Long Term Operation of Renewable Energy Building

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ABSTRACT
As part of a renewable energy project, a building was designed and constructed to demonstrate several renewable energy technologies at the Wind Test Center of the Alternative Energy Institute (AEI). The systems are passive and active heating, solar hot water, daylighting, passive cooling, and generation of electricity from a 10 kW wind turbine and 1.9 kW of photovoltaic panels, each connected to the utility grid through inverters. Since 1991, 16,900 kWh have been purchased and 31,300 kWh returned to the utility grid. A significant portion of the purchased power has been used in charging our electric van. The building does not have auxiliary heating or cooling systems powered by fossil fuels. A data acquisition system monitors building, exterior, and system temperatures as well as power outputs of the wind and PV systems. The data are sampled at 1 Hz and averaged each 15 minutes. Annual, seasonal and diurnal patterns are shown in graphical format. Temperatures for the coldest days of winter and hottest summer days are also presented.

INTRODUCTION

The renewable energy demonstration project was begun in 1991 and finished in 1992. The building was designed by L.M. Holder III, Austin, TX. All the heating and cooling features were selected and optimized using computer simulations. The 30' X 75' metal building is divided into a 50' long workroom and a 25' long tech room. Systems included in the building are: passive heating by direct gain for the tech and work rooms, two solar hot air collectors with rock storage under the work room, solar hot water, daylighting, and night ventilation (manual) for cooling. Low 'E' glass in a wood frame was used for all windows, with minimum glass on the north and west and seasonally shaded glass on the east. Spraying a radiant barrier paint on the underside of the roof panels and using a ventilated ridge reduced the impact of the sun during the summer and decreased "black sky" radiation on clear winter nights. Tyvek infiltration barrier was installed throughout the roof and wall systems. Daylighting for the entire workroom area is provided by a continuous glass strip above the solar panels. With the white insulation and metal surfaces painted white, lights are only necessary at night, even on the most cloudy days. Ceiling fans in the work room provided increased air movement during the cooling season. A 10 kW wind turbine and 1.9 kW PV panels provide utility power for the building (Fig. 1). The charger for an electric van is included in the load of the building. Two utility meters measure the amounts of electricity purchased or fed back to the utility company. The project also includes standalone photovoltaic yard lights and sign.

The hot air systems (Fig. 2) were designed by Jimmy Walker, Vega County Extension Agent, who also helped in the construction. There are 234 square feet of solar air collectors mounted vertically to the south face of the building. One solar collector has tempered glass glazing and the other an FRP glazing. The thermal mass consists of 1' of washed rock under the work room area with 6" of concrete on top. In the tech room there are 5 water tubes and a filled concrete block wall on the north for thermal mass. The tech room has a 8' ceiling and small storage area which contains the data acquisition system, the storage tank for the hot water system and the inverters for the wind and PV systems.

MONITORING

These systems are monitored by AEI personnel (recording kWh, times of opening and closing of windows and repairs) and a PC with an interface designed and built at AEI. This interface connects wind speed, wind direction, and 16 temperature sensors located in the building, outdoors and in the solar systems directly to the parallel printer port. A C++ program samples these signals each second, adds the current point to a running summary and then averages the values every fifteen minutes along with calculating the standard deviation and recording the maximum and minimums each day. Instantaneous data and the fifteen minute averages, today and previous day, are displayed on a monitor. The screen is updated every 30 s, showing each sensor in turn.

RESULTS

Heating The yearly pattern of interior, tech room and work room temperatures show the same basic shape (Fig. 3). Solar buildings are not isolated from the environment, however they capture the solar energy and moderate the flow of the heat. In general the nights are cool in the summer (Fig. 4), as shown by the temperature for the average day in a month. The average interior temperatures are much above the outside temperature in winter and reach the same value in the summer. The tech room temperatures (Fig. 5) in winter are a little higher because the walls have R 21 insulation and a lower ceiling compared to the work room with R 13 insulation in the walls. Even after 4 cloudy days of below freezing weather, the temperatures inside are still acceptable (Fig. 6), especially since there is no auxiliary heating or cooling. The same is true during the summer, inside temperatures are acceptable (Fig. 7).

