VeraSol

Technical Notes

Estimating the Available Daily Electrical Energy for Solar Energy Kits in a Product Family

ISSUE NO. 34
APRIL 2021

THIS DOCUMENT SUMMARIZES THE CALCULATIONS PERFORMED TO ESTIMATE THE AVAILABLE DAILY ELECTRICAL ENERGY FOR SOLAR ENERGY KITS THAT HAVE NOT BEEN FULLY TESTED BUT ARE INCLUDED IN A PRODUCT FAMILY. THESE CALCULATIONS ARE CARRIED OUT USING VERASOL'S **WH/DAY ESTIMATOR TOOL**.

SUMMARY

The available daily electrical energy is a metric calculated for all fully tested, VeraSol-certified solar energy kits. This metric is expressed as watt-hours per day (Wh/day) and describes the daily energy service available to a user from a given solar energy kit after a day of solar charging. Previously determined only for fully tested kits using the energy service calculations found in IEC TS 62257-9-5:2018, the available daily electrical energy may now be estimated for any solar energy kit in a VeraSol certified family using VeraSol's Wh/day Estimator Tool.

The availability of the Wh/day metric for all kits provides more flexibility and opportunity to solar energy kit manufacturers, program implementers, and other stakeholders when comparing products and assessing performance. The availability of the Wh/day metric may specifically unlock many opportunities for kits in VeraSol product families such as allowing program eligibility and/or tier level of energy service within the Multi-tier Framework to be assessed. Finally, this service provides the VeraSol program the opportunity for data analysis of partially tested kits. The Wh/day Estimator Tool delivers a standard metric that may be used to compare all solar energy kits certified through the VeraSol program.

The inputs used for the Wh/day Estimator derive from rated, referenced, and calculated values drawn from VeraSol test reports. The necessary inputs for the Wh/day Estimator Tool include battery capacity, PV power, battery efficiency, solar operation efficiency, battery-charging circuit efficiency, lighting full-battery run time energy removed, and port efficiency. These metrics and explanations of their derivations are described in this tech note. Note that the Wh/day Estimator Tool is *not* interchangeable with the energy service calculations method; the Wh/day Estimator Tool is *not* defined in IEC 62257-9-5:2018.

AVAILABLE DAILY ELECTRICAL ENERGY (WH/DAY) METRIC

The available daily electrical energy is a metric defined in IEC TS 62257-9-5:2018, Annex GG, to estimate the daily energy service available from a solar energy kit. This metric can be used by development programs or government entities to compare solar products to others, for example to determine eligibility for program participation or the tier level of energy service accessible. VeraSol provides this Information in product Specification Sheets (SSS's) and Specification Books (spec books) as a standardized tool for comparing products. The Wh/day metric is valuable for manufacturers, consumers, investors, and development programs because it provides a tool for comparing products and evaluating how a product might meet each stakeholder's needs.

The available daily electrical energy from a solar energy kit is calculated using the energy service calculations (ESC) found in IEC TS 62257-9-5:2018, Annex GG if the kit was fully tested. This calculation uses measured results from product testing, as well as a number of standardized assumptions about operating conditions and user behavior, as inputs for a series of calculations to determine the Wh/day. The VeraSol Standardized Specifications Sheet (SSS) for VeraSol-certified kits fully tested to IEC TS 62257-9-5:2018 includes the Wh/day metric. VeraSol-certified kits are listed in the VeraSol product database.

VERASOL PRODUCT FAMILIES AND FULLY TESTED KITS

As stipulated in VeraSol's Framework for Testing Product Component Families policy, families of products are certified by fully testing at least one solar energy kit in the family, and at least half of the additional components in the family, which must include the smallest and largest of each component type (a "component" here refers to the control units, PV modules, lights, and appliances included in a family). Component-level testing includes all tests except for system-level tests. System level tests (for fully tested kits) include the full-battery run time test, standby loss test, and the solar charge test. All VeraSol-certified solar energy kits that are fully tested have had Wh/day calculated using the ESC method. Kits that include tested components can be included in the product family even if they are only partially tested.

