NOAA Technical Memorandum NWS WR-161

SOLAR RADIATION AS A SOLE SOURCE OF ENERGY FOR PHOTOVOLTAICS IN LAS VEGAS, NEVADA, FOR JULY AND DECEMBER

Salt Lake City, Utah
April 1981

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)

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Las Vegas, Nevada
April 1981

UNITED STATES DEPARTMENT OF COMMERCE / NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service
Richard E. Hallgren, Director

This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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SOLAR RADIATION AS A SOLE SOURCE OF ENERGY FOR PHOTOVOLTAICS IN LAS VEGAS, NEVADA, FOR JULY AND DECEMBER

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ABSTRACT. Hourly global radiation data collection by the National Weather Service in Las Vegas, Nevada, is analyzed. Only the data for July and December 1977 and 1978 are used. Global radiation data represent the total direct solar radiation plus diffuse sky radiation received by a horizontal surface. The median, maximum, and minimum radiation days for both July and December are identified. In addition, the diurnal variation in the cumulative frequency distribution of the hourly global radiation data is graphed for both months. Based on photovoltaics, these charts are used to evaluate the expected solar energy supply for a given area of exposure. Example calculations are given to demonstrate how to find the total area of solar cells needed to supply the total energy demands of an all-electric home. Calculations show that if the solar cells are at least 20% efficient, enough energy is usually available to meet total household demands in July if at least 75 to 80 m of area are available with an unobstructed view of the sun. Twice as much area is needed for a 10% efficiency rating. Analysis of the data suggests that solar energy is a restricted resource in December.

I. INTRODUCTION

"Enough solar energy reaches the earth in one day (4×10^{15} KWh) to supply the entire energy demands of the world for one year (8×10^{13} KWh)", states the enthusiast for solar energy. Of course, this statement is the truth but not the whole truth. Locally, the amount of solar radiation reaching the ground depends on the distance from the sun to the earth, the time of day, the date, latitude, cloud cover, and the transmissivity of the atmosphere. The processes of scattering, absorption, and reflection also contribute to the depletion of solar radiation. Consequently, by the time the radiant energy arrives at the ground, it is very dilute, requiring a large collection surface to produce large quantities of energy (e.g., see Beckmann, 1980). This shortcoming does not mean that solar energy should be overlooked as an important supplemental energy source. However, it should not be oversold as a panacea for our national energy demands. The reason is quite simple.

Solar energy is a restricted resource in the sense that it is not always available on demand. Perhaps the greatest restriction is that the maximum possible amount of solar radiation received <u>at sea level</u> is approximately

1 KW/m^2 or 317 $BTU/ft^2/hr$.† Of course, this amount of radiation is only available under ideal conditions; for example, at local noon, with clear skies, excellent transmissivity, and with a collection/conversion system that is 100% efficient. At night, no solar radiation is available for energy production so that storage or a supplemental source is required for those who desire to use energy.

One question a thoughtful consumer will ask is whether or not the expense of installing and maintaining a solar energy system is economically justified when mass-produced energy is available at about 5¢/KWh. This question is rather complex; however, one fundamental part of it relates to the availability of solar radiation at the geographical location of interest. If the solar resource is small, then the practicality and cost effectiveness of solar energy may not be justifiable.

This report is designed to provide quantitative information on the diurnal distribution of solar radiation received on a horizontal surface in a very sunny place: Las Vegas, Nevada. The analyzed data can be used as input for determining the collection area needed to meet energy demands in the Las Vegas area. If not enough solar energy is received in Las Vegas, other areas surely will find solar radiation a limited resource. Indeed, for the continental United States, Las Vegas receives more solar radiation than most cities. Consequently, it can be regarded as a fairly accurate approximation to the upper limit to the availability of solar radiation at the ground. A brief summary of solar energy conversion systems has been prepared by Jannuzzi (1978) and therefore will not be addressed here.

II. DATA

Recent hourly solar radiation data for Las Vegas, Nevada, are used to portray the solar energy received during two extreme months: July and December. These two months were selected because the 1977 and 1978 data sets were more complete than those from June and January. The data were extracted from the Monthly Summary, Solar Radiation Data, published by the National Oceanic and Atmospheric Administration, Environmental Data and Information Service. Hourly totals of solar radiation for each day of July and December 1977 and 1978 were used to develop the charts in this report. The hourly data end on the hour, local standard time. There were three days with some missing hourly values for the July data so that total global radiation was available for a total of 59 July days.

Global radiation is the total direct solar radiation plus the diffuse sky radiation received by a horizontal surface. An Eppley (PSP) pyranometer is used to measure global radiation at the National Weather Service Office at McCarran International Airport, elevation 670 m above mean sea level (MSL).

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†An hourly value of 1.0 KW/m^2 is suggested as useful maximum value because a review of the available solar radiation data for the United States shows that this value is rarely exceeded by more than 5% for sea-level stations. A flux of 1 KW/m^2 happens to be approximately 75% of the solar constant of 1.4 KW/m^2.

III. GLOBAL RADIATION FOR JULY

A. Median Day:

Hourly global radiation data for both July 1977 and 1978 show that the total daily solar radiation received in Las Vegas ranged from a maximum of 9.1 KWh/m^2 on July 2, 1978, to a minimum of nearly 4.0 KWh/m^2 on July 28, 1978. Between these two extremes, a useful representation of the total global radiation is the median value. Identification of the median global radiation day tells us that 50% of the July days for 1977 and 1978 received more energy than the median day and the others 50% less energy. After tabulating, summing, and then ranking the total daily global radiation data for both July 1977 and 1978, the median radiation day was found to be July 27, 1977. On this day, 98% of the total possible sunshine was received and the maximum afternoon temperature was 43°C (109°F). Figure 1 shows that on July 27, 1977, a total of 8.2 KWh/m^2 of solar energy was received on a horizontal surface (the sun was about 13° from the zenith at local noon).

