

Lighting Global Quality Assurance Framework :

Quality Standards & Test Methods



Lighting Global Quality Standards

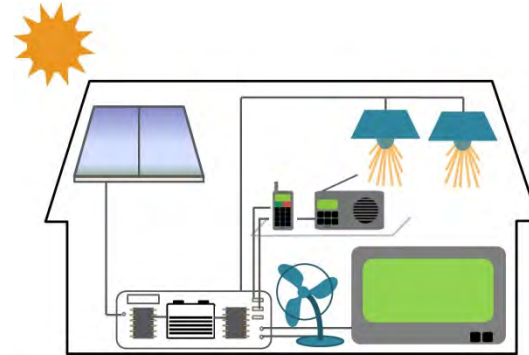
Pico-PV Quality Standards



($\leq 10-15 W_p$)

Category*	Metric	Quality Standard
Trust In Advertising	Manufacture, Model # and Declared Name	Accurately specified
	Light Output and Delta Time	Accurately specified on packaging for the highest setting. For other settings, if reported, accurately specified. If there are both per- <i>Wp</i> and per- <i>Wp</i> (P- <i>Wp</i>) and non- <i>Wp</i> (N- <i>Wp</i>) versions of a product, each must be truthfully advertised with respect to energy savings provided.
	Change Rating	If reported, accurately specified (e.g. 5% power on maximum change time).
	Longevity	If reported, accurately specified.
Lumen Maintenance	Lumen Maintenance at 2000 hours	Impact of multiple phase changing on product performance accurately described on packaging. ³
	AC-DC Charge Safety	The P- <i>Wp</i> system should be capable of accurately measuring voltage to maintain its rated ability per the metric that is paid for.
Health and Safety	Hazardous Substances Bar	If reported, accurately specified.
	Battery Protection	Average relative light output $\geq 85\%$ of rated light output at 2,000 hours with only one sample allowed to fall below 70%. CR: All 4 samples measured $\geq 85\%$ of rated light output at 1,000 hours. ⁴ If an included lighting appliance provides ≥ 13 lumens, it is subject to the lumen maintenance standard. ⁴
Energy	Battery Protection	Any multi-AC-DC charge must approval from a recognized consumer electronics safety certification organization. ⁵
	Battery Durability	No battery may contain substances in amounts in excess greater than those amounts: (1) 0.0001% Hg and (2) 0.002% Cd by weight as measured with the EU Battery Directive. Powered by an appropriate charge controller that protects battery life and protects the safety of the user. First cut-off voltage must meet the requirements outlined below. ⁶ Batteries of included appliances must also meet this standard. For P- <i>Wp</i> systems, appropriate battery protection must remain active regardless of whether the system is in an enabled or disabled state. To avoid damage to a battery during long-term periods of non-powered disabled system status, the solar module must be able to charge the battery until it is enabled at the disabled state. The average capacity loss of 4 samples must not exceed 25% and only one sample may have a capacity loss greater than 20% following the battery durability storage test as defined in IEC 62527-6:3 Annex B8. If an included lighting appliance provides ≥ 13 lumens, it is subject to the battery durability standard. All other appliances are not required to meet this standard.
Quality and Durability ¹⁵	Physical Damage Protection	Pass 100% IFT
	Temperature Resistance at Ambient Conditions	Other: 25% AT 95° Ambient: 25%

SHS Kit Quality Standards



($10 W_p - 350 W_p$)

Category*	Metric	Quality Standard
Trust In Advertising	Manufacture	Accurately specified
	Product Name & Model No.	Accurately specified
	Performance Claim: Light Output, Run Time, Appliance Power Consumption	If reported, accurately specified. ³ If there are both per- <i>Wp</i> (P- <i>Wp</i>) and non- <i>Wp</i> (N- <i>Wp</i>) versions of a product, each must be truthfully advertised with respect to energy savings provided.
	Longevity, Full Power, Battery Capacity, Charge Rating, Other Aspects	P- <i>Wp</i> power must be accurately specified on the packaging packaging. All other aspects, if reported, must be accurately specified. ⁴
Lumen Maintenance	Lumen Maintenance at 2000 Hours	The P- <i>Wp</i> system should be capable of accurately measuring voltage to maintain its rated ability per the metric that is paid for.
	AC-DC Charge Safety	Any multi-AC-DC charge must approval from a recognized consumer electronics safety certification organization. ⁵
Health and Safety	Hazardous Substances Bar	If reported, accurately specified.
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Quality and Durability ¹⁵	Physical Damage Protection	Pass 100% IFT
	Temperature Resistance at Ambient Conditions	Other: 25% AT 95° Ambient: 25%

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
 - **Pico-PV**: International Electrotechnical Commission (IEC) Technical Specification 62257-9-5
 - **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
- **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

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



Quality Requirements

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



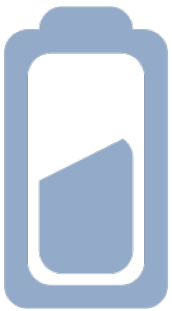
<i>Quality and Durability</i> ^{g,h}	Physical Ingress Protection (for components containing electronics or electrical connections)	<i>Fixed Outdoor</i>	IP5x
		<i>Others</i>	IP2x
		<i>All PV Modules</i>	IP3x OR IP2x with circuit protection
	Water Protection ⁱ (for components containing electronics or electrical connections)	<i>Fixed Indoor^{b,j}</i>	No requirement
		<i>Portable Separate^b</i>	Occasional rain: <i>IPx1 OR technical protection OR warning label</i>
		<i>Portable Integrated</i>	Frequent rain, which requires meeting one of: 1) <i>IPx3</i> 2) <i>IPx1 + technical protection</i> 3) <i>IPx1 + warning label</i> 4) <i>Technical protection + warning label</i>
<i>Fixed Outdoor</i>		Permanent outdoor exposure: <i>IPx5 OR IPx3 with circuit protection</i>	
<i>All PV Modules</i>		Outdoor rooftop installation: <i>Modified IPx4 OR circuit protection</i>	

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

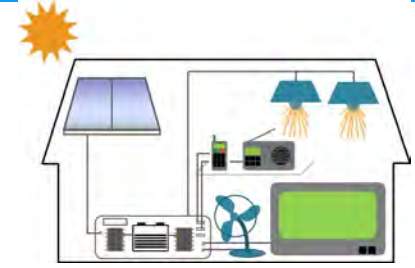
- **Pay-as-you-go (PAYG)**

- 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

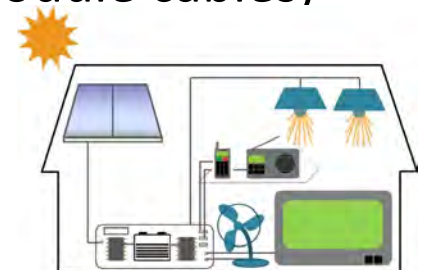
SHS Kits: Additional Requirements

- **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

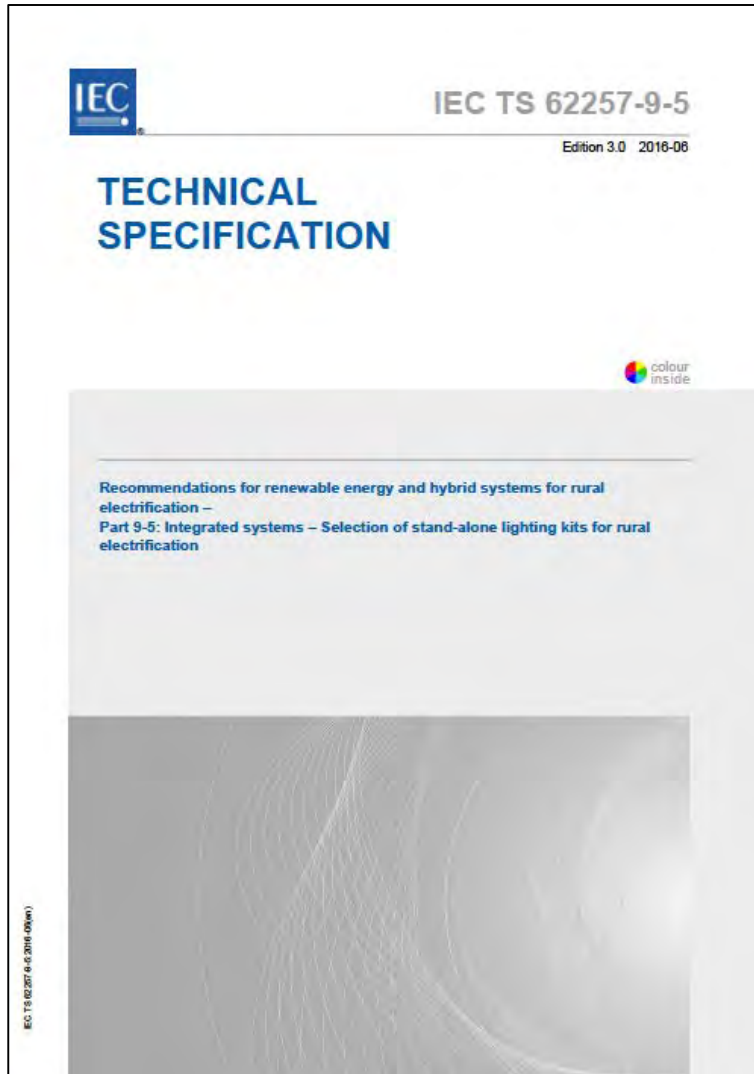
IEC Technical Specification 62257-9-5

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



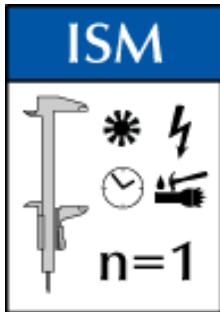
- Pico-PV products must be:
 - tested to the latest edition of IEC TS 62257-9-5
 - by a test lab that is ISO 17025 accredited for IEC TS 62257-9-5
- **QTM** test results are required for Lighting Global's assessment to meet the Quality Standards
 - $n=6$ for pico products ($\leq 10 W_p$)
 - 3.5% of the 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 ($\geq 10 W_p$ & $\leq 350 W_p$)
 - 8% of warehouse stock for SHS-QTM (≥ 200 units)
- 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



Technical Specification
62257-9-5

Component Tests	Sampling	<ul style="list-style-type: none"> Randomly selected from warehouse or marketplace
	Photometrics	<ul style="list-style-type: none"> Luminous flux (lumens—total output) Standardized distribution (illuminance)
	Battery & Charge Control	<ul style="list-style-type: none"> Battery Capacity (Amp-hours, voltage) Degree of protection (voltage cutoffs)
	Solar Module	<ul style="list-style-type: none"> Power output (Watts) Current-voltage characteristics (I-V Curve)
System Tests	Full Battery Run Time	<ul style="list-style-type: none"> Measured using standardized cycle (hours of operation)
	Solar Charge Run Time	<ul style="list-style-type: none"> Modeled estimate (daily hours of operation after solar charging)
	Physical Ingress & Water Protection	<ul style="list-style-type: none"> Incorporates enclosure (IP class) and system-level protection (coatings, etc.)
	Durability	<ul style="list-style-type: none"> Drop test from one meter (pass/fail) Switch and connector durability Internal wiring and solder inspection Lumen Maintenance Battery durability storage test