For the kits included in families of products that are only partially tested, the available daily electrical energy (Wh/day) metric cannot be calculated using the ESC method. The Wh/day Estimator Tool was developed to determine the Wh/day metric for any solar energy kit in a family, even for kits that have not been fully tested at system-level. This tool allows for inputs including rated, referenced, or calculated values, as an alternate pathway to performing the complete energy service calculations.

Using the Wh/day Estimator Tool, the calculated Wh/day for kits that have not been fully tested can be reported in VeraSol spec books and published to the VeraSol product database. After January 1, 2021, manufacturers may request Wh/day estimates for partially tested kits in their product families for a fee. Formulas and calculation assumptions used in the tool may be found in Appendices A and B, respectively; whereas, Appendix C provides pages of an example spec book with more description of product families.

Note that the Wh/day Estimator Tool is not interchangeable or directly comparable with the IEC TS 62257-9-5:2018 ESC method for fully tested kits. The tool does not produce accredited test results in compliance with the Lighting Global Quality Standards or IEC TS 62257-9-8:2020, and these results will not be listed in a VeraSol test report. The VeraSol program accepts the Wh/day Estimator Tool Wh/day metric results, however, for

partially tested kits in families for purposes of listing in published spec books and for data analysis.

TABLE 1. ESC TEST METHOD VERSUS WH/DAY ESTIMATOR TOOL METHOD

Energy Service Calculations (ESC)	Wh/day Estimator Tool
A test method defined in IEC 62257-9-5:2018 and reported in a product's VeraSol test report	Not defined in IEC 62257-9-5:2018; not an accredited test result; not reported in a product's VeraSol test report
Uses measurements from the test lab using IEC 62257-9-5:2018 tests to calculate the Wh/day	Uses either measured values from IEC 62257-9-5:2018 tests, rated, referenced, or calculated values as inputs to calculate the Wh/day
Can only be used for fully tested products	Can be used for partially tested kits in families of products
Historically, has been the only way of determining Wh/day for solar energy kits	Was developed and put into use through the VeraSol program January 1, 2021.
Reported on VeraSol SSS's and in spec books for the fully tested kit	Reported in family spec books for partially tested kits

ESTIMATING AVAILABLE DAILY ELECTRICAL ENERGY (WH/DAY)

For products in a VeraSol certified family, the Wh/day metric can be estimated using data from the test report(s) for kits and components in the family. Estimating the Wh/day metric additionally requires incorporating assumptions regarding system efficiencies, power consumption, and user behavior, parallel to the assumptions in the energy service calculations. Assumptions incorporated in the tool calculations are listed in Appendix B. Because the calculations in the Wh/day Estimator Tool are based on multiple assumptions, there will be some degree of variation from the values that would be calculated if the ESC method was used to evaluate a product using measured values for inputs.

THE WH/DAY ESTIMATOR TOOL USES A COMBINATION OF MEASURED VALUES FROM VERASOL TEST REPORTS, RATED VALUES FOR COMPONENTS, AND SEVERAL ASSUMPTIONS, AS OUTLINED IN TABLE 2.

TABLE 2. WH/DAY ESTIMATOR TOOL INPUTS

Metric	Value Source
Battery capacity (Ah)	Measured or rated value
PV power (W)	Measured or rated value. If measured value is not available; the rating is used and PV Power at TMOT is calculated using referenced results
Battery efficiency (%)	Measured or average of measured values for kits in the family
Solar operation efficiency (%)	Measured or referenced average of measured values for kits in the family with same battery voltage. If there are not any fully tested kits with the same battery voltage in the family, then reference the measurements from the fully tested kit in the family.
Battery-charging circuit efficiency (%)	Measured or referenced average of measured values for kits in the family with same battery voltage. If there are not any fully tested kits with the same battery voltage in the family, then reference the measurements from the fully tested kit in the family.
Lighting full-battery run time energy removed (Wh)	Measured or calculated
Port efficiency	Average of measured values

Additionally, there are two calculations that are done in the tool using these inputs to calculate (1) the energy service from the PV module and (2) the battery Wh limit. These metrics are then compared in the tool to assess which is the Wh/day "limiting factor". For instance, if a PV module is undersized for a kit and does not completely charge the kit's battery in a solar day of charging, then amount of energy delivered by the PV module would limit the total amount of energy available for the kit. On the other hand, if the PV module is oversized for the kit, then the amount of energy able to be stored by and used from the battery would limit the total amount of usable energy, which is called the battery Wh limit. See Appendix A.1 and A.4 for definitions and how each is calculated.

