TM 00474A-12

COMMERCIAL MANUAL ADOPTED FOR U. S. MARINE CORPS USE

OPERATOR AND ORGANIZATIONAL MANUAL

FOR

FAMILY OF SOLAR PANELS
360W KIT PANELS

NSN 6117-01-715-8640

DISTRIBUTION STATEMENT D: Distribution authorized to Department of Defense and U.S. DoD contractors only for CTI use as determined 31 October 2024. Other requests for this document must be referred to Marine Corps Systems Command, Program Manager, Engineer Systems, 2200 Lester Street, Quantico, Virginia 22134-5050.

DESTRUCTION NOTICE: Destroy by making this publication unreadable, indecipherable, and unrecoverable IAW DoDI 5200.48.

OCTOBER 2024
PCN 500 900739 00

UNITED STATES MARINE CORPS
Marine Corps Systems Command
2200 Lester Street
Quantico, VA 22134-5050

31 October 2024

1. This Commercial Technical Manual, TM 00474A, adopted for Marine Corps use and effective upon receipt, provides information for the SOLAR CELL PANELS (360W KIT), NSN: 6117-01-715-8640, TAMCN B00122B, I.D. No 00474A

2. Per MCO 5100.34A, Commanders, Commanding Officers, and Officers-In-Charge shall identify and report situations that negatively affect the safety of operation via the Automated Message Handling System to: COMMARCORSYSCOM OOT QUANTICO VA, PEO LS QUANTICO VA, CMC PPO WASHINGTON DC, CMC I WASHINGTON DC, CMC L WASHINGTON DC, and CMC DCI WASHINGTON DC. Individuals may report potential hazards to MARCORSYSCOM Safety at MCSC_Safety@usmc.mil and/or to Commandant of the Marine Corps Safety Division (CMC SD) at hqmc_safety_division@usmc.mil.

All significant safety hazards that have the potential to affect other commands and require widespread dissemination shall be reported via a Hazard Report per MCO 5100.29C.

4. Recommendations for publication errors and/or requests for Logistics Product Data (LPD) and suggested technical data changes may be reported by submitting a Change Request in TDM-CATALYST. Users must have a registered account to submit a Change Request. For instructions on how to submit a Change Request go to https://app.mcboss.usmc.mil/suite/sites/support/page/knowledge-base/. Questions or concerns regarding the change request system process should be reported via Support Case within TDM-Publications or by email to catalyst_support@usmc.mil.

OFFICIAL

D.M. FITZGERALD
Product Manager,
Engineer Systems

Distribution: EDO

TABLE OF CONTENTS

List Of Illustrations

List of Appendices

List Of Tables

SECTION I. GENERAL INFORMATION

1. Scope

This Technical Manual (TM) contains information on the Solar Cell Panel, 360W Kit and instructions for operating and conducting Operator Maintenance. The 360 Watt (W) Solar Panel kit is a fully integrated renewable energy source that provides a portable, direct current power supply, and battery charging capability. The system comes with two 180 Solar Panels that connect to a NATO Y cable and are stored in a soft case for easy transport. The solar panels contain integrated power electronics that supply 28.8VDC through plug-and-play SAE connector which is connected to a NATO Y-Cable. The system can supply up to 360W of power for battery charging or continuous power support to electrical loads when adequate solar irradiance is available.

2. Preparation for Storage or Shipment

Preservation and other protective measures taken in the preparation of materiel and accompanying tools and equipment for shipment must be sufficient to protect the materiel against deterioration and physical damage during shipment. Prior to shipment:

a. Clean all surfaces completely.

b. Ensure all surfaces are completely dry.

The 360W Kit includes a zippered and reinforced tactical fabric bag design to store and carry all kit components. The 360W Kit can be stored and transported in the 360W Kit Bag. SBM Solar recommends that the 360W Kit be placed in an appropriate box or container for shipment to mitigate damage to the bag and other kit components.

3. Transportation

The 360W Kit can be transported via all modes of transport without restrictions.

