day for each month of the year. This data was used in CEEP's spreadsheet model to simulate the AC output of the PV array; Table 2 identifies the key technical assumptions used in this part of the analysis.

Table 2
Technical Parameters of PV System

Array DC Conversion Efficiency	10.24 %
Inverter DC to AC Efficiency	93 %
Battery Round-Trip Efficiency	75 %
Array Angle	Latitude - 15 Degrees

Peak-shaving values were estimated based on the PV system's dispatched AC output and the building's load profile. The array size, dispatch hours, and battery storage size were tailored to each building type's load characteristics. Twenty one building types were analyzed. Table 3 lists the building types that were analyzed and their corresponding size in square feet, peak load, and size of the PV array modeled in the analysis. The array sizes range from 1 kW for residential buildings to 10 kW for a large state office building. The array size was determined based on the building's absolute peak load and the variance between shoulder hours' demand. In addition, dispatch hours were established in an effort to achieve maximum peak-shaving values. Buildings with relatively sharp peaks require shorter dispatch periods to achieve significant peak-shaving values. The battery storage component of the system varied between building types and regions. The battery size was automatically set within the model based on the day when the maximum energy produced during non-dispatch hours occurred.

Table 3
Building Types and Size

Building Type	Building Size (Sq. Ft.)	Peak Load (kW)	PV Array Size (kW)
Fast Food Northeast (electric heat)	4,000	154 kW	10 kW
Fast Food Northeast (no electric heat)	4,000	128 kW	10 kW
Fast Food Southwest (electric heat)	4,000	150 kW	10 kW
Fast Food Southwest (no electric heat)	4,000	126 kW	10 kW
Full Service Restaurant Northeast (electric heat)	7,000	63 kW	5 kW
Full Service Restaurant Northeast (no electric heat)	7,000	58 kW	7 kW
Full Service Restaurant Southwest (electric heat)	7,000	67 kW	7 kW
Full Service Restaurant Southwest (no electric heat)	7,000	58 kW	5 kW
Hotel Northeast (electric heat)	40,000	129 kW	5 kW
Hotel Northeast (no electric heat)	40,000	112 kW	10 kW
Hotel Southwest (electric heat)	40,000	119 kW	5 kW
Hotel Southwest (no electric heat)	40,000	117 kW	10 kW
Large State Office	N/A	2,649 kW	10 kW
Office Northeast	50,000	242 kW	3 kW
Office Southwest	50,000	220 kW	3 kW
Residential Northeast	N/A	1.5 kW	1 kW
Residential Southwest	N/A	1.65 kW	1 kW
Retail Store Northeast (electric heat)	40,000	148 kW	4 kW
Retail Store Northeast (no electric heat)	40,000	148 kW	4 kW
Retail Store Southwest (electric heat)	40,000	142 kW	4 kW
Retail Store Southwest (no electric heat)	40,000	142 kW	4 kW

N/A = not available

Economic Analysis

The system technical analysis provided monthly peak-shaving estimates and monthly kWh values for use in the economic analysis. These values were utilized to estimate the potential electricity bill savings that would accrue to a customer over the 25-year life of a dispatchable peak-shaving PV system. Rate information was obtained from twelve different utilities and three different residential rates were assumed for the analysis. Table 4 lists the utilities that were studied along with their peak energy and demand charges. In addition, Table 4 indicates whether northeast or southwest building load profiles were used for the particular utility service territory and the three residential rates that were assumed for the analysis.

Table 4
Electric Utilities Analyzed

Electric Utility	**Peak Demand Charge ($/kW)**	**Peak Energy Charge (¢/kWh)**
Southwest		
Southern California Edison	$15.60/kW	15.38 ¢/kWh
Pacific Gas & Electric	$13.35/kW	9.91 ¢/kWh
Duke Power	$13.31/kW	3.50 ¢/kWh
Crescent Electric Membership Co.	N/A	71.00 ¢/kWh
Sacramento Municipal Utility District	$9.40/kW	5.90 ¢/kWh
City of Austin Electric Department	$12.60/kW	2.80 ¢/kWh
Northeast		
Boston Edison	$24.52/kW	3.98 ¢/kWh
Long Island Lighting Company	$45.60/kW	9.84 ¢/kWh
Consolidated Edison	$43.43/kW	6.85 ¢/kWh
Niagara Mohawk Power Co.	$11.16/kW	$6.70 ¢/kWh
Delmarva Power & Light	$13.25/kW	4.04 ¢/kWh
Residential		
High	N/A	12 ¢/kWh
Medium	N/A	9 ¢/kWh
Low	N/A	6 ¢/kWh

N/A = not applicable

A variety of additional cost and financial data were used to estimate a stream of benefits and costs associated with an investment in dispatchable peak-shaving PV systems. Table 5 provides the key cost and financial assumptions used in the analysis. In addition to the electric bill savings, customer's investing in renewable energy technologies are eligible for a 10% investment tax credit which was established under the 1992 Energy Policy Act. For North Carolina Utilities, a 35% state renewable energy tax credit was also included. Tax credits were included in the analysis along with the tax benefits associated with the deduction of depreciation, O&M, and interest payments.

Table 5
Key Cost and Financial Assumptions

Installed Capital Cost (not including storage)	$8,700/kW
Installed Battery Cost	$200/kWh
System Book Life	25 years
Battery Replacement Cost (every 7 years)	$150/kWh
Annual Maintenance Cost	$500
O&M Escalation Rate	4%
Customer Average Income Tax Rate	39%
Customer Debt Ratio	0%
Customer Discount Rate	12%
Loan Rate	12%
Loan Period	10 years
Equipment Depreciation Period	5 years
Evaluation Period	25 years
Electric Rate Escalation Rate*	4%

* (includes fuel adjustment charges)

The discounted flow of benefits and costs were summarized into benefit-cost ratios and simple payback periods for comparison purposes. Benefit-cost ratios above 1.00 indicate that the system is cost-effective. A simple payback period equals the number of years it would take to pay for the investment (net of tax benefits) from the electricity bill savings. The results of the analysis are discussed and summarized in the following section.

IV. MAJOR FINDINGS AND RESULTS

117 different runs were performed for various combinations of building types and regions. The analysis was developed to identify building types and regions that are most favorable for dispatchable peak-shaving PV applications. A present value analysis of costs and benefits was performed to achieve this objective. From this information, benefit-cost ratios were calculated

along with simple payback periods. This section describes the results of the analysis in three parts: regional analysis, building type analysis, and statistical analysis.

Regional Analysis of Dispatchable Peak-Shaving PV Systems

Each region of the U.S. is characterized by a unique set of policy, resource, and electric rate characteristics which have direct implications for the economic viability of dispatchable peak-shaving PV systems. Through our modeling efforts, we were able to capture these differences to determine which regions in the U.S. offer the best opportunity for cost-effective installations. Table 6 presents benefit-cost ratios and payback periods for dispatchable PV systems located in each utility service territory under consideration. These results illustrate clear regional differences in the economics of dispatchable peak-shaving PV systems. In particular, the economics of these systems appears to be most favorable in the northeast, northern California, and North Carolina.

Table 6
Regional Analysis Results

Electric Utility	**Benefit-Cost Ratios**			**Payback Period in Years**		
(sorted by average B/C ratios)	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
Crescent Electric Membership	96%	100%	93%	12.8	14.5	10.7
Duke Power	93%	102%	87%	20.4	36.1	9.5
Long Island Lighting	86%	102%	72%	15.3	22.6	10.2
Consolidated Edison	81%	101%	66%	20.1	32.5	10.2
Niagara Mohawk Power	71%	79%	68%	25.5	29.7	18.1
Pacific Gas & Electric	71%	80%	64%	26.2	34.3	17.5
Boston Edison	71%	84%	62%	32.4	54.5	15.8
Southern California Edison	70%	78%	64%	25.6	33.2	18.4
Residential High	69%	80%	59%	32.9	41.3	24.6
Delmarva Power & Light	68%	75%	64%	31.9	40.2	21.7
City of Austin Electric	68%	77%	61%	35.9	63.0	20.9
Residential Medium	67%	78%	56%	42.6	53.7	31.4
Sacramento Municipal Utility	66%	74%	62%	36.2	45.4	22.6
Residential Low	65%	76%	54%	61.8	78.6	45.1

Source: Center for Energy and Environmental Policy

Although the northeast is not known for having abundant solar insolation, dispatchable peak-shaving PV systems appear to be close to being cost-effective based on our modeling results. This is primarily due to the relatively high electric rates that characterize this region of the country. Based on Table 3, the three utilities with the highest rates are located in the northeast. In addition, Pacific Gas & Electric, which services a large portion of northern California, is also characterized by high electric rates. As a result, the economics of dispatchable PV systems are also favorable in northern California.

The results of the analysis clearly illustrate that North Carolina offers great potential for cost-effective dispatchable peak-shaving PV system installations. This is due to the 35% renewable energy tax credit offered in the state. This, in addition to the 10% federal tax credit, effectively creates a 45% tax savings on capital costs. As a result, according to our analysis, there exist cost-effective applications in North Carolina based on current PV prices.

Building Analysis of Dispatchable Peak-Shaving PV Systems

A second objective of the analysis was to identify building types for which the economics of dispatchable peak-shaving PV systems are most favorable. The load characteristics of a particular building type influence the peak-shaving ability of the PV system. In particular, buildings that experience sharp peaks during the afternoon hours and have large variations between hourly loads offer significant peak-shaving opportunities. Relatively flat peaks that occur after the sun sets make it difficult for dispatchable peak-shaving PV systems to achieve cost-effective peak-shaving. Table 7 illustrates the benefit-cost ratios and payback periods for each of the 21 building types analyzed.

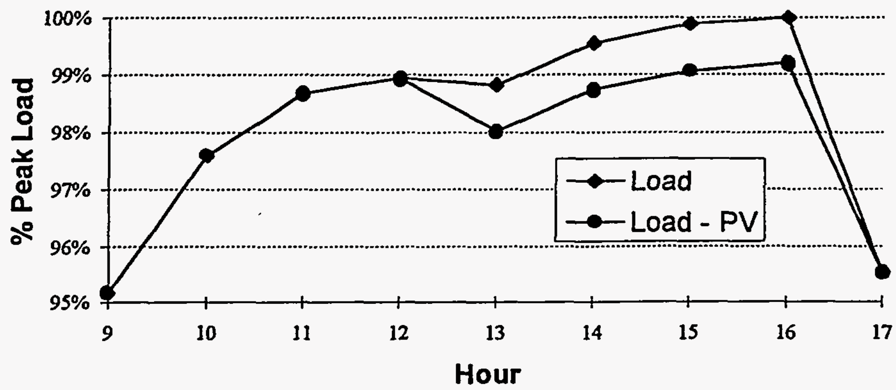
Table 7
Building Type Analysis

Building Type (sorted by average B/C ratios)	Benefit-Cost Ratios			Payback Period in Years		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Large State Office	86%	102%	74%	16.2	22.6	10.2
Fast Food Northeast (no electric heat)	83%	97%	71%	18.4	27.0	11.2
Fast Food Southwest (no electric heat)	82%	102%	65%	20.5	37.7	9.5
Fast Food Southwest (electric heat)	81%	100%	64%	21.8	40.6	10.3
Fast Food Northeast (electric heat)	81%	96%	70%	19.6	29.2	11.4
Residential Southwest	78%	80%	76%	33.7	45.1	24.6
Office Southwest	77%	93%	67%	23.4	30.2	14.5
Retail Store Southwest (electric heat)	77%	94%	64%	25.6	40.7	13.7
Retail Store Southwest (no electric heat)	76%	94%	64%	27.7	45.3	13.7
Retail Store Northeast (electric heat)	75%	85%	67%	23.1	33.0	14.8
Retail Store Northeast (no electric heat)	75%	84%	66%	23.4	34.1	15.2
Full Service Restaurant Southwest (no electric heat)	75%	96%	64%	28.6	35.3	13.0
Office Northeast	74%	84%	67%	23.8	32.9	15.1
Full Service Restaurant Southwest (electric heat)	74%	94%	64%	28.6	34.4	13.9
Hotel Southwest (electric heat)	73%	94%	64%	31.5	37.8	14.0
Hotel Southwest (no electric heat)	73%	97%	61%	37.1	63.0	12.4
Full Service Restaurant Northeast (electric heat)	71%	81%	64%	28.3	42.3	16.4
Hotel Northeast (electric heat)	69%	76%	64%	29.5	42.9	19.3
Full Service Restaurant Northeast (no electric heat)	68%	81%	62%	33.3	49.4	16.7
Hotel Northeast (no electric heat)	67%	72%	62%	35.6	54.5	22.6
Residential Northeast	56%	59%	54%	57.9	78.6	41.3