Differences in test methods for SHS Kits

Comment

		Comment	
Component tests	Ports and Control Box	<ul style="list-style-type: none"> Power capabilities and port efficiencies Circuit protection 	Additional tests, such as ports, miswiring, PV overvoltage and overcurrent protection included
	Non-lighting appliances	<ul style="list-style-type: none"> Functionality and durability check Power consumption Battery tests as necessary 	Balance rigor with cost of testing
System Tests	Full Battery Run Time	<ul style="list-style-type: none"> Measure single FBRT with lighting appliances as input to Energy Service Calculations 	Only required for one setting, rather than multiple
	Solar Charge Test	<ul style="list-style-type: none"> Measure single solar charge test as input to Energy Service Calculations 	Only required for one setting, rather than multiple
	Energy Service Calculations	<ul style="list-style-type: none"> Modeled estimate (full battery and daily hours of operation in various configurations) 	Mainly to support truth in advertising assessment
	Durability and Safety	<ul style="list-style-type: none"> Lumen maintenance $\geq 90\%$ Additional safety requirements for Li-ion PV cables rated for outdoor use (UV) Declare wire and cable sizing 	Included to address concerns about larger products with longer expected lifespans
	User Manual and Packaging	<ul style="list-style-type: none"> Battery replacement statement Installation, maintenance and safety Report PV power on packaging 	
	Warranty	<ul style="list-style-type: none"> 2 years for system, battery and included light points, 1 year for appliances 	

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



IEC Technical Specification 62257-9-5

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

Component tests	Ports and Control Box	<ul style="list-style-type: none"> Power capabilities and port efficiencies Circuit protection
	Non-lighting appliances	<ul style="list-style-type: none"> Functionality and durability check Power consumption Battery tests as necessary
System Tests	Full Battery Run Time	<ul style="list-style-type: none"> Measure single FBRT with lighting appliances as input to Energy Service Calculations
	Solar Charge Test	<ul style="list-style-type: none"> Measure single solar charge test as input to Energy Service Calculations
	Energy Service Calculations	<ul style="list-style-type: none"> Modeled estimate (full battery and daily hours of operation in various configurations)
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		<ul style="list-style-type: none"> PV cables rated for outdoor use (UV) Declare wire and cable sizing
	User Manual and Packaging	<ul style="list-style-type: none"> Battery replacement statement Installation, maintenance and safety Report PV power on packaging
Warranty	<ul style="list-style-type: none"> 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

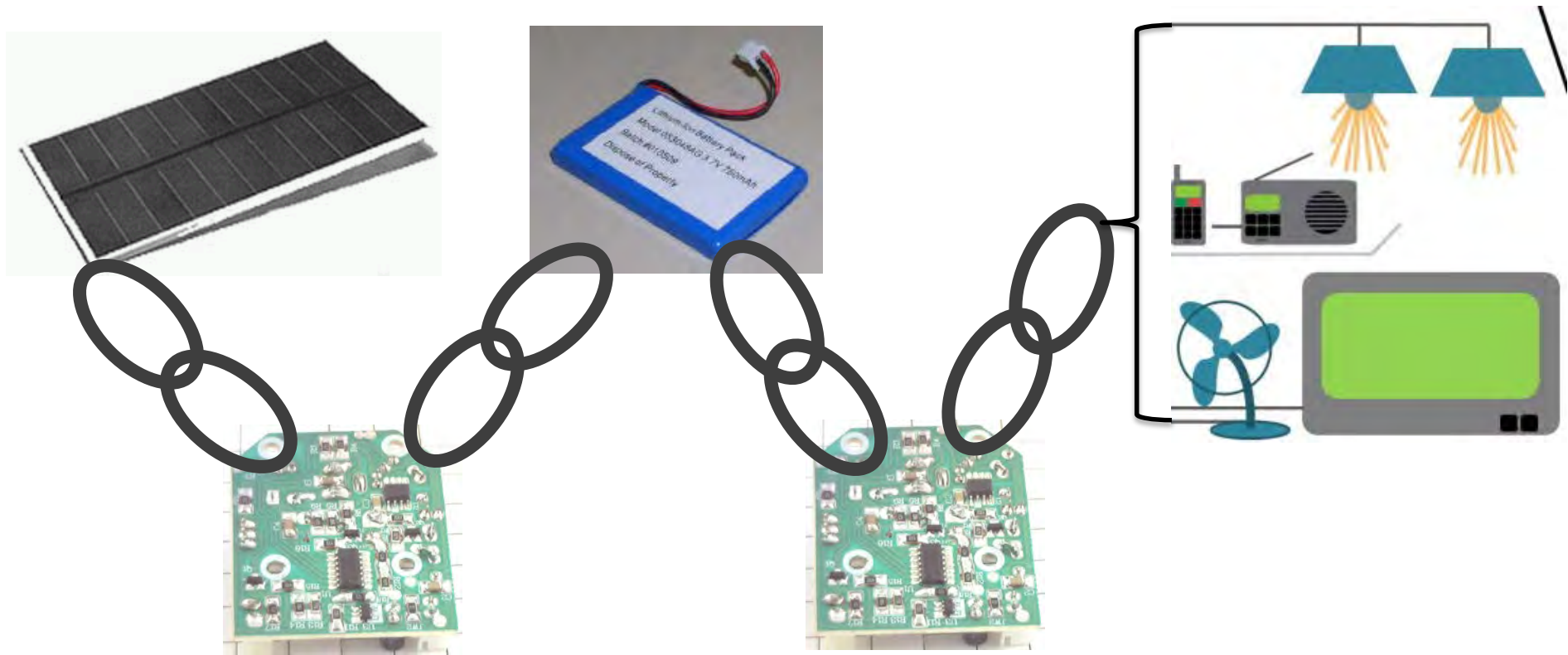
Section A:

Deeper understanding of off-grid energy systems

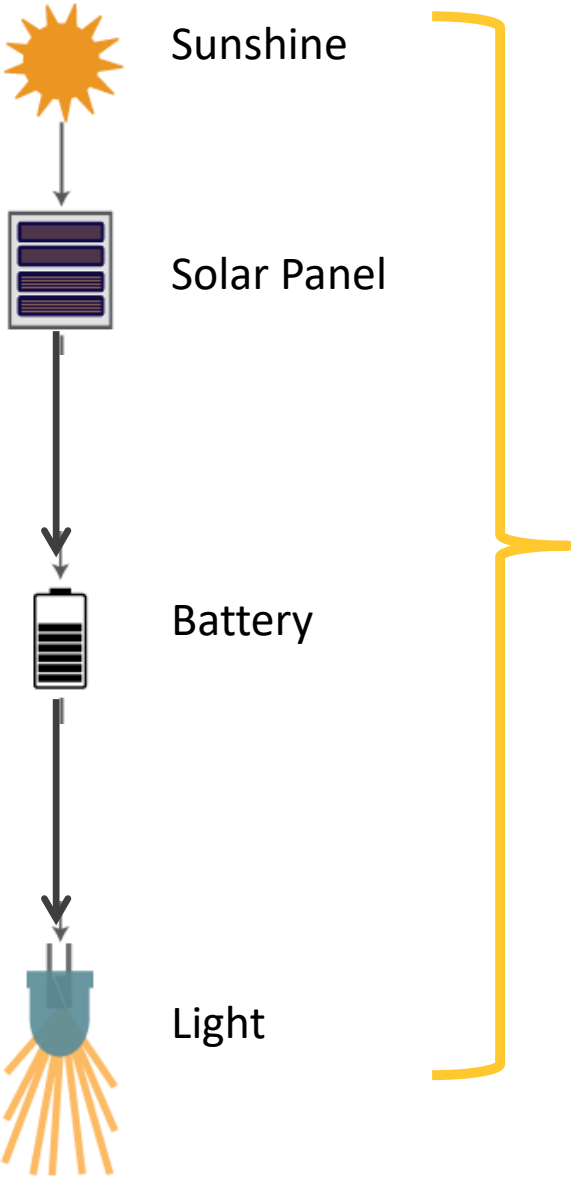
Summary

- System components
- Review pico-PV test procedure
- Explain testing flow diagram
- Follow samples through process, summarizing measurements/evaluation at each step

System Components

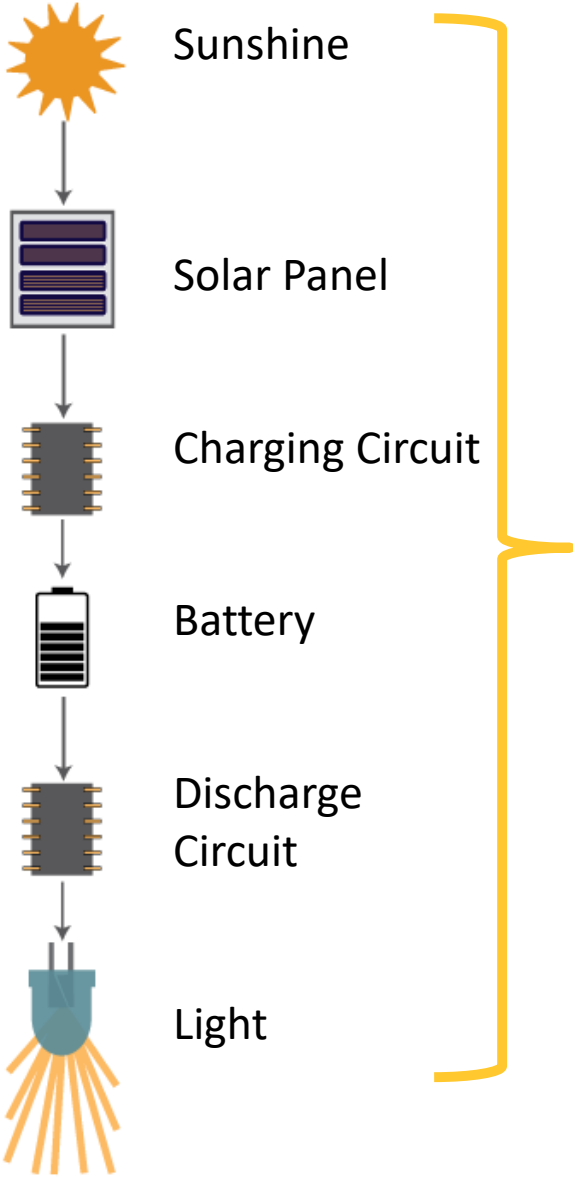


These are the parts of lighting products.



http://www.dlightdesign.com/products_the_solata_global.php

There are circuits that link the parts.

