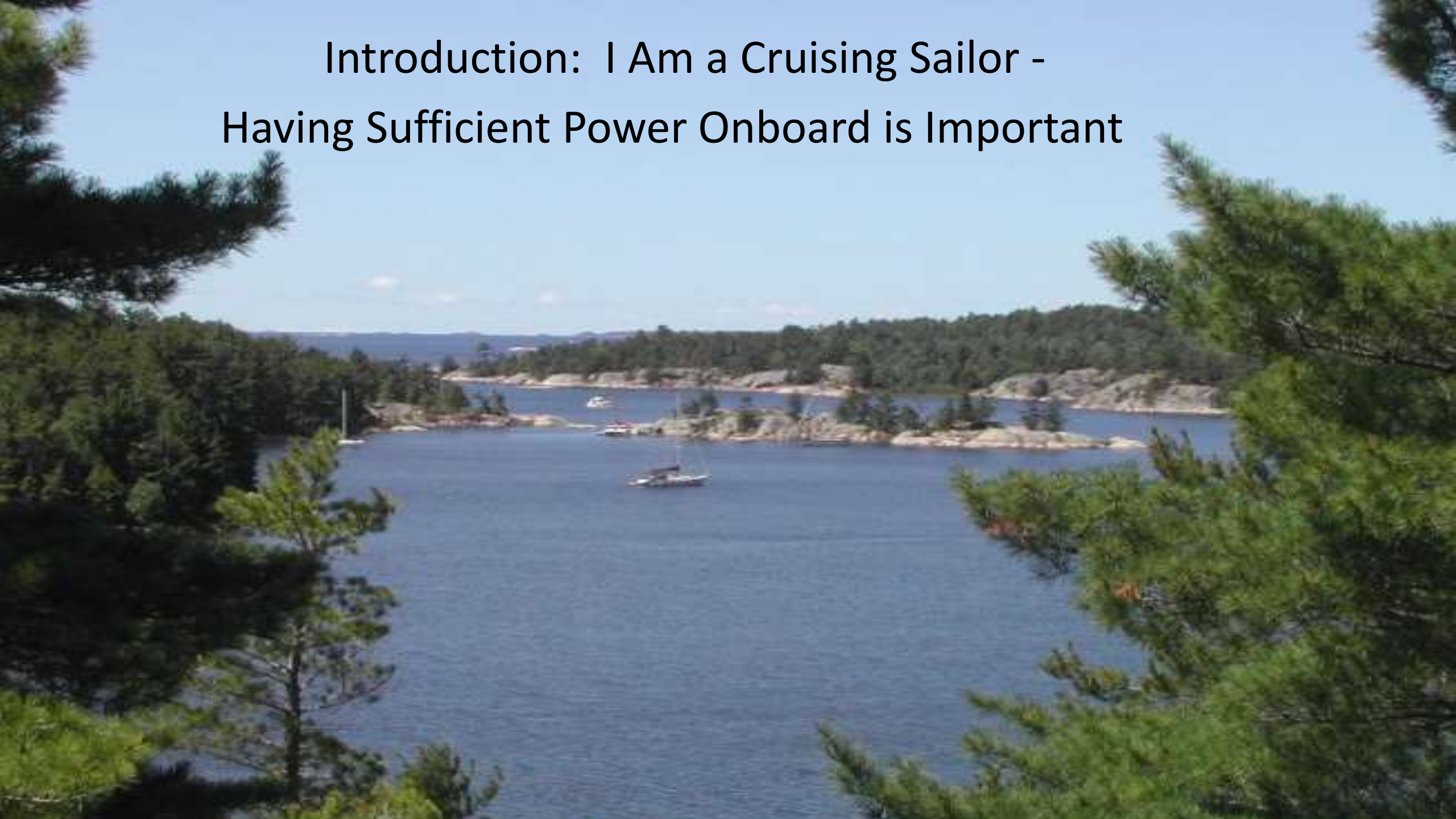


# *Designing the Proper Solar System for Your Boat*



Tom Trimmer  
Custom Marine Products  
2026

# Introduction: I Am a Cruising Sailor - Having Sufficient Power Onboard is Important





# Topics for Discussion

## Section 1 –

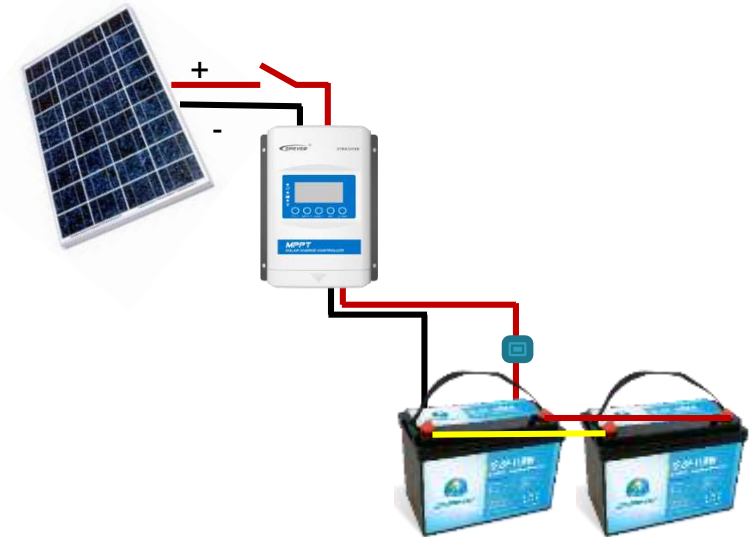
- Introduction to PV solar panels
- Introduction to solar controllers
- What is a balanced solar system?

## Section 2 -

- Designing your solar system
  - A case study
- Selecting the proper equipment

## Section 3 -

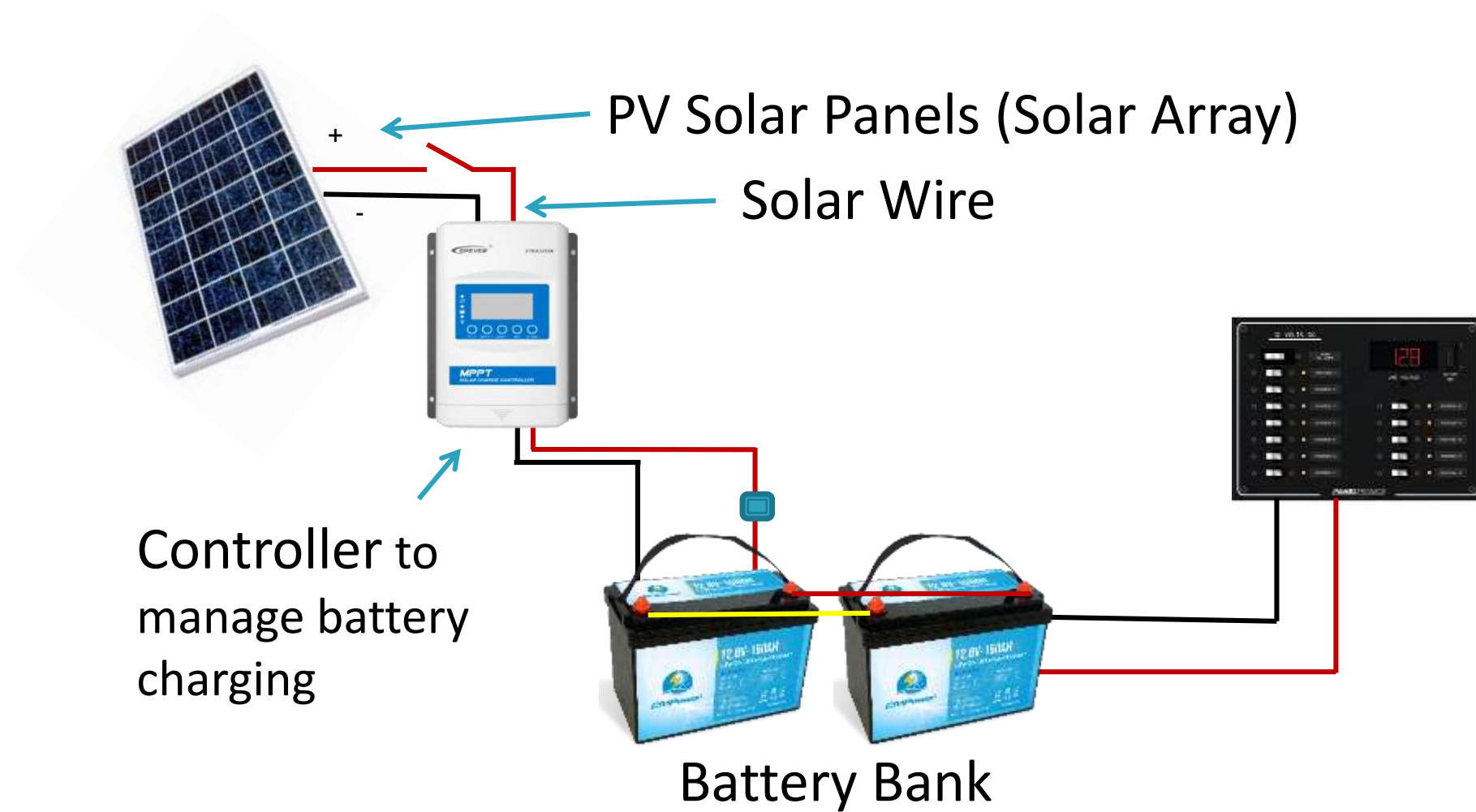
- Installation and wiring considerations
- Q & A



Slides at: [custommarineproducts.com](http://custommarineproducts.com)  
Handy Info, System Design

# Components of a Mobile PV Solar System

(PhotoVoltaic)



# A Few things to Know About PV Solar Panels

(PhotoVoltaic)

**Monocrystalline, Polycrystalline or Bifacial?**

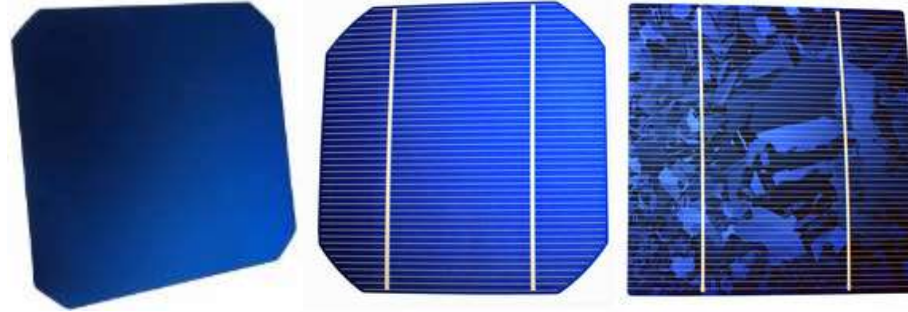
**Grade A or B or C?**

**Rigid, Semi-rigid or Semi-flexible?**

**Commercial or Marine?**



# Monocrystalline or Polycrystalline or Bifacial?



## Monocrystalline

- Cell efficiency typically 16 % to 25.5%, thus highest power generation
- More expensive than polycrystalline (\$3 - \$9 per watt)
- Front contact vs back contact (SunPower, PERC, HJT) solar cells

## Polycrystalline

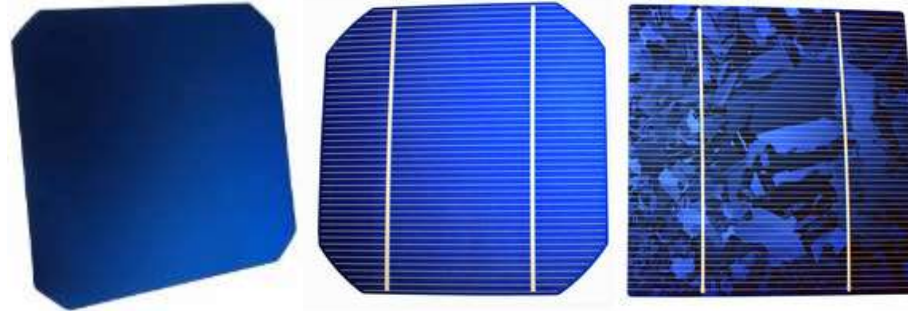
- Cell efficiency typically 12% to 18%
- Less expensive than monocrystalline (\$2 - \$5 per watt)

## Bifacial

- Power generation on both sides of the cells using reflected light (up to 20% gain)
- Limited application in the marine environment

Cell Efficiency – Amount of light energy converted to electrical energy

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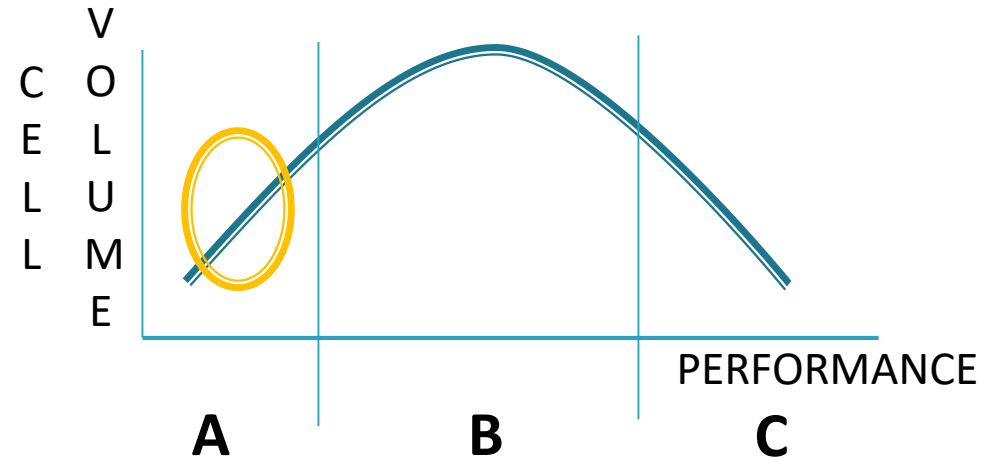
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## Bifacial

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Cell Efficiency – Amount of light energy converted to electrical energy

# Grade A or B or C?



## All solar cells are not created equal

- Cells are graded under a standard artificial light and sorted by power output.
- The distribution of performance is a Bell Curve with most cells being a B grade.
- **Grade A will typically perform above rating in full sun light.**
- Grade B is typically used for residential and solar farms.
- **Grade A+ is desirable on a boat where space is limited.**

We want maximum output per square inch.  
SunPower makes four grades of solar cells.