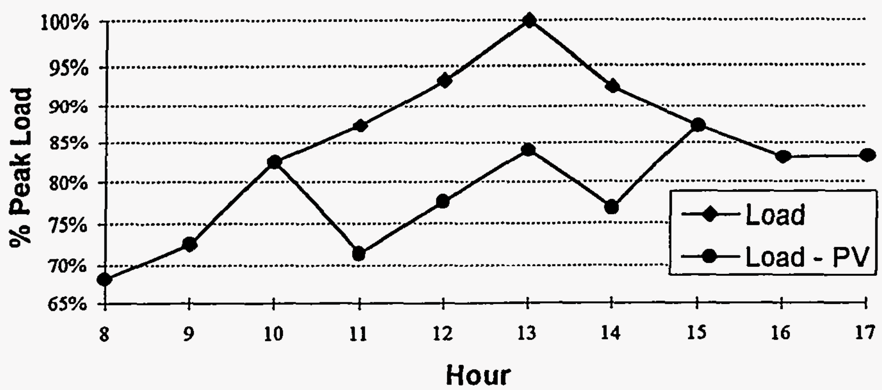
Source: Center for Energy and Environmental Policy

The results in Table 7 indicate that large state office buildings and fast food restaurants could make good candidates for cost-effective dispatchable peak-shaving PV system installations in the future with continued cost reduction in PV technologies. These building types have load characteristics that enable the PV system to achieve significant peak-shaving. To illustrate why, Graphs 1 and 2 present the loads of these two building types with and without the dispatchable peak-shaving PV system's output. A 10 kW PV array was used for these building types.

Graph 1
Normalized August Load Profiles for
Large State Office Bldg.



Graph 2
Normalized August Load Profiles for
Fast Food Restaurant



As the two graphs illustrate, dispatchable peak-shaving PV systems effectively reduce these buildings' peak demand. In the case of the state office building, the 10 kW system results in approximately a 1% reduction in the building's peak load. For the fast food restaurant, a 10 kW system shaves approximately 15% of the building's peak load. Again, the fact that these building loads peak during the afternoon hours and are relatively sharp may make dispatchable peak-shaving PV systems an economically viable option for these building types in the near-future as expected PV price reductions are realized.

Statistical Analysis

To further analyze the data, two least-squares (LSQ) multiple regression models were developed to determine which parameters have the greatest impact on the cost-effectiveness of dispatchable peak-shaving PV systems. The first model specifies the benefit-cost ratio as the dependent variable while the second uses the simple payback period. The same three independent variables were used in each model. The peak demand charge and peak energy charge were used along with a parameter that captures the summer peak-shaving potential for each building type. The peak-shaving potential parameter equals the average of the three summer month peak-shaving values divided by the rated capacity of the PV array. These three variables capture regional differences, as they relate to electric rates, and building load profile differences measured as peak-shaving potential. The residential building analyses and the analyses for Crescent Electric Membership of North Carolina were excluded from the regression because these do not include demand charges. Table 8 presents the results of the regression analysis.

Table 8
Statistical Analysis Results

Model #1 $R^2 = 0.36$ (benefit-cost ratio as dependent variable)		
Variable	**Coefficient**	**t statistic**
Intercept	0.5577	16.55*
Peak Demand Charge	0.0035	5.05*
Peak Energy Charge	-0.0033	-1.35
Peak-shaving potential	0.1341	5.22*
Model #2 $R^2 = 0.56$ (payback period as dependent variable)		
Variable	**Coefficient**	**t statistic**
Intercept	54.7159	20.69*
Peak Demand Charge	-0.3086	-5.64*
Peak Energy Charge	-0.5314	-2.81*
Peak-shaving potential	-17.4864	-8.68*

*significant at the 95% confidence level

V. CONCLUSIONS

The commercial building sector may represent a significant market for dispatchable peak-shaving applications. The analysis presented in this report identifies those building types and regions most favorable for early cost-effective installations. Large state office buildings and fast food restaurants share load characteristics suitable for effective peak-shaving. Due to high electric rates, the northeast and northern California and the favorable tax treatment of renewable technologies in North Carolina may make peak-shaving a cost effective application for PV technologies in these regions of the country.

REFERENCES

Byrne, John, Steven Letendre, Chandrasekhar Govindarajalu, Young-Doo Wang, and Ralph Nigro, (1996), "Evaluating the Economics of Photovoltaics in a Demand-Side Management Role," *Energy Policy*: Vol. 24, No 2.

Byrne, John, Young-Doo Wang, Ralph Nigro, and Steven Letendre, (1995), "Photovoltaics: A Dispatchable Peak-Shaving Option," *Public Utilities Fortnightly*, September 1.

Byrne, John, Young-Doo Wang, Ralph Nigro, and Steven Letendre, (1994), "Photovoltaics in a Demand-Side Management Role," in the Proceedings of the American Council for and Energy Efficient Economy's 1994 Summer Study on Energy Efficiency in Buildings: Washington, DC.

Center for Energy and Environmental Policy, (1995), "PV-DSM Spreadsheet Analytical Tool," Reported submitted to the National Renewable Energy Laboratory.

Appendix C - Survey of Utility Energy Managers

Overview

As a result of the Phase I qualitative research, utility company energy management staff were explored through survey analysis, as potential early adoption candidates for dispatchable PV systems. The goal was to identify marketing opportunities and to identify potential barriers for commercialization of the technology. Even through customers don't thinks it's appropriate for electric utility companies to sell the technology, they do however feel that utility companies should support or back the technology. To make an assessment of those electric utility company issues, we conducted a survey of Utility Energy Management Representatives as a key group for both supplying information regarding likely customer awareness and response to the technology and for helping to define the utilities' role in its commercialization and marketing. Electric utility company representatives were also asked about consideration of PV as a distributed resource technology for system applications.

The following table outlines the approach used in conducting the market research subtask.

Task	Description	Sample Group	Sample Size	Completions
3-1	"Green" Firms	EEI National Accounts	100	
3-2	"Early Adopter" Interviews	Utilities	30	19
3-3	Commercial Businesses	National list	500	

The next section details the survey findings for Task 3-1, 3-2, and 3-3.

Market Survey Findings

Market Segments

The first series of questions posed to this group of respondents was intended to determine the number of national accounts (defined as customers with multiple locations in several utility service areas), the number of key accounts (defined as customers with locations in only one utility's service area), and the number of customers from both groups who were concerned with conservation and load management. Of the total group of 19 respondents, 10 were able to provide estimated answers pertaining to the number of customer accounts. However, the responses varied significantly from one respondent to the next, and in most cases, respondents provided a "best estimate" of the information rather than specific data. Only 4 people were able to provide a specific count of the number of customers in both groups. The number of national account customers ranged from as few as 30 to as many as 400, and for key accounts there were as few as 20 and as many as 1300.

In contrast, eight respondents reported that they did not know how many national account customers their utility company served, nor could they indicate the number of key account customers. However, they did know who the customers were by name, but reported that their customers were not segmented in such a way that they could easily account for the exact population in each group. The typical utility customer segmentation is by market category such as retail, restaurant, office, etc. and therefore most respondents were not able to provide a response without significant accountability efforts.

Next, respondents were asked in terms of their company's impact, what was their level of concern for the environmental. The response categories were "very concerned," "somewhat concerned," "somewhat unconcerned," or "not at all concerned." In every case except for one, they reported that their utility company was "very concerned" about the environment. In comparison they were also asked whether key account customers considered consumer attitudes about the environment to be "very important," "somewhat important," "somewhat unimportant," or "not at all important" to their business. In this case, respondents overwhelmingly reported (16 out of 19) "somewhat important" but not "very important." These responses suggest that the environment is an important issue, but not the most important issue.

Initial Awareness Concerning Solar PV Technology

Another goal of the study was to assess the initial awareness and knowledge of the respondent about solar PV technologies. This was accomplished by reemphasizing DOE's role in the study and interest in the commercialization effort. Approximately half (11 of 19) of the respondents reported that they were "very familiar" with the technology, and an additional six reported that they were "somewhat familiar." Only two people indicated that they were either "somewhat or not at all familiar" with the technology. As a follow-up to the question, they were also asked to identify the ways in which they were aware that PV could be used. The following tables shows the categories and responses.

Awareness of PV Applications

Application Type	Responses
Street Lighting	8
Parking Lot Lighting	6
Signage (to illuminate signs)	6
Remote or Off-Grid Power	10
Emergency or Back-Up Power	10
Other Methods	5
Don't Know/Not Sure	2
Total	47

Price Issues

In terms of customer motivation, 16 of 19 utility representatives reported that they believed the primary motivation for customers to use new energy technologies was to "save money." Other motivational responses were "to increase the level of customer service," "to be more competitive," and "to increase environmental awareness."

Prior to probing additional price or cost related issues, respondents were provided with a brief description of the envisioned 32-kW system that included the actual price ($90,000 - $110,000 including installation), and the approximate cost per kW for the system ($3,000 - $3,500). Following the description, respondents were asked what they thought the system should cost for customers to be interested. The goal of this question was to obtain a range of perceivable cost amounts for such a system. The following tables show the cost and pay back period reported.

System Cost for Customer Interest

Cost Categories ($/kW)	Responses
$100 or less	1
$100 -$300	2
$300 - $1,000	4
$1,000 - $1,500	2
$1,500 - $2,000	3
Don't Know/Not Sure	7
Total	19

Pay back Period for Customer Interest

Number of Years	Responses
1 year or less	0
1 -2 years	11
2 - 3 years	4
3 - 4 years	2
4 - 5 years	1
5 or more years	0
Don't Know/Not Sure	1
Total	9

Clearly, utility energy managers overwhelmingly reported that customers would not be willing to accept a pay back period of more than two years. Reasons given for this response include. As a follow up question, they were asked if they thought customers would tolerate a longer pay back period given the system's secondary benefits such as the "green" appeal of solar technology. Only two respondents reported that customers would tolerate a longer pay back (one from the 1-2 year category and one from the 2-3 year category). In both cases, they indicated that customers would only tolerate one additional year (increased from 1-2 to 2-3 years, and 2-3 to 3-4 years).

Furthermore, this group of respondents does not report that it was realistic to think that customers might consider the side benefits of the technology worth the extra cost. Seventeen said "no" it was not worth the extra cost, while two were "not sure or did not know." Nor do they believe that customers would be willing to pay a premium for the product (16 said "no," 2 "yes," and 1 "10 % of their customers."

Sixteen out of 19 representatives reported that their companies are currently involved with renewable technology projects. Seven of the 16 indicated projects that involve fuel cells, biomass, wind, and heat pump technologies. Utility energy managers provided a variety of responses when queried about ownership of a PV system installed at a customer site. However, nine respondents indicated that "it should be determined by the customer's preference and individual need." Four reported that the "utility company" should own the system, two thought the system should be "leased," and three selected "customer ownership."

Ten also indicated that they felt the technology would offer more independence to customers as back-up or peak shaving options, while the remaining 9 did not think the system offered more independence. In terms of on-grid versus off-grid applications within their utility service territory, nine people reported that "on-grid" applications were the most viable option, versus seven who reported "off-grid" and three who were "not sure" about either option. The seven who reported off-grid options were also asked about the level of demand for off-grid power in their service territory. Even though they reported that the off-grid applications were more viable, they indicated "low" demand overall.

To assess barriers to widespread adoption of the product, respondents were asked to rate the significance of nine items, on a scale of one to four, with one being "very significant" and four being "not at all significant." The responses are shown in the following table.