4. Warranty

SBM Solar warrants the 360W Kit to be free from defects in materials and workmanship for a period of three (3) years from the date the product is delivered to the delivery destination specified on the Purchase Order (PO). This warranty does not cover defects or failure caused by improper handling, storage, maintenance, or repair or by any modification, improper connection, abuse, abnormal use or use not complying with this TM.

Warranty claims must be made to SBM Solar by way of a Request Order (RS) through Global Combat Support System – Marine Corps (GCSS-MC) after discovering the defect and within the 3-year warranty period or are forever waived.

SECTION II. HOW TO HANDLE THE SOLAR PANELS

1. To ensure the safety of the user, a lengthy service life and maintain serviceability of the system follow the guidelines below.

    - Handle the panels with care.
    - Use the panels during sunlight hours and put them away during storms.
    - Close and fold the panel when not in use.
    - Store the panel out of direct sunlight.
    - Try not to drop the solar panel on the ground; always place it down gently.
    - Always disconnect the solar panel from the cable before moving the panel.
    - Always fold the panel properly (with the strap securing it tightly) before storing it. Don't fold the panel loosely (without the strap secured) during storage or stowing. To use, disconnect the strap keeping the panel closed, unfold the panel, and by holding the camo webbing, gently lay out the panel in a sunny spot while avoiding shade.
    - Do not throw the panel because as it can hold up to drops, it will maintain a longer life if treated gently.
    - Do not carry the panel by the SAE connectors as doing so will also shorten its lifespan.
    - To put the panel away, disconnect the panel from the cable and pick up the panel by its webbing, allowing it to cool in shaded conditions for at least 5 minutes, before folding it.
    - To fold the panel, fold it length wise first and then diagonally together, while wrapping the Velcro strap around it and securing it on itself.
    - Do not stand, walk, or drop things on the panels. Doing so will cause breakage of solar cells and lower its power output.
    - The panel will maintain a longer life if kept out of standing water, heavy storms, and wet weather conditions for a long period of time.
    - To clean the panel, wash it with clean water, mild soap, and a soft rag at least once a week – not with chemicals, brushes, pressure washers, or anything else that could damage the panel's surface.

SECTION III. OPERATOR INSTRUCTIONS

WARNING

TO PREVENT A RISK OF ELECTRIC SHOCK, CONNECT THE NATO CABLE TO THE VEHICLE FIRST.

1. Connect the NATO end of the 15 Foot Y-cable to the vehicle or other battery source or device.

Figure 1-1. Vehicle Connection

WARNING

TO PREVENT A RISK OF ELECTRIC SHOCK, ALWAYS CONNECT THE SOLAR PANEL TO THE SYSTEM IN THE LAST STEP.

2. Layout the panels in a sunny place while avoiding shade and connect the SAE connectors of the Y-cable to the panels, one at a time.

CAUTION

DO NOT PLACE THE SOLAR PANELS ON TOP OF A HOT VEHICLE THIS MAY RESULT IN DAMAGE TO THE PANELS.

NOTE

Connecting both panels is optional, as the system will work with only one panel connected.

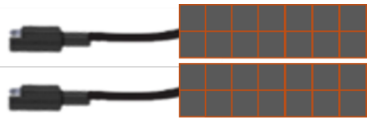


Figure 1-2. Panel Layout

3. If needed, connect the power meter in between one of the panels and the Y-cable to test the power output.

Figure 1-3. Power Meter Connection

4. To remove from use and stow follow the steps below.

WARNING

THE PANEL SURFACE CAN BE VERY HOT AND MIGHT CAUSE BURNS IF TOUCHED WITH BARE HANDS. IT IS ADVISED TO LET THE PANEL COOL DOWN FOR AT LEAST 10 MINUTES AFTER BEING REMOVED FROM DIRECT SUNLIGHT BY THE WEBBING EDGE OF THE PANEL BEFORE FOLDING FOR STORAGE. FAILURE TO OBSERVE THIS WARNING MAY RESULT IN PERSONAL INJURY.