# Rigid, Semi-rigid or Semi-flexible?

## Rigid panels

- Have a life span >18 years - robust
- Excellent for pole, arch, frame and davit mounting



## Semi-rigid panels

- Have a life span >11 years – robust
- Excellent for cabin top, rigid surface mounting
- Can be walked on



## Semi-flexible panels

- Have a life span >7 years
- Excellent for canvas bimini and rigid surface mounting
- Light weight



All *CMPower* panels use premium solar cells and have comparable performance within 5%.

# Rigid, Semi-rigid or Semi-flexible?

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- Have a life span >18 years - robust
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## Semi-rigid panels – walk-on

- Have a life span >11 years – robust
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# How is a Marine Solar Panel Different from a Commercial Solar Panel?

## Marine Solar Panel

- Junction box is filled with inert silicone to prevent corrosion
- Rigid panels have strong frames and extra sealants
- Panels have high power generation – Grade A+ cells
- Output compatible with marine battery bank systems
- Some panels are wired to accommodate shading
- Sized to fit constraints on boats

## Commercial Solar Panel

- Junction box not filled with inert material
- Frames designed for rack mounting
- Output typically 60+ volts
- Panel cells are typically Grade A- to B
- Warranty may be void for marine installations



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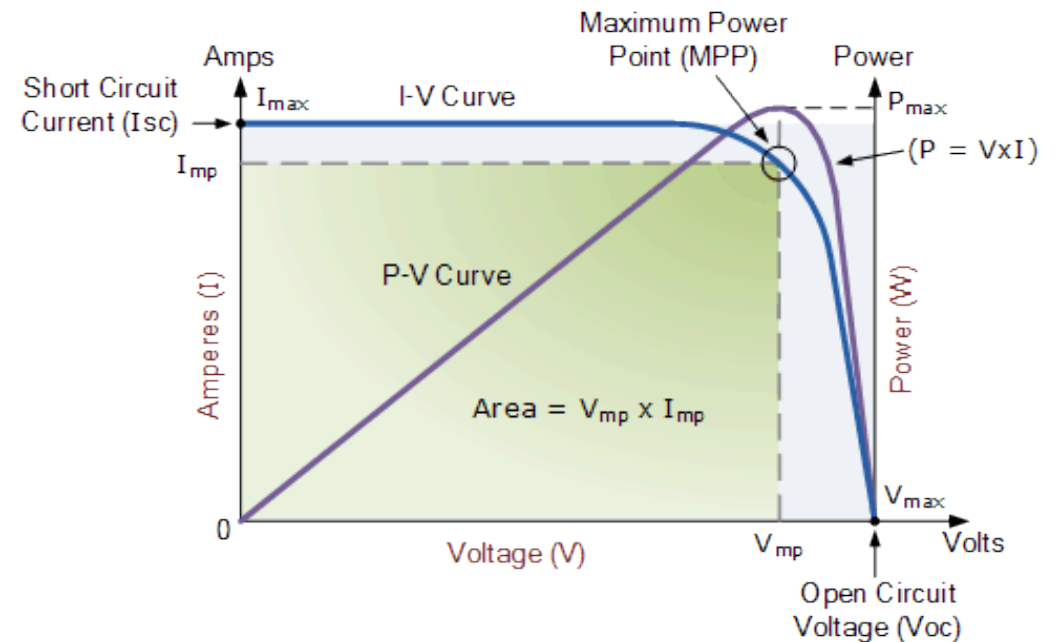
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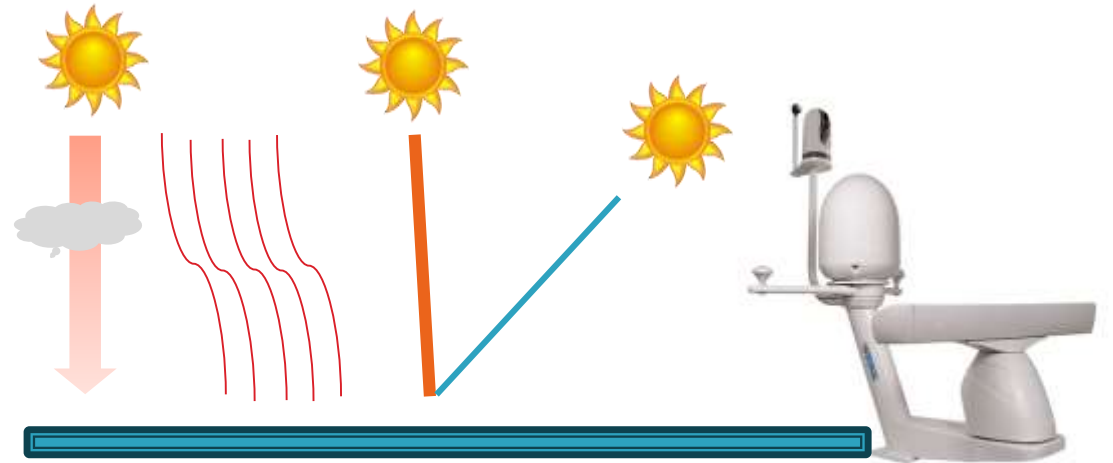
# PV Solar Panel Specifications – What to Look For

Nominal Peak Power (Pmax)	Maximum power point (Watts at STC)	130 W
Nominal Voltage (Vmp)	Voltage at maximum output power	22.3V
Nominal Current (Imp)	Current at maximum output power	5.8A
Open Circuit Voltage (Voc)	Maximum voltage output with no load	26.3V
Short circuit Current (Isc)	Maximum current (amps) output at zero voltage	6.8A
Cell Efficiency %	Amount of light energy converted to electrical energy	24.7%
Cell Manufacturer		
Panel Efficiency %		
Temp. Coefficient (%/°C)	% degradation per °C	



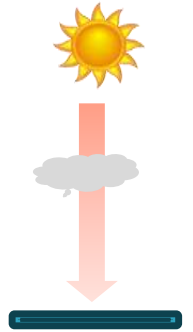
## PV Solar Panel Performance is Affected by the Following:

- Light intensity
- Solar cell temperature
- Sun angle of incidence
- Shading
- Quality of the solar cells

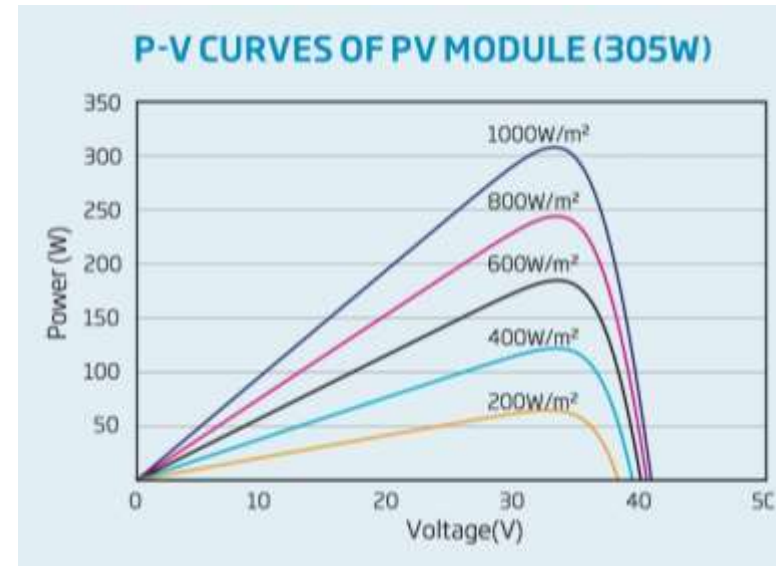
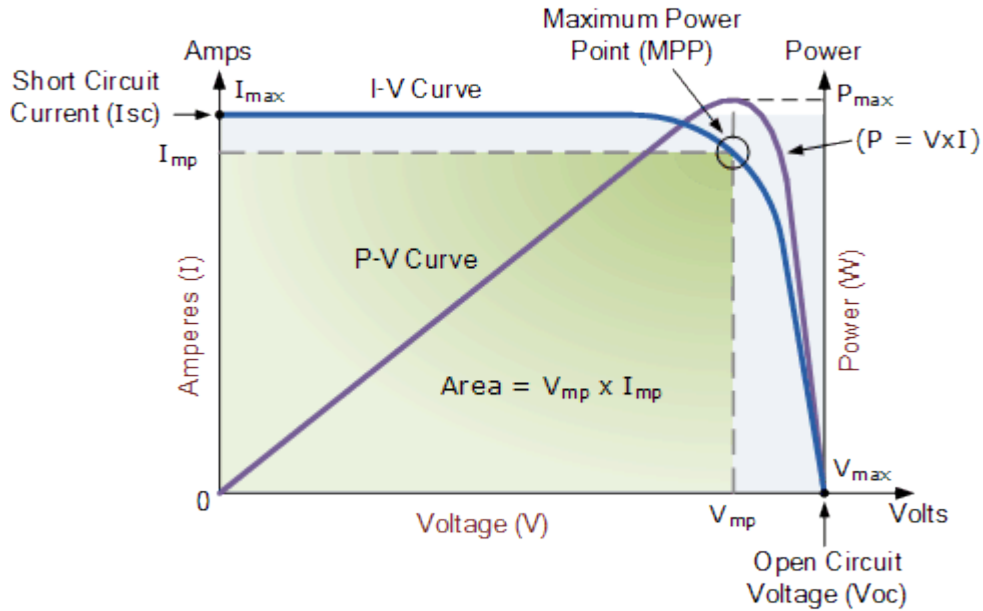


# PV Solar Panel Performance – Effect of Light Intensity

Solar Panels are Rated at Standard Test Conditions (Pmax = 130 Watts)

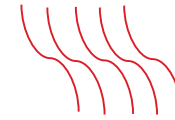


**STC - Standard Test Conditions**  
77°F (25°C) light intensity 1,000 watts/sq. meter



**Solar panel performance is proportional to light intensity**

# PV Solar Panel Performance – Effect of Temperature

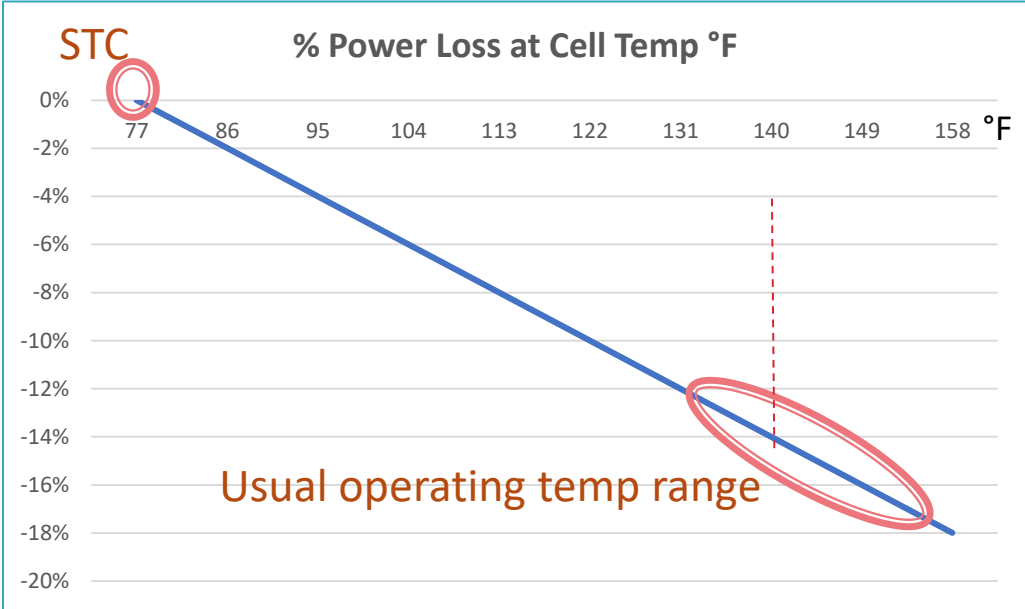


Solar Panels are Rated at Standard Test Conditions (Pmax = 130 Watts)

