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Stand-Alone Flat-Plate Photovoltaic Power Systems: System Sizing and Life-Cycle Costing Methodology for Federal Agencies

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ABSTRACT

A simple methodology to estimate photovoltaic system size and life-cycle costs in stand-alone applications is presented in this document. It is designed to assist engineers at Government agencies in determining the feasibility of using small stand-alone photovoltaic systems to supply ac or dc power to the load. Photovoltaic system design considerations are presented as well as the equations for sizing the flat-plate array and the battery storage to meet the required load. Cost effectiveness of a candidate photovoltaic system is based on comparison with the life-cycle cost of alternative systems. Examples of alternative systems addressed herein are batteries, diesel generators, the utility grid, and other renewable energy systems. A companion document, Flat-Plate Photovoltaic Power Systems Handbook for Federal Agencies (Reference 10), is recommended for discussion of issues for evaluating the viability of potential photovoltaic applications; descriptions of present photovoltaic system applications; synthesis of lessons learned from photovoltaic system design, installation, and operation; and identification of procurement strategies for Federal agencies.

FOREWORD

This system sizing and life-cycle costing methodology provides a tool for Federal agencies to use in estimating photovoltaic system size and life-cycle costs for non-utility grid-interactive applications. It is specifically intended for use by the Federal Government since use by non-Government entities would require additional considerations such as the effect of taxes. It is not intended for detailed system design, but rather provides a Government engineer, having limited background in photovoltaic technology, with the concepts required to estimate the photovoltaic system size and corresponding life-cycle cost. The methodology is appropriate for sizing remote photovoltaic systems that use fixed flat-plate photovoltaic collector technology with or without battery storage. In addition, the procedures for determining initial capital costs and life-cycle costs can be used to estimate funding requirements for system procurement.

To evaluate the life-cycle costs for a photovoltaic system, a comparison must be made with those of any alternative system. The methodology permits calculations of the life-cycle cost of both a photovoltaic power system and that of any alternative system.

Should questions arise from the use of this methodology, contact the Federal Photovoltaic Utilization Program Office at the Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California, 91109, telephone (818) 577-9523 or FTS 961-9523.

ACKNOWLEDGMENT

The U.S. Department of Energy Federal Photovoltaic Utilization Program, under the direction of Mr. Michael Pulscak, Program Manager, provides for the acquisition and installation of photovoltaic systems within various Federal agencies. This methodology has been prepared as part of this program.

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SECTION I

INTRODUCTION

A.   ABOUT THIS DOCUMENT

1.   Purpose

Photovoltaic (PV) power systems are potentially a cost-effective alternative to conventional power sources (e.g., diesel generators, batteries) in a variety of remote applications where the operation, maintenance, and fuel costs of the conventional sources are high. This document describes a photovoltaic system sizing and life-cycle costing methodology that has been prepared to assist Federal Government agencies in determining the feasibility of using stand-alone photovoltaic systems that can supply either ac or dc power to a specified load. In addition, the procedure for determining initial capital costs and life-cycle costs can be used to estimate funding requirements for system procurement.

2.   Scope

The methodology in this report applies to stand-alone fixed flat-plate photovoltaic systems (which include the array, voltage regulator, battery storage, and dc-ac inverter or dc-dc converter) as well as various possible alternatives such as battery storage, diesel generators, other renewable energy technologies, and extension of the utility grid to the remote site. The methodology, therefore, permits a comparison of the economic viability of photovoltaics with that of the possible alternatives, thereby facilitating final selection of the preferred generating option.

This document considers only the relative cost effectiveness as a selection factor in comparing photovoltaic and its alternatives. Additional non-cost-related factors in selecting a power system such as land limitations, limitations on noise generation, physical accessibility for maintenance, etc., although critical in some applications, are beyond the scope of this document.

Finally, this methodology applies to flat-plate photovoltaic-only systems. It does not address hybrid arrangements that combine photovoltaics with another conventional generation mode into a single power system. Sizing the various generating elements of a hybrid system can be accomplished only after a preliminary trade study to determine the most cost-effective configuration for the overall power system, given an intended load.

3.   Organization of the Document

The remainder of Section I presents a description of photovoltaic technology and its application to typical remote loads. In addition, the various characteristics of solar irradiation (i.e., insolation) are described. Special attention is paid to insolation characteristics that may affect the manner in which the photovoltaic system is sized for an intended load.

Section II covers photovoltaic array and battery storage system sizing. Required inverter/converter and voltage regulator sizes are also addressed. Once the size calculations have been made, Section III is used to determine the life-cycle cost of both the photovoltaic power system and any alternatives being considered. A comparison of these life-cycle costs will provide the basis for selecting the power generation technology most appropriate for a given application.

B.   POTENTIAL APPLICATIONS FOR PHOTOVOLTAIC POWER SYSTEMS

Photovoltaic power systems may be considered potentially viable for a number of remote applications. Typical loads that represent current and potential near-term photovoltaic applications are listed below:

(1)   Telecommunications.
       Example: radio repeater.

(2)   Navigational aids.
       Examples: beacon, buoy, lighthouse.

(3)   Aviation aids.
       Examples: radar beacon, anemometer.

(4)   Environmental sensors.
       Examples: radiation sampler, noise monitor.

(5)   Intrusion detectors.
       Examples: entry monitor, electric fence.

(6)   Battery charging.

(7)   Lighting.

(8)   Refrigeration.
       Example: medical supplies refrigerator.

(9)   Space conditioning.
       Examples: small cooler, ventilator.

(10)   Water pumping.

(11)   Water purification/desalination.

(12)   Cathodic protection (corrosion protection).
       Examples: transmission tower, bridge, well, pipeline.

C.   PHOTOVOLTAIC POWER SYSTEM DESCRIPTION

1.   The Solar Cell, Module, and Array

Photovoltaic systems are electrical generating systems based on photovoltaic, or solar, cells (Figure 1-1). The cells convert photons from incident sunlight directly into dc electricity. The solar cell typically

1-2
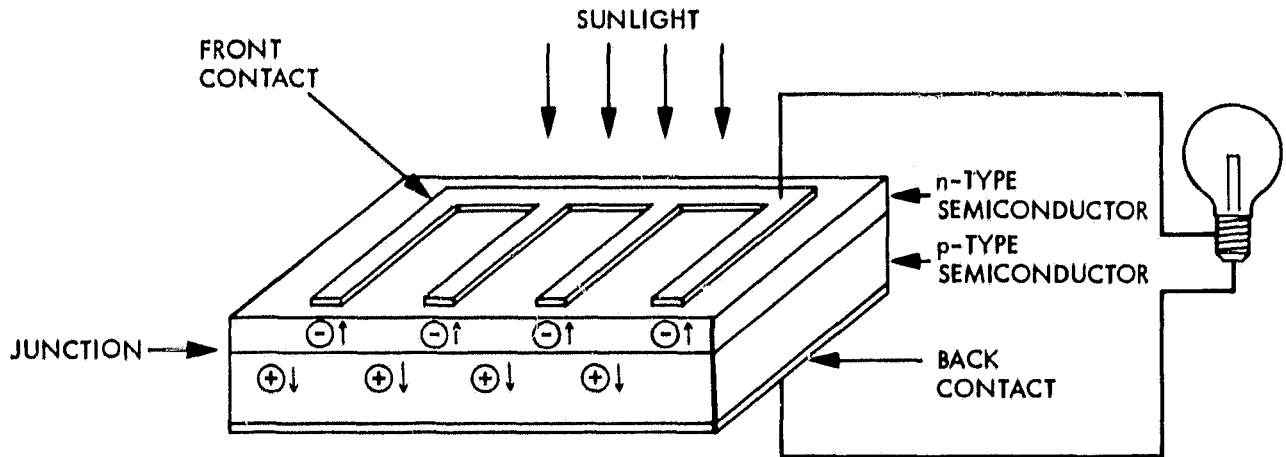
Figure 1-1. Typical Solar Cell

consists of two different types of semiconductor material, called n-type and p-type. Energy carried by the photons frees positive and negative charges within the cell material. The junction between the n- and p-type materials creates an electric field, causing the freed charges to separate across the junction and resulting in a voltage across the cell. Electrical contacts placed on the p-side and on the n-side of the solar cell allow the current generated within the cell to be applied to an external load.

The amount of electric current generated by a solar cell is primarily dependent on the intensity of solar radiation striking its exposed area. The open-circuit voltage produced, however, is primarily dependent on the temperature of the cell. Voltage and cell temperature are inversely related [i.e., an increase in temperature lowers both the output voltage and the output power, thereby reducing the cell's efficiency (Figure 1-2)].

Because the power output of a single solar cell is small [approximately 1 watt for a typical cell (100 cm^2, 10% efficient)], a number of cells are interconnected in series and parallel and sold as a package called a photovoltaic module (Figure 1-3a). These, in turn, can be wired together into an array (Figure 1-3b) to generate the amount of power required by the application.

2.   The Photovoltaic System

A practical stand-alone photovoltaic power system typically requires several elements in addition to the array in order to satisfy the intended load. A typical configuration for a dc load is shown in Figure 1-4.

Battery storage, most commonly involving a lead-acid battery in present applications, stores electrical energy produced by the solar array in daytime for use during the night or under cloudy conditions. To be considered practical for remote applications, a storage battery should have a long life, require low maintenance, and be able to survive a number of deep discharge cycles with subsequent recharge by the array.
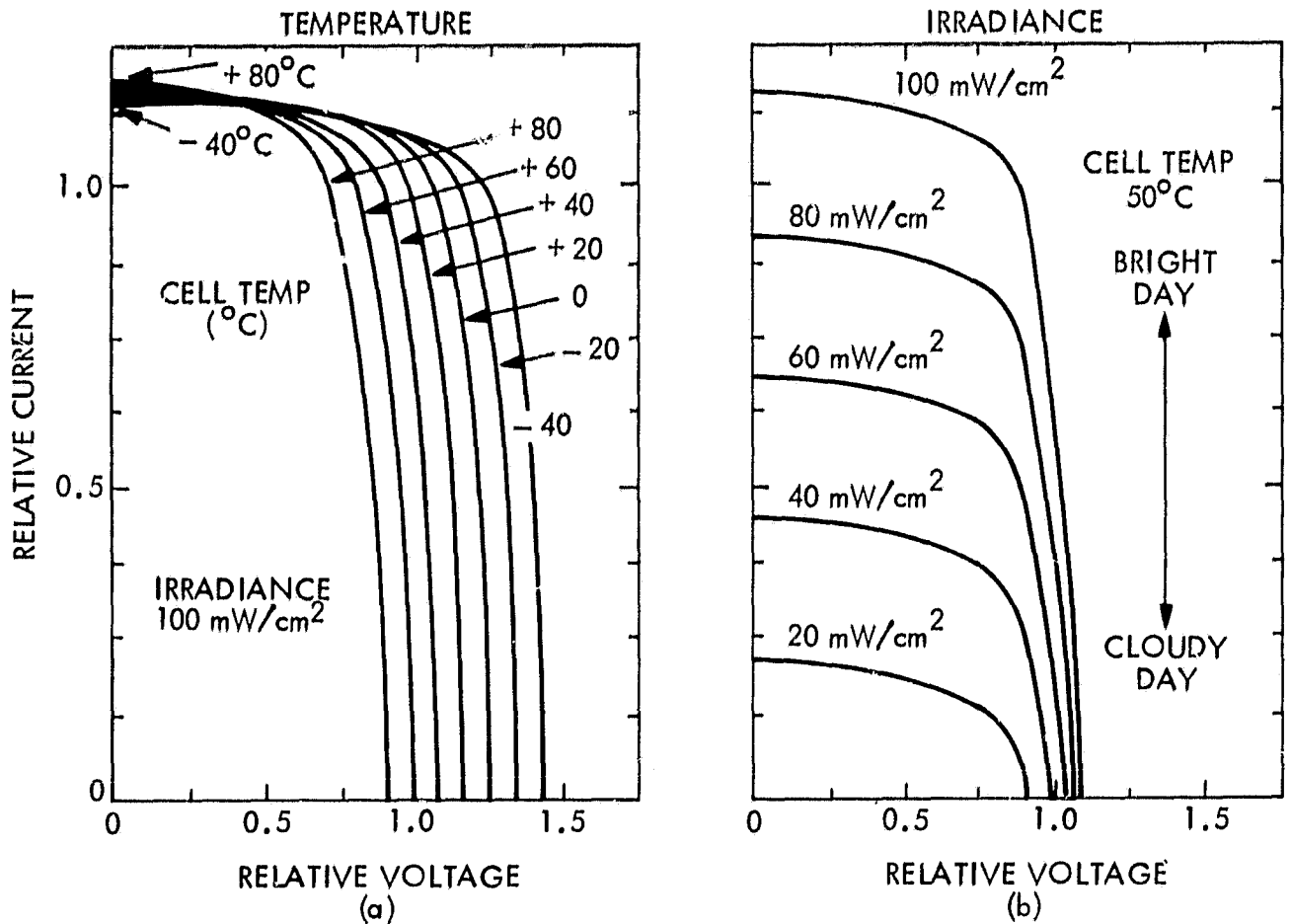
Figure 1-2. The Output of a Solar Cell Varies with Changes in the
Environment: (a) Temperature and Solar Cell Voltage are
Inversely Related, (b) Irradiance and Solar Cell Current
are Directly Related

Another important component of a photovoltaic power system using storage
is a voltage regulator that controls the output voltage from the array when
used to charge the battery. The regulator also limits the loss of water that
would occur from gassing of the battery if it were permitted to become
overcharged. At night or on cloudy days, a blocking diode (see Figure 1-4)
prevents the electrical energy stored within the battery from discharging
through the voltage regulator or the array.

A system serving a dc load may require a dc-dc converter to match the
system output voltage to the rated voltage of the load.

Some photovoltaic applications do not necessarily require battery
storage. An example of this is water pumping, which needs only a photovoltaic
array, a water pump, a water storage tank, and minimum power regulation. In
this case, water is pumped into the storage tank during sunlight hours. The
storage tank then acts as a reservoir, providing water during non-sunny
periods.
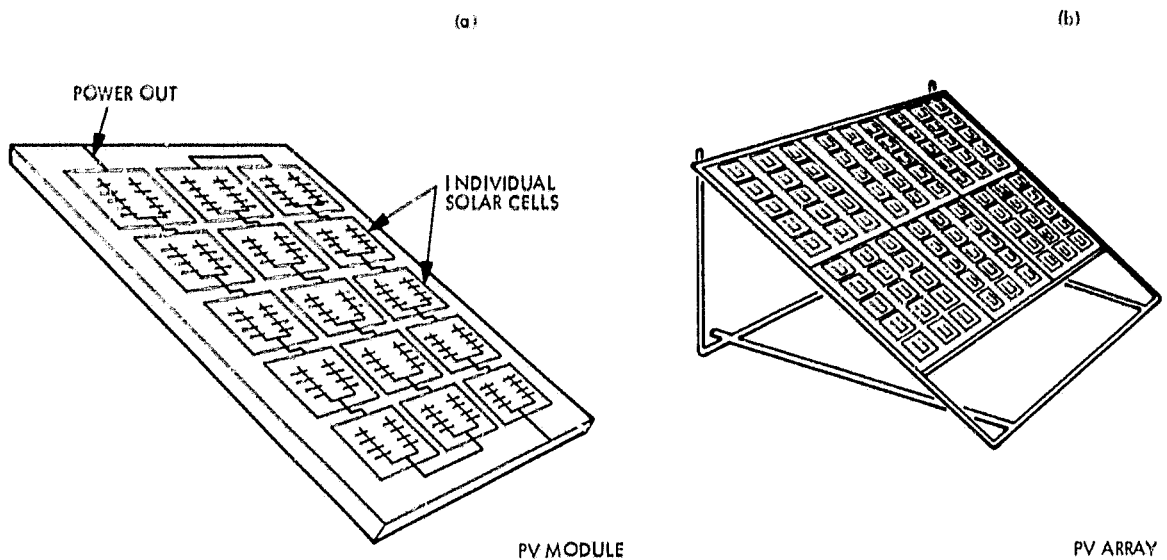
Figure 1-3. Photovoltaic Module and Array: (a) Solar Cells Packaged
into a Photovoltaic Module, (b) Modules are Grouped ' an
Array to Increase Power Output
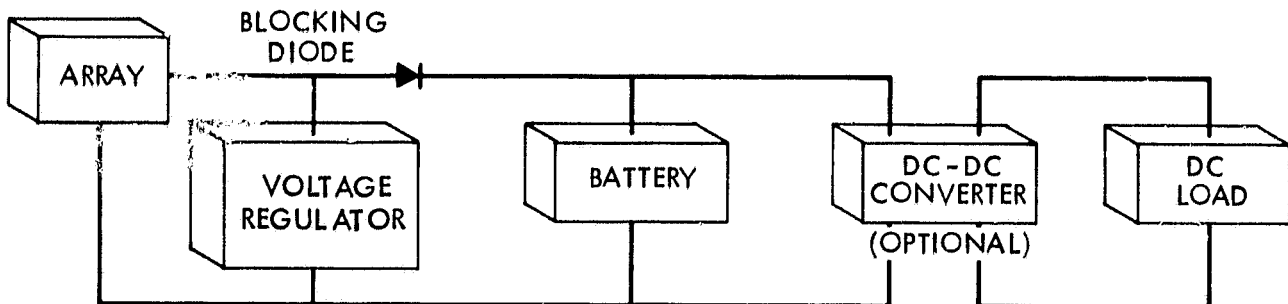
Figure 1-4. Stand-Alone Photovoltaic System Configuration to Serve a dc Load

Other applications may require power conditioning to provide the
required power characteristics to an ac load. In this case, an inverter is
used to convert the dc voltage from the array into an ac voltage (Figure 1-5).

3. Insolation Characteristics and Their Effect on System Sizing

Array and battery storage size requirements to adequately serve
the load energy requirement ultimately depend on the amount of insolation at
the location of the site. Since the amount of energy received from the sun
will depend on location, season, weather, and array orientation, it is
essential to account for these factors in sizing the system. Furthermore,
since the intended load may also vary seasonally, sizing will normally require
a systematic accounting approach to ensure that sufficient solar energy will
be captured by the array to achieve acceptable system reliability throughout
the year.

Figure 1-5.   Stand-Alone Photovoltaic System Configuration
to Serve an ac Load

    Insolation characteristics important for sizing photovoltaic system
components include the following: diurnal variation, regional and seasonal
variability, weather, and array orientation relative to the direction of the
sun. These characteristics are described below:

    (1)   Diurnal Variation. The most important characteristic of
           insolation is its diurnal pattern. The expected power available
           to a fixed flat-plate array over a 24-hour period under clear sky
           conditions will follow a curve similar to that in Figure 1-6. Any
           load that does not closely approximate this power output profile,
           or accommodate deviations from it, will necessitate battery
           storage or other backup to the photovoltaic system.

    (2)   Regional and Seasonal Variability. A second major factor in sizing
           the system is the regional and seasonal variability in insolation.
           Figure 1-7a shows the total insolation on a fixed collector tilted
           at latitude during the winter in the contiguous United States.
           Note that the insolation in kWh/m^2-day varies by up to a factor
           of 2.5, depending on region. Also, note in Figure 1-7b the manner
           in which the total insolation differs between winter and summer
           for a given location. The summer-to-winter difference in
           insolation in prime locations such as the northern portions of
           California and Nevada, for example, is seen to be a factor of

Figure 1-6.   Clear Sky Array Power Output Profile

1-6

(a)

LINES SHOW INSOLATION IN kWh/m² - DAY

WINTER

(b)

LINES SHOW INSOLATION IN kWh/m² - DAY
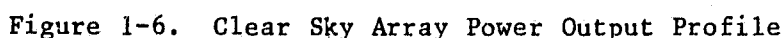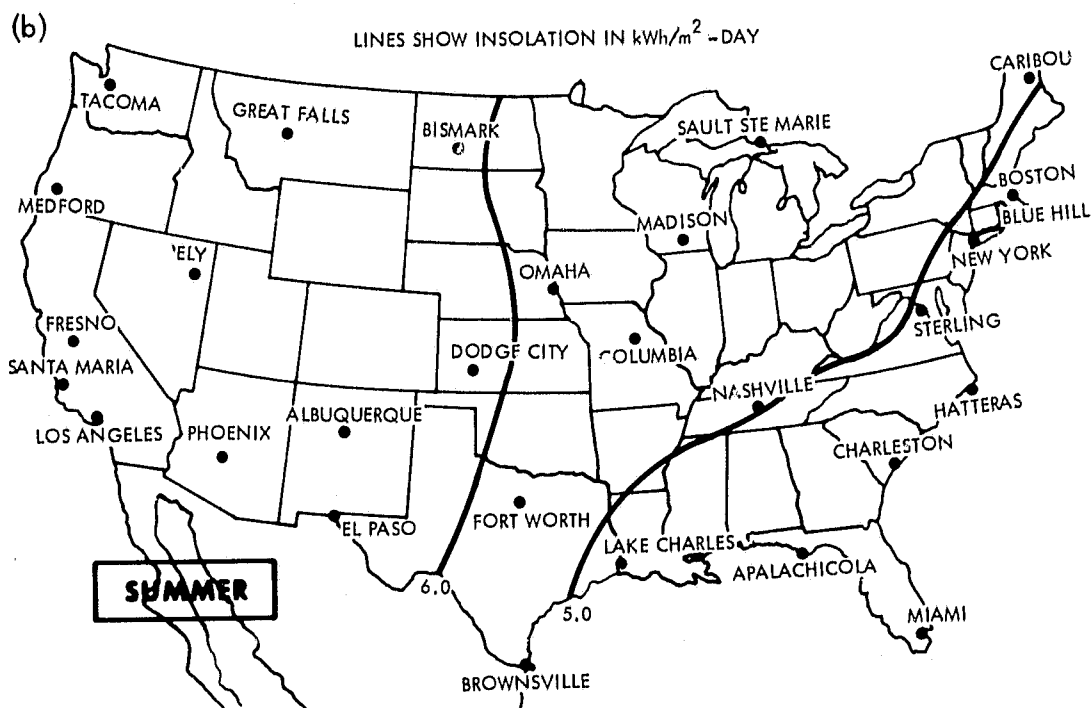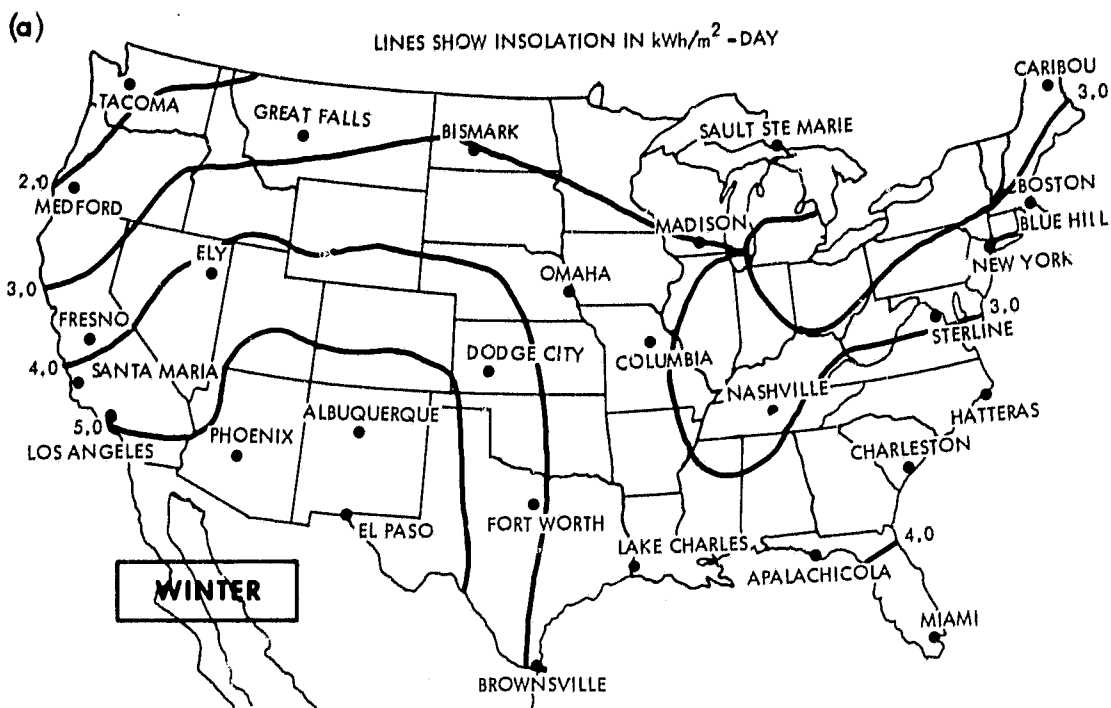
SUMMER

Figure 1-7. Effect of Season and Region on Insolation Level
(a) Winter, (b) Summer. (Reference 1)

1-7

between 1.5:1 and 2:1. These differences must be identified and allowed for in order to correctly size a system for a given load and location.

As noted previously, these variations will require that the sizing method accounts for these differences to ensure that the solar energy incident on the array is sufficient to serve the planned load during all months of the year.

(3) Weather. Cloudy weather will considerably reduce the amount of insolation and, thus, the output from the photovoltaic system (see Figure 1-8). (The output typically will not drop to zero since flat-plate systems generate power roughly in proportion to the amount of light falling on the surface of the photovoltaic cells.) Since cloudy weather can occasionally persist for several days in any location, photovoltaic systems serving most loads will require storage or other electrical backup to ensure reliable power. In sizing a photovoltaic system, the amount of storage is primarily determined by the probable amount of cloudy weather at a given site during the worst month of the year. The method for sizing the battery storage in Section II.C.6 is based on estimates of this probability derived from historical weather records. Although previous weather history is not a perfect predictor of future weather patterns, it does serve as a useful guideline for estimating photovoltaic system requirements.

(4) Orientation of the Array. Since there are seasonal differences in the daily path of the sun across the sky, the amount of solar energy striking a fixed array will vary seasonally according to its orientation. Note that these effects are due only to annual changes in sun angle and are distinct from typical seasonal

a CLEAR SKY

b GENERAL OVERCAST

c INTERMITTENT CLOUD COVER
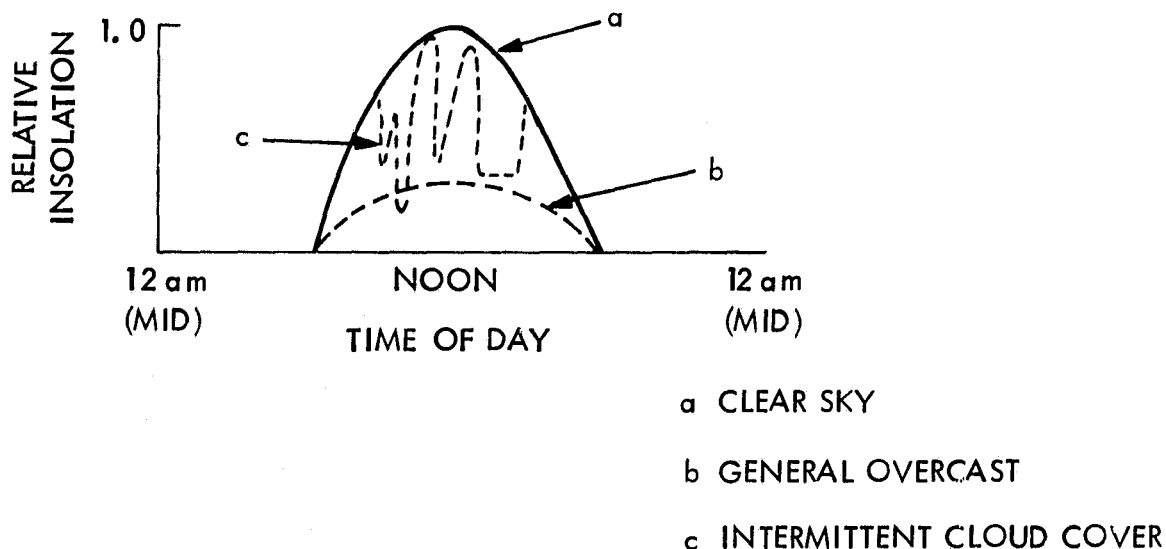
Figure 1-8. Insolation Available to the Array Under Clear Sky and Cloudy Conditions

1-8

changes in insolation due to changing weather patterns. Figure 1-9
illustrates the effect of array tilt on power output.[1] In this
figure, array outputs are normalized and appear as fractions of
the output from an array at latitude tilt.

Under typical weather conditions, the maximum annual energy output
from a fixed array occurs when the array is tilted at an angle
equal to the latitude where it is sited. However, if the load
varies seasonally, latitude tilt may not be the most cost-effective
angle for the array; i.e., the smallest array size that satisfies
the load. The method for selecting the correct tilt angle for
sizing purposes will be described under II.C.3, Calculate
"Worst-Month" Insolation and Load.
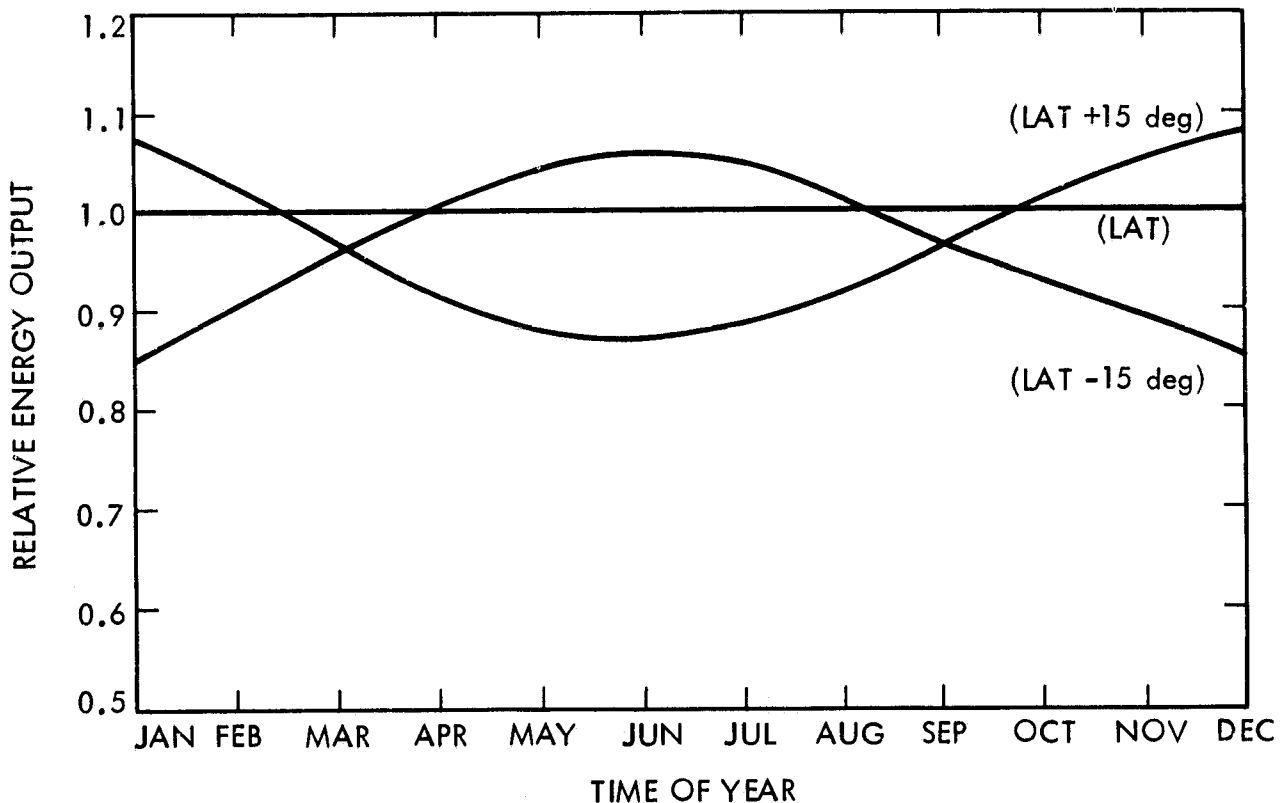
Figure 1-9. Relative Energy Output at Various Array Tilt Angles.
(Adapted From Reference 2)

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[1]Array tilt is measured from the horizontal. In the northern hemisphere, the
array faces toward the south; in the southern hemisphere, it faces toward the
north.

SECTION II

SYSTEM SIZING

A. RATIONALE

The term "sizing," as it is used in this document, means estimating the required size or capacity of all major photovoltaic system elements so that the system will be able to satisfactorily serve the intended load.[2] The sizing methodology described in this section is based on a target level of photovoltaic system reliability that is equivalent to conventional diesel or battery alternatives. The size estimates obtained by this methodology are used to cost the system according to the method described in Section III. The cost estimates, in turn, are compared with estimates for other possible power generating options in order to determine whether selection of a photovoltaic power system is justified on a comparative life-cycle cost basis.

