Lighting Global Quality Assurance Framework:

Quality Standards & Test Methods
# Lighting Global Quality Standards

## Pico-PV Quality Standards

- Power Output: \( \leq 10 - 15 \, W_p \)

## SHS Kit Quality Standards

- Power Output: \( 10 \, W_p - 350 \, W_p \)

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### Table 1: Solar Light User Access Quality Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
<th>Quality Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Test &amp; Wiring</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Long Life</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Power Output</td>
<td>-</td>
<td>Automate standard</td>
</tr>
<tr>
<td>Lumen Maintenance</td>
<td>-</td>
<td>100% of nominal</td>
</tr>
<tr>
<td>Host &amp; Copy</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Battery</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Protective Devices</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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### Table 2: Solar Power User Access Quality Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
<th>Quality Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection Time</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Life Expectancy</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Durability</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Power Output</td>
<td>-</td>
<td>Automate standard</td>
</tr>
<tr>
<td>Lumen Maintenance</td>
<td>-</td>
<td>100% of nominal</td>
</tr>
<tr>
<td>Efficiency</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Host &amp; Copy</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Battery</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Protective Devices</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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Quality Standards Basics

- The Quality Standards are benchmarks that set a baseline level of **quality, durability, and truth-in-advertising** to protect consumers of off-grid lighting products.

- Conformance is evaluated based on results from laboratory testing
  - **SHS**: Lighting Global SHS test methods

- The tests are conducted at a third-party, approved test center
  - **Pico-PV**: ISO 17025 accredited lab
  - **SHS**: Lighting Global approved lab

- Testing is done on randomly-procured product samples
Quality Requirements

• **Truth in consumer-facing rating**
  - System performance numeric ratings
  - System components numeric ratings
  - Qualitative statements

  Product performance such as run time, light output and PV power must not be more than 15% less than rated value

• **Performance labeling requirement** (not required for SHS kits)
  - Luminous flux and solar run time on packaging
  - Qualitative effect of mobile phone charging or auxiliary appliances must be on packaging

• **Warranty**
  - Accurately specified and consumer facing
  - Minimum coverage of one year
  - Must cover entire product
## Quality Requirements

- **Safety and durability**
  - Water exposure protection
  - Physical ingress protection

<table>
<thead>
<tr>
<th>Quality and Durability&lt;sub&gt;g,h&lt;/sub&gt;</th>
<th>Physical Ingress Protection (for components containing electronics or electrical connections)</th>
<th>Fixed Outdoor</th>
<th>Others</th>
<th>All PV Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IP5x</td>
<td></td>
<td>IP2x</td>
<td>IP3x OR IP2x with circuit protection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Protection&lt;sub&gt;i&lt;/sub&gt; (for components containing electronics or electrical connections)</th>
<th>Fixed Indoor&lt;sup&gt;b,j&lt;/sup&gt;</th>
<th>Portable Separate&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Portable Integrated</th>
<th>Fixed Outdoor</th>
<th>All PV Modules</th>
</tr>
</thead>
</table>
| No requirement                                                                                  | Occasional rain: IP<sub>x</sub>1 OR technical protection OR warning label | Frequent rain, which requires meeting one of:  
1. IP<sub>x</sub>3  
2. IP<sub>x</sub>1 + technical protection  
3. IP<sub>x</sub>1 + warning label  
4. Technical protection + warning label | Permanent outdoor exposure: IP<sub>x</sub>5 OR IP<sub>x</sub>3 with circuit protection | Outdoor rooftop installation: Modified IP<sub>x</sub>4 OR circuit protection |
Quality Requirements

• Safety and durability
  – Water exposure protection
  – Physical ingress protection
  – Drop test
  – Mechanical durability
    • Connectors
    • Moving parts
    • Cable strain relief
  – AC / DC charger safety

• Workmanship
  – Good quality soldering and electrical connections
Quality Requirements

• Battery
  – Protection
    Charge controller prolongs battery life by maintaining within acceptable voltage levels
  – Long-term storage durability
    Limit on permanent capacity loss after storage at high temperature
  – Composition
    No battery may contain cadmium or mercury at levels greater than trace amounts
Quality Requirements

• Lumen maintenance
  Limit on permanent loss of light output after long-term use of LED

• Pay-as-you-go (PAYG)
  – Capable of accurately metering service to customers
  – Battery protection must remain active regardless of whether the system is in an enabled or disabled state
SHS Kits: Additional Requirements