**STC - Standard Test Conditions**  
77°F (25°C) light intensity 1,000 watts/sq. meter

Example: A solar cell operating at 60°C (140°F) with a temp coef. of -.4%

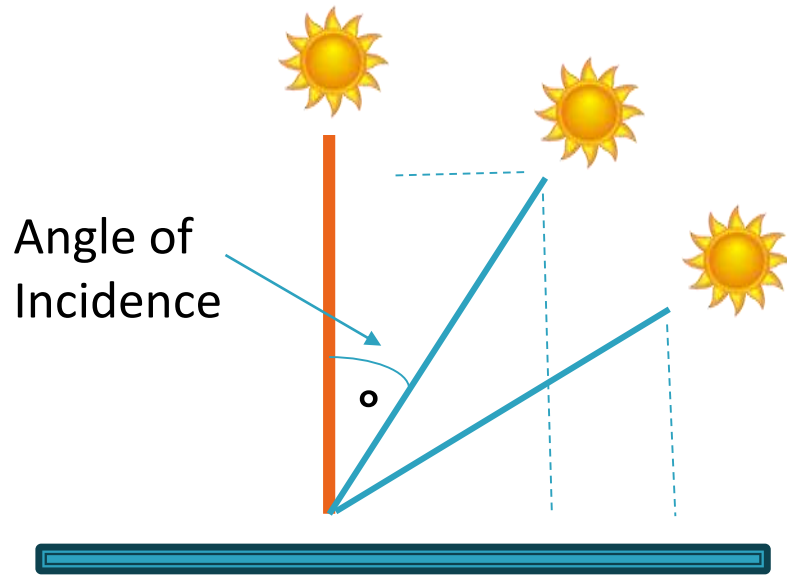
60°C – 25°C = 35°C     35°C x -.4% = 14% power loss  
140°F – 77°F = 63°F



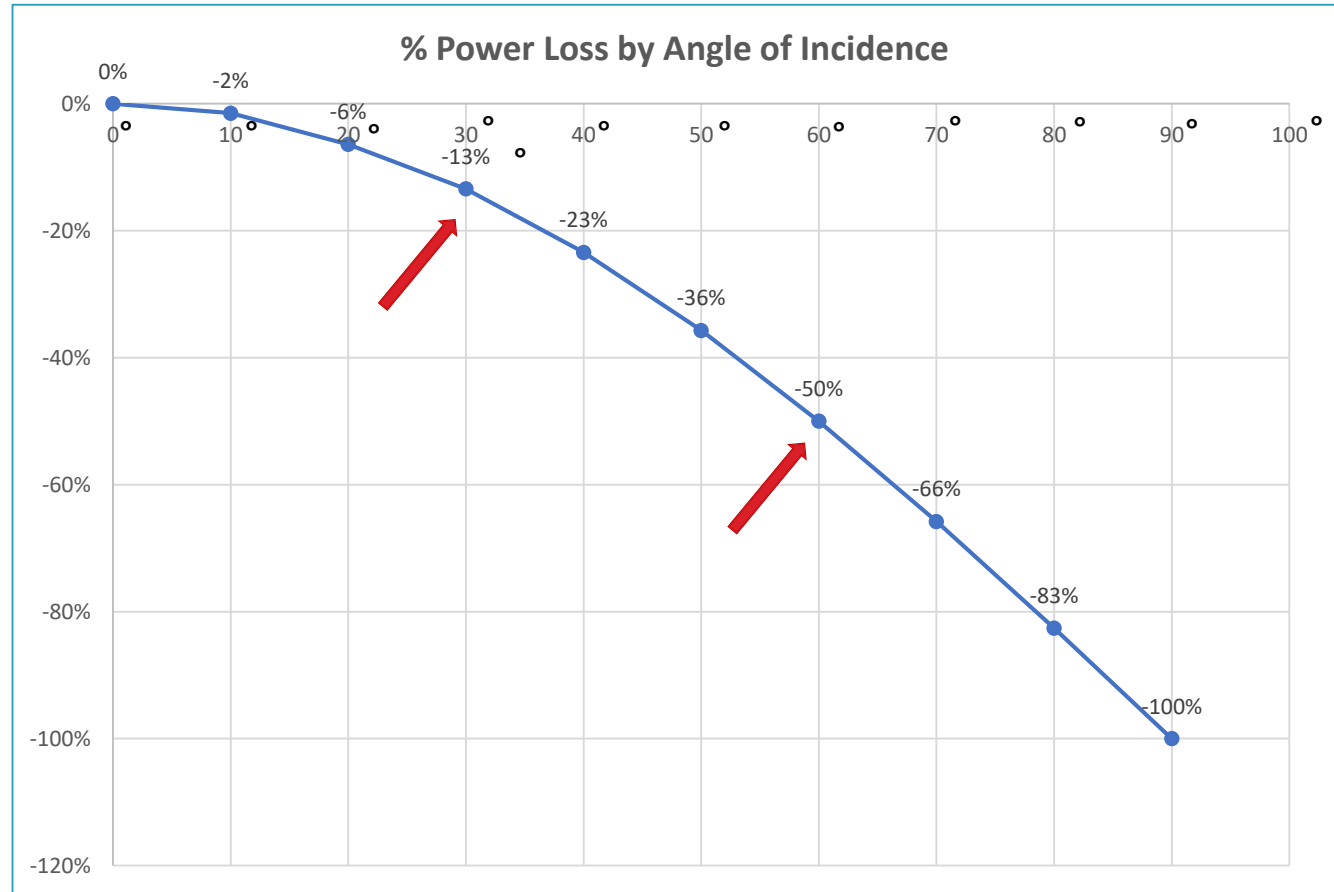
**For every 10°F above 77°F the solar cells will have a ~2.2% power loss.**

A 130 Watt solar panel operating at 140 °F will produce 112 Watts

# PV Solar Panel Performance – Effect of the Sun Angle of Incidence



Cosine Effect

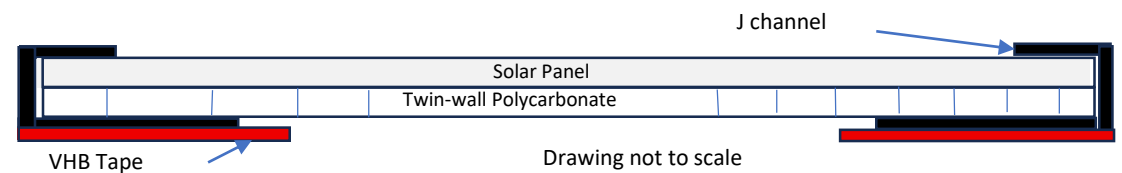
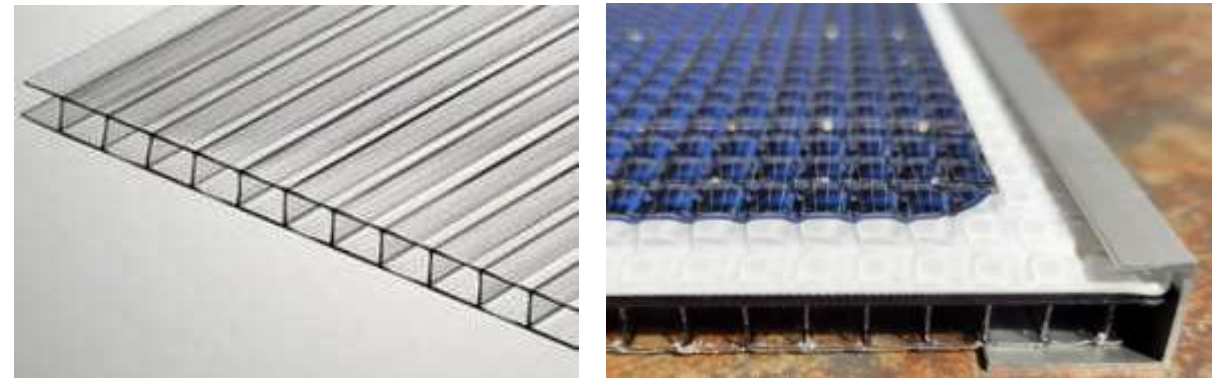


# PV Solar Panel Performance – Effect of Temperature

## A Successful Approach to Cooling the Solar Panel

Air cooling between the panel and the rigid mounting surface can increase the panel performance significantly.

- Twin wall polycarbonate is a strong material that has flutes for air flow between the panel and the mounting surface.
- J shaped channels can be used to mount entire assembly.



Solar Panel Kit Assembly Ready for Installation

This approach has been so successful for our customers, we include these components in all of our walk-on solar panel kits.

# PV Solar Panel Performance – Effect of the Sun Angle of Incidence

## Successful Approaches to Improving the Sun Angle of Incidence



A tilt and rotate mechanism on a pole can improve watts generated per day by up to 40%

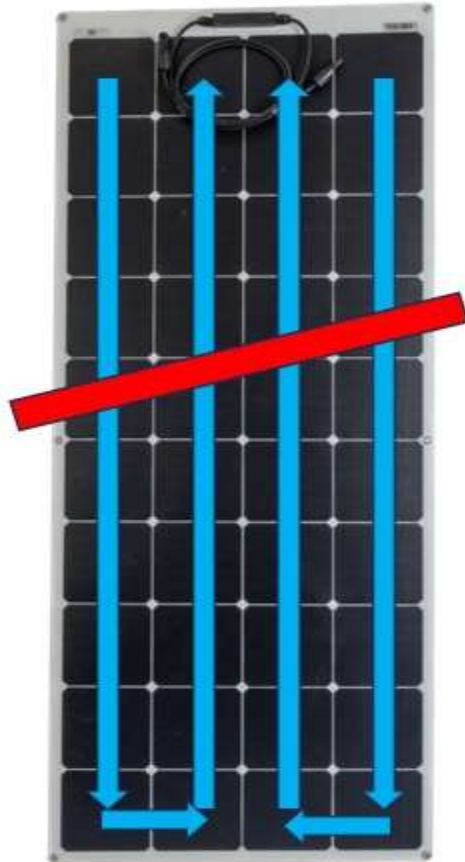
A tilt mechanism can improve watts generated per day by up to 30%

# PV Solar Panel Performance – Effect of Shading

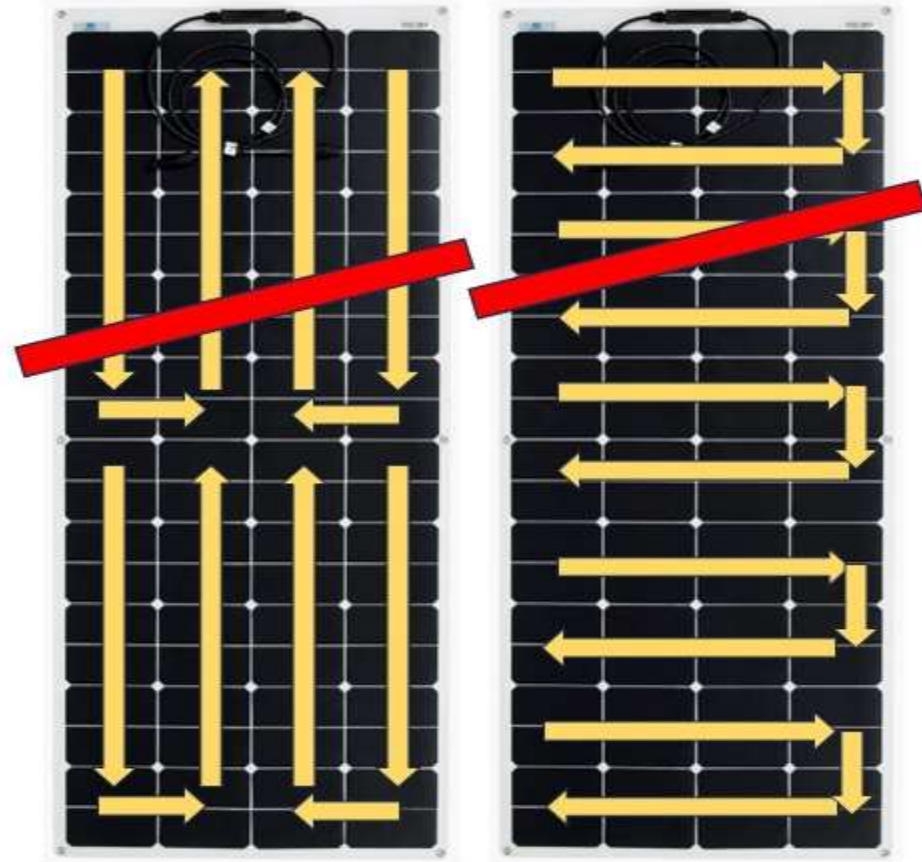


Shading will knock out a typical solar panel but only a small section of a **Shade Tolerant** solar panel.

Red bar represents shading.