Technology Adoption Barriers

Barriers	Very Significant	Somewhat Significant	Somewhat Insignificant	Not At All Significant
a. High initial cost	16	1	0	0
b. Effectiveness of PV	8	3	4	2
c. Reliability of PV	6	6	3	2
d. Unproved technology	7	4	6	0
e. System control	3	4	6	4
f Dependence on weather	6	5	4	2
g. Battery disposal	4	6	5	2
h. Appearance	3	6	4	4
i. Size (32 kW output)	8	4	3	2

Respondents were asked to rate the top three advantages of PV technology. Out of a total of 17 respondents, six reported that "peak savings management" was the number one advantage, followed by four who indicated "uninterruptible power supply/electric back-up." Five people reported that the second most popular selection was the technology being "good for environment," followed by four who indicated that PV was a "clean economic means to produce energy." The responses are shown in the following table.

Top Three Advantages of PV Technology

Options	First	Second	Third
1. Good for the environment	2	5	3
2. Uninterrupted power supply/backup	4	1	3
3. Clean way to produce energy	3	4	4
4. Low maintenance requirements	1	3	6
5. Peak savings management	6	3	1
6. Other	1	1	0

Respondents were also asked to rate the top three disadvantages of PV technology. As shown in the table below, 15 respondents overwhelmingly reported that the "high initial cost" was the number one disadvantage. Five people reported that the second most popular selection was the "technology's dependence on weather," followed by four who indicated that the "reliability of PV" was also a concern. The responses are shown in the following table.

Top Three Disadvantages of PV Technology

Options	First	Second	Third
1. High initial cost	15	1	0
2. Effectiveness of PV technology	1	1	1
3. Reliability of PV technology	0	4	5
4. Unproved technology	1	3	2
5. System control	0	0	0
6. Technology's dependence on weather	0	5	2
7. Battery disposal	0	1	4
8. Appearance	0	0	1
9. Design flexibility (32 kW size)	0		2
10. Other	0	2	0

In considering commercialization efforts of PV, utility energy managers were asked about what specific roles they would consider in promoting the technology. The majority of respondents (nine) indicated that they preferred a "turnkey" approach to promoting the product, followed by three people who preferred to "perform technology research and development," and two who opted for "owning and operating the units on a customer's property."

As a follow-up to the preceding question, respondents were asked to indicate on a scale of one to four, with one being "most preferred" and four being "not at all preferred" how much they preferred to offer a series of potential utility services for the promotion of the PV product. The responses are shown in the following table.

Preference for Providing Utility PV Services

Options	Most Pref.	Some-what Pref.	Some-what Not Pref.	Not At All Pref.	Don't Know
a. Maintenance contracts	6	4	1	3	1
h. System design and installation	6	5	0	3	1
c. Financing alternatives	5	3	4	1	1
d. Battery replacement and disposal	3	1	3	7	1
e. Equipment repair and maintenance	6	3	2	3	1
f Technical assistance	9	4	1	0	1
g. Coordination of roofing maintenance	2	3	2	7	1
h. Training services	3	5	3	2	2
1. System monitoring	8	2	3	1	1
j. System operation	8	4	1	1	1
k. Reporting assistance	4	4	3	3	1
1. Coordination with DSM programs	6	4	1	3	1
m. Alliance with EMS manufacturers	5	7	1	0	2

Competitive Issues

The majority of the respondents (13) indicated that their utility company has competition for the electric services they provide, while four reported no competition. When asked about key account customer perception of their rates, four representatives reported that they perceived their rates as being much higher compared to other utility companies, three who reported somewhat higher, six who thought they were comparable, two who said somewhat lower, and two who indicated much lower rates than other utilities. In terms of demand charges, the responses were almost the same with the exception of two respondents.

Ten out of eighteen utility representatives reported that their utility company is currently promoting renewable energy technologies or new electrotechnologies through a program, while the remaining eight had no such program in place. Of those ten, four reported that photovoltaics were included in the types of technologies offered. The other six representatives reported that their programs offered geothermal heat pumps, fuel cells, wind, and biomass technologies. From the eight utility companies that offered no renewable programs, two representatives thought such a program would be useful for their customers, while six representatives reported that they "didn't know" if such a program would be useful or not. In terms of distribution of the PV product, one of the same two respondents said that their utility would be interested in distributing the product within their service territory, while the other respondent reported no interest in product distribution.

Representatives were also queried about whether their utility company was currently distributing other products to key account customers. Fourteen of the 18 representatives reported that their utility company was in fact currently distributing products to their key account customers. Products identified included surge protectors, power quality, meters, and UPS products.

Distributed resource options were considered by 12 utility companies, while three were not. Of those 12, three reported that they were already considering photovoltaics and fuel cell technologies. The remaining nine representatives reported consideration of technology types that include cogeneration and energy storage. Eight representatives reported that they thought their key account customers may currently be interested in serving as a demonstration site for a PV project.

Appendix D - Survey of Buildings Specialists

INTRODUCTION

The following tables summarize the results of the Survey of Building Specialists performed under Phase 2 of the PV:BONUS Program. The overall purpose of this survey was to identify patterns in attitudes or geography that would be helpful in the future development and marketing of the dispatchable PV peak shaving system and the PV-GI system.

A total of 2,000 surveys were sent to building owners and managers using a purchased mailing list. A total of 209 completed surveys were received, about a 10% response rate. This response rate is consistent with expected responses to mailed surveys. A copy of the survey is attached to the results. The survey was structured to gather basic background information first, followed by data concerning the respondents overall concern about energy costs, use and understanding of energy technologies, and attitudes towards the value of PV technology.

Although additional analysis is possible, two patterns emerged immediately in the responses. First, building owners and managers are receptive to PV technology (including the PV peak shaving system and the PV-GI system) as long as there is an economic or reliability benefit. Relatively high value was also placed on the environmental value of PV, although not as high as the economic and reliability benefits. Second, building owners and managers favor multi-functional systems rather than single- or dual-purpose systems.

In summary, there appears to be no inherent bias against renewable or PV technologies among building owners and managers. In comparison to other sectors, the approach to developing and marketing any type of PV system to commercial building owners is straightforward. The most important criteria is simply cost. Reliability enhancement is important, and environmental benefits are also significant. Any product development or marketing approach must also account for the intensely competitive nature of the building products market, including equipment like uninterruptible power supply (UPS) systems and back up generators.

BACKGROUND INFORMATION

Respondents were asked to provide several pieces of background information concerning the type and number of facilities they operated. Table 1 shows that a significant number (46.6%) were responsible for the operation of more than 15 facilities. Of those who knew their ownership status (184 respondents, or 88%), a very large portion of the facilities were owned by the respondents' companies (82%), as indicated in Table 2. The most frequent type of building owned were commercial office buildings (54.1%), followed by warehouse/industrial (29.2%), educational (27.3%) and Retail (25.4%), as shown in Table 3.

Table 1. Number of Facilities Company Operates

Number of Facilities	Number of Responses
1-5	59 (30.9%)
6-10	31 (16.2%)
11-15	12 (6.3%)
Over 15	89 (46.6)

Table 2. Percentage of Facilities Owned Vs. Rented/Leased

	Percentage
Owned	82%
Leased or Rented	18%
Don't Know	24 responses

Table 3. Types of Buildings Operated By Company

	Number of Responses
Commercial Offices	113 (54.1%)
Warehouse/Industrial	61 (29.2%)
Educational	57 (27.3%)
Retail	53 (25.4%)
Government Offices	41 (19.6%)
Apartment/Condominium	40 (19.1%)
Hospital/Health Care	27 (12.9%)
Shopping Centers/Malls	24 (11.5%)
Full Service Restaurants	22 (10.5%)
Hotels/Motels	14 (6.7%)
Grocery/Convenience Store	13 (6.2%)
Fast Food Restaurants	12 (5.7%)
Other	31 (14.8%)

BUSINESS AND ENERGY COSTS

The second section of the survey was used to gather information related to the importance of energy costs in relation to other business costs, the use of conservation and peak shaving technologies, and renewable energy. As shown in Table 4, a very large number of the respondents indicated that energy costs were very important (79.9%). This is substantiated by the results shown in Table 10. This table indicates that 83% of the respondents ranked electricity as one of the top five costs of doing business. Based on the data collected to construct Table 10, electricity represented about 26% of total annual operating costs, with an average ranking between second and third highest cost. Although roughly 2 out of 3 did not use active peak shaving equipment (diesel generators, etc.), nearly half used some type of load shedding or load management. Slightly more than two-thirds of the respondents used energy management systems.

Table 4. Importance of Controlling Electric Bills

	Number of Responses
Very Important	167 (79.9%)
Somewhat Important	37 (17.7%)
Somewhat Unimportant	4 (1.9%)
Not Important	1 (0.05%)

Table 5. Facilities Employ Peak Shaving Equipment

	Number of Responses
Yes	49 (23.4%)
No	134 (64.1%)
Under Consideration	23 (11.0%)
Don't Know	3 (1.4%)

Table 6. Facilities Employ Load Shedding or Load Management

	Number of Responses
Yes	98 (46.9%)
No	89 (42.6%)
Under Consideration	20 (9.6%)
Don't Know	2 (0.9%)

Table 7. Company Currently Participates in Time-of-Use Rates

	Number of Responses
Yes	66 (31.6%)
No	109 (52.2%)
Under Consideration	17 (8.1%)
Don't Know	17 (8.1%)

Table 8. Company Participates in Other Peak Shaving Programs

	Number of Responses
Yes	51 (24.4%)
No	127 (60.8%)
Under Consideration	20 (9.6%)
Don't Know	11 (5.3%)

Table 9. Buildings Use Energy Management Systems

	Number of Responses
Yes	142 (68.6%)
No	44 (21.3%)
Under Consideration	17 (8.2%)
Don't Know	4 (1.9%)

Table 10. Items Representing the Highest Percentages of Company's Total Annual Operating Costs

	Average ranking of those who responded (Highest to Lowest)	Number of responses who ranked between 1 and 5	Average % this item is of total annual operating costs	Number of responses providing %
Purchase of Goods for Re-Sale	2.10	10	42%	3
Interest on Debt	2.27	55	36%	10
Labor	2.36	146	40	18
Electricity	2.54	173	26	46
Materials or Ingredients Used in Finished Products	2.64	35	12	7
Taxes	2.96	74	17	18
Rent and Leases	2.97	33	20	7
Fuel Oil	3.35	23	6	9
Depreciation	3.41	36	15	7
Natural Gas	3.44	91	10	19
Other Services (sub contractors)	3.67	58	10	17
Other Utilities (water, sewer)	3.69	65	8	18
Other Fuels	3.77	13	5	6
Advertising and Public Relations	4.22	17	4	4
Other	n/a	n/a		

KNOWLEDGE OF RENEWABLE AND ADVANCED ENERGY TECHNOLOGIES

Approximately half of the respondents indicated that they had tested advanced energy technologies (Table 11), and most were familiar with a range of advanced and renewable energy technologies (Table 12). However, few have seriously considered using advanced or renewable technologies in day-to-day applications (Table 13).