The active air collector systems are typically operated from September 1st to April 1st. Collector temperatures are still monitored year round but the heat is not dumped to the rock storage. The summer temperatures are not as high as winter since the collector is vertical and actually has greater intercept area in the winter than in the summer. Air temperatures from the rock storage show that they heat up during the early autumn after the system is initially turned on and then fall gradually throughout the winter, rising again in the spring. The peak in the summer is from residual heat in the building affecting the temp sensor. The collector with the fiberglass glazing heats up sooner in the early winter mornings, the fan turns on sooner and runs longer. During construction, the rocks and piping system were left uncovered over a weekend during a rainstorm. After 2 years of operating the system, most of the moisture was driven from the rocks. There were several small desiccant packages placed in the solar panels as they were assembled. However there were some water leaks and there has been condensation on the interior of the glazing.

Cooling Nighttime ventilation has worked well, however manual operations are not always done consistantly. Personnel need to open windows in the afternoon or evening and must remember to close windows early in the morning and leave them closed until internal temperatures are uncomfortable. Several times the windows were left open continuously since the feeling of a breeze makes the personnel feel better. But by examining the data, it was shown that this just allowed hotter exterior air into the cooler interior space, equalizing the two. When the interior ceiling and floor fans were combined to increase air circulation inside the work and tech areas, workers expressed satisfaction with the system.

Daylighting The eave of the roof extends about 8", which allows direct sunlight, and corresponding heat, to enter the building during the fall and winter seasons and indirect light during the summer. The large windows to the East give direct and indirect light throughout the year, controlled by installing and removing shutters seasonally. Lights are only needed at night.

Solar Hot Water The typical water temperatures from the collector range from 176 - 248 degrees F. The storage system is a dual input hot water tank with insulated input and hot output lines. The heat exchange coil inside the tank takes up about 5 gallons of the 35 gallon capacity. The propylene glycol mixture has a color additive to show if there are any system leaks inside the tank.

PV Standalone Lighting The PV remote lights worked at the beginning, but failures of ballasts and controllers, and replacement of batteries has made their continued operation difficult and expensive. However, the sign lighting system has worked flawlessly, so it is a quality control problem.

Wind and Solar Electricity The wind turbine and PV panels are each connected to an inverter, which means they are independent. More electricity is generated than used on site, typically double. Since 1992, 31,300 kWh have been fed back and 16,900 kWh have been purchased from the utility. The PV panels are fixed and the average power output is very predictable (Fig. 8) with the peak period between 10:00 and 15:00. An unexpected benefit of having the PV panels on hand was when the electric van charger failed. The battery voltage on the van fell below the 1.2 volts/cell needed for the charger to recognize that the batteries were connected. Using the solar panels as a slow charger we were able to bring the volts/cell back up to 2.0 and then the standard charger would operate on the battery pack normally.

Wind power is much more variable, both by day and season (Fig. 9). There have been some problems with both inverters and for the wind turbine the alternator and blades have been replaced.

CONCLUSION

Overall it has been a successful project. Personnel now have a place to work on wind turbines which is out of the wind and in a temperature ameliorated from the outside temperature. In 1994 this project received a National Energy Award for Energy Technology and Education, sponsored by the U.S. Department of Energy.

We have had more than 40 groups of visitors including local, national and international groups. K-12 schools visit at regular intervals. We have sponsored visits from international renewable energy trainees from more than 12 countries for hands on work experience at the demo project.