Figure 1 helps demonstrate the rapid increase of global radiation immediately after sunrise and the rapid decrease after local noon. Calculations show that two-thirds of the solar radiation are received in the 6-hour period between 0900 and 1500 LST. Although there is evidence of an abundant supply of solar energy in Figure 1, the hourly values must be multiplied by the efficiency of the energy conversion system to obtain the energy available for use.

B. Minimum Day:

The minimum global radiation day for July 1977 and 1978 combined was July 28, 1978. Figure 2 portrays the diurnal variation in hourly global radiation received on this day. A total of 3.97 KWh/m^2 was received. In Figure 2, notice that an hourly maximum of nearly 0.96 KWh/m^2 occurred between 1100 and 1200 LST. However, much less energy was received during the afternoon hours when thunderstorms shaded the ground from the sun. For the 4-hour period between 1200 and 1600 LST, a total of only 0.36 KWh/m^2 was received; less than 0.1 KWh/m^2 for each hour. A flux density of 0.1 KWh/m^2 (or 100 W/m^2) for 1 hour with a conversion efficiency of 100% is enough power to light one 100-watt light bulb for 1 hour. During such periods of limited energy availability, a supplemental energy source would probably be needed by most users.

C. Maximum Day:

Maximum total daily global radiation for both Julys occurred on July 2, 1978, when 9.1 KWh/m^2 were measured. The diurnal variation for this day is shown in Figure 3. The peak hourly energy was 1.06 KWh/m^2 for the hour ending at local noon. This hourly value was slightly less than the absolute hourly maximum of 1.07 KWh/m^2 observed on July 11, 1978. Values approximately 10% greater than 1.0 KW/m^2 (or 1.0 KWh/m^2 for one hour) can be expected. Almost 10% more solar radiation will be received than at sea level because Las Vegas is about 610 m above MSL and has an average station pressure

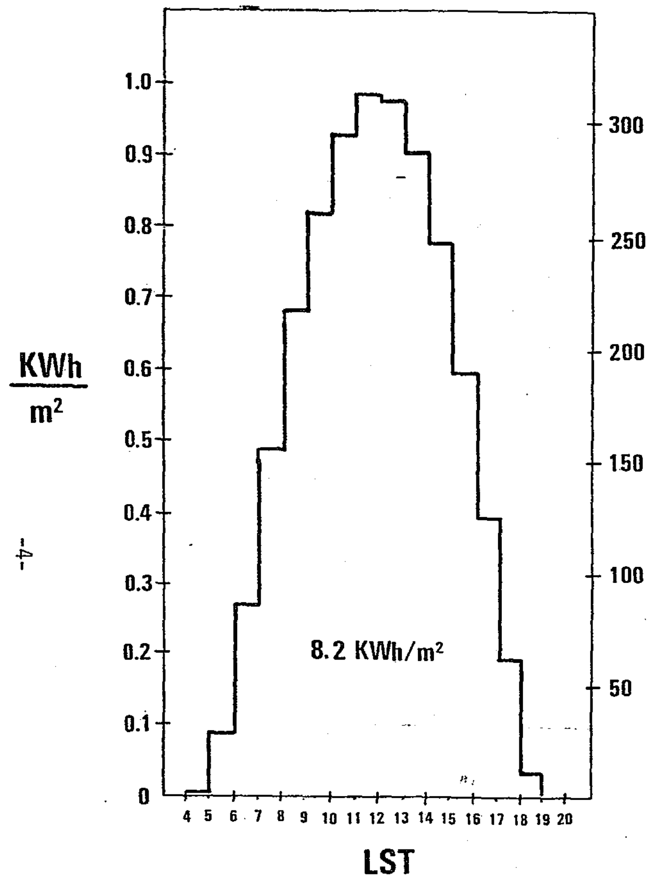

Figure 1. Median global radiation day for July 1977 and 1978 represented by July 27, 1977. Total energy received was 8.2 KWh/m². The plotted data represent hourly values ending on the hour.

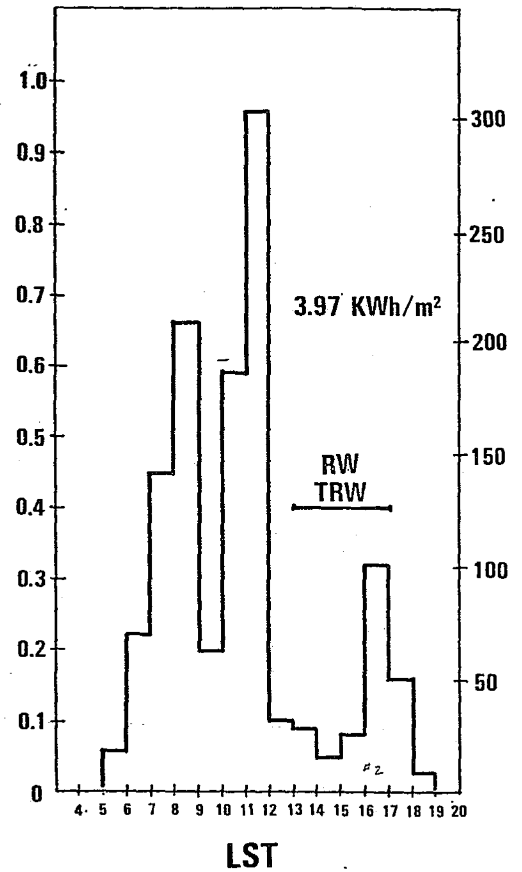

Figure 2. Minimum global radiation day for July 1977 and 1978 represented by July 28, 1978. Total energy received was 3.97 KWh/m². The time period associated with dense clouds and precipitation is identified by RW and TRW. The plotted data represent hourly values ending on the hour.