BATTERY CAPACITY

The battery capacity metric describes the amount of electric charge the battery can deliver, expressed in ampere hours (Ah).

The rated value for the battery capacity will be used as an input for the tool if the battery included in the kit was not tested. Otherwise, the measured value for battery capacity will be used. This value will be taken from the VeraSol Specification Book.

PV POWER

PV power represents the maximum power output in watts either measured or rated for a PV module.

The efficiency of a PV module depends on temperature. PV power is reported in the VeraSol test report both at Standard Test Conditions (STC), defined as a PV module temperature of 25 °C and solar irradiance of 1000 W/m^2, and Typical Module Operating Temperature (TMOT) conditions, defined as a module temperature of 50 °C and irradiance of 1000 W/m^2, which more closely approximates the expected operating conditions. The tool calculates TMOT PV power for PV modules that have not been tested from the module's rated PV power at STC and the measured temperature coefficient (Appendix A.2).

BATTERY EFFICIENCY

When a battery is discharged, there are energy losses associated with releasing energy such that the amount of energy available for use is less than the amount of energy delivered to the battery during charging. The ratio between stored energy and released energy is described as the battery efficiency.

The battery efficiencies for both fully tested kits and batteries tested as components are calculated during testing. If a kit in a product family includes an untested battery, then an average of the battery efficiencies of tested batteries in the same family will be used as the input to the tool.

SOLAR OPERATION EFFICIENCY

The solar operation efficiency is a measure of a product's ability to regulate and optimize the collection of energy from the PV module during a typical solar day. To calculate this efficiency, the total amount of PV energy measured at the product's PV input is divided by the maximum available energy throughout a solar day, that is, the energy that would be obtained if the PV module operated continuously at its maximum power point. (See Appendix B.)

If a kit has not been fully tested, then an average of solar operation efficiencies from fully tested kits in the same family with the same battery voltage is used as an input to the tool. If there aren't fully tested kits with the same battery voltage, then reference the solar operation efficiency from the fully tested kit in the family.

BATTERY-CHARGING CIRCUIT EFFICIENCY

The battery-charging circuit efficiency is calculated by dividing the total PV energy that enters the product by the total energy delivered to the battery during a solar day. This efficiency accounts for losses in the product's wiring, connectors, and other electronics, as well as the energy consumed by the product itself during charging.

If a kit has not been fully tested, then an average of battery-charging circuit efficiencies from fully tested kits in the same family with the same battery voltage is used as an input to the tool. If there aren't fully tested kits with the same battery voltage, then reference the battery-charging circuit efficiency from the fully tested kit in the family.

LIGHTING FULL-BATTERY RUN TIME ENERGY REMOVED

This metric is measured during the lighting full-battery run time test (FBRT), and it represents the amount of energy removed from the battery over the entire run time when all included lights are operated on their brightest settings during the test. This metric is used to calculate the battery limit of a fully tested kit; if a fully tested kit does not have ports, the battery limit is equal to the lighting FBRT energy removed.

If a kit was not fully tested, then the lighting full-battery run time energy removed will be calculated using an average of the values referenced from all fully tested kits in the same family (see Appendix A.3).

PORT EFFICIENCY

The port efficiency, named battery-to-port efficiency in IEC TS 62257-9-5:2018, represents the percentage of energy usable for appliances out of the total energy provided to the port.

If available, this input will come from an average of the port effiencies of all fully tested products in the same family; otherwise, it will be an assumed value of 85%. See Appendix B.2.

NEXT STEPS

The available daily electrical energy of a product is used in many ways by solar energy kit manufacturers, customers, country governments, development programs, and other stakeholders. This can help inform how a solar energy kit may be used and compared to other like products.

In addition, VeraSol has produced a series of technical notes and eco design notes on off-grid lighting that you may find helpful going forward; they are available on the VeraSol Publications and Technical Notes webpage. Contact the VeraSol team for further information to inquire about adding Wh/day calculations to a spec book or using Wh/day calculations in your program via email at testing@verasol.org. Please note that VeraSol is no longer communicating these values directly to development programs, and that it can take up to one week to process these requests.