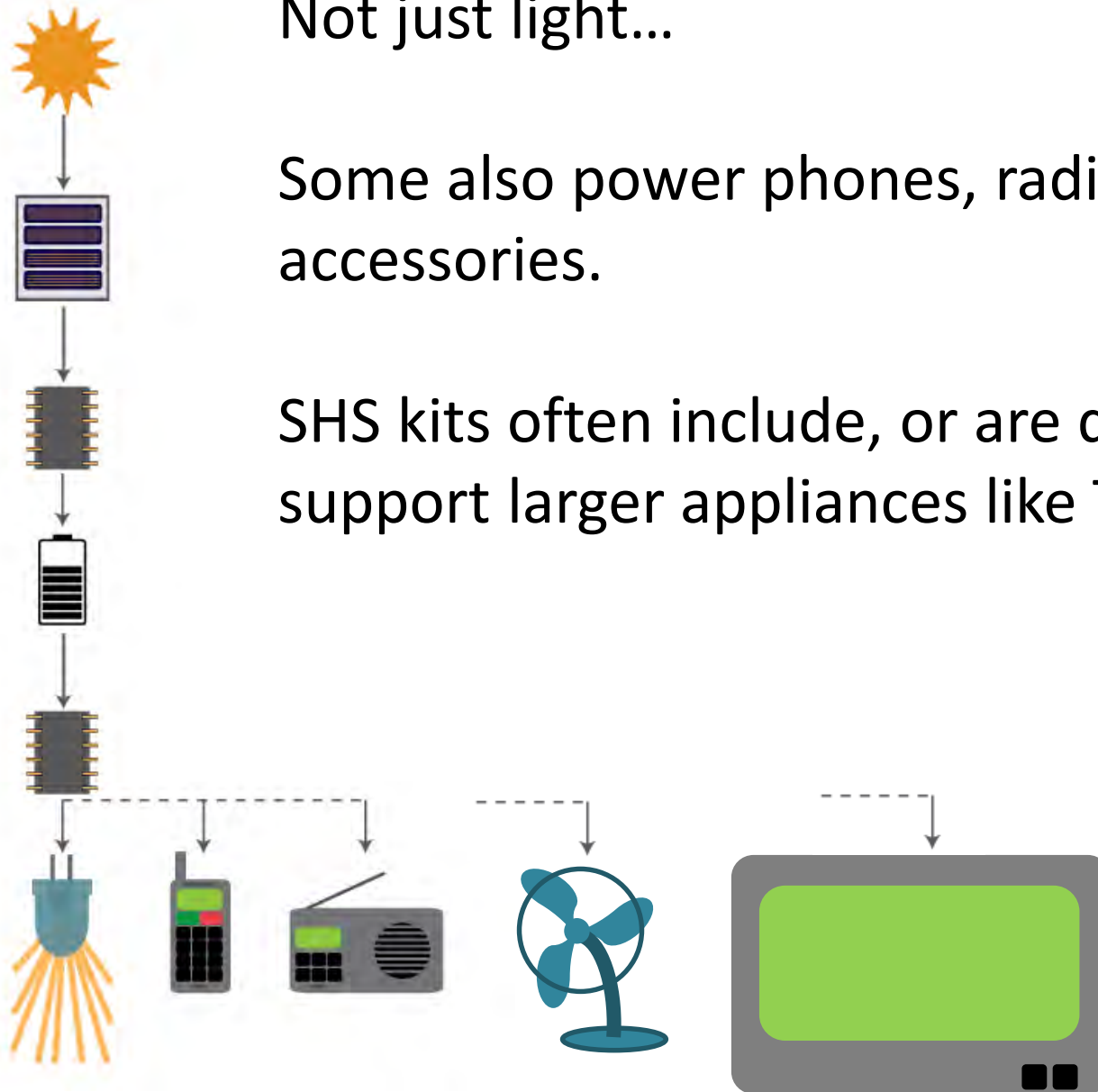


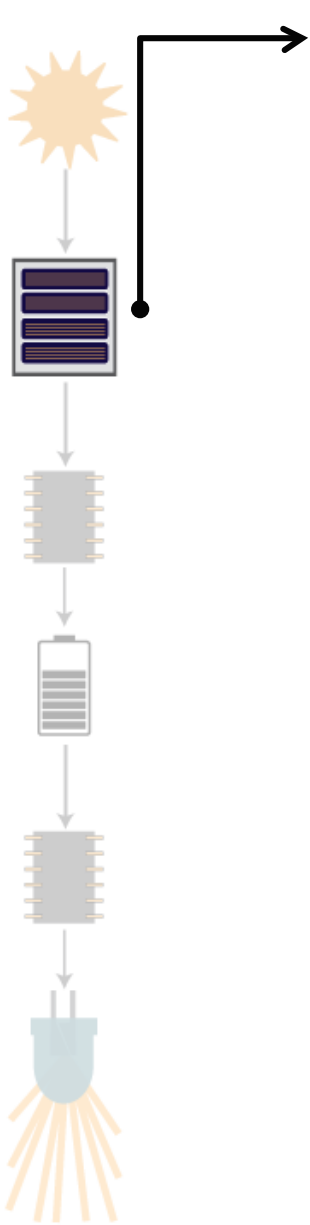
http://www.dlightdesign.com/products_the_solata_global.php

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.

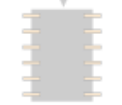
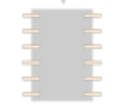




Solar Panels

- 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



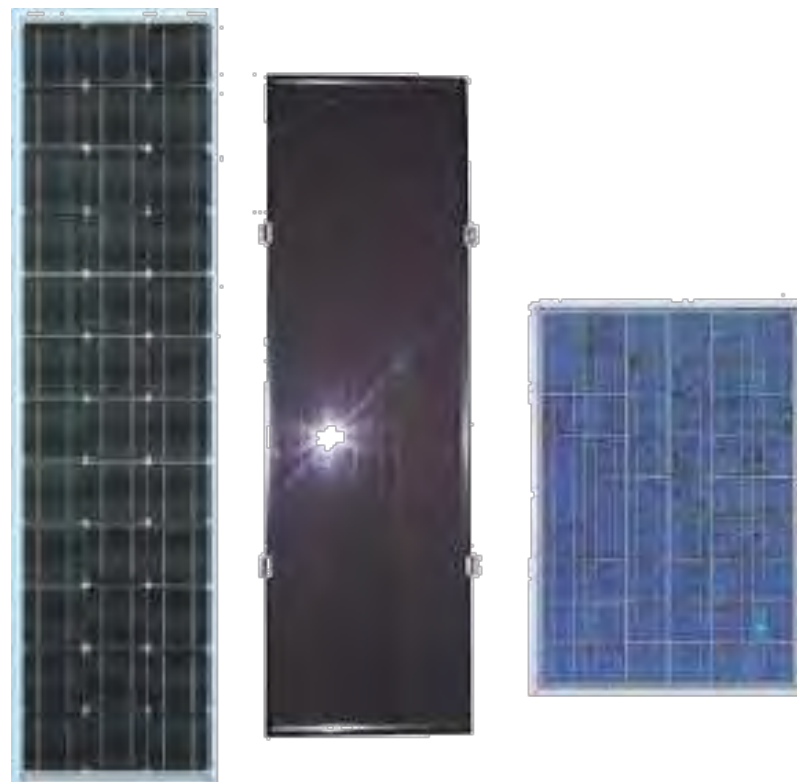
- Usually are not the “weak link” in the solar lighting chain; can last **20 years or more**.

- **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)**

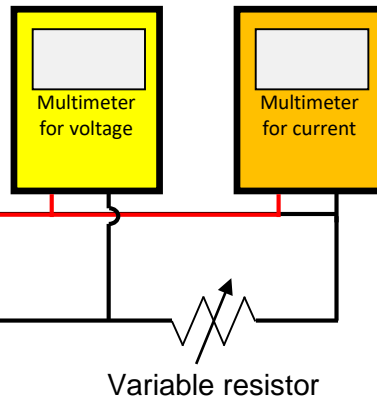
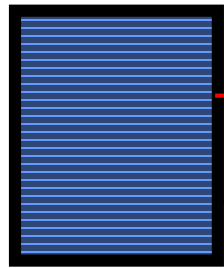