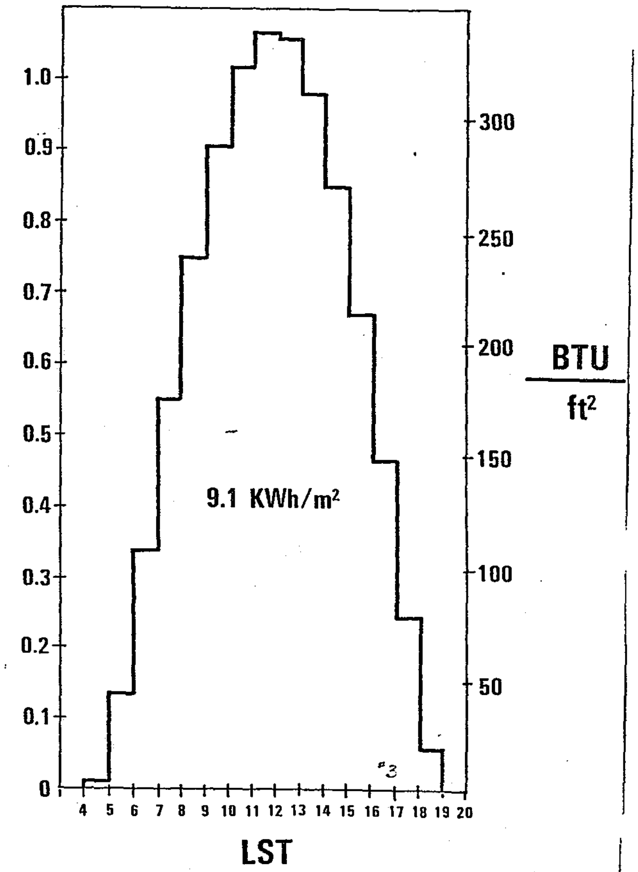

Figure 3. Maximum global radiation day for July 1977 and 1978 represented by July 2, 1978. Total energy received was 9.1 KWh/m². The plotted data represent hourly values ending on the hour.

of about 935 mb in July, 78 mb less than the standard sea-level pressure. This reduction in pressure should lead to an increase in solar radiation of 7.8% or, say, almost 10% considering the variability of the atmosphere and the accuracy of the measurements.

Even though July 2, 1978, was the maximum global radiation day for both 1977 and 1978, it was also a mild, windy July day with a maximum afternoon temperature of 98°F (37°C), 6°F (3°C) below the normal daily maximum for July. The average wind speed was 20.7 mph (9.3 m/s), and 100% of the total possible sunshine was received. A total of 20 cooling degree days occurred on this day, 5 degree days below normal for July.

D. Application:

To attempt to view the maximum radiation day (Figure 3) from a practical aspect, consider the energy needs of an all-electric home on this July day.† A 205 m^2 (2200 ft^2) home for a family of four that is reasonably well insulated will use approximately 100 KWh of energy to cool and to provide the basic daily energy needs. The basic needs account for about 25 KWh daily and include energy uses such as cooking, heating water, and lighting. Assuming that the total energy demand can be met best through the use of photovoltaics, a conversion efficiency of 20% is specified. A 20% efficiency is large for most photovoltaic cells (Kelly 1978) so that the calculations of the energy available may be a bit optimistic by as much as a factor of 2. With this assumption, calculations show that the basic daily energy demand can be supplied by a 14-m^2 (150-ft^2) collecting area. This area can be found by dividing the energy demand (25 KWh) by both the total energy supply (9.1 KWh/m^2, Figure 3) and the efficiency (0.2). For the same conditions, the remaining 75 KWh would require 41 m^2 (nearly 450 ft^2) of area. Consequently, for the observed maximum radiation day, the collecting area needed to supply the 100 KWh demand is about 55 m^2 (nearly 600 ft^2). Although the above calculations indicate that this area may be used to supply the total daily energy demand, in practice it may not be large enough to supply some peak hourly demands (see next Section).

Having identified an appropriate collection area, is the space available for use and does it have a good exposure to the sun? A popular location for siting the collecting medium is on the roof of a home or building. If so, will the roof sustain the additional load of 10 kg/m^2 (2 lb/ft^2)? Is the financial investment justifiable when mass-produced energy is available at 5¢/KWh?

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†Power consumption for the specified home is based on data collected since 1976 by the author for his all-electric home.

Energy demands greater than 100 KWh/day can occur on days of extreme heat. Such conditions can be specified arbitrarily as those days requiring more than 30 cooling-degree days.† These values can be related to energy demand by assuming that the specified home consumes approximately 4 KWh per cooling-degree day. Consequently, 120 to 140 KWh of energy may be needed on such days. Therefore, on days of extreme heat, up to 77 m^2 (828 ft^2) of collecting area may be required to supply most of the energy demands of the specified home.

If a 100 KWh demand is made on the minimum radiation day (3.97 KWh/m^2) then about 125 m^2 (1355 ft^2) of area would be required. Incidentally, the 77^2m (828 ft^2) calculated above may be adequate on the minimum radiation day if the daily demand is 61 KWh or less and if peak hourly demands are kept small.

E. Data Summary:

All the global radiation data for July 1977 and 1978 are summarized by Figure 4. This diagram represents the diurnal variation in the cumulative frequency distribution of the hourly global radiation data for Las Vegas, Nevada. The graphical form of Figure 4 was obtained by ranking the hourly radiation observations for each hour of the day by month and then determining the cumulative frequency distribution for each hour. The hourly cumulative frequencies for the 25, 50, 75, and 90% percentiles were then determined. As a final step, the observed hourly maximum (MAX) and minimum (MIN) values were plotted to identify the boundaries of the data. Caution is advised in using Figure 4 (and Figures 5, 9, and 10) because the curves in these diagrams have been smoothed to simplify the displayes. The curves are not really continuous. They actually represent hourly averages that end on the hour as do the bargraphs in Figures 1, 2, and 3.