- **Consumer-facing information**
  - PV power on packaging
  - Statement about battery replacement on packaging
  - Port voltage and current accurately specified and compatible with appliances that are charged/powered through the ports.
  - User manual information/instructions
    - PV module placement, orientation & connection
    - How to make permanent & appliance connections
    - How to determine battery state-of-charge
  - Component specifications & replacement methods
    (during and after warranty period)

- **Warranty**
  - Accurately specified and consumer facing
  - Minimum of two years for main control unit, battery and PV module
  - Minimum of one year for accompanying appliances
SHS Kits: Additional Requirements

• **Battery**
  – Lithium batteries must carry UN38.3 certification and have circuit protection for individual cells or sets of parallel-connected cells.

• **Safety & Durability**
  – Circuit and overload protection must be part of the system
  – Wires, cables and connectors must be appropriately sized for the expected current and voltage
  – PV overvoltage protection
  – User interface must be designed such that the user cannot make improper or reversed polarity connections
  – Any cable intended to be placed outdoors (e.g. PV module cables) must be outdoor-rated and UV resistant.
Test Methods: Pico-PV


Comprehensively addresses pico-PV products:

• Describes and categorizes applicable products, including system components

• Establishes framework for measuring and observing system characteristics and performance

• Provides detailed test methods for evaluating product quality

• Current version does not currently include quality standards
Test Methods: Pico-PV

• Pico-PV products must be:
  – tested to the latest edition of IEC TS 62257-9-5
  – by a test lab that is ISO 17025 accredited for IEC TS 62257-9-5

• QTM test results are required for Lighting Global's assessment to meet the Quality Standards
  – n=6 for pico products (≤ 10 \( W_p \))
  – 3.5% of the warehouse stock for Pico-QTM (≥ 500 units); random sampling used

• Purchase document from IEC Webstore; 75% “discount” available for eligible stakeholders
Test Methods: SHS Kits

- SHS products must be:
  - tested to the latest edition of the Lighting Global Solar Home System Test Methods
  - by a test lab that is approved by Lighting Global to conduct the SHS tests

- SHS-QTM test results are required for Lighting Global's assessment to meet the SHS Quality Standards
  - n=4 for SHS products
  - 8% of warehouse stock for SHS-QTM

- The Lighting Global SHS test methods can be obtained from LG QA upon request
Testing Methodologies

- **ISM** = initial screening method
  
  For quick evaluation of product quality

- **QTM** = quality test method
  
  For full evaluation of product quality

- **AVM** = accelerated verification method
  
  For expedited evaluation of products from eligible companies

- **AR** = renewal test
  
  For renewal of product quality verification

- **MCM** = market check method
  
  For market surveillance of product performance
## Summary of Pico-PV Test Procedure

### Component Tests

<table>
<thead>
<tr>
<th>Test Category</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling</strong></td>
<td>• Randomly selected from warehouse or marketplace</td>
</tr>
<tr>
<td><strong>Photométrics</strong></td>
<td>• Luminous flux (lumens—total output)</td>
</tr>
<tr>
<td></td>
<td>• Standardized distribution (illuminance)</td>
</tr>
<tr>
<td><strong>Battery &amp; Charge Control</strong></td>
<td>• Battery Capacity (Amp-hours, voltage)</td>
</tr>
<tr>
<td></td>
<td>• Degree of protection (voltage cutoffs)</td>
</tr>
<tr>
<td><strong>Solar Module</strong></td>
<td>• Power output (Watts)</td>
</tr>
<tr>
<td></td>
<td>• Current-voltage characteristics (I-V Curve)</td>
</tr>
<tr>
<td><strong>Full Battery Run Time</strong></td>
<td>• Measured using standardized cycle (hours of operation)</td>
</tr>
<tr>
<td><strong>Solar Charge Run Time</strong></td>
<td>• Modeled estimate (daily hours of operation after solar charging)</td>
</tr>
<tr>
<td><strong>Physical Ingress &amp; Water Protection</strong></td>
<td>• Incorporates enclosure (IP class) and system-level protection (coatings, etc.)</td>
</tr>
</tbody>
</table>