Monocrystalline, thin film and polycrystalline modules

Generating an IV Curve

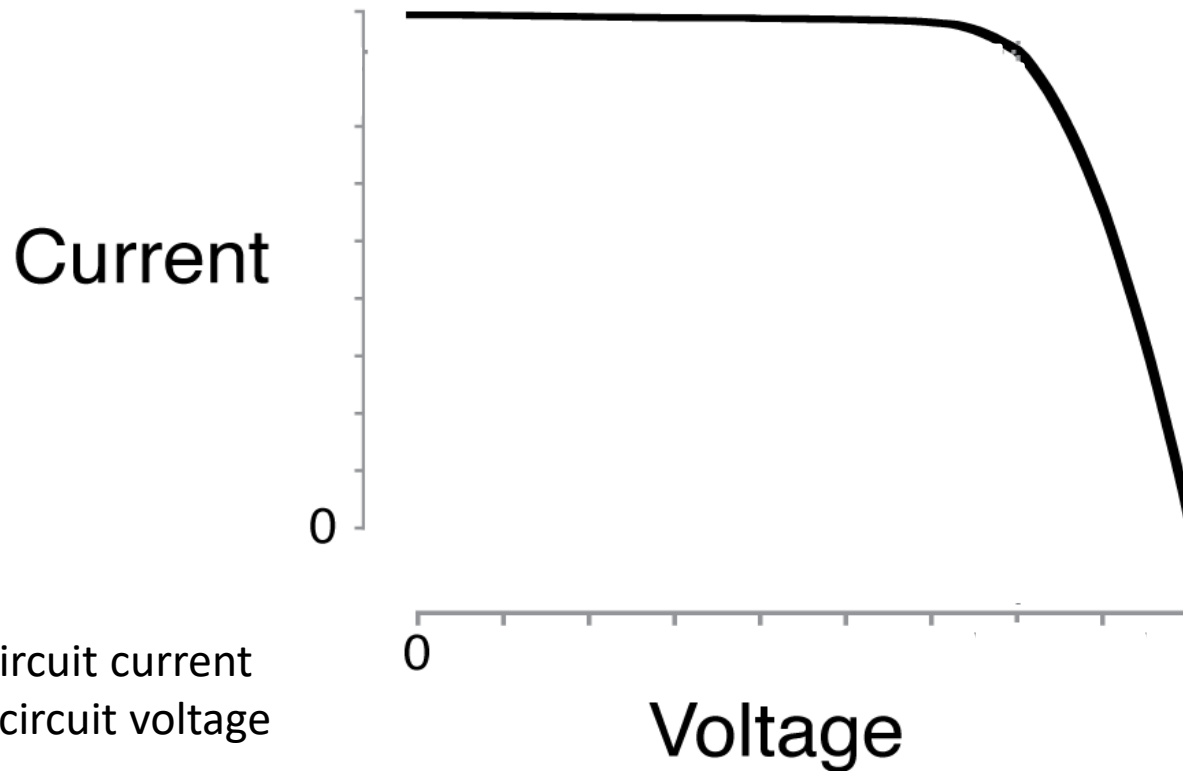


PV module



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

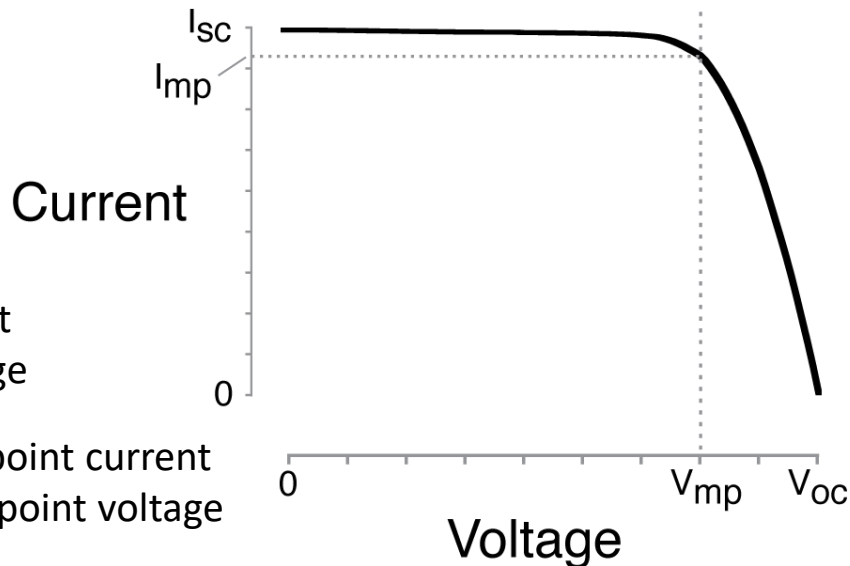
V_{mp} = maximum power-point voltage

IV Curve Example

← i_p = maximum power

Multiply the current and voltage pairs

$$P = V * I$$

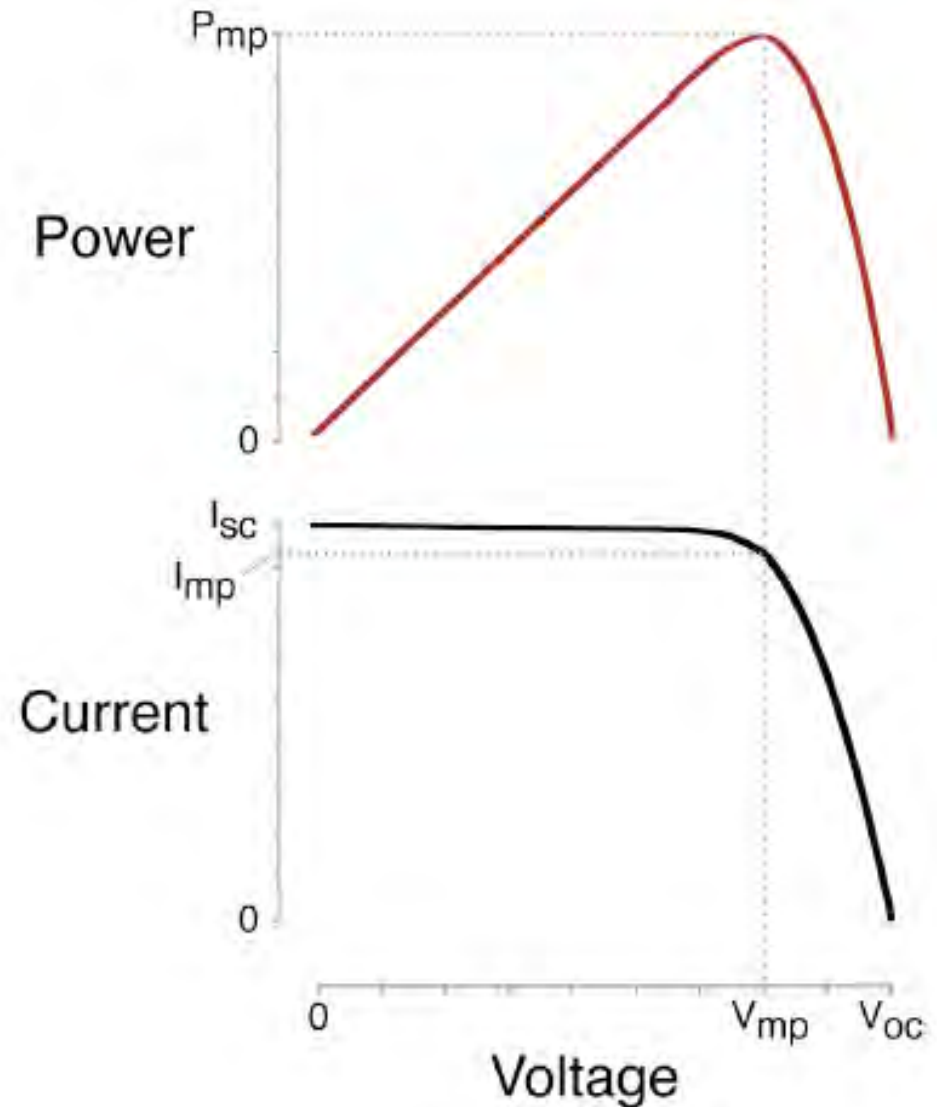


I_{sc} = short circuit current
 V_{oc} = open circuit voltage

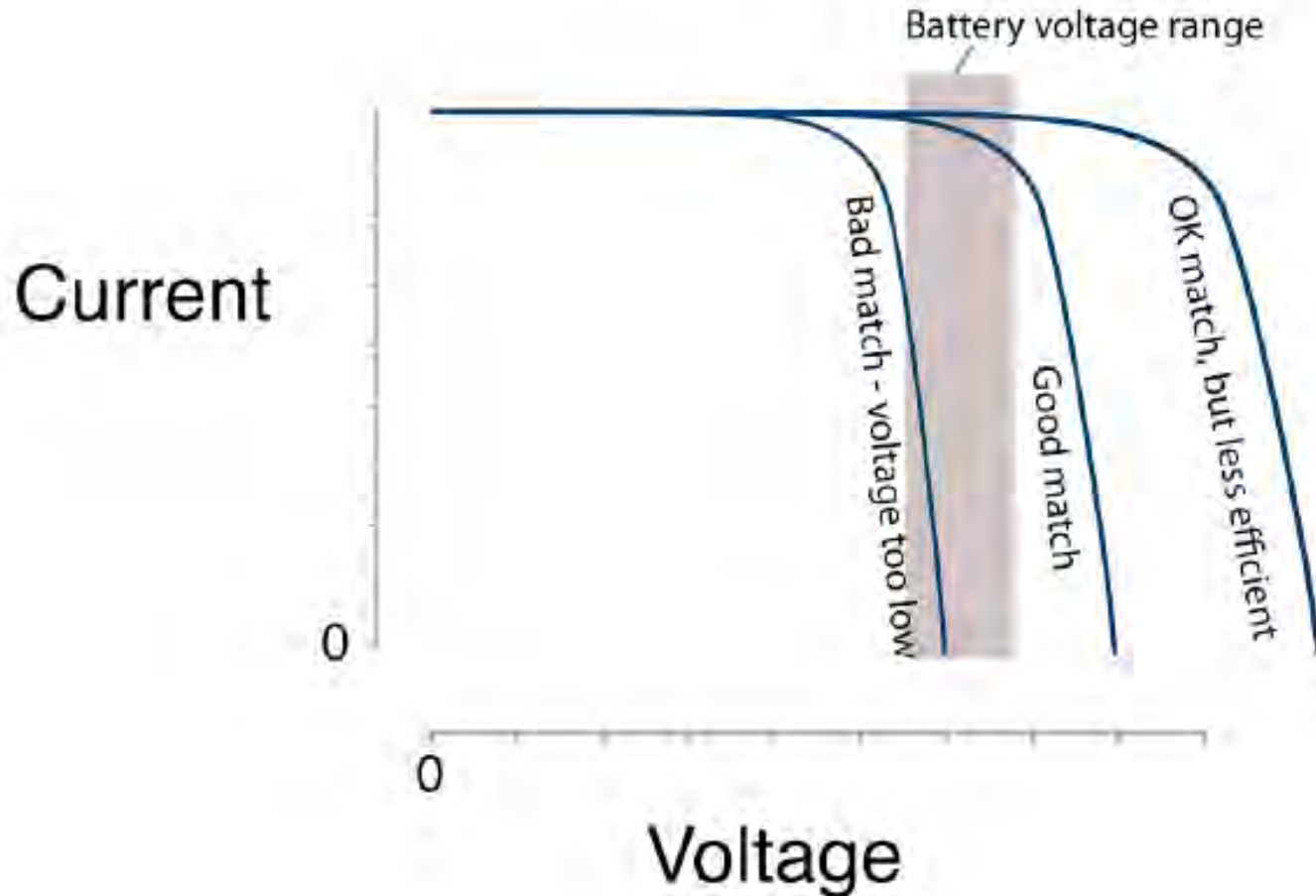
I_{mp} = maximum power-point current
 V_{mp} = maximum power-point voltage

Matching PV module and battery operating voltages: the I-V Curve

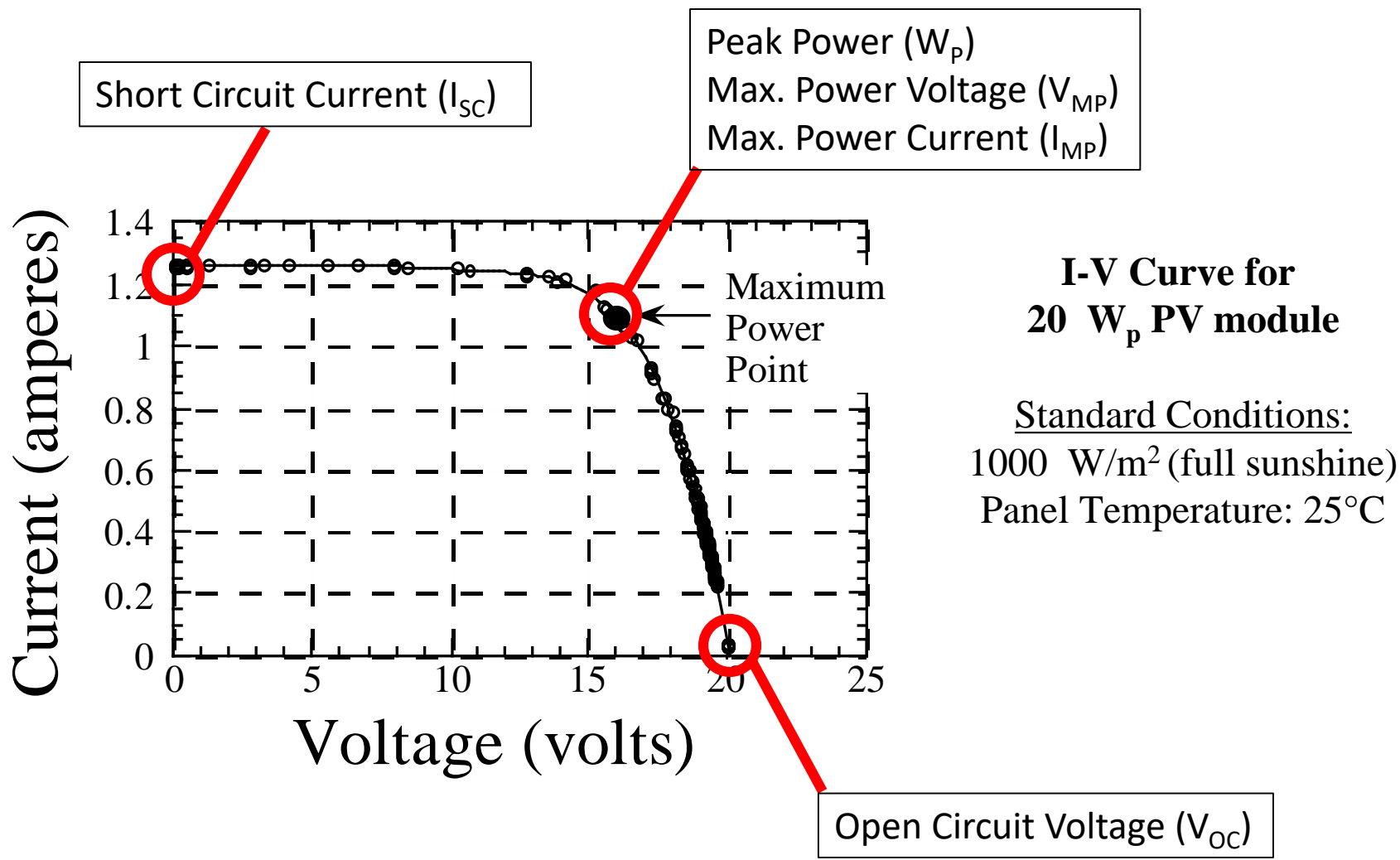
Power = Voltage x Current
($P = VI$)