The diurnal frequency distribution curves in Figure 4 represent the expectation of receiving a given value of energy for a corresponding hour of the day. For example, at 12 LST, the 75% curve tells us that at this time of day 75% of the radiation values were 0.95 KWh/m^2 or larger, the upper limit being specified by the MAX curve as 1.07 KWh/m^2. In other words, from a practical aspect, this example tells us that on 75% of the July days, at least 0.95 KWh/m^2 of energy can be expected at local noon in Las Vegas, Nevada. This diurnal curve also reflects the fact that on 25% of the July days, less than 0.95 KWh/m^2 are available. The 50% curve represents the distribution of the median values.

Through simple mathematics, Figure 4 can be used to determine the energy available for a given time of day for a given percentile. If E is the efficiency of the energy conversion system, A is the total collecting area of the solar panels, and P(Q,T) is the energy received at time T for percentile Q, then the energy available for use, K, is given by

$$K = P(Q,T) \times E \times A.$$

†During the 10-year period from 1970 to 1979, July averaged eight such cooling-degree days, with July 1976 having no such days and July 1971 having 14.

For example, if you have 50 m^2 of solar cells that are 10% efficient ($E = 0.1$) and you want to work at the 90% percentile level at 8 LST, the use of Figure 4 and the computation of K tells you that on 90% of the July days, at least 1.45 KWh (and not more than 2.8 KWh) of energy will be available for use.† This computational procedure can be applied for any percentile and for any time of day. As an additional point, notice that the ordinate in Figure 4 could be modified to represent the energy available for a given collection area by simply multiplying the ordinate values by the selected area.

Figure 4 can be used to estimate the solar energy supply for a given collection area in or near Las Vegas, Nevada. Based on the 77-m^2 collection area calculated for days of extreme heat in Section D, assume that a collection area of 75 m^2 is available to supply the energy demands of the author's home. Also assume that the solar cells are 20% efficient and that the diurnal energy supply for the 75% percentile is needed. Using these assumptions, the hourly energy supply, K, can be calculated; thereby, obtaining the diurnal energy supply curve plotted in Figure 5. Based on the assumptions, the total energy supply for the day is 116 KWh. Limited data collected by the author suggests that the average hourly energy demand for the author's home is as plotted in Figure 5. Peak hourly demand values could be higher. A comparison of the energy supply and demand curves shows a large energy excess between 8 a.m. and 4 p.m. and a large energy deficit after 5 p.m.; however, there is a total excess of 16 KWh. If the nighttime demand is to be met, the daytime excess must be stored for later use. A storage system requires additional space (for batteries) as well as the installation of an electrical control system.

As noted earlier, a 20% efficiency is presently rather high for photovoltaics. If a 15% efficiency is used, the total electrical energy supply is about 87 KWh, 13 KWh below the expected energy demand. Consequently, under the assumed conditions, a decrease in the efficiency of the solar cells (or an increase in the demand) would require the use of additional solar cells to prevent an energy deficit. Using the data summarized in Figure 4, you can construct a diagram similar to Figure 5 by simply knowing your hourly energy demands, the area available for solar cell display, and the efficiency of the cells.

IV. GLOBAL RADIATION FOR DECEMBER

A. Median Day:

Hourly global radiation data for both December 1977 and 1978 show that the total available solar radiation for Las Vegas ranged from a maximum of 3.2 KWh/m^2 on December 2, 1978, to a minimum of 0.47 KWh/m^2 on December 17, 1978. The absolute hourly maximum was 0.56 KWh/m^2 between 1200 and 1300 LST on December 6, 1978. The absolute

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†$K = (0.29\ KWh/m^2) \times (0.1) \times (50\ m^2) = 1.45$ KWh.