Table 11. Company Tests Advanced Energy Technologies

	Number of Responses
Yes	102 (49.3%)
No	102 (49.3%)
Don't Know	3 (1.4%)

Table 12. How Familiar With Following Advanced or Renewable Energy Systems

Technology	Very Familiar	Somewhat Familiar	Not Familiar
Thermal Solar Systems (hot water)	42 (20.2%)	127 (61.1%)	39 (18.8%)
Photovoltaic Systems	18 (8.7%)	94 (45.6%)	94 (45.6%)
Biomass Systems (wood and waste)	15 (7.3%)	67 (32.5%)	124 (60.2%)
Wind Energy Systems	14 (6.8%)	131 (63.3%)	62 (30.0%)
Congeneration Systems	49 (23.7%)	94 (45.4%)	64 (30.9%)
Fuel Cells	9 (4.5%)	65 (32.5%)	126 (63.0%)
Other	N/A	N/A	N/A

Other:

	Very Familiar	Somewhat Familiar
Geothermal	5 responses	2 responses
Hydro	4 responses	n/a
Generator	1 response	n/a
TES	2 responses	2 responses
Ice storage	n/a	1 response

Table 13. Company Considered Using Any of the Technologies

Technology	Considered	Used	Not Considered or Used
Thermal Solar Systems (hot water)	35 (17.5%)	24 (12.0%)	141 (70.5%)
Photovoltaic Systems	17 (8.8%)	8 (4.1%)	168 (87.0%)
Biomass Systems (wood and waste)	9 (4.7%)	8 (4.2%)	175 (91.1%)
Wind Energy Systems	12 (6.3%)	5 (2.6%)	175 (91.1%)
Congeneration Systems	44 (22.3%)	21 (10.7%)	132 (67.0%)
Fuel Cells	12 (6.3%)	3 (1.6%)	175 (92.1%)
Other	N/A	N/A	N/A

Other:

	Considered	Used
Geothermal	3 responses	4 responses
Elec Deep Heat	1 response	n/a
Skylights	1 response	n/a
Hydro	1 response	n/a
Ice Storage for Cooling	2 responses	n/a
Thermal Energy Storage	2 responses	n/a

PERCEIVED VALUE OF PV SYSTEMS AND RELIABILITY

A very large percentage of the respondents indicated that power outages were severely disruptive (85.6%), as shown in Table 14. Over three-fourths employed uninterruptible power supply (UPS) systems to help reduce the impacts of disruptions (Table 15). When asked what the most important features of a PV system would be to them, respondents indicated that their highest priority was to reduce their electric bills (58.4% indicated that this was their first priority – see Table 16.). This is not surprising considering the emphasis placed on cost control revealed in earlier questions. However, a significant number indicated that providing power during outages was their highest priority (22.9%). Although costs and reliability are clearly the highest priorities, a significant number (37.3%) also indicated that helping to improve the environment was their second or third priority. Over 81% believed that their company played a very or somewhat important role in environmental protection, and around 90% engage in either the installation of energy-efficient equipment or recycling (Tables 18 and 19).

Table 14. Short-Term Power Outages Severely Disrupt Equipment

	Number of Responses
Yes	179 (85.6%)
No	28 (13.4%)
Don't Know	2 (1.0%)

Table 15. Company Operates UPS Systems

	Number of Responses
Yes	158 (76.0%)
No	43 (20.7%)
Don't Know	7 (3.4%)

Table 16. Ranking By Number of Responses: Importance for Considering Solar and Other Energy Systems

	Highest							Lowest	# of Responses
	1	2	3	4	5	6	7	8	
Rapid payback from electric bill savings	111	35	22	12	7	2	1	0	190
Reducing utility power dependence	45	46	37	27	16	4	3	0	178
Providing back-up power during outages	41	51	42	22	17	6	0	0	179
Helping to improve the environment	13	23	40	48	30	8	7	0	169
Replacing broken or worn out equipment	11	13	24	30	37	21	7	1	144
Supplying power to remote locations	11	7	7	7	26	38	28	0	124
Attracting additional customers	10	5	11	8	15	22	44	1	116

Table 17. Ranking By Percentage: Importance for Considering Solar and Other Energy Systems

	Highest							Lowest	# of Responses
	1	2	3	4	5	6	7	8	
Rapid payback from electric bill savings	58.4	18.4	11.6	6.3	3.7	1.1	0.5	0	190
Reducing utility power dependence	25.3	25.8	20.8	15.2	8.9	2.2	1.7	0	178
Providing back-up power during outages	22.9	28.5	23.5	12.3	9.5	3.4	0	0	179
Supplying power to remote locations	8.9	5.6	5.6	5.6	21.0	30.6	22.6	0	124
Attracting additional customers	8.6	4.3	9.5	6.9	12.9	19.0	37.9	0.9	116
Helping to improve the environment	7.7	13.6	23.7	28.4	17.8	4.7	4.1	0	169
Replacing broken or worn out equipment	7.6	9.0	16.7	20.8	25.7	14.6	4.9	0.7	144

Table 18. Importance of Company's Role in Environmental Protection

	Number of Responses
Very Important	70 (33.7%)
Somewhat Important	99 (47.6%)
Somewhat Unimportant	14 6.7(%)
Not Important	18 (8.7%)
Don't Know	7 (3.4%)

Table 19. Company Promotes or Participates In

	Number of Responses
Installation of energy efficient equipment in buildings	188 (90.0%)
Recycling	187 (89.5%)
Use of alternative fuel vehicles	42 (20.1%)
Use of environmental messages in advertising	38 (18.2%)
Other	6 (2.9%)
None	6 (2.9%)

Muliple responses accepted.

POTENTIAL PURCHASES

Between one-fourth and one-third of the respondents indicated an interest in purchasing a PV system for testing, demonstration, educational or public relations purposes (Table 21). Of the those interested in purchasing a system, the largest percentage (61%) preferred a multi-function system that included the capabilities of peak shaving and UPS back-up.

Table 20. Purchase PV System

Type of Application	Number of Responses		
	Yes	No	Don't Know
Testing	76 (37.3%)	50 (24.5%)	78 (38.2%)
Demonstration	61 (31.8%)	59 (30.7%)	72 (37.5%)
Educational	45 (25.1%)	70 (39.1%)	64 (35.8%)
Public Relations	39 (22.5%)	69 (39.9%)	65 (37.6%)

Table 21. Type of PV System Interested In

Type of System	Number of Responses
Peak Shaving Only	21
UPS Only	12
Combined Peak Shaving/UPS System	75
Remote Power System	15

GEOGRAPHIC SENSITIVITY

Although cross tabulations were developed to determine if there was a geographic dimension to the responses, no patterns emerged. In fact, the geographic analysis indicated a general uniformity in the responses for all states.

SURVEY OF BUILDING SPECIALISTS

October 18, 1996

Dear Building Professional:

The purpose of this letter is to ask for your support in a national survey of experts on buildings and facility management. This work is funded by the U.S. Department of Energy under a program which is developing solar electric power systems for buildings. Applied Energy Group, Inc., a national energy consulting firm, and the University of Delaware Center for Energy and Environmental Policy are administering the survey.

The results of this survey will be published in a report scheduled for release in early 1997. When you fill out this survey, you can choose to receive a copy of the report. ***Please note that all individual responses will be strictly confidential. Only combined results will be published.***

Partial funding is also available for companies interested in testing the hardware under development.

If you have any questions about this survey or the program under which it is being performed, please call Mr. Ralph Nigro of Applied Energy Group, Inc. at (302) 239-8325.

We have included a self-addressed, postage paid envelope for your convenience. We would appreciate your response no later than Friday December 13, 1996.

Thank you for your assistance in this important work.

Purpose of This Survey

The purpose of this survey is to determine the interest of selected types of companies in applications of ***"photovoltaic"*** (PV) technology. PV technology enables electricity to be generated at a building site directly from sunlight with no moving parts or emissions. When combined with battery systems, PV can be used for reducing a building's peak demand for electricity, which is often a large portion of commercial electric bills. A PV/battery system can also be used to provide back-up power, and to provide power in remote places where utility power is not available. A more detailed description of the technology is provided later in this survey.

Background Information

The first section of this survey is intended to gather some basic information about you and your company.

1. Please provide the following information:

   a. Name: ______________________
   b. Title: ______________________
   c. Name of Firm: ______________________
   d. Address: ______________________
   e. City: ______________________
   f. State: __________
   g. Zip Code: __________
   h. Telephone: (____) __________
   i. Fax: (____) __________

2. Approximately how many facilities does your company operate?

   ____

3. If known, please indicate the approximate percentage of your company's facilities which are leased or rented versus facilities which are owned:

   a. Percent Owned ____
   b. Percent Leased or Rented ____

c. Don't Know Percentages ____

4. Please indicate the types of buildings operated by your company *(please check all that apply):*

a. Commercial Offices ___
b. Retail ___
c. Educational ___
d. Government Offices ___
e. Shopping Centers/Malls ___
f. Hotels/Motels ___
g. Hospital/Health Care ___
h. Apartment/Condominium ___
i. Fast Food Restaurants ___
j. Full Service Restaurants ___
k. Grocery/Convenience Store ___
l. Warehouse/Industrial ___
m. Other (please specify) ____________________ ___

Business and Energy Costs

5. Please indicate how your company rates the importance of controlling electric bills for its facilities *(please check only one):*

___ Very Important
___ Somewhat Important
___ Somewhat Unimportant
___ Not Important

6. Do any facilities operated by your company employ peak shaving equipment such as engine-generators to control electric bills?

___ Yes ___ No ___ Under Consideration ___ Don't Know

7. Do any facilities operated by your company employ load shedding or load management strategies (for example, manually turning off lights or air conditioning, or shutting down production lines) to reduce peak electrical loads?

___ Yes ___ No ___ Under Consideration ___ Don't Know

8. Does your company currently participate in time-of-use electric rates where offered by utilities?

___ Yes ___ No ___ Under Consideration ___ Don't Know

9. Does your company participate in other Peak Shaving Programs offered by your electric utility company(s)?

___ Yes ___ No ___ Under Consideration ___ Don't Know

10. Do any of your buildings use Energy Management Systems to control the use of electricity?

___ Yes ___ No ___ Under Consideration ___ Don't Know

11. From the following list, please identify the *five* items which account for the highest percentages of your company's total annual operating costs and rank them from 1 to 5 where "1" represents the highest percentage. If known, please include actual percentages in the second column.

Item	***Rank***	***Percentage***
a. Electricity	___	___
b. Fuel Oil	___	___
c. Natural Gas	___	___
d. Other Fuels	___	___
e. Labor	___	___
f. Taxes	___	___
g. Interest on Debt	___	___
h. Rents and Leases	___	___
i. Materials or Ingredients Used in Finished Products	___	___
j. Purchase of Goods for Re-Sale	___	___
k. Advertising and Public Relations	___	___
l. Depreciation	___	___
m. Other Utilities (e.g., water, sewer costs)	___	___
n. Other Services (e.g., sub contractors)	___	___

o. Other (please specify) ________________ ___ ___

Advanced Building and Energy Technologies

Many technologies and materials are available to help control or reduce energy bills. These include energy management systems, advanced fluorescent lighting, ground source heat pumps, high efficiency air conditioning systems, high performance windows, and advanced building materials. Renewable energy technologies are also available which can produce electricity or provide heating and cooling from renewable energy resources such as solar energy, wind, and geothermal energy.

12. Does your company test advanced energy technologies or building materials in your facilities?

___ Yes ___ No ___ Don't Know

13. Please indicate how familiar you are with the following advanced or renewable energy systems:

Technology	*Very Familiar*	*Somewhat Familiar*	*Not Familiar*
a. Thermal solar systems (hot water)	_____	_____	_____
b. Photovoltaic systems	_____	_____	_____
c. Biomass systems (wood and waste)	_____	_____	_____
d. Wind energy systems	_____	_____	_____
e. Cogeneration systems	_____	_____	_____
f. Fuel cells	_____	_____	_____
g. Other, specify: __________	_____	_____	_____

14. Has your company ***considered or used*** any of the technologies listed above? *(Please check all that apply)*

Technology	*Considered*	*Used*	*Not Considered or Used*
a. Thermal solar systems	___	___	___
b. Photovoltaic systems	___	___	___
c. Biomass systems	___	___	___
d. Wind energy systems	___	___	___
e. Cogeneration systems	___	___	___
f. Fuel cells	___	___	___
g. Other, specify ____________	___	___	___

UPS Systems

Uninterruptible Power Supply (UPS) systems are used to insure that electricity is provided to critical equipment, even during a power failure. UPS systems are often used for computer systems, telephone systems, sensitive control systems, and important safety and fire protection systems.