The sizing methodology is restricted to stand-alone systems serving either ac or dc loads. If the application involves both ac and dc loads, the method may be applied by sizing the system for the ac and dc loads separately and then combining the results. This methodology is intended primarily to treat photovoltaic systems with storage since the majority of remote load applications will require at least part of their total energy needs at night or during cloudy day periods of reduced system output. Some applications, however, do not require regular power availability and may be served adequately by photovoltaic systems without battery storage capabilities. The primary example of this kind of application is a water pumping system in which water to serve periods of low pump output is stored in a reservoir or storage tank. The methodology will also address applications of this kind.

The required sequence of steps in the sizing methodology to be described is summarized in Figure 2-1.

B. SUMMARY OF THE PHOTOVOLTAIC SYSTEM SIZING METHODOLOGY

Figure 2-2 schematically depicts a photovoltaic system serving a load. This simple representation illustrates the key factors involved in system sizing. Radiant energy from the sun, or insolation (I) is converted to dc electrical energy by the array at a conversion efficiency e_a. A fraction of the load energy, f_a, may be received from the dc array output through an inverter if the load is ac, or directly if the load is dc. A dc-dc converter is used if the load operates at a dc voltage above that produced by the array configuration. The remaining load fraction, f_b, is received from the storage batteries that are periodically recharged by the array during periods when array output exceeds the load requirements. Conversion efficiencies for the voltage regulator, battery, and inverter or converter are e_{vr}, e_b, and

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[2]Major system elements include the array, voltage regulator, battery storage, and dc-ac inverter or dc-dc converter.
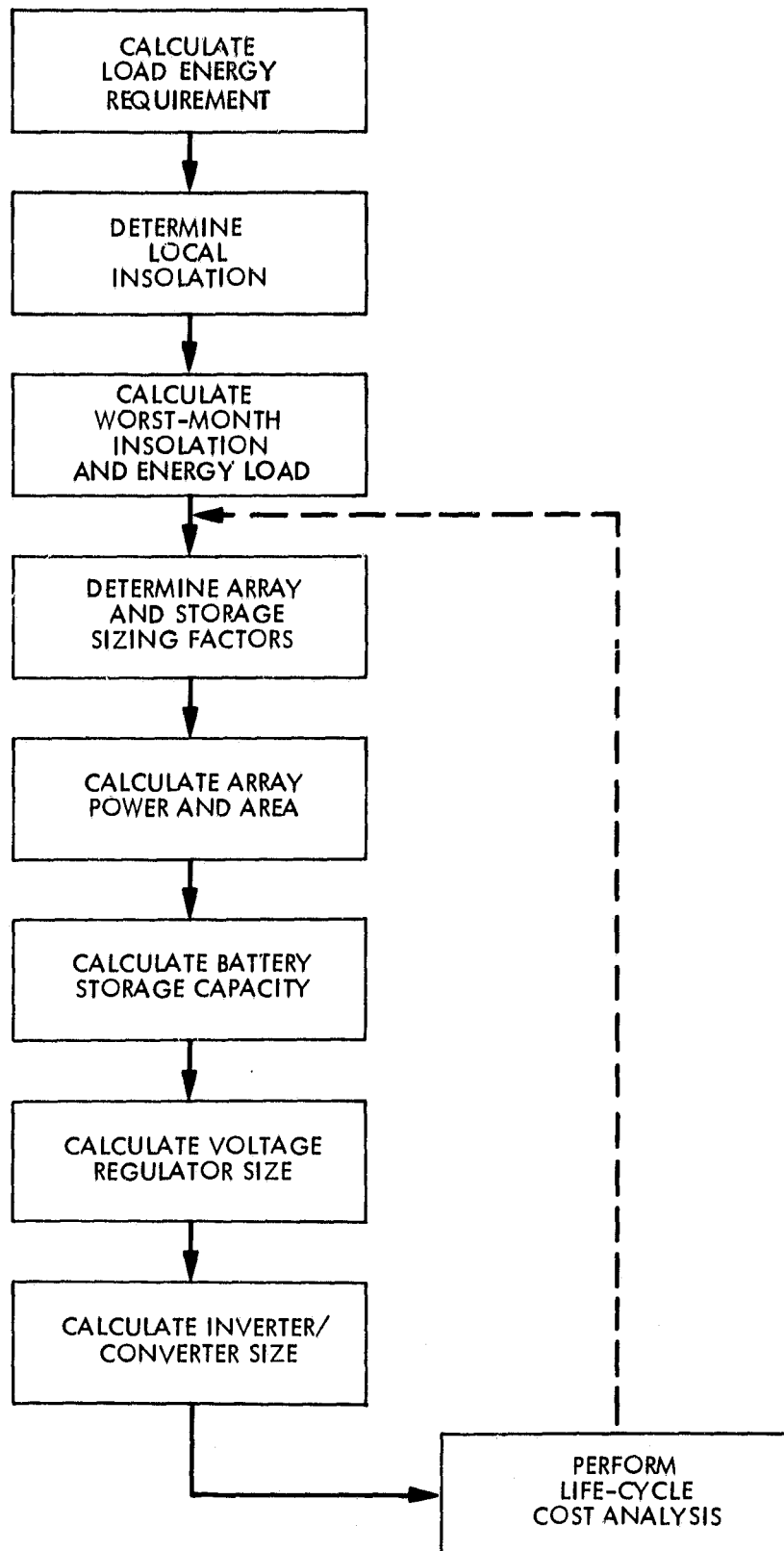
Figure 2-1.   Sequence of Steps in Sizing a Remote, Stand-Alone
Photovoltaic System

INSOLATION
I

ARRAY

e_a

f_a

INVERTER/
CONVERTER*

$e_{i/c}$

LOAD

VOLTAGE
REGULATOR

e_{vr}

f_b

BATTERY
STORAGE

e_b

*AS REQUIRED
BY LOAD
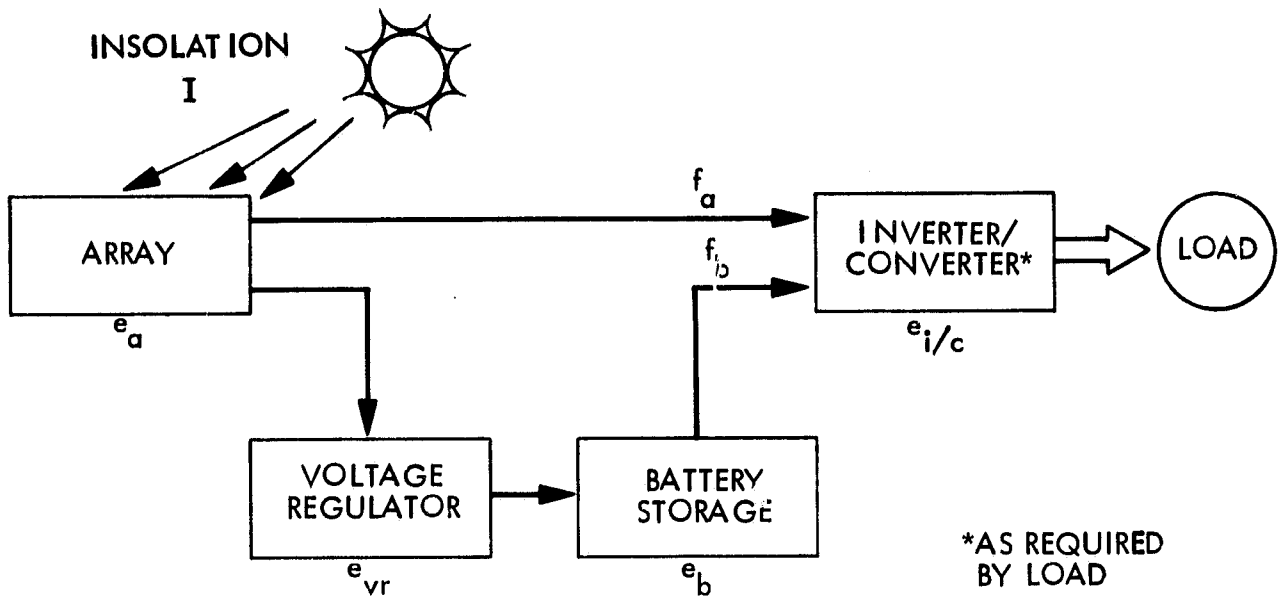
Figure 2-2. Photovoltaic System Model Showing Key System Sizing Parameters

$e_{i/c}$, respectively.[3] As appropriate, these terms should be used in system sizing to account for losses occurring in these system elements during system operation.

The steps in the sizing methodology shown in Figure 2-1 are summarized below (complete details of the sizing procedure are presented in Section II.C.):

(1) Calculate the Load. The average daily energy load in kilowatt-hours is calculated for each month of the year. In the simplest case, a single load element draws constant power at all times. If several load elements are present, the individual elements must be summed. If the load totals vary from day to day, an average daily load over each month of the year will be required.

(2) Determine the Local Insolation. The appropriate amount of input energy (i.e., insolation, I) to the photovoltaic system at the application site may be obtained from tables in Appendix D for various array tilt angles. As insolation values will vary from month to month, average daily values for all months are included in the tables.

---

[3]In cases where neither an inverter or converter is required by the system, the $e_{i/c}$ term in the sizing calculations is equal to 1.0 (i.e., no conversion losses). Similarly, if no storage is required, both e_{vr} and e_b are set equal to 1.0.

(3) <u>Calculate "Worst-Month" Insolation and Load Values.</u> The sizing approach requires identification of the load and insolation values expected during the "worst month" of the year. This is done by constructing a table of average insolation and load values for each month of the year and then determining the month with the lowest ratio of insolation to load. The insolation and load values for the selected worst month are used in subsequent steps to calculate required array size and battery storage capacity.

(4) <u>Determine Array and Battery Storage Sizing Factors.</u> The approach used in the methodology to size the array and storage is to apply previously determined "sizing factors" in the array and storage calculations in order to scale the system to achieve a desired level of autonomy (i.e., availability). These factors are displayed in a nomograph to facilitate selection of the appropriate sizing factor values for use in subsequent array and battery size calculations.[4]

   (a) In some sizing applications, the user may specify the level of system autonomy by placing a requirement on the number of sunless days during which the system must be able to satisfy the intended load. The sizing method in this document may also be applied in that case.

   (b) Estimate the load fractions supplied by the array and battery storage. Since energy supplied by the array directly to the load suffers less power loss than that passing through the battery storage, the fraction flowing to the load by each pathway should be estimated. In cases where these estimates are especially difficult to make, the user may follow a conservative sizing approach by letting the fraction from the array equal zero and the fraction from the battery equal one.

(5) <u>Calculate Array Power and Area.</u> Calculating array size means calculating both its required peak power output in watts and its corresponding area in square meters. The array sizing calculations incorporate the worst-month load, array sizing factor based on the worst-month insolation, efficiencies of all major system elements, and a term to account for long-term array degradation.

   A modification of the sizing methodology may be applied to certain specialized applications that require no battery storage to back up the photovoltaic array, such as the case of pumping water to a storage reservoir.

(6) <u>Calculate Battery Storage Size.</u> Calculating battery storage size requires scaling the storage to supply the daily energy load for a sufficient period of time to assure that the photovoltaic system meets the load requirements at least 96 to 98% of the time (or

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[4]This approach has been adapted from Reference 3.

equivalently, a 0.1 "loss of energy probability" (LOEP) during the worst month of the year). Alternatively, the storage can be sized to supply the load for a specified number of sunless days. In either case, the actual rated capacity is adjusted to ensure battery operation within acceptable depth of discharge limits.

(7) Calculate the Voltage Regulator Size. The battery charging voltage regulator is sized to handle the maximum amount of array output power (dc) that is not being used to supply the load. For conservatism, this will be considered to be the full rated peak array output power to account for situations in which the load has been disconnected.

(8) Calculate the Inverter/Converter Size. The inverter or converter, if either is required, is rated according to its output capacity in watts or kilowatts ac or dc, respectively. These units are sized to match or exceed the maximum steady state load power requirement (or maximum surge current for inductive loads) occurring at any time during the expected system life.

The remainder of Section II describes the sizing procedure in detail.

C.   PHOTOVOLTAIC SYSTEM SIZING PROCEDURE

This section describes the procedure for sizing the photovoltaic system using the steps identified in Figure 2-1. An example implementation of this procedure, along with sample data, is shown in Appendix A. The associated life-cycle cost analysis procedure is described in Section III.

1.   Calculate the Load

Sizing the photovoltaic system first requires a calculation of the average daily energy load for each month of the year. The daily energy load for a single device or element is calculated as the power it draws in kilowatts times the number of hours that it is in service during every 24-hour period. If more than one load element is to be served, the total daily energy load is obtained by summing the individual loads as shown in Equation (1).

$$L_{td} = \sum_{i=1}^{n} P_i D_i / 1000 \qquad (1)$$

where

L_{td} = total daily energy load in kilowatt-hours per day

P_i = power drawn by load element i while it is in service, in watts

D_i = amount of time per day in hours that load element i is in service

n = number of separate load elements

For loads that vary from day to day, an average daily load is calculated for each month of the year. An average daily load for a given month is the sum of all daily loads divided by the number of days in the month.[5] If the load consists of both ac and dc elements, the load calculations and subsequent system sizing procedures should be applied separately to the ac and dc loads. The final array and battery sizes are then obtained by summing the separate array and battery sizes calculated for the ac and dc elements.

Note that this assumes that system and load are co-located. If the distance from a power source to dc load is increased beyond a few meters, resistive wiring losses will begin to become apparent. These losses will necessitate a compensating increase in the required system size. If deemed significant, the user of this methodology may allow for dc wiring losses by increasing the calculated load size served by the photovoltaic system to include the I^2R power losses calculated for the dc run.

2. Determine Local Insolation

Average daily insolation values for each month of the year must be determined for the application site. Appendix D contains insolation values for three possible array tilt angles for a variety of United States sites. Insolation for United States sites not listed may be estimated by interpolation between nearest tabulated values. Other sources may be consulted for non-United States locations. Insolation values determined for the site will be used in the next step of the sizing methodology.

3. Calculate "Worst-Month" Insolation and Load

This methodology requires the remote, stand-alone photovoltaic system to be sized to meet the load during the "worst month" of the year. The worst month is the one with the smallest ratio of energy falling on the array (insolation) to the energy required by the load. If the system is sized to meet the load during the worst month, it will automatically be sized adequately for all other months.[6] The worst-month insolation and load values (i.e., values for which the insolation-load ratio is the smallest) are most conveniently identified by setting up a table that lists daily average insolation for each month along with daily average load.

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[5]If the daily load variation is sufficiently large, or if load peaks appear on consecutive days, it may be necessary to use the peak load levels in place of monthly averages. Otherwise, the system may be inadequately sized to accommodate cloudy periods coinciding with these high load periods.

[6]System designers will often reduce the required array size and system cost by relying on "long term storage" in which energy stored during months of high insolation will be held for use during months of low insolation. In the present sizing method, the worst-month approach has been adopted to provide a somewhat more conservative size estimate.

In Table 2-1, the insolation data (in kWh/m^2-day) are those listed in Appendix D for China Lake, California; the load data (in kWh/day) were chosen arbitrarily to illustrate the procedure. Note that in the table, the load data are listed next to insolation data corresponding to three different array tilt angles. The sizing procedure uses these insolation-load ratios in order to accommodate non-constant insolation and loads over the year. The three tilt angles, tilt equal to latitude, latitude +15 deg, and latitude -15 deg, will typically bound the range of array orientations required to best match the load whether the load is constant year round, winter peaking, or summer peaking. Using the tabular approach described below will assure a good estimate of the minimum array size necessary to serve the load regardless of the annual load pattern.

Table 2-1. Example of Method for Determining the Appropriate Insolation and Load Combinations for Sizing the Array and Battery Storage. (Sample Insolation Data are for China Lake, California.) Note that the example load is month-dependent, i.e., not constant (see text for details).

Month	Tilt Angle = Latitude -15 deg Insolation (I) ÷ Load (L_{td}) = ___	Tilt Angle = Latitude Insolation (I) ÷ Load (L_{td}) = ___	Tilt Angle = Latitude +15 deg Insolation (I) ÷ Load (L_{td}) = ___
January	3.88 ÷ 2.8 = 1.39	4.38 ÷ 2.8 = (1.56)	[4.63] ÷ [2.8] = (1.65)*
February	4.77 ÷ 2.8 = 1.70	5.13 ÷ 2.8 = 1.83	5.20 ÷ 2.8 = 1.86
March	6.19 ÷ 2.5 = 2.48	6.34 ÷ 2.5 = 2.54	6.13 ÷ 2.5 = 2.45
April	7.33 ÷ 2.5 = 2.93	7.07 ÷ 2.5 = 2.83	6.46 ÷ 2.5 = 2.58
May	7.88 ÷ 2.5 = 3.15	7.26 ÷ 2.5 = 2.90	6.32 ÷ 2.5 = 2.53
June	8.30 ÷ 2.5 = 3.32	7.50 ÷ 2.5 = 3.00	6.38 ÷ 2.5 = 2.55
July	8.07 ÷ 2.5 = 3.23	7.43 ÷ 2.5 = 2.97	6.45 ÷ 2.5 = 2.58
August	8.63 ÷ 2.5 = 3.45	8.34 ÷ 2.5 = 3.34	7.61 ÷ 2.5 = 3.04
September	7.16 ÷ 2.0 = 3.58	7.36 ÷ 2.0 = 3.68	7.14 ÷ 2.0 = 3.57
October	5.88 ÷ 2.0 = 2.94	6.41 ÷ 2.0 = 3.21	6.57 ÷ 2.0 = 3.29
November	4.53 ÷ 2.0 = 2.27	5.17 ÷ 2.0 = 2.59	5.51 ÷ 2.0 = 2.76
December	3.82 ÷ 2.8 = (1.36)	4.43 ÷ 2.8 = 1.58	4.78 ÷ 2.8 = 1.71

To determine the worst-month insolation and load values, Table 2-1 is applied as follows. In the columns below each tilt angle, enter the insolation value for each month as it appears in Appendix D for the appropriate application site. To the right of each insolation value, enter the calculated daily average load value for each month (see Step 1). The same load values should appear in each of the three tilt angle columns. Note that in the case of a constant, year-round load, all load values in the table will be identical. For each pair of insolation and load values, calculate the ratio of insolation to load, as shown. For each tilt angle column, select and circle the smallest resulting ratio. There may be duplicate values in one or more columns. Next, select the largest of the circled values. This value is indicated by "*." This value is a best estimate of the worst-month insolation/load ratio for the example application. Insolation and load values obtained in this manner are used in the following sizing steps. In Table 2-1, these values appear in boxes. Note that in this example, the array tilt angle selected is latitude +15 deg, denoting the choice that the array is oriented to serve a winter peaking load.

4.   Determine Array and Battery Storage Sizing Factors

The next step in the sizing procedure is to determine the factors for array and battery sizing to be used in subsequent calculations of the actual array size and battery storage capacity.[7] These factors have been derived from prior analyses of how the photovoltaic system loss of energy probability (LOEP) depends on array and battery size for a range of possible worst-month insolation levels (Reference 4).[8] By determining the required size of array and battery storage per unit of load, dependent on the worst-month insolation, the proper array and battery sizes can then be calculated using insolation and load values determined in Step 3, above.

This probability value is the "worst-month LOEP;" i.e., the probability that the system will be unable to meet load requirements during the month having the smallest insolation/load ratio. The methodology in this document is based on a worst-month LOEP value of 0.1. This LOEP value for the worst insolation month corresponds to a monthly average LOEP of approximately 0.02-0.04. This value will provide a service availability roughly equivalent to that of conventional competitor power systems such as diesel, etc. If comparing photovoltaic to other renewable energy systems, an equivalent availability analysis is required for the other technologies. Reference 3 also presents results for LOEP values of 0.01 and 0.001; i.e., higher system availabilities. (Generalized approaches are described in References 4 and 5 which allow sizing the system to any LOEP value that may be required by the specific application.) It should be noted that the LOEP is based on the characteristics of insolation only and does not take into account photovoltaic equipment reliability.

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[7]Adapted from Reference 3.

[8]The loss of energy probability is an estimate of the probability that during a given time period, the energy output of the power system will be insufficient to meet the energy load demand.
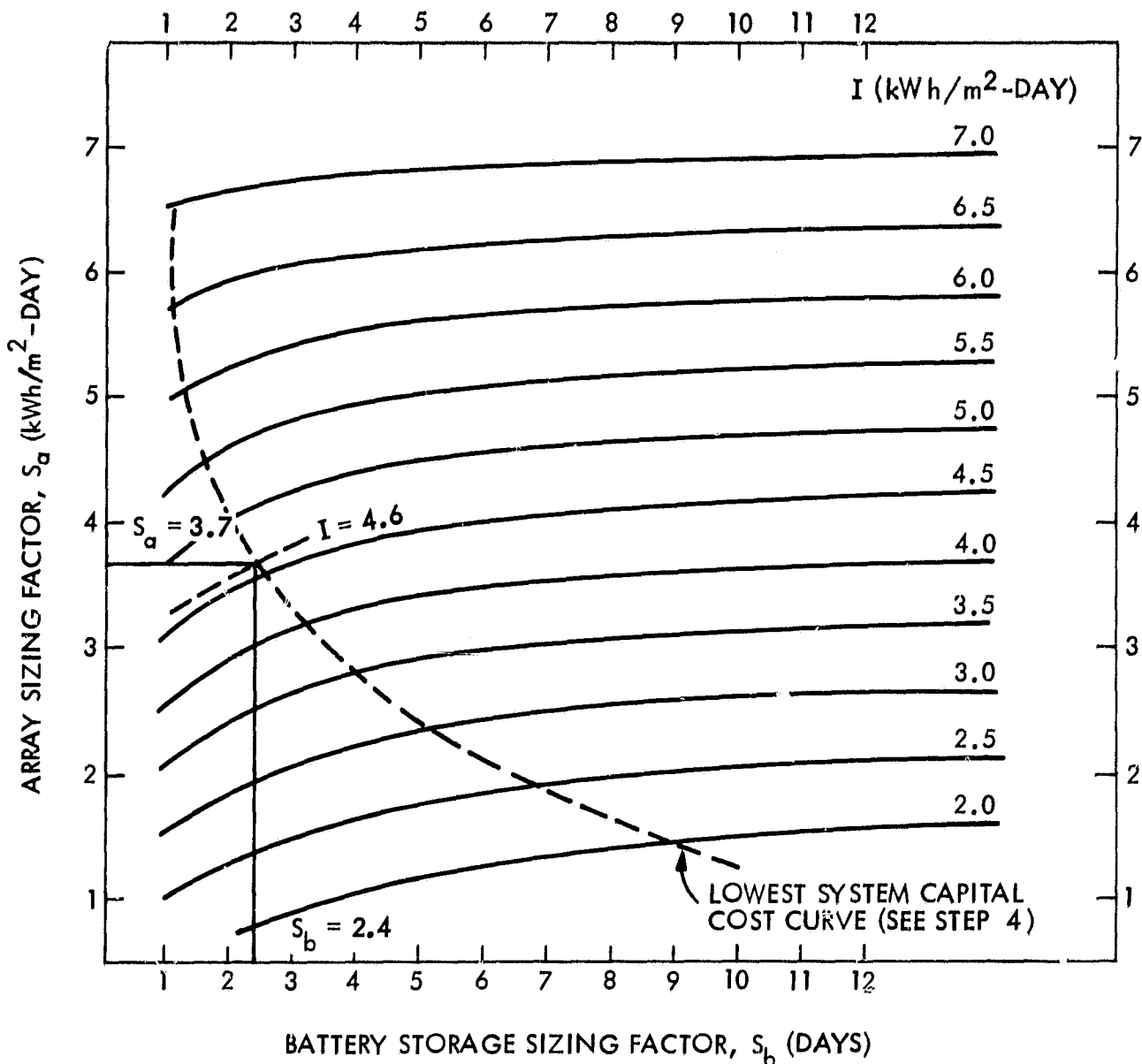
Figure 2-3. Determining Array and Battery Storage Sizing Factors
(at LOEP = 0.1) for Various Worst-Month Insolation
Values. (Adapted from Reference 3)

The sizing factors for the array and battery storage appear in
Figure 2-3 in the form of a nomograph. In the nomograph, the solid curves
each correspond to an insolation value as marked. Each solid curve shows the
relationship between the array sizing factor, S_a, and the battery storage
sizing factor, S_b, for that insolation value. S_a and S_b values to be
used in subsequent array sizing calculations are selected by first choosing
the solid curve whose worst-month insolation value equals that found by the
method in Step 3. Interpolation may be used to obtain more precise results.
A trial point on the selected solid curve is chosen next: the point of

intersection of the dashed line with the solid curve is the best initial choice. (The significance of the dashed line will be discussed below.) The array sizing factor, S_a, is found by extending a horizontal line from that point on the curve to the scale on the left of the nomograph. Similarly, the battery sizing factor, S_b, is found by extending a vertical line down from the same point on the solid curve to the scale at the bottom of the nomograph.

An example is shown in Figure 2-3 for the case in which the worst-month insolation = 4.6 (see Table 2-1). Any point on a given insolation curve will result in a worst-month LOEP exactly equal to 0.1. Different points on the insolation curve, however, will result in different combinations of array and battery sizes. For example, selecting a point on the solid curve farther to the left will result in a system with larger array and smaller battery storage, although it will still provide the same level of power availability (i.e, the same LOEP).

System capital cost will vary for different battery and array size combinations. For this reason, a dashed line intersecting the solid curves also appears in the nomograph. The intersection of the dashed line with the relevant insolation level defines the sizing factors that lead to lowest photovoltaic system capital costs for each insolation curve as derived from earlier photovoltaic component cost experience in remote, stand-alone system applications (Reference 3). The dashed line may thus be used as a guide for the initial selection of sizing factor values.

It should be recognized, however, that use of this dashed curve will not necessarily result in a lowest life-cycle cost estimate since it is based only on initial system capital costs. Other life-cycle cost factors such as operation, maintenance, and various financial parameters, have not been incorporated into the nomograph. Furthermore, since photovoltaic array costs are expected to decline in the future more rapidly than battery costs, the lowest capital cost system configuration is likely to be determined from points on the curves to the left of the present dashed line. The recommended approach in using this methodology is to initially select the point of intersection of the dashed line and the sol1 line nearest the worst-month insolation for the site. After determining the corresponding S_a and S_b values and calculating the array and battery storage sizes, the life-cycle cost should be computed according to the procedure in Section III. If it is found in this initial cost estimate that the photovoltaic system appears less economical than its competitors, additional array/battery size combinations should be examined. In this case, points on the solid curve to the left and right of the original point are chosen, corresponding array and storage sizes are calculated, and new life-cycle costs estimated. This process may be repeated until an approximate lowest (i.e., local optimum) life-cycle cost is obtained.

a.   Determine Sizing Factors for a Specified Number of Sunless Days. A photovoltaic system will frequently have to be sized under the condition that the system must be able to serve the load for a specified number of consecutive sunless days (or days of autonomy). The nomograph in Figure 2-3 may also be applied in these circumstances, but its use is somewhat different.

In this case, the specified number of sunless days is simply used as the battery sizing factor, S_b. The user is cautioned that the chosen S_b must be at least as large as the S_b displayed in Figure 2-3 to ensure adequate power to serve the load and recharge batteries at the stated level of reliability (i.e., LOEP = 0.1). From the point on the scale in Figure 2-3 where S_b is equal to the number of sunless days, a vertical line is drawn to intersect the solid curve whose value is closest to the appropriate worst-month insolation. From this intersection point, a line drawn left to the S_a scale determines the proper value of S_a. Sizing the system according to a specified number of sunless days generally will not yield the lowest capital-cost system having a given LOEP. However, specialized requirements of the application (e.g., very high reliability requirements as in the case of microwave repeaters) will sometimes dictate this approach.

b. <u>Estimate Load Fractions Supplied by the Array and Storage</u>. The energy load fraction supplied by the array, f_a, is that portion of the load energy that flows directly from the array, via an inverter or converter if one is used. The fraction f_b is the portion of the load supplied from battery storage. By definition, $f_a + f_b = 1$. Energy that flows from the array through battery storage is subjected to greater losses than that flowing directly from array to load. Therefore, the relative sizes of f_a and f_b will affect the required size of the array.

The equation to be used to calculate the array size in this methodology (Equation (2)) contains the load fractions f_a and f_b. However, precise calculation of the load fractions is difficult due to varying photovoltaic output by time of day and can be additionally complicated for complex or irregular load profiles. A means of estimating these fractions is described in Appendix B. The user may prefer to use the simplifying assumption that all of the array energy passes through the battery storage before passing to the load; i.e., letting $f_a = 0$ and $f_b = 1$. This is a conservative approach that tends to overestimate the system size since in most applications the load in part is supplied directly from the array, thus avoiding storage losses. For today's component efficiencies, the degree of oversizing will range from 0 to 25%, respectively, for the case of a nighttime-only load and the case in which load and array output are perfectly matched. The degree of oversizing for a constant, 24-hours/day load is typically less than 10%.

5. Calculate Array Power and Area

Calculating the array size means calculating both its peak power output in watts and its area in square meters. Both results are required for system costing.

The array size calculation requires the worst-month load value, L_{td} (determined in step 3), the array sizing factor, S_a (found from Figure 2-3), and the load fractions f_a and f_b. Also, the efficiencies of the storage batteries, voltage regulator, and inverter or converter are required. Typical values of these efficiencies appearing in Appendix A may be used in case they are not otherwise available. Finally, a factor, F, will be included in the

array calculation to account for array degradation over the lifetime of the system. This factor initially oversizes the array slightly to ensure that the system will meet load requirements until the end of its design life despite gradual array power output degradation.

The required array power is now calculated from Equation (2).

$$P_a = \frac{L_{td} \times 1000}{S_a \times F \times e_{i/c} \, [f_b \, (e_{vr} \times e_b) + f_a]} \tag{2}$$

where

P_a = array power in watts

L_{td} = energy load value in kilowatt-hours/day

S_a = array sizing factor in kilowatt-hours per square meter per day

$e_{i/c}$ = inverter or converter efficiency at maximum steady state load, if used; otherwise, $e_{i/c} = 1$

F = factor to account for array degradation over the system lifetime

e_{vr} = efficiency of voltage regulator if used; otherwise, $e_{vr} = 1$

e_b = battery efficiency

f_a = fraction of load energy supplied directly by the array

f_b = fraction of the load energy supplied from battery storage

1000 = 1000 watts/m^2; a term to convert S_a into an equivalent number of hours per day that 1000 watts/m^2 insolation would be received by the array

This equation may also be applied to systems without storage. As in the case with storage, the array output energy on an average daily basis must match the average daily load energy requirements. Equation (2) can be applied by setting $f_b = 0$, $f_a = 1$, $e_b = 1$, and S_a = the worst-month insolation value. Note that in this case the LOEP of the photovoltaic system has not been estimated; thus, this case departs from the comparable-reliability sizing approach that underlies the balance of the document.

Array area is based on the array power level determined in Equation (2) and is shown in Equation (3) below:

$$A_a = \frac{P_a}{e_m \left[1 + P_{TC} \left(T_{op} - 28^{\circ}C\right)\right] \times 1000} \tag{3}$$

where

A_a = array area in square meters

P_a = array power in watts obtained from Equation (2)

e_m = module efficiency at standard test conditions (STC)

P_{TC} = module temperature coefficient; typically = $-0.005/C^{\circ}$

T_{op} = actual module operating temperature in degrees Celsius. For temperate climates, use the nominal operating cell temperature (800 mW/cm^2, 20°C ambient, 1 m/s wind speed, 1.5 air mass) (NOCT). For hot climates (peak summer temperature over 110 to 115°F), use NOCT +10°C

1000 = 1000 W/m^2 at standard test conditions

6. Calculate Battery Storage Size

The next step in sizing the system is to calculate the required size of the battery storage in kilowatt-hours. Battery storage size is based on S_b from Figure 2-3 (or on a prior specification of the number of sunless days) and an allowance for the "depth of discharge" limit on the batteries. Operating within this limit prolongs battery life and protects the batteries in applications subject to freezing temperatures. Calculating the required battery capacity also requires the worst-month load value previously used in the array sizing equations. Finally, the inverter or converter efficiency used to calculate storage size is the same value used for the array calculation.