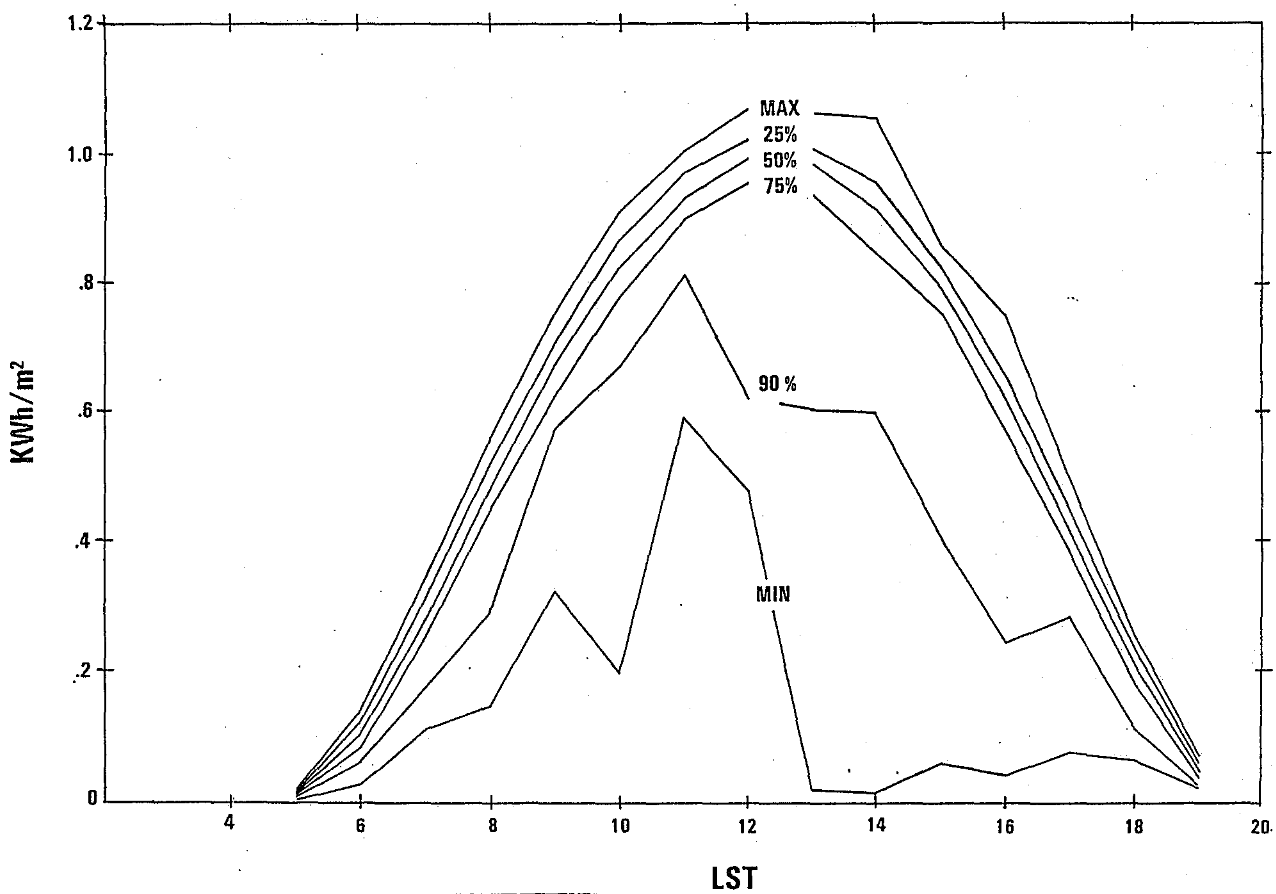


Figure 4. Diurnal variation in the cumulative frequency distribution of the hourly global radiation data for Las Vegas, Nevada, for July 1977 and 1978.

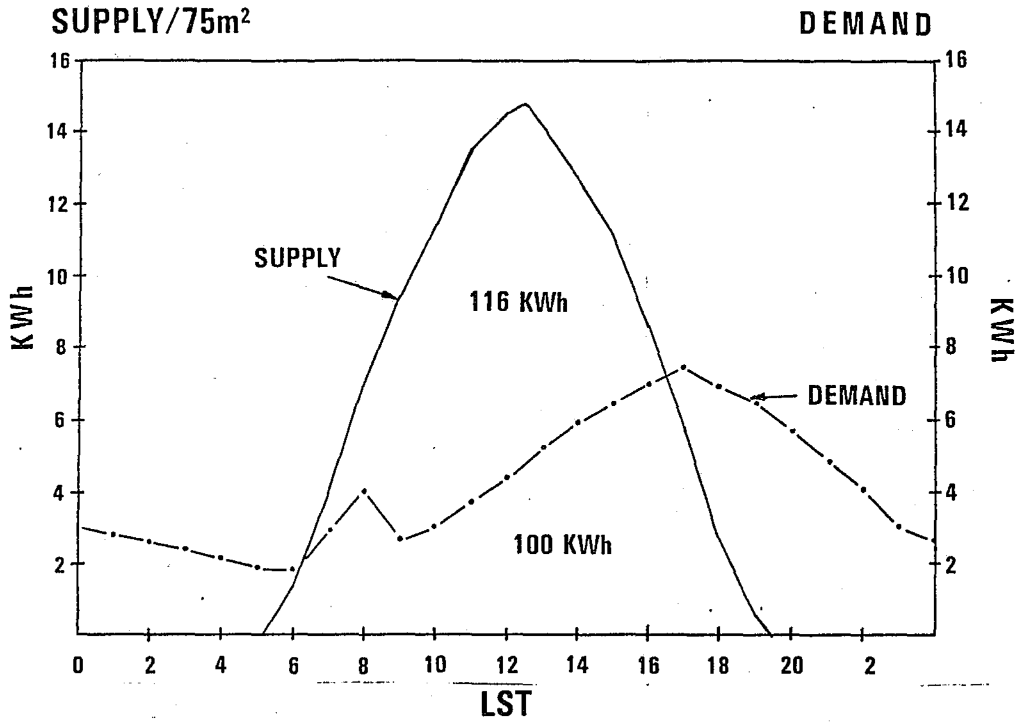


Figure 5. Calculated hourly energy supply versus approximate hourly energy demand. Supply values are based on 75 m of collection area, a 20% efficiency, and energy values based on the 75% percentile in Figure 4. Demand values are based on limited hourly observations by the author for his all-electric home.

hourly minimum for near noon hours was 0.06 KWh/m^2 which occurred between 1200 and 1300 LST during rainy, foggy conditions on December 17, 1978. Such an energy flux is only enough to light a 60-watt bulb for 1 hour if the energy conversion process is 100% efficient.

After ranking all the total global radiation data for both December 1977 and 1978, the median day was found to be December 18, 1977, with a total of 2.9 KWh/m^2. On this day, 94% of the total possible sunshine was received and the maximum afternoon temperature was 61°F (16°C). The hourly distribution of energy for December 18 is shown in Figure 6. On this date, nearly 75% of the global radiation was confined to the 5-hour period between 0900 and 1400 LST. The maximum hourly value is less than half that for July 27, 1977; the median day for July (0.99 KWh/m^2 versus 0.47 KWh/m^2). In fact, the total energy supply for the December median day is 5.3 KWh less than for the July median day. Consequently, only 35% of what is available on a horizontal surface for the July median energy day is available on the same surface for the December median day. Clearly, such a difference will have a profound effect on the ability of solar radiation to supply the total energy demands during the winter months, even in the sunny desert southwest, but more on that topic later.