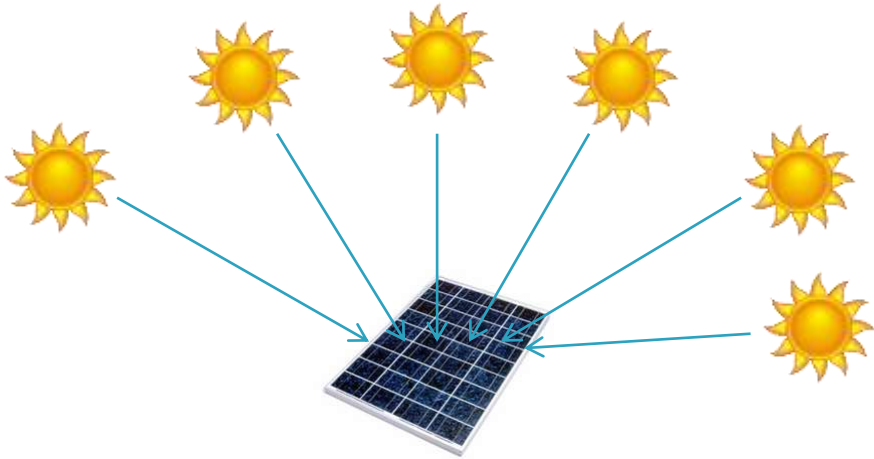


**Typical** Solar Panel with 2 series strings of solar cells.  
Loss of Power: 40-80%



**Shade Tolerant** Solar Panel with 4+ series strings of solar cells.  
Loss of Power: 10-30%

# PV Solar Panel Performance – Quality of Solar Cells is Important



Average sun hours in a typical day  
– 5 to 6 hours –

It's all about **watt hours**

Higher performance solar cells produce more power at sub-optimal sun angles than lower performance solar cells - up to 30% more power.

A lower performance 100 watt panel will produce up to 100 watts x 5 hours or 500 watt hours in a day.

A higher performance 100 watt panel will produce up to 650 watt hours in a day.

**That's 150 watt hours or 12.5 amp hrs. more power**

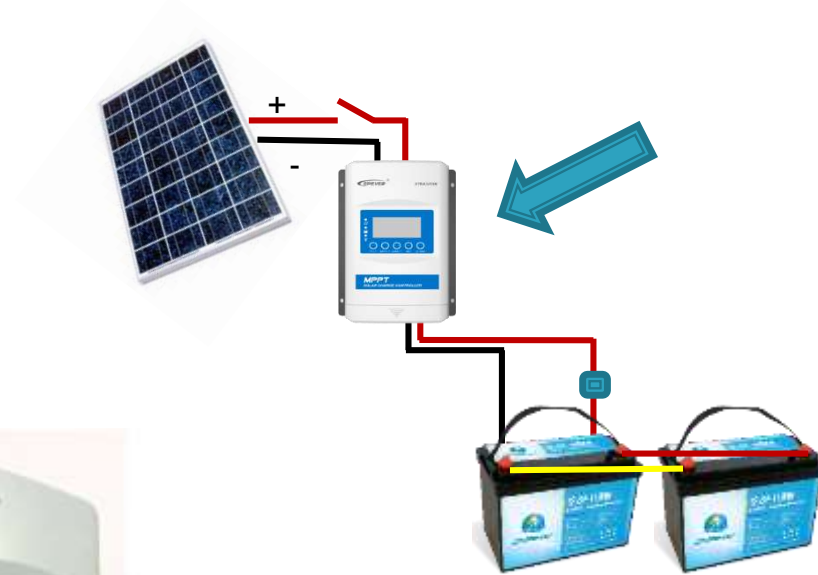
## PV Solar Panel Performance is Affected by the Following:

	Example
• Light Intensity	-15%
• Solar cell temperature	-14%
• Sun angle of incidence	-13%
• Shading	<u>-15%</u>
	-57%

Solar cell quality will affect all performance factors.

Battery bank acceptance of power is another factor we will talk about later.

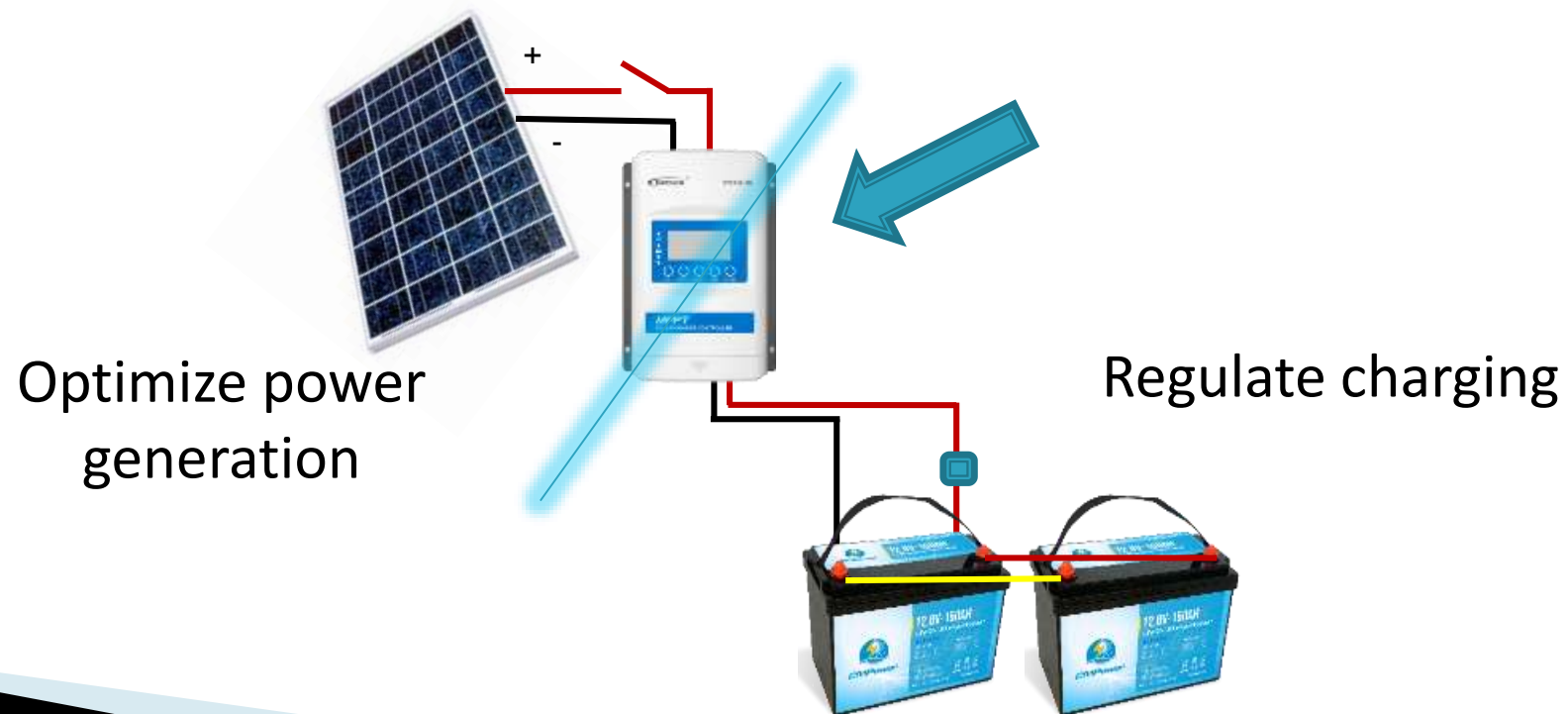
# Introduction to Solar Controllers



# A Few Things to Know About Solar Controllers

The purpose of a solar controller is to:

- Optimize the power generation of the solar array
- Regulate the amount of power going to the battery bank
- Prevent battery bank overcharging and overheating
- Prevent solar panels from absorbing power at night



# There Are Two Types of Solar Controllers

## (PWM) Pulse Width Modulation

- Pulse Width Modulation provides efficient battery charging
- Streams full power to battery bank when bank is low
- Useful if panel voltage is similar to battery voltage
- Less expensive than MPPT controllers



## (MPPT) Maximum Power Point Tracking

- Essential to use with commercial solar panels  
(usually above 40 volts)
- Optimizes power generation from the solar array
- Reduces voltage to battery voltage and increases amperage  
 $P_w = V * I$  (Watts = Volts x Amps)
- Of limited value for panels rated under 20 volts and for small solar arrays (under 100 watts).
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# There Are Two Types of Solar Controllers

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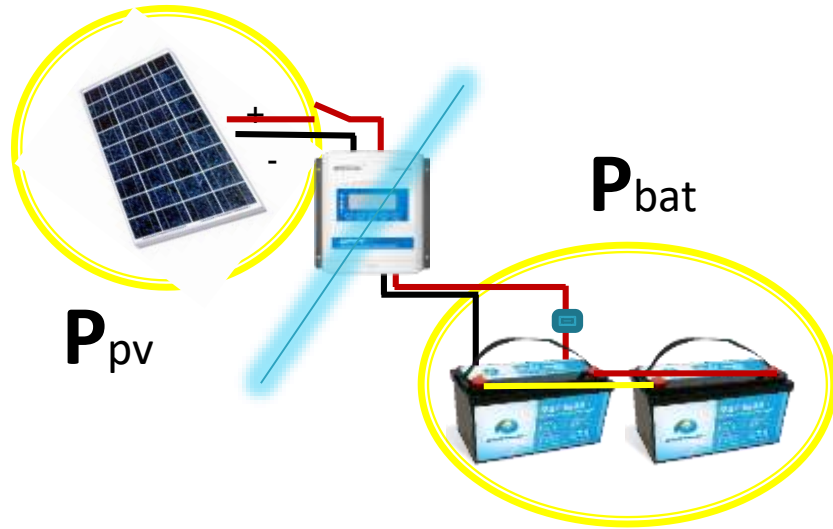
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# MPPT Maximum Power Point Tracking Technology



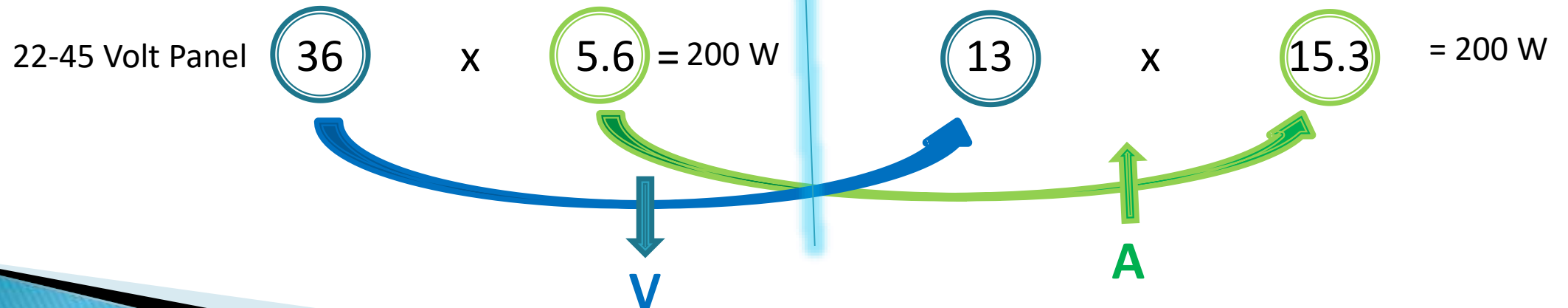
$$\text{Input power (} P_{pv} \text{)} = \text{Output power (} P_{bat} \text{)}$$