The required battery storage size is calculated using Equation (4).

$$E_b = \frac{L_{td} \times S_b}{d \times e_{i/c}} \tag{4}$$

where

E_b = rated battery energy storage in kWh

L_{td} = worst-month average daily load value in kWh/day (see Step 3)

S_b = battery sizing factor in days

d = maximum allowable depth of discharge

$e_{i/c}$ = efficiency of the inverter or converter. If neither is used, $e_{i/c} = 1$

7. Determine Voltage Regulator Size

The battery charging voltage regulator is sized to handle the maximum amount of array output power likely to be available for charging the batteries. For conservatism, the regulator [or battery protector as it is known for small systems (<3 kW)] must be able to handle the array output at noon on a cold, clear day with the load disconnected. The voltage regulator is therefore sized to match array output at standard test conditions (1 kW/m^2, 28°C cell temperature).

8. Determine Inverter or Converter Size

The inverter or converter typically is sized according to the maximum steady-state load power requirement in watts, ac or dc, respectively. However, if the photovoltaic system is to be used to power an inductive load, the inverter must be able to supply the full surge current required by the load. In the case of an induction motor, the starting current can be as large as 4 to 5 times the rated motor requirements.

SECTION III

SYSTEM COST ANALYSIS

A.   SCOPE

Cost effectiveness is the primary criterion for evaluation of candidate photovoltaic system applications. This section presents the life-cycle costing methodology to be used for determining photovoltaic system cost effectiveness. The methodology is intended primarily for estimating the viability of a photovoltaic power system compared to a non-photovoltaic power alternative, rather than precise energy cost estimation. Furthermore, it is solely intended for use by Government agencies since use by private entities would involve additional considerations such as the effect of taxes.

B.   COST ANALYSIS METHODOLOGY

To determine whether a photovoltaic system is cost effective in a given application, the life-cycle cost of the photovoltaic system should be compared to the life-cycle cost of the alternative power system such as diesel generator, batteries, utility grid connection, or renewable energy technologies (see Figure 3-1). For the purpose of this comparison, the capabilities of satisfying load (i.e., availability) of all power systems being evaluated are assumed to be identical. The sizing analysis in Section II has been designed to ensure that photovoltaic system performance is adequate to satisfy the specified load.

1.   Photovoltaic System Life-Cycle Cost

Photovoltaic power system life-cycle cost is estimated from the initial cost of the system installed at the site and the present value of all recurrent costs associated with system operation. Photovoltaic systems are typically capital intensive (i.e., they require a large initial capital expenditure), but have low operating costs (i.e., zero fuel cost and small expenditures for replacement, operation, and maintenance). The sum of capital and recurrent expenditures represents the equivalent amount of money required at the time of system installation to completely cover all costs associated with the photovoltaic system, including a return on the investment, over its operating lifetime.[9] Life-cycle cost of the alternative to a photovoltaic system similarly combines the associated first cost and operating cost for comparison with the photovoltaic option.

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[9]The "lifetime" of a photovoltaic, or any other power system, may be interpreted as the "financial lifetime" for the purposes of a life-cycle cost analysis. As such, the photovoltaic system operating lifetime provides a guideline, but not a constraint, on the lifetime chosen for the life-cycle cost analysis. Equal lifetimes must be chosen between competing technologies in the cost analysis described in this document.
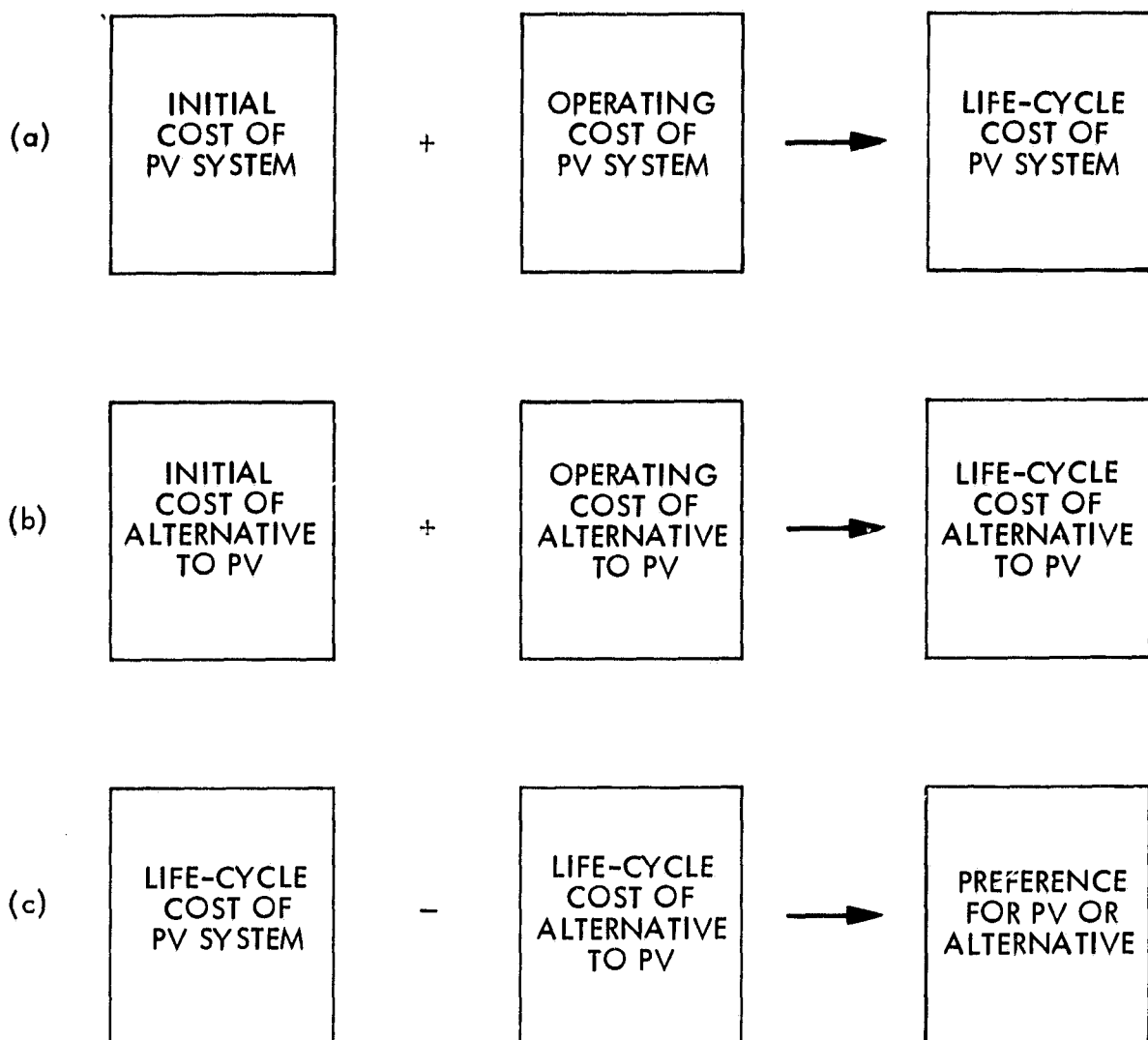
Figure 3-1. Approach for Determining Photovoltaic Power System
Cost Effectiveness

The initial cost of a photovoltaic system can be determined from the co
of the array (in $/W); power-related balance-of-system cost [i.e., battery
storage in $/kWh; voltage regulator in $/W regulator input power, and inverte
(or converter) costs in $/W ac (or dc)]; area-related balance-of-system costs
(i.e., structures and wiring costs in $/m^2 of array); system installation and
testing cost in percent of equipment cost, and any indirect costs (i.e.,
engineering and management fees, delivery, and contingency) in percent of
equipment cost. Equation (5a) describes the analytical relationships and
Equation (5b) displays the detailed procedure for estimating initial installe
photovoltaic system cost (IC).

$$\text{Initial cost} = [1 + \text{indirect } (\%) + \text{installation } (\%)]$$

$$\times [\text{delivered equipment cost } (\$)] \tag{5a}$$

$$IC = (1 + IND + INST) [(MOD \times P_a) + (ABOS \times A_a) + (CONV \times W_{DC})$$

$$+ (INV \times W_{AC}) + (REG \times W^*) + (BAT \times BWh)] \tag{5b}$$

where

IND = fractional indirect costs on equipment including engineering, management, and contingency fees

INST = fractional cost on equipment for installation, site preparation, testing, and checkout cost of the system

MOD = module cost in dollars per peak watt of array

P_a = peak watts of solar array (dc)

ABOS = area-related balance-of-system cost per square meter of array including cost of array structure, land, wiring, connectors, etc.

A_a = array area in square meters

CONV = converter cost per peak watt (dc)

W_{DC} = rated size of converter in peak watts (dc)

INV = inverter cost per peak watt (ac)

W_{AC} = rated size of the inverter in peak watts (ac). If more than one inverter is used, sum the peak watts of each. If commercially available inverters do not match the load requirement exactly, select the smallest unit sufficiently large to satisfy the load

REG = voltage regulator cost per peak watt (dc) of maximum regulator input power. (Note that cost may vary as a function of input voltage level)

W^* = maximum voltage regulator input power

BAT = battery cost per kilowatt-hour of energy storage

BWh = battery storage size in kilowatt-hours

Equipment cost estimates are assumed to include delivery to the site. All dollar amounts should be expressed in the same "base year" (e.g., 1984) for

consistency. Current dollar cost estimates based on prior year information will need to be escalated to the appropriate "base-year" level.

In addition to the initial installed system cost described above, recurrent costs associated with photovoltaic system operations are to be included in the estimation of life-cycle cost. Estimates of operation, maintenance, and replacement costs are based on hardware performance characteristics and system operating strategy. Expenditures are primarily for battery replacement (if battery storage is included in the system design) and array, inverter or converter, and battery operation and maintenance. The photovoltaic system operating strategy (e.g., the system may or may not be required to operate autonomously for a prolonged period of time) will affect both the initial system cost and the recurrent costs.

Battery lifetimes are typically between 5 to 10 years depending on manufacturer-specific battery characteristics, number of discharge cycles, design depth of discharge, and operating temperature. In contrast, the anticipated life of a photovoltaic array is estimated to be about 30 years. Battery replacement at regular intervals are, therefore, required throughout the operating lifetime of the photovoltaic array. The cost for each replacement of storage batteries (BR) is shown in Equation (6):

$$BR = (BAT \times BWh)(1 - SV) + LREP \qquad (6)$$

where

BAT X BWh = delivered cost of batteries from Equation (5b)

SV = fractional salvage value of batteries at time of replacement

LREP = labor cost of battery replacement (in base-year dollars)

Salvage value of the batteries is typically based on prices in the scrap metal market (e.g., for lead or nickel) at the time of replacement. The present value of the sum of all battery replacements (RPV) over the photovoltaic system lifetime, escalated and discounted to account for the timing of the expenditure, is estimated using Equation (7) as follows:

$$RPV = \sum_{j=1}^{nrep} BR \times \left(\frac{1 + esc_b}{1 + dr}\right)^{j \times k} \qquad (7)$$

where

j = counter for number of battery replacements (1, nrep)

k = battery lifetime (years)

$j \times k$ = constrained to be strictly less than photovoltaic system
lifetime or lifetime used in life-cycle cost analysis (years)

BR = single-time battery replacement cost from Equation (6)
in base-year dollars

esc_b = real (above inflation) annual escalation rate for storage
batteries (fraction)

dr = discount rate (cost of money to system owner, typically defined
as 10% (real) for Government applications)

Expenditures for replacement of capital equipment (other than batteries)
with lifetimes shorter than the assumed photovoltaic system lifetime can also
be determined using Equation (7), appropriately modified to reflect their cost
and timing. For the purpose of this document, such replacements are
considered minimal and are incorporated in the annual operation and
maintenance cost equation described below.

Regular operation and maintenance costs can be estimated on an annual
cost basis. These costs include expenditures for activities such as array,
battery, and inverter maintenance; component replacements (other than
batteries); and grounds, structural and electrical upkeep. Annual operation
and maintenance costs (OM) can be estimated on the basis of the number of
required visits to the site per year times the cost per trip in base-year
dollars. A heuristic frequently used to estimate annual operation and
maintenance expenditures is to assume that annual expenses are a fixed
percentage of the initial cost of equipment. The present value of the cost of
operation and maintenance procedures is the derived annual amount summed over
the system lifetime, including any real escalation and discounting of
expenditures over time. Annual expenditures are, therefore, growing in dollar
amount at the constant rate of real escalation, if any. Present value of
operation and maintenance cost (OMPV) is presented in Equation (8) as follows:

$$OMPV = OM \times \left(\frac{1 + esc_{om}}{dr - esc_{om}}\right) \times \left[1 - \left(\frac{1 + esc_{om}}{1 + dr}\right)^N\right] \text{, if } dr \neq esc_{om} \qquad (8)$$

or

$$OMPV = OM \times N \text{, if } dr = esc_{om}$$

where

OM = annual operation and maintenance cost in base year dollars

esc_{om} = real (above inflation) annual escalation rate for operation
and maintenance activities (fraction), typically 0%

dr = real discount rate (fraction); typically 10%

N = system lifetime (years)

Photovoltaic system life-cycle cost (LCC) can now be determined from its constituent parts described above. Life-cycle cost is displayed in Equation (9) as the sum of the initial installed system cost, Equation (5) and the present value of recurrent costs, Equation (7) plus Equation (8).

$$LCC = IC + RPV + OMPV \tag{9}$$

All costs are in base year dollars. Typical values for parameters in Equation (5b) are presented in an example in Appendix A. As a guide for photovoltaic system cost analysis, initial installed system costs (IC) presently range from approximately $17 to $25/watt.

2. Alternative Power System Life-Cycle Cost

Photovoltaic system cost effectiveness is determined by comparison of the photovoltaic system life-cycle cost with the life-cycle cost of the competing energy technology. For a given application, photovoltaics may be competing with fossil fuel, battery, utility grid, or other renewable energy alternatives. In this section of the report, the cost of alternative technologies to photovoltaics are characterized. Section III.B.3 selects the least-cost non-photovoltaic alternative as the basis for the cost-competitiveness assessment.

Small stand-alone photovoltaic systems are potentially competitive with a number of alternatives including diesel generators, batteries, extension of a distant utility grid, and other current solar technologies. The life-cycle cost estimated for each alternative is consistent with the photovoltaic cost approach shown in Equation (9). Initial installed costs (IC), present value of capital replacements over the system lifetime (RPV), and present value of operation and maintenance costs (OMPV) are summed to their respective life-cycle cost. For the purpose of this analysis, the capability of all power systems to satisfy load (i.e., their availability) is assumed to be identical.

Diesel power generation systems require initial capital expenditures for diesel generators, a fuel storage system, and installation (IC). Diesel generators will require periodic repair, overhaul, and replacement within the time frame of the analysis (approximately 20 to 30 years). Recurrent maintenance and fuel costs for these types of systems are also of great importance. In many remote, stand-alone applications, the cost of fuel, labor, transportation and materials can be significant. Estimation of annual diesel generator operation and maintenance costs (OM) should be based on actual cost data.

Initial capital costs for battery systems are estimated in a manner similar to the battery cost term in Equation (5b), Bat x BWh, plus the cost of associated control equipment, indirect costs, and installation. However, the battery system in this case must be sized to satisfy the entire load, accounting for system inefficiencies and assumed interval between recharges. Battery lifetimes are less than that of photovoltaic systems and thus will require replacement at regular time intervals within the assumed 20 to 30 year photovoltaic system lifetime. Battery electrical characteristics, cycling requirements, depth of discharge, and operating temperature contribute to the estimate of battery life. The present value of the cost of replacement is calculated as described in Equations (6) and (7). Remaining salvage value of used batteries is explicitly taken into account. Operation and maintenance costs, Equation (8), include battery inspections, recharge, and equalization at regular intervals depending on battery capacity, load being served, and depth of discharge.

Extension of an existing utility grid line can be very expensive for a remote application with a relatively small load. The costs for extending grid power to a remote site and for the kilowatt-hour meter are treated as initial capital costs (IC). Cost estimates for this equipment can be obtained from the local utility company. Once the utility line is installed, the primary recurrent cost is the cost of energy to serve the load. Current utility rate structures provide the basis for this cost over the photovoltaic system lifetime (OMPV). Note that in some locations, utility reliability may also be a factor in the comparison between photovoltaics and utility-supplied power.

Life-cycle cost estimates for other renewable energy alternatives (non-photovoltaic) require cost information as described in Equation (9). Specific system design and associated cost inputs will need to be developed by the organization performing the system comparison.

In addition to competing with the capital and operating costs associated with installing capacity to satisfy a new load is the potential for photovoltaics to operate in a fuel-displacement mode for an already existing application. Energy cost-intensive technologies in remote areas may provide a potentially cost effective use for photovoltaic technology. Though there would be no savings for initial capital expenditure on the alternative technology, the photovoltaic system would provide savings on operation and maintenance cost (OMPV) and, potentially, on delaying capital replacement (RPV) of the non-photovoltaic alternative. In this fuel-displacement mode, daytime photovoltaic system output can be used to satisfy coincident load. Battery storage can be added if it is found to be cost effective in this application. Either with or without battery storage, reliability of the alternative technology combined with the photovoltaic system would be enhanced.

C.   PHOTOVOLTAIC VERSUS ALTERNATIVE POWER SYSTEM COST COMPARISON

Photovoltaic system cost competitiveness can be determined by comparison with the least-cost non-photovoltaic power system that satisfies all performance and reliability requirements. Using the approach displayed in Figure 3-1(c), and repeated in Figure 3-2, the life-cycle cost of the non-photovoltaic system
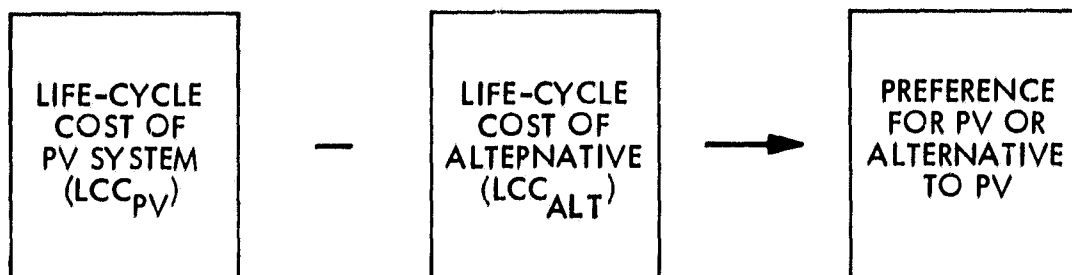
Figure 3-2. Life-Cycle Cost Comparison of Photovoltaic System (LCC_{PV}) and the Non-Photovoltaic System (LCC_{ALT})

(LCC_{ALT}) is subtracted from the life-cycle cost of the photovoltaic system (LCC_{PV}). Three outcomes are possible:

(1) $LCC_{PV} - LCC_{ALT} < \$0$. The photovoltaic system is cost effective compared to the alternative system. The absolute value of the difference is a first-order measure of the preference for photovoltaics.

(2) $LCC_{PV} - LCC_{ALT} > \$0$. The photovoltaic system is more expensive than the alternative; thus, it is not cost effective.

(3) $LCC_{PV} - LCC_{ALT} = \$0$. The photovoltaic and alternative systems are of equal cost in present value terms.

This differential cost (or net present value) measure of cost competitiveness provides the basis for deciding to pursue or terminate photovoltaic system analysis and design activities. If in the initial estimate of photovoltaic system life-cycle cost the system is determined not to be cost effective, the sizing procedure should be repeated from the estimation of array and battery sizing factors (see discussion, Section II-4).

If the photovoltaic system is determined to be cost effective (or reasonably close to cost effective) for a specific application, it is useful to perform a sensitivity analysis on important cost parameters over an appropriate range of values. This sensitivity analysis is useful to the decision maker since small variations in cost drivers, such as escalation in diesel fuel or electricity prices over the system lifetime and the price of photovoltaic modules, can significantly alter the relative preference for competing power systems. The result of this analysis is an understanding of the effect of uncertainty in parameter values on photovoltaic system cost effectiveness.

SECTION IV

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APPENDIX A
PHOTOVOLTAIC SYSTEM SIZING
AND COSTING EXAMPLE

APPENDIX A

PHOTOVOLTAIC SYSTEM SIZING AND COSTING EXAMPLE

This appendix presents an example of sizing and costing a hypothetical photovoltaic system using the methodology described in this report. Estimates of currently relevant photovoltaic system parameter values are shown as a guide for users of the methodology. A sample comparison of photovoltaic system cost effectiveness compared to competing technologies is then presented.

To illustrate the system sizing procedure, an example is presented based on the sample case described in Section II of this report. The application is a small, seasonally variable load located near China Lake, California. Determination of photovoltaic system size follows the step-by-step procedure described in Section II of this document and repeated in Figure A-1. Typical values (and ranges) for several of the photovoltaic system sizing parameters are displayed in Table A-1. The table should be consulted frequently in using this appendix for a description of each parameter name.

Step 1: Calculate Load

Total daily energy load (L_{td}) is determined from Equation (1) as follows:

$$L_{td} = \sum_{i=1}^{n} P_i D_i / 1000 \tag{1}$$

It is assumed that each season has a separate, single (n = 1) ac load (P) for 8 hours/day (D) during daytime hours. The power drawn by the single load i for each month is:

> 350 watts: December, January, February
> 312.5 watts: March, April, May, June, July, August
> 250 watts: September, October, November

The corresponding daily energy load (L_{td}) is 2.8 kilowatt-hours, 2.5 kilowatt-hours, and 2.0 kilowatt-hours, respectively.

Step 2: Determine Local Insolation

Appendix D contains the daily average insolation values for each month of the year and for three array tilt angles for a number of United States sites. Locate the site insolation values for China Lake, California, on page D-2. These values will be used in the following step of the methodology.
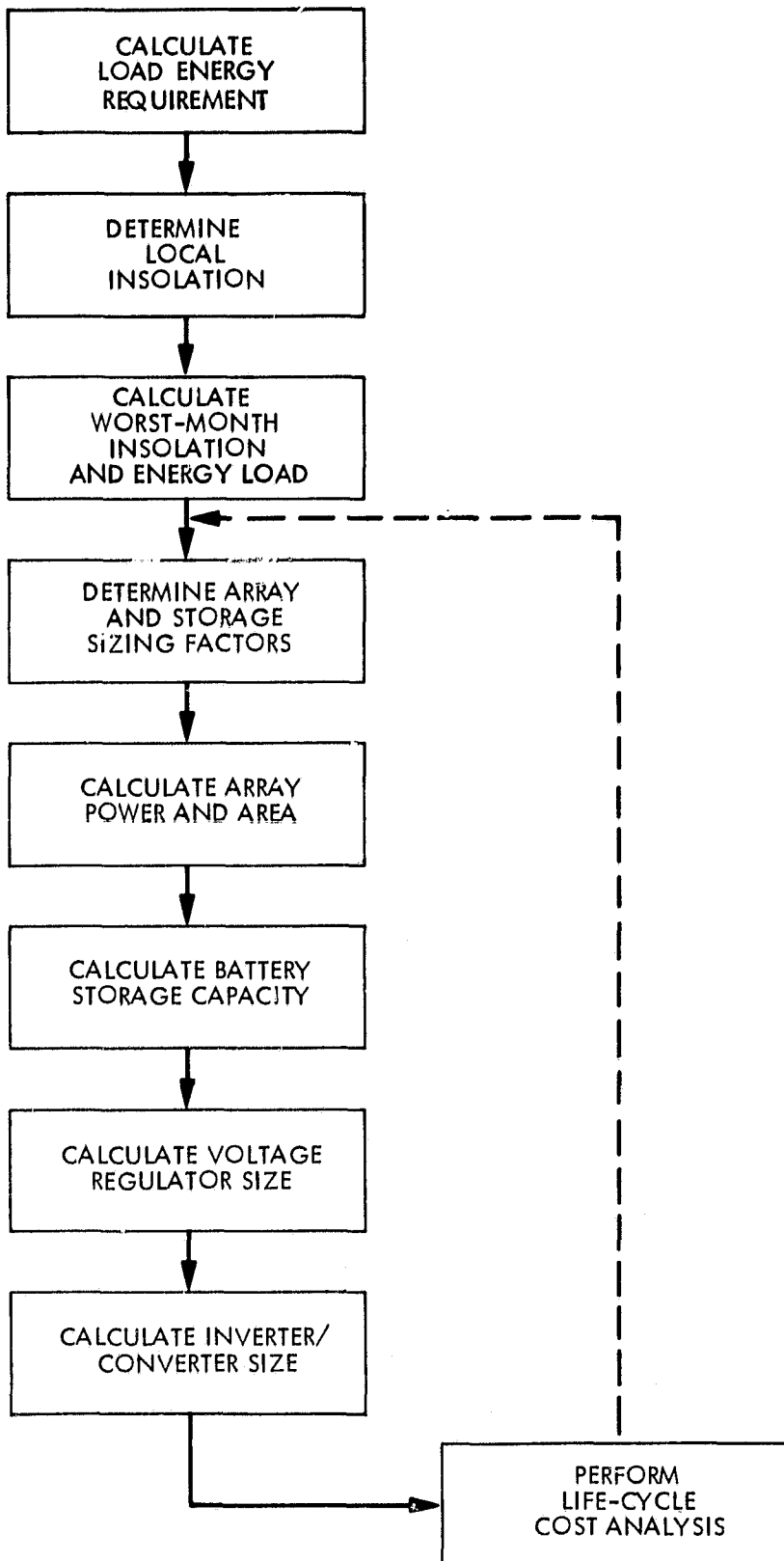
Figure A-1. Photovoltaic System Sizing Procedure

Table A-1. Photovoltaic System Sizing Parameters: Relevant
Ranges and Default Values

Parameter	Parameter Name	Units	Range	Value
Array area	A_a	m^2	--	a
Battery depth of discharge	d	fraction	0.05-0.80	0.60
Load i duration	D_i	hours/day	--	b
Battery efficiency	e_b	fraction	0.80-0.90	0.88
Inverter/converter efficiency	$e_{i/c}$	fraction	0.85-0.97	0.93
Module efficiency	e_m	fraction	0.06-0.11	0.10
Voltage regulator efficiency	e_{vr}	fraction	0.85-0.93	0.91
Degradation factor	F	fraction	0.75-0.95	0.85
Load fraction: array	f_a	fraction	--	c
Load fraction: batteries	f_b	fraction	--	c
Worst-month insolation	I	kWh/m^2-day	--	d,e
Worst-month load	L_{td}	kWh/day	--	b,e
Load i power requirement	P_i	watts	--	b
Array power requirement	P_a	watts	--	f
Module temperature coefficient	P_{TC}	fraction/C^o	-0.005	-0.005
Array sizing factor	S_a	kWh/m^2-day	--	g
Battery sizing factor	S_b	days	--	g
Module operating temperature	T_{op}	^oC	45-55	48 or 55h

[a] See Equation (3).
[b] See Equation (1).
[c] See Appendix B.
[d] See Appendix D.
[e] See Table 2-1.
[f] See Equation (2).
[g] See Figure 2-3.
[h] Temperate climate = 48°C and hot climate = 55°C.

Step 3: Calculate Worst-Month Insolation and Load

Construct a table of monthly insolation and load values using the information generated from steps 1 and 2. Display them as shown in Table A-2, below. (This example is the same as shown in Table 2-1). For each month and tilt angle, divide the insolation value by the load and enter the ratio into the table.

For each tilt angle column shown in Table A-2, identify the month with the smallest ratio of insolation-to-load. Next, select the largest one of these values (identified by "*"). The insolation (I = 4.6) and load (L_{td} = 2.8) values corresponding to this particular value are the ones to be used in later sizing steps. This allows the system (array and battery) to be sized sufficiently large to supply the load for the worst month (i.e., month of lowest insolation relative to load) and allows some optimization of array and

Table A-2. Monthly Insolation and Example Energy Load Values for
Three Array Tilt Angles for China Lake, California

Month	Tilt Angle = Latitude -15 deg Insolation (I) ÷ Load (L_{td}) = ___	Tilt Angle = Latitude Insolation (I) ÷ Load (L_{td}) = ___	Tilt Angle = Latitude +15 deg Insolation (I) ÷ Load (L_{td}) = ___
January	3.88 ÷ 2.8 = 1.39	4.38 ÷ 2.8 = (1.56)	☐4.63☐ ÷ ☐2.8☐ = (1.65)*
February	4.77 ÷ 2.8 = 1.70	5.13 ÷ 2.8 = 1.83	5.20 ÷ 2.8 = 1.86
March	6.19 ÷ 2.5 = 2.48	6.34 ÷ 2.5 = 2.54	6.13 ÷ 2.5 = 2.45
April	7.33 ÷ 2.5 = 2.93	7.07 ÷ 2.5 = 2.83	6.46 ÷ 2.5 = 2.58
May	7.88 ÷ 2.5 = 3.15	7.26 ÷ 2.5 = 2.90	6.32 ÷ 2.5 = 2.53
June	8.30 ÷ 2.5 = 3.32	7.50 ÷ 2.5 = 3.00	6.38 ÷ 2.5 = 2.55
July	8.07 ÷ 2.5 = 3.23	7.43 ÷ 2.5 = 2.97	6.45 ÷ 2.5 = 2.58
August	8.63 ÷ 2.5 = 3.45	8.34 ÷ 2.5 = 3.34	7.61 ÷ 2.5 = 3.04
September	7.16 ÷ 2.0 = 3.58	7.36 ÷ 2.0 = 3.68	7.14 ÷ 2.0 = 3.57
October	5.88 ÷ 2.0 = 2.94	6.41 ÷ 2.0 = 3.21	6.57 ÷ 2.0 = 3.29
November	4.53 ÷ 2.0 = 2.27	5.17 ÷ 2.0 = 2.59	5.51 ÷ 2.0 = 2.76
December	3.82 ÷ 2.8 = (1.36)	4.43 ÷ 2.8 = 1.58	4.78 ÷ 2.8 = 1.71

battery size as influenced by the potential benefit of varying array tilt angle. In this example, the array tilt angle of latitude +15 deg is preferred based on January insolation and load conditions.

Step 4: Determine Array and Storage Sizing Factors

Using the results from Table A-2, insert the relevant insolation value (4.6 kWh/m^2-day) into Figure 2-3 (repeated as Figure A-2). For an initial estimate of array and battery sizing factors (S_a) and (S_b), respectively, locate the intersection of insolation (I) equal to 4.6 and the dashed line. The resulting array sizing factor S_a is 3.7 and battery sizing factor S_b is 2.4.

Based on the monthly load and insolation levels, the fraction of the load supplied directly by the array (f_a) can be estimated. For this example, 50% of the load served directly by the array is predicted (see step 1 for the assumptions on loads). Therefore, array fraction f_a = 0.5 and battery fraction f_b = 0.5.