B. Minimum Day:

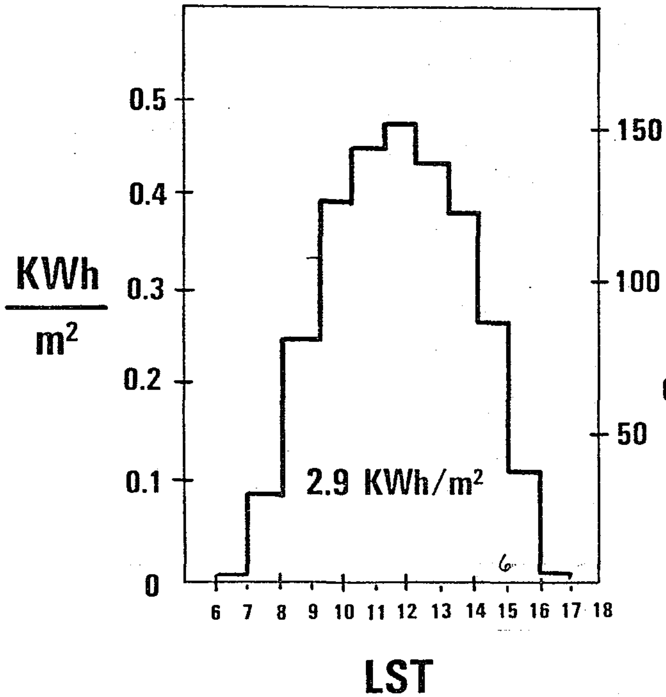
The day of minimum global radiation was December 17, 1978, for which the hourly distribution of energy is shown in Figure 7. The total energy received for the day was 0.47 KWh/m^2. Solar energy was effectively attenuated by dense clouds, rain, and fog so that little sunlight was received. Between 1000 and 1100 LST, a maximum radiation flux of 0.09 KWh/m^2 occurred. Maximum temperature for the day was 48°F (9°C) and 21 heating-degree days were required. On such rainy winter days a supplemental energy source would be needed by most users.

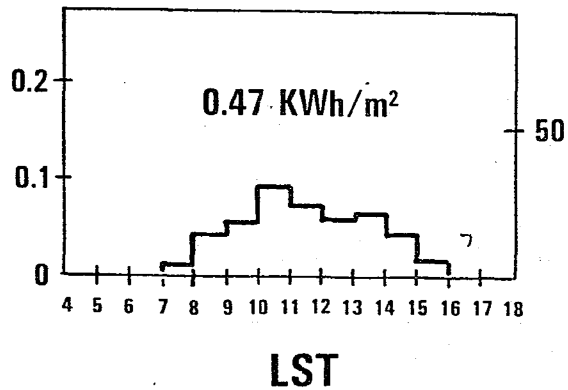
C. Maximum Day:

Maximum daily global radiation for both Decembers occurred on December 2, 1978, when a total of 3.2 KWh/m or only 40% of the July median was received (Figure 8). Ninety-nine percent of the total sunshine was reported, the maximum temperature was 54°F (12°C), and 17 heating-degree days resulted. Figure 8 shows that the maximum hourly flow of solar radiation amounted to 0.55 KWh/m^2. The absolute hourly maximum for both Decembers was 0.56 KWh/m^2 on December 6, 1978.

D. Application:

Can the available solar energy supply the total energy demands of the home specified in this report? To provide an answer to this question, assume a December weather condition that is not exceedingly cold or unusually mild so that the total daily energy demand for the home is approximately 75 KWh. Then, for the median day (Figure 6) and a 20% efficiency, a collection are of 130 m^2 (1392 ft^2) would be adequate on 50% of the days and inadequate on the other 50%. For the minimum day (Figure 7), a total of nearly 800 m^2 (8610 ft^2) would be required to supply 75 KWh. On the maximum day, 117 m^2 (1260 ft^2) would be required.





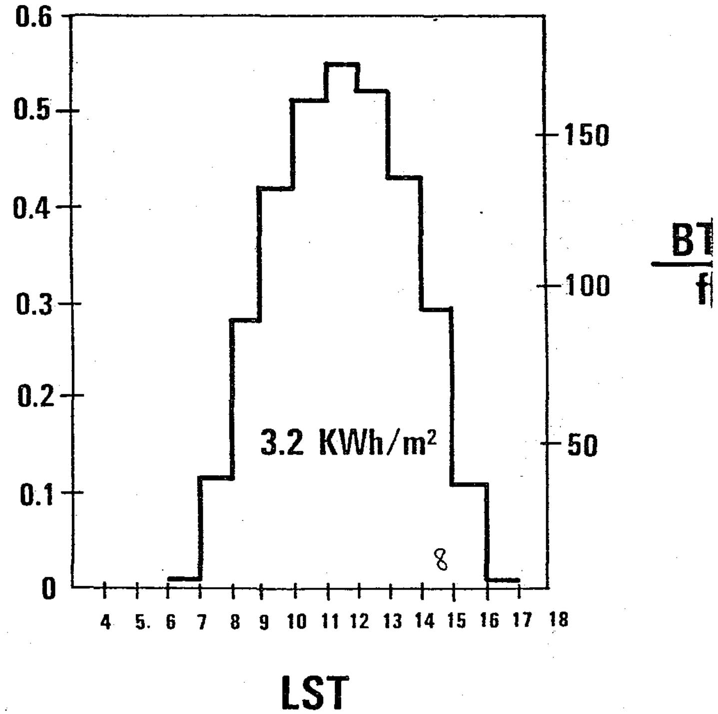


Figure 6. Median global radiation day for December 1977 and 1978 represented by December 18, 1977. Total energy received was 2.9 KWh/m². The plotted data represent hourly values on the hour.

Figure 7. Minimum global radiation day for December 1977 and 1978 represented by December 17, 1978. Total energy received was 0.47 KWh/m². The plotted data represent hourly values ending on the hour.