WARNING

THE MPPT AREA, THE METAL PLATE WITH A LABEL AND CONNECTOR. CAN BE OVER 20-25^{0}C (68-74^{0}F) HOTTER THAN THE AMBIENT TEMPERATURE. FAILURE TO OBSERVE THIS WARNING MAY RESULT IN PERSONAL INJURY.

Figure 1-4. Maximum Power Point Tracking

a. Remove the solar panel from direct sunlight using the webbing edge. If not possible to remove the panel from direct sunlight fold the panel over onto itself to remove the solar cells from any sunlight.

b. Disconnect the SAE connector(s) from the Y-cable. Allow the panel to cool in shaded conditions for at least 5 minutes, before folding it.

WARNING

ALWAYS FOLD THE SOLAR PANEL WHEN NOT IN USE, EVEN INDOORS. AVOID ANY SUNLIGHT FALLING ON THE SURFACE OF THE SOLAR PANEL, WHETHER THAT BE THROUGH WINDOWS OR IN SHADED AREAS. THE SOLAR CELLS ARE VERY SENSITIVE AND CAN ABSORB SOLAR ENERGY THAT WILL CUMULATE INSIDE THE SOLAR PANEL. IF THE CONNECTORS ARE TOUCHED BY BARE HANDS ACCIDENTALLY, THE USER COULD GET SHOCKED.

c. To fold the panel, fold it length wise first and then diagonally together, while wrapping the Velcro strap around it and securing it on itself.

d. Disconnect the power meter from the Y-cable if used.

e. Disconnect the NATO plug from the vehicle or other battery source or device.

f. Store the solar panels, power meter and Y-cable in the storage case.

SECTION IV. MAXIMIZING SOLAR POWER

Solar Panel Orientation and Sunlight Angle

1. Since different locations result in different sunlight angles, different locations will generate different amounts of power. All locations and their optimal sunlight angles are listed in Appendixes A. To maximize the sunlight absorption at various areas, one must understand how to set up the solar panel properly at the designated locations and with the proper orientation. Due to the circumstances of deployment situations, the ideal conditions to set up solar panels are rarely met. Here is the simple way to set up a solar panel in the field:

    - If there is a slope that faces south, southwest, or southeast, place the panels on that slope. Table 1 shows ~30^0 degrees is the most common optimal sunlight angle for most of the locations.
    - If setting up the solar panel on an angle is not feasible, place it on a flat surface. There is no need to check on the orientation of panel if positioned horizontally. By our calculations, the solar panel might suffer a potential loss of around ~15% efficiency.

2. As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected. Therefore, those factors will reduce the efficiency of the panel's sunlight collection. This is called *diffuse solar radiation*. As a result of this, it will reduce overall solar panel efficiency in certain locations. These factors are part of natural phenomena and cannot be adjusted or optimized[1]:

    - Air molecules
    - Water vapor
    - Clouds
    - Dust
    - Pollutants

3. Solar panel performs in the field will be affected by other factors. Those factors can be adjusted or optimized to maximize solar panel power output in the field.

Weather. The solar panel will generate more power when the weather is clear without clouds.

- Sunny day: the best condition for panels since more solar power is generated.
- Cloudy day: will reduce the panel's efficiency by 10-25%, depending on cloud covers.
- Light rain day: the panel will still produce some solar power but at a reduced rate, possibly as little as 10%.

Season. The tilt's orientation with respect to space does not change during the year; thus, the Northern Hemisphere is tilted toward the sun in June and away from the sun in December. This means the sun's rays will hit the earth at different angles at different times of the year and thus, the collectable solar energy will change as well.

NOTE: Seasons are caused by the fact that the earth is tilted on its axis by 23.5°.

- Summer: The United States, which lies in the middle latitudes, receives more solar energy in the summer not only because days are longer, but also because the sun is nearly overhead.
- Winter: The sun's rays are far more slanted during the shorter days of the winter months. The sunlight irradiance is not as strong as during the summertime.