Step 5: Calculate Array Power and Area

Array size (P_a) is now calculated using Equation (2) as follows:

$$P_a = \frac{L_{td} \times 1000}{S_a \times F \times e_{i/c} [f_b (e_{vr} \times e_b) + f_a]} \tag{2}$$

$$= \frac{2.8 \times 1000}{3.7 \times 0.85 \times 0.93 [0.5(0.91 \times 0.88) + 0.5]}$$

$$= 1063 \text{ watts}$$

Array area (A_a) associated with this array size is determined using Equation (3) below:

$$A_a = \frac{P_a}{e_m[1 + P_{TC} (T_{op} - 28^{\circ}C)] \times 1000} \tag{3}$$

$$= \frac{1063}{0.10 [1 - 0.005(55 - 28)] \times 1000}$$

$$= \frac{1063}{86.5} = 12.3 \text{ m}^2$$
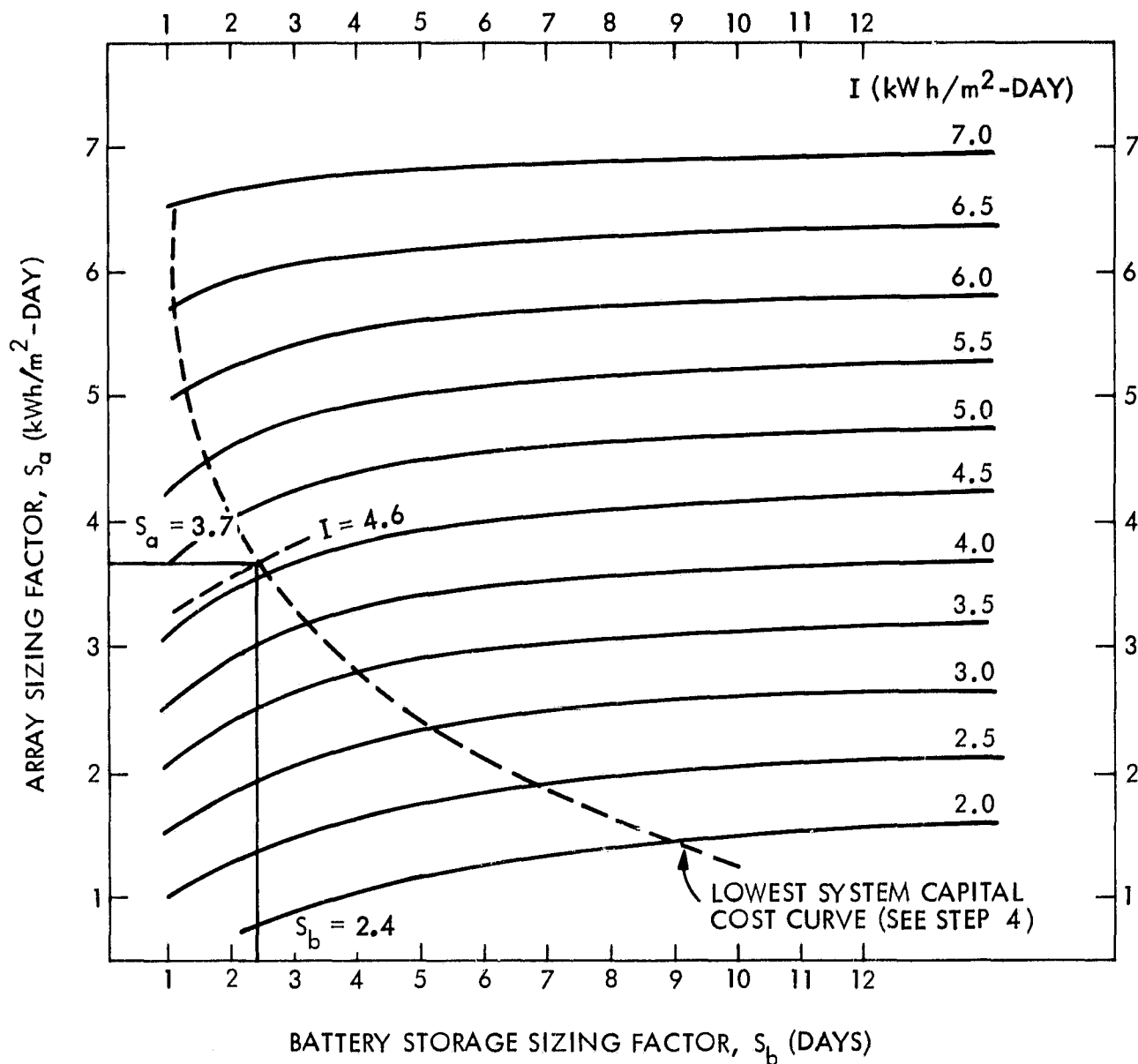
Figure A-2. Determining Array and Battery Storage Sizing Factors
(at LOEP = 0.1) for Various Worst-Month Insolation Values.
(Adapted from Reference 3)

For the purpose of this example, China Lake, California, is considered a hot climatic area. Therefore, module operating temperature (T_{op}) reflects the high point of the temperature range (55°C) rather than the typical value of 48°C (which reflects nominal operating cell temperature (NOCT) at 800 W/m², 20°C ambient air temperature, and air mass 1.5).

Step 6: Calculate Battery Storage Capacity

Battery storage (E_b) required for this application is based on the average daily load for the worst month of the year (L_{td}, from step 3), the battery sizing factor (S_b) based on the system reliability chart (Figure A-2), battery depth of discharge limit (d), and inverter efficiency ($e_{i/c}$). These factors are combined in Equation (4) as follows:

$$E_b = \frac{L_{td} \times S_b}{d \times e_{i/c}}$$

(4)

$$= \frac{2.8 \times 2.4}{0.6 \times 0.93} = 12.0 \text{ kWh}$$

Step 7: Calculate Voltage Regulator Size

The voltage regulator is sized at the peak array output at standard test conditions (1 kW/m^2 and 28°C cell temperature) and assumes no load. Voltage regulator size is, therefore, 1063 watts.

Step 8: Calculate Inverter/Converter Size

In order to satisfy the peak power requirements of the load, 350 watts during the winter months, an inverter size of 350 W ac is required, assuming that the load is not inductive.

Having completed the sample photovoltaic system sizing analysis, the estimation of system life-cycle cost follows. As necessary, array and battery size refinements may be made so that life-cycle cost is reduced while retaining equivalent reliability (see the life-cycle costing iteration step in Figure A-1).

The cost analysis is composed of three parts. First, photovoltaic system life-cycle costs are estimated. Second, the cost of alternative energy systems in competition with photovoltaics are determined. Finally, the alternative energy generation systems are compared on the basis of least cost. Figure A-3 displays the procedure.

Typical values and ranges for the current cost of photovoltaic equipment (in 1984 dollars, delivered to the site) and operational attributes (e.g., battery lifetime) are presented in Table A-3. Data is based on available information for small stand-alone systems, current cost estimates, and catalog information (e.g., see Reference 6). The table should also be consulted throughout this appendix for a description of each parameter name.
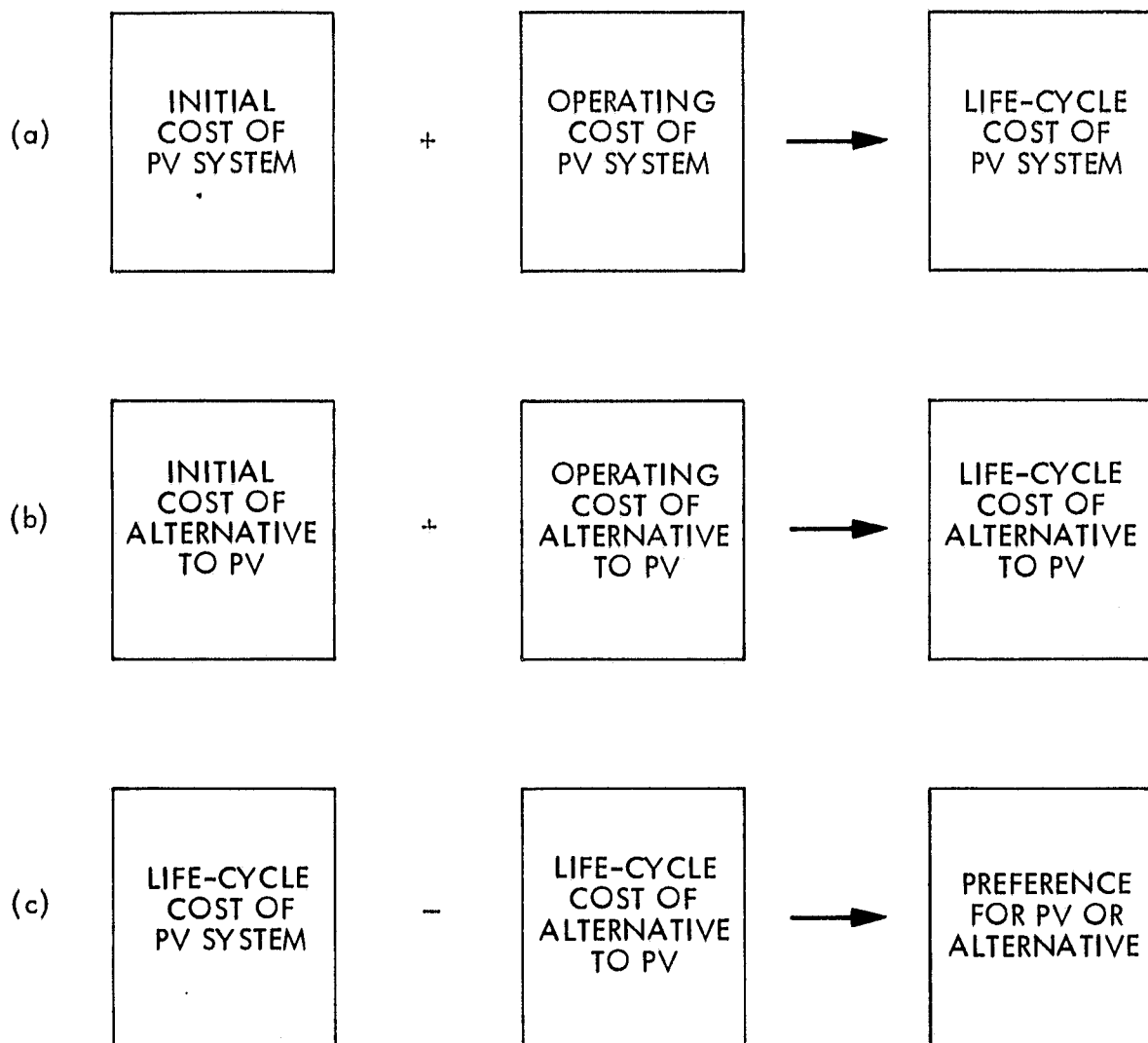
Figure A-3. Approach for Determining Photovoltaic System Cost Effectiveness

Photovoltaic system life-cycle cost is determined in three steps: estimation of initial cost, estimation of operating costs, and summation to life-cycle cost. These steps are illustrated below:

Step 1. <u>Estimate Initial Cost of Photovoltaic System</u>

The initial cost of a photovoltaic system (IC) includes expenditures for capital equipment, installation, testing, and any indirect costs as shown in Equation (5a) below:

$$\text{Initial cost} = [1 + \text{indirect } (\%) + \text{installation } (\%)] \times [\text{delivered equipment cost } (\$)] \tag{5a}$$

Table A-3. Photovoltaic System Cost Parameters:
Relevant Ranges and Default Values

Parameter	Parameter Name	Units	Range	Value
Array-related BOS cost	ABOS	$/M^2	20–300[a]	150
Array area	A_a	M^2	--	b
Battery cost	BAT	$/kWh	50–250	80
Battery storage size	BWh	kWh	--	c
Converter cost	CONV	$/W$_{dc}$	0.70–200	0.80
Discount rate (real)	dr	fraction	0.10[d]	0.10
Battery cost escalation rate (real)	esc_b	fraction	0–0.03	0
OM cost escalation rate (real)	esc_{om}	fraction	0–0.1	0
Indirect cost	IND	fraction	0.10–0.25	0.16
Installation and testing cost	INST	fraction	0.20–0.50	0.30
Inverter cost	INV	$/W$_{ac}$	0.30–0.80	0.40
Battery lifetime	k	years	5–10	10
Labor cost for battery replacement	LREP	$	0[e]	0[e]
Module cost	MOD	$/P$_a$	7–10	10
Photovoltaic system lifetime	N	years	20–30	30
Number of battery replacements	nrep	number	2–5	2
Annual OM cost	OM	$ or fraction	0.005–0.03[f]	f
Voltage regulator cost	REG	$/W*	0.20–0.50	0.45
Battery salvage value	SV	fraction	0–0.2	0.1
Peak watts ac	W_{ac}	watts	--	g
System peak watts dc	W_{dc}	watts	--	g
Array peak watts dc	P_a	watts	--	h
Voltage regulator input power	W*	watts	--	i

[a]Low-end value reflects very low cost structures and zero land cost.
[b]See Equation (3).
[c]See Equation (4).
[d]For Government applications, a 10% real discount rate is used.
[e]Included in annual OM cost.
[f]Relevant for fraction of delivered equipment cost; see Equation (5a).
Range is based on photovoltaic systems without batteries.
[g]See Section II.C.8.
[h]See Equation (2).
[i]See Section II.C.7.

Indirect costs (IND) include engineering, management, and contingency fees and are assumed to be a fractional multiple of delivered equipment cost. Similarly, the cost of installation, site preparation, and test of the photovoltaic system (INST) is assumed to be a fractional multiple of delivered equipment cost. All costs associated with the initial installation of the photovoltaic system, excluding the cost of equipment itself, are to be included in the multipliers described above.

Delivered equipment cost represents the initial capital expenditures for all photovoltaic power-related equipment, structures, inverter or converter, protection equipment (e.g., voltage regulator), and battery-related equipment. Each cost element is described in terms of its "natural units" for costing purposes as shown in Table A-4.

The initial installed cost (IC) of the photovoltaic system can now be presented as in Equation (5b):

$$IC = (1 + IND + INST) [(MOD \times P_a) + (ABOS \times A_a) + (CONV \times W_{DC})$$

$$+ (INV \times W_{AC}) + (REG \times W*) + (BAT \times BWh)]$$

(5b)

Table A-4. Cost Elements

Cost Element	Cost Basis	Engineering Units
Module	Dollars per peak watt of array (MOD)	Peak watts of array power output (P_a)
Area-related balance of system	Dollars per square meter of array (ABOS)	Array area in square meters (A_a)
Inverter or converter	Dollars per rated peak watt ac (INV) or dc (CONV), respectively	Rated size of inverter, watts ac (W_{AC}) or converter, watts dc (W_{DC})
Regulator	Dollars per watt of maximum regulator input power (REG)	Maximum regulator input power, watts ($W*$)
Battery-related equipment	Dollars per kilowatt-hour of storage (BAT)	Battery storage size in kilowatt-hours (BWh)

Using the assumed values from Table A-3 and from the sizing analysis, initial installed cost is calculated to be:

$$IC = (1 + 0.16 + 0.30) [(10 \times 1063) + (150 \times 12.3) + (0)$$

$$+ (0.40 \times 350) + (0.45 \times 1063) + (80 \times 12.0)]$$

$$= (1.46) [\$14,053] = \$20,517$$

The initial installed system cost (IC) per peak watt of array (P_a) for this example is:

$$\frac{\$20,517}{1063 \text{ watts}} = \$19.30/\text{watt}$$

This falls within the present-day range of $17 to $25/watt initial system cost.

Step 2: Estimate Photovoltaic System Operating Costs

In addition to the initial installed system cost described above, recurrent costs associated with photovoltaic system operations are to be included in the estimation of life-cycle cost. Estimates of operation, maintenance and replacement costs are based on hardware performance characteristics and system operating strategy. Expenditures are primarily for battery replacement (if battery storage is included in the system design) and array, power conditioning unit, and battery operation and maintenance.

The cost of each battery replacement (BR) in base year dollars is estimated from the initial cost of batteries shown in Equation (5b), BAT x BWh, less an allowance for salvage value (SV), plus the labor cost for replacement (LREP). This is displayed in Equation (6):

$$BR = (BAT \times BWh) (1 - SV) + LREP \tag{6}$$

Using the financial inputs from Table A-3, battery replacement cost is:

$$BR = (80 \times 12.0)(1-0.1) + 0$$

$$= \$864$$

Over the photovoltaic system operating lifetime, a number of battery replacements (nrep) will need to be made. The present value of these

replacements (RPV), escalated (at the real rate, esc_b) and discounted (at a real rate, dr) to account for the timing of the expenditure, is estimated using Equation (7) as follows:

$$RPV = \sum_{j=1}^{nrep} BR \times \left(\frac{1 + esc_b}{1 + dr}\right)^{j \times k} \tag{7}$$

where k is the battery lifetime. Using the baseline inputs, assuming two replacements during the system lifetime, the present value of battery replacements is:

$$RPV = \sum_{j=1}^{2} (864) \times \left(\frac{1.0}{1.1}\right)^{j \times 10} = \$462$$

The present value of expenditures for replacement of capital equipment (other than batteries) with lifetimes shorter than the assumed photovoltaic system lifetime can also be determined using Equation (7), appropriately modified to reflect their cost and timing. For the purpose of this example, such replacements are considered minimal and are incorporated in the annual operation and maintenance cost equation described below.

Regular operation and maintenance costs can be estimated on an annual cost basis. These costs include expenditures for activities such as array, battery, and inverter maintenance; component replacements (other than batteries); and grounds, structural, and electrical upkeep. Annual operation and maintenance costs (OM) can be estimated on the basis of the number of required visits to the site per year times the cost per trip in base year dollars. A heuristic frequently used to estimate operations and maintenance expenditures is to assume that annual expenses are a fixed percentage of the initial cost of equipment. The present value of the cost of operation and maintenance procedures is the derived annual amount summed over the system lifetime, including any real escalation (esc_{om}) and discounting (dr) of expenditures over the photovoltaic system lifetime (N). Annual expenditures are, therefore, growing in dollar amount at the constant rate of real escalation, if any. Present value of operation and maintenance cost (OMPV) is presented in Equation (8) as follows:

$$OMPV = OM \times \left(\frac{1 + esc_{om}}{dr - esc_{om}}\right) \times \left[1 - \left(\frac{1 + esc_{om}}{1 + dr}\right)^{N}\right], \qquad \text{if } dr \neq esc_{om} \tag{8}$$

or

$$OMPV = OM \times N, \text{ if } dr = esc_{om}$$

For this example, annual operation and maintenance cost is assumed to include site visits once every 2 months for 4 hours per visit at a cost of $25 per hour. Annual operation and maintenance cost (OM) is therefore $600. The present value (OMPV) of these expenditures is:

$$OMPV = 600 \times \left(\frac{1.0}{0.10 - 0}\right) \times \left[1 - \left(\frac{1.0}{1.1}\right)^{30}\right]$$

$$= \$5656$$

Step 3: Sum to Life-cycle Cost

Photovoltaic system life-cycle cost (LCC) can now be determined from its constituent parts described above. Life-cycle cost is displayed in Equation (9) as the sum of the initial installed system cost, Equation (5), and the present value of recurrent costs, Equation (7) plus Equation (8).

$$LCC = IC + RPV + OMPV$$

$$= \$20,517 + \$462 + \$5656 \tag{9}$$

$$= \$26,635$$

The life cycle cost in this example is expressed in 1984 dollars.

Cost estimates for alternative power systems in competition with photovoltaics are now required. For illustrative purposes, life-cycle cost estimates are prepared for batteries and diesel generators. Load energy and power requirements are identical to the assumptions used in the photovoltaic system sizing and life-cycle cost assessment.

1. Battery Cost Example

Battery storage size in kWh is based on the energy load, days of storage required between recharging, battery depth of discharge, and inverter or converter efficiency. The sizing algorithm is shown below:

$$\text{Battery size} = \frac{\text{Energy load} \times \text{days of storage}}{\text{Maximum depth of discharge} \times \text{inverter/converter efficiency}}$$

where the maximum daily energy load battery depth of discharge and inverter/converter efficiency are the same as in the photovoltaic example; and required days of storage is based on a first order trade-off between the initial cost of storage and the required recharging and maintenance costs (at the assumed labor rates and maintenance frequency).

Therefore,

$$\text{Battery size} = \frac{2.8 \times \text{days of storage}}{0.6 \times 0.93}$$

Since the operating costs associated with service personnel used to recharge and maintain batteries can be extremely high, sufficient battery storage to supply one month's energy load is assumed in this example. A smaller battery size would require more frequent visits and, thus, be more expensive from a life-cycle cost perspective. It is further assumed that once-a-month site visits for maintenance are required to ensure adequate system performance to satisfy the load. Battery size is thus:

$$\text{Battery size} = \frac{2.8 \times 30}{0.6 \times 0.93}$$

$$= 150 \text{ kWh}$$

Using battery cost estimates from Table A-3, including indirect and installation costs, initial battery system capital cost (IC) is:

$$IC = (1 + 0.16 + 0.30) \, (150 \text{ kWh} \times \$80/\text{kWh}) = \$17,520$$

The cost of battery replacement (BR) every k years is based on Equation (6) and the battery assumptions in Table A-3.

$$BR = (\text{Battery size} \times \text{battery cost per kWh}) \times (1\text{-salvage fraction}) + \text{labor cost}$$

$$= (150 \times 80) \, (1-0.1) + 0 = \$10,800$$

For this example, labor cost is assumed to be included in the regular operation and maintenance expenditure. In present value terms, battery replacement present value (RPV) per Equation (7) is:

$$RPV = \sum_{j=1}^{nrep} BR \times \left(\frac{1 + esc_b}{1 + dr}\right)^{j \times k}$$

Using the values from the previous tables,

$$RPV = \sum_{j=1}^{2} \$10,800 \times \left(\frac{1.0}{1.1}\right)^{j \times 10}$$

$$= \$10,800 \, (0.39 + 0.15) = \$5830$$

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Annual cost for operation and maintenance includes battery recharging and maintenance on the batteries and balance of system. For this example, monthly site visits are assumed, consistent with the sizing and cost trade-off described above. Each visit requires one maintenance person for 8 hours at $25 per hour. Annual operation and maintenance cost (OM) for 12 site visits is therefore:

$$OM = 8 \text{ hours/visit} \times \$25/\text{hour} \times 12 \text{ visits/year} = \$2400$$

The cost of equipment used for recharging and maintenance is typically included in the estimate of the labor rate. Over the assumed 30 year lifetime, the present value of operation and maintenance cost (OMPV) is:

$$OMPV = \$2400 \times \left(\frac{1 + esc_b}{dr - esc_b} \right) \times \left[1 - \left(\frac{1 + esc_b}{1 + dr} \right)^N \right]$$

$$= \$2400 \times \left(\frac{1.0}{0.10 - 0} \right) \times \left[1 - \left(\frac{1.0}{1.1} \right)^{30} \right]$$

$$= \$22,625$$

The life-cycle cost (LCC) of the battery system alternative is the sum of the initial installed capital cost (IC), present value of battery replacement cost (RPV), and the present value of operation and maintenance costs (OMPV) as shown below:

$$LCC = IC + RPV + OMPV$$

$$= \$17,520 + \$5830 + \$22,625$$

$$= \$45,975$$

This life-cycle cost value will be used in the subsequent cost comparison of energy generation system alternatives.

2.   Diesel Generator Cost Example

Though the peak power required by the load is 350 W, a standard, small size production diesel generator is typically 3 to 4 kW. In this example, a single 4 kW Kohler diesel generator has been chosen. All unit

capital costs and maintenance requirements are identified in Reference 9. Installed costs in 1980 dollars are shown below:

Diesel generator	$ 4566
Fuel tank, 500 gallons	400
Valves/piping	125
Mounting frame	50
Engine shelter	750
	$ 5891

For consistency with the cost estimates for competing technologies, diesel generating installed costs can be inflated from 1980 to 1984 dollars using the Gross National Product Implicit Price Deflator (which results in a multiplier equal to 1.30). Installed cost is therefore (1.30)($5891) = $7658. This value is assumed to include the cost of system installation. Therefore, diesel generator system initial capital cost (IC) increments this amount only by the indirect cost fraction (16%) as shown below:

$$IC = (1.16)(\$7658) = \$8883$$

The Kohler diesel is a long-life unit that is assumed to require replacement costs equal to the cost of one unit after 15 years. Present value of replacements (RPV) is, therefore, the initial generator cost in 1980 dollars inflated to 1984 dollars by the 1.30 multiplier and discounted for 15 years as:

$$RPV = \$4566 \ (1.30) \left(\frac{1 + esc_{om}}{1 + dr} \right)^{15}$$

$$= \$4566 \ (1.30) \left(\frac{1.0}{1.10} \right)^{15} = \$1421$$

Annual expenditures for ongoing operation and maintenance are estimated based on: (1) the operating strategies described and costed in the referenced report, and (2) consistent labor hours and costs for the photovoltaic and battery examples in this appendix. Maintenance schedule and costs in 1984 dollars are shown below:

200 hours	$29 parts + 4 hours labor	= $ 129	= $0.65/hour
500 hours	2 days labor (16 hours)	= $ 400	= $0.80/hour
10,000 hours	$1000 for parts and labor	= $1000	= $0.10/hour
			$1.55/hour

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The asssumed load operates 8 hours/day, 365 days/year, or 2920 hours/year. Annual maintenance expense is, therefore:

$$\$1.55 \times 2920 = \$4526/\text{year}$$

Annual fuel costs are estimated from the yearly hours of energy load, diesel engine fuel consumption, and fuel price. Kohler engine fuel consumption for the assumed load is 0.19 gallons/hour. Fuel price is assumed to be $1/gallon. Annual fuel cost is:

$$2920 \text{ hours/year} \times 0.19 \text{ gallons/hour} \times \$1/\text{gallon} = \$555/\text{year}$$

The present value of operation and maintenance costs (OMPV) over the 30 year lifetime is:

$$\text{OMPV} = (\$4526 + \$555) \left(\frac{1 + \text{esc}_{om}}{dr - \text{esc}_{om}}\right) \times \left[1 - \left(\frac{1 + \text{esc}_{om}}{1 + dr}\right)^{N}\right]$$

$$= \$5081 \left(\frac{1.0}{0.10 - 0.0}\right) \times \left[1 - \left(\frac{1.0}{1.1}\right)^{30}\right]$$

$$= \$47,914$$

Diesel generator system life-cycle cost (LCC) is the sum of the initial cost (IC), present value of replacements (RPV), and operation and maintenance (OMPV) costs as shown below:

$$\text{LCC} = \text{IC} = \text{RPV} + \text{OMPV}$$

$$= \$8883 + \$1421 + \$47,914$$

$$= \$58,218$$

The life-cycle cost comparison between photovoltaic and the battery and diesel alternatives can now be finalized. Life-cycle costs are summarized below:

Photovoltaics	$26,635
Batteries only	$45,975
Diesel generator	$58,218

By inspection, the photovoltaic system is shown to be the least-cost alternative. On this basis, a decision to pursue photovoltaic system analysis and design activities is warranted. As stated in the text, however, it may be additionally useful to perform sensitivity analyses on important cost parameters to understand the effect of uncertainty in parameter values on photovoltaic system cost effectiveness.

APPENDIX B
ESTIMATION OF LOAD FRACTIONS SUPPLIED BY PHOTOVOLTAIC ARRAY AND BATTERY STORAGE

APPENDIX B

ESTIMATION OF LOAD FRACTIONS SUPPLIED
BY PHOTOVOLTAIC ARRAY AND BATTERY STORAGE

An operating photovoltaic system is typically required to satisfy
coincident load as well as to recharge battery storage. By using the
photovoltaic array to satisfy load directly, rather than going through battery
storage, power losses due to round-trip battery inefficiencies are avoided.
Therefore, for the purpose of sizing a photovoltaic system, it may be
important to explicitly consider this to avoid unintended oversizing and thus
increased life-cycle cost.

Load can be served by either the photovoltaic array or battery storage
as shown in Figure B-1.

Relating Figure B-1 to the discussion in Section II.C.4.b and to
Equation (2) in Section II.C.5, the fraction of load supplied directly by the
photovoltaic array is the cross-hatched area, denoted as f_a. The remaining
fraction of the load is supplied by batteries, f_b.

Quantifying array output supplied directly to the load, f_a, is a
non-trivial exercise due to the highly stochastic nature of array output and
potentially variable loads. As part of a system design optimization effort,
but not as part of the present methodology, the most precise way of estimating
array output sent directly to the load is by means of a computer simulation of
site-specific weather conditions, array output, and user load over a typical
year calculated on an hourly basis. Using this information, array size can be
calculated using Equation (2). Since this approach is inappropriate for use
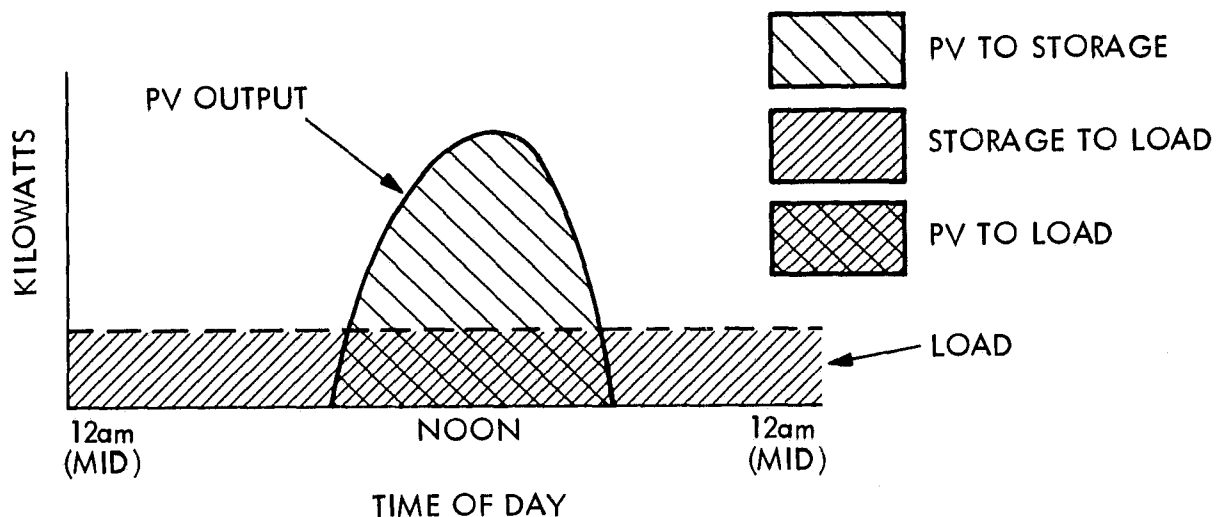
Figure B-1. Idealized Energy Usage by Time-of-Day for a Given Month

in combination with the sizing and costing methodology described earlier, two alternative approaches are described below:

(1) <u>Bound and Estimate Load Fraction Supplied by Photovoltaic Array</u>. In this case, the fraction of energy supplied directly to the load by the photovoltaic array can vary between 0% (for nighttime only demand) and 100% (for demand perfectly matched to photovoltaic output). For the 0% array-to-load assumption, all array output must pass through the battery and all battery-resultant efficiency losses incurred. Conversely, if all array output supplies the load directly, no battery efficiency penalties apply. In general, most photovoltaic systems operate between these two extremes.

The assumption that all array output goes through the battery in those applications where the array could supply the load directly is a simplifying assumption that would cause the photovoltaic system to be somewhat oversized relative to the requirements of the load. Conservative approaches have already been incorporated in the methodology to ensure adequate system size. The user should be careful not to unintentionally bias system size larger than required due to this photovoltaic array-to-load factor.

At one boundary condition, the array is sized correctly for 0% (nighttime only demand) array-to-load case compared to the required size, assuming all energy goes through the battery. Conversely, with a perfect match between array and load, the array would be oversized approximately 25% based on the current baseline values for voltage regulation and round-trip battery storage efficiencies (see Appendix A). A more realistic estimate of array oversizing is between these two values. For example, the degree of oversizing for a constant, 24 hours/day load is typically less than 10%.

(2) <u>Calculate Load Fraction Supplied by Photovoltaic Array Using a Simplified Procedure</u>. A simple algorithm can be constructed to help estimate the load fraction supplied directly by the photovoltaic array under some rather limiting constraints. Assuming clear-sky conditions, an idealized time-of-day profile of array output can be constructed, as shown in Figure B-1, for each month of the year. Then, a representation of the deterministic time-of-day load for each month is incorporated. The load need not be constant by time-of-day or between months. For the "worst" month (see Section II.B.3), estimate the fraction of the load supplied by the array, f_a. This is the cross-hatched area divided by the total load. Insert this fraction into Equation (2). Battery sizing is not affected by this procedure. Repeat this procedure for each month of the year to ensure that array-to-load differences are adequately incorporated. Select the maximum array size, P_a, from Equation (2) to adequately cover each month of the year for the selected array tilt angle.

Use of this procedure requires acceptance of certain limitations. Most importantly, to the extent that there is any variability in time-of-day photovoltaic output (or load) such that the load cannot be served according to the idealized pattern displayed in Figure B-1, this algorithm will overestimate the amount of array power sent directly to the load. Based on the degree of variability, this overestimate will result in the array and battery to be sized smaller than required to meet the load by some varying amount.

APPENDIX C
COMPARISON OF SIZING METHODOLOGY
WITH ALTERNATIVE APPROACHES

APPENDIX C

COMPARISON OF SIZING METHODOLOGY WITH ALTERNATIVE APPROACHES

This section compares the results of applying the sizing methodology in this document with the results of several other sizing approaches. Each methodology has been applied to the same application load example. The example is derived from Reference 3, and was discussed along with the alternative sizing methods.

The application load for this comparison is a constant power load of 4.2 kWh/day. The site has a worst-month insolation value of 2.3 kWh/m²-day. Additional data used for the initial sizing are as follows:

$$f_b = 0.6 \quad \text{(i.e., the fraction of the load met by the}$$
$$\text{battery. Therefore, } f_a = 1 - f_b = 0.4)$$

$$e_{vr} \cdot e_b = 0.80$$

$$e_{i/c} = 0.93$$

Application of the sizing methodology as described in Section II is simplified by the constant load and the prior stipulation of the worst-month insolation. Therefore, L_{td} = 4.2 kWh/day and I = 2.3 kWh/M²/day. The array sizing factor, S_a, corresponding to I = 2.3 in Figure 2-3, is 1.7. No array degradation factor appears in the other sizing approaches. For comparison of the present method, therefore, F = 1.0.