15. Does your company use equipment which can be severely disrupted by short-term power outages?

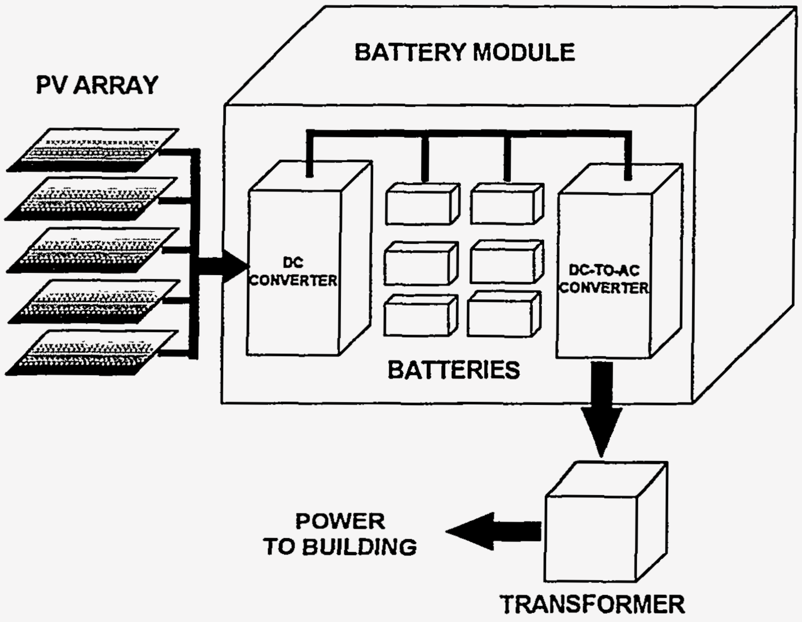
    ___ Yes ___ No ___ Don't Know

16. Does your company operate UPS systems in any of its facilities?

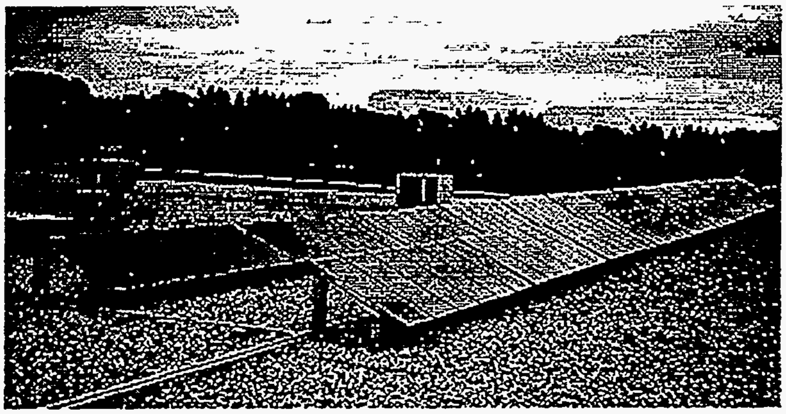
    ___ Yes ___ No ___ Don't Know

Photovoltaic Technology Background

Photovoltaic (PV) systems produce electricity directly from the sun's energy using "solar cells." Unlike other conventional technologies which are used to generate electricity, there are no moving parts in a typical PV system, there is no fuel required, and no emissions which can pollute the air. The following diagram illustrates the major components of a PV system combined with batteries. A prototype of this system has been in operation since 1993 in the Mid-Atlantic region.



A photo of a PV array mounted on the roof of a typical commercial building is shown below. PV arrays can also be ground-mounted.



There are three main applications for the system described above:

- For peak shaving on commercial buildings to reduce electric bills during periods of high demand (for example, during hot weather when air conditioning systems use significant amounts of electricity);
- To provide emergency back-up power for critical systems like computers, telephone systems and emergency lighting;
- To provide power for remote facilities where it is too difficult or expensive to extend utility lines.

Remote power systems are now cost-effective in many applications. PV systems for peak shaving are expected to be cost-effective in about five years. PV systems for emergency power are cost-effective in some applications now. As costs continue to decrease, PV systems could be used to provide some or all of the electricity required by residential and commercial buildings. In the meantime, PV systems are being installed for test, demonstration and educational purposes.

Interest in PV Technology and Additional Information

Given the background information presented above, the following questions are intended to gather information regarding potential interest in using PV technology for peak shaving, UPS systems and remote power systems.

17. Please rank the following items in terms of their importance in considering solar energy and other renewable energy systems. "1" indicates highest importance.

a. Reducing dependence upon utility power ___
b. Achieving rapid pay back through savings on electric bills ___
c. Replacing broken or worn out equipment ___
d. Supplying power to remote locations ___
e. Helping to improve the environment ___
f. Providing back-up power in case of outages ___
g. Attracting additional customers ___
h. Other, (please specify) ____________________ ___

18. Generally speaking, how important is it that your company plays an active role in environmental protection _in the eyes of your customers_? *(please check only one):*

___ Very Important
___ Somewhat Important
___ Somewhat Unimportant
___ Not Important
___ Don't Know

19. Please indicate the activities which your company promotes or participates in *(check all that apply):*

a. ___ Recycling
b. ___ Installation of energy efficient equipment in buildings
c. ___ Use of environmental messages in advertising
d. ___ Use of alternative fuel vehicles
e. ___ Other____
f. ___ None
g. ___ Don't know

20. Would your company consider purchasing a PV system for one or more of your company's facilities for testing, demonstration, educational or public relations purposes? *(Please check all that apply)*

a. Testing	___ Yes	___ No	___ Don't Know
b. Demonstration	___ Yes	___ No	___ Don't Know
c. Educational	___ Yes	___ No	___ Don't Know
d. Public Relations	___ Yes	___ No	___ Don't Know

21. If you answered "Yes" or "Don't Know" to any of the categories in Question 21 above, please indicate which type of PV system you would be most interested in. *(Check only one).*

a. ___ Peak Shaving Only
b. ___ UPS Only
c. ___ Combined Peak Shaving/UPS System
d. ___ Remote Power System

22. A test program is currently in progress for qualified participants with some funding available. If you would be interested in participating in a cost-shared test program for the systems described above, please check the box below.

☐ Yes, please forward additional information about test program participation.

23. If you would like to receive a copy of the final report please check the box below. Please provide your telephone number for follow -up: (____)________________

☐ Yes, please forward a copy of the completed study when it is available.

Thank you for taking the time to complete this survey.

Appendix E - Distribution Feeder Analysis

TABLE OF CONTENTS

Section — Page

I. EXECUTIVE SUMMARY 1

II. OVERVIEW 6
- 1. GENERAL DESCRIPTION OF PV SYSTEM TECHNOLOGY 6
- 2. BACKGROUND OF PROJECT 6
- 3. GOALS AND OBJECTIVES OF PROJECT 8

III. METHODOLOGY 9
- 1. APPROACH 9
- 2. DATA COLLECTION 10
- 3. CORRELATION ANALYSES 11
- 4. LOAD ANALYSIS 13

IV. ANALYSIS RESULTS 15
- 1. CORRELATION ANALYSIS 15
- 2. FEEDER/TRANSFORMER LOAD ANALYSIS 19
- 3. CUSTOMER LOAD ANALYSIS 20

V. CONCLUSIONS AND RECOMMENDATIONS 21

APPENDIX A - FEEDER/TRANSFORMER CORRELATION ANALYSIS A-1

APPENDIX B - SUMMARY OF FEEDER/TRANSFORMER LOAD ANALYSIS B-1

APPENDIX C - INDIVIDUAL FEEDER/TRANSFORMER LOAD ANALYSIS C-1

APPENDIX D - SUMMARY OF CUSTOMER LOAD ANALYSIS RESULTS D-1

APPENDIX E - INDIVIDUAL CUSTOMER LOAD ANALYSIS RESULTS E-1

I. EXECUTIVE SUMMARY

1. INTRODUCTION

Delmarva Power & Light Company (Delmarva) retained Applied Energy Group, Inc. (AEG) to develop an analysis of load data on distribution feeders and substation transformers and a group of commercial and industrial customers to ascertain how their load patterns correlated with the availability of solar resources. In terms of the feeder/transformer data, the related issue of distribution utilization was also addressed through analysis of the load data. This report is the result of the analysis.

Organization of the Report

The report is organized into four chapters, with appendices, as follows:

I. EXECUTIVE SUMMARY - Includes a summary of the goals and objective, methodology, and analysis results

II. OVERVIEW - Includes a general description of PV System Technology, project background, goals and objectives

III. METHODOLOGY - Includes a description of the approach, data collection, and analysis methodology

IV. ANALYSIS RESULTS - Describes the results of the project

V. CONCLUSIONS AND RECOMMENDATIONS

APPENDICES - There are five appendices, as follows:

- A - Feeder/Transformation Correlation Analysis Tables
- B - Summary of Feeder/Transformer Load Analysis Results
- C - Individual Feeder/Transformer Load Analysis Results
- D - Summary of Customer Load Analysis Results
- E - Individual Customer Load Analysis Results

2. GOALS AND OBJECTIVES OF PROJECT

The goals of the project are:

a. To determine the correlation between solar resources (instantaneous and cumulative daily insolation) and utility load data, defined as (1) Delmarva Feeders and Substations and (2) Customer-level data designed to identify the characteristics of feeders/transformers and customers best suited to the solar resources available in the service area.

   High correlation between loads and instantaneous solar resource indicates good candidates for PV Systems without storage. High correlation between loads and daily cumulative solar resource indicate good candidates for dispatchable PV Systems with batter storage.

b. Assess the degree of utilization of distribution feeders and transformers in the Delmarva service area, with an eye toward using PV Systems and other distributed technologies and measures, to increase their utilization and extend their life.

3. METHODOLOGY

AEG calculated the correlation between solar resources (with battery storage) and key load statistics for the utility load data categories indicated below, as well as for the instantaneous solar resource (without battery storage) and weekday daytime period loads. The key load statistics are categorized by the following time periods:

a. Afternoon peak period (hours 15-19)
b. All hours
c. System Peak hour (e.g. hour 17)
d. Weekday daytime period (hours 9-20)

e. PV System Peak Period (hours 11-14)

Correlation is defined as the degree of explanatory strength for one variable against another. A correlation of 1.0 would mean a perfect positive correlation, i.e., an increase in one variable would result in a proportional and constant increase in the other variable. Zero correlation would mean that there is no explanatory relationship between the variables. A negative correlation would mean perfect negative correlation, i.e., an increase in one variable would result in a proportional and constant <u>decrease</u> in the other variable.

Additional load summary statistics (monthly and annual load factors) and graphic representations of the load patterns of feeders/transformers and customers were also used to identify those characteristics and statistics associated with loads well matched to PV System installation.

4. ANALYSIS RESULTS

Based on the analysis, a set of criteria for identification of feeder/transformer types and customer types judged to be well-suited to PV System implementation were developed. A combination of the following characteristics would be considered important:

Primary Criteria:

1. High positive correlation ("r" value) between hour 15-19 loads and cumulative solar resource, on the order of +0.2 or higher. Observed correlations ranged from +0.37 to -0.40. Approximately 35 of the 385 total feeder/transformer data points (approximately 10%) produced correlations of at least +.20 or higher.

2. Reasonably high positive correlation ("r") between all hours and cumulative solar resource, on the order of 0.2 or higher, given high correlation already exists for hours 15-19. Approximately 60% of the feeder/transformer observations had

correlations exceeding +0.2 for both the total of 385 total feeder/transformers and also the 13 already meeting the first criteria above.

3. Low annual load factors, on the order of 30% or less, indicate high seasonality and, thus, fewer operating hours to reduce annual peaks.

Secondary Criteria:

4. Low average monthly load factors, with 70% load factors the maximum. High monthly load factors indicate too many hours for the PV resource to serve.

5. High percent maximum for top 10 hours. Given the same load level, higher percentage reductions achievable with 10 hours indicate better potential for PV System load reduction impacts.

A list of approximately 10 feeder/transformers meeting these criteria, along with about 20-30 others with relatively poor matches for comparison were then developed. All 27 customers analyzed were also evaluated against the criteria, with retail and supermarkets showing the best correlation, and hospitals and offices showing generally favorable, but mixed results.

5. CONCLUSIONS AND RECOMMENDATIONS

Analysis Conclusions

The results of the analysis confirmed that criteria could be established that would reasonably predict the degree of applicability of Dispatchable PV systems, as well as other distribution system measures and technologies, to specific categories of distribution feeders and substation transformers. Overall, the conclusion is that between 3-7% of the feeders/transformers would make good candidates for dispatchable PV.

The feeders/transformers are generally underutilized, based on the low load factors and relatively high amount of peak demand (as much as 20% - 25%) that could be reduced with as few as ten hours of load management, including Dispatchable PV.

Based on the customer correlation and load analysis results, Retail, Supermarket and Hospital sites are the best suited to Dispatchable PV Systems, with Offices possible candidates, given additional qualification.