ACKNOWLEDGMENTS

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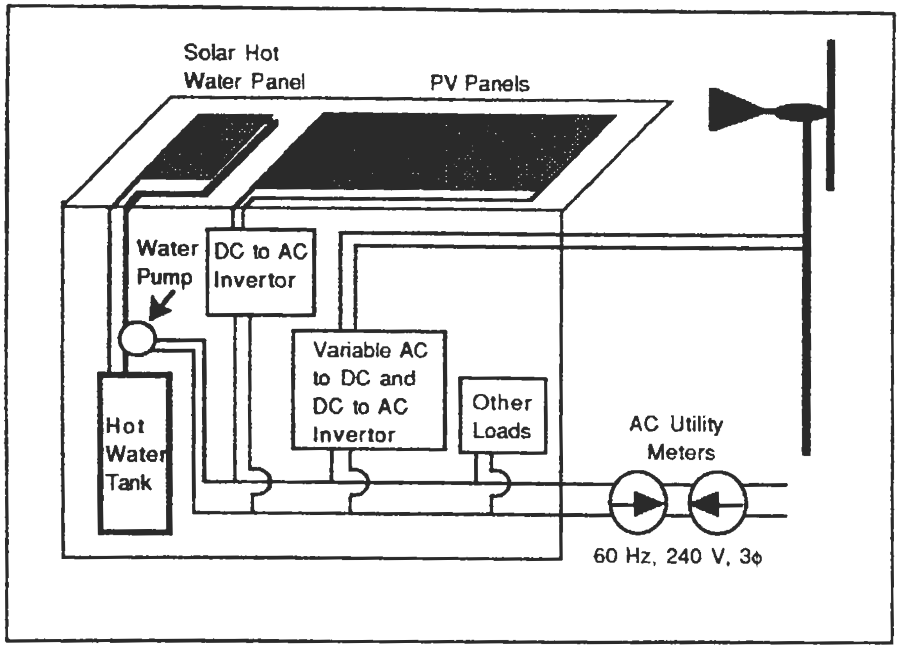

Figure 1. Schematic layout of electrical systems of demo building

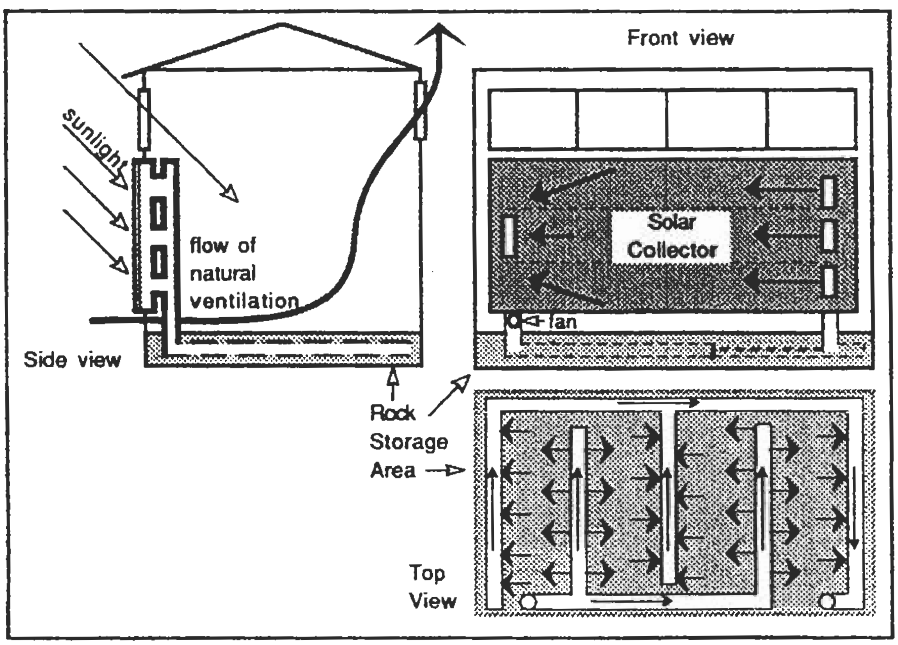

Figure 2. Solar hot air collector schematic, side, front and top view.