The array power from Equation (2) is therefore:

$$P_a = \frac{L_{td} \times 1000}{S_a \times F \times e_{i/c} \, [f_b \, (e_{vr} \times e_b) + f_a]}$$

$$= \frac{4.2 \times 1000}{1.7 \times 1.0 \times 0.93 \, [0.6 \, (0.8) + 0.4]}$$

$$= \frac{4200}{1.7 \times 1.0 \times 0.93 \times 0.88} = \frac{4200}{1.39}$$

Therefore,

$$P_a = 3020 \text{ W (peak) ac}$$

C-1

Note that if an array degradation factor, F, equal to 0.85 is included, the result becomes:

$$P_a = 3550 \text{ W (peak) ac}$$

The battery storage sizing factor, S_b, from Figure 2-3 is 7.5. The required battery storage capacity, assuming an 80% depth of discharge (d), is therefore:

$$E_b = \frac{L_{td} \times S_b}{d \times e_{1/c}}$$

$$= \frac{4.2 \times 7.5}{0.8 \times 0.93}$$

$$= 42 \text{ kWh}$$

These results are compared with three other approaches in the table below:

Table C-1. Array and Battery Storage Sizing Comparison

Method	Reference	Array Size, W_p	Battery Storage Size, kWh
NASA	7	3000	42
ROSSA	3	3140	42
Solarex[a]	7	3150	30
FPUP (present document)	--	3020	42

[a] Solarex designed and built a system with this array and storage size for the site in question. This system was designed for a load of 4.0 kWh/day rather than for 4.2, as in the other examples.

This comparison shows that the present sizing method yields results similar to those of three other approaches when applied to this load and

location. It should be recognized, however, that different sizing approaches will frequently yield different results due to the built-in design margin or loss-of-energy probability (LOEP) selected as the basis of the sizing approach. These differences argue for the use of an LOEP-based sizing approach in order to ensure that power system alternatives being sized for comparison purposes are all sized to the same level of estimated performance.

APPENDIX D
AVERAGE DAILY INSOLATION TABLES
FOR UNITED STATES SITES
(ADAPTED FROM REFERENCE 8)

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
JUNEAU AK			LATITUDE:	58 DEGREES	22 MINUTES									
LATITUDE -15:	1.04	1.70	2.57	3.72	4.07	4.28	4.02	3.47	2.73	1.74	1.24	.68	951.8	2.6
LATITUDE :	1.16	1.81	2.57	3.53	3.71	3.86	3.67	3.28	2.72	1.83	1.39	.78	922.7	2.5
LATITUDE +15:	1.22	1.82	2.43	3.18	3.24	3.32	3.20	2.96	2.58	1.83	1.45	.83	853.6	2.3
KING SALMON AK			LATITUDE:	58 DEGREES	41 MINUTES									
LATITUDE -15:	1.25	2.22	3.68	4.40	4.73	4.68	4.38	3.73	3.54	3.08	2.07	1.08	1183.5	3.2
LATITUDE :	1.39	2.36	3.72	4.19	4.32	4.22	4.00	3.54	3.57	3.32	2.35	1.25	1164.2	3.2
LATITUDE +15:	1.46	2.37	3.56	3.78	3.77	3.63	3.48	3.19	3.41	3.36	2.49	1.34	1090.5	3.0
KODIAK AK			LATITUDE:	57 DEGREES	45 MINUTES									
LATITUDE -15:	1.13	1.92	3.50	4.38	4.35	4.65	4.46	4.20	3.55	3.06	1.90	.99	1160.0	3.2
LATITUDE :	1.26	2.03	3.53	4.16	3.98	4.20	4.08	3.99	3.58	3.29	2.15	1.13	1137.8	3.1
LATITUDE +15:	1.31	2.02	3.37	3.76	3.47	3.61	3.55	3.60	3.42	3.32	2.27	1.20	1062.9	2.9
NOME AK			LATITUDE:	64 DEGREES	30 MINUTES									
LATITUDE -15:	.34	1.56	3.29	4.63	5.14	5.40	4.57	3.74	3.53	2.59	1.16	.01	1095.5	3.0
LATITUDE :	.38	1.65	3.32	4.39	4.69	4.85	4.15	3.54	3.58	2.79	1.32	.01	1055.8	2.9
LATITUDE +15:	.40	1.65	3.17	3.96	4.06	4.14	3.60	3.19	3.42	2.82	1.39	.01	968.4	2.7
BIRMINGHAM AL			LATITUDE:	33 DEGREES	34 MINUTES									
LATITUDE -15:	2.75	3.53	4.44	5.39	5.72	5.83	5.58	5.57	5.01	4.54	3.44	2.70	1658.7	4.5
LATITUDE :	3.02	3.73	4.49	5.19	5.31	5.33	5.17	5.36	5.08	4.87	3.84	3.05	1657.0	4.5
LATITUDE +15:	3.14	3.74	4.31	4.75	4.68	4.63	4.57	4.91	4.89	4.94	4.03	3.23	1577.2	4.3
MOBILE AL			LATITUDE:	30 DEGREES	41 MINUTES									
LATITUDE -15:	3.11	3.92	4.74	5.51	5.78	5.69	5.30	5.25	4.89	4.72	3.64	2.94	1688.3	4.6
LATITUDE :	3.43	4.16	4.80	5.31	5.37	5.22	4.93	5.06	4.95	5.06	4.07	3.32	1694.8	4.6
LATITUDE +15:	3.58	4.19	4.63	4.87	4.75	4.55	4.36	4.64	4.77	5.14	4.28	3.53	1620.9	4.4
MONTGOMERY AL			LATITUDE:	32 DEGREES	18 MINUTES									
LATITUDE -15:	2.87	3.66	4.56	5.56	5.85	5.99	5.67	5.62	5.01	4.67	3.59	2.87	1703.1	4.7
LATITUDE :	3.17	3.88	4.61	5.36	5.43	5.47	5.26	5.42	5.08	5.01	4.02	3.25	1703.0	4.7
LATITUDE +15:	3.29	3.89	4.43	4.91	4.78	4.75	4.64	4.96	4.89	5.08	4.22	3.45	1622.1	4.4
FORT SMITH AR			LATITUDE:	35 DEGREES	20 MINUTES									
LATITUDE -15:	3.03	3.75	4.56	5.23	5.90	6.33	6.37	6.11	5.27	4.64	3.55	2.94	1756.2	4.8
LATITUDE :	3.37	3.98	4.61	5.03	5.46	5.76	5.88	5.89	5.35	4.98	3.99	3.34	1754.8	4.8
LATITUDE +15:	3.52	4.00	4.43	4.60	4.81	4.98	5.16	5.38	5.15	5.05	4.20	3.56	1669.3	4.6

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
LITTLE ROCK AR LATITUDE: 34 DEGREES 44 MINUTES														
LATITUDE −15:	2.93	3.73	4.54	5.21	5.95	6.38	6.27	6.04	5.30	4.71	3.47	2.84	1746.4	4.8
LATITUDE :	3.24	3.96	4.59	5.01	5.51	5.82	5.80	5.82	5.38	5.06	3.89	3.22	1744.7	4.8
LATITUDE +15:	3.39	3.98	4.41	4.59	4.85	5.03	5.09	5.32	5.19	5.14	4.09	3.43	1659.4	4.5
PHOENIX AZ LATITUDE: 33 DEGREES 26 MINUTES														
LATITUDE −15:	4.19	5.21	6.36	7.67	8.26	8.28	7.66	7.46	7.13	6.11	4.83	4.??	2348.9	6.4
LATITUDE :	4.74	5.62	6.51	7.40	7.60	7.48	7.06	7.20	7.32	6.66	5.52	4.66	2366.3	6.5
LATITUDE +15:	5.02	5.72	6.31	6.76	6.60	6.36	6.15	6.57	7.10	6.83	5.89	5.03	2260.9	6.2
PRESCOTT AZ LATITUDE: 34 DEGREES 39 MINUTES														
LATITUDE −15:	4.30	5.14	6.30	7.44	8.11	8.34	7.12	6.82	6.97	6.09	4.94	4.15	2304.2	6.3
LATITUDE :	4.88	5.54	6.45	7.18	7.47	7.53	6.57	6.58	7.16	6.64	5.66	4.83	2327.1	6.4
LATITUDE +15:	5.18	5.64	6.24	6.56	6.50	6.41	5.74	6.01	6.94	6.81	6.05	5.23	2229.6	6.1
TUCSON AZ LATITUDE: 32 DEGREES 7 MINUTES														
LATITUDE −15:	4.42	5.35	6.47	7.66	8.23	8.24	7.21	7.06	6.90	6.08	4.94	4.18	2335.1	6.4
LATITUDE :	5.00	5.77	6.63	7.39	7.57	7.44	6.65	6.81	7.07	6.62	5.65	4.85	2356.1	6.5
LATITUDE +15:	5.30	5.87	6.42	6.74	6.57	6.33	5.81	6.22	6.84	6.79	6.02	5.25	2255.1	6.2
WINSLOW AZ LATITUDE: 35 DEGREES 1 MINUTES														
LATITUDE −15:	4.19	5.15	6.34	7.47	8.01	8.19	7.24	7.00	6.90	6.01	4.90	4.04	2295.2	6.3
LATITUDE :	4.75	5.55	6.49	7.21	7.37	7.39	6.67	6.74	7.07	6.54	5.61	4.69	2314.0	6.3
LATITUDE +15:	5.03	5.64	6.28	6.57	6.40	6.29	5.81	6.15	6.84	6.70	5.99	5.07	2213.3	6.1
YUMA AZ LATITUDE: 32 DEGREES 40 MINUTES														
LATITUDE −15:	4.45	5.43	6.70	7.84	8.42	8.50	7.56	7.56	7.20	6.??	5.04	4.26	2410.2	6.6
LATITUDE :	5.05	5.87	6.88	7.57	7.75	7.68	6.97	7.31	7.40	6.83	5.77	4.97	2434.4	6.7
LATITUDE +15:	5.37	5.98	6.67	6.91	6.73	6.53	6.08	6.67	7.18	6.98	6.17	5.38	2331.3	6.4
BAKERSFIELD CA LATITUDE: 35 DEGREES 25 MINUTES														
LATITUDE −15:	3.15	4.19	5.63	6.85	7.75	8.31	8.29	7.97	7.19	5.79	4.03	2.92	2194.8	6.0
LATITUDE :	3.50	4.46	5.74	6.60	7.14	7.50	7.62	7.69	7.39	6.30	4.56	3.33	2187.2	6.0
LATITUDE +15:	3.67	4.50	5.54	6.03	6.22	6.38	6.61	7.01	7.16	6.45	4.83	3.55	2068.6	5.7
CHINA LAKE CA LATITUDE: 35 DEGREES 41 MINUTES														
LATITUDE −15:	3.88	4.77	6.19	7.33	7.88	8.30	8.07	8.63	7.16	5.88	4.53	3.82	2328.1	6.4
LATITUDE :	4.38	5.13	6.34	7.07	7.26	7.50	7.43	8.34	7.36	6.41	5.17	4.43	2338.3	6.4
LATITUDE +15:	4.63	5.20	6.13	6.46	6.32	6.38	6.45	7.61	7.14	6.57	5.51	4.78	2227.5	6.1

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
DAGGETT CA		LATITUDE:	34 DEGREES		52 MINUTES									
LATITUDE -15:	4.02	4.92	6.29	7.44	8.01	8.36	8.03	7.82	7.20	5.98	4.68	3.90	2334.1	6.4
LATITUDE :	4.55	5.30	6.44	7.18	7.38	7.55	7.40	7.56	7.41	6.53	5.35	4.52	2348.6	6.4
LATITUDE +15:	4.82	5.38	6.24	6.56	6.42	6.43	6.43	6.90	7.19	6.69	5.71	4.89	2241.3	6.1
EL TORO CA		LATITUDE:	33 DEGREES		40 MINUTES									
LATITUDE -15:	3.85	4.65	5.60	6.25	6.39	6.65	7.29	7.00	6.07	5.17	4.24	3.73	203?.	5.6
LATITUDE :	4.33	4.98	5.71	6.02	5.91	6.05	6.73	6.76	6.20	5.59	4.81	4.30	2051.4	5.6
LATITUDE +15:	4.57	5.05	5.52	5.51	5.20	5.22	5.87	6.17	5.99	5.69	5.10	4.63	1963.7	5.4
FRESNO CA		LATITUDE:	36 DEGREES		46 MINUTES									
LATITUDE -15:	2.72	3.89	5.59	6.89	7.69	8.26	8.31	8.04	7.27	5.81	3.90	2.50	2158.6	5.9
LATITUDE :	3.01	4.14	5.70	6.64	7.08	7.46	7.64	7.76	7.48	6.33	4.41	2.83	2146.5	5.9
LATITUDE +15:	3.14	4.17	5.51	6.07	6.18	6.36	6.63	7.08	7.26	6.48	4.68	3.00	2025.7	5.5
LONG BEACH CA		LATITUDE:	33 DEGREES		49 MINUTES									
LATITUDE -15:	3.77	4.56	5.61	6.28	6.37	6.48	7.09	6.83	5.94	5.05	4.14	3.62	2001.8	5.5
LATITUDE :	4.24	4.89	5.72	6.06	5.90	5.91	6.55	6.59	6.06	5.45	4.69	4.18	2015.9	5.5
LATITUDE +15:	4.48	4.95	5.53	5.54	5.18	5.11	5.73	6.02	5.86	5.55	4.98	4.49	1929.4	5.3
LOS ANGELES CA		LATITUDE:	33 DEGREES		56 MINUTES									
LATITUDE -15:	3.78	4.57	5.65	6.32	6.36	6.43	7.12	6.76	5.88	5.02	4.16	3.65	1999.6	5.5
LATITUDE :	4.25	4.89	5.76	6.10	5.89	5.86	6.57	6.52	5.99	5.41	4.72	4.21	2014.3	5.5
LATITUDE +15:	4.48	4.96	5.57	5.58	5.18	5.07	5.75	5.96	5.79	5.51	5.00	4.53	1928.6	5.3
NEEDLES CA		LATITUDE:	34 DEGREES		46 MINUTES									
LATITUDE -15:	4.15	5.23	6.49	7.59	8.19	8.44	7.84	7.45	7.21	6.07	4.87	4.09	2362.5	6.5
LATITUDE :	4.70	5.65	6.65	7.33	7.54	7.62	7.22	7.19	7.42	6.62	5.58	4.76	2381.9	6.5
LATITUDE +15:	4.98	5.76	6.45	6.69	6.56	5.48	6.29	6.57	7.20	6.79	5.96	5.16	2277.5	6.2
OAKLAND CA		LATITUDE:	37 DEGREES		44 MINUTES									
LATITUDE -15:	3.05	3.97	5.22	6.32	6.85	7.12	7.19	6.78	6.19	4.89	3.66	2.98	1955.4	5.4
LATITUDE :	3.40	4.23	5.31	6.09	6.32	6.46	6.62	6.53	6.33	5.28	4.13	3.40	1951.7	5.3
LATITUDE +15:	3.56	4.27	5.12	5.56	5.54	5.55	5.78	5.96	6.12	5.37	4.37	3.64	1851.7	5.1
RED BLUFF CA		LATITUDE:	40 DEGREES		9 MINUTES									
LATITUDE -15:	2.53	3.58	4.95	6.36	7.29	7.87	8.31	7.79	7.00	5.24	3.29	2.44	2033.9	5.6
LATITUDE :	2.80	3.79	5.02	6.11	6.80	7.11	7.63	7.51	7.19	5.68	3.70	2.77	2013.7	5.5
LATITUDE +15:	2.92	3.81	4.83	5.57	5.93	6.07	6.61	6.85	6.96	5.79	3.89	2.94	1893.3	5.2

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
SACRAMENTO CA LATITUDE: 38 DEGREES 31 MINUTES														
LATITUDE -15:	2.55	3.69	5.27	6.63	7.55	8.11	8.35	7.92	7.11	5.47	3.53	2.45	2090.9	5.7
LATITUDE :	2.81	3.91	5.36	6.38	6.95	7.33	7.67	7.65	7.31	5.94	3.98	2.77	2073.2	5.7
LATITUDE +15:	2.93	3.94	5.17	5.83	6.36	6.25	6.65	6.97	7.09	6.07	4.20	2.94	1951.6	5.3
SAN DIEGO CA LATITUDE: 32 DEGREES 44 MINUTES														
LATITUDE -15:	3.90	4.70	5.64	6.25	6.18	6.26	6.74	6.65	5.95	5.16	4.31	3.79	1994.8	5.5
LATITUDE :	4.39	5.04	5.75	6.03	5.72	5.72	6.23	6.42	6.07	5.58	4.89	4.37	2014.9	5.5
LATITUDE +15:	4.63	5.11	5.56	5.52	5.04	4.95	5.46	5.87	5.87	5.68	5.19	4.71	1934.5	5.3
SAN FRANCISCO CA LATITUDE: 37 DEGREES 37 MINUTES														
LATITUDE -15:	3.04	3.93	5.22	6.31	6.90	7.19	7.41	7.00	6.35	4.94	3.64	2.94	1975.5	5.4
LATITUDE :	3.39	4.19	5.30	6.08	6.36	6.52	6.82	6.75	6.49	5.33	4.11	3.36	1970.1	5.4
LATITUDE +15:	3.55	4.22	5.11	5.55	5.57	5.60	5.95	6.16	6.28	5.43	4.34	3.59	1867.3	5.1
SANTA MARIA CA LATITUDE: 34 DEGREES 54 MINUTES														
LATITUDE -15:	3.51	4.31	5.56	6.25	6.60	7.12	7.22	6.88	6.11	5.26	4.11	3.52	2023.8	5.5
LATITUDE :	3.93	4.61	5.66	6.03	6.11	6.46	6.67	6.64	6.25	5.70	4.66	4.06	2032.8	5.6
LATITUDE +15:	4.14	4.66	5.47	5.51	5.36	5.56	5.82	6.06	6.04	5.82	4.95	4.36	1940.4	5.3
SUNNYVALE CA LATITUDE: 37 DEGREES 25 MINUTES														
LATITUDE -15:	3.17	4.04	5.32	6.39	7.05	7.42	7.55	7.17	6.41	5.03	3.74	3.02	2019.1	5.5
LATITUDE :	3.54	4.31	5.41	6.15	6.50	6.72	6.95	6.91	6.55	5.43	4.22	3.45	2013.9	5.5
LATITUDE +15:	3.72	4.34	5.21	5.62	5.68	5.76	6.05	6.30	6.34	5.53	4.46	3.69	1908.7	5.2
COLORADO SPRINGS CO LATITUDE: 38 DEGREES 49 MINUTES														
LATITUDE -15:	4.17	4.81	5.66	6.39	6.60	7.17	6.86	6.72	6.51	5.72	4.50	3.92	2100.9	5.8
LATITUDE :	4.74	5.18	5.77	6.15	6.09	6.50	6.32	6.48	6.67	6.23	5.16	4.57	2125.1	5.8
LATITUDE +15:	5.04	5.27	5.57	5.62	5.34	5.59	5.53	5.91	6.45	6.38	5.50	4.95	2042.8	5.6
DENVER CO LATITUDE: 39 DEGREES 45 MINUTES														
LATITUDE -15:	4.01	4.65	5.65	6.24	6.62	7.12	7.05	6.82	6.45	5.55	4.29	3.75	2076.2	5.7
LATITUDE :	4.56	5.01	5.76	6.00	6.11	6.46	6.50	6.57	6.60	6.04	4.90	4.36	2095.9	5.7
LATITUDE +15:	4.84	5.08	5.56	5.48	5.35	5.55	5.67	6.00	6.39	6.17	5.22	4.72	2009.0	5.5
GRAND JUNCTION CO LATITUDE: 39 DEGREES 7 MINUTES														
LATITUDE -15:	3.65	4.56	5.70	6.59	7.38	7.86	7.65	7.28	6.86	5.70	4.41	3.66	2171.0	5.9
LATITUDE :	4.12	4.89	5.81	6.34	6.79	7.10	7.03	7.02	7.03	6.20	5.03	4.25	2180.1	6.0
LATITUDE +15:	4.35	4.96	5.61	5.78	5.92	6.06	6.12	6.39	6.81	6.34	5.36	4.58	2078.0	5.7

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
PUEBLO CO — LATITUDE: 38 DEGREES 17 MINUTES														
LATITUDE -15:	4.12	4.73	5.68	6.46	6.69	7.36	7.15	6.97	6.55	5.67	4.49	3.86	2122.9	5.8
LATITUDE :	4.68	5.09	5.79	6.22	6.17	6.67	6.59	6.72	6.71	6.16	5.12	4.48	2142.6	5.9
LATITUDE +15:	4.97	5.16	5.59	5.68	5.40	5.71	5.74	6.13	6.49	6.30	5.46	4.85	2053.1	5.6
HARTFORD CT — LATITUDE: 41 DEGREES 56 MINUTES														
LATITUDE -15:	2.14	2.85	3.51	4.33	4.86	5.11	5.11	4.70	4.22	3.53	2.27	1.81	1352.9	3.7
LATITUDE :	2.35	3.00	3.53	4.15	4.49	4.66	4.72	4.51	4.26	3.76	2.51	2.02	1337.8	3.7
LATITUDE +15:	2.44	2.99	3.37	3.78	3.96	4.05	4.16	4.11	4.08	3.79	2.61	2.13	1262.1	3.5
GUANTANAMO BAY CU — LATITUDE: 19 DEGREES 54 MINUTES														
LATITUDE -15:	4.66	5.38	6.17	6.69	6.36	6.10	6.50	6.31	5.84	5.17	4.76	4.39	2079.2	5.7
LATITUDE :	5.27	5.79	6.31	6.48	5.93	5.62	6.06	6.12	5.96	5.56	5.40	5.07	2115.9	5.8
LATITUDE +15:	5.60	5.90	6.12	5.95	5.23	4.89	5.33	5.62	5.77	5.67	5.74	5.47	2046.1	5.6
WASHINGTON-STERLINDC — LATITUDE: 38 DEGREES 57 MINUTES														
LATITUDE -15:	2.44	3.15	3.98	4.77	5.32	5.76	5.62	5.30	4.81	4.02	2.86	2.16	1528.7	4.2
LATITUDE :	2.69	3.32	4.01	4.58	4.93	5.26	5.20	5.10	4.87	4.29	3.19	2.43	1518.5	4.2
LATITUDE +15:	2.80	3.33	3.85	4.19	4.35	4.56	4.58	4.66	4.68	4.34	3.34	2.57	1437.8	3.9
WILMINGTON DE — LATITUDE: 39 DEGREES 40 MINUTES														
LATITUDE -15:	2.49	3.25	4.11	4.85	5.30	5.71	5.65	5.32	4.76	3.97	2.90	2.26	1539.3	4.2
LATITUDE :	2.76	3.43	4.14	4.65	4.90	5.21	5.22	5.11	4.82	4.25	3.23	2.55	1530.0	4.2
LATITUDE +15:	2.87	3.44	3.97	4.25	4.32	4.51	4.59	4.66	4.63	4.29	3.39	2.70	1449.3	4.0
APALACHICOLA FL — LATITUDE: 29 DEGREES 44 MINUTES														
LATITUDE -15:	3.16	3.98	4.94	6.02	6.45	6.08	5.60	5.39	5.16	4.93	3.94	3.12	1788.9	4.9
LATITUDE :	3.49	4.22	5.01	5.81	5.98	5.56	5.21	5.21	5.24	5.31	4.42	3.54	1795.8	4.9
LATITUDE +15:	3.65	4.25	4.84	5.32	5.26	4.83	4.61	4.78	5.05	5.40	4.67	3.77	1716.4	4.7
DAYTONA BEACH FL — LATITUDE: 29 DEGREES 11 MINUTES														
LATITUDE -15:	3.56	4.29	5.19	6.02	6.07	5.57	5.51	5.36	4.94	4.45	3.89	3.32	1769.5	4.8
LATITUDE :	3.96	4.56	5.28	5.81	5.63	5.11	5.12	5.18	5.00	4.75	4.35	3.77	1780.2	4.9
LATITUDE +15:	4.15	4.60	5.09	5.32	4.96	4.46	4.53	4.75	4.81	4.80	4.58	4.02	1705.4	4.7
JACKSONVILLE FL — LATITUDE: 30 DEGREES 30 MINUTES														
LATITUDE -15:	3.40	4.16	5.14	5.95	6.03	5.73	5.56	5.42	4.85	4.40	3.81	3.18	1753.7	4.8
LATITUDE :	3.77	4.42	5.22	5.74	5.60	5.25	5.17	5.23	4.91	4.71	4.27	3.61	1761.6	4.8
LATITUDE +15:	3.95	4.46	5.03	5.26	4.94	4.57	4.57	4.80	4.73	4.76	4.50	3.85	1685.2	4.6

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
MIAMI FL		LATITUDE:	25 DEGREES		48 MINUTES									
LATITUDE -15:	3.74	4.50	5.27	5.90	5.71	5.25	5.46	5.17	4.76	4.46	3.99	3.69	1761.3	4.8
LATITUDE :	4.17	4.80	5.36	5.70	5.33	4.84	5.09	5.00	4.83	4.76	4.47	4.21	1781.2	4.9
LATITUDE +15:	4.38	4.85	5.18	5.24	4.72	4.24	4.52	4.60	4.65	4.82	4.71	4.50	1715.6	4.7
ORLANDO FL		LATITUDE:	28 DEGREES		33 MINUTES									
LATITUDE -15:	3.68	4.37	5.29	6.06	6.14	5.60	5.56	5.33	4.99	4.61	4.08	3.50	1801.8	4.9
LATITUDE :	4.10	4.65	5.38	5.86	5.71	5.14	5.18	5.15	5.06	4.94	4.59	3.99	1817.2	5.0
LATITUDE +15:	4.31	4.70	5.19	5.37	5.03	4.49	4.58	4.73	4.87	5.01	4.85	4.26	1744.9	4.8
TALLAHASSEE FL		LATITUDE:	30 DEGREES		23 MINUTES									
LATITUDE -15:	3.30	4.05	4.98	5.84	5.98	5.73	5.39	5.36	5.03	4.78	3.86	3.16	1748.3	4.8
LATITUDE :	3.66	4.31	5.06	5.63	5.55	5.25	5.02	5.17	5.10	5.13	4.33	3.58	1757.6	4.8
LATITUDE +15:	3.82	4.34	4.87	5.16	4.89	4.57	4.44	4.74	4.91	5.21	4.56	3.81	1682.6	4.6
TAMPA FL		LATITUDE:	27 DEGREES		58 MINUTES									
LATITUDE -15:	3.68	4.39	5.30	6.09	6.18	5.65	5.42	5.26	4.95	4.73	4.08	3.49	1802.0	4.9
LATITUDE :	4.10	4.68	5.40	5.88	5.74	5.19	5.05	5.09	5.02	5.07	4.59	3.98	1819.3	5.0
LATITUDE +15:	4.31	4.73	5.22	5.40	5.07	4.53	4.48	4.67	4.84	5.15	4.85	4.25	1748.7	4.8
ATLANTA GA		LATITUDE:	33 DEGREES		39 MINUTES									
LATITUDE -15:	2.80	3.55	4.47	5.43	5.72	5.81	5.59	5.51	4.89	4.50	3.55	2.76	1661.6	4.6
LATITUDE :	3.08	3.75	4.52	5.23	5.31	5.31	5.19	5.31	4.96	4.82	3.98	3.12	1661.3	4.6
LATITUDE +15:	3.21	3.76	4.34	4.79	4.68	4.62	4.58	4.86	4.77	4.89	4.18	3.32	1582.5	4.3
AUGUSTA GA		LATITUDE:	33 DEGREES		22 MINUTES									
LATITUDE -15:	2.94	3.72	4.59	5.58	5.75	5.78	5.55	5.37	4.84	4.57	3.69	2.97	1684.7	4.6
LATITUDE :	3.25	3.94	4.64	5.37	5.34	5.29	5.15	5.17	4.89	4.90	4.14	3.37	1687.5	4.6
LATITUDE +15:	3.38	3.96	4.46	4.92	4.71	4.59	4.55	4.74	4.71	4.97	4.36	3.58	1610.3	4.4
MACON GA		LATITUDE:	32 DEGREES		42 MINUTES									
LATITUDE -15:	2.97	3.70	4.65	5.60	5.81	5.83	5.50	5.53	4.92	4.63	3.74	2.94	1699.3	4.7
LATITUDE :	3.28	3.92	4.71	5.39	5.39	5.34	5.11	5.33	4.99	4.97	4.20	3.34	1703.3	4.7
LATITUDE +15:	3.42	3.94	4.53	4.94	4.76	4.64	4.51	4.88	4.80	5.05	4.42	3.55	1626.3	4.5
SAVANNAH GA		LATITUDE:	32 DEGREES		8 MINUTES									
LATITUDE -15:	3.06	3.77	4.75	5.66	5.72	5.60	5.49	5.21	4.63	4.48	3.70	3.02	1677.2	4.6
LATITUDE :	3.38	3.99	4.81	5.46	5.31	5.13	5.10	5.02	4.68	4.79	4.15	3.43	1681.1	4.6
LATITUDE +15:	3.52	4.01	4.63	5.00	4.68	4.47	4.50	4.59	4.80	4.05				

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
BARBERS POINT	HI	LATITUDE: 21 DEGREES 19 MINUTES													
LATITUDE -15:		4.06	4.75	5.29	5.79	6.13	6.26	6.28	6.22	5.85	5.15	4.39	3.97	1951.9	5.3
LATITUDE :		4.54	5.07	5.38	5.61	5.72	5.74	5.85	6.02	5.96	5.53	4.94	4.54	1974.8	5.4
LATITUDE +15:		4.78	5.14	5.21	5.16	5.05	4.98	5.15	5.53	5.77	5.63	5.23	4.86	1900.3	5.2
HILO	HI	LATITUDE: 19 DEGREES 43 MINUTES													
LATITUDE -15:		3.69	4.04	4.29	4.52	4.85	5.17	5.07	5.02	4.94	4.46	3.64	3.37	1614.9	4.4
LATITUDE :		4.09	4.29	4.35	4.39	4.56	4.79	4.76	4.88	5.01	4.76	4.03	3.81	1634.2	4.5
LATITUDE +15:		4.29	4.32	4.21	4.06	4.08	4.21	4.25	4.50	4.85	4.81	4.23	4.04	1577.0	4.3
HONOLULU	HI	LATITUDE: 21 DEGREES 20 MINUTES													
LATITUDE -15:		3.97	4.60	5.22	5.67	6.07	6.21	6.22	6.21	5.84	5.10	4.27	3.85	1924.4	5.3
LATITUDE :		4.43	4.90	5.31	5.49	5.66	5.70	5.80	6.01	5.95	5.48	4.80	4.39	1944.7	5.3
LATITUDE +15:		4.65	4.96	5.13	5.05	5.00	4.95	5.11	5.52	5.76	5.57	5.07	4.69	1869.8	5.1
BURLINGTON	IA	LATITUDE: 40 DEGREES 47 MINUTES													
LATITUDE -15:		2.63	3.46	4.21	5.07	5.82	6.42	6.48	6.09	5.23	4.45	3.11	2.31	1684.2	4.6
LATITUDE :		2.92	3.67	4.26	4.86	5.38	5.84	5.98	5.86	5.32	4.79	3.49	2.62	1674.1	4.6
LATITUDE +15:		3.06	3.68	4.08	4.44	4.73	5.03	5.23	5.35	5.12	4.86	3.68	2.78	1584.1	4.3
DES MOINES	IA	LATITUDE: 41 DEGREES 32 MINUTES													
LATITUDE -15:		2.71	3.52	4.31	5.16	5.80	6.43	6.51	6.12	5.36	4.57	3.16	2.42	1707.7	4.7
LATITUDE :		3.02	3.74	4.35	4.94	5.35	5.84	6.00	5.88	5.45	4.92	3.55	2.75	1699.3	4.7
LATITUDE +15:		3.16	3.76	4.18	4.51	4.70	5.04	5.25	5.36	5.25	5.00	3.74	2.93	1609.3	4.4
MASON CITY	IA	LATITUDE: 43 DEGREES 9 MINUTES													
LATITUDE -15:		2.71	3.53	4.34	5.06	5.90	6.40	6.49	6.19	5.34	4.46	3.00	2.31	1697.1	4.6
LATITUDE :		3.02	3.75	4.39	4.84	5.44	5.80	5.97	5.95	5.43	4.80	3.37	2.62	1685.9	4.6
LATITUDE +15:		3.17	3.77	4.21	4.41	4.76	5.00	5.22	5.42	5.23	4.86	3.54	2.79	1593.7	4.4
SIOUX CITY	IA	LATITUDE: 42 DEGREES 24 MINUTES													
LATITUDE -15:		2.73	3.49	4.31	5.24	5.91	6.44	6.60	6.20	5.36	4.51	3.17	2.40	1716.6	4.7
LATITUDE :		3.04	3.71	4.35	5.03	5.45	5.84	6.08	5.96	5.45	4.86	3.57	2.73	1707.0	4.7
LATITUDE +15:		3.18	3.72	4.17	4.58	4.78	5.03	5.31	5.43	5.25	4.93	3.76	2.90	1615.2	4.4
BOISE	ID	LATITUDE: 43 DEGREES 34 MINUTES													
LATITUDE -15:		2.33	3.57	4.95	6.18	7.13	7.48	8.20	7.55	6.87	5.20	3.23	2.30	1980.0	5.4
LATITUDE :		2.58	3.80	5.03	5.94	6.56	6.76	7.53	7.28	7.06	5.65	3.64	2.62	1962.5	5.4
LATITUDE +15:		2.69	3.82	4.84	5.41	5.73	5.79	6.53	6.63	6.84	5.77	3.84	2.78	1847.2	5.1