Recommendations

We recommend that Delmarva expand the analysis of Dispatchable PV compatibility to the development of a true simulation model that can assess the performance characteristics of a Dispatchable PV System. A simulation model would determine how the solar resource would be assigned, either to the load or to battery charging and how the load would be met, through direct (instantaneous) PV or through battery discharge. The assignments would also be dependent on the targeted load reduction.

Additionally, analysis of the feeders and transformers could be expanded to include the nameplate ratings to assess the actual utilization, rather than just the utilization relative to the feeder/transformer peaks. This would also enable the identification and refinement of control strategies, including Dispatchable PV Systems, direct load control and targeted DSM.

II. OVERVIEW

1. GENERAL DESCRIPTION OF PV SYSTEM TECHNOLOGY

The promise of generating electricity from sunlight has always been appealing. Through the use of photovoltaics (PV), solar electric power generation has already become a cost-effective option for "off-grid" power generation (i.e., with no connection to the main utility power grid) because it provides environmental benefits (zero emissions), modularity, flexibility and low operating costs. For "on-grid" applications, there are a number of constraints, including poor coincidence between PV output and customer loads, poor coincidence with system peaks and lack of standardization. Delmarva Power & Light (Delmarva) has developed a modular and flexible dispatchable packaged system designed for on-grid applications that overcomes many of these problems by its modular design, battery storage and sophisticated control system. PV array energy output can be stored in the battery system and accessed during the period of declining PV System availability.

2. BACKGROUND OF PROJECT

Delmarva is interested in assessing the potential for grid-connected, dispatchable PV Systems in their service area. Delmarva seeks to take advantage of two of the principal uses of on-grid PV Systems - peak reduction and peak period energy shifting - to improve the cost-effectiveness of its capacity utilization, specifically its distribution system. Since the effectiveness of these strategies is largely dependent on the existing characteristics of the loads to which the PV System is to be applied, Delmarva initiated a Project to assemble data already collected on PV System performance and various load patterns and have it analyzed to assess PV System potential and target its efforts. Applied Energy Group, Inc. was retained to perform this project.

With the first system installed in Newark, Delaware in 1993, extensive instrumentation of the site was undertaken, including variables such as the Plane of Array (POA), which represents the Solar Resource available, temperature and system performance. With the availability of this detailed (15 minute or hourly interval) data, Delmarva was interested in assessing how well the PV System could be applied to other sites in its service area. Two scenarios were envisioned for this assessment:

1. Distribution feeders and substation transformers - Installation of a dispatchable grid-connected PV System at the utility's distribution feeder or substation transformer sites would enable Delmarva to reduce the system peak and also the local transformer loads. The cost-effectiveness of installing PV at these sites would be dependent on how well PV Systems could reduce loads at the time of local distribution system peaks.

2. Customer sites - Installation of a dispatchable grid-connected PV System at a customer site would enable Delmarva to reduce local distribution peaks, as well as offer the potential for customers to reduce their billing peaks. The cost-effectiveness for these sites would be dependent on both the utility distribution system peak reduction, but also the customer perspective billing peak reduction.

What was anticipated for the distribution feeders and substation transformers was that most were underutilized, requiring the equipment to meet peak load levels at or near the transformer capacity for only a small number of hours per year. Thus, if the loads for these hours could be adequately met by the use of PV or PV with battery storage, it could extend the life of the transformers and defer the upgrades significantly, reducing Delmarva's capital budgets. The degree of distribution system utilization is a major consideration in the PV System cost-effectiveness.

AEG was able to use the PV System load and weather data from the Newark, Delaware site, interval load data from all the distribution feeders and substation transformers in the Delmarva service area and a select group of customers covering a cross-section of commercial business types. This enabled an analysis of these loads and how well they correlated to the availability of the PV System resources, both with and without battery storage.

3. GOALS AND OBJECTIVES OF PROJECT

The primary goal of the project was to determine the correlation between the solar resource data (defined as the Plane of Array, or POA, in W/m^2) and two levels of utility load data, defined as (1) Delmarva Feeder/transformers and Substations (approximately 400 sites) and (2) Customer-level data (approximately 30 sites). The result of the project will be correlation analyses designed to identify the characteristics of feeder/transformers and customers best suited to the solar resources available in the Delmarva service area, and describe how well various types of feeder/transformers and customers, as well as the Delmarva System, relate to the solar resources available. The project deliverables will include this report, describing the results of the correlation analysis, and accompanying load shape analysis reports for categories of feeder/transformers and customers determined as well-suited to PV Systems.

As a secondary goal, the analysis of the feeder/transformers will assess the degree of utilization of the feeders and transformers in the Delmarva service area, with an eye toward developing strategies for increasing their utilization and extending their life. Some of these strategies could include other forms of distributed generation (small engine-generators, fuel cells), battery energy storage, and targeted DSM and direct load control.

III. METHODOLOGY

The way in which AEG accomplished the goals and objectives of the project was through analysis of the feeder/transformer loads, the customer loads and their correlation to the PV System resource; and further analysis of the load patterns of the feeder and transformer data, which provided statistics on the utilization of the feeders and transformers.

1. APPROACH

AEG performed analysis to measure the degree of correlation between two measures of solar resources and four levels of key load statistics for the utility load data categories. The two measures of solar resource are (1) instantaneous solar resource, recorded as the Plane of Array (POA) variable; and (2) cumulative solar resource, calculated by accumulating the POA variable for each day. The four key load statistics are categorized by the following time periods:

a. Afternoon peak period (hours 15-19)
b. All hours
c. System Peak hour (e.g. hour 17)
d. Weekday daytime period (hours 9-20)
e. PV System Peak Period (hours 11-14)

Solar resource data collected by Delmarva from a single station was considered a reasonable proxy for site-specific solar resources, since weather and solar insolation are consistent within a localized area such as the Delmarva Service Area.

Statistical tables and graphics were then generated to supplement the analysis and interpretation of the load vs. PV resource availability. Additional statistics were also developed to illustrate feeder and transformer utilization.

2. DATA COLLECTION

AEG obtained the following PV and weather-related hourly (or 15 minute interval) data:

1. Solar Resource, as defined by the Plane of Array (POA) variable in the database previously supplied from an instrumented PV site. The POA variable data included July 1993 through October 1994, except for a few days with missing data (12/10/93, hour 13 through 12/14/93, hour 14).
2. Weather data, including temperature, windspeed and humidity, for the same time period.

The following load data was obtained:

1. Hourly load data for all distribution feeders and substation transformers (approximately 400 in all) for the Delmarva System - This was provided on 9-track tape for the feeder/transformers in EEI 80-column format. Data for July 1993 through October 1994 were provided, but September 1993 through August 1994 was analyzed as the most complete 12 month period. The data was "cleaned" by reversing negative entries and excluding those defined by Delmarva as not applicable for analysis. Since EEI format is restricted to 5 digits of precision and data was provided in kW, the resolution of the data was limited to ± 1 kW per hour. For some of the smaller customers, this resulted in some loss of individual hour precision, but was not an major issue in the overall results.

2. Hourly load data for approximately 30 C&I customers covering a variety of business types, with business types identified - Load data was provided in LODESTAR direct output format. Data was provided for September 1993 through October 1994. To achieve the most complete data set, November 1993 through October 1994 was analyzed. Of the 30 customers provided, 3 were missing too much data to use and six others had minor data gaps (two

months), but were usable for the analysis, with minimal editing.

3. CORRELATION ANALYSES

AEG constructed separate correlation models designed to assess how well the solar resources (PV with battery) matched loads on feeder/transformers and customers for five key statistics (afternoon peak period, all hours, System Peak hour, daytime hours and PV System peak hours).

The "PV with battery" variable was defined as the cumulative POA variable, reset each day, which simulated the accumulation of solar resources into the battery system. This was considered the best proxy for this variable, although it could tend to overstate the available PV resources during the evening, since it does not reduce the available battery resource, as would occur in an actual installation.

The analysis was designed to qualify each feeder/transformer's potential for PV System applicability by performing a correlation analysis (Pearson's Product of Moment Correlation Coefficient, which produces a correlation "r") based on hour 15-19 load vs. "PV with battery". Based on this correlation statistic, the approximately 400 feeder/transformer loads were ranked and three sets of ten to fifteen load points identified - one set for the best correlation (well-matched), one for no correlation and one for negative correlation (load pattern counter to the PV resource availability).

A set of statistics was then prepared, and are presented on the attached Tables, entitled Summary of Correlation Analysis, provided at the end of Chapter IV, and in Appendix A. These consisted of the following, with descriptions and significance of the variable indicated. The "Col." refers to the column number for the statistic on the "Summary of Correlation Analysis" Table.

Col.	Statistic	Description and Significance

3	% Max load Top 10 Hrs	Based on load duration curve analysis of feeder/ transformer/customer, the load reduction percentage achievable if the highest ten hours were eliminated - Where the peak is concentrated in only a few hours, significant load reduction can be achieved by measures such as PV System implementation.
4	Correlation - Hrs 15-19	Correlation (Pearson "r" statistic) between hour 15-19 loads and cumulative solar insolation - Where the system critical hours are highly correlated with cumulative solar insolation, the site could be a good candidate for dispatchable PV.
5	Correlation - All Hrs	Correlation between all hours and cumulative solar insolation - Where all hours are highly correlated with cumulative insolation, the site could be a good candidate for dispatchable PV, given that peak hours are also highly correlated.
6	Correlation - Hr 17	Correlation between hour 17 (system peak hour) and cumulative solar insolation - Where the system peak hour is highly correlated with cumulative solar insolation, the site could be a good candidate for dispatchable PV, given that other periods are highly correlated.
7	Correlation - Hrs 9-20	Correlation between hour 9-20 (daytime) loads and cumulative solar insolation - Where all daytime hours are highly correlated with cumulative solar insolation, the site could be a good candidate for dispatchable PV.
8	Correlation - Hrs 11-14	Correlation between hour 11-14 (time of solar insolation peak) loads and cumulative solar insolation.
9	Corr. - PV Only 9-20	Correlation between hour 9-20 (daytime) loads and instantaneous solar insolation.
10	Load Factor - Annual	Ratio of average hourly demand (i.e., kWh divided by hours) to annual feeder/transformer/customer peak - High annual load factor would indicate more hours that PV resources would need to be available to reduce peak. Lower annual load factor would either indicate seasonal load or typical low daily load factors, either could indicate a good PV installation site.
11	Load Factor - Avg. Mon.	Average of monthly average hourly demand (i.e., kWh

		divided by hours) to monthly feeder/ transformer/ customer peak for all available months - High monthly load factors would indicate more hours for PV resources to supply, which may not be available if the load was not sufficiently weather sensitive.
12	Period kWh	Total of Period kWh - This establishes the general size of the feeder/transformer/customer
13	Peak kW	Peak kW - Larger customers would need a lower percentage of peak reduction to assess the sizing requirements for the PV System.

4. LOAD ANALYSIS

Three types of load analysis reports were used to support the qualitative and quantitative analysis of the PV vs. load profile data. These reports are:

a. General Load Model (GLM) summary statistics - These statistics were produced by AEG's PC-IDEAS System and imported into the AEG GLM Model analysis spreadsheet. These provide typical seasonal load shapes (tables and graphs) for peak day, weekday and weekend day, monthly load allocation and ratios of peak to average weekday and weekend day to weekday loads. These statistics support the interpretation of the load shape and assessment of its applicability to a PV System.

b. Load Duration Curves - This model produces both an annual load duration curve and a subset representing 10% of annual hours.

c. Load Factor Distributions - These tables and graphs illustrate the distribution of annual and monthly load factors for each of the feeder/transformers, which demonstrates the current degree of utilization in the Delmarva distribution system. Poor load factors indicate potential candidates for use of PV Systems and other distributed technologies.

Reports (1) and (2) were produced for each of the 27 customers and each of the 39 feeder/transformer load points included in the high, medium and low correlation groups. Report (3) was produced for the feeder/transformers only.