$$200 \text{ W} = 200 \text{ W}$$



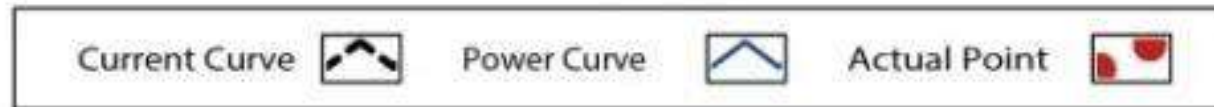
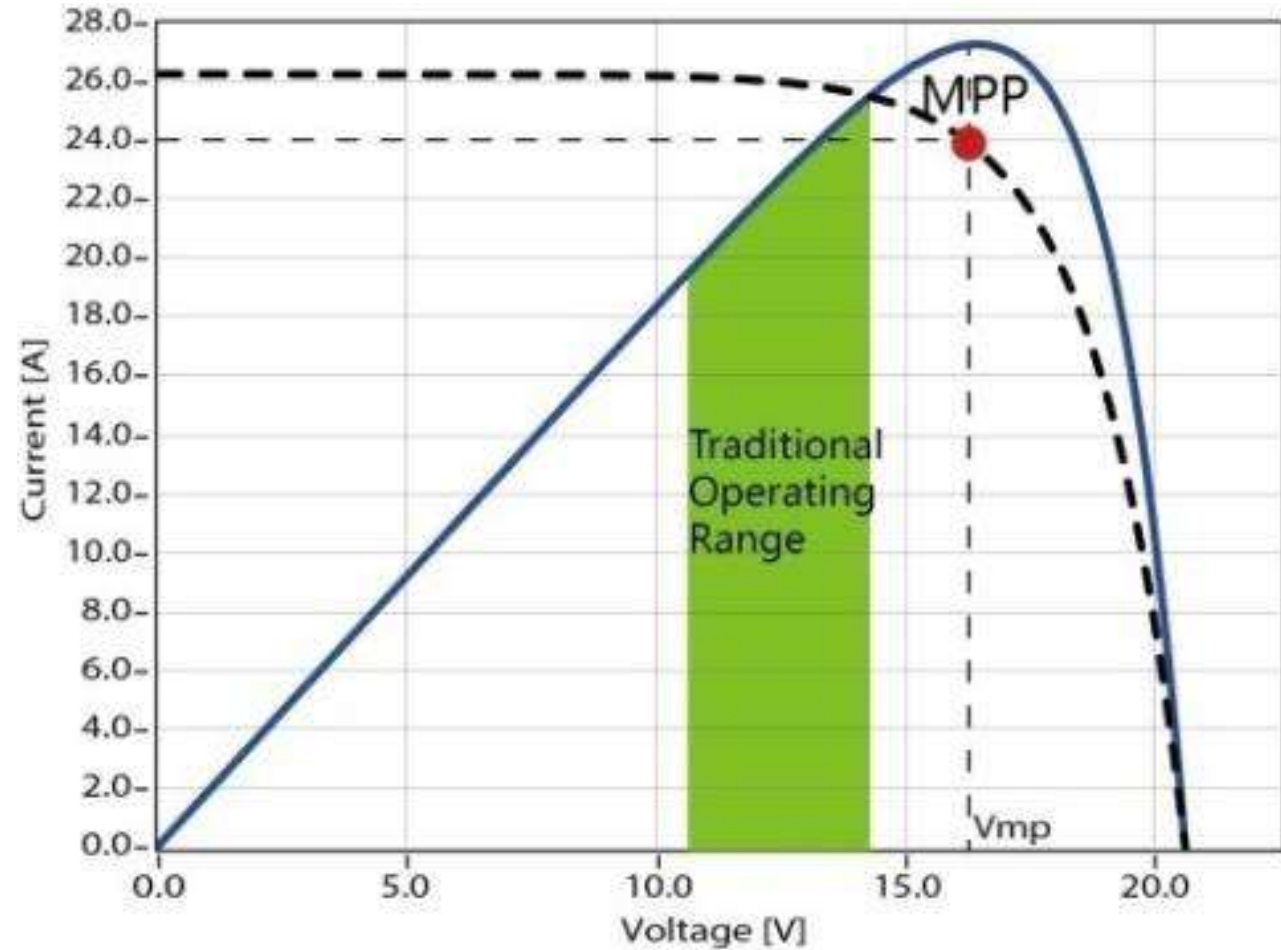
$$P = V \times I \quad \text{Watts} = \text{Volts} \times \text{Amps}$$

$$\text{Input Voltage (} V_{mpp} \text{)} \times \text{Input Current (} I_{pv} \text{)} = \text{Battery Voltage (} V_{bat} \text{)} \times \text{Battery Current (} I_{bat} \text{)}$$



At 100% conversion efficiency

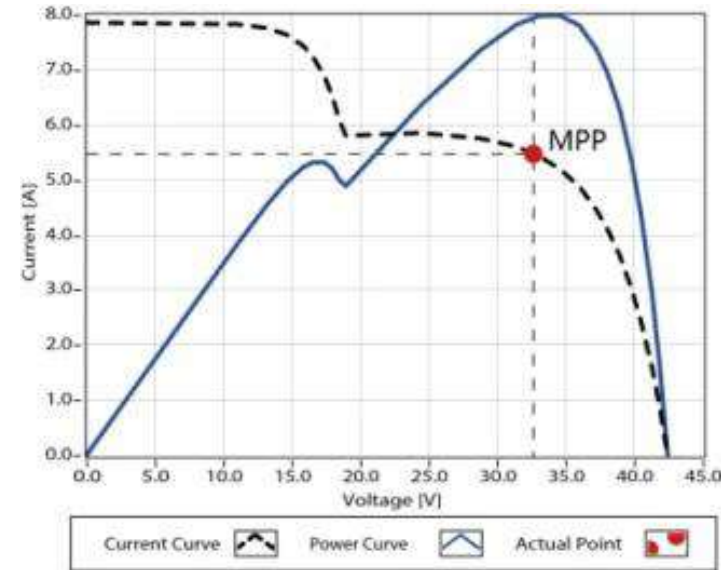
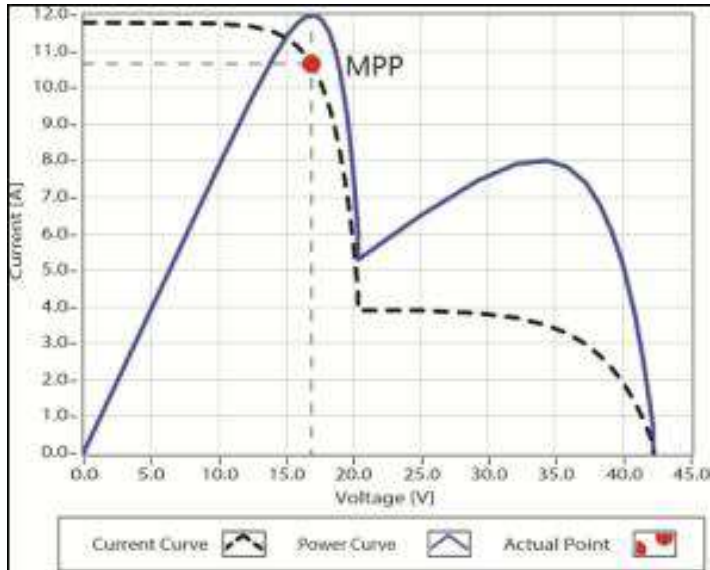
# Maximum Power Point Curve



EP Solar

# Maximum Power Point Tracking Technology

## Impact of Shading and Dissimilar Panels



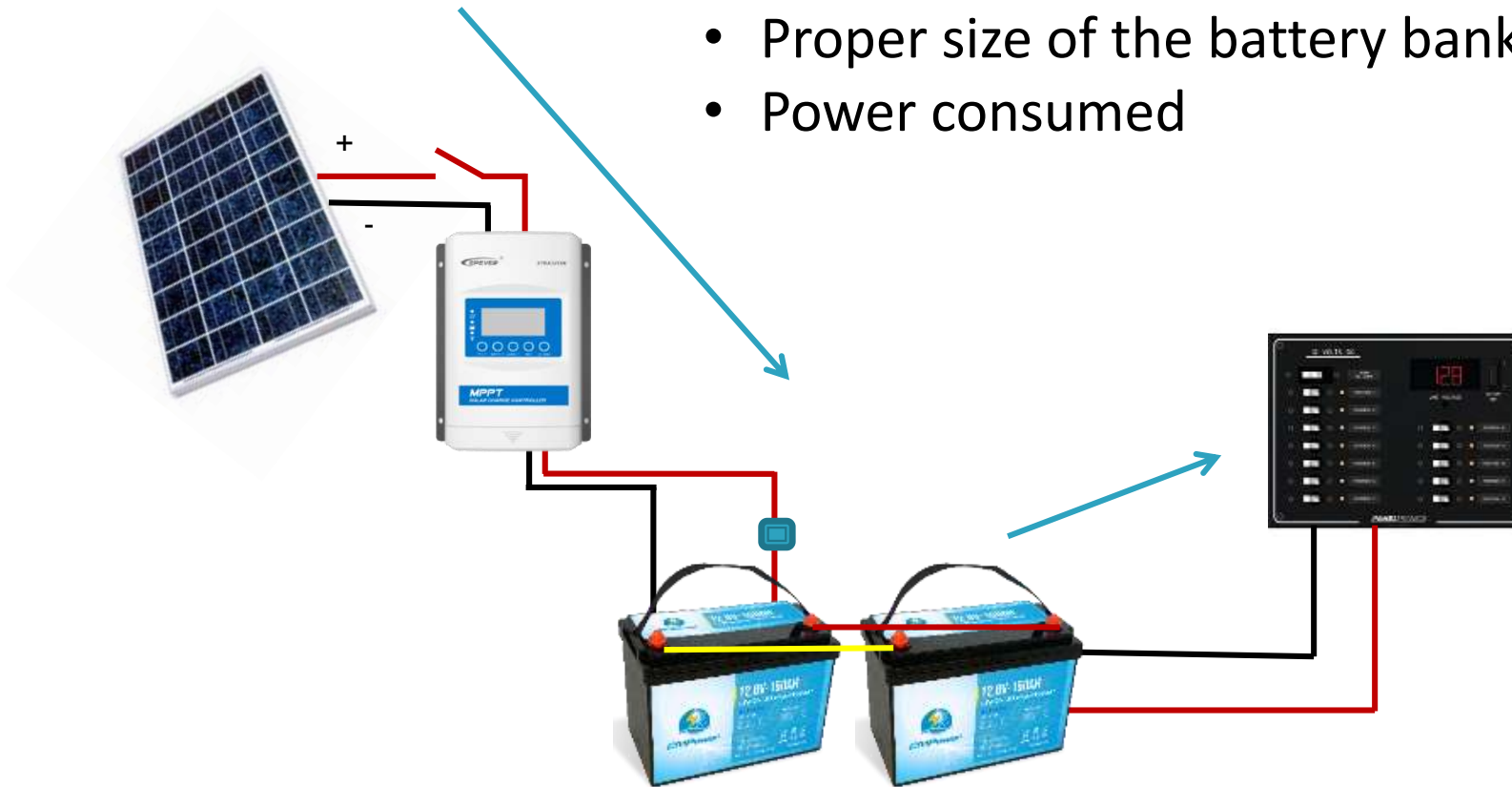
EP Solar

## Multiple Power Points

Dissimilar solar panels wired to a single controller will result in lower than optimal power generation.

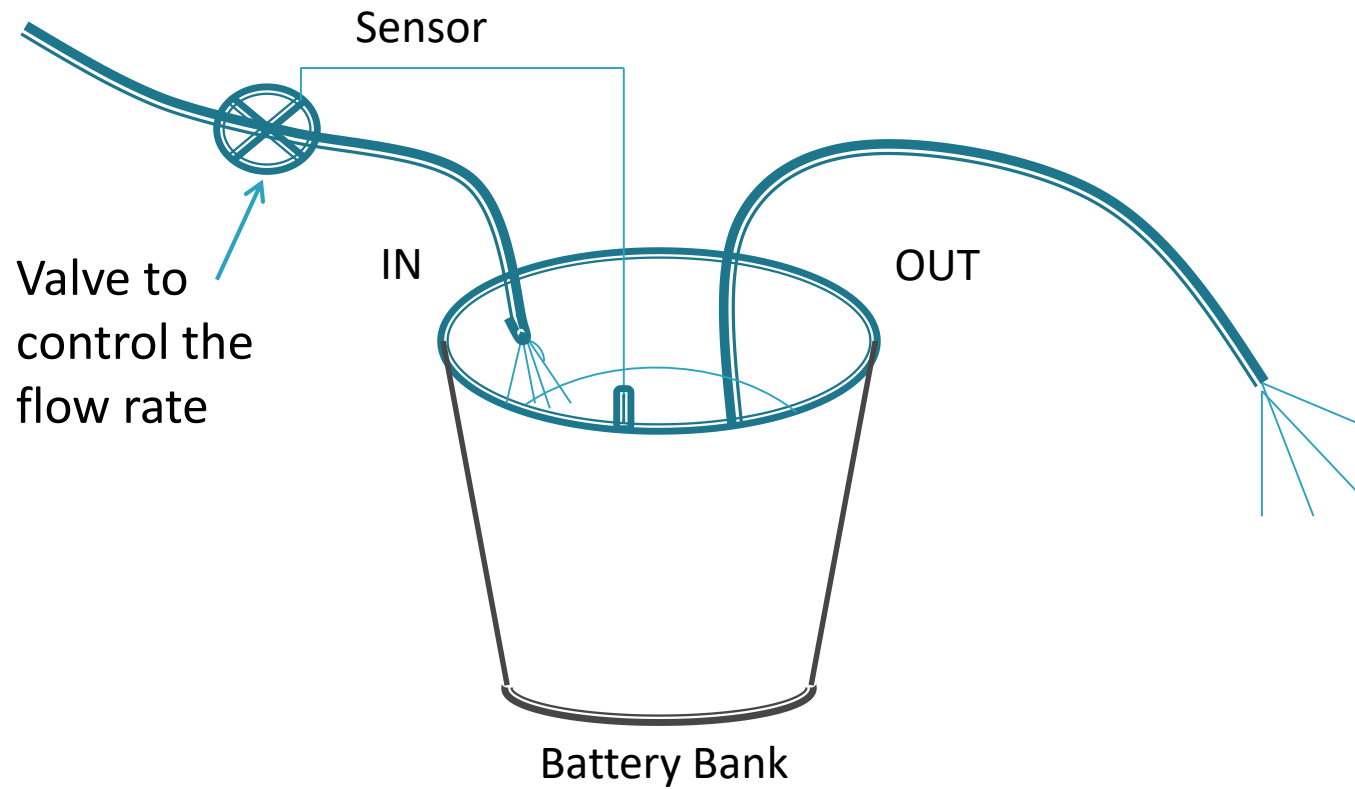
# A Balanced System

- Solar power generated
- Proper size of the battery bank
- Power consumed



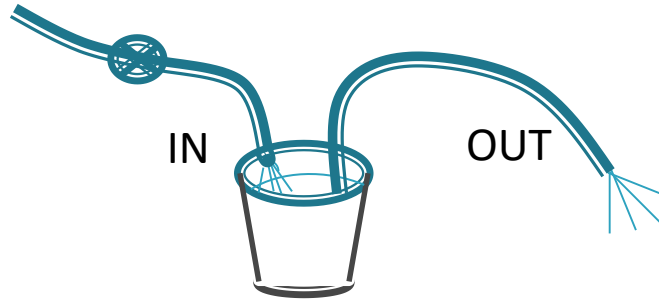
# A Balanced System

- Water in
- Size of the bucket
- Water consumed

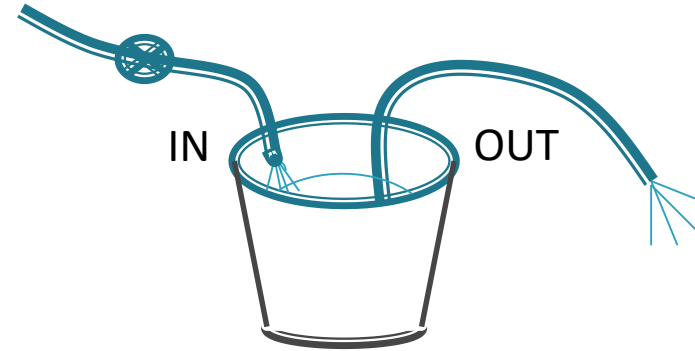


# Sizing Your Battery Bank

Battery capacity is measured in Amp Hours (AH)