Matching PV module and battery operating voltages: the I-V Curve

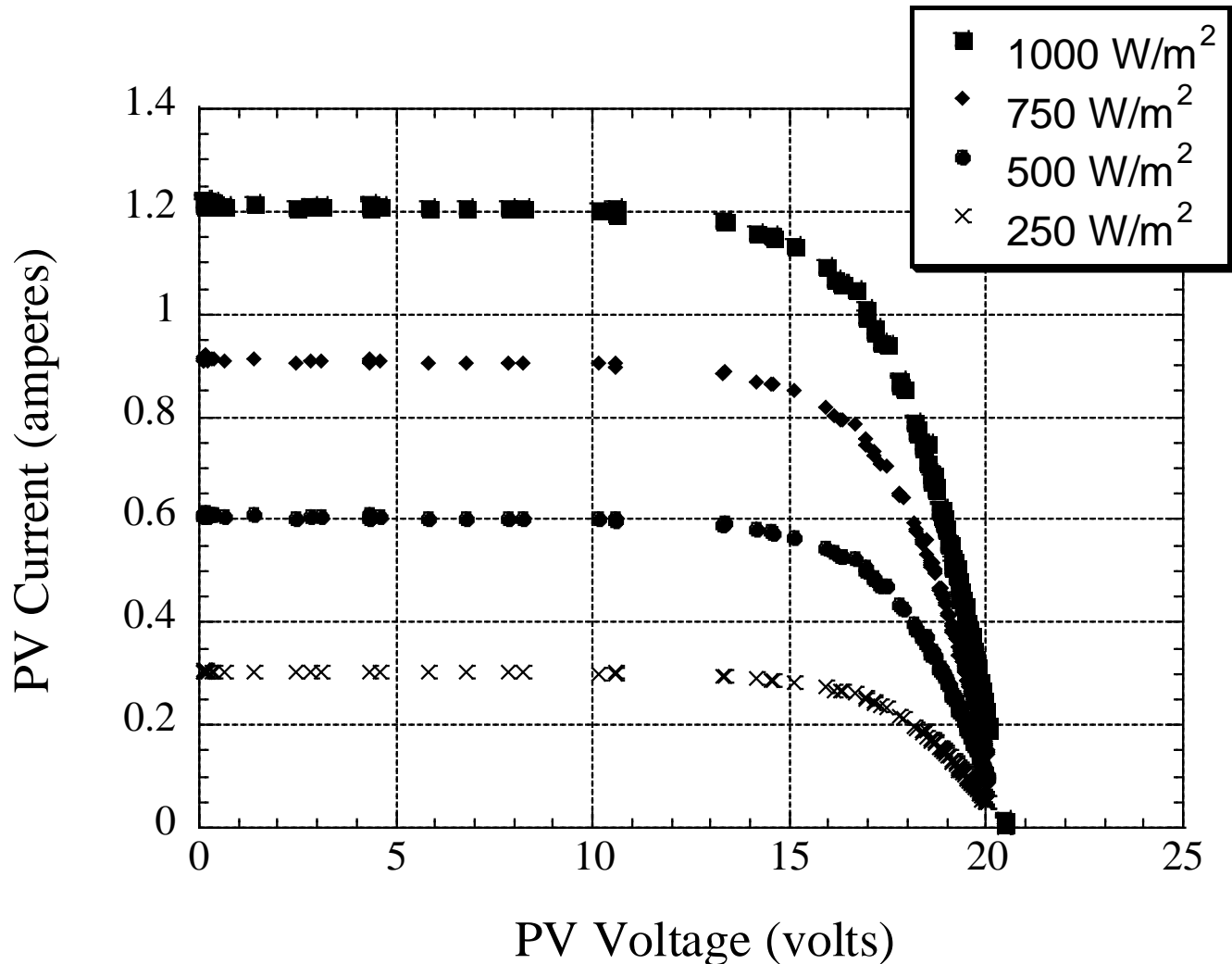


PV Module Performance and the I-V Curve



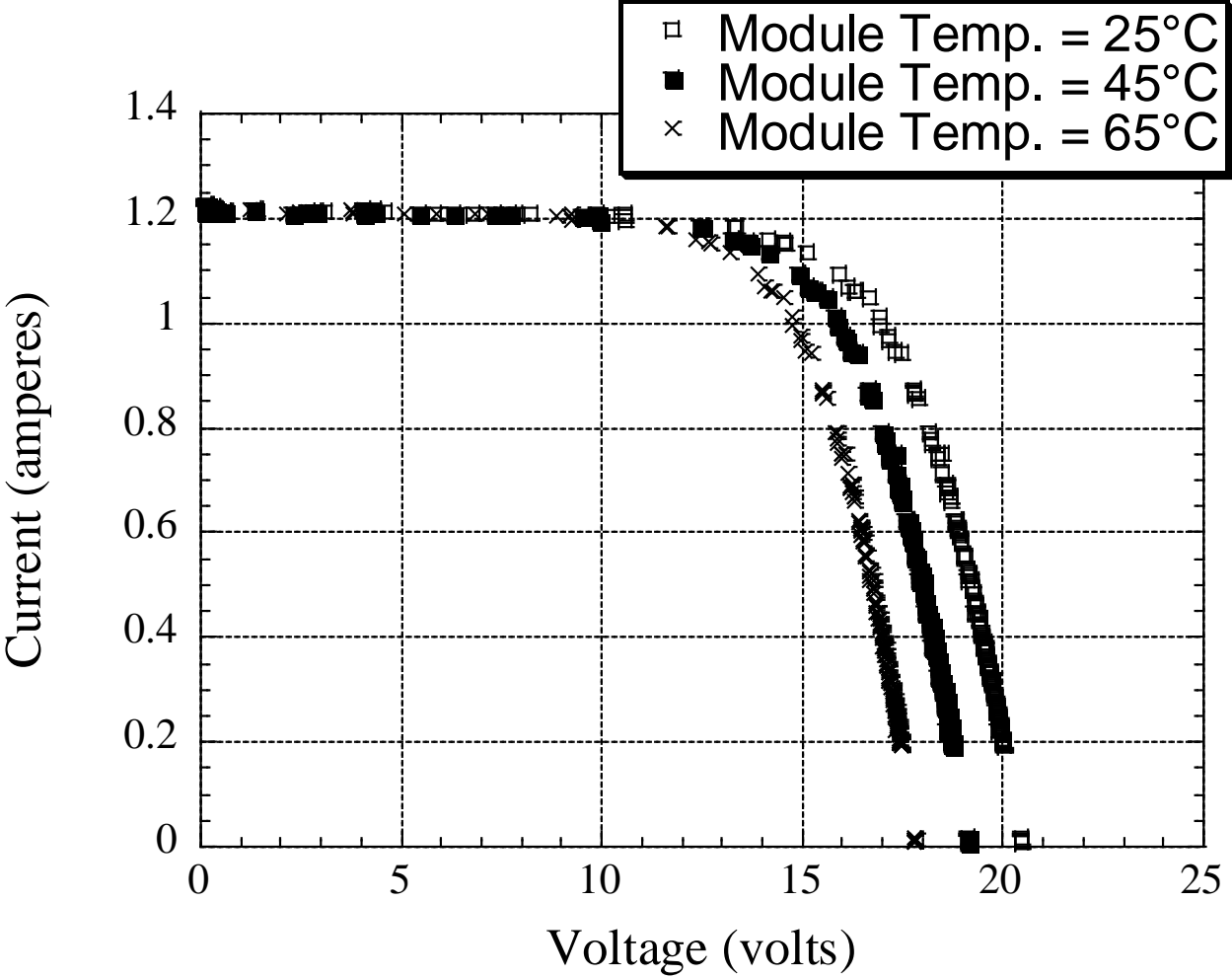
Effect of Sunshine on PV Module Output

(PV current is proportional to solar radiation)

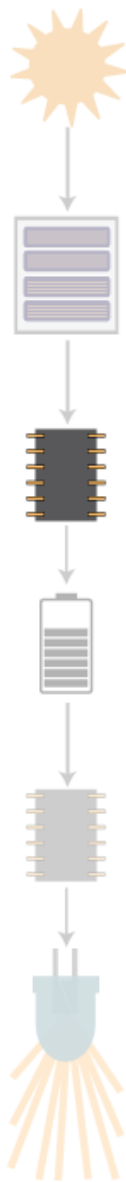


Effect of Temperature on PV Module Output

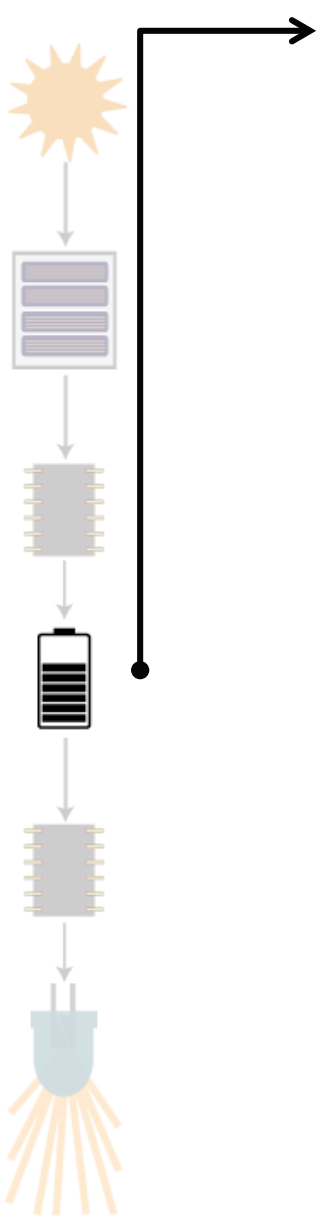
(Voltage decreases at higher temperatures)



Charge control circuit



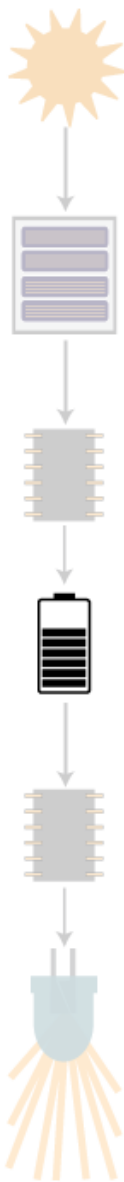
- **Protects battery**
 - Regulates power input
 - Prevents over-charge and over-discharge
- Specific designs for each battery with special voltage setpoints
- There is a large range of features; common terms you might hear are:
 - Maximum Power Point Tracking (MPPT)
 - Pulse-Width Modulation (PWM)
 - 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

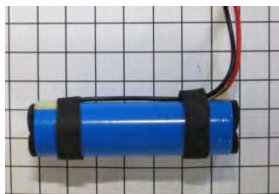
Battery



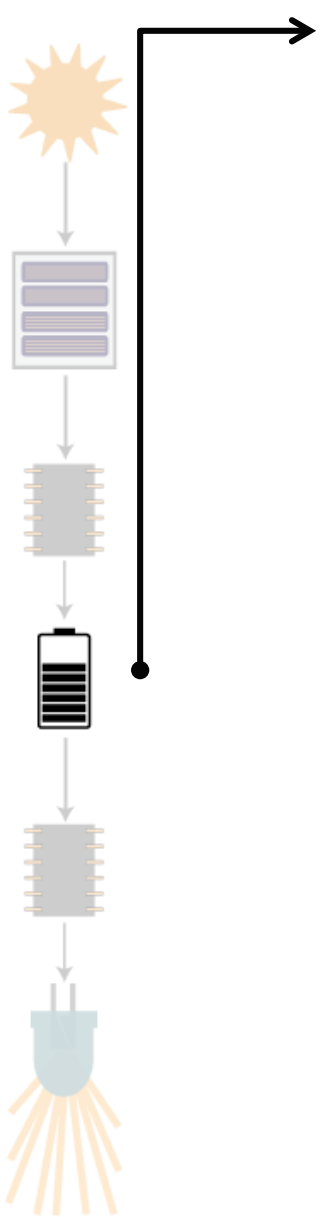
- **Sealed lead-acid (SLA)**
 - Cheap, heavy
 - Harmed by over-discharging or lack of charge; requires periodic “top-off” charge.
- **Nickel-metal-hydride (NiMH)**
 - Harmed by overcharging; should be “fully cycled” to maintain.
- **Nickel Cadmium (NiCd)**
 - Not allowed by Lighting Global
- **Lithium Ion (Li-ion) and Lithium Iron Phosphate (LiFePO₄)**
 - Very common, lightweight and high performance



Battery Characteristics by Chemistry



Battery Type (Chemistry)	Voltage per cell (V)	Cycle Life (Cycles)	Self Discharge (% / month)	In Use Since	Toxicity
SLA	2	200 - 300	5	1800s	High
NiCd	1.2	1000	20	1950	High
NiMH	1.2	300 - 500	30	1990	Low
Li-ion	3.7	500 - 1000	< 5	1991	Low
LiFePO ₄	3.3	1000 - 2000	< 5	1999	Low



Battery Failures

Lifetime depends on how well they are treated:

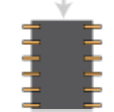
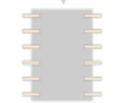
- Charge / discharge rate & voltage
- Temperature
- Storage

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.

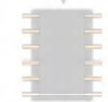
Lithium last 5-10 years and are the most durable, but require more complex charging circuits. Dangerous if overheated.

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.