IV. ANALYSIS RESULTS

1. CORRELATION ANALYSIS

Based on the analysis of the statistical characteristics of the loads, combined with their corresponding degree of correlation to the cumulative solar insolation pattern characteristics (which simulate the resources available from PV Systems with battery storage), AEG has developed a set of criteria, based on the load pattern and correlation statistics, that indicate "good" and "poor" fits of load profile types to dispatchable PV Systems. The resulting criteria is actually a combination of statistics, because the analysis shows that no single load statistic can absolutely dictate whether the installation would be suitable for Dispatchable PV System implementation. The resulting conclusions are designed to enable targeting of Dispatchable PV Systems to those types of customers and feeders/transformers best suited, and thus most cost-effective, to a Dispatchable PV System installation.

Primary Assessment Criteria:

1. Correlation for Weekday Hours 15-19 - Correlation between hour 15-19 loads and cumulative solar insolation. All "good" candidates had relatively high correlations between these variables, on the order of 0.2 or higher. Observed correlations ranged from +0.37 to -0.40. Approximately 35 of the 385 total feeder/transformer data points (approximately 10%) produced correlations of at least +.20 or higher.

2. Correlation for All Hours - Correlation between all hours and cumulative solar insolation. Reasonably positive high correlations, on the order of +0.2 or higher, in conjunction with already high correlations for hours 15-19 are necessary to indicate a good candidate for Dispatchable PV. This criterion indicates that the differential between daytime loads and night-time loads are sufficiently different to mirror the solar resource available from the Dispatchable PV System. Approximately 60% of the feeder/transformer observations had correlations exceeding +0.2 for both the total

of 385 total feeder/transformers and also the 13 already meeting the first criteria above.

3. Annual Load Factor - The ratio of average hourly demand (i.e., kWh divided by hours) to annual feeder/transformer/customer peak. Low annual load factors, on the order of 30% or less, indicate high seasonality and, thus, few load reduction hours to reduce annual peaks. Sites with winter peaks would tend to have low correlations for all hours and peak hours, so low load factors, combined with positive results for the first two criteria, would indicate summer seasonality, a favorable characteristics for PV.

Secondary Assessment Criteria:

4. Average Monthly Load Factor - Average of monthly average hourly demand (i.e., kWh divided by hours) to monthly feeder/transformer/customer peak for all available months. This criteria is relevant in a negative sense if very high, on the order of 70% or more. High monthly load factors indicate high daily load factors and too many hours for the solar resource to serve.

5. Percent Maximum for Top 10 Hours - Based on the load duration curve analysis of feeder/transformer/customer, the load reduction percentage achievable if the highest ten hours were eliminated. The load level should be considered but, given the same load level, higher percentage reductions achievable with 10 hours indicate better potential for PV System load reduction impacts.

Other criteria, particularly other correlations, tended to mirror the results of primary criteria, so were not included as criteria.

Table 1 (for feeder/transformers) and Table 2 (for customers) are provided to summarize the results of the assessment. Appendix A includes the results of the correlation of the Hour 15-

19 load vs. PV with battery variables for every feeder/transformer (approximately 400).

Table 1 includes three sets of feeder/transformers:

(1) The 10 best-correlated (based on Hour 15-19 load vs. PV with battery variables, indicated in Column 4) and three others of the largest feeder/transformers. These were separated into groups "best", "better", "poor" and "worst" (Column 14), based on examination of all three principal criteria, i.e., cumulative solar insolation vs. All Hours (Column 5) and Annual Load Factor (Column 10).

(2) Ten poorly correlated (based on Hour 15-19 load vs. PV with battery variables, indicated in Column 4), plus four other large feeder/transformers. Similar feeder/transformers were grouped, with comments provided for each group (Column 14) on how each did not match the criteria.

(3) Ten negatively correlated (based on Hour 15-19 load vs. PV with battery variables, indicated in Column 4), plus two other large feeder/transformers. Similar feeder/transformers were grouped, with comments provided for each group (Column 14).

Table 2 lists all 27 customers analyzed, grouped based on business type. Comments are provided in Column 14.

In assessing the business type patterns, the following were observed:

- Retail - This was the best overall candidate, due to the late opening, summer seasonality, reasonably low load factors and good correlation for the key statistics (hours 15-19 and all hours)

- Supermarket - These showed reasonably good correlation, but load factors were generally too high because of the refrigeration load to make excellent candidates.

- Hospitals - Large hospitals showed good results for two of the three criteria (correlations between PV with battery and hours 15-19 and all hours), but the high annual load factors would preclude their designation as excellent candidates for PV Systems.

- Offices - The load patterns were not that consistent within this group. Most were well-correlated in all hours, but not during hours 15-19. Load factors were somewhat higher than optimal. These appear to be only marginally good candidates.

- Hotels - Poor correlations due to winter peaks

- Residential - These were generally not favorable, due to low daytime correlation or winter seasonal.

- Schools - These were not favorable, due to low correlation and low summer consumption levels.

- Other Groups - Warehouses could be good candidates, but load patterns in this group may not be consistent with the example used. The Dupont Research site is very large and probably too high a load factor.

The feeder/transformer results were generally more definitive than the customer results, owing primarily to a much larger base to choose from (400 feeder/transformers vs. 30 customers), out of which only the best, medium and worst correlated were selected.

2. FEEDER/TRANSFORMER LOAD ANALYSIS

The analysis of the feeder loads showed conclusively that distribution feeder/transformers and transformers in the Delmarva Service Area operate at low load factors, and may be underutilized relative to capital investment. Both annual and monthly load factors showed significant room for improvement. Annual load factors were generally clustered in the 30% to 50% range. Due to seasonality, especially in the summer, annual load factors may not be improvable, so monthly load factors were also analyzed, with the result that clustering between 50%and 75% was observed during most months.

Table 3 on the following page illustrates the distribution of monthly and annual load factors for all 382 feeder/transformers analyzed. Figure 1 and Figure 2 graphically illustrate the annual and monthly distribution, respectively.

In addition, for each of the feeder/transformers analyzed, a number of tabular and graphic statistics are provided in Appendices B and C, as follows:

- Appendix B provides annual statistics for each of the approximately 400 feeder/transformers and monthly analysis for each of the 39 feeder/transformers analyzed in detail.

- Appendix C provides a graphic analysis of each of the 39 feeder/transformers analyzed in detail, using the AEG General Load Model (GLM). This includes monthly breakdown, load ratios (load factor, coincidence factor, weekend day to weekday, peak day to typical day) and graphs of monthly breakdown, and seasonal hourly load shapes for peak day, typical weekday and typical weekend day. A set of load duration curves are also provided that illustrate the annual load duration and top 10% of hours load duration. Tables are also provided to show the load reductions possible based on a range of hours of load eliminated or shifted.

In analyzing the load duration curves of the larger feeder/transformers analyzed within the 39 selected for detailed analysis, the range of percentage load reductions achievable for only 10 hours of load control (via PV or other means) varied, but was 4% to 7% for the feeder/transformers most suited to PV System implementation (Table 1, page 1).

These factors clearly indicate that analysis based on load factors and load duration of loadings on feeder/transformers show significant potential for load reduction and higher utilization with the application of only modest load control or peak shifting measures, such as achievable with grid-connected dispatchable PV Systems. The analysis would be improved by converting each of the individual load factors, which are based on peak demands, to utilization factors, based on nameplate rating of the transformers and conductors associated with each feeder/transformer. Presumably, the transformers and other equipment are not typically overloaded, so the utilization factors would be even lower than the load factors illustrated in the analysis.

3. CUSTOMER LOAD ANALYSIS

For each of the 27 customers analyzed, a number of tabular and graphic statistics are provided in Appendices D and E, as follows:

- Appendix D provides customer information and load statistics for each of the 27 customers analyzed.

- Appendix E provides a graphic analysis of each of the 27 customers, using the AEG General Load Model (GLM), as provided for the feeder/transformers in Appendix C. That is, monthly breakdown, load ratios and graphs of monthly breakdown, seasonal hourly load shapes by day type and load duration curves.

TABLE 1

DELMARVA PHOTOVOLTAIC ANALYSIS

Summary of Feeder Correlation Analysis

			Correlation Coefficient						Load Factor				
		% Max. Load from	Cumulative Solar Resource					Inst. Solar Resource			Period kWh	Peak kW	
Group	ID Number	Top 10 hrs.	*hrs. 15-19*	*all hrs.*	*hr. 17*	*hrs. 9-20*	*hrs. 11-14*	*hrs. 9-20*	*annual*	*average monthly*	*(9/1/93 - 8/31/94)*		Conclusions
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Feeders with HIGH Levels of Correlation between Load and PV Data during Hours 15-19													
A-1	CARZT1W	25.8%	0.2891	0.3059	0.3171	0.2157	0.2838	0.3461	23.08%	41.22%	62,689	31	BEST MATCH
A-2	L6724WW	20.8%	0.2859	0.2317	0.2743	0.2158	0.2830	0.1852	18.01%	35.57%	75,712	48	The pattern of demand to the feeder closely matches
A-3	OCYZT1W	20.0%	0.3543	0.3647	0.3773	0.3093	0.3422	0.2115	27.45%	40.02%	36,070	*15*	that of a PV system. The feeder is supplying load
			highest	highest	highest	highest	highest	higher	low	higher			during the hours when a PV system would be active.
B-1	EMSAT1W	7.0%	0.2686	0.0522	0.2838	0.1592	0.1964	0.1461	38.42%	40.10%	336,523	100	BETTER MATCH
B-2	L3031CW	5.9%	0.2375	0.1127	0.2441	0.1838	0.2128	0.1347	31.60%	49.01%	188,119	205	The feeder is supplying a bit more load in the
B-3	L3009KW	4.6%	0.2774	0.1143	0.2764	0.1750	0.2476	0.1457	43.44%	48.84%	689,378	348	evening hours, also not conducive to a PV system.
B-4	L3009SW	4.4%	0.2803	0.1178	0.2798	0.1772	0.2511	0.1478	43.65%	49.16%	692,978	341	
B-5	L3832CW	4.2%	0.2500	0.1933	0.2451	0.1648	0.2308	0.1577	48.83%	42.18%	607,431	142	
			higher	high	higher	high	higher	high	high	higher			
C-1	SBR305W	3.7%	0.2160	0.2395	0.2741	0.0386	0.1875	0.3541	58.92%	35.82%	139,360	27	POOR MATCH
C-2	EMPF13W	0.0%	0.3213	0.3507	0.3611	0.2337	0.2972	0.2500	37.91%	36.41%	43,173	*13*	The feeder is providing more load during the evening
			higher	higher	higher	high	higher	higher	higher	high			hours than the daylight hours - not conducive to a
													PV system.
D-1	KNYA51W	*19.9%*	0.3089	0.0730	0.3058	0.2379	0.2928	0.1828	63.31%	50.02%	3,432,896	693	WORST MATCH
D-2	KNYA50W	1.9%	0.3091	0.0736	0.3059	0.2373	0.2958	0.1808	67.58%	45.66%	3,384,049	646	The feeder is supplying a maximum amount of load
D-3	TEXOILW	1.9%	0.2188	0.0916	0.2173	0.1685	0.2008	0.1019	81.73%	37.21%	386,620	54	for most of the hours during the day. The effect of a
			higher	low	higher	high	higher	high	highest	higher			PV system woulf be minimal due to the consistently
													high operating levels.