Time of the Day. In the early morning and late afternoon, the sun is low in the sky. Its rays travel further through the atmosphere to the earth's surface than at noon when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar energy collector around solar noon. Therefore, the strongest sunlight is at that time of day.

Location. The solar panel will generate power differently if the panel is in Hawaii or in Alaska. This is because the location affects the panel's sunlight angle difference. Please see Fig. 2 as it shows the sunlight irradiance difference from one state to another. In general, the sunlight is stronger in the southwest region, and weaker in the northwest region. Therefore, the solar panel will perform better in a region with strong sunlight irradiance.

NOTE: For example, if you use a solar panel in Quantico, VA, you should expect to receive less solar power than if you are using the same solar panel at Camp Pendleton, CA[3].

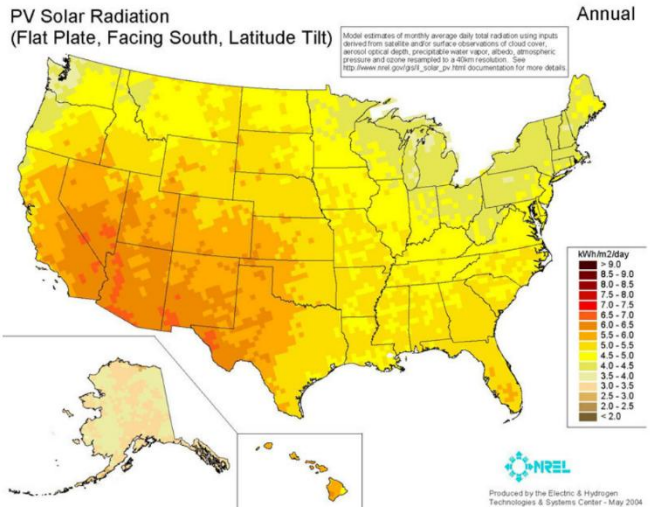


Figure. 4-1: Solar Irradiance Map in US[3]

Altitude. Solar irradiance increases along with altitude in the atmosphere, due to decreasing amounts of air molecules, ozone layers, aerosols and clouds above the relevant surface. This means the solar panel will perform better and produce more power at higher altitudes.

NOTE: For example, a solar panel on top of a mountain in Honolulu can receive more solar power a day than a panel at typical sea level.

Solar Panel Orientation and Sunlight Angle. Since different locations result in different sunlight angles, different locations will generate different amounts of power. All locations and their optimal sunlight angles are listed in Appendixes A. To maximize the sunlight absorption at various areas, one must understand how to set up the solar panel properly at the designated locations and with the proper orientation. Due to the circumstances of deployment situations, the idea conditions to set up solar panels are rarely met. Here is the simple way to set up a solar panel in the field:

- If there is a slope that faces south, southwest, or southeast, place the panels on that slope. Table 1 shows ~30^0 degrees is the most common optimal sunlight angle for most of the locations.
- If setting up the solar panel on an angle is not feasible, place it on a flat surface. There is no need to check on the orientation of panel if positioned horizontally. According to our calculations, the solar panel might suffer a potential loss of around ~15% efficiency.

Table 4-1. Examples of Optimal Sunlight Angles in Various Locations

Location	Year around (^{0})
Camp Pendleton, CA	33
Camp Lejeune, NC	34
Camp Kinser Okinawa, JP	26
Kaneohe, HI	21
Quantico, VA	39

SECTION V. EXPECTED COLLECTION PER DAY?

1. In general, in the optimal environment, the solar panel performs at about 75% (efficiency) of its power rating.

NOTE: For example, on a perfect sunny day, with the solar panel laying true south for 4 hours, a 360W panel will generate 1080W (360W x 75% x 4 hours = 1080W). This assumes the solar panel is in a fixed position. Several other factors will also affect panel power output in the field. Those factors can be manipulated or adjusted to optimize solar panel performance. They are:

- Temperature
- Battery capacity
- Local landscape

2. In Appendix A below for the nine locations, where the Marines' bases are, their projected daily solar power collections in kilowatts separated by month are listed. The kilowatts are based on the solar panel lying flat on the ground, without an elevated angle or other negative factors. Solar panel power output depends on several specific factors so those tables provide some guidance on how many watts the panels will generate at each location.