### System Tests

<table>
<thead>
<tr>
<th>Test Category</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Durability</strong></td>
<td>• Drop test from one meter (pass/fail)</td>
</tr>
<tr>
<td></td>
<td>• Switch and connector durability</td>
</tr>
<tr>
<td></td>
<td>• Internal wiring and solder inspection</td>
</tr>
<tr>
<td></td>
<td>• Lumen Maintenance</td>
</tr>
<tr>
<td></td>
<td>• Battery durability storage test</td>
</tr>
</tbody>
</table>
# Differences in test methods for SHS Kits

<table>
<thead>
<tr>
<th>Component tests</th>
<th>Ports and Control Box</th>
<th>Non-lighting appliances</th>
<th>Full Battery Run Time</th>
<th>Solar Charge Test</th>
<th>Energy Service Calculations</th>
<th>Durability and Safety</th>
<th>User Manual and Packaging</th>
<th>Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Power capabilities and port efficiencies</td>
<td>• Functionality and durability check</td>
<td>• Measure single FBRT with lighting appliances as input to Energy Service Calculations</td>
<td>• Measure single solar charge test as input to Energy Service Calculations</td>
<td>• Modeled estimate (full battery and daily hours of operation in various configurations)</td>
<td>• Lumen maintenance ≥90%</td>
<td>• Battery replacement statement</td>
<td>• 2 years for system, battery and included light points, 1 year for appliances</td>
</tr>
<tr>
<td></td>
<td>• Circuit protection</td>
<td>• Power consumption</td>
<td>• Battery tests as necessary</td>
<td></td>
<td></td>
<td>• Additional safety requirements for Li-ion</td>
<td>• Installation, maintenance and safety</td>
<td></td>
</tr>
<tr>
<td>Comment</td>
<td>Additional tests, such as ports, miswiring, PV overvoltage and overcurrent protection included</td>
<td>Balance rigor with cost of testing</td>
<td>Only required for one setting, rather than multiple</td>
<td>Only required for one setting, rather than multiple</td>
<td>Mainly to support truth in advertising assessment</td>
<td>Included to address concerns about larger products with longer expected lifespans</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Methods in IEC 62257-9-5 were originally designed in 2008 - 2009 for simple lighting products with at most one port for mobile phone charging.

Market now full of products with multiple light points, multiple ports and appliances, below the 10-15 W range
In 2018, we plan to extend tests to pico-products with ports

<table>
<thead>
<tr>
<th>Component tests</th>
<th>System Tests</th>
</tr>
</thead>
</table>
| Ports and Control Box | • Power capabilities and port efficiencies  
• Circuit protection |
| Non-lighting appliances | • Functionality and durability check  
• Power consumption  
• Battery tests as necessary |
| Full Battery Run Time | • Measure single FBRT with lighting appliances as input to Energy Service Calculations |
| Solar Charge Test | • Measure single solar charge test as input to Energy Service Calculations |
| Energy Service Calculations | • Modeled estimate (full battery and daily hours of operation in various configurations) |
| Durability and Safety | • Lumen maintenance ≥90%  
• Additional safety requirements for Li-ion  
• PV cables rated for outdoor use (UV)  
• Declare wire and cable sizing |
| User Manual and Packaging | • Battery replacement statement  
• Installation, maintenance and safety  
• Report PV power on packaging |
| Warranty | • 2 years for system, battery and included light points, 1 year for appliances |

The ports tests, protection tests, and energy service calculations would apply to all products with ports, and the lumen maintenance threshold and Li-ion requirements would be aligned for all products.

Only applicable to products > 10 W [Related to the cost & expected lifetime of the system]
Product Quality Verification Process

Refer to Lighting Global Testing Steps document
Overview:
Afternoon Session

Section A
From Sunlight to energy services
Understanding how solar energy is harnessed, stored, used (and lost) in off-grid solar products

Section B
Laboratory testing off-grid solar products
Follow product samples through the testing process and observe how tests are conducted
Section A:
Deeper understanding of off-grid energy systems

Summary

• System components
• Review pico-PV test procedure
• Explain testing flow diagram
• Follow samples through process, summarizing measurements/evaluation at each step
System Components
These are the parts of lighting products.

- Sunshine
- Solar Panel
- Battery
- Light

[Link to product: http://www.dlightdesign.com/products_the_solata_global.php]
There are circuits that link the parts.

Sunshine → Solar Panel → Charging Circuit → Battery → Discharge Circuit → Light
Not just light...