TABLE 1

DELMARVA PHOTOVOLTAIC ANALYSIS

Summary of Feeder Correlation Analysis

Group (1)	ID Number (2)	% Max. Load from Top 10 hrs. (3)	Correlation Coefficient: hrs. 15-19 (4)	Correlation Coefficient: Cumulative Solar Resource, all hrs. (5)	Cumulative Solar Resource, hr. 17 (6)	Cumulative Solar Resource, hrs. 9-20 (7)	Cumulative Solar Resource, hrs. 11-14 (8)	Inst. Solar Resource hrs. 9-20 (9)	Load Factor: annual (10)	Load Factor: average monthly (11)	Period kWh (9/1/93 - 8/31/94) (12)	Peak kW (9/1/93 - 8/31/94) (13)	Conclusions (14)
Feeders with MEDIUM Levels of Correlation between Load and PV Data during Hours 15-19													
	This group of feeders would be good candidates for PV plus battery systems, but not for purely PV systems. The load is poorly correlated with PV data during daylight hours. However, it is highly correlated over all hours.												Unlike PV systems, ...
A-1	WWIZT2W	19.6%	-0.0266	0.3938	-0.0254	-0.0008	-0.0066	-0.0126	35.86%	34.34%	144,502	46	... loads remain relatively high throughout the
A-2	EATOWNW	17.6%	-0.0176	0.3447	-0.0150	-0.0644	-0.0501	0.0343	38.10%	38.33%	226,944	68	afternoon hours.
			low	high	low	low	low	low	high	high			
B-1	HREZT1W	15.4%	-0.0202	0.4169	-0.0347	0.0357	-0.0233	-0.1305	50.77%	47.60%	92,206	23	... loads remain relatively high throughout the
B-2	CARAT1W	12.7%	-0.0128	0.4682	-0.0219	0.0829	-0.0173	-0.0982	45.56%	40.77%	283,360	71	afternoon hours.
B-3	NSAZT1W	11.4%	-0.0141	0.5153	-0.0150	0.1021	0.0055	-0.0868	46.99%	41.96%	144,073	35	
			low	highest	low	low	low	low	higher	higher			
C-1	MERZT1W	9.7%	-0.0195	0.3405	-0.0324	0.0092	-0.0647	-0.2142	*26.49%*	31.05%	71,930	31	... winter loads are relatively high peaking in the
C-2	L3719BW	7.2%	-0.0358	0.2775	-0.0450	-0.0276	-0.0775	-0.1018	45.83%	37.25%	516,468	156	morning.
C-3	MTHZT2W	7.9%	-0.0185	***0.4137***	0.0074	-0.0947	-0.0238	0.0965	49.16%	41.13%	163,658	38	
			low	higher	low	low	low	lower	higher	high			
D-1	L6835DW	7.5%	-0.0228	0.2326	-0.0352	-0.0334	-0.0485	-0.0073	23.00%	29.76%	80,607	40	... loads peak in the winter.
D-2	L6768CW	4.1%	-0.0208	0.2252	-0.0209	-0.0497	-0.0578	-0.0977	***39.29%***	27.48%	168,652	49	
			low	higher	low	low	low	low	low	low			
E-1	EMPZG3W	3.5%	-0.0269	0.2644	0.0233	-0.0734	-0.0957	-0.0334	60.33%	35.23%	454,532	86	... loads tend to remain high and flat throughout the
E-2	DELZG2W	3.2%	-0.0185	0.2551	-0.0150	0.0352	-0.0351	-0.0041	68.73%	39.13%	186,645	31	afternoon and evening hours.
E-3	DELZG1W	3.1%	-0.0256	0.2998	-0.0314	0.1072	-0.0431	-0.0446	76.19%	34.90%	213,585	32	
E-4	EMPZG4W	1.8%	-0.0160	0.4002	0.0196	0.0059	-0.0582	-0.0486	72.32%	37.30%	1,051,670	166	
			low	higher	low	low	low	low	highest	high			

TABLE 1

DELMARVA PHOTOVOLTAIC ANALYSIS

Summary of Feeder Correlation Analysis

Feeders with LOW Levels of Correlation between Load and PV Data during Hours 15-19

Although this group of feeders would not be the first choice of candidates for PV plus battery systems, purely PV systems would provide little benefit. The load is poorly correlated with PV data during daylight hours.

Unlike PV systems, ...

Group (1)	ID Number (2)	% Max. Load from Top 10 hrs. (3)	Correlation Coefficient: Cumulative Solar Resource hrs. 15-19 (4)	Cumulative Solar Resource all hrs. (5)	Cumulative Solar Resource hr. 17 (6)	Cumulative Solar Resource hrs. 9-20 (7)	Cumulative Solar Resource hrs. 11-14 (8)	Inst. Solar Resource hrs. 9-20 (9)	Load Factor annual (10)	Load Factor average monthly (11)	Period kWh (9/1/93 - 8/31/94) (12)	Peak kW (9/1/93 - 8/31/94) (13)	Conclusions (14)
A-1	L22039W	9.9%	-0.2813	0.3469	-0.2709	-0.1853	-0.2396	-0.1571	*28.10%*	48.92%	929,511	618	... loads peak in the winter, and loads are relatively
A-2	HOCZT3W	5.9%	-0.2851	0.2880	-0.3111	-0.2190	-0.3421	-0.3450	42.41%	48.47%	48,201	*16*	high throughout the afternoon and evening hours.
A-3	L6739SW	5.1%	-0.2402	0.2775	-0.2565	-0.1362	-0.2385	-0.2677	50.26%	33.01%	171,724	39	
			lower	higher	lower	low	lower	lowest	high	high			
B-1	L6702VW	10.5%	-0.2212	0.2097	-0.2302	-0.2140	-0.1877	-0.1139	42.69%	41.94%	284,182	76	... loads peak in the winter, and the peak occurs in
B-2	L3002PW	8.0%	-0.2407	0.2349	-0.2352	-0.1947	-0.1924	-0.1308	54.83%	48.26%	870,899	229	the morning.
B-3	L3002IW	7.9%	-0.2344	0.2391	-0.2280	-0.1892	-0.1847	-0.1265	54.44%	48.34%	853,718	223	
B-4	L6742HW	5.6%	-0.3901	0.1541	-0.3832	-0.3534	-0.3330	-0.1582	50.59%	35.61%	159,543	36	
B-5	L22043W	2.5%	-0.2559	0.3469	-0.2454	-0.1643	-0.2205	-0.1552	47.17%	47.83%	1,219,542	447	
B-6	IRPZG4W	0.7%	-0.2515	0.1141	-0.2628	-0.1645	-0.2098	-0.1635	66.55%	55.12%	1,243,028	430	
			lower	lower	lower	lower	lower	lower	higher	higher			
C-1	CHRYLDW	10.4%	-0.3420	-0.0664	-0.3455	-0.2524	-0.3143	-0.2344	21.34%	35.05%	448,703	240	... load peaks in the winter.
			lowest	low	lowest	lower	lowest	lower	low	high			
D-1	IRPZG1W	8.7%	-0.2474	0.0864	-0.2434	-0.2360	-0.2491	-0.1465	64.17%	50.53%	226,684	92	... load tends to remain relatively high and flat.
			lower	higher	lower	lower	low	lower	higher	higher			
E-1	L6734HW	5.8%	-0.2603	0.2349	-0.2528	-0.2424	-0.2546	-0.1707	43.06%	31.44%	196,141	52	... load peaks in the winter.
			lower	higher	lower	lower	lower	lower	higher	high			

TABLE 2

DELMARVA PHOTOVOLTAIC ANALYSIS

Summary of Customer Correlation Analysis

Group	ID Number	% Max. Load from Top 10 hrs.	Correlation Coefficient: Cumulative Solar Resource hrs. 15-19	all hrs.	hr. 17	hrs. 9-20	hrs. 11-14	Inst. Solar Resource hrs. 9-20	Load Factor annual	Load Factor average monthly	Period kWh (11/1/93 - 10/31/94)	Peak kW	Conclusions
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Data on 27 Delmarva Customers													
NRS HOME-1	A4N0941	6.7%	-0.1914	0.1071	-0.1856	-0.2193	-0.2193	-0.1268	29.30%	56.92%	1,178,035	551	Relatively flat shape with load peaking in the winter.
HEALTH-1	A3N2661	4.8%	0.0964	0.2613	0.1046	-0.0651	0.1245	0.3036	43.92%	58.81%	1,616,224	420	GOOD
HEALTH-2	A3N2425	2.5%	0.2595	0.2991	0.2733	0.2278	0.2594	0.4042	58.99%	74.52%	13,533,070	3,145	GOOD
HEALTH-3	A3N3145	2.3%	0.3995	0.3608	0.4279	0.3210	0.3736	0.2962	55.32%	72.43%	29,553,590	6,099	GOOD
HOTEL-1	A5N1881	7.7%	0.0094	0.2121	0.0244	-0.0210	-0.0208	-0.4826	39.62%	62.50%	1,283,327	444	Load peaks in the winter.
HOTEL-2	A5N1261	7.1%	-0.3875	0.1301	-0.3930	-0.3662	-0.3701	-0.1576	52.12%	76.43%	4,542,079	995	Relatively flat shape with load peaking in the winter.
HOTEL-3	A3N2131	6.6%	-0.0818	0.1310	-0.0791	-0.1346	-0.1091	-0.3023	39.67%	58.50%	1,901,035	547	Load peaks in the winter.
OFFICE-1	A5N1791	27 5%	-0.0730	0.2975	-0.0398	-0.0842	-0.0889	0.1028	39.67%	57.37%	3,687,649	1,274	Low weekend usage.
OFFICE-2	DUPBAR1	14.1%	-0.1454	0.0788	-0.0871	-0.3084	-0.1183	0.1786	26.56%	43.05%	18,569,920	7,980	Low weekend usage with load peaking in the winter.
OFFICE-3	A3N1075	11.0%	-0.0154	0.3478	0.0722	-0.1789	0.0661	0.3403	47.87%	59.13%	8,645,815	2,476	Low daytime correlation.
OFFICE-4	A5N1401	10.5%	0.1687	0.2683	0.2726	0.1507	0.2583	0.2607	32.82%	46.68%	2,563,070	891	Low weekend usage with load peaking in the winter.
OFFICE-5	A5N163A1	7.1%	0.0491	0.2066	0.1063	0.0525	0.0827	0.0708	47.42%	57.97%	2,341,079	564	Low weekend usage.
OFFICE-6	DUPCHS1	3.1%	0.1132	0.1632	0.1767	-0.0736	0.1294	0.3359	49.01%	59.58%	36,028,490	8,391	Low weekend usage.
OFFICE-7	A3N3241	2.5%	0.0133	0.2845	0.0495	-0.0210	0.0246	-0.0442	73.19%	79.04%	12,087,130	1,885	Relatively high and flat load shape (poss. load cntrl.).
OFFICE-8	A5N1021	1.9%	0.1938	0.2317	0.2658	0.1656	0.2171	0.1142	49.11%	52.94%	3,005,130	699	Low weekend usage.
RESEARCH-1	DUPEXB1	1.9%	0.2476	0.2412	0.3056	0.0827	0.2403	0.3421	60.79%	74.86%	130,909,600	24,584	Low weekend usage.
HTG. RESDNT.-	A3N1121	7.7%	-0.1952	0.0489	-0.2126	-0.1565	-0.2373	-0.2123	32.96%	56.65%	1,583,071	548	Relatively flat shape with load peaking in the winter.
N H. RESDNT.-1	A3N2511	2.0%	0.1632	0.3798	0.1454	0.0977	0.1157	-0.5988	59.35%	74.82%	7,007,602	1,348	High load factor.
RETAIL-1	A3N1675	15.8%	0.3737	0.5983	0.4051	0.4875	0.3728	0.0291	35.61%	50.25%	1,936,104	621	GOOD
RETAIL-2	A3N3481	11.1%	0.2130	0.4849	0.2508	0.2839	0.0644	0.1511	44.12%	54.79%	1,802,674	560	GOOD
RETAIL-3	A3N1571	4.4%	0.3648	0.6978	0.3686	0.4989	0.2876	-0.1370	48.51%	55.86%	21,040,000	4,952	GOOD
SCHOOL-1	A3N1901	4.9%	-0.1684	0.1995	-0.1681	-0.3288	-0.1576	0.2758	40.32%	47.24%	1,787,124	506	Low weekend usage with load peaking in the winter.
SCHOOL-2	A3N1441	4.5%	0.1069	0.2474	0.1466	0.1976	0.1380	0.2424	45.70%	53.71%	4,770,737	1,192	Low weekend usage.
SCHOOL-3	A5N0771	2.7%	0.0598	0.2357	0.0784	-0.2142	-0.0305	0.2679	39.20%	48.00%	1,763,747	514	Low weekend usage.
SUPERMRK -1	A3N2681	3.3%	0.3707	0.4681	0.3772	0.2620	0.2456	0.1285	67.05%	80.89%	2,477,505	422	GOOD
SUPERMRK -2	A5N1321	0.8%	0.4534	0.5744	0.4688	0.4321	0.4024	0.1301	72.40%	82.34%	3,300,382	520	GOOD
WAREHSE -1	A3N1551	2.7%	0 2948	0.3901	0.3194	0.3325	0.2285	0 2569	51.24%	66.54%	9,526,429	2,123	Relatively flat shape with low weekend usage.