Temperature. SBM's solar panels' power output rate depends on the temperature of the panel and its surrounding area. All rated SBM solar panels are measured at Standard Test Conditions (STC). STC is solar irradiance of 1,000 Watts per square (1000W/m^2), 25^{o}C cell temperature, air mass equal to 1.5, and measured on the ASTM G173-03 standard spectrum. The reality is that when the solar panel performs in the field, the condition is far from STC. Every degree Celsius that the solar panel temperature goes up, its output loses 0.27% of its power. Therefore, the power output is normally lower than what the panel is labeled as. In Appendix B, "Solar Panel Temperature Coefficient," briefly lists how temperature affects the solar panel's efficiency.

- The temperature of the solar panel surface is typically 20-25^{0}C (68-74^0 F) higher than the ambient temperature.
- For example, if the weather is 40^{0}C (104^0 F) in the field, the panel surface can go as high as 60-65^{0}C (140-149^0 F). (See Appendix B)
- It is the same with the MPPT area, the metal plate with a label and connector. It will be over 20-25^{0}C (68-74^0 F) more than the ambient temperature.

- Since the solar panel surface is made with polymer material, it can lose heat quickly with little air flow. Any breeze or light wind will reduce the surface temperature of the panel fast. Therefore, the panel will perform better in an open space where air flow is present.
- To reduce the panel heat in the field, it is advised to have the panel placed at a slightly elevated position. It allows the panel temperature to cool more efficiently.
  For example, place the panel in a position with a six" space underneath to allow more air flow.
- It is also advised to have the panel NOT placed on cement, driveways, airstrips, asphalt roads, or any other ground surfaces that have a high "heat reflection" effect.

Battery Capacity. Depending on the type of batteries, the most common issue for solar charging is that when the battery is almost full (around 80%), the solar panel charge rate becomes slower. As shown in Appendix A, SBM lists projected solar insolation wattages that the 90W and 180W panels should receive on average daily in each month for each location. If the battery is almost full, and the power meter is used to check the power output of the solar panel, you will find that actual wattage flowing from the solar panel is much less than the projected ones, i.e. 20W. This is because the battery is nearly full, so the charging mode has changed.

Local Landscape. It is a known fact in the solar industry that a solar panel surrounded with a reflective environment, such as snow or a large body of water for example, has a slightly higher efficiency than one on dark or black ground. The sunlight reflection from the surrounding area increases the irradiance absorption. Therefore, the panel would perform slightly better if it were placed near a lake or ocean or surrounded by shiny metal objects.

SECTION VI. PREVENTATIVE MAINTENANCE

There are no moving components inside the solar panel. You only need to check for wear around the junction box and connectors, rivet tightness, and surface. Holes indicate water leakage; in which case the panel needs to be replaced.

Table 6-1. Preventative Maintenance PMCS

Item	Before	During	After	Items To Be Inspected	Procedures	Comments
1	X			Case	1. Check for damaged bag. Ensure the bag is not torn or ripped and the zipper is fully functionable. Check if the IUID label is intact.	
2	X			Cord	1. Check if the cord is dry rotted, frayed or cut.	
3	X			Y Cable	1. Check for exposed wiring, split, cut or damaged insulation 2. Check all connections. Ensure all pins and NATO connectors are serviceable. 3. Check solar leads for corrosion or damage connections.	
4	X			Meter	1. Check for cracks and damage. 2.Check seals, dry rotted or missing	
5	X			Panel	1. Check for rips and tears. 2. Check for cracks in the panels. 3.Check connections for corrosion and damage.	