Some also power phones, radios and other accessories.

SHS kits often include, or are designed to support larger appliances like TVs and fans.
Solar Panels

- Provide power at a voltage and current matched to each lighting product

- Performance specifications are given for “full sun”, often printed on back
  - **Voltage**
    (open circuit and max power)
  - **Current**
    (short circuit and max power)
  - **Power**
    (max power)
Solar Panel Failure

• Usually are not the “weak link” in the solar lighting chain; can last 20 years or more.

• Common failures:
  1. Break when dropped or damaged
  2. Junction box short or loose wire
  3. Broken cable
Commercially Available PV Technologies

- **Monocrystalline** solar cells
  the most efficient at converting solar energy into electricity.
- **Polycrystalline** solar cells
  Slightly less efficient but less expensive to produce.
- **Amorphous (thin-film)** solar cells
  less than half as efficient as the best cells, but least expensive to produce.
- **Multi-Junction**
  Uses two or more layers of cells on top of each other to combine output
- **Cadmium Telluride, CIGS (Copper Indium Gallium Selenide)**
Generating an IV Curve

1. PV module in series with resistor
2. Measure PV current and voltage
IV Curve Example

$I_{SC}$ = short circuit current
$V_{OC}$ = open circuit voltage
$I_{mp}$ = maximum power-point current
$V_{mp}$ = maximum power-point voltage
IV Curve Example

- $I_{mp} = \text{maximum power-point current}$
- $V_{mp} = \text{maximum power-point voltage}$
- $I_{sc} = \text{short circuit current}$
- $V_{oc} = \text{open circuit voltage}$

Multiply the current and voltage pairs

$P = V \times I$
Matching PV module and battery operating voltages: the I-V Curve

Power = Voltage x Current
(P = VI)
Matching PV module and battery operating voltages: the I-V Curve
PV Module Performance and the I-V Curve

I-V Curve for 20 Wp PV module

Standard Conditions:
1000 W/m² (full sunshine)
Panel Temperature: 25°C

- Short Circuit Current ($I_{SC}$)
- Peak Power ($W_p$)
- Max. Power Voltage ($V_{MP}$)
- Max. Power Current ($I_{MP}$)
- Maximum Power Point
- Open Circuit Voltage ($V_{OC}$)
Effect of Sunshine on PV Module Output

(PV current is proportional to solar radiation)
Effect of Temperature on PV Module Output

(Voltage decreases at higher temperatures)
Charge control circuit

- **Protects battery**
  - Regulates power input
  - Prevents over-charge and over-discharge

- Specific designs for each battery with special voltage setpoints

- There is a large range of features; common terms you might hear are:
  - Maximum Power Point Tracking (MPPT)
  - Pulse-Width Modulation (PWM)
  - Series regulator
  - Shunt regulator
  - Cell balancing
  - Charge control setpoints
Battery

- **Stores electricity** for later use
- Some power is lost from inefficiency
- **Battery Capacity**
  - The amount of electric charge stored
  - Units: Ampere-hours (Ah)
- Batteries lose capacity over time and repeated usage
Battery

- **Sealed lead-acid (SLA)**
  - Cheap, heavy
  - Harmed by over-discharging or lack of charge; requires periodic “top-off” charge.

- **Nickel-metal-hydride (NiMH)**
  - Harmed by overcharging; should be “fully cycled” to maintain.

- **Nickel Cadmium (NiCd)**
  - Not allowed by Lighting Global

- **Lithium Ion (Li-ion) and Lithium Iron Phosphate (LiFePO₄)**
  - Very common, lightweight and high performance
# Battery Characteristics by Chemistry

<table>
<thead>
<tr>
<th>Battery Type (Chemistry)</th>
<th>Voltage per cell (V)</th>
<th>Cycle Life (Cycles)</th>
<th>Self Discharge (% / month)</th>
<th>In Use Since</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLA</td>
<td>2</td>
<td>200 - 300</td>
<td>5</td>
<td>1800s</td>
<td>High</td>
</tr>
<tr>
<td>NiCd</td>
<td>1.2</td>
<td>1000</td>
<td>20</td>
<td>1950</td>
<td>High</td>
</tr>
<tr>
<td>NiMH</td>
<td>1.2</td>
<td>300 - 500</td>
<td>30</td>
<td>1990</td>
<td>Low</td>
</tr>
<tr>
<td>Li-ion</td>
<td>3.7</td>
<td>500 - 1000</td>
<td>&lt; 5</td>
<td>1991</td>
<td>Low</td>
</tr>
<tr>
<td>LiFePO$_4$</td>
<td>3.3</td>
<td>1000 - 2000</td>
<td>&lt; 5</td>
<td>1999</td>
<td>Low</td>
</tr>
</tbody>
</table>

http://batteryuniversity.com/learn/article/secondary_batteries
Battery Failures

Lifetime depends on how well they are treated:

- Charge / discharge rate & voltage
- Temperature
- Storage

Lead acid last 1-5 years, harmed by over-discharging or lack of charge; good to top-off often.

NiMH and NiCd last 2-7 years, harmed by overcharging; should be “fully cycled” to maintain.

Lithium last 5-10 years and are the most durable, but require more complex charging circuits. Dangerous if overheated.
Power Control Circuit

• Provides power to loads
• Can be as simple as a switch...but sometimes complicated with integrated circuits.

• Regulates power
  • On/off
  • Multiple settings

• Regulates current and voltage
  • Different levels for LED, phone charging, etc.
• **Lights**
  • LED lights are most common

• **Phone Charging** (very common)
  • Some able to charge smart phones & tablets

• **Others** (most common with larger systems)
  • Portable light
  • Radio
  • Fan
  • TV
  • More as efficiencies increase
LED Lights

- LED = “Light Emitting Diode”
- A semiconductor that emits light when electric current is passed through it
- Technology is getting cheaper and more efficient
- Integrated into many devices, growing market
- Several types, some “through hole” and other “surface mount” with a range of power.

http://www.lightfair.com
Two key types of LED

**Surface Mount**
- Often higher power / brightness
- Better efficiency
- More expensive
- Requires “heat sink”

**Through-hole**
- Requires more to get same light
- Older design – also used for indicator lights
- Less expensive
LED Lights: Measurements

Key aspects we measure:

- **Light output**
  - Total amount of light produced in all directions
  - Measured in lumens

- **Light distribution**
  - Light striking a surface
  - Narrow, wide, or omnidirectional

- **Lumen Maintenance**
  - How fast a light becomes dim
  - Good designs stay bright for 30,000 hours + (many years); bad designs last a few months
  - All “quality-verified” products stay bright at least 2,000 hours – several years.
LED Lights

- **Advantages**
  - Long life (up to 30,000 hours of service)
  - Relatively high efficacy (lumens/watt)
  - Durable, solid state
  - Flexible (many colors, sizes, and powers)
  - Non-toxic (no mercury)

- **Disadvantages**
  - Glare (sometimes)
  - Heat, voltage, and current sensitive, which can lead to short life if not properly designed
LED Light “Lumen Maintenance”

LEDs do not burn out in normal use, but slowly lose brightness.
(can burn out if exposed to high voltage or current)
“Lumen Maintenance” describes how fast they become dim.

Causes:
- Overheating / bad heat dissipation
- Optics can get cloudy

Good designs can last 30,000 hours + (many years)
Bad designs only last a few months

All quality verified products last at least 2,000 hours – several years.
**Example: Low Luminous Efficacy**

**Orb Soelectric 30 (Low)**

- **Solar Capacity**: 52.5 Wh
- **Solar Output**: 43.2 Wh
- **Charging Circuit**: 39.4 Wh
- **Battery**: 38.9 Wh
- **Driver, LED, Optics**: 3039 lm-hr
- **Lighting Service**
  - 1% Battery Loss
  - 9% Circuit Loss
  - 14% MPP Loss
  - 4% Excess Solar Capacity*

**Energy System Efficiency**
- **77%**

**Light Output Efficacy**
- **78 lm/W**

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*Excess solar capacity is generation capacity in excess of the capacity required to fully charge the battery. In products with ports, a portion of this energy can be used to power or charge appliances during the day.

**Includes MPP loss, circuit loss, and battery loss.

***Driver and optics losses are accounted for in result.*
Example: High Luminous Efficacy

**NRS Enlight Solar Smart All In One (Room Light High)**

- **Solar Capacity**: 10.2 Wh
- **Solar Output**: 8.8 Wh
- **Charging Circuit**: 7.7 Wh
- **Battery**: 7.4 Wh
- **Driver, LED, Optics**: 1124 lm-hr

- **Energy System Efficiency***: 81%
- **Light Output Efficacy***: 151 lm/W

* Excess solar capacity is generation capacity in excess of the capacity required to fully charge the battery. In products with ports, a portion of this energy can be used to power or charge appliances during the day.