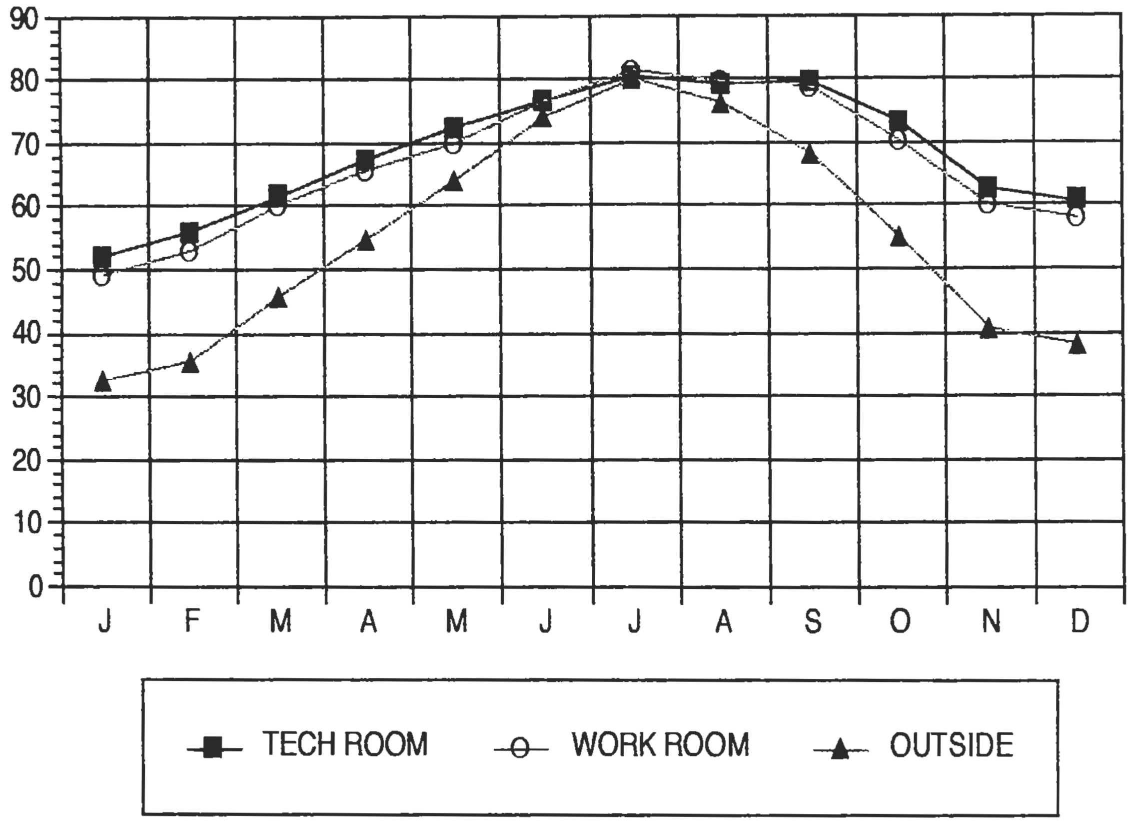

Figure 3. Yearly pattern of outside ambient, technology and work areas.