Table 6-1. Preventative Maintenance PMCS (continued)

Item	Before	During	After	Items To Be Inspected	Procedures	Comments
6		X		Meter	1. Check and monitor the meter for proper readings and function. 2.Check for proper connection.	6
7		X		Panel	1. Check the panel to ensure it is free and clear of obstructions and dirt. 2.Check the rope. Ensure it is tight and secure.	
8			X	Case	1. Check for damaged bag. Ensure bag is not torn or ripped and the zipper is fully functionable. 2. Clean inside and out with a cloth soaked in a mild detergent solution. Dry surface with a clean cloth.	
9			X	Y Cable	1. Check for exposed wiring, split, cut or damaged insulation 2. Check all connections. Ensure all pins are serviceable. 3. Check solar leads for corrosion or damage connections.	
10			X	Panel	1. Clean with a cloth soaked in a mild detergent solution. 2. Dry surface with a clean cloth.	

Table 6-1. Preventative Maintenance PMCS (continued)

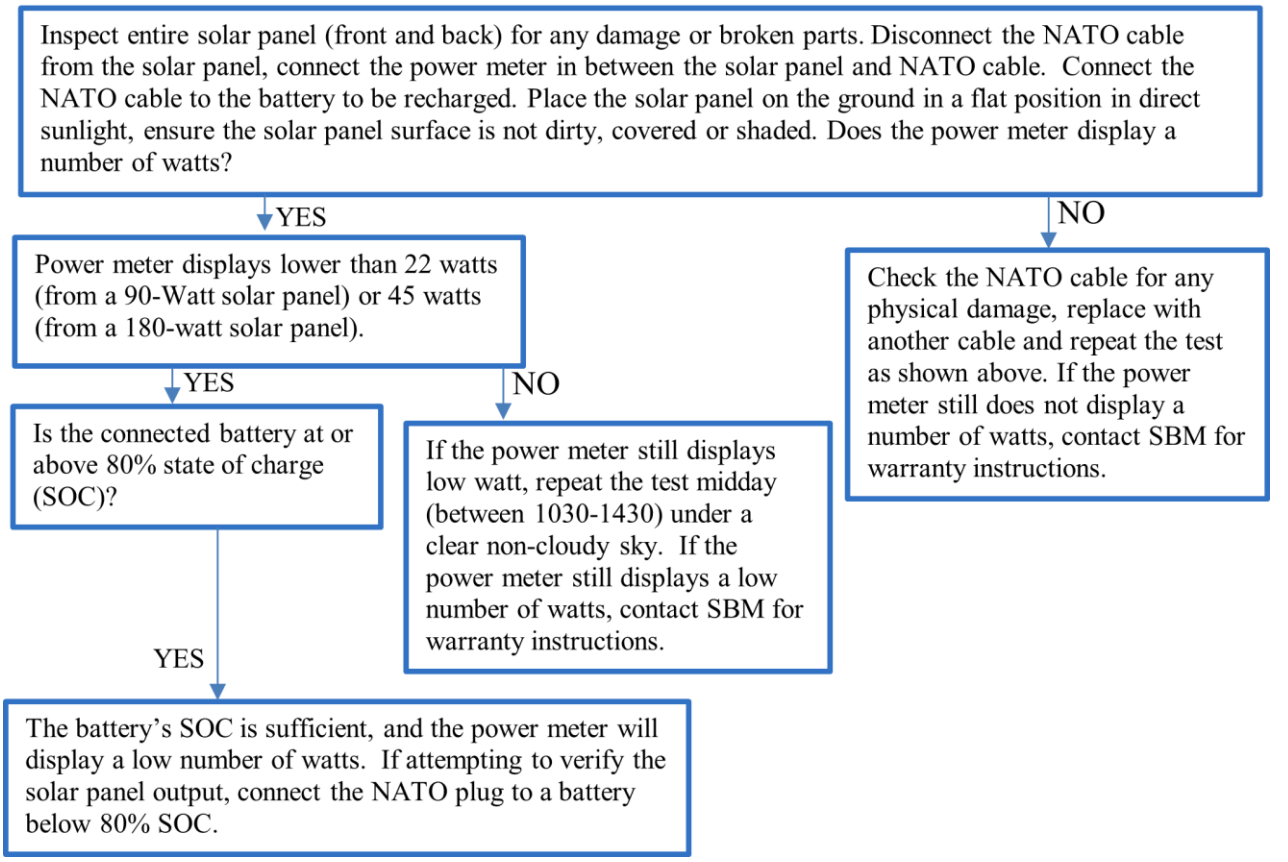
Item	Before	During	After	Items To Be Inspected	Procedures	Comments
11			X	Meter	1. Check for cracks and damage. **2.** Check seals, dry rotted or missing. **3.** 3 Clean with a cloth soaked in a mild detergent solution. Dry surface with a clean cloth.	
12			X	Cord	1. Check if the cord is dry rotted, frayed or cut. 2. Clean with a cloth soaked in a mild detergent solution. 3. Dry surface with a clean cloth.	