APPENDIX A. EQUATIONS

1. Battery Wh Limit (Wh/day)

The battery Wh limit a Wh/day value that is derived from multiplying the energy removed from the battery during lighting full-battery run time ($\mathbf{E_{FBRT}}$), port efficiency ($\boldsymbol{\eta_{port}}$), and the percentage of daytime use of the kit by the user ($\mathbf{D_{\%}}$); see Appendix B.3 for the definition of daytime use. Note that the energy removed from the battery during lighting full-battery run time is only available for fully tested kits; therefore, this metric will be derived using values referenced from a fully tested kit in the product family.

$$\textbf{Battery limit } \left[\frac{\textbf{Wh}}{\textbf{day}}\right] = \mathbf{E_{FBRT}(Wh)} * \boldsymbol{\eta_{port}}(\%) * \mathbf{D_{\%}}$$

2. PV Power at TMOT (W)

If a kit in a family includes a PV module that is untested, then the PV Power at TMOT ($\mathbf{P_{TMOT}}$) will be calculated using the rated PV Power at STC ($\mathbf{P_{STC}}$), the average temperature coefficient of open circuit voltage ($\boldsymbol{\beta}_{\text{rel}}$) of all tested PV modules in the family, and the temperature difference between PV Power at STC and PV Power at TMOT (always 25 °C). The relationship between the PV module's open-circuit voltage and cell temperature is used for this calculation, and the relationship between current and temperature is neglected.

$$\mathbf{P_{TMOT}} = \mathbf{P_{STC}}(\mathbf{1} + \boldsymbol{\beta_{rel}} * \mathbf{25}^{\circ}\text{C})$$

3. Lighting full-battery run time energy removed (Wh/day)

If a kit has not been fully tested, then this metric will be calculated using a referenced, measured battery capacity ($\mathbf{B_{Ah}}$) and $\mathbf{E_{FBRT}}$ from a fully tested kit from the same family. The FBRT energy is assumed to be proportional to the battery capacity. If the battery included in the untested kit has been tested, the measured battery capacity will be input and used; otherwise, the rated metric is used.

$$\mathbf{E_{FBRT,1}} = \mathbf{B_{Ah,1}} * \frac{\mathbf{E_{FBRT,2}}}{\mathbf{B_{Ah,2}}}$$

4. Energy service from PV Module

To calculate the amount of available energy that can be utilized by a kit, the PV energy service is calculated using $\mathbf{P_{TMOT}}$, system efficiencies including battery efficiency ($\boldsymbol{\eta_{batt}}$), solar operation efficiency ($\boldsymbol{\eta_{sol-op}}$), battery-charging circuit efficiency ($\boldsymbol{\eta_{BCC}}$), and port efficiency ($\boldsymbol{\eta_{port}}$); and an assumed sun-hours available per day ($\mathbf{SH}$).

$$\textbf{PV energy service } \left[\frac{\textbf{Wh}}{\textbf{day}}\right] = \mathbf{P_{TMOT}} * \boldsymbol{\eta_{batt}} * \boldsymbol{\eta_{sol-op}} * \boldsymbol{\eta_{BCC}} * \boldsymbol{\eta_{port}} * \mathbf{SH}$$

APPENDIX B. CALCULATION ASSUMPTIONS

1. Solar resource (or solar day)

In the Wh/day Estimator Tool calculations, the solar resource (sun-hours available per day) is assumed to be 5 hours, equivalent to a solar exposure (also called insolation or solar irradiation) of 5 kWh/m^2/day. This standard assumption is found in IEC TS 62257-9-5:2018 and used in the energy service calculations for fully tested kits.

2. Port efficiency

Port efficiency is either a referenced average of port efficiencies from all the fully tested kits in the same product family, or an assumed standard value of 85% efficiency is used. The 85% value corresponds to the lower quartile of port efficiencies calculated for recent products that were tested to IEC TS 62257-9-5:2018 testing through the VeraSol program. If the kit has ports, then the port efficiency is included in the calculations in Appendix A.1 and A.4. For kits without ports, the port efficiency and daytime use metrics are not included in the battery limit calculation.