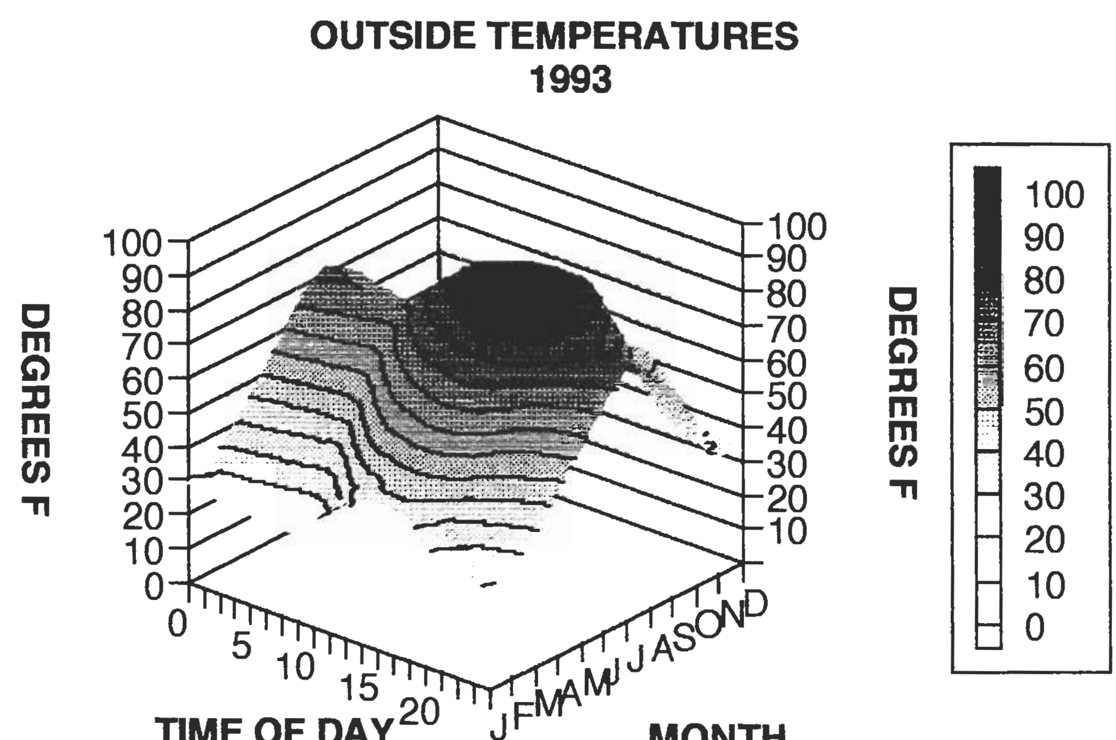

Figure 4 Outside ambient temperatures averaged by month and time of day.

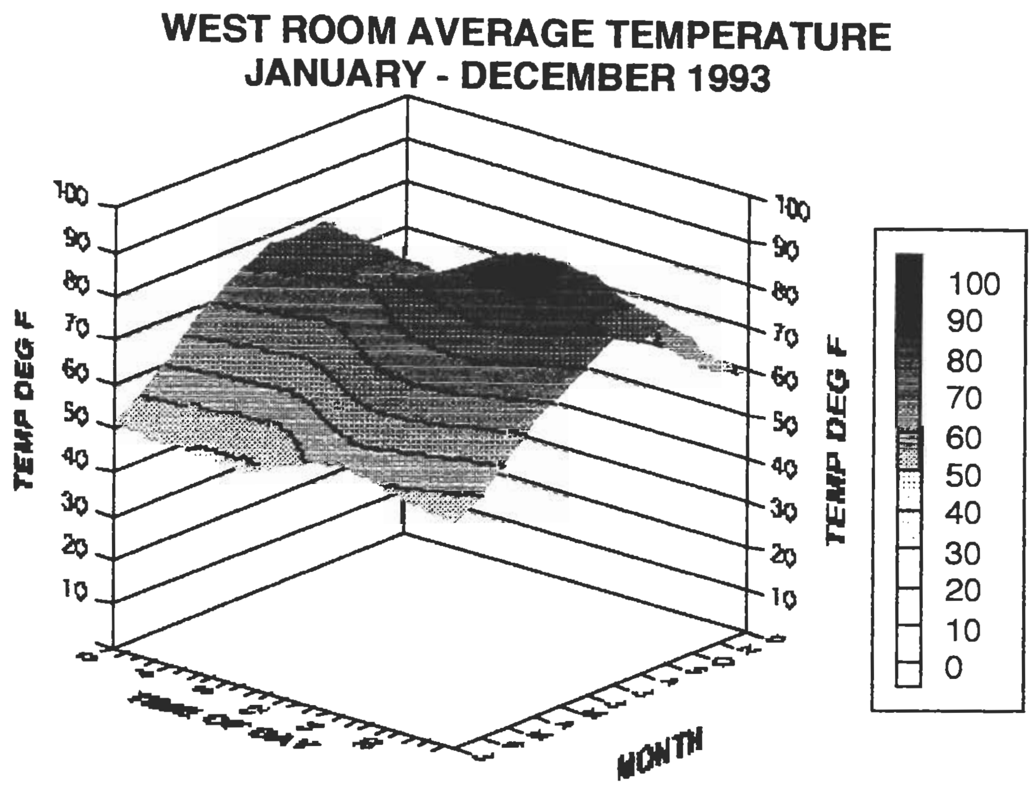

Figure 5.