SECTION VII. TROUBLESHOOTING

SBM Solar Panel Trouble Shooting Chart

WARNING
Failure to use caution while performing the following procedures may result in electrical shock and injury.

Standard Testing Condition: Place the solar panel on the ground in a flat position during a clear day with full sunlight and no shading between 1030 and 1400. The solar panel must connect with a SOC less than 80%. If the power meter indicates the wattage is less than 25% of its listed output (i.e. 90W or 180W), the panel is no longer working properly.



What happens if one or more of the panel sections are damaged?

Both the 360W panels have fourteen sections with a bypass diode in each of them. If one section does not work from damage or shading, the remaining sections should still produce power.

Ref:

1. https://www.energy.gov/eere/solar/solar-radiation-basics
2. https://gml.noaa.gov/grad/solcalc/
3. https://www.nrel.gov/docs/fy24osti/87524.pdf
4. https://clouglobal.com/higher-ground-the-efficiency-of-solar-power-at-high-altitudes/

APPENDIX A

Solar Power Efficiency by Location

The electricity generated by the solar panel each day varies depending on the seasons as well as the location. The estimation of solar radiation per month for different locations is based on the data from the program of National Renewable Energy Laboratory (NREL). The following calculations are based on this data (ref) data in two steps processes. The first step is to obtain the solar insolation at various locations (kWh/m2/day, [Ref]) from PVWatts Calculator (nrel.gov). The second step is to insert the [Ref] value along with several other factors into the following EQUATION.

- Apply kWh/m2[Ref]
- 360W panel (2 x 180W)
- 3 hours full sunlight per day as projected. (It can be used for 6 – 8 hours in some locations during the summer.)
- 25% of power was lost from the field condition and the DC conversion from the solar panel to the battery via MPPT system.

Equation: kWh/m2/day [Ref] x 360W x 3 hours/day x 0.75% (efficiency) = kWh/day

Tables A-1 –A- 9 lists the estimated solar power performance (kWh) per day at nine locations in different months. For example, at Pendleton CA location, 360W solar panels will generate approximately 2.58 kW/day in the month of January, but 5.69kW/day solar power in the month of July. It assumes the solar panels are laying on the flat ground without any shade under clear sunny conditions.

Table A-1. Projected kWh per day at Pendleton, CA.

Pendleton, CA	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.58	3.10	4.20	4.91	4.97	5.55
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	5.69	5.43	4.58	3.61	2.79	2.37

Table A-2. Projected kWh per day at 29Palms, CA.

29 Palms, CA	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.83	3.69	4.90	5.99	6.80	7.10
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	6.28	5.84	5.23	4.21	3.09	2.64

Table A-3. Projected kWh/day at Yuma, AZ

Yuma, AZ	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.84	3.72	4.83	5.90	6.58	6.81
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	6.27	5.76	5.14	4.18	3.15	2.56

Table A-4. Projected kWh/day at Kaneohe, Hawaii.