Figure 8. Maximum global radiation day for December 1977 and 1978 represented by December 2, 1978. Total energy received was 3.2 KWh/m². The plotted data represent hourly values ending on the hour.

Perhaps the 117 m^2 can be thought of as the minimum collection area needed for December. However, if total energy demands are to be met for most weather conditions, an area of 800 m^2 (8610 ft^2) would be needed. Many homes do not have that much space available for practical use.

Large collection areas would be required to provide the total energy demands for the specified home during very cold weather (≥30 heating-degree days). The maximum heating-degree day for Las Vegas (1970-1979) is 35. Power consumption data for the specified home point to a consumption rate of 6 KWh per heating-degree day. Consequently, for very cold, clear days, approximately 180 to 210 KWh may be demanded. If a 180-KWh demand is made, then for the median day radiation (2.9 KWh/m^2) and 20% efficiency, a total of 310 m^2 (3340 ft^2) of collection area would be needed. For 210 KWh, 362 m^2 (3890 ft^2) would be required.

E. Data Summary:

The global radiation data for the 62 days in December 1977 and 1978 are summarized by Figure 9. This figure was constructed using the same procedure as for Figure 4 (see Section III, E). The legend is also the same; however, the data are for December.

Several differences between Figure 9 and Figure 4 are obvious. Perhaps the most striking difference is between the magnitudes of the energy values in both diagrams. The December values are nearly half those for July. Another difference is that the December days are approximately 5 hours shorter than those in July so that less total energy is available diurnally in December. In addition, the 75% curve in Figure 9 is farther below the 50% curve than is the corresponding curve in Figure 4. For example, at local noon, in Figure 4, the energy value for the 75% percentile is roughly 0.3 KWh/m^2 less than the 50% percentile, while in Figure 9, it is about 1.2 KWh/m^2 less. Figure 9 shows that at local noon in December, 75% of the days will receive at least 0.38 KWh/m^2 and 25% of the days less than this value.

A diagram similar to Figure 5 can be constructed for the December data so that an evaluation of energy supply versus demand can be made. Working with the 75% percentile and assuming 75 m^2 of solar cells with an efficiency of 20%, the diurnal distribution of both the received energy and the estimated demand are plotted in Figure 10. Obviously, the demand exceeds the supply, especially at night when energy is needed for heating. If the nighttime demand is to be met, a supplemental energy supply will be required. Of course, the demand will be a function of individual household requirements for nighttime energy. To provide the energy demands plotted in Figure 10 would require an area of exposure of 240 m^2 (2583 ft^2). Any excess daytime energy could be stored for use at night.

The reason for the large discrepancy between supply and demand is that solar energy is represented by the amount of sunlight falling on a horizontal surface. By tilting the solar panels into the sunlight, more energy can be received. A maximum increase in the energy received at local noon can be achieved by tilting the solar

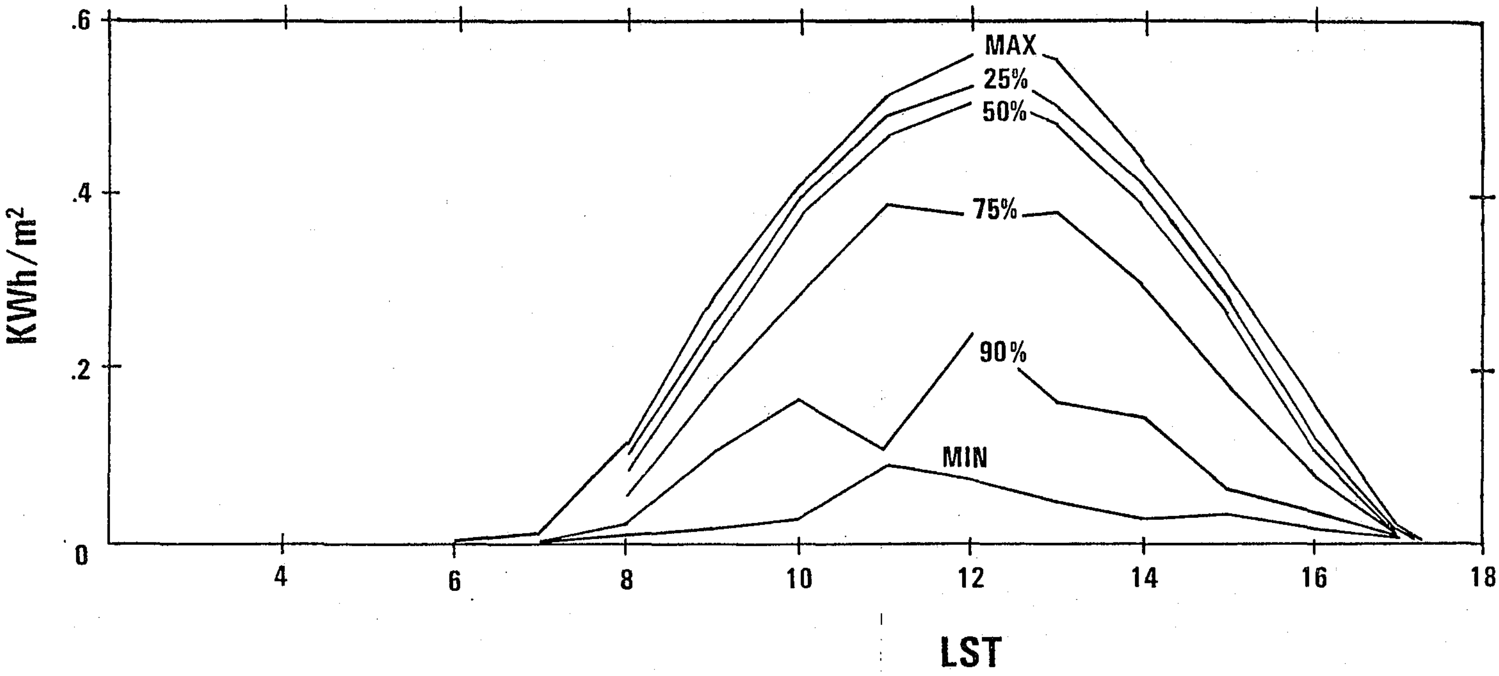


Figure 9. Diurnal variation in the cumulative frequency distribution of the hourly global radiation data for Las Vegas, Nevada, for December 1977 and 1978.