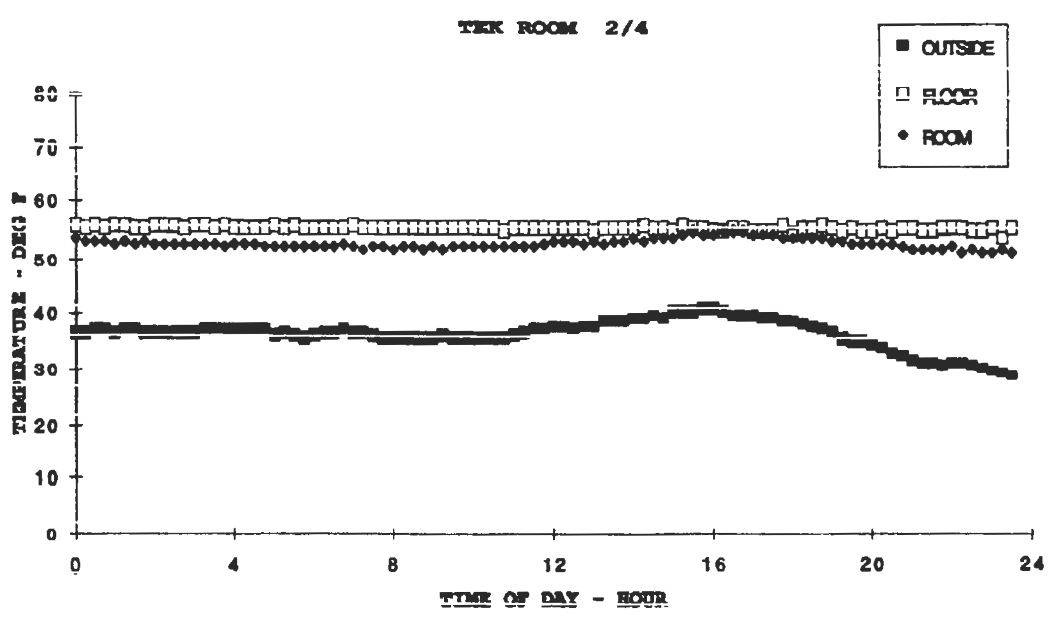

Figure 6 Tech room temperatures after 4 cloudy days of below freezing weather.

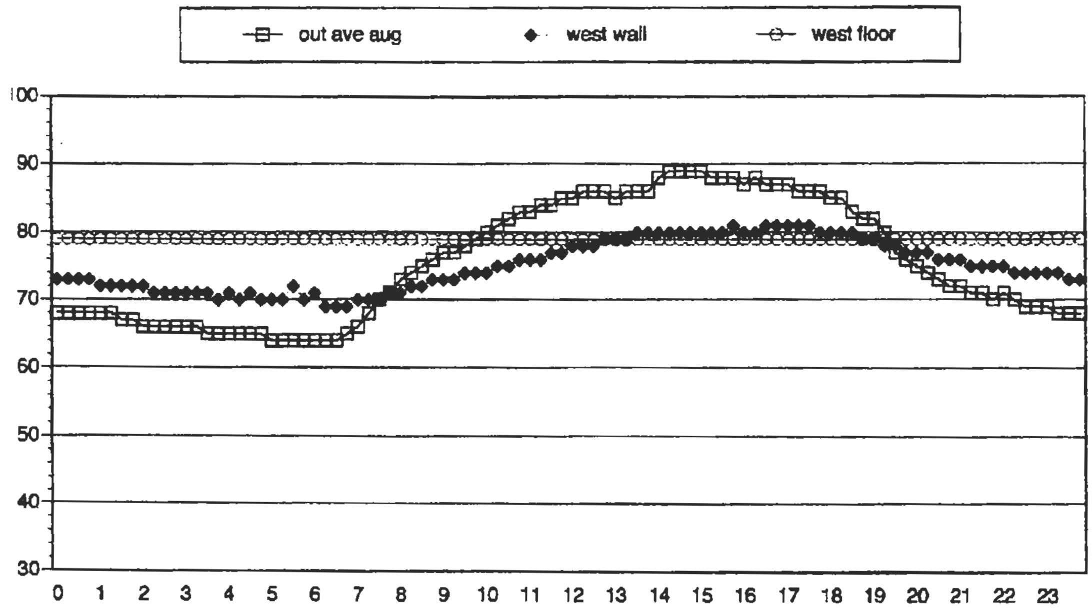

Figure 7 Tech room average temperatures August 1993.