Kaneohe, Hawaii	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.66	2.98	3.22	3.48	3.80	4.33
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	4.48	3.99	3.94	3.18	2.62	2.57

Table A-5. Projected kWh/day at Dededo, Guam.

Dededo, Guam	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	4.38	4.65	5.33	5.83	5.73	5.39
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	4.86	4.04	4.05	3.65	4.11	3.95

Table A-6. Projected kWh/day at Okinawa, Japan.

Okinawa, Japan	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	1.90	2.43	3.17	3.65	4.16	4.63
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	5.09	4.58	4.20	3.19	2.16	1.67

Table A-7. Projected kWh/day at Camp Lejeune, NC.

Camp LeJeune, NC	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.24	2.80	3.66	4.61	5.27	5.65
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	5.32	4.58	3.78	3.08	2.40	2.08

Table A-8. Projected kWh/day at Albany, GA.

Albany, GA	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	2.56	2.99	4.23	4.81	5.57	5.23
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	5.22	4.76	4.09	3.46	2.73	1.97

Table A-9. Projected kWh/day at Quantico, VA.

Quantico, VA	Jan	Feb	Mar	April	May	June
360W (2 x 180W)/kWh	1.90	2.53	3.21	4.23	4.62	5.29
	July	Aug	Sep	Oct	Nov	Dec
360W (2 x 180W)/kWh	5.27	4.66	3.68	2.75	1.96	1.56

Ref: http://www.solarelectricityhandbook.com/solar-irradiance.html

Appendix B

Solar Panel Temperature Coefficient

The solar panel power output decreases as the temperature increases. Below is data based on specifications from the solar cell manufacturer:

Table B-1. Temperature co-efficiency

Condition	^{0}F	^{0}C	Power Output (W)	
At STC	77	25	90W	180W
If the field temperature is	113	45	89	179
	115	46	89	179
	117	47	88	178
	118	48	88	178
	120	49	88	178
	122	50	88	178
	124	51	88	178
	126	52	88	178
	127	53	88	178
	129	54	88	178
	131	55	88	178
	133	56	88	178
	135	57	88	178
	136	58	88	178
	138	59	88	178
	140	60	88	178
	142	61	88	178
	144	62	87	177
	145	63	87	177
	147	64	87	177
Then the surface of panel is in this temperature range	149	65	87	177
	151	66	87	177
	153	67	87	177
	154	68	87	177
	156	69	87	177
	158	70	87	177

The chart shows two things:

1. When the panel temperature goes up, the panel's power output efficiency goes down. For example, when the panel is at 158ºF, the power output is 87W instead of 90W (-3W).
2. The surface of the solar panel on a sunny day will be 20-25ºC (68-74 ^{0} F) degrees higher than the ambient temperature.

Appendix C

8000 Poplar Tent Road, Suite C
Concord, NC 28027
www.sbmsolar.com
704-788-2881 Phone
704-793-1909 Fax

May 22, 2024

RE: Copyright Release

To Whom It May Concern:

SBM Solar Inc., the copyright holder of the SBM Solar Panel Technical and Training Manual and Quick Reference Card, hereby grants the right of possession and distribution of the previously mentioned materials to the United States Marine Corps, with no limitations to their reproduction.

If there are any questions about these terms, please contact me to sort them out.
Thank you for your time.

Sincerely,

SBM SOLAR INC

Osbert H. Cheung, Ph.D.
President
OHC:zd

Appendix D
List of Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
C	Celsius
F	Fahrenheit
kWh	kilowatt-hour
MPPT	Maximum Power Point Tracking
NATO	North Atlantic Treaty Organization
NREL	National Renewable Energy Laboratory
PV	photovoltaic
PV Watts	Application for estimating the energy production of a grid-connected photovoltaic (PV) system
SAE	Society of Automotive Engineers
STC	Standard Test Conditions
W	Watts
^{0}	Degrees
~	Approximate
VDC	Volts, Direct Current