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
LEWISTON	ID	LATITUDE: 46 DEGREES 23 MINUTES													
LATITUDE -15:		1.62	2.59	3.88	4.84	5.77	6.11	7.36	6.70	5.76	3.98	2.13	1.50	1593.0	4.4
LATITUDE :		1.76	2.71	3.91	4.63	5.31	5.54	6.76	6.44	5.87	4.27	2.37	1.68	1562.4	4.3
LATITUDE +15:		1.81	2.70	3.74	4.21	4.65	4.77	5.88	5.86	5.66	4.33	2.47	1.76	1458.1	4.0
POCATELLO	ID	LATITUDE: 42 DEGREES 55 MINUTES													
LATITUDE -15:		2.59	3.73	5.19	6.14	7.13	7.53	8.15	7.67	6.95	5.47	3.54	2.49	2028.8	5.6
LATITUDE :		2.89	3.97	5.28	5.90	6.57	6.81	7.49	7.40	7.14	5.95	4.01	2.85	2018.7	5.5
LATITUDE +15:		3.02	4.00	5.09	5.38	5.74	5.84	6.51	6.75	6.93	6.09	4.25	3.04	1907.2	5.2
CHICAGO	IL	LATITUDE: 41 DEGREES 47 MINUTES													
LATITUDE -15:		2.30	3.05	4.03	4.82	5.55	6.09	6.04	5.74	5.03	4.09	2.65	1.91	1562.9	4.3
LATITUDE :		2.54	3.22	4.06	4.62	5.13	5.54	5.57	5.51	5.11	4.39	2.96	2.14	1546.6	4.2
LATITUDE +15:		2.64	3.22	3.89	4.22	4.51	4.78	4.88	5.03	4.91	4.44	3.10	2.26	1457.9	4.0
SPRINGFIELD	IL	LATITUDE: 39 DEGREES 50 MINUTES													
LATITUDE -15:		2.58	3.41	4.08	4.97	5.78	6.35	6.38	5.98	5.33	4.40	3.09	2.28	1663.6	4.6
LATITUDE :		2.86	3.61	4.12	4.77	5.34	5.78	5.88	5.75	5.42	4.73	3.46	2.58	1653.3	4.5
LATITUDE +15:		2.98	3.63	3.95	4.36	4.70	4.99	5.15	5.25	5.22	4.80	3.63	2.74	1564.5	4.3
FORT WAYNE	IN	LATITUDE: 41 DEGREES 0 MINUTES													
LATITUDE -15:		1.95	2.73	3.50	4.46	5.18	5.57	5.53	5.27	4.65	3.80	2.31	1.65	1419.2	3.9
LATITUDE :		2.13	2.85	3.51	4.27	4.78	5.07	5.10	5.05	4.70	4.05	2.54	1.83	1397.2	3.8
LATITUDE +15:		2.19	2.84	3.35	3.89	4.21	4.40	4.48	4.60	4.51	4.09	2.64	1.91	1311.9	3.6
INDIANAPOLIS	IN	LATITUDE: 39 DEGREES 44 MINUTES													
LATITUDE -15:		2.09	2.88	3.67	4.58	5.23	5.66	5.59	5.42	4.79	3.95	2.55	1.84	1469.6	4.0
LATITUDE :		2.28	3.02	3.69	4.39	4.84	5.17	5.17	5.20	4.85	4.22	2.82	2.05	1452.7	4.0
LATITUDE +15:		2.36	3.02	3.53	4.01	4.27	4.48	4.54	4.75	4.66	4.26	2.95	2.15	1369.2	3.8
SOUTH BEND	IN	LATITUDE: 41 DEGREES 42 MINUTES													
LATITUDE -15:		1.77	2.57	3.56	4.57	5.34	5.83	5.75	5.55	4.76	3.78	2.25	1.52	1439.3	3.9
LATITUDE :		1.92	2.69	3.57	4.38	4.93	5.30	5.30	5.33	4.82	4.03	2.48	1.67	1414.3	3.9
LATITUDE +15:		1.97	2.67	3.42	4.00	4.34	4.59	4.66	4.86	4.63	4.07	2.58	1.73	1324.9	3.6
DODGE CITY	KS	LATITUDE: 37 DEGREES 46 MINUTES													
LATITUDE -15:		3.67	4.46	5.31	6.20	6.47	7.14	7.11	6.79	6.14	5.31	4.05	3.47	2012.6	5.5
LATITUDE :		4.15	4.78	5.40	5.97	5.98	6.48	6.55	6.54	6.27	5.76	4.60	4.01	2023.5	5.5
LATITUDE +15:		4.38	4.84	5.21	5.45	5.24	5.57	5.72	5.97	6.07	5.88	4.88			

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ...)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
GOODLAND KS			LATITUDE: 39 DEGREES 22 MINUTES											
LATITUDE -15:	3.67	4.28	5.19	6.05	6.39	7.13	7.19	6.81	6.07	5.34	4.07	3.47	1999.4	5.5
LATITUDE :	4.15	4.58	5.27	5.82	5.90	6.46	6.62	6.56	6.20	5.80	4.63	4.01	2008.8	5.5
LATITUDE +15:	4.38	4.63	5.08	5.31	5.17	5.54	5.77	5.98	5.98	5.92	4.92	4.32	1917.5	5.3
TOPEKA KS			LATITUDE: 39 DEGREES 4 MINUTES											
LATITUDE -15:	3.03	3.72	4.50	5.39	5.93	6.44	6.59	6.32	5.54	4.72	3.55	2.76	1781.4	4.9
LATITUDE :	3.38	3.95	4.55	5.18	5.48	5.85	6.08	6.08	5.64	5.08	4.00	3.15	1778.0	4.9
LATITUDE +15:	3.55	3.98	4.37	4.73	4.81	5.04	5.31	5.54	5.43	5.16	4.22	3.36	1688.6	4.6
WICHITA KS			LATITUDE: 37 DEGREES 39 MINUTES											
LATITUDE -15:	3.43	4.15	5.01	5.84	6.30	6.86	6.93	6.71	5.84	5.06	3.92	3.21	1926.1	5.3
LATITUDE :	3.85	4.43	5.09	5.62	5.82	6.23	6.39	6.47	5.96	5.47	4.44	3.69	1931.4	5.3
LATITUDE +15:	4.05	4.48	4.90	5.14	5.11	5.36	5.58	5.90	5.75	5.57	4.70	3.95	1841.3	5.0
LEXINGTON KY			LATITUDE: 38 DEGREES 2 MINUTES											
LATITUDE -15:	2.25	2.95	3.85	4.81	5.39	5.74	5.72	5.52	4.85	4.15	2.83	2.12	1528.7	4.2
LATITUDE :	2.46	3.10	3.88	4.62	4.99	5.23	5.28	5.30	4.91	4.43	3.14	2.37	1513.9	4.1
LATITUDE +15:	2.54	3.09	3.71	4.22	4.40	4.54	4.64	4.84	4.72	4.47	3.29	2.50	1429.3	3.9
LOUISVILLE KY			LATITUDE: 38 DEGREES 11 MINUTES											
LATITUDE -15:	2.26	3.00	3.87	4.78	5.31	5.76	5.67	5.51	4.86	4.14	2.82	2.14	1526.7	4.2
LATITUDE :	2.47	3.15	3.89	4.59	4.92	5.26	5.24	5.29	4.92	4.42	3.13	2.40	1512.8	4.1
LATITUDE +15:	2.55	3.14	3.73	4.19	4.34	4.56	4.61	4.83	4.73	4.47	3.27	2.53	1429.0	3.9
BATON ROUGE LA			LATITUDE: 30 DEGREES 32 MINUTES											
LATITUDE -15:	2.92	3.74	4.64	5.38	5.77	5.86	5.38	5.37	4.93	4.71	3.48	2.83	1675.1	4.6
LATITUDE :	3.22	3.96	4.70	5.19	5.36	5.37	5.01	5.18	5.00	5.06	3.88	3.19	1677.2	4.6
LATITUDE +15:	3.35	3.98	4.53	4.76	4.74	4.67	4.43	4.75	4.81	5.13	4.07	3.39	1600.1	4.4
LAKE CHARLES LA			LATITUDE: 30 DEGREES 7 MINUTES											
LATITUDE -15:	2.67	3.56	4.39	5.01	5.71	5.99	5.51	5.29	4.99	5.01	3.45	2.67	1651.9	4.5
LATITUDE :	2.91	3.75	4.44	4.83	5.31	5.48	5.12	5.11	5.06	5.39	3.84	3.00	1650.6	4.5
LATITUDE +15:	3.01	3.76	4.27	4.43	4.69	4.75	4.53	4.68	4.87	5.47	4.02	3.16	1571.8	4.3
NEW ORLEANS LA			LATITUDE: 29 DEGREES 59 MINUTES											
LATITUDE -15:	3.09	3.93	4.74	5.70	6.08	6.11	5.60	5.49	5.09	4.81	3.66	2.98	1743.3	4.8
LATITUDE :	3.41	4.17	4.81	5.50	5.65	5.59	5.21	5.30	5.17	5.17	4.09	3.37	1747.9	4.8
LATITUDE +15:	3.56	4.20	4.63	5.05	4.98	4.85	4.61	4.86	4.99	5.25	4.30	3.58	1669.2	4.6

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
SHREVEPORT LA LATITUDE: 32 DEGREES														
LATITUDE -15:	2.93	3.77	4.56	5.18	5.82	6.27	6.20	6.05	5.33	4.85	3.67	2.94	1753.2	4.8
LATITUDE :	3.23	3.99	4.62	4.99	5.40	5.72	5.74	5.84	5.42	5.22	4.11	3.33	1753.8	4.8
LATITUDE +15:	3.37	4.01	4.44	4.57	4.76	4.95	5.05	5.34	5.22	5.30	4.32	3.54	1670.6	4.6
BOSTON MA LATITUDE: 42 DEGREES														
LATITUDE -15:	2.17	2.86	3.69	4.37	5.02	5.50	5.43	4.93	4.67	3.74	2.34	1.97	1421.2	3.9
LATITUDE :	2.38	3.00	3.71	4.18	4.64	5.01	5.01	4.73	4.72	3.99	2.59	2.21	1405.3	3.9
LATITUDE +15:	2.47	2.99	3.54	3.81	4.08	4.34	4.40	4.31	4.53	4.02	2.70	2.33	1325.0	3.6
BALTIMORE MD LATITUDE: 39 DEGREES														
LATITUDE -15:	2.55	3.28	4.13	4.87	5.29	5.69	5.63	5.25	4.79	4.01	2.94	2.29	1544.2	4.2
LATITUDE :	2.81	3.47	4.17	4.67	4.90	5.19	5.20	5.04	4.84	4.28	3.28	2.58	1534.8	4.2
LATITUDE +15:	2.93	3.47	3.99	4.26	4.31	4.50	4.57	4.60	4.65	4.32	3.44	2.73	1453.9	4.0
PATUXENT RIVER MD LATITUDE: 38 DEGREES														
LATITUDE -15:	2.59	3.33	4.17	5.02	5.45	5.73	5.61	5.33	4.85	4.05	3.10	2.42	1572.7	4.3
LATITUDE :	2.86	3.52	4.21	4.82	5.04	5.23	5.19	5.12	4.91	4.32	3.47	2.74	1565.0	4.3
LATITUDE +15:	2.98	3.53	4.04	4.40	4.44	4.53	4.56	4.67	4.72	4.36	3.64	2.91	1484.2	4.1
BANGOR ME LATITUDE: 44 DEGREES														
LATITUDE -15:	2.25	3.09	4.11	4.83	5.39	5.63	5.80	5.45	4.80	3.69	2.36	2.02	1504.8	4.1
LATITUDE :	2.49	3.27	4.15	4.62	4.97	5.12	5.34	5.22	4.86	3.95	2.63	2.29	1489.3	4.1
LATITUDE +15:	2.60	3.27	3.98	4.21	4.36	4.43	4.68	4.76	4.67	3.98	2.75	2.43	1404.1	3.8
CARIBOU ME LATITUDE: 46 DEGREES														
LATITUDE -15:	2.21	3.24	4.40	4.78	4.93	5.33	5.51	5.10	4.26	3.07	1.85	1.74	1413.0	3.9
LATITUDE :	2.46	3.44	4.46	4.58	4.54	4.84	5.07	4.88	4.30	3.27	2.03	1.97	1394.9	3.8
LATITUDE +15:	2.57	3.46	4.28	4.16	3.99	4.19	4.44	4.44	4.12	3.28	2.11	2.08	1312.1	3.6
PORTLAND ME LATITUDE: 43 DEGREES														
LATITUDE -15:	2.12	2.79	3.54	4.31	4.86	5.18	5.15	4.87	4.32	3.51	2.18	1.81	1359.8	3.7
LATITUDE :	2.33	2.93	3.56	4.13	4.49	4.72	4.75	4.67	4.36	3.74	2.41	2.03	1343.3	3.7
LATITUDE +15:	2.43	2.93	3.40	3.76	3.95	4.10	4.17	4.25	4.18	3.77	2.51	2.14	1265.6	3.5
ALPENA MI LATITUDE: 45 DEGREES														
LATITUDE -15:	1.67	2.55	3.85	4.71	5.36	5.69	5.87	5.35	4.39	3.23	1.81	1.49	1400.8	3.8
LATITUDE :	1.82	2.66	3.88	4.50	4.94	5.16	5.40	5.12	4.43	3.42	1.98	1.70	1371.6	3.8
LATITUDE +15:	1.87	2.65	3.71	4.10	4.33	4.46	4.73	4.66	4.24	2.44	2.04	1.91	12??.?	3.?

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
DETROIT MI														
LATITUDE: 42 DEGREES 25 MINUTES														
LATITUDE -15:	1.83	2.71	3.61	4.63	5.32	5.66	5.70	5.24	4.65	3.69	2.19	1.58	1425.7	3.9
LATITUDE :	1.99	2.84	3.63	4.43	4.92	5.15	5.26	5.02	4.70	3.93	2.42	1.75	1401.6	3.8
LATITUDE +15:	2.05	2.83	3.47	4.04	4.32	4.46	4.61	4.58	4.51	3.96	2.51	1.83	1313.9	3.6
FLINT MI														
LATITUDE: 42 DEGREES 58 MINUTES														
LATITUDE -15:	1.65	2.53	3.46	4.42	5.15	5.49	5.59	5.19	4.43	3.49	1.94	1.60	1369.4	3.8
LATITUDE :	1.79	2.64	3.47	4.24	4.76	5.00	5.16	4.98	4.48	3.72	2.13	1.82	1345.7	3.7
LATITUDE +15:	1.83	2.62	3.31	3.86	4.19	4.34	4.53	4.54	4.30	3.75	2.20	1.94	1261.1	3.5
GRAND RAPIDS MI														
LATITUDE: 42 DEGREES 53 MINUTES														
LATITUDE -15:	1.78	2.57	3.69	4.68	5.46	5.93	5.95	5.62	4.71	3.63	2.03	1.60	1452.3	4.0
LATITUDE :	1.98	2.69	3.71	4.48	5.04	5.40	5.49	5.39	4.77	3.87	2.23	1.83	1428.6	3.9
LATITUDE +15:	2.08	2.68	3.55	4.09	4.43	4.67	4.81	4.92	4.58	3.90	2.32	1.95	1339.2	3.7
HOUGHTON MI														
LATITUDE: 47 DEGREES 10 MINUTES														
LATITUDE -15:	1.23	1.96	3.54	4.61	5.18	5.56	5.76	5.19	3.88	3.01	1.58	1.05	1297.0	3.6
LATITUDE :	1.35	2.02	3.56	4.40	4.77	5.04	5.29	4.96	3.90	3.19	1.76	1.17	1262.7	3.5
LATITUDE +15:	1.40	1.98	3.40	4.00	4.18	4.36	4.62	4.51	3.73	3.20	1.84	1.23	1172.0	3.2
SAULT STE. MARIE MI														
LATITUDE: 46 DEGREES 28 MINUTES														
LATITUDE -15:	1.52	2.56	3.93	4.66	5.26	5.49	5.74	5.16	4.00	2.96	1.58	1.48	1351.2	3.7
LATITUDE :	1.64	2.69	3.96	4.45	4.85	4.98	5.28	4.94	4.03	3.14	1.72	1.69	1321.4	3.6
LATITUDE +15:	1.69	2.68	3.79	4.05	4.25	4.31	4.62	4.49	3.86	3.15	1.76	1.80	1231.9	3.4
TRAVERSE CITY MI														
LATITUDE: 44 DEGREES 44 MINUTES														
LATITUDE -15:	1.53	2.27	3.72	4.69	5.39	5.80	5.96	5.44	4.40	3.25	1.74	1.37	1388.7	3.8
LATITUDE :	1.70	2.36	3.74	4.49	4.97	5.27	5.49	5.21	4.45	3.46	1.90	1.55	1358.7	3.7
LATITUDE +15:	1.77	2.33	3.58	4.09	4.36	4.55	4.81	4.75	4.26	3.47	1.96	1.64	1267.1	3.5
DULUTH MN														
LATITUDE: 46 DEGREES 50 MINUTES														
LATITUDE -15:	1.99	2.97	3.97	4.63	5.13	5.35	5.81	5.27	4.23	3.27	1.95	1.59	1405.7	3.9
LATITUDE :	2.20	3.14	4.00	4.43	4.73	4.86	5.34	5.05	4.27	3.49	2.15	1.79	1383.8	3.8
LATITUDE +15:	2.29	3.14	3.83	4.03	4.15	4.21	4.68	4.59	4.09	3.51	2.24	1.89	1298.1	3.6
INTERNATIONAL FALL MN														
LATITUDE: 48 DEGREES 34 MINUTES														
LATITUDE -15:	1.93	3.05	4.13	4.94	5.38	5.62	6.04	5.60	4.45	3.32	1.86	1.63	1460.5	4.0
LATITUDE :	2.13	3.24	4.17	4.73	4.95	5.10	5.55	5.36	4.51	3.55	2.06	1.84	1436.4	3.9
LATITUDE +15:	2.22	3.25	3.99	4.29	4.33	4.40	4.85	4.88	4.32	3.57	2.14	1.95	1345.2	3.7

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
MINNEAPOLIS-ST.PAUMN — LATITUDE: 44 DEGREES 53 MINUTES														
LATITUDE -15:	2.31	3.29	4.16	4.84	5.84	5.84	6.16	5.73	4.81	3.81	2.43	1.85	1541.8	4.2
LATITUDE :	2.57	3.49	4.20	4.63	5.41	5.31	5.67	5.50	4.87	4.08	2.71	2.09	1525.4	4.2
LATITUDE +15:	2.69	3.50	4.03	4.22	4.38	4.59	4.96	5.01	4.68	4.12	2.83	2.21	1437.2	3.9
ROCHESTER MN — LATITUDE: 43 DEGREES 55 MINUTES														
LATITUDE -15:	2.31	3.16	4.02	4.70	5.28	5.76	5.95	5.60	4.72	3.77	2.42	1.88	1510.0	4.1
LATITUDE :	2.56	3.35	4.06	4.50	4.87	5.24	5.49	5.38	4.79	4.03	2.70	2.12	1494.0	4.1
LATITUDE +15:	2.67	3.36	3.89	4.10	4.28	4.54	4.81	4.90	4.60	4.07	2.82	2.24	1408.3	3.9
COLUMBIA MO — LATITUDE: 38 DEGREES 49 MINUTES														
LATITUDE -15:	2.64	3.41	4.19	4.99	5.82	6.33	6.55	6.21	5.24	4.47	3.13	2.38	1686.8	4.6
LATITUDE :	2.93	3.61	4.23	4.79	5.39	5.76	6.05	5.98	5.33	4.80	3.50	2.69	1676.9	4.6
LATITUDE +15:	3.05	3.62	4.06	4.38	4.74	4.98	5.30	5.46	5.13	4.87	3.68	2.86	1587.2	4.3
KANSAS CITY MO — LATITUDE: 39 DEGREES 18 MINUTES														
LATITUDE -15:	2.88	3.53	4.30	5.17	5.80	6.30	6.51	6.16	5.29	4.48	3.37	2.66	1718.9	4.7
LATITUDE :	3.21	3.74	4.34	4.96	5.36	5.72	6.03	5.93	5.37	4.81	3.78	3.02	1712.9	4.7
LATITUDE +15:	3.36	3.76	4.17	4.53	4.71	4.94	5.25	5.41	5.17	4.88	3.99	3.22	1624.9	4.5
SPRINGFIELD MO — LATITUDE: 37 DEGREES 14 MINUTES														
LATITUDE -15:	2.89	3.55	4.34	5.23	5.82	6.28	6.37	6.14	5.28	4.53	3.36	2.70	1720.5	4.7
LATITUDE :	3.21	3.76	4.38	5.02	5.38	5.72	5.88	5.91	5.36	4.87	3.76	3.06	1714.8	4.7
LATITUDE +15:	3.36	3.77	4.21	4.59	4.73	4.94	5.15	5.40	5.16	4.94	3.95	3.26	1627.2	4.5
ST. LOUIS MO — LATITUDE: 38 DEGREES 45 MINUTES														
LATITUDE -15:	2.72	3.46	4.28	5.12	5.79	6.34	6.34	5.99	5.28	4.45	3.20	2.42	1687.1	4.6
LATITUDE :	3.02	3.66	4.33	4.92	5.36	5.77	5.85	5.76	5.37	4.79	3.59	2.74	1679.1	4.6
LATITUDE +15:	3.16	3.68	4.15	4.50	4.71	4.99	5.13	5.26	5.17	4.85	3.77	2.91	1591.1	4.4
JACKSON MS — LATITUDE: 32 DEGREES 19 MINUTES														
LATITUDE -15:	2.88	3.71	4.66	5.49	5.98	6.14	5.88	5.73	5.16	4.72	3.54	2.83	1726.7	4.7
LATITUDE :	3.17	3.93	4.72	5.29	5.55	5.61	5.45	5.52	5.23	5.06	3.95	3.20	1725.1	4.7
LATITUDE +15:	3.30	3.94	4.54	4.84	4.89	4.86	4.80	5.05	5.04	5.14	4.14	3.39	1641.5	4.5
MERIDIAN MS — LATITUDE: 32 DEGREES 20 MINUTES														
LATITUDE -15:	2.84	3.66	4.51	5.33	5.73	5.96	5.62	5.60	4.96	4.66	3.51	2.79	1679.7	4.6
LATITUDE :	3.13	3.88	4.57	5.14	5.32	5.45	5.21	5.03	5.03	5.00	3.92	3.15	1679.2	4.6
LATITUDE +15:	3.25	3.89	4.39	4.71	4.69	4.73	4.60	4.94	4.84	5.07	4.11	3.24	1500.5	4.4

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
BILLINGS MT LATITUDE: 45 DEGREES 48 MINUTES														
LATITUDE -15:	2.55	3.36	4.59	5.15	5.99	6.61	7.51	7.02	5.87	4.65	3.08	2.45	1792.7	4.9
LATITUDE :	2.85	3.57	4.65	4.93	5.52	5.99	6.90	6.76	5.99	5.02	3.48	2.81	1781.6	4.9
LATITUDE +15:	2.99	3.59	4.47	4.49	4.83	5.15	6.01	6.16	5.79	5.11	3.67	3.00	1683.0	4.6
CUT BANK MT LATITUDE: 48 DEGREES 36 MINUTES														
LATITUDE -15:	2.28	3.20	4.50	5.10	5.93	6.22	7.25	6.68	5.57	4.36	2.89	2.17	1711.5	4.7
LATITUDE :	2.55	3.40	4.56	4.87	5.45	5.63	6.65	6.42	5.68	4.71	3.26	2.49	1696.8	4.6
LATITUDE +15:	2.67	3.42	4.38	4.43	4.77	4.84	5.79	5.85	5.47	4.78	3.44	2.66	1599.3	4.4
DILLON MT LATITUDE: 45 DEGREES 15 MINUTES														
LATITUDE -15:	2.76	3.75	4.96	5.56	6.23	6.50	7.53	6.99	6.05	4.79	3.30	2.59	1858.4	5.1
LATITUDE :	3.09	4.00	5.04	5.32	5.73	5.89	5.91	6.72	6.18	5.19	3.73	2.97	1850.8	5.1
LATITUDE +15:	3.25	4.03	4.85	4.85	5.01	5.06	6.01	6.12	5.97	5.28	3.94	3.18	1751.6	4.8
GLASGOW MT LATITUDE: 48 DEGREES 13 MINUTES														
LATITUDE -15:	2.13	3.08	4.37	5.09	5.73	6.22	6.93	6.53	5.48	4.34	2.82	2.12	1671.4	4.6
LATITUDE :	2.37	3.26	4.42	4.87	5.27	5.62	6.36	6.27	5.58	4.68	3.17	2.43	1654.7	4.5
LATITUDE +15:	2.48	3.27	4.24	4.42	4.61	4.84	5.54	5.71	5.38	4.75	3.34	2.59	1557.9	4.3
GREAT FALLS MT LATITUDE: 47 DEGREES 29 MINUTES														
LATITUDE -15:	2.28	3.28	4.62	5.07	5.80	6.39	7.36	6.76	5.60	4.52	2.85	2.02	1723.5	4.7
LATITUDE :	2.55	3.48	4.68	4.85	5.33	5.79	6.76	6.50	5.71	4.88	3.21	2.31	1707.5	4.7
LATITUDE +15:	2.66	3.50	4.50	4.41	4.67	4.97	5.88	5.92	5.50	4.96	3.38	2.46	1608.4	4.4
HELENA MT LATITUDE: 46 DEGREES 36 MINUTES														
LATITUDE -15:	2.18	3.13	4.44	5.04	5.82	6.20	7.36	6.70	5.67	4.41	2.90	2.13	1706.7	4.7
LATITUDE :	2.43	3.32	4.50	4.82	5.36	5.62	6.76	6.44	5.79	4.76	3.26	2.43	1690.7	4.6
LATITUDE +15:	2.53	3.33	4.32	4.39	4.69	4.84	5.88	5.87	5.58	4.83	3.44	2.59	1592.8	4.4
LEWISTOWN MT LATITUDE: 47 DEGREES 3 MINUTES														
LATITUDE -15:	2.24	3.09	4.40	4.90	5.66	6.25	7.22	6.62	5.52	4.35	2.83	2.19	1684.1	4.6
LATITUDE :	2.49	3.27	4.45	4.68	5.20	5.66	6.62	6.35	5.62	4.69	3.18	2.50	1667.2	4.6
LATITUDE +15:	2.60	3.28	4.27	4.26	4.55	4.86	5.76	5.78	5.41	4.76	3.35	2.66	1569.7	4.3
MILES CITY MT LATITUDE: 46 DEGREES 26 MINUTES														
LATITUDE -15:	2.43	3.32	4.61	5.23	5.94	6.52	7.22	6.88	5.80	4.59	3.10	2.38	1767.4	4.8
LATITUDE :	2.71	3.53	4.67	5.01	5.47	5.90	6.63	6.61	5.92	4.96	3.51	2.72	1755.3	4.8
LATITUDE +15:	2.84	3.54	4.48	4.56	4.78	5.07	5.77	6.02	5.71	5.04	3.70	2.91	1657.2	4.5

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT		LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
MISSOULA	MT	LATITUDE: 46 DEGREES 55 MINUTES														
LATITUDE -15:			1.46	2.43	3.74	4.67	5.58	5.87	7.35	6.54	5.43	3.77	2.16	1.41	1537.4	4.2
LATITUDE :			1.58	2.55	3.77	4.47	5.14	5.33	6.76	6.28	5.54	4.04	2.40	1.57	1506.6	4.1
LATITUDE +15:			1.62	2.53	3.60	4.06	4.51	4.60	5.88	5.72	5.34	4.08	2.51	1.64	1405.2	3.8
ASHEVILLE	NC	LATITUDE: 35 DEGREES 26 MINUTES														
LATITUDE -15:			2.93	3.65	4.54	5.41	5.57	5.63	5.47	5.27	4.73	4.40	3.56	2.82	1643.1	4.5
LATITUDE :			3.25	3.86	4.59	5.20	5.16	5.15	5.07	5.07	4.79	4.72	3.99	3.20	1645.1	4.5
LATITUDE +15:			3.40	3.88	4.42	4.76	4.55	4.48	4.47	4.64	4.60	4.78	4.21	3.41	1569.4	4.3
CAPE HATTERAS	NC	LATITUDE: 35 DEGREES 16 MINUTES														
LATITUDE -15:			2.75	3.55	4.61	5.76	6.05	6.17	5.92	5.53	5.14	4.35	3.66	2.82	1714.8	4.7
LATITUDE :			3.04	3.76	4.66	5.55	5.60	5.62	5.48	5.32	5.22	4.66	4.11	3.20	1711.1	4.7
LATITUDE +15:			3.17	3.77	4.48	5.07	4.93	4.87	4.82	4.87	5.02	4.72	4.34	3.40	1625.9	4.5
CHARLOTTE	NC	LATITUDE: 35 DEGREES 13 MINUTES														
LATITUDE -15:			2.91	3.64	4.57	5.50	5.72	5.83	5.64	5.50	4.93	4.51	3.62	2.88	1681.8	4.6
LATITUDE :			3.22	3.85	4.62	5.29	5.30	5.32	5.23	5.29	5.00	4.83	4.06	3.28	1682.8	4.6
LATITUDE +15:			3.36	3.87	4.44	4.84	4.67	4.62	4.60	4.84	4.81	4.90	4.28	3.49	1603.7	4.4
CHERRY POINT	NC	LATITUDE: 34 DEGREES 54 MINUTES														
LATITUDE -15:			3.06	3.83	4.82	5.82	5.94	5.89	5.64	5.29	4.96	4.46	3.78	3.07	1721.2	4.7
LATITUDE :			3.40	4.07	4.88	5.61	5.50	5.38	5.23	5.09	5.03	4.79	4.26	3.51	1726.8	4.7
LATITUDE +15:			3.56	4.10	4.70	5.13	4.85	4.67	4.61	4.66	4.84	4.85	4.51	3.75	1649.7	4.5
GREENSBORO	NC	LATITUDE: 36 DEGREES 5 MINUTES														
LATITUDE -15:			2.95	3.67	4.59	5.47	5.76	5.92	5.75	5.52	4.98	4.43	3.58	2.89	1689.5	4.6
LATITUDE :			3.28	3.89	4.64	5.26	5.33	5.40	5.32	5.30	5.05	4.75	4.02	3.28	1689.4	4.6
LATITUDE +15:			3.42	3.91	4.46	4.80	4.69	4.68	4.67	4.84	4.85	4.81	4.23	3.50	1608.9	4.4
RALEIGH-DURHAM	NC	LATITUDE: 35 DEGREES 52 MINUTES														
LATITUDE -15:			2.83	3.55	4.44	5.34	5.58	5.66	5.47	5.22	4.81	4.25	3.40	2.74	1622.3	4.4
LATITUDE :			3.13	3.75	4.49	5.14	5.18	5.17	5.07	5.03	4.87	4.55	3.81	3.11	1622.5	4.4
LATITUDE +15:			3.27	3.77	4.32	4.70	4.57	4.50	4.48	4.60	4.69	4.60	4.01	3.31	1546.1	4.2
BISMARCK	ND	LATITUDE: 46 DEGREES 46 MINUTES														
LATITUDE -15:			2.53	3.51	4.55	4.94	5.79	6.26	6.88	6.52	5.40	4.31	2.82	2.22	1697.8	4.7
LATITUDE :			2.83	3.75	4.61	4.73	5.33	5.67	6.32	6.26	5.51	4.65	3.18	2.54	1686.3	4.6
LATITUDE +15:			2.97	3.77												