** Includes MPP loss, circuit loss, and battery loss.

*** Driver and optics losses are accounted for in result.
Example: High System Efficiency

Solarway Solar Home Power System (1 Bulb On)

- Solar Capacity: 11.6 Wh
- Solar Output: 10.8 Wh
- Charging Circuit: 9.9 Wh
- Battery: 9.5 Wh
- Driver, LED, Optics: 957 lm·hr

Losses:
- 4% Battery Loss
- 8% Circuit Loss
- 7% MPP Loss
- 0% Excess Solar Capacity

Energy System Efficiency**: 82%
Light Output Efficacy***: 100 lm/W

* Excess solar capacity is generation capacity in excess of the capacity required to fully charge the battery. In products with ports, a portion of this energy can be used to power or charge appliances during the day.
** Includes MPP loss, circuit loss, and battery loss.
*** Driver and optics losses are accounted for in result.
Example: Low System Efficiency

Greenlight Planet Sun King Eco (Turbo)

- Solar Capacity
- Solar Output
- Charging Circuit
- Battery
- Driver, LED, Optics

4.6 Wh → 3.2 Wh → 1.8 Wh → 1.7 Wh → 239 lm/hr

- Lighting Service
- 4% Battery Loss
- 45% Circuit Loss
- 25% MPP Loss
- 7% Excess Solar Capacity

Energy System Efficiency: 40%

Light Output Efficacy: 138 lm/W

* Excess solar capacity is generation capacity in excess of the capacity required to fully charge the battery. In products with ports, a portion of this energy can be used to power or charge appliances during the day.

** Includes MPP loss, circuit loss, and battery loss.

*** Driver and optics losses are accounted for in result.
How does it all work?
Open up your product!

Greenlight Planet
Sun King Pro

Futura Energy Station

d.light S300
Identify the components!

Greenlight Planet
Sun King Pro

LED and driver
Battery
Charge control circuit
Why are there wires sticking out of the product?

Black = Battery -
Red = Battery +
White = LED/Electronics +
Green = Electronics -

These wires are for testing.
Section B: Lab Visit

Summary

• Introduction
• Review pico-PV test procedure
• Explain testing flow diagram
• Follow samples through process, summarizing measurements/evaluation at each step
## Summary of Pico-PV Test Procedure

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<tbody>
<tr>
<td><strong>Component Tests</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sampling</strong></td>
<td>Randomly selected from warehouse or marketplace</td>
</tr>
<tr>
<td><strong>Photometrics</strong></td>
<td>Luminous flux (lumens—total output)</td>
</tr>
<tr>
<td></td>
<td>Standardized distribution (illuminance)</td>
</tr>
<tr>
<td><strong>Battery &amp; Charge Control</strong></td>
<td>Battery Capacity (Amp-hours, voltage)</td>
</tr>
<tr>
<td></td>
<td>Degree of protection (voltage cutoffs)</td>
</tr>
<tr>
<td><strong>Solar Module</strong></td>
<td>Power output (Watts)</td>
</tr>
<tr>
<td></td>
<td>Current-voltage characteristics (I-V Curve)</td>
</tr>
<tr>
<td><strong>Full Battery Run Time</strong></td>
<td>Measured using standardized cycle (hours of operation)</td>
</tr>
<tr>
<td><strong>Solar Charge Run Time</strong></td>
<td>Modeled estimate (daily hours of operation after solar charging)</td>
</tr>
<tr>
<td><strong>Physical Ingress &amp; Water Protection</strong></td>
<td>Incorporates enclosure (IP class) and system-level protection (coatings, etc.)</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>Drop test from one meter (pass/fail)</td>
</tr>
<tr>
<td></td>
<td>Switch and connector durability</td>
</tr>
<tr>
<td></td>
<td>Internal wiring and solder inspection</td>
</tr>
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<td>Lumen Maintenance</td>
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<td>Battery durability storage test</td>
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</tbody>
</table>

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Technical Specification 62257-9-5
Test Flow: Pico-PV Products
Test Flow: SHS Kits