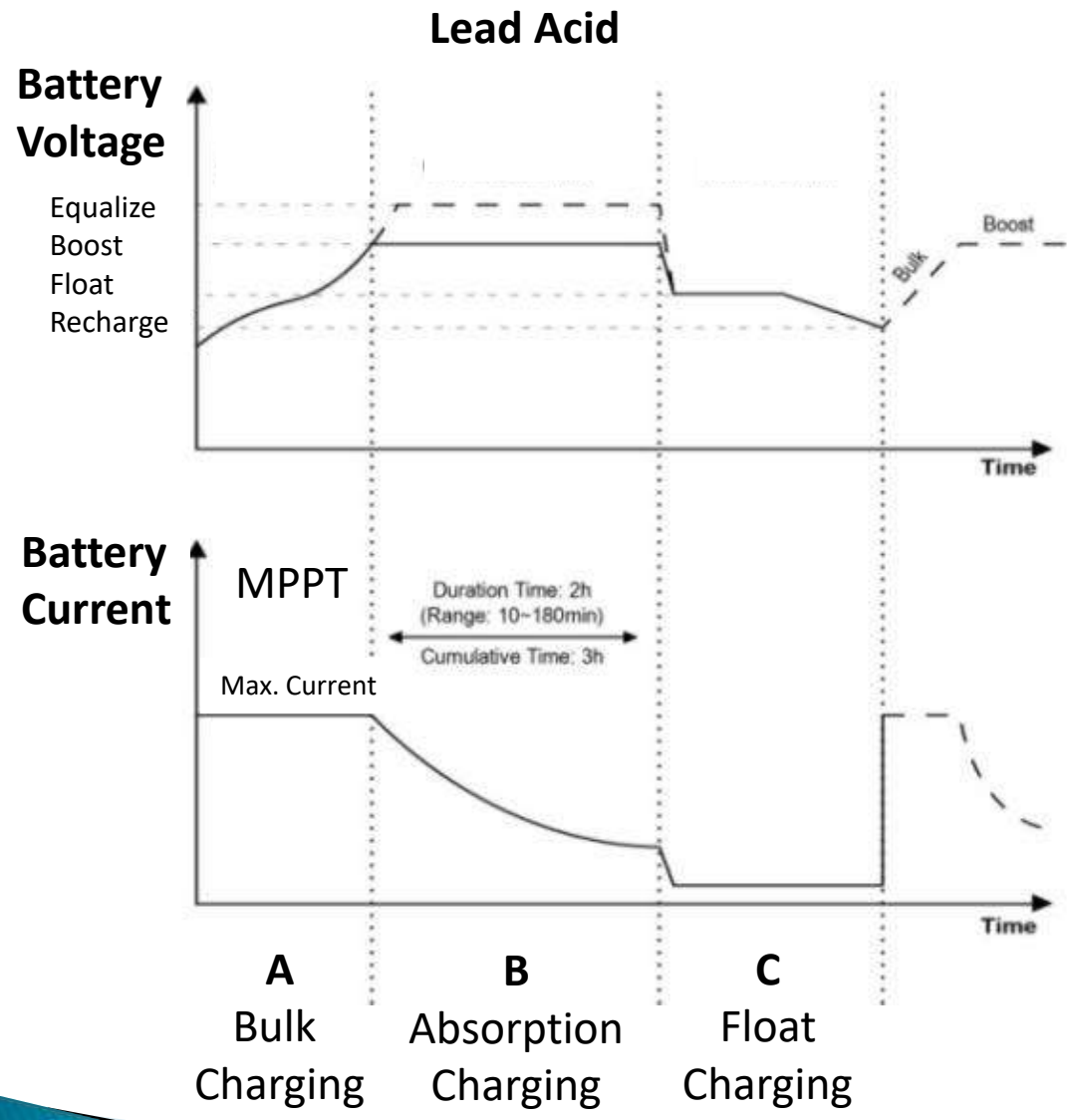


- A limited capacity battery bank
- Unable to store all the power your solar panels produce
  - No reserve for cloudy days
  - Must always be monitored because continually stressed

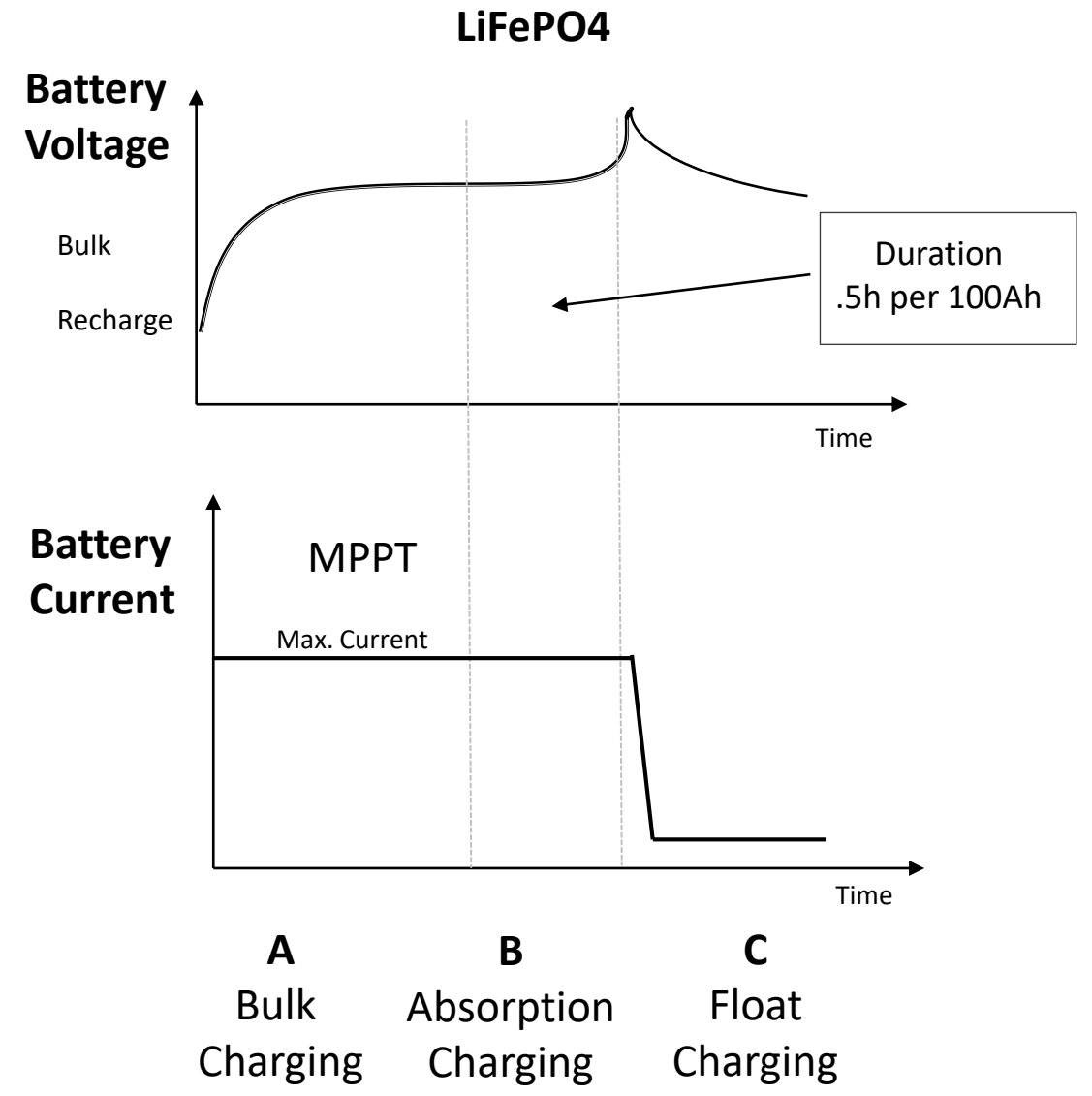


Your battery bank should have the capacity to support your boat's power requirements for at least 24 to 48 hours

# Battery Charging Curves



EP Solar



CMPower

# Designing a Solar System to Meet Your Needs

## Our Case Study Boat



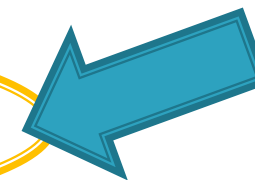
# What Do You Want to Achieve with Your Solar System?

- A. Keep the batteries charged while on a mooring.
- B. Supplement current power generation capability.  
(Run my engine or generator less to charge the batteries)
- C. Generate all the power needed while at anchor.
- D. Generate all the power needed at anchor and on passage.