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
FARGO	ND	LATITUDE:		46 DEGREES		54 MINUTES									
LATITUDE -15:		2.18	3.15	4.25	5.00	5.75	6.05	6.67	6.32	5.19	4.13	2.49	1.95	1618.6	4.4
LATITUDE :		2.42	3.34	4.30	4.79	5.29	5.49	6.13	6.07	5.28	4.44	2.79	2.22	1601.1	4.4
LATITUDE +15:		2.53	3.35	4.12	4.36	4.64	4.73	5.35	5.53	5.08	4.51	2.93	2.36	1507.0	4.1
MINOT	ND	LATITUDE:		48 DEGREES		16 MINUTES									
LATITUDE -15:		2.11	2.99	4.10	4.99	5.80	6.00	6.62	6.29	5.18	4.18	2.52	1.92	1606.1	4.4
LATITUDE :		2.34	3.17	4.14	4.77	5.34	5.43	6.07	6.03	5.26	4.50	2.83	2.19	1586.7	4.3
LATITUDE +15:		2.45	3.18	3.97	4.33	4.66	4.68	5.29	5.49	5.06	4.56	2.97	2.33	1491.4	4.1
GRAND ISLAND	NE	LATITUDE:		40 DEGREES		58 MINUTES									
LATITUDE -15:		3.10	3.75	4.62	5.62	6.13	6.80	6.89	6.50	5.63	4.86	3.58	2.86	1837.6	5.0
LATITUDE :		3.48	3.99	4.68	5.40	5.66	6.17	6.35	6.26	5.74	5.26	4.05	3.28	1836.5	5.0
LATITUDE +15:		3.66	4.02	4.50	4.93	4.97	5.31	5.55	5.71	5.54	5.35	4.29	3.52	1745.5	4.8
NORTH OMAHA	NE	LATITUDE:		41 DEGREES		22 MINUTES									
LATITUDE -15:		3.00	3.66	4.48	5.16	5.81	6.43	6.55	6.22	5.08	4.46	3.06	2.56	1719.8	4.7
LATITUDE :		3.36	3.89	4.53	4.95	5.36	5.84	6.03	5.98	5.16	4.80	3.43	2.91	1712.3	4.7
LATITUDE +15:		3.53	3.91	4.35	4.51	4.71	5.03	5.27	5.45	4.96	4.87	3.61	3.11	1622.5	4.4
NORTH PLATTE	NE	LATITUDE:		41 DEGREES		8 MINUTES									
LATITUDE -15:		3.31	3.95	4.91	5.73	6.17	6.87	7.09	6.67	5.88	5.09	3.74	3.13	1905.3	5.2
LATITUDE :		3.72	4.22	4.98	5.50	5.69	6.22	6.52	6.42	6.00	5.51	4.24	3.61	1907.1	5.2
LATITUDE +15:		3.92	4.25	4.79	5.01	4.98	5.35	5.68	5.85	5.79	5.62	4.49	3.87	1814.5	5.0
SCOTTSBLUFF	NE	LATITUDE:		41 DEGREES		52 MINUTES									
LATITUDE -15:		3.29	3.98	4.85	5.55	6.02	6.78	7.12	6.75	6.08	5.01	3.61	3.02	1889.5	5.2
LATITUDE :		3.71	4.25	4.92	5.33	5.55	6.15	6.55	6.50	6.22	5.42	4.09	3.48	1892.9	5.2
LATITUDE +15:		3.91	4.29	4.74	4.87	4.87	5.29	5.72	5.93	6.01	5.53	4.33	3.73	1802.4	4.9
CONCORD	NH	LATITUDE:		43 DEGREES		12 MINUTE									
LATITUDE -15:		2.14	2.78	3.54	4.35	4.90	5.~	5.19	4.83	4.22	3.45	2.17	1.77	1355.8	3.7
LATITUDE :		2.36	2.92	3.56	4.16	4.53	4.70	4.79	4.63	4.25	3.67	2.39	1.98	1337.6	3.7
LATITUDE +15:		2.45	2.91	3.40	3.79	3.98	4.08	4.20	4.21	4.07	3.69	2.49	2.08	1258.8	3.4
LAKEHURST	NJ	LATITUDE:		40 DEGREES		2 MINUTES									
LATITUDE -15:		2.47	3.13	3.96	4.78	5.17	5.38	5.26	5.04	4.55	3.88	2.81	2.22	1480.9	4.1
LATITUDE :		2.73	3.30	3.99	4.58	4.78	4.90	4.86	4.83	4.60	4.13	3.13	2.50	1470.9	4.0
LATITUDE +15:		2.84	3.30	3.82	4.18	4.21	4.26	4.28	4.41	4.41	4.17	3.28	2.65	1392.8	3.8

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
NEWARK NJ LATITUDE: 40 DEGREES 42 MINUTES														
LATITUDE -15:	2.47	3.15	3.98	4.76	5.23	5.44	5.46	5.16	4.63	3.90	2.72	2.14	1493.2	4.1
LATITUDE :	2.73	3.32	4.01	4.57	4.84	4.96	5.04	4.95	4.69	4.16	3.03	2.41	1483.1	4.1
LATITUDE +15:	2.85	3.33	3.85	4.17	4.26	4.31	4.43	4.52	4.50	4.20	3.18	2.55	1404.2	3.8
ALBUQUERQUE NM LATITUDE: 35 DEGREES 3 MINUTES														
LATITUDE -15:	4.35	5.22	6.28	7.29	7.83	8.09	7.67	7.50	7.07	6.17	4.98	4.23	2334.2	6.4
LATITUDE :	4.94	5.62	6.43	7.03	7.21	7.30	7.06	7.24	7.26	6.73	5.70	4.92	2356.8	6.5
LATITUDE +15:	5.24	5.72	6.22	6.42	6.27	6.22	6.14	6.60	7.03	6.90	6.09	5.33	2257.0	6.2
CLAYTON NM LATITUDE: 36 DEGREES 27 MINUTES														
LATITUDE -15:	4.24	4.88	5.92	6.69	6.86	7.31	7.05	6.89	6.51	5.80	4.62	4.04	2155.5	5.9
LATITUDE :	4.81	5.25	6.05	6.44	6.34	6.63	6.50	6.64	6.66	6.31	5.28	4.71	2179.6	6.0
LATITUDE +15:	5.11	5.33	5.84	5.88	5.55	5.69	5.68	6.06	6.45	6.46	5.63	5.10	2092.3	5.7
FARMINGTON NM LATITUDE: 36 DEGREES 45 MINUTES														
LATITUDE -15:	4.19	5.09	6.10	7.02	7.59	8.06	7.66	7.44	7.05	6.04	4.76	3.94	2280.6	6.2
LATITUDE :	4.75	5.49	6.24	6.77	6.99	7.29	7.05	7.18	7.25	6.59	5.45	4.59	2301.7	6.3
LATITUDE +15:	5.05	5.59	6.03	6.18	6.10	6.22	6.14	6.55	7.03	6.76	5.83	4.96	2203.8	6.0
ROSWELL NM LATITUDE: 33 DEGREES 24 MINUTES														
LATITUDE -15:	4.30	5.20	6.33	7.21	7.58	7.90	7.52	7.29	6.73	5.88	4.73	4.12	2276.3	6.2
LATITUDE :	4.87	5.61	6.48	6.96	6.99	7.14	6.93	7.03	6.89	6.40	5.40	4.78	2297.1	6.3
LATITUDE +15:	5.16	5.71	6.27	6.35	6.10	6.10	6.04	6.42	6.67	6.55	5.76	5.17	2199.6	6.0
TRUTH OR CONSEQUENM NM LATITUDE: 33 DEGREES 14 MINUTES														
LATITUDE -15:	4.64	5.53	6.62	7.60	7.89	8.01	7.28	7.20	6.82	6.10	5.13	4.37	2348.5	6.4
LATITUDE :	5.28	5.98	6.79	7.33	7.27	7.24	6.72	6.95	6.98	6.64	5.88	5.09	2377.3	6.5
LATITUDE +15:	5.61	6.09	6.58	6.69	6.32	6.18	5.86	6.34	6.76	6.81	6.29	5.52	2282.5	6.3
TUCUMCARI NM LATITUDE: 35 DEGREES 11 MINUTES														
LATITUDE -15:	4.33	5.02	6.08	6.86	7.14	7.51	7.24	7.08	6.53	5.70	4.67	4.14	2201.1	6.0
LATITUDE :	4.91	5.41	6.21	6.61	6.59	6.80	6.67	6.83	6.68	6.20	5.34	4.82	2223.5	6.1
LATITUDE +15:	5.21	5.49	6.00	6.04	5.76	5.82	5.82	6.23	6.46	6.34	5.69	5.22	2132.1	5.8
ZUNI NM LATITUDE: 35 DEGREES 6 MINUTES														
LATITUDE -15:	4.20	5.02	5.98	7.08	7.63	7.86	6.98	6.79	5.78	5.93	4.75	4.04	2223.0	6.1
LATITUDE :	4.76	5.40	6.11	6.83	7.03	7.11	6.44	6.54	6.94	6.46	5.43	4.69	2243.3	6.1
LATITUDE +15:	5.05	5.49	5.90	6.23	6.13	6.07								

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
ELKO	NV	LATITUDE: 40 DEGREES 50 MINUTES													
LATITUDE −15:		3.25	4.31	5.44	6.34	7.17	7.67	8.18	7.84	7.28	5.80	4.01	3.16	2145.9	5.9
LATITUDE :		3.65	4.62	5.55	6.10	6.61	6.94	7.52	7.57	7.50	6.33	4.57	3.65	2149.4	5.9
LATITUDE +15:		3.85	4.67	5.35	5.57	5.77	5.94	6.53	6.90	7.28	6.49	4.86	3.92	2043.2	5.6
ELY	NV	LATITUDE: 39 DEGREES 17 MINUTES													
LATITUDE −15:		3.84	4.69	5.93	6.68	7.17	7.61	7.60	7.46	7.31	6.04	4.48	3.63	2204.7	6.0
LATITUDE :		4.34	5.04	6.06	6.43	6.60	6.88	6.99	7.19	7.52	6.59	5.12	4.21	2220.7	6.1
LATITUDE +15:		4.60	5.11	5.85	5.87	5.76	5.89	6.08	6.56	7.29	6.75	5.46	4.54	2122.5	5.8
LAS VEGAS	NV	LATITUDE: 36 DEGREES 5 MINUTES													
LATITUDE −15:		4.28	5.30	6.58	7.64	8.18	8.39	7.99	7.76	7.43	6.27	4.88	4.11	2398.8	6.6
LATITUDE :		4.86	5.72	6.74	7.37	7.52	7.56	7.35	7.49	7.64	6.85	5.59	4.79	2418.3	6.6
LATITUDE +15:		5.16	5.83	6.53	6.72	6.53	6.43	6.38	6.83	7.41	7.03	5.97	5.18	2311.4	6.3
LOVELOCK	NV	LATITUDE: 40 DEGREES 4 MINUTES													
LATITUDE −15:		3.85	4.88	6.20	7.26	7.95	8.32	8.67	8.40	7.76	6.41	4.64	3.70	2376.4	6.5
LATITUDE :		4.37	5.26	6.34	6.99	7.31	7.49	7.95	8.10	7.99	7.02	5.31	4.29	2387.9	6.5
LATITUDE +15:		4.62	5.34	6.13	6.38	6.35	6.38	6.89	7.38	7.75	7.21	5.67	4.63	2274.7	6.2
RENO	NV	LATITUDE: 39 DEGREES 30 MINUTES													
LATITUDE −15:		3.75	4.74	6.12	7.21	7.85	8.17	8.37	8.10	7.58	6.19	4.43	3.55	2316.2	6.3
LATITUDE :		4.24	5.10	6.26	6.95	7.22	7.37	7.68	7.82	7.80	6.78	5.06	4.12	2326.3	6.4
LATITUDE +15:		4.49	5.18	6.06	6.34	6.29	6.29	6.66	7.13	7.58	6.96	5.40	4.44	2215.6	6.1
TONOPAH	NV	LATITUDE: 38 DEGREES 4 MINUTES													
LATITUDE −15:		4.23	5.20	6.54	7.47	7.99	8.41	8.38	8.14	7.65	6.45	4.90	4.10	2419.3	6.6
LATITUDE :		4.81	5.62	6.71	7.20	7.35	7.58	7.69	7.86	7.85	7.06	5.62	4.78	2439.2	5.7
LATITUDE +15:		5.10	5.71	6.49	6.57	6.39	6.44	6.67	7.16	7.62	7.26	6.01	5.18	2331.1	6.4
WINNEMUCCA	NV	LATITUDE: 40 DEGREES 54 MINUTES													
LATITUDE −15:		3.26	4.27	5.48	6.59	7.37	7.79	8.36	7.97	7.35	5.81	4.01	3.18	2175.9	6.0
LATITUDE :		3.67	4.58	5.59	6.34	6.78	7.04	7.68	7.69	7.57	6.34	4.56	3.67	2178.2	6.0
LATITUDE +15:		3.87	4.63	5.40	5.79	5.92	6.02	6.67	7.02	7.35	6.50	4.85	3.95	2069.0	5.7
YUCCA FLATS	NV	LATITUDE: 36 DEGREES 57 MINUTES													
LATITUDE −15:		4.25	5.07	6.39	7.42	7.98	8.27	8.21	7.90	7.44	6.25	4.75	4.07	2375.0	6.5
LATITUDE :		4.84	5.47	6.55	7.17	7.35	7.47	7.55	7.63	7.66	6.84	5.45	4.75	2396.5	6.6
LATITUDE +15:		5.14	5.57	6.35	6.54	6.40	6.37	6.56	6.96	7.45	7.03	5.83	5.14	2292.6	6.3

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
ALBANY	NY			LATITUDE: 42 DEGREES 45 MINUTES											
LATITUDE -15:		2.08	2.77	3.57	4.40	4.86	5.24	5.35	4.98	4.32	3.41	2.09	1.68	1363.8	3.7
LATITUDE :		2.28	2.91	3.59	4.22	4.50	4.78	4.94	4.78	4.36	3.63	2.30	1.88	1344.6	3.7
LATITUDE +15:		2.37	2.90	3.43	3.84	3.96	4.15	4.34	4.35	4.18	3.65	2.39	1.97	1264.5	3.5
BINGHAMTON	NY			LATITUDE: 42 DEGREES 13 MINUTES											
LATITUDE -15:		1.84	2.20	3.05	4.07	4.63	5.09	5.19	4.71	4.13	3.20	1.80	1.48	1259.3	3.5
LATITUDE :		2.0_	2.27	3.04	3.89	4.28	4.64	4.74	4.51	4.16	3.39	1.96	1.67	1236.8	3.4
LATITUDE +15:		2.15	2.23	2.89	3.55	3.77	4.03	4.17	4.11	3.98	3.40	2.01	1.77	1159.4	3.2
BUFFALO	NY			LATITUDE: 42 DEGREES 56 MINUTES											
LATITUDE -15:		1.65	2.27	3.18	4.34	4.96	5.47	5.52	5.04	4.25	3.26	1.78	1.43	1315.2	3.6
LATITUDE :		1.83	2.41	3.18	4.15	4.58	4.98	5.10	4.83	4.29	3.47	1.94	1.61	1291.3	3.5
LATITUDE +15:		1.92	2.42	3.03	3.78	4.03	4.32	4.48	4.40	4.12	3.48	2.00	1.71	1209.3	3.3
CENTRAL PARK	NY			LATITUDE: 40 DEGREES 47 MINUTES											
LATITUDE -15:		2.19	2.82	3.70	4.48	5.07	5.18	5.22	4.89	4.40	3.65	2.38	1.84	1395.3	3.8
LATITUDE :		2.40	2.96	3.72	4.29	4.69	4.73	4.83	4.69	4.44	3.88	2.63	2.05	1380.0	3.8
LATITUDE +15:		2.49	2.95	3.56	3.92	4.14	4.12	4.25	4.28	4.26	3.91	2.74	2.16	1302.0	3.6
LA GUARDIA	NY			LATITUDE: 40 DEGREES 46 MINUTES											
LATITUDE -15:		2.45	3.16	4.02	4.79	5.24	5.47	5.52	5.23	4.66	3.90	2.71	2.16	1501.8	4.1
LATITUDE :		2.71	3.34	4.05	4.60	4.85	4.98	5.10	5.02	4.72	4.17	3.02	2.44	1491.7	4.1
LATITUDE +15:		2.82	3.34	3.89	4.20	4.27	4.33	4.49	4.58	4.53	4.21	3.16	2.59	1412.3	3.9
MASSENA	NY			LATITUDE: 44 DEGREES 56 MINUTES											
LATITUDE -15:		1.84	2.56	3.63	4.48	5.03	5.39	5.45	4.99	4.23	3.17	1.83	1.43	1341.4	3.7
LATITUDE :		2.02	2.68	3.65	4.29	4.64	4.90	5.02	4.78	4.28	3.37	2.00	1.58	1316.2	3.6
LATITUDE +15:		2.09	2.67	3.49	3.91	4.08	4.25	4.41	4.35	4.10	3.39	2.07	1.66	1231.7	3.4
ROCHESTER	NY			LATITUDE: 43 DEGREES 7 MINUTES											
LATITUDE -15:		1.77	2.16	3.25	4.43	4.98	5.50	5.53	5.06	4.29	3.27	1.80	1.43	1325.1	3.6
LATITUDE :		1.97	2.23	3.25	4.24	4.60	5.00	5.09	4.85	4.33	3.47	1.96	1.61	1298.4	3.6
LATITUDE +15:		2.06	2.19	3.09	3.86	4.05	4.33	4.47	4.42	4.15	3.48	2.02	1.71	1213.6	3.3
SYRACUSE	NY			LATITUDE: 43 DEGREES 7 MINUTES											
LATITUDE -15:		1.68	2.21	3.19	4.38	4.89	5.39	5.46	5.01	4.32	3.26	1.77	1.45	1310.7	3.6
LATITUDE :		1.82	2.29	3.19	4.18	4.52	4.90	5.03	4.80	4.36	3.45	1.93	1.64	1283.0	3.5
LATITUDE +15:		1.86	2.25	3.03	3.81	3.97	4.24	4.42	4.37	4.18	3.16	1.??	1.??		

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
AKRON-CANTON	OH	LATITUDE: 40 DEGREES 55 MINUTES													
LATITUDE -15:		1.79	2.49	3.41	4.45	5.17	5.58	5.54	5.28	4.64	3.71	2.23	1.54	1396.3	3.8
LATITUDE :		1.94	2.59	3.42	4.27	4.79	5.09	5.12	5.07	4.69	3.96	2.45	1.69	1372.9	3.8
LATITUDE +15:		1.99	2.57	3.27	3.90	4.22	4.42	4.50	4.63	4.50	3.99	2.55	1.76	1287.7	3.5
CINCINNATI	OH	LATITUDE: 39 DEGREES 4 MINUTES													
LATITUDE -15:		2.08	2.82	3.60	4.56	5.17	5.57	5.47	5.37	4.70	3.97	2.55	1.90	1454.5	4.0
LATITUDE :		2.26	2.95	3.62	4.37	4.78	5.08	5.06	5.15	4.76	4.23	2.82	2.11	1436.8	3.9
LATITUDE +15:		2.33	2.93	3.46	3.99	4.21	4.40	4.45	4.70	4.56	4.27	2.94	2.21	1353.6	3.7
CLEVELAND	OH	LATITUDE: 41 DEGREES 24 MINUTES													
LATITUDE -15:		1.80	2.29	3.26	4.43	5.21	5.59	5.67	5.24	4.54	3.56	2.05	1.55	1377.5	3.8
LATITUDE :		2.00	2.37	3.26	4.24	4.82	5.09	5.23	5.03	4.58	3.79	2.25	1.76	1353.7	3.7
LATITUDE +15:		2.10	2.33	3.11	3.87	4.24	4.41	4.59	4.58	4.40	3.82	2.32	1.87	1268.8	3.5
COLUMBUS	OH	LATITUDE: 40 DEGREES 0 MINUTES													
LATITUDE -15:		1.91	2.58	3.45	4.42	5.09	5.49	5.43	5.41	4.63	3.83	2.35	1.70	1410.4	3.9
LATITUDE :		2.07	2.68	3.46	4.23	4.71	5.00	5.01	5.19	4.68	4.08	2.59	1.87	1388.7	3.8
LATITUDE +15:		2.13	2.66	3.30	3.86	4.15	4.34	4.41	4.73	4.49	4.12	2.69	1.95	1304.3	3.6
DAYTON	OH	LATITUDE: 39 DEGREES 54 MINUTES													
LATITUDE -15:		2.07	2.79	3.62	4.60	5.26	5.68	5.60	5.43	4.77	3.93	2.48	1.80	1462.8	4.0
LATITUDE :		2.26	2.93	3.64	4.41	4.87	5.18	5.18	5.21	4.83	4.19	2.75	2.00	1444.8	4.0
LATITUDE +15:		2.33	2.92	3.48	4.03	4.30	4.49	4.56	4.76	4.64	4.23	2.86	2.10	1360.8	3.7
TOLEDO	OH	LATITUDE: 41 DEGREES 36 MINUTES													
LATITUDE -15:		1.87	2.67	3.57	4.55	5.33	5.69	5.74	5.36	4.69	3.79	2.25	1.60	1434.9	3.9
LATITUDE :		2.04	2.79	3.59	4.36	4.92	5.18	5.29	5.15	4.74	4.04	2.48	1.77	1411.6	3.9
LATITUDE +15:		2.10	2.77	3.43	3.98	4.33	4.49	4.65	4.69	4.55	4.07	2.58	1.85	1324.2	3.6
YOUNGSTOWN	OH	LATITUDE: 41 DEGREES 16 MINUTES													
LATITUDE -15:		1.77	2.21	3.13	4.18	4.91	5.33	5.37	4.97	4.35	3.48	1.99	1.53	1317.5	3.6
LATITUDE :		1.97	2.28	3.13	4.00	4.54	4.86	4.96	4.76	4.39	3.70	2.17	1.73	1294.8	3.5
LATITUDE +15:		2.06	2.25	2.98	3.65	4.00	4.21	4.36	4.34	4.20	3.72	2.24	1.84	1214.2	3.3
OKLAHOMA CITY	OK	LATITUDE: 35 DEGREES 24 MINUTES													
LATITUDE -15:		3.30	3.99	4.89	5.60	5.91	6.49	6.57	6.37	5.47	4.78	3.82	3.16	1837.9	5.0
LATITUDE :		3.69	4.25	4.96	5.39	5.47	5.91	6.07	6.13	5.57	5.15	4.31	3.61	1841.6	5.0
LATITUDE +15:		3.87	4.28	4.78	4.93	4.82	5.10	5.31	5.60	5.37	5.23	4.55	3.86	1755.8	4.8

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
TULSA, OK — LATITUDE: 36 DEGREES 12 MINUTES														
LATITUDE -15:	3.04	3.71	4.57	5.20	5.62	6.12	6.26	6.10	5.20	4.54	3.52	2.90	1729.3	4.7
LATITUDE :	3.38	3.94	4.62	5.00	5.21	5.58	5.78	5.87	5.28	4.87	3.95	3.30	1728.5	4.7
LATITUDE +15:	3.54	3.96	4.44	4.57	4.59	4.83	5.07	5.36	5.08	4.94	4.16	3.52	1645.0	4.5
ASTORIA, OR — LATITUDE: 46 DEGREES 9 MINUTES														
LATITUDE -15:	1.66	2.23	3.20	4.19	5.00	4.91	5.45	5.07	4.57	3.16	1.93	1.29	1300.5	3.6
LATITUDE :	1.85	2.32	3.20	3.99	4.61	4.47	5.01	4.85	4.63	3.35	2.13	1.42	1274.8	3.5
LATITUDE +15:	1.94	2.29	3.05	3.63	4.04	3.87	4.39	4.41	4.43	3.37	2.21	1.48	1:91.7	3.3
BURNS, OR — LATITUDE: 43 DEGREES 35 MINUTES														
LATITUDE -15:	2.35	3.34	4.44	5.53	6.41	6.92	7.70	7.13	6.33	4.67	3.00	2.26	1831.1	5.0
LATITUDE :	2.61	3.54	4.49	5.31	5.91	6.27	7.08	6.86	6.48	5.04	3.38	2.57	1813.6	5.0
LATITUDE +15:	2.72	3.55	4.31	4.84	5.17	5.38	6.16	6.25	6.27	5.13	3.55	2.73	1707.5	4.7
MEDFORD, OR — LATITUDE: 42 DEGREES 22 MINUTES														
LATITUDE -15:	1.76	2.99	4.16	5.47	6.33	6.90	7.73	7.20	6.08	4.22	2.35	1.54	1728.7	4.7
LATITUDE :	1.91	3.15	4.19	5.25	5.83	6.25	7.10	6.93	6.22	4.53	2.60	1.70	1695.6	4.6
LATITUDE +15:	1.96	3.15	4.02	4.78	5.11	5.37	6.18	6.32	6.00	4.58	2.71	1.77	1581.9	4.3
NORTH BEND, OR — LATITUDE: 43 DEGREES 25 MINUTES														
LATITUDE -15:	2.03	2.89	3.90	5.03	5.79	6.04	6.57	6.03	5.24	3.85	2.57	1.91	1579.9	4.3
LATITUDE :	2.23	3.04	3.92	4.82	5.33	5.49	6.05	5.80	5.33	4.12	2.86	2.15	1557.5	4.3
LATITUDE +15:	2.31	3.04	3.75	4.39	4.68	4.74	5.28	5.28	5.12	4.16	3.00	2.27	1462.2	4.0
PENDLETON, OR — LATITUDE: 45 DEGREES 41 MINUTES														
LATITUDE -15:	1.62	2.57	3.95	5.07	6.02	6.52	7.54	6.91	6.00	4.18	2.23	1.49	1649.4	4.5
LATITUDE :	1.76	2.69	3.98	4.85	5.55	5.91	6.93	6.64	6.14	4.50	2.48	1.66	1618.1	4.4
LATITUDE +15:	1.81	2.68	3.81	4.41	4.86	5.08	6.03	6.05	5.93	4.56	2.59	1.74	1510.0	4.1
PORTLAND, OR — LATITUDE: 45 DEGREES 36 MINUTES														
LATITUDE -15:	1.59	2.25	3.31	4.37	5.18	5.37	6.38	5.70	4.68	3.16	1.88	1.46	1382.1	3.8
LATITUDE :	1.76	2.34	3.31	4.18	4.77	4.89	5.87	5.46	4.74	3.35	2.07	1.66	1353.9	3.7
LATITUDE +15:	1.84	2.31	3.16	3.80	4.19	4.23	5.13	4.97	4.55	3.37	2.15	1.77	1264.0	3.5
REDMOND, OR — LATITUDE: 44 DEGREES 16 MINUTES														
LATITUDE -15:	2.43	3.31	4.50	5.68	6.50	6.94	7.68	7.11	6.25	4.52	2.95	2.30	1833.4	5.0
LATITUDE :	2.70	3.50	4.55	5.45	5.98	6.28	7.05	6.84	6.39	4.88	3.31	2.62	1814.4	5.0
LATITUDE +15:	2.82	3.52	4.36	4.96	5.23	5.39	6.13	6.23	6.17	4.95	3.49	2.78	1706.8	5.7

AVERAGE DAILY INSOLATION IN ....

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
SALEM OR LATITUDE: 44 DEGREES 55 MINUTES														
LATITUDE -15:	1.68	2.39	3.50	4.58	5.42	5.61	6.72	6.04	5.14	3.34	1.98	1.53	1461.0	4.0
LATITUDE :	1.88	2.49	3.51	4.38	5.00	5.10	6.18	5.81	5.22	3.55	2.18	1.74	1434.1	3.9
LATITUDE +15:	1.97	2.47	3.36	3.99	4.39	4.41	5.40	5.29	5.03	3.58	2.26	1.86	1340.9	3.7
ALLENTOWN PA LATITUDE: 40 DEGREES 39 MINUTES														
LATITUDE -15:	2.33	3.01	3.86	4.63	5.07	5.38	5.47	5.10	4.49	3.79	2.57	2.00	1452.4	4.0
LATITUDE :	2.57	3.17	3.89	4.44	4.69	4.91	5.05	4.89	4.54	4.04	2.85	2.24	1439.4	3.9
LATITUDE +15:	2.67	3.17	3.72	4.05	4.14	4.27	4.44	4.46	4.36	4.07	2.98	2.36	1360.1	3.7
ERIE PA LATITUDE: 42 DEGREES 5 MINUTES														
LATITUDE -15:	1.59	2.20	3.28	4.48	5.10	5.58	5.69	4.82	4.41	3.43	1.81	1.34	1332.2	3.6
LATITUDE :	1.75	2.27	3.28	4.28	4.71	5.08	5.24	4.61	4.45	3.64	1.96	1.50	1303.8	3.6
LATITUDE +15:	1.82	2.24	3.12	3.90	4.14	4.40	4.60	4.20	4.26	3.66	2.02	1.59	1217.3	3.3
HARRISBURG PA LATITUDE: 40 DEGREES 13 MINUTES														
LATITUDE -15:	2.34	3.02	3.86	4.62	5.11	5.47	5.45	5.10	4.59	3.80	2.60	2.07	1462.7	4.0
LATITUDE :	2.58	3.18	3.89	4.43	4.73	4.99	5.04	4.89	4.63	4.05	2.88	2.32	1449.2	4.0
LATITUDE +15:	2.68	3.18	3.72	4.04	4.17	4.33	4.43	4.46	4.44	4.08	3.01	2.45	1369.0	3.8
PHILADELPHIA PA LATITUDE: 39 DEGREES 53 MINUTES														
LATITUDE -15:	2.42	3.11	3.95	4.69	5.14	5.49	5.45	5.18	4.62	3.87	2.78	2.17	1488.2	4.1
LATITUDE :	2.67	3.28	3.98	4.50	4.76	5.01	5.04	4.98	4.67	4.13	3.10	2.44	1478.5	4.1
LATITUDE +15:	2.78	3.28	3.82	4.11	4.20	4.35	4.43	4.54	4.49	4.17	3.24	2.59	1400.4	3.8
PITTSBURGH PA LATITUDE: 40 DEGREES 30 MINUTES														
LATITUDE -15:	1.75	2.36	3.32	4.30	4.96	5.34	5.23	4.97	4.36	3.63	2.20	1.68	1343.8	3.7
LATITUDE :	1.88	2.45	3.33	4.12	4.59	4.87	4.83	4.77	4.41	3.87	2.42	1.91	1323.1	3.6
LATITUDE +15:	1.92	2.42	3.17	3.76	4.05	4.23	4.25	4.35	4.22	3.89	2.51	2.03	1243.0	3.4
WILKES-BARRE-SCRAN PA LATITUDE: 41 DEGREES 20 MINUTES														
LATITUDE -15:	1.98	2.69	3.54	4.39	4.92	5.33	5.41	5.00	4.37	3.70	2.18	1.67	1376.0	3.8
LATITUDE :	2.16	2.82	3.55	4.20	4.55	4.86	4.99	4.79	4.41	3.94	2.40	1.84	1355.7	3.7
LATITUDE +15:	2.22	2.80	3.39	3.83	4.01	4.22	4.39	4.37	4.22	3.97	2.49	1.93	1274.1	3.5
KOROR ISLAND PN LATITUDE: 7 DEGREES 20 MINUTES														
LATITUDE -15:	4.14	4.72	5.04	5.36	5.05	4.72	4.65	4.70	4.73	4.56	4.29	3.93	1698.9	4.7
LATITUDE :	4.60	5.03	5.15	5.23	4.77	4.41	4.40	4.59	4.82	4.87	4.78	4.45	1736.1	4.8
LATITUDE +15:	4.84	5.10	5.00	4.85	4.27	3.91	3.95	4.27	4.68	4.95	5.04	4.75	1690.1	4.6