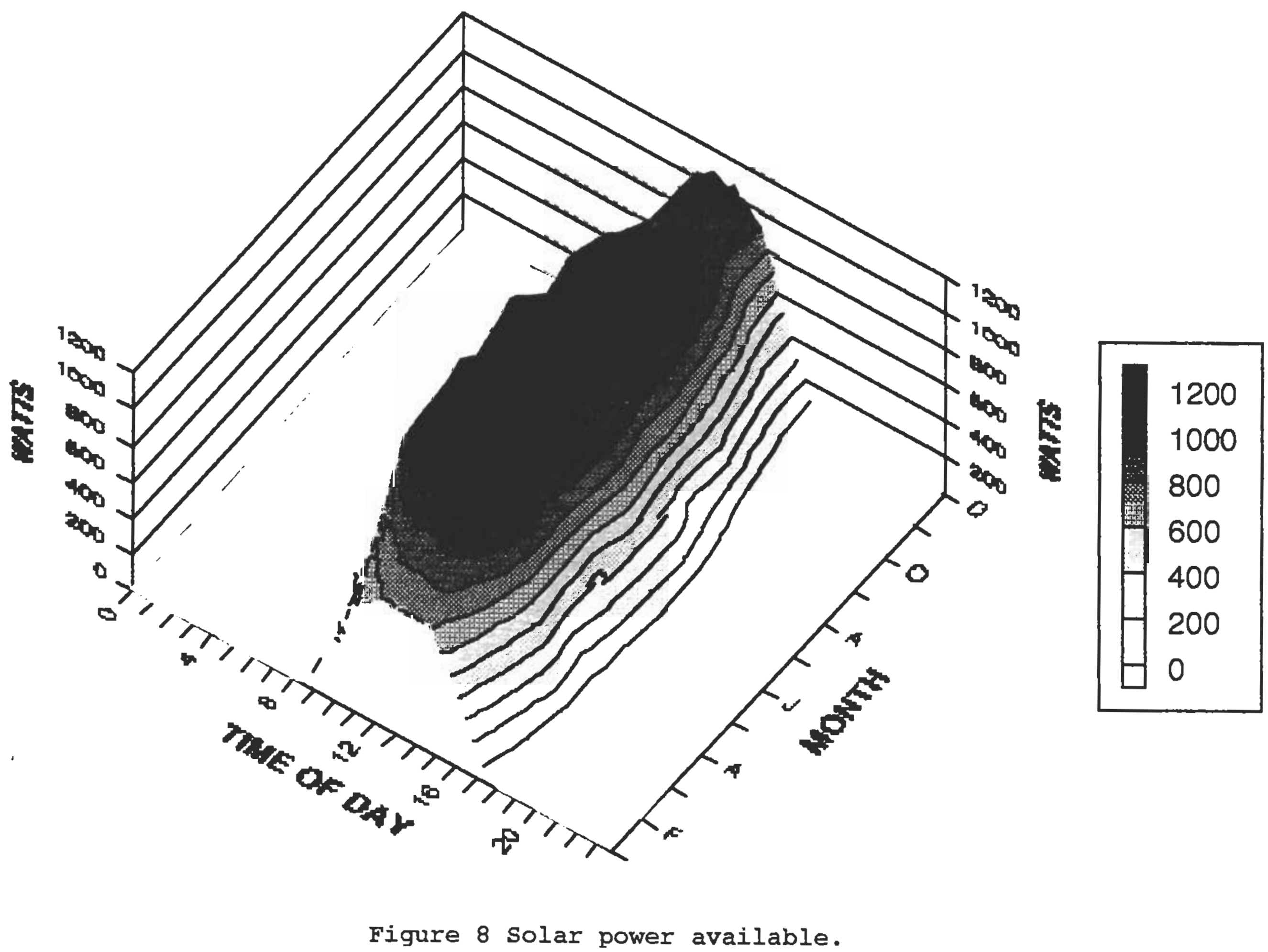

Figure 8 Solar power available.