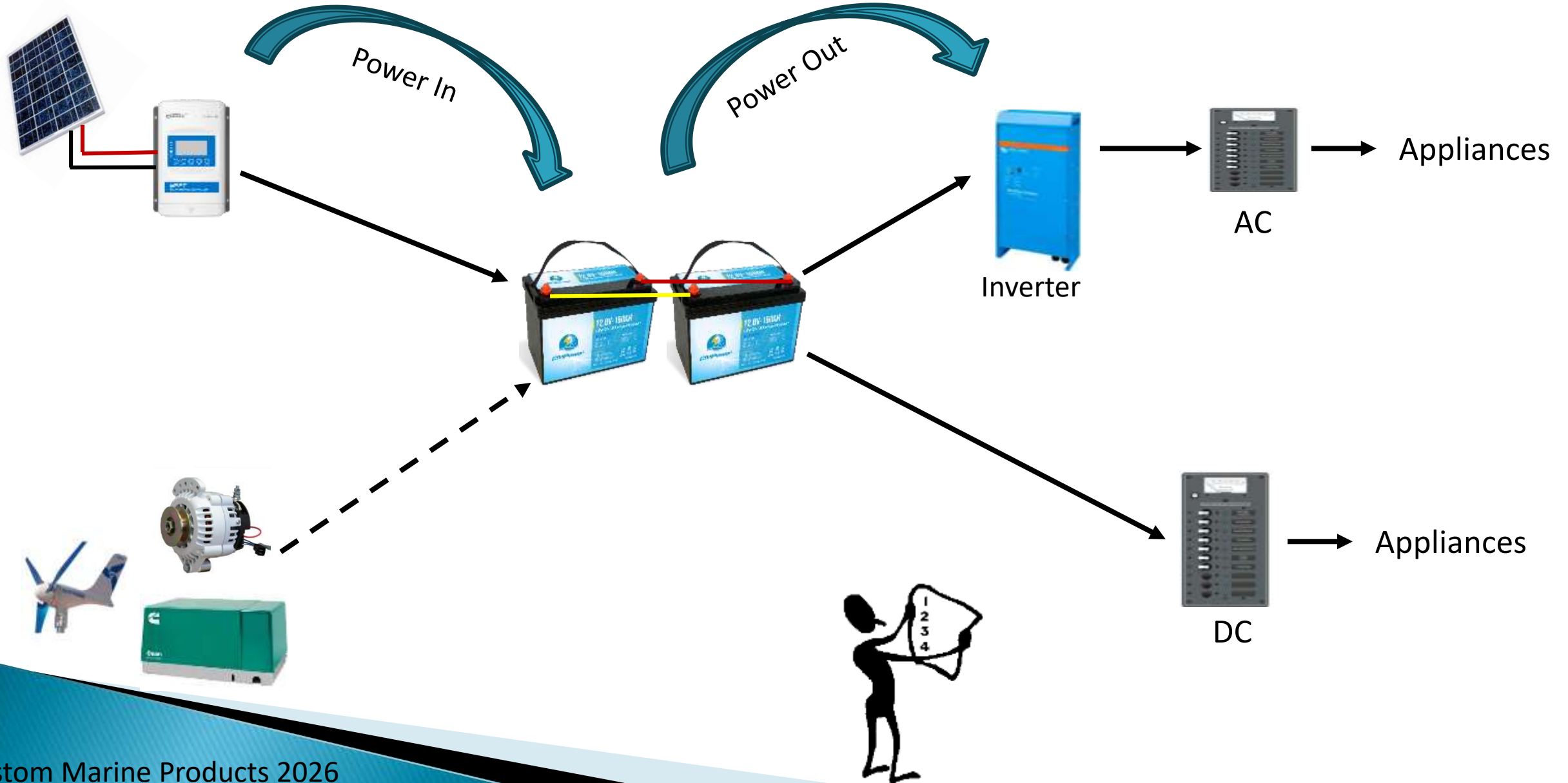


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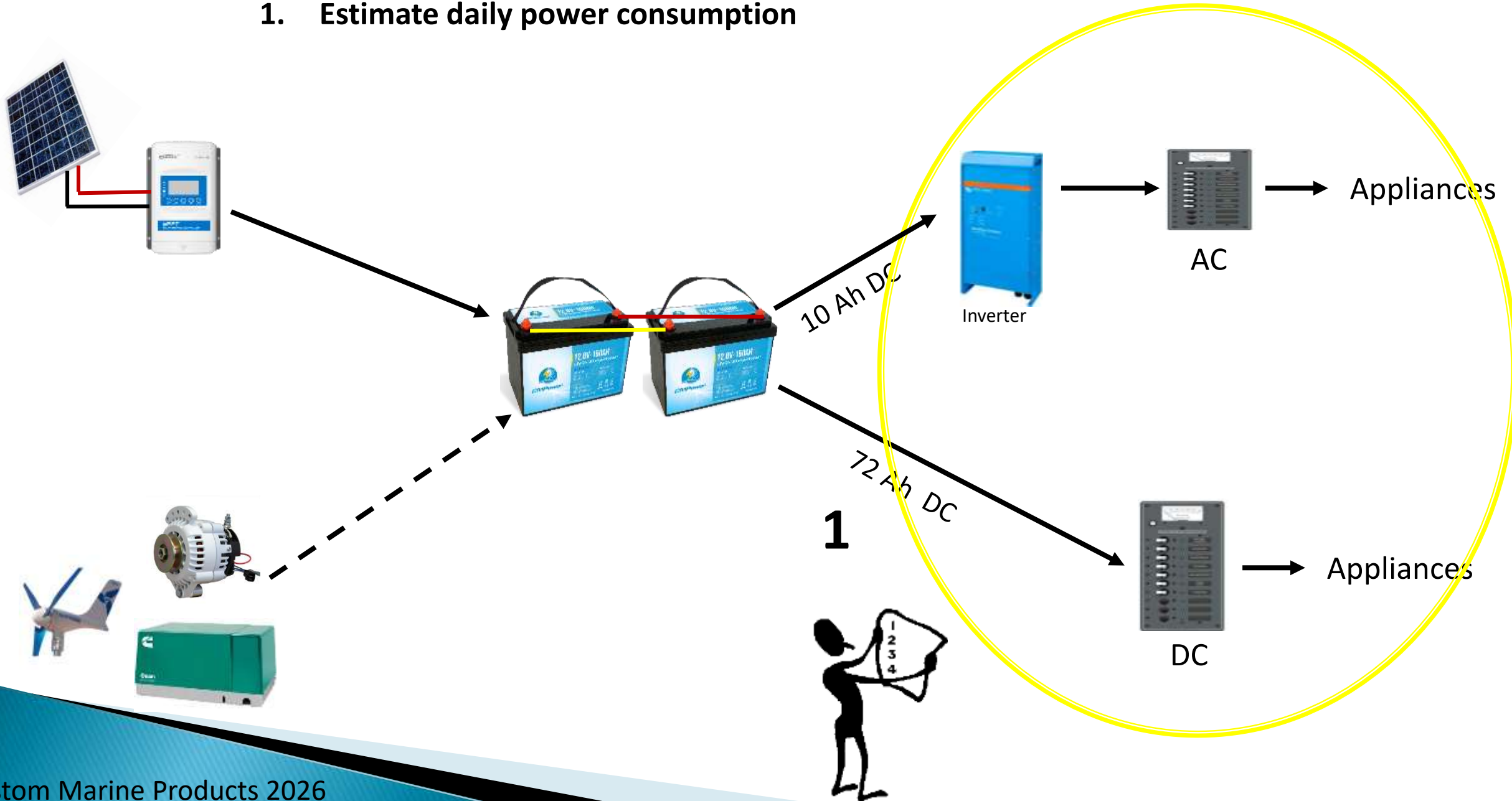


# Designing a Solar System to Meet Your Needs



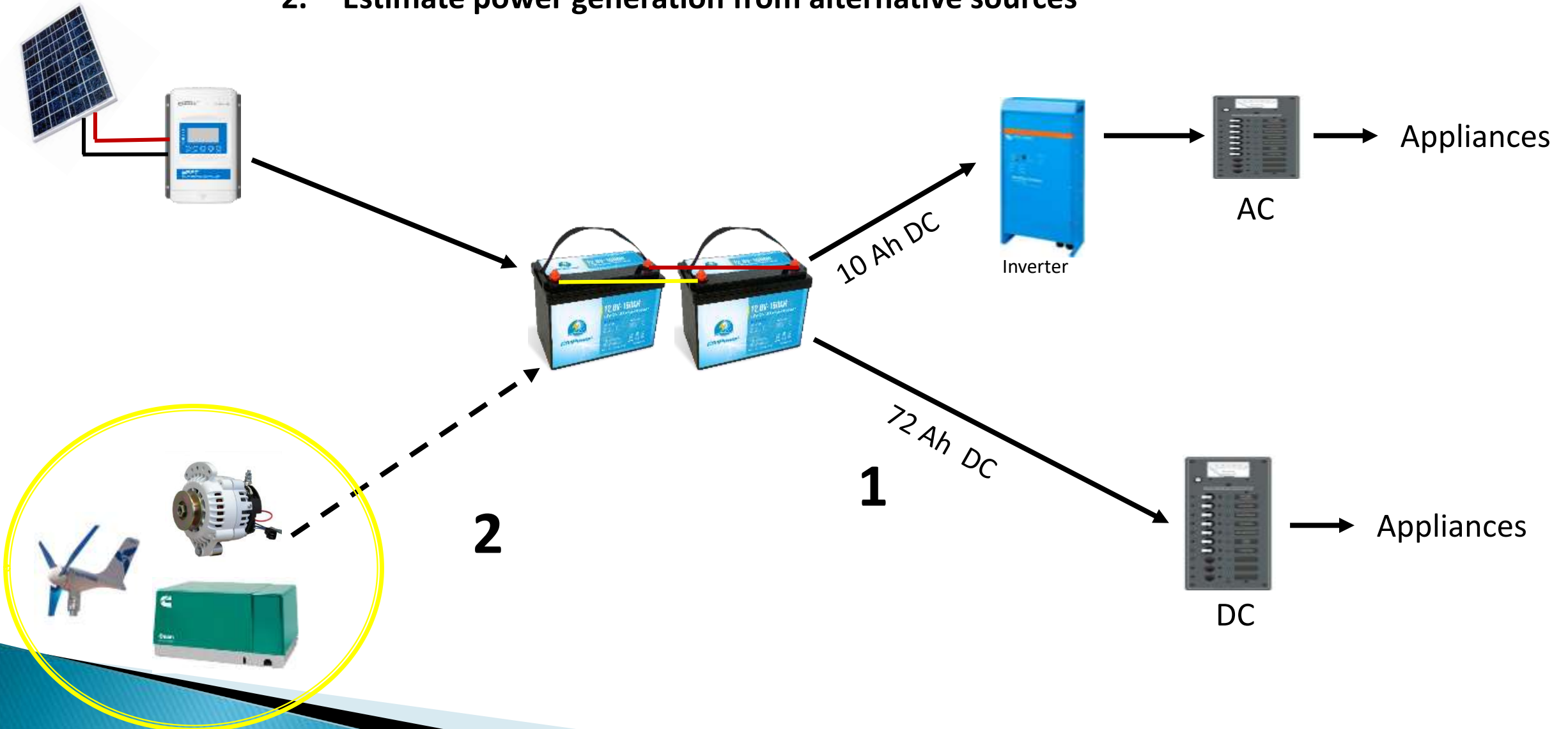
# Designing a Solar System to Meet Your Needs

## 1. Estimate daily power consumption



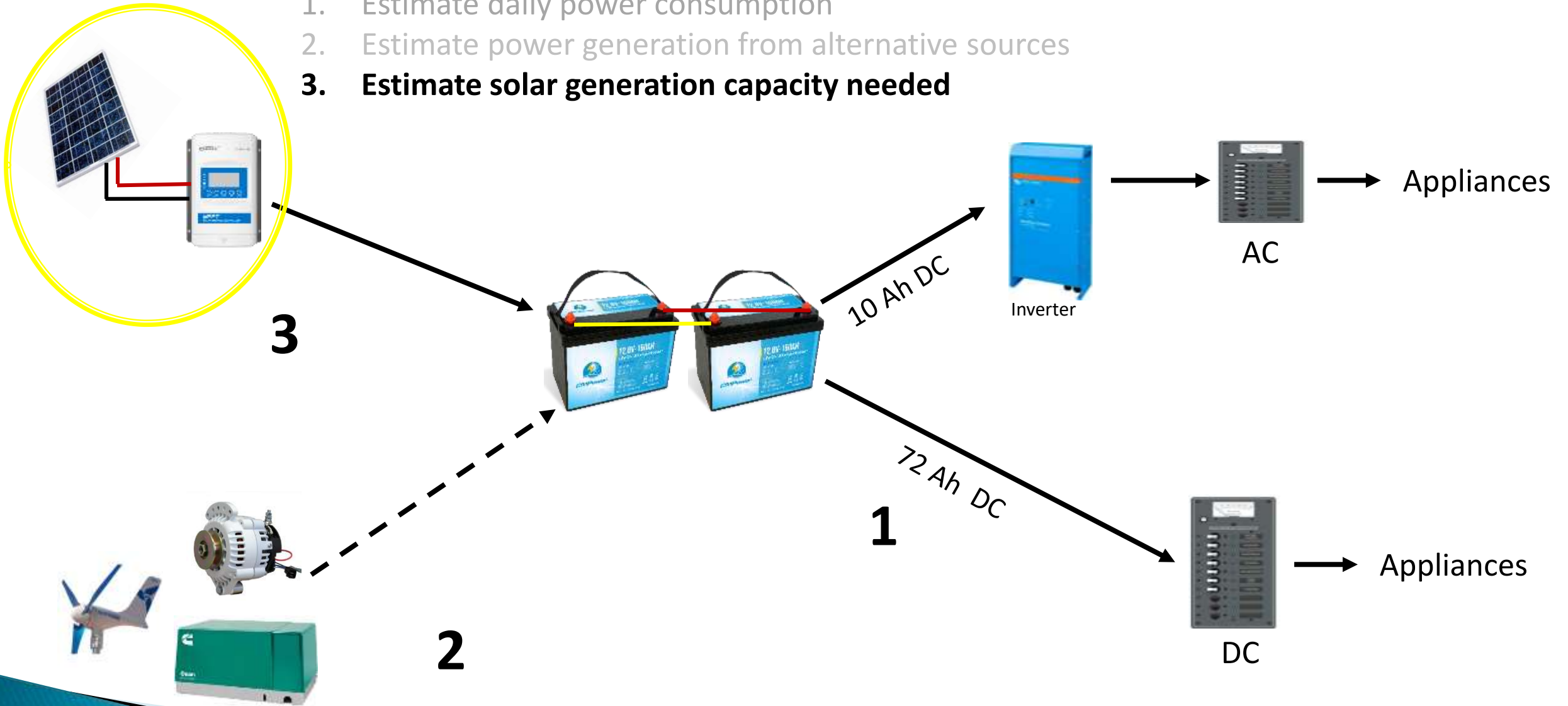
# Designing a Solar System to Meet Your Needs