Loads



- **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

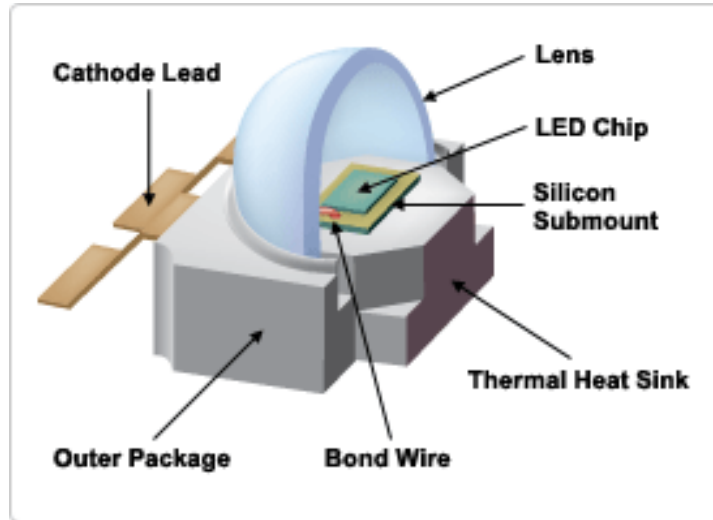
LED Lights



- **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.

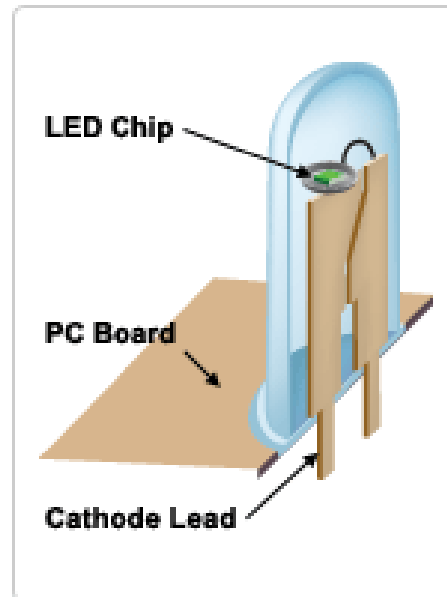


Two key types of LED



Surface Mount

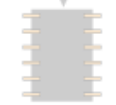
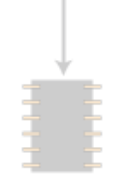
- Often higher power / brightness
- Better efficiency
- More expensive
- Requires “heat sink”



Through-hole

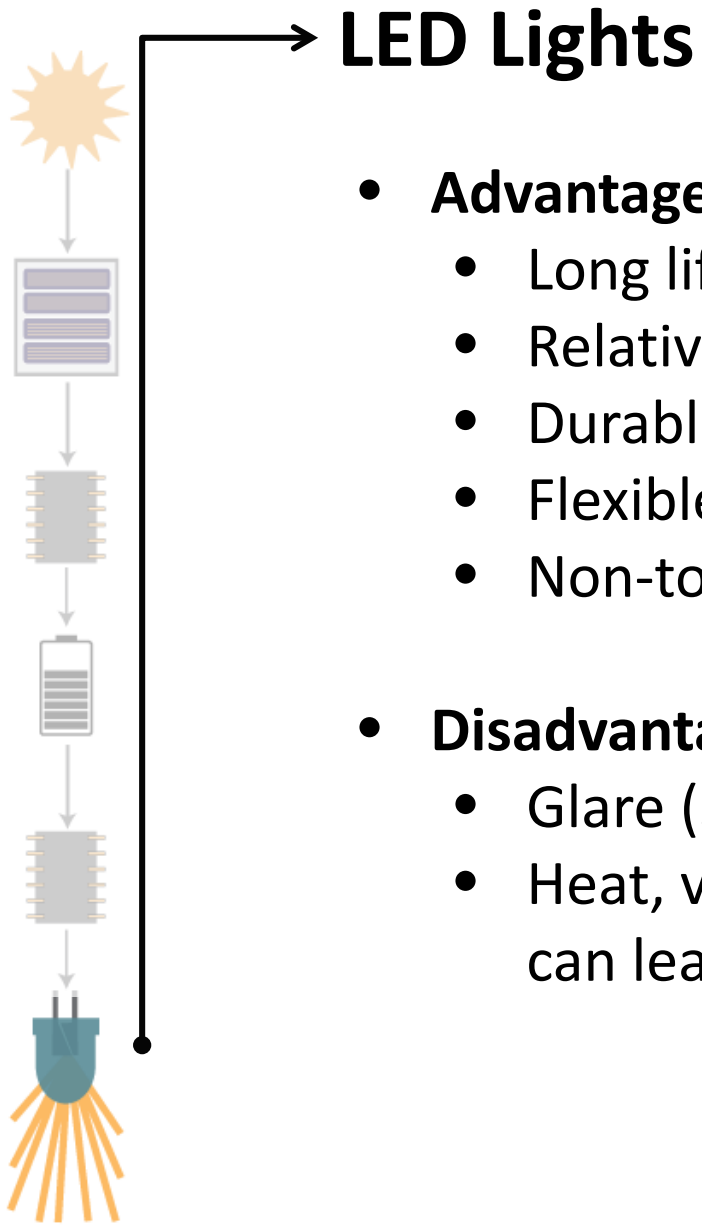
- Requires more to get same light
- Older design – also used for indicator lights
- Less expensive

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.



- **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:

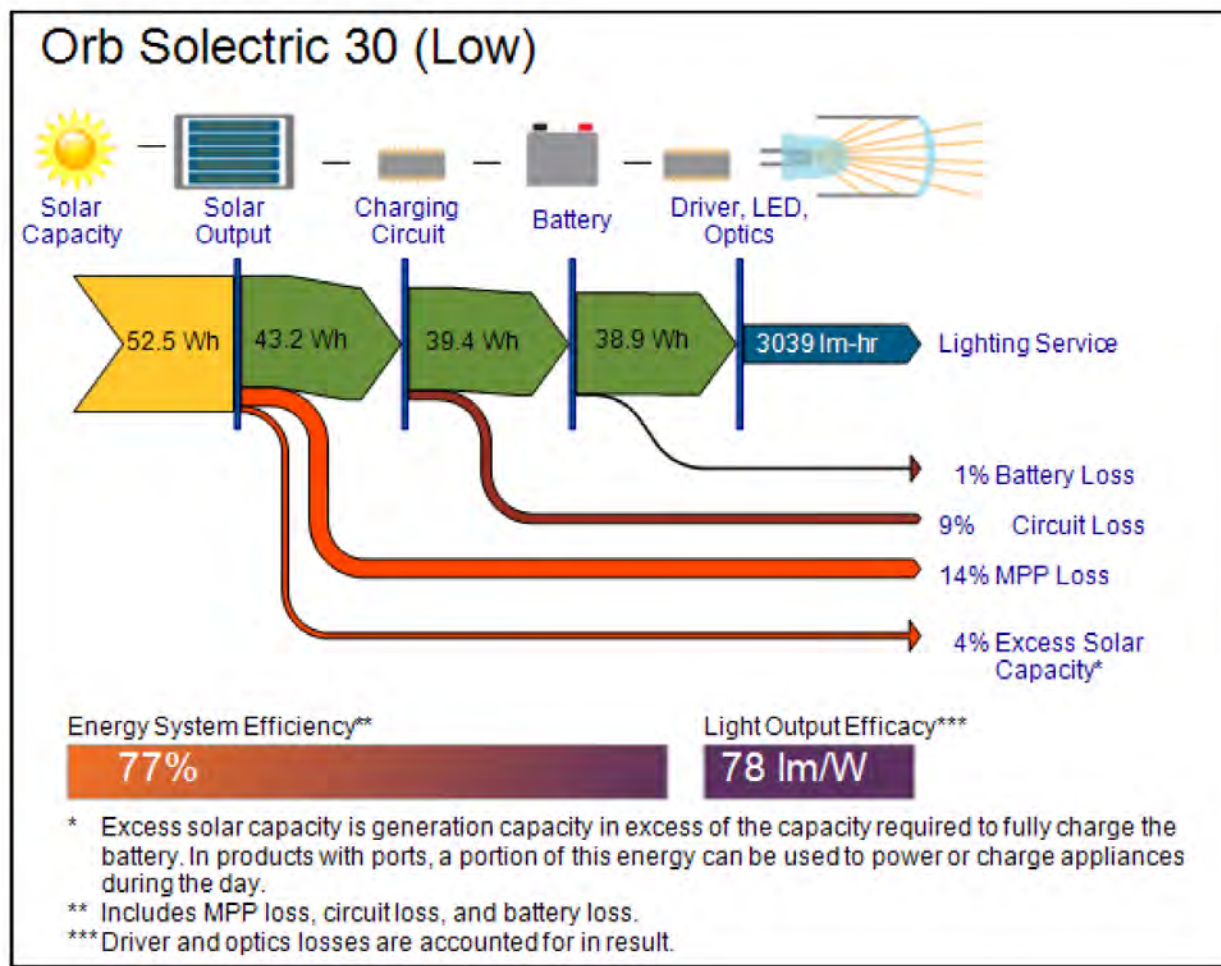
- Overheating / bad heat dissipation
- Optics can get cloudy

Good designs can last 30,000 hours + (many years)

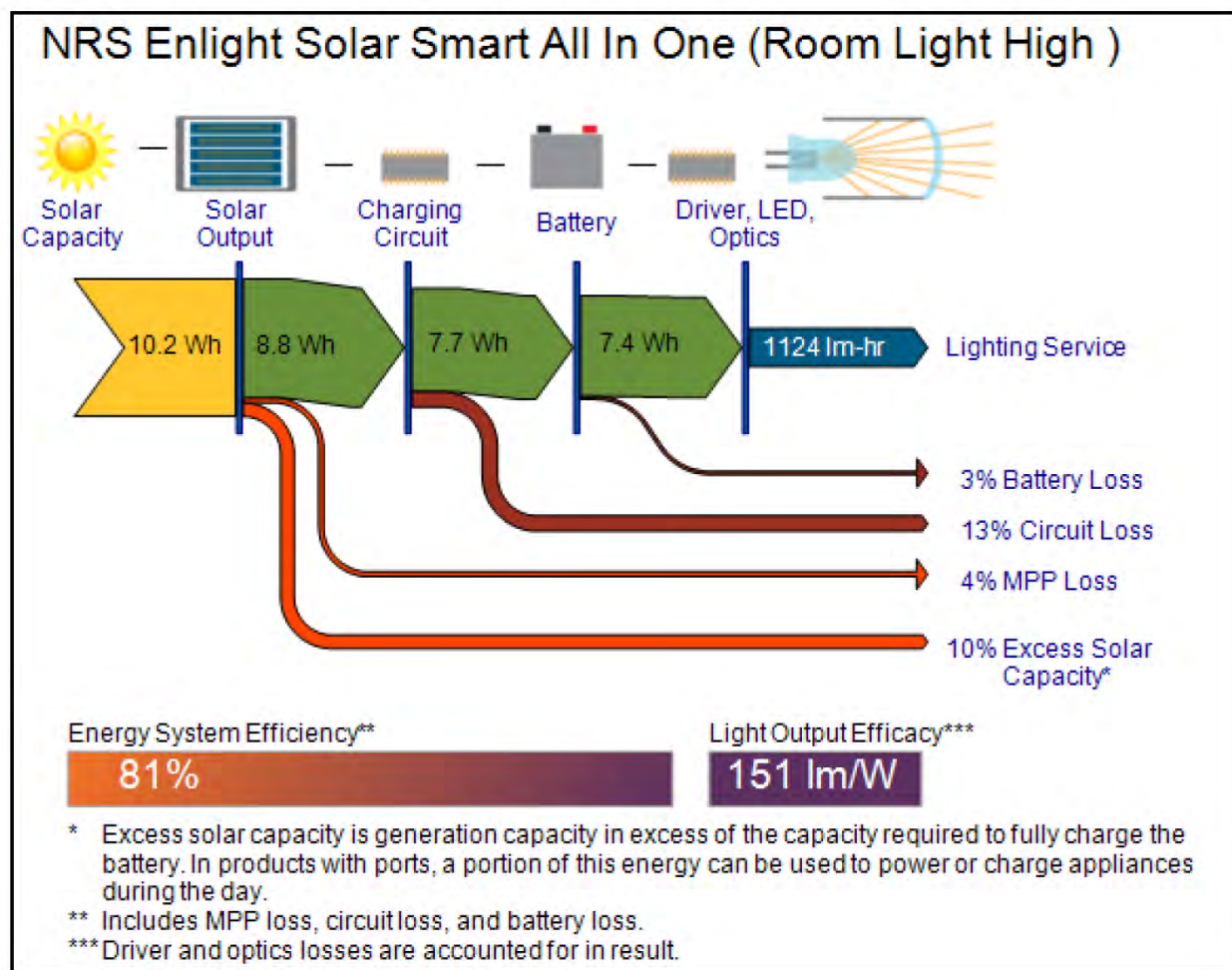
Bad designs only last a few months

All quality verified products last at least 2,000 hours – several years.