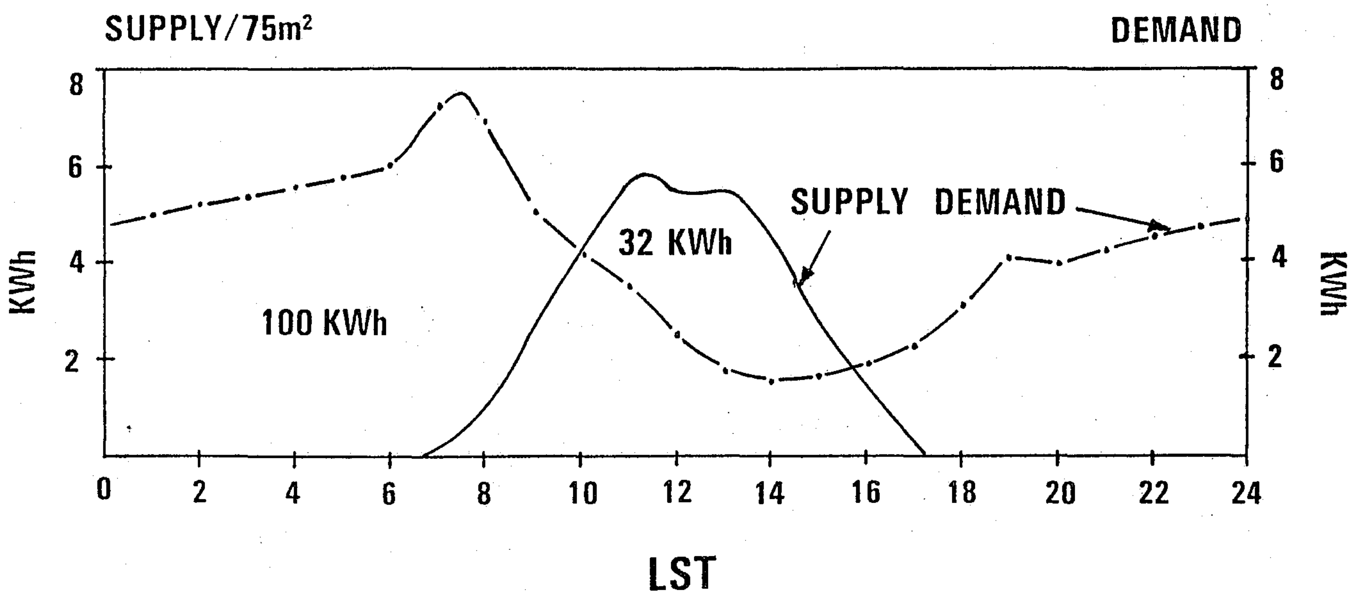


Figure 10. Calculated hourly energy supply versus estimated hourly energy demand. Supply values are based on 75 m^2 of collection area, a 20% efficiency, and energy values based on the 75% percentile in Figure 9.

panels 60° from horizontal so that the cells face the sun and are perpendicular to the light from it at local noon. Such a procedure could double the energy received for the 75% percentile. In fact, varying the angle of exposure throughout the day would yield a marked increase in the receipt of solar energy, especially in the wintertime. However, the expense of such a system increases dramatically with increasing sophistication and, as a topic, is beyond the scope of this report.

In retrospect, to supply most energy needs during December will require much more horizontal collection area than July. For very cold, overcast days with precipitation, roughly 5 times more area may be needed in December relative to the maximum required for July. In addition, a storage capability or a supplemental energy source will be needed to supply nighttime and cloudy-day energy demands.

V. SUMMARY

Provided the solar cells are 20% efficient, there appears to be an adequate amount of solar energy in July to supply the energy needs for a reasonably well-insulated 204 m^2 (2200 ft^2) home for a family of four. In December, solar energy supplies are quite dilute and total energy needs are not likely to be met with any degree of regularity. A supplemental energy source must be available for cold weather and especially for cold, cloudy weather. Peak hourly demands may occasionally exceed demand, especially during winter months.

Although the implication in this report may be that photovoltaics need to be used, that is not the intent. Instead, the reader should pay particular attention to the global radiation data and extract the appropriate energy values from Figures 1 through 10. In addition, technological advances in solar energy conversion are a certainty so that efficiency ratings of near 20% will be achieved. Lighter-weight solar cells will also be developed so that load restrictions on roofs can be met. Furthermore, no mention has been made of the use of passive or active solar energy systems and the use of architecture to take advantage of design techniques for providing shading and sunlight as a function of season.

Complete dependence on solar energy for home or business structures built without good insulation may require a major expenditure of funds. For these type structures, caution is advised in being oversold on solar energy. Improved insulation and conservation efforts may provide the required savings on energy costs.

In this report, global radiation has been used. This parameter represents radiation incident on a <u>horizontal</u> surface. By exposing the solar cells at an optimum angle, additional energy will be available (some example calculations are given by Sellers, 1967, and others). However, no matter how much money is invested, the sun will not supply more than about 1 KW/m^2 at sea level (1.1 KW/m^2 at Las Vegas) and that is usually restricted to the warm season, near local noon, on a clear day with good transmissivity.

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