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
KWAJALEIN ISLAND PN — LATITUDE: 8 DEGREES 40 MINUTES														
LATITUDE −15:	4.69	5.32	5.57	5.50	5.23	5.20	5.16	5.34	5.01	4.64	4.35	4.28	1832.8	5.0
LATITUDE :	5.27	5.72	5.69	5.37	4.94	4.84	4.88	5.21	5.11	4.96	4.86	4.89	1876.2	5.1
LATITUDE +15:	5.58	5.82	5.53	4.97	4.41	4.27	4.36	4.82	4.96	5.04	5.13	5.26	1827.7	5.0
WAKE ISLAND PN — LATITUDE: 19 DEGREES 17 MINUTES														
LATITUDE −15:	4.45	5.11	5.79	6.16	6.41	6.37	6.02	5.90	5.56	5.11	4.75	4.36	2007.1	5.5
LATITUDE :	5.01	5.48	5.91	5.97	5.98	5.84	5.61	5.71	5.66	5.49	5.38	5.02	2039.2	5.6
LATITUDE +15:	5.30	5.56	5.72	5.48	5.26	5.06	4.96	5.25	5.47	5.58	5.71	5.41	1969.7	5.4
SAN JUAN PR — LATITUDE: 18 DEGREES 26 MINUTES														
LATITUDE −15:	4.33	4.96	5.69	5.95	5.68	5.67	5.86	5.80	5.33	4.89	4.47	4.05	1907.1	5.2
LATITUDE :	4.85	5.31	5.81	5.77	5.32	5.24	5.48	5.62	5.42	5.24	5.03	4.63	1938.3	5.3
LATITUDE +15:	5.12	5.38	5.63	5.31	4.72	4.58	4.85	5.17	5.24	5.32	5.33	4.97	1874.?	5.1
PROVIDENCE RI — LATITUDE: 41 DEGREES 44 MINUTES														
LATITUDE −15:	2.30	2.95	3.72	4.53	5.14	5.38	5.25	4.95	4.43	3.77	2.48	2.01	1428.2	3.9
LATITUDE :	2.53	3.10	3.74	4.34	4.75	4.90	4.85	4.75	4.47	4.02	2.76	2.26	1415.1	3.9
LATITUDE +15:	2.64	3.10	3.58	3.96	4.18	4.26	4.27	4.33	4.29	4.06	2.88	2.39	1337.0	3.7
CHARLESTON SC — LATITUDE: 32 DEGREES 54 MINUTES														
LATITUDE −15:	2.87	3.61	4.56	5.58	5.73	5.60	5.55	5.10	4.76	4.42	3.73	2.92	1656.9	4.5
LATITUDE :	3.17	3.82	4.62	5.38	5.33	5.14	5.15	4.91	4.82	4.73	4.19	3.31	1660.5	4.5
LATITUDE +15:	3.30	3.84	4.45	4.93	4.70	4.48	4.55	4.50	4.64	4.79	4.42	3.52	1585.6	4.3
COLUMBIA SC — LATITUDE: 33 DEGREES 57 MINUTES														
LATITUDE −15:	3.01	3.76	4.66	5.64	5.85	5.91	5.68	5.50	4.97	4.57	3.76	3.01	1714.5	4.7
LATITUDE :	3.34	3.99	4.72	5.44	5.42	5.41	5.27	5.30	5.04	4.91	4.23	3.43	1719.3	4.7
LATITUDE +15:	3.49	4.02	4.55	4.98	4.78	4.69	4.65	4.85	4.85	4.98	4.47	3.65	1642.0	4.5
GREENVILLE-SPARTANSC — LATITUDE: 34 DEGREES 54 MINUTES														
LATITUDE −15:	2.93	3.66	4.60	5.50	5.67	5.82	5.65	5.50	4.88	4.50	3.66	2.84	1680.4	4.6
LATITUDE :	3.25	3.88	4.66	5.30	5.26	5.32	5.24	5.30	4.94	4.83	4.11	3.22	1683.3	4.6
LATITUDE +15:	3.39	3.90	4.48	4.85	4.64	4.62	4.62	4.85	4.75	4.90	4.34	3.43	1606.1	4.4
HURON SD — LATITUDE: 44 DEGREES 23 MINUTES														
LATITUDE −15:	2.42	3.16	4.18	5.13	5.84	6.37	6.84	6.46	5.50	4.48	3.00	2.17	1692.0	4.6
LATITUDE :	2.70	3.34	4.22	4.91	5.38	5.78	6.29	6.20	5.60	4.83	3.37	2.06	1677.?	4.?
LATITUDE +15:	2.82	3.?5												

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
PIERRE	SD	LATITUDE:	44 DEGREES		23 MINUTES										
LATITUDE -15:		2.68	3.42	4.57	5.43	6.14	6.66	7.13	6.83	5.86	4.83	3.31	2.43	1806.6	4.9
LATITUDE :		3.00	3.63	4.63	5.21	5.65	6.03	6.56	6.57	5.98	5.22	3.74	2.78	1797.0	4.9
LATITUDE +15:		3.15	3.65	4.45	4.74	4.95	5.18	5.71	5.99	5.77	5.31	3.95	2.96	1699.3	4.7
RAPID CITY	SD	LATITUDE:	44 DEGREES		3 MINUTES										
LATITUDE -15:		2.73	3.55	4.65	5.33	5.88	6.46	6.95	6.70	5.92	4.85	3.43	2.63	1799.9	4.9
LATITUDE :		3.06	3.77	4.71	5.11	5.42	5.85	6.38	6.44	6.04	5.25	3.88	3.01	1794.2	4.9
LATITUDE +15:		3.20	3.79	4.52	4.65	4.75	5.03	5.56	5.86	5.83	5.34	4.10	3.21	1700.4	4.7
SIOUX FALLS	SD	LATITUDE:	43 DEGREES		34 MINUTES										
LATITUDE -15:		2.62	3.38	4.30	5.15	5.90	6.36	6.71	6.25	5.40	4.47	3.09	2.33	1704.4	4.7
LATITUDE :		2.92	3.59	4.34	4.94	5.44	5.77	6.18	6.00	5.49	4.82	3.48	2.65	1693.6	4.6
LATITUDE +15:		3.06	3.61	4.17	4.50	4.77	4.97	5.39	5.47	5.29	4.89	3.66	2.82	1601.3	4.4
CHATTANOOGA	TN	LATITUDE:	35 DEGREES		2 MINUTES										
LATITUDE -15:		2.48	3.16	4.04	5.01	5.33	5.56	5.34	5.27	4.63	4.21	3.16	2.41	1540.7	4.2
LATITUDE :		2.72	3.32	4.07	4.81	4.94	5.08	4.95	5.07	4.68	4.50	3.51	2.70	1533.0	4.2
LATITUDE +15:		2.81	3.31	3.90	4.40	4.36	4.42	4.37	4.63	4.49	4.54	3.68	2.85	1454.4	4.0
KNOXVILLE	TN	LATITUDE:	35 DEGREES		49 MINUTES										
LATITUDE -15:		2.48	3.21	4.12	5.19	5.56	5.77	5.56	5.41	4.84	4.31	3.15	2.40	1583.2	4.3
LATITUDE :		2.72	3.38	4.16	4.99	5.16	5.27	5.15	5.21	4.90	4.62	3.51	2.70	1576.1	4.3
LATITUDE +15:		2.82	3.38	4.00	4.57	4.55	4.58	4.54	4.76	4.71	4.67	3.68	2.86	1495.4	4.1
MEMPHIS	TN	LATITUDE:	35 DEGREES		3 MINUTES										
LATITUDE -15:		2.73	3.52	4.42	5.30	5.81	6.19	6.07	5.93	5.14	4.63	3.37	2.65	1697.8	4.7
LATITUDE :		3.01	3.71	4.46	5.10	5.38	5.64	5.62	5.71	5.21	4.97	3.76	2.99	1691.6	4.6
LATITUDE +15:		3.13	3.72	4.29	4.66	4.73	4.88	4.93	5.21	5.01	5.04	3.95	3.18	1605.3	4.4
NASHVILLE	TN	LATITUDE:	36 DEGREES		7 MINUTES										
LATITUDE -15:		2.30	3.06	3.91	5.01	5.62	5.94	5.83	5.66	4.91	4.32	2.95	2.18	1574.0	4.3
LATITUDE :		2.51	3.21	3.93	4.81	5.21	5.42	5.40	5.44	4.97	4.62	3.27	2.43	1559.6	4.3
LATITUDE +15:		2.59	3.20	3.77	4.40	4.59	4.69	4.74	4.97	4.77	4.67	3.42	2.55	1472.9	4.0
ABILENE	TX	LATITUDE:	32 DEGREES		26 MINUTES										
LATITUDE -15:		3.63	4.34	5.42	5.94	6.28	6.70	6.59	6.32	5.49	4.90	4.03	3.57	1923.9	5.3
LATITUDE :		4.06	4.63	5.51	5.72	5.82	6.10	6.09	6.09	5.58	5.27	4.54	4.10	1933.6	5.3
LATITUDE +15:		4.27	4.68	5.32	5.24	5.12	5.26	5.34	5.57	5.38	5.36	4.80	4.40	1848.2	5.1

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
AMARILLO TX — LATITUDE: 35 DEGREES 14 MINUTES														
LATITUDE -15:	4.09	4.80	5.76	6.59	6.82	7.23	7.03	6.87	6.26	5.53	4.47	3.93	2112.4	5.8
LATITUDE :	4.62	5.16	5.88	6.35	6.30	6.56	6.48	6.63	6.40	5.99	5.09	4.56	2130.9	5.8
LATITUDE +15:	4.89	5.23	5.68	5.80	5.51	5.63	5.66	6.05	6.18	6.12	5.42	4.93	2041.5	5.6
AUSTIN TX — LATITUDE: 30 DEGREES 18 MINUTES														
LATITUDE -15:	3.24	4.00	4.81	5.13	5.66	6.30	6.49	6.19	5.43	4.83	3.76	3.21	1797.6	4.9
LATITUDE :	3.58	4.25	4.87	4.95	5.26	5.75	6.01	5.98	5.52	5.18	4.20	3.64	1801.9	4.9
LATITUDE +15:	3.74	4.28	4.69	4.54	4.65	4.98	5.27	5.47	5.33	5.26	4.42	3.88	1719.6	4.7
BROWNSVILLE TX — LATITUDE: 25 DEGREES 54 MINUTES														
LATITUDE -15:	3.20	3.86	4.78	5.52	5.97	6.48	6.84	6.44	5.58	4.96	3.74	3.08	1841.3	5.0
LATITUDE :	3.54	4.09	4.85	5.34	5.56	5.93	6.34	6.23	5.68	5.34	4.17	3.47	1843.4	5.1
LATITUDE +15:	3.69	4.12	4.68	4.91	4.91	5.14	5.56	5.71	5.49	5.43	4.38	3.68	1756.7	4.8
CORPUS CHRISTI TX — LATITUDE: 27 DEGREES 46 MINUTES														
LATITUDE -15:	3.23	3.97	4.73	5.23	5.77	6.39	6.75	6.35	5.62	4.99	3.81	3.11	1825.4	5.0
LATITUDE :	3.57	4.21	4.80	5.05	5.37	5.84	6.25	6.14	5.72	5.37	4.26	3.51	1829.8	5.0
LATITUDE +15:	3.73	4.24	4.62	4.64	4.75	5.06	5.49	5.62	5.53	5.46	4.48	3.73	1746.0	4.8
DALLAS TX — LATITUDE: 32 DEGREES 51 MINUTES														
LATITUDE -15:	3.21	3.91	4.86	5.23	5.82	6.47	6.54	6.30	5.47	4.77	3.73	3.19	1812.3	5.0
LATITUDE :	3.57	4.15	4.93	5.04	5.41	5.91	6.05	6.08	5.56	5.13	4.19	3.64	1816.3	5.0
LATITUDE +15:	3.74	4.18	4.75	4.62	4.77	5.11	5.31	5.56	5.37	5.21	4.42	3.89	1732.7	4.7
DEL RIO TX — LATITUDE: 29 DEGREES 22 MINUTES														
LATITUDE -15:	3.57	4.27	5.30	5.43	5.64	6.16	6.34	6.20	5.32	4.87	3.99	3.47	1844.1	5.1
LATITUDE :	3.97	4.54	5.39	5.24	5.25	5.63	5.88	5.98	5.41	5.24	4.46	3.96	1855.9	5.1
LATITUDE +15:	4.17	4.58	5.21	4.80	4.64	4.88	5.17	5.48	5.22	5.32	4.73	4.23	1777.7	4.9
EL PASO TX — LATITUDE: 31 DEGREES 48 MINUTES														
LATITUDE -15:	4.49	5.51	6.62	7.65	8.02	8.12	7.56	7.39	6.89	6.20	5.06	4.30	2367.7	6.5
LATITUDE :	5.10	5.96	6.79	7.39	7.39	7.34	6.97	7.14	7.07	6.77	5.80	5.01	2395.1	6.6
LATITUDE +15:	5.42	6.08	6.59	6.75	6.43	6.26	6.08	6.52	6.86	6.94	6.20	5.43	2297.8	6.3
FORT WORTH TX — LATITUDE: 32 DEGREES 50 MINUTES														
LATITUDE -15:	3.13	3.90	4.82	5.20	5.83	6.53	6.65	6.41	5.59	4.84	3.74	3.13	1820.3	5.0
LATITUDE :	3.48	4.14	4.89	5.01	5.42	5.95	6.15	6.19	5.70	5.20	4.20	3.56	1823.3	5.0
LATITUDE +15:	3.64	4.17	4.71	4.50	4.78	5.15								

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
HOUSTON TX			LATITUDE: 29 DEGREES 59 MINUTES											
LATITUDE -15:	2.84	3.64	4.33	4.86	5.48	5.79	5.65	5.39	4.94	4.57	3.46	2.76	1635.1	4.5
LATITUDE :	3.11	3.85	4.38	4.69	5.11	5.31	5.25	5.21	5.01	4.90	3.85	3.10	1636.8	4.5
LATITUDE +15:	3.24	3.86	4.22	4.31	4.53	4.62	4.64	4.78	4.83	4.97	4.04	3.29	1561.7	4.3
KINGSVILLE TX			LATITUDE: 27 DEGREES 31 MINUTES											
LATITUDE -15:	3.29	4.02	4.75	5.28	5.77	6.22	6.51	6.12	5.39	4.88	3.76	3.12	1800.0	4.9
LATITUDE :	3.63	4.26	4.81	5.10	5.37	5.69	6.04	5.92	5.48	5.24	4.20	3.53	1804.6	4.9
LATITUDE +15:	3.80	4.29	4.64	4.69	4.75	4.94	5.31	5.42	5.29	5.32	4.42	3.75	1722.6	4.7
LAREDO TX			LATITUDE: 27 DEGREES 32 MINUTES											
LATITUDE -15:	3.46	4.15	5.02	5.49	6.03	6.33	6.58	6.41	5.67	4.94	3.79	3.28	1862.0	5.1
LATITUDE :	3.84	4.40	5.10	5.30	5.61	5.79	6.10	6.19	5.78	5.31	4.23	3.72	1868.4	5.1
LATITUDE +15:	4.02	4.44	4.92	4.87	4.95	5.02	5.36	5.67	5.58	5.40	4.45	3.96	1784.3	4.9
LUBBOCK TX			LATITUDE: 33 DEGREES 39 MINUTES											
LATITUDE -15:	4.25	5.04	6.18	7.04	7.40	7.69	7.44	7.19	6.39	5.65	4.68	4.05	2222.(	6.1
LATITUDE :	4.82	5.43	6.32	6.80	6.83	6.97	6.86	6.94	6.54	6.13	5.34	4.71	2242.0	6.1
LATITUDE +15:	5.11	5.52	6.11	6.21	5.96	5.97	5.98	6.34	6.33	6.27	5.70	5.09	2147.3	5.9
LUFKIN TX			LATITUDE: 31 DEGREES 14 MINUTES											
LATITUDE -15:	2.99	3.84	4.65	5.20	5.76	6.24	6.18	5.98	5.20	4.95	3.73	3.02	1758.3	4.8
LATITUDE :	3.30	4.06	4.71	5.01	5.35	5.70	5.73	5.77	5.28	5.33	4.17	3.42	1760.2	4.8
LATITUDE +15:	3.44	4.09	4.53	4.59	4.72	4.93	5.04	5.28	5.08	5.41	4.39	3.64	1678.1	4.6
MIDLAND-ODESSA TX			LATITUDE: 31 DEGREES 56 MINUTES											
LATITUDE -15:	4.30	5.12	6.36	7.08	7.50	7.76	7.36	7.15	6.37	5.71	4.75	4.17	2241.4	6.1
LATITUDE :	4.87	5.51	6.52	6.84	6.93	7.04	6.80	6.91	6.52	6.21	5.42	4.84	2264.1	6.2
LATITUDE +15:	5.16	5.61	6.32	6.26	6.05	6.02	5.94	6.31	6.31	6.36	5.78	5.24	2170.7	5.9
PORT ARTHUR TX			LATITUDE: 29 DEGREES 57 MINUTES											
LATITUDE -15:	2.95	3.78	4.53	5.14	5.78	6.13	5.70	5.56	5.14	4.75	3.58	2.87	1701.5	4.7
LATITUDE :	3.25	4.00	4.58	4.96	5.38	5.61	5.30	5.37	5.21	5.11	4.00	3.23	1704.2	4.7
LATITUDE +15:	3.38	4.02	4.42	4.56	4.75	4.87	4.69	4.92	5.03	5.19	4.20	3.43	1626.2	4.5
SAN ANGELO TX			LATITUDE: 31 DEGREES 22 MINUTES											
LATITUDE -15:	3.72	4.38	5.48	5.94	6.27	6.63	6.54	6.32	5.48	4.92	4.10	3.61	1929.2	5.3
LATITUDE :	4.16	4.67	5.58	5.73	5.81	6.04	6.05	6.10	5.57	5.29	4.62	4.14	1940.3	5.3
LATITUDE +15:	4.37	4.72	5.38	5.25	5.11	5.21	5.31	5.58	5.37	5.38	4.88	4.45	1856.2	5.1

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE / ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
SAN ANTONIO TX			LATITUDE:	29 DEGREES	32 MINUTES									
LATITUDE -15:	3.32	4.08	4.85	5.15	5.85	6.30	6.54	6.23	5.52	4.85	3.79	3.24	1818.1	5.0
LATITUDE :	3.68	4.33	4.92	4.96	5.44	5.75	6.06	6.01	5.61	5.21	4.24	3.68	1823.7	5.0
LATITUDE +15:	3.85	4.37	4.74	4.56	4.80	4.98	5.32	5.51	5.42	5.29	4.47	3.92	1741.4	4.8
SHERMAN TX			LATITUDE:	33 DEGREES	43 MINUTES									
LATITUDE -15:	3.15	3.82	4.69	5.19	5.71	6.42	6.41	6.26	5.48	4.80	3.73	3.09	1789.0	4.9
LATITUDE :	3.50	4.05	4.75	5.00	5.30	5.85	5.93	6.03	5.58	5.16	4.19	3.53	1792.4	4.9
LATITUDE +15:	3.66	4.08	4.57	4.58	4.68	5.06	5.20	5.52	5.38	5.25	4.43	3.76	1709.5	4.7
WACO TX			LATITUDE:	31 DEGREES	37 MINUTES									
LATITUDE -15:	3.18	3.95	4.84	5.17	5.48	6.41	6.56	6.31	5.47	4.78	3.72	3.20	1799.0	4.9
LATITUDE :	3.53	4.19	4.91	4.98	5.09	5.85	6.08	6.09	5.56	5.14	4.17	3.64	1803.3	4.9
LATITUDE +15:	3.69	4.22	4.73	4.57	4.50	5.06	5.33	5.57	5.37	5.22	4.39	3.89	1720.8	4.7
WICHITA FALLS TX			LATITUDE:	33 DEGREES	58 MINUTES									
LATITUDE -15:	3.47	4.18	5.10	5.70	6.22	6.73	6.68	6.39	5.57	4.91	3.93	3.39	1895.9	5.2
LATITUDE :	3.87	4.46	5.18	5.49	5.77	6.13	6.17	6.16	5.67	5.29	4.44	3.90	1903.8	5.2
LATITUDE +15:	4.07	4.50	5.00	5.03	5.07	5.29	5.41	5.63	5.48	5.39	4.70	4.18	1818.4	5.0
BRYCE CANYON UT			LATITUDE:	37 DEGREES	42 MINUTES									
LATITUDE -15:	4.14	4.97	6.13	7.05	7.60	8.03	7.51	7.14	7.09	6.10	4.74	3.98	2267.0	6.2
LATITUDE :	4.70	5.36	6.27	6.80	7.01	7.26	6.92	6.89	7.28	6.67	5.43	4.63	2288.9	6.3
LATITUDE +15:	4.99	5.45	6.07	6.21	6.11	6.20	6.03	6.29	7.06	6.84	5.80	5.02	2192.4	6.0
CEDAR CITY UT			LATITUDE:	37 DEGREES	42 MINUTES									
LATITUDE -15:	3.97	4.71	5.94	6.92	7.65	8.19	7.76	7.43	7.29	6.07	4.61	3.78	2262.1	6.2
LATITUDE :	4.50	5.06	6.07	6.67	7.05	7.39	7.14	7.17	7.50	6.63	5.27	4.38	2278.0	6.2
LATITUDE +15:	4.77	5.14	5.87	6.09	6.14	6.30	6.22	6.54	7.28	6.80	5.63	4.74	2176.3	6.0
SALT LAKE CITY UT			LATITUDE:	40 DEGREES	46 MINUTES									
LATITUDE -15:	2.96	4.07	5.40	6.32	7.36	7.76	8.08	7.61	7.05	5.64	3.86	2.84	2100.2	5.8
LATITUDE :	3.31	4.35	5.50	6.08	6.78	7.02	7.42	7.34	7.25	6.14	4.38	3.26	2096.1	5.7
LATITUDE +15:	3.48	4.39	5.31	5.55	5.92	6.00	6.45	6.69	7.03	6.29	4.65	3.48	1986.1	5.4
NORFOLK VA			LATITUDE:	36 DEGREES	54 MINUTES									
LATITUDE -15:	2.83	3.55	4.50	5.46	5.83	6.07	5.72	5.48	4.93	4.22	3.50	2.77	1669.8	4.6
LATITUDE :	3.14	3.76	4.55	5.26	5.40	5.53	5.30	5.27	5.00	4.52	3.94	3.15	1668.1	4.6
LATITUDE +15:	3.28	3.78	4.38	4.81	4.76	4.79	4.66					3.--		

SITE ARRAY TILT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	DAY (KWH/SQ. M)
RICHMOND VA														
LATITUDE: 37 DEGREES 30 MINUTES														
LATITUDE -15:	2.65	3.35	4.25	5.10	5.44	5.68	5.47	5.22	4.77	4.05	3.16	2.52	1572.6	4.3
LATITUDE :	2.93	3.54	4.29	4.90	5.04	5.18	5.07	5.01	4.83	4.32	3.53	2.85	1567.2	4.3
LATITUDE +15:	3.05	3.54	4.12	4.48	4.44	4.50	4.46	4.58	4.64	4.36	3.71	3.03	1488.6	4.1
ROANOKE VA														
LATITUDE: 37 DEGREES 19 MINUTES														
LATITUDE -15:	2.78	3.44	4.35	5.15	5.45	5.71	5.54	5.28	4.81	4.25	3.31	2.64	1604.6	4.4
LATITUDE :	3.08	3.64	4.39	4.95	5.05	5.21	5.13	5.08	4.86	4.55	3.71	2.99	1601.9	4.4
LATITUDE +15:	3.22	3.64	4.22	4.52	4.45	4.52	4.51	4.64	4.67	4.60	3.90	3.18	1523.8	4.2
BURLINGTON VT														
LATITUDE: 44 DEGREES 28 MINUTES														
LATITUDE -15:	1.78	2.46	3.45	4.30	4.89	5.24	5.36	4.94	4.21	3.17	1.71	1.54	1311.3	3.6
LATITUDE :	1.94	2.57	3.46	4.11	4.51	4.77	4.94	4.73	4.24	3.36	1.86	1.76	1286.8	3.5
LATITUDE +15:	2.00	2.55	3.30	3.74	3.97	4.13	4.33	4.30	4.06	3.37	1.92	1.87	1204.5	3.3
OLYMPIA WA														
LATITUDE: 46 DEGREES 58 MINUTES														
LATITUDE -15:	1.39	2.04	3.14	4.21	5.10	5.14	6.00	5.28	4.51	2.80	1.67	1.27	1297.0	3.6
LATITUDE :	1.54	2.11	3.14	4.02	4.70	4.67	5.52	5.06	4.56	2.96	1.83	1.44	1256.6	3.5
LATITUDE +15:	1.60	2.08	2.99	3.65	4.12	4.05	4.83	4.60	4.37	2.97	1.89	1.53	1179.3	3.2
SEATTLE-TACOMA WA														
LATITUDE: 47 DEGREES 27 MINUTES														
LATITUDE -15:	1.38	2.02	3.19	4.35	5.36	5.46	7.10	5.56	4.50	2.95	1.69	1.23	1366.3	3.7
LATITUDE :	1.52	2.10	3.19	4.16	4.93	4.96	6.51	5.32	4.55	3.13	1.86	1.39	1330.4	3.6
LATITUDE +15:	1.58	2.07	3.04	3.78	4.32	4.28	5.67	4.84	4.36	3.14	1.92	1.48	1234.3	3.4
SPOKANE WA														
LATITUDE: 47 DEGREES 38 MINUTES														
LATITUDE -15:	1.54	2.65	4.05	5.10	6.03	6.34	7.47	6.81	5.88	4.03	2.15	1.38	1628.7	4.5
LATITUDE :	1.68	2.80	4.09	4.88	5.55	5.74	6.86	6.55	6.01	4.33	2.39	1.54	1596.9	4.4
LATITUDE +15:	1.73	2.79	3.92	4.44	4.85	4.94	5.96	5.96	5.80	4.39	2.50	1.61	1489.2	4.1
WHIDBEY ISLAND WA														
LATITUDE: 48 DEGREES 21 MINUTES														
LATITUDE -15:	1.60	2.29	3.53	4.57	5.52	5.51	6.24	5.50	4.69	3.02	1.92	1.27	1392.0	3.8
LATITUDE :	1.79	2.40	3.55	4.36	5.07	5.00	5.73	5.27	4.75	3.21	2.13	1.41	1361.1	3.7
LATITUDE +15:	1.88	2.38	3.39	3.96	4.44	4.32	5.00	4.79	4.56	3.22	2.22	1.48	1267.9	3.5
YAKIMA WA														
LATITUDE: 46 DEGREES 34 MINUTES														
LATITUDE -15:	1.81	2.91	4.34	5.45	6.31	6.59	7.44	6.88	6.01	4.19	2.36	1.58	1702.5	4.7
LATITUDE :	1.98	3.07	4.39	5.22	5.80	5.96	6.83	6.61	6.14	4.51	2.63	1.78	1674.1	4.6
LATITUDE +15:	2.05	3.07	4.21	4.75	5.07	5.12	5.94	6.02	5.93	4.58	2.76	1.87	1565.2	4.3

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
EAU CLAIRE	WI	LATITUDE: 44 DEGREES 52 MINUTES													
LATITUDE -15:		2.23	3.20	4.10	4.77	5.24	5.67	5.89	5.48	4.54	3.63	2.23	1.76	1484.4	4.1
LATITUDE :		2.48	3.39	4.14	4.57	4.84	5.16	5.43	5.26	4.59	3.88	2.48	1.98	1466.5	4.0
LATITUDE +15:		2.58	3.40	3.97	4.16	4.25	4.46	4.75	4.79	4.41	3.91	2.58	2.09	1380.3	3.8
GREEN BAY	WI	LATITUDE: 44 DEGREES 29 MINUTES													
LATITUDE -15:		2.20	3.06	4.14	4.81	5.35	5.78	5.89	5.47	4.62	3.57	2.30	1.79	1491.8	4.1
LATITUDE :		2.43	3.24	4.18	4.60	4.94	5.25	5.42	5.25	4.67	3.81	2.55	2.02	1472.1	4.0
LATITUDE +15:		2.53	3.24	4.01	4.19	4.33	4.54	4.75	4.78	4.48	3.84	2.66	2.15	1384.0	3.8
LA CROSSE	WI	LATITUDE: 43 DEGREES 52 MINUTES													
LATITUDE -15:		2.32	3.22	4.10	4.75	5.33	5.78	5.93	5.62	4.68	3.73	2.42	1.87	1514.7	4.1
LATITUDE :		2.58	3.41	4.14	4.55	4.92	5.25	5.46	5.39	4.74	3.99	2.69	2.10	1498.5	4.1
LATITUDE +15:		2.69	3.42	3.96	4.15	4.33	4.54	4.79	4.91	4.55	4.02	2.81	2.22	1412.3	3.9
MADISON	WI	LATITUDE: 43 DEGREES 8 MINUTES													
LATITUDE -15:		2.48	3.37	4.21	4.64	5.41	5.90	6.01	5.73	4.89	3.92	2.42	1.94	1550.6	4.2
LATITUDE :		2.75	3.57	4.25	4.44	4.99	5.36	5.54	5.50	4.95	4.20	2.68	2.18	1534.5	4.2
LATITUDE +15:		2.87	3.58	4.07	4.04	4.38	4.63	4.85	5.01	4.75	4.24	2.80	2.30	1446.4	4.0
MILWAUKEE	WI	LATITUDE: 42 DEGREES 57 MINUTES													
LATITUDE -15:		2.24	3.01	4.01	4.79	5.50	5.99	6.11	5.77	4.92	3.88	2.52	1.85	1540.7	4.2
LATITUDE :		2.47	3.18	4.04	4.59	5.08	5.45	5.63	5.55	4.99	4.16	2.80	2.08	1522.9	4.2
LATITUDE +15:		2.57	3.18	3.87	4.18	4.46	4.71	4.94	5.06	4.80	4.20	2.93	2.19	1433.8	3.9
CHARLESTON	WV	LATITUDE: 38 DEGREES 22 MINUTES													
LATITUDE -15:		2.02	2.64	3.52	4.41	5.06	5.39	5.20	4.95	4.52	3.84	2.63	1.39	1402.6	3.8
LATITUDE :		2.20	2.75	3.53	4.23	4.69	4.92	4.81	4.75	4.56	4.09	2.91	2.10	1386.2	3.8
LATITUDE +15:		2.26	2.73	3.37	3.86	4.14	4.28	4.24	4.34	4.38	4.12	3.04	2.19	1307.2	3.6
HUNTINGTON	WV	LATITUDE: 38 DEGREES 22 MINUTES													
LATITUDE -15:		2.16	2.87	3.74	4.72	5.28	5.59	5.46	5.17	4.65	3.98	2.75	2.04	1474.5	4.0
LATITUDE :		2.36	3.00	3.76	4.53	4.89	5.10	5.05	4.96	4.70	4.24	3.05	2.28	1459.7	4.0
LATITUDE +15:		2.44	2.99	3.60	4.14	4.31	4.43	4.45	4.53	4.51	4.28	3.19	2.40	1378.1	3.8
CASPER	WY	LATITUDE: 42 DEGREES 55 MINUTES													
LATITUDE -15:		3.49	4.41	5.49	6.23	6.88	7.59	7.95	7.62	6.85	5.55	4.05	3.31	2114.3	5.8
LATITUDE :		3.95	4.74	5.60	5.99	6.34	6.86	7.30	7.36	7.04	6.04	4.63	3.84	2121.9	5.8
LATITUDE +15:		4.18	4.80	5.40	5.46	5.54	5.88	6.35	6.71	6.83	6.10	4.93	4.15	2021.?	5.?

AVERAGE DAILY INSOLATION BY MONTH (KWH/SQ. M)

SITE ARRAY TILT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL (KWH/SQ. M)	AVERAGE DAY (KWH/SQ. M)
CHEYENNE	WY	LATITUDE: 41 DEGREES 9 MINUTES													
LATITUDE -15:		3.77	4.50	5.34	5.90	6.19	6.83	6.93	6.60	6.33	5.44	4.15	3.58	1995.7	5.5
LATITUDE :		4.27	4.83	5.44	5.66	5.71	6.19	6.37	6.34	6.47	5.91	4.73	4.16	2011.4	5.5
LATITUDE +15:		4.52	4.90	5.24	5.16	5.00	5.32	5.56	5.78	6.26	6.03	5.03	4.49	1925.5	5.3
ROCK SPRINGS	WY	LATITUDE: 41 DEGREES 36 MINUTES													
LATITUDE -15:		3.63	4.65	5.78	6.53	7.31	7.80	7.96	7.60	7.10	5.83	4.24	3.50	2190.3	6.0
LATITUDE :		4.11	5.01	5.90	6.28	6.73	7.05	7.31	7.33	7.30	6.36	4.84	4.07	2200.7	6.0
LATITUDE +15:		4.35	5.08	5.70	5.73	5.87	6.03	6.35	6.69	7.08	6.52	5.16	4.39	2098.0	5.7
SHERIDAN	WY	LATITUDE: 44 DEGREES 46 MINUTES													
LATITUDE -15:		2.65	3.41	4.58	5.17	5.88	6.55	7.31	6.90	5.91	4.61	3.14	2.46	1784.6	4.9
LATITUDE :		2.96	3.62	4.64	4.95	5.42	5.94	6.72	6.64	6.04	4.98	3.54	2.82	1775.2	4.9
LATITUDE +15:		3.11	3.64	4.46	4.51	4.75	5.11	5.85	6.05	5.83	5.07	3.74	3.01	1678.9	4.6

ORIGINAL OF POOR