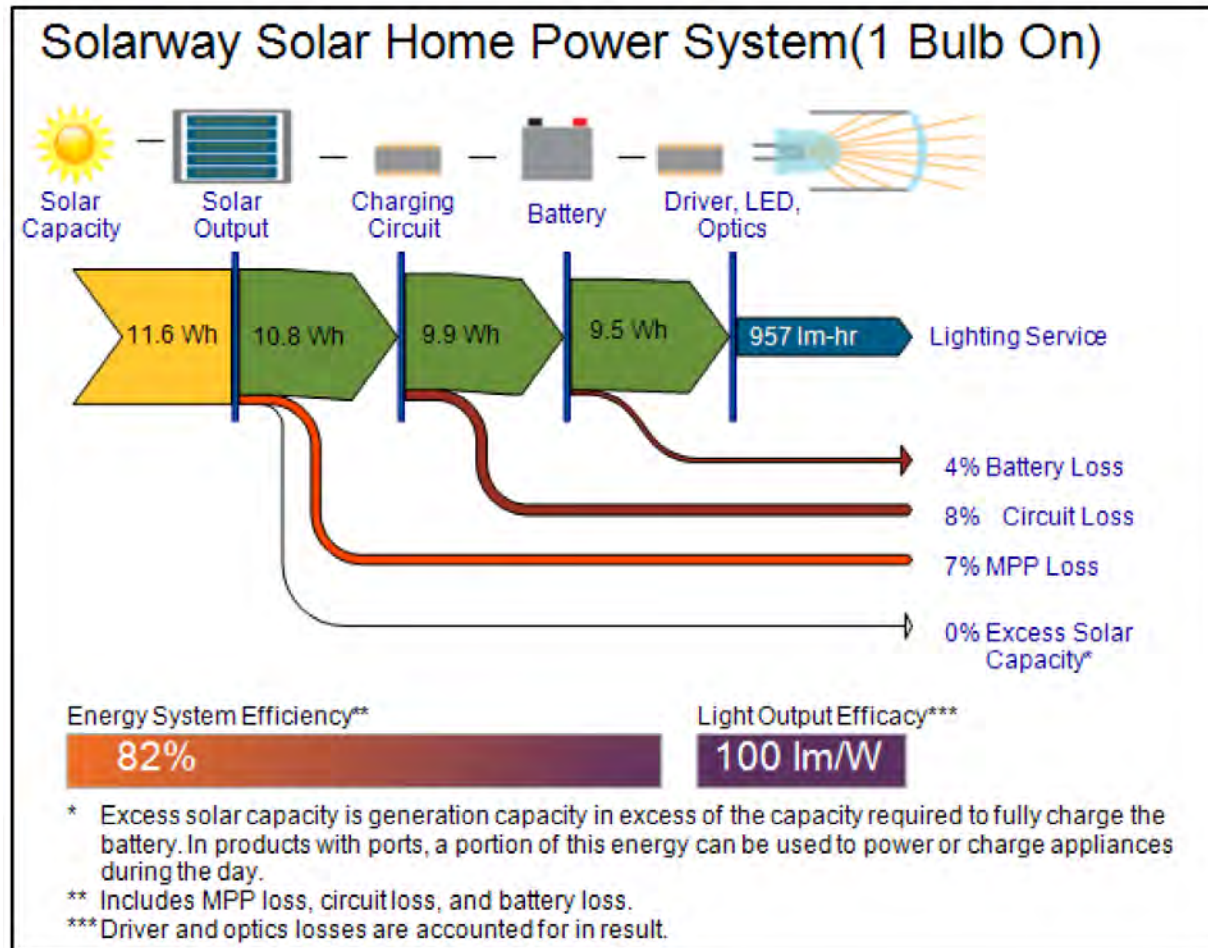
Example: Low Luminous Efficacy



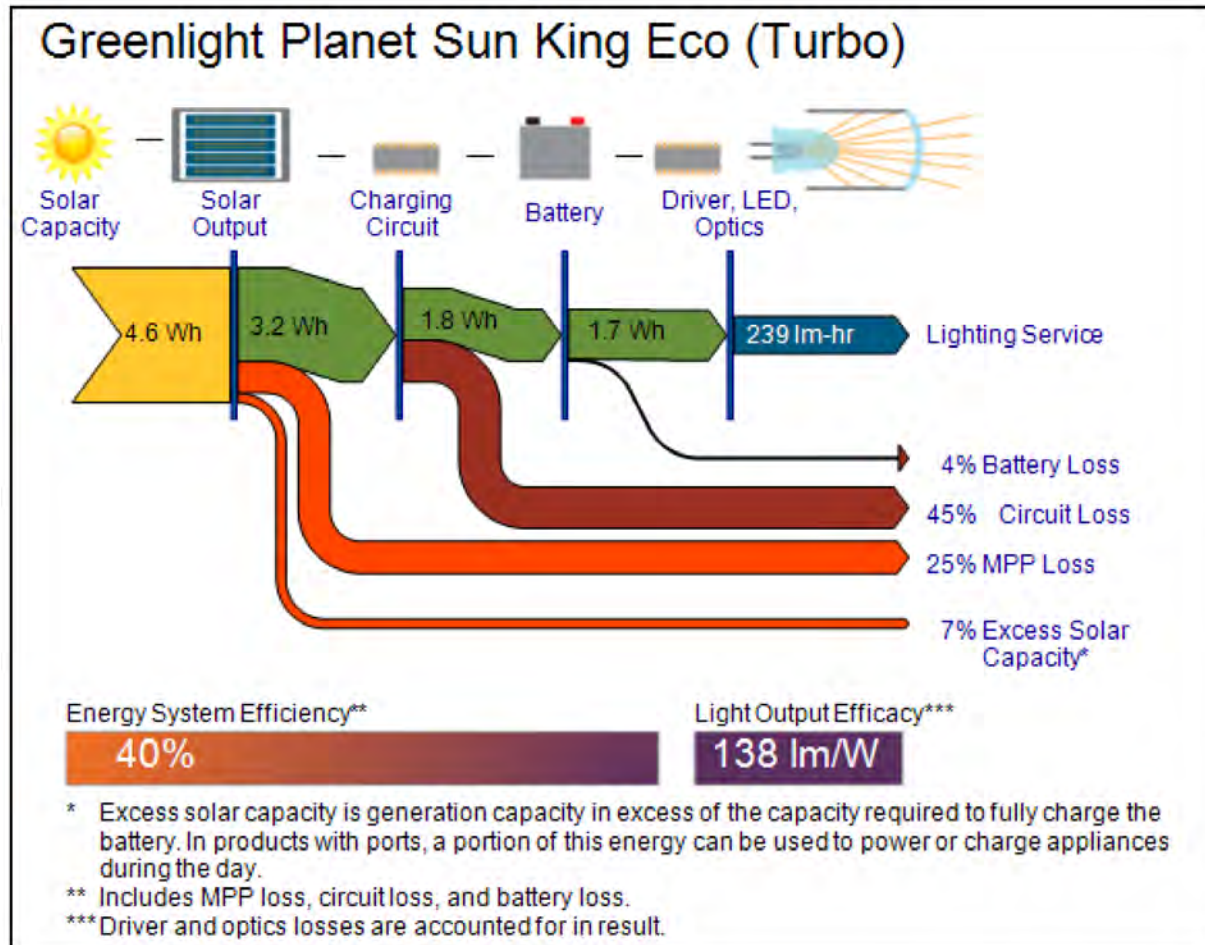
Example: High Luminous Efficacy



Example: High System Efficiency



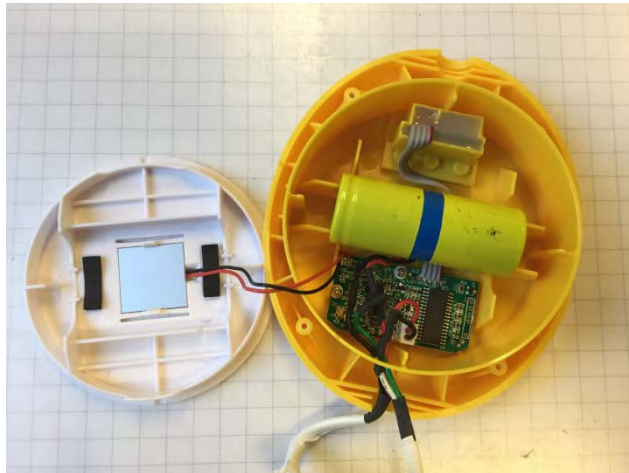
Example: Low System Efficiency



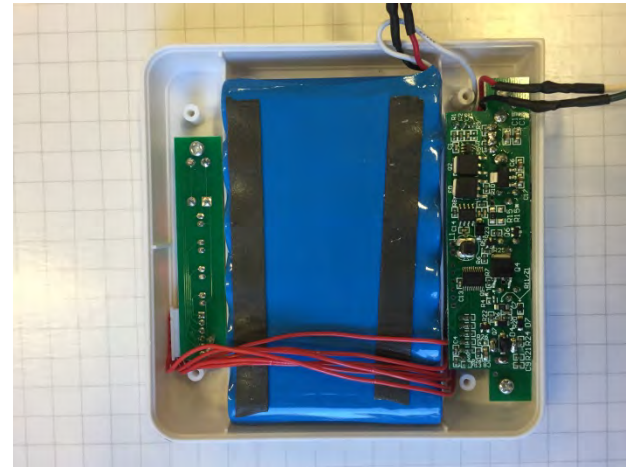
How does it all work?

Open up your product!