3. Daytime use multiplier

If a kit can charge appliances or power non-lighting appliances, a multiplier is used in the equation in Appendix A.1 to account for charging or energy use that may occur during the day. For products with a PV power at STC of 10 W and under, a 1.10 multiplier is assumed, and for products with a PV power of 40 W and above, a 1.25 multiplier is assumed. For products with a PV power between 10 W and 40 W, the multiplier increases linearly between 1.10 and 1.25. The multipliers correspond to the average of a selection of products recently tested to IEC TS 62257-9-5:2018 within these two ranges of PV size.

APPENDIX C. PHOTO APPENDIX

1. Example spec book with the kit list.

The example spec book list of kits shows the fully tested kits, indicated with an asterisk, and the partially tested kits that may include tested and non-tested components, which are listed in the top row. In this example, the SunnyKit1, SunnyKit2, and SunnyKit3 would each have its own, separate SSS with its Wh/day listed and calculated using the energy service calculations. SunnyKit4, SunShine Kit 1, Sunshine Kit 2, Sunshine Kit 3, and Sunshine Kit 4, on the other hand, are the partially tested kits: some of their included components may or may not be tested, and they are eligible for having Wh/day caluclated using the Wh/day Estimator Tool. The fully tested kits shown below underwent system-level testing with each included component in the specific, listed configuration in the table.

List of Covered Systems

SunShine Co.

SunShine Basic Kit Family

VeraSol

	Number of each component included in each system								
System Name	**Sun Lamp 1**	**Sun Lamp 2**	**SunShine Light 1**	**SunShine Light 2**	**SunShine Light 3**	**Sun Battery 1**	**Sun Battery 2**	**Sun PV module***	**SunShine PV module**
SunShine Kit 1	2					1			1
SunShine Kit 2	3					1			1
SunShine Kit 3		1					1		1
SunShine Kit 4		2	3				1		1
SunnyKit1**			1	1		1		1	
SunnyKit2**			1	1		1		1	
SunnyKit3**			1	3	1		1	1	
SunnyKit4			1	4	1		1	1	

**Tested as full systems. Individual SSS available on VeraSol website.

NOTICE:

Only the SunnyKit1, SunnyKit2, and SunnyKit3 were fully tested as systems according to Edition 4 of IEC 62257-9-5. Individual Standardized Specifications Sheets (SSS) that report system-level performance are available for the SunnyKit1, the SunnyKit2, and theSunnyKit3 at https://data.verasol.org/products/sek/. Systems that were not tested, but that were developed using components from the component family will perform differently than the system(s) shown in the individual system-level SSS. All systems listed above are regarded to have passed the applicable Lighting Global Quality Standards.

FIGURE C1. EXAMPLE SPEC BOOK KIT LIST

APPENDIX C. PHOTO APPENDIX

2. Example spec book with Wh/day list

The example spec book list of Wh/day reports the Wh/day value determined for each listed kit in the table. The fully tested kits denoted with two asterisks report the Wh/day as calculated by the ESC, which matches the Wh/day reported on their individual SSS, and the partially tested kits list the Wh/day as calculated by the Wh/day Estimator Tool.

Available Daily Electrical Energy and Port Information

SunShine Co.

SunShine Basic Kit Family

System Name	Available Daily Electrical Energy (Wh/day)
SunShine Kit 1	20
SunShine Kit 2	30
SunShine Kit 3	40
SunShine Kit 4	50
SunnyKit1**	35
SunnyKit2**	35
SunnyKit3**	45
SunnyKit4	45

**Tested as full systems. Individual SSS available on VeraSol website.

NOTICE:
The available daily electrical energy (Wh/day) is calculated for fully tested systems following the energy service calculations as described in IEC/TS 62257-9-5 Ed. 4. For products in a family that are not tested as a full system, estimations of available daily electrical energy (Wh/day) are calculated according to an alternative method using data from the test reports of fully-tested products and components. Estimating Wh/day values requires making assumptions about system efficiencies, power consumption, and user behavior. As with any calculation based on multiple assumptions, there is some degree of error in the Wh/day estimate, which may be greater or less than the actual value for a given product.

FIGURE C2. EXAMPLE SPEC BOOK WH/DAY LIST

VeraSol

VeraSol.org

info@VeraSol.org

@VeraSol_QA

VeraSol Quality Assurance