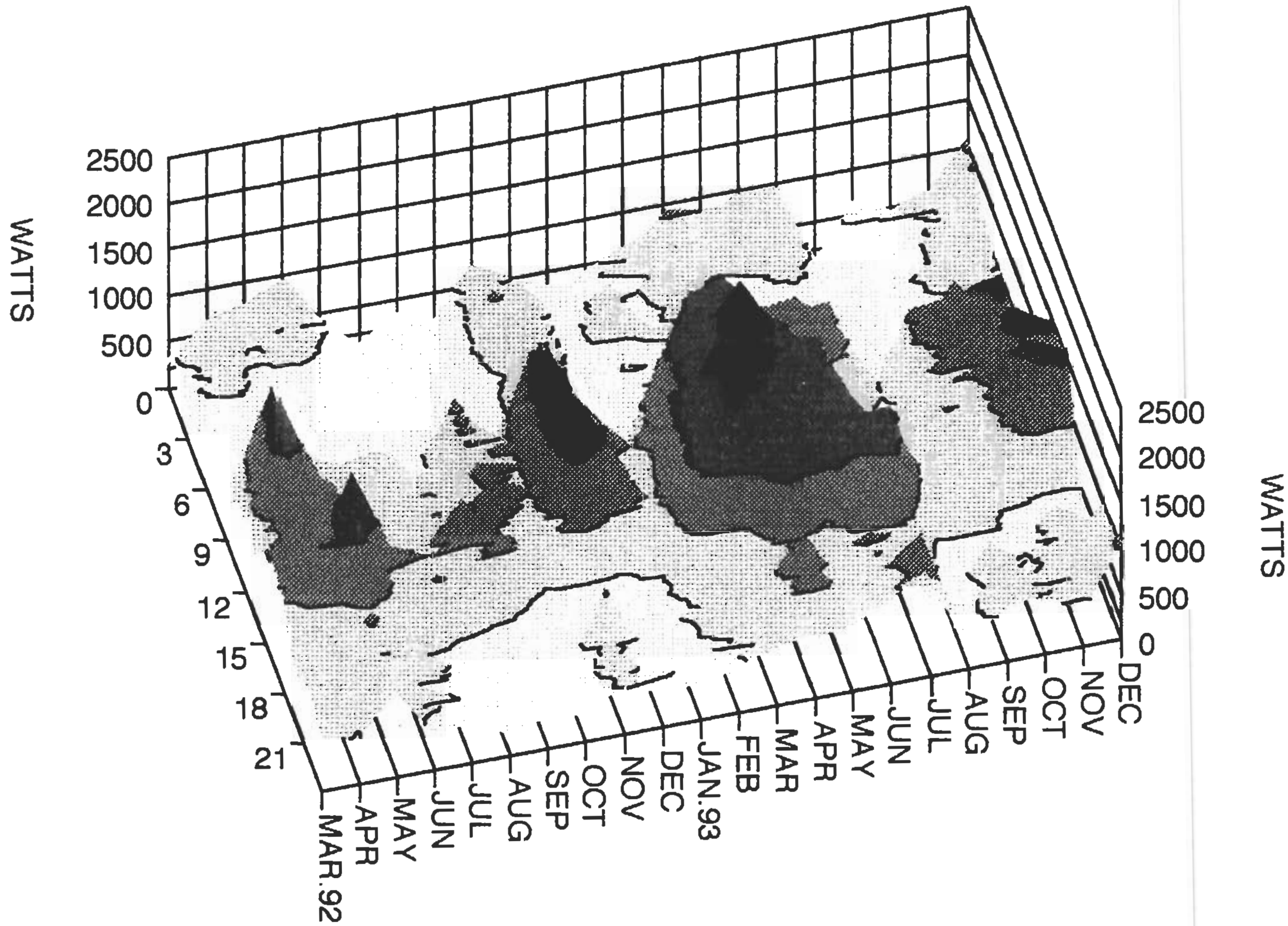

Figure 9.Wind power available.