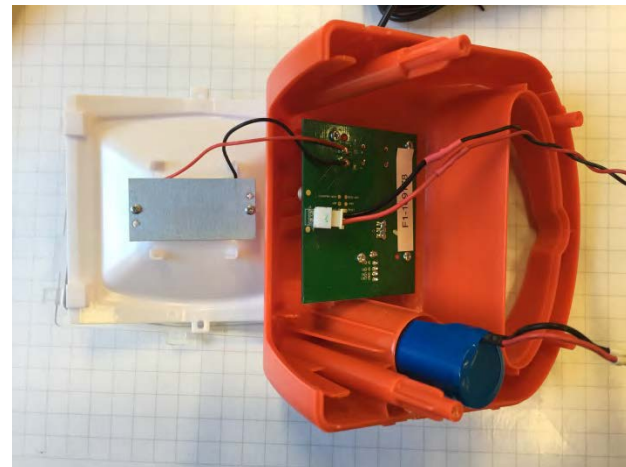
Greenlight Planet
Sun King Pro



Futura Energy Station

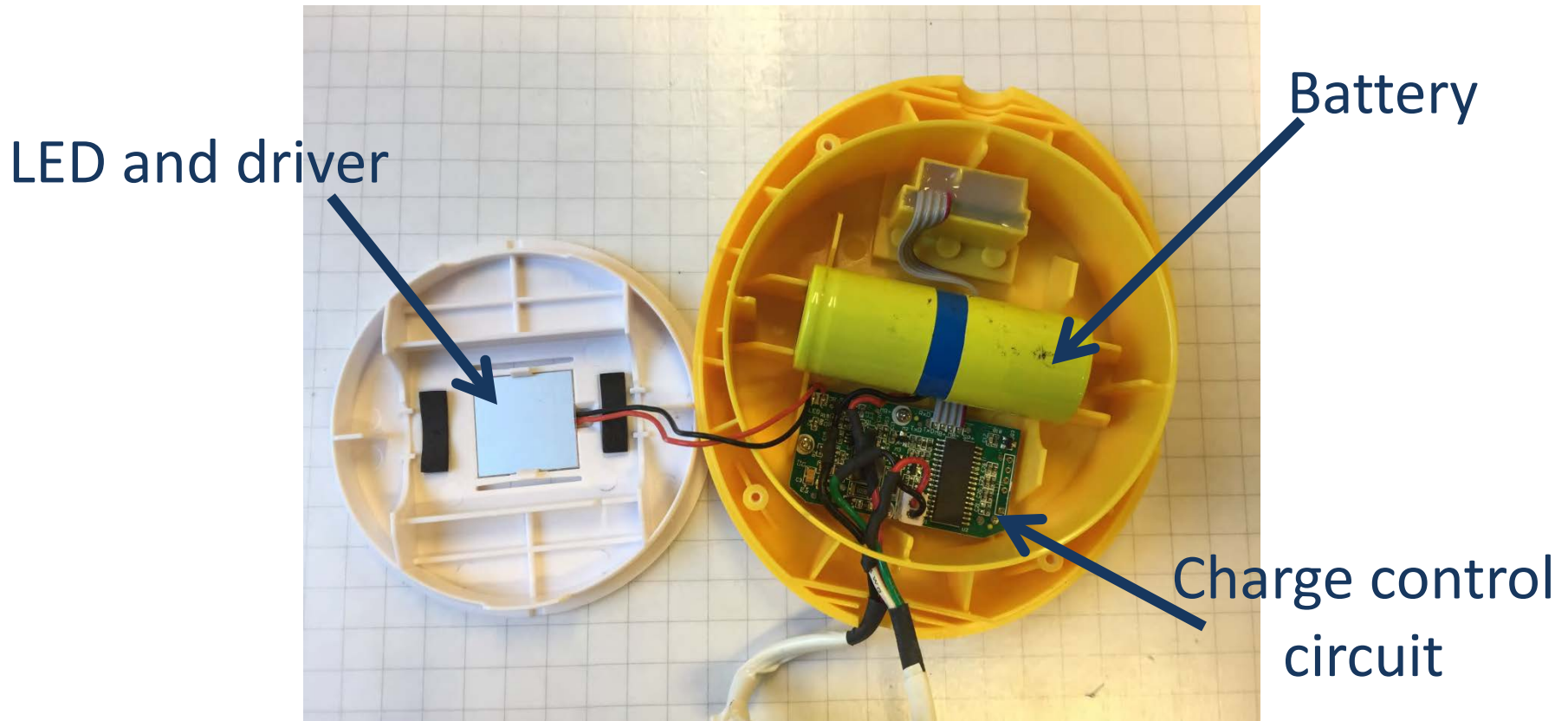


d.light S300

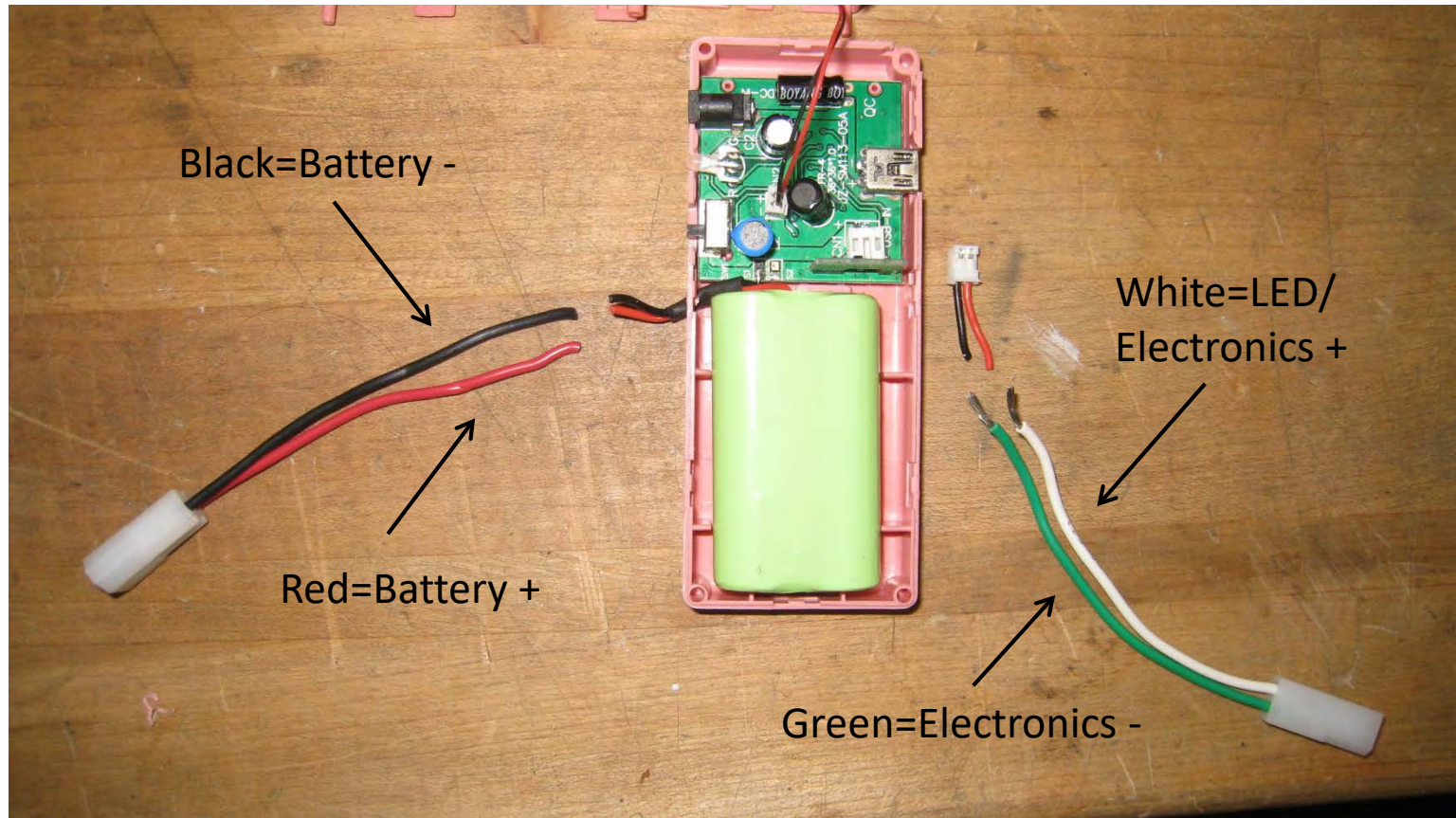


Identify the components!

Greenlight Planet Sun King Pro



Why are there wires sticking out of the product?



These wires are for testing.

Section B: Lab Visit

Summary

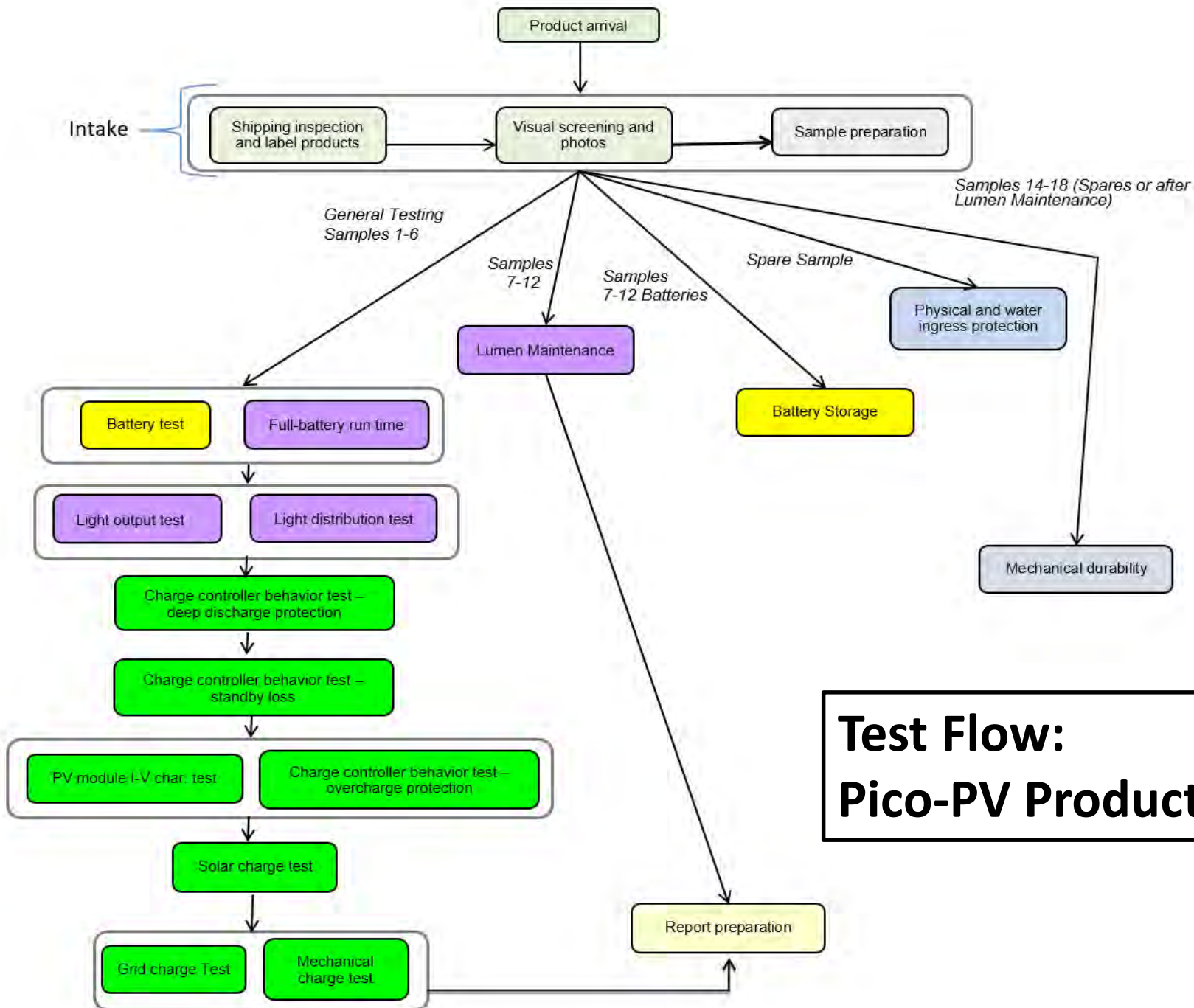
- Introduction
- Review pico-PV test procedure
- Explain testing flow diagram
- Follow samples through process, summarizing measurements/evaluation at each step

Summary of Pico-PV Test Procedure



Technical Specification
62257-9-5

Component Tests	Sampling	<ul style="list-style-type: none"> Randomly selected from warehouse or marketplace
	Photometrics	<ul style="list-style-type: none"> Luminous flux (lumens—total output) Standardized distribution (illuminance)
	Battery & Charge Control	<ul style="list-style-type: none"> Battery Capacity (Amp-hours, voltage) Degree of protection (voltage cutoffs)
	Solar Module	<ul style="list-style-type: none"> Power output (Watts) Current-voltage characteristics (I-V Curve)
System Tests	Full Battery Run Time	<ul style="list-style-type: none"> Measured using standardized cycle (hours of operation)
	Solar Charge Run Time	<ul style="list-style-type: none"> Modeled estimate (daily hours of operation after solar charging)
	Physical Ingress & Water Protection	<ul style="list-style-type: none"> Incorporates enclosure (IP class) and system-level protection (coatings, etc.)
	Durability	<ul style="list-style-type: none"> Drop test from one meter (pass/fail) Switch and connector durability Internal wiring and solder inspection Lumen Maintenance Battery durability storage test



Test Flow: Pico-PV Products

Test Flow: SHS Kits