1. Estimate daily power consumption
2. Estimate power generation from alternative sources



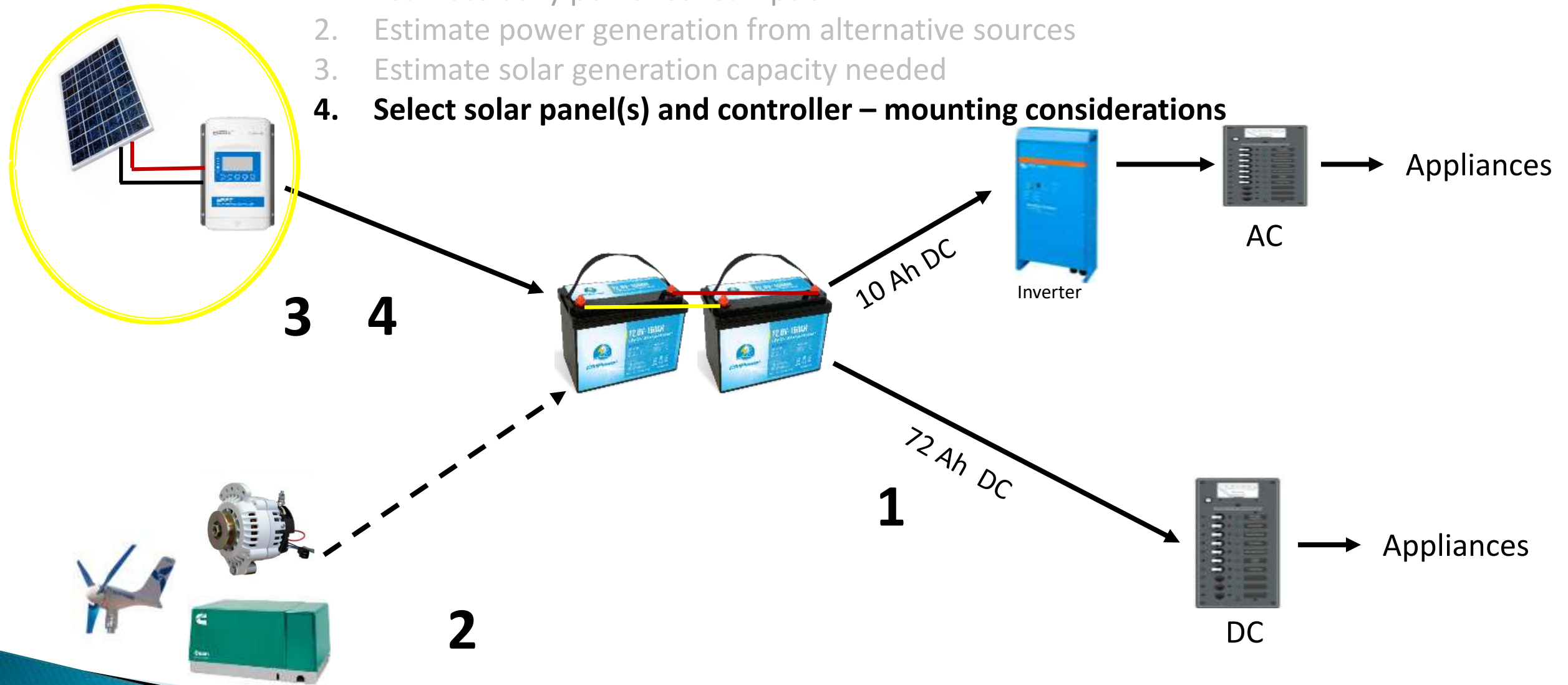
# Designing a Solar System to Meet Your Needs

1. Estimate daily power consumption
2. Estimate power generation from alternative sources
3. **Estimate solar generation capacity needed**



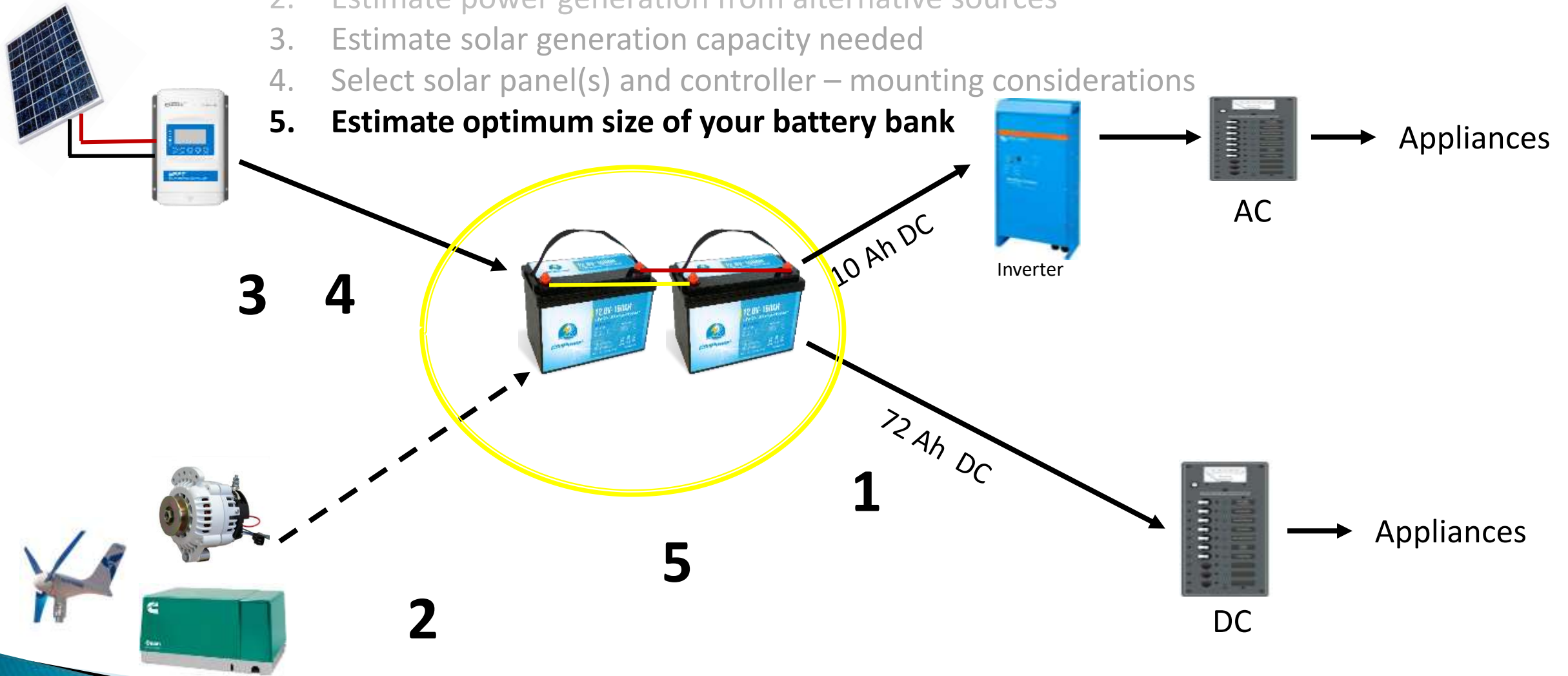
# Designing a Solar System to Meet Your Needs

1. Estimate daily power consumption
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3. Estimate solar generation capacity needed
4. **Select solar panel(s) and controller – mounting considerations**



# Designing a Solar System to Meet Your Needs

1. Estimate daily power consumption
2. Estimate power generation from alternative sources
3. Estimate solar generation capacity needed
4. Select solar panel(s) and controller – mounting considerations
5. **Estimate optimum size of your battery bank**



# Worksheet for Designing a Solar System Based on Power Consumption

Input fields in Grey

Worksheet for Designing a Solar System Based on Power Consumption						Input fields in Grey			
<b>1. Daily Power Consumption Analysis</b>									
Appliance	Amps	Hours	Hours	Daily AH *1*	Daily AH				
DC		At Anchor	On Passage	At Anchor	On Passage				
Refrigeration	5	10	10	50	50				
Radar	4		4	0	16				
Computer - Laptop	4	1	10	4	40				
Autopilot	4		10	0	40				
Cabin Lights (LED)	1	4		4	0				
Nav/Anchor Lights	0.2	10	10	2	2				
Stereo	1	3	3	3	3				
VHF Radio	0.5	10	10	5	5				
Instruments	1		8	0	8				
Pressure Water	6	0.25	0.1	1.5	0.6				
Phone Charger	1	2	2	2	2				
Other				0	0				
Other				0	0				
Windlass *2*				0	0				
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>				
<b>AC - Equipment powered by an Inverter (Watts)</b>									
	Watts	Hours	Hours	AH	AH				
Microwave (Watts)	1100	0.1	0.1	10.2	10.2				
Other				0.0	0.0				
Other				0.0	0.0				
Other				0.0	0.0				
Other				0.0	0.0				
<b>Total Amp Hours</b>				<b>10.2</b>	<b>10.2</b>				
<b>Total Amp Hours Consumed per Day</b>				<b>81.7</b>	<b>176.8</b>				
Battery Charging Voltage			13						
<b>Total Watt Hours Consumed per Day</b>				<b>1,061.5</b>	<b>2,297.8</b>				
<b>2. Alternative Power Sources</b>									
Alternator	30		2	0	60				
Generator				0	0				
Other				0	0				
<b>Total Amp Hours</b>				<b>0</b>	<b>60</b>				
<b>Total Watt Hours Produced per Day</b>				<b>0</b>	<b>780</b>				
<b>Net Watt Hours per Day Consumed or Produced</b>				<b>1,061.50</b>	<b>1,517.80</b>				
Custom Marine Products						custommarineproducts.com			
info@custommarineproducts.com 248 705-8337									
<b>3. Solar Power Requirement Analysis (Full Sun)</b>								<b>At Anchor</b>	<b>On Passage</b>
Average Hours of Sun per Day						5	*3*		
Battery Charge Inefficiency Factor						1.2	*4*		
<b>Watts of Solar to Replenish Battery Bank Daily</b>								<b>254.8</b>	<b>364.3</b>
<b>Solar System Design Analysis (MPPT Controller)</b>									
Capacity of Each Solar Panel (Watts)						130			
Number of Solar Panels Required								2.2	3.1
Number of Solar Panels Installed						3			
Minimum Capacity of Solar Controller (Amps)						30.0			
Daily Useable Solar Power in Full Sun (Watt Hrs)						1,560.0			
Daily Power Drawn from Battery Bank (Watt Hrs)								1,061.5	1,517.8
Excess or (Deficit) of Power (Watt Hrs)								498.5	42.2
<b>4. Factor for Cloudy Days</b>									
Solar Efficiency on Cloudy Days (percentage)						30%	*5*		
Solar Power Generated on a Cloudy Day						468.0			
Power Drawn from Batteries on a Cloudy Day (Wh)								593.5	1,049.8
Number of Continuous Cloudy Days						2			
Sunny Days to Make Up Battery Draw Down								2.4	49.8
<b>5. Battery Capacity Analysis</b>								<b>Amp Hrs</b>	<b>Amp Hrs</b>
								<b>at Anchor</b>	<b>on Passage</b>
Scenario 1 - Based on Cloudy Days - with Solar									
Ah Drawn from Batteries on Cloudy Days								91.3	161.5
% of Battery Capacity Useable						50%	*6*		
Rated Battery Capacity Required (AH)								182.6	323.0
Rated Battery Capacity (Ah)						120			
Number of Batteries Required (in parallel)								1.5	2.7
Scenario 2 - Based on Days of Reserve Capacity (no solar)									
Number of Days of Reserve Battery Capacity						2			
% of Battery Capacity Useable						50%			
Rated Battery Capacity Required (AH)								326.6	467.0
Rated Battery Capacity (Ah)						120			
Number of Batteries Required (in parallel)								2.7	3.9
*1* AH - Amp Hours - Amps of current consumed in one hour									
*2* Windlass is often not considered because the engine alternator is running when used									
*3* 5 hours avg. is a good estimate for horizontal panels, 7 for panels with tilt & rotate See <a href="http://www.bigfrogmountain.com/SunHoursPerDay.html">http://www.bigfrogmountain.com/SunHoursPerDay.html</a> for hours in your area.									
*4* Charge efficiency factor - Lead Acid ≈ 1.2, AGM ≈ 1.1, LiFePO4 ≈ 1.04									
*5* Solar efficiency - Partly cloudy ≈ 70%, Mostly cloudy ≈ 50%, Very cloudy ≈ 30%									
*6* Useable battery capacity - Lead Acid ≈ 50%, AGM ≈ 60%, LiFePO4 ≈ 95%									

Available at:  
**custommarineproducts.com**  
 - Handy Info - System Design

# Worksheet for Designing a Solar System Based on Power Consumption

Input fields in Grey

1. Estimate daily power consumption
2. Estimate power generation from alternative sources
3. Estimate solar generation capacity needed
4. Select solar panel(s) and controller – mounting considerations
5. Estimate optimum size of your battery bank

Available at:  
[custommarineproducts.com](http://custommarineproducts.com)  
 - Handy Info - System Design

Worksheet for Designing a Solar System Based on Power Consumption						Input fields in Grey		
<b>1. Daily Power Consumption Analysis</b>						<b>3. Solar Power Requirement Analysis (Full Sun)</b>		
Appliance	Amps	Hours	Hours	Daily AH *1*	Daily AH	Average Hours of Sun per Day	At Anchor	On Passage
DC		At Anchor	On Passage	At Anchor	On Passage	5 *3*		
Refrigeration	5	10	10	50	50	Battery Charge Inefficiency Factor	1.2 *4*	
Radar	4		4	0	6	Watts of Solar to Replenish Battery Bank Daily	254.8	364.3
Computer - Laptop	4	1	10	4	4	<b>Solar System Design Analysis (MPPT Controller)</b>		
Autopilot	4		10	0	40	Capacity of Each Solar Panel (Watts)	130	
Cabin Lights (LED)	1	4		4	0	Number of Solar Panels Required		2.2
Nav/Anchor Lights	0.2	10	10	2	2	Number of Solar Panels Installed	3	
Stereo	1	3	3	3	3	Minimum Capacity of Solar Controller (Amps)	30.0	
VHF Radio	0.5	10	10	5	5	Daily Useable Solar Power in Full Sun (Watt Hrs)	1,560.0	
Instruments	1		8	0	8	Daily Power Drawn from Battery Bank (Watt Hrs)		1,061.5
Pressure Water	6	0.25	0.1	1.5	0.6	Excess or (Deficit) of Power (Watt Hrs)		498.5
Phone Charger	1	2	2	2	2	<b>4. Factor for Cloudy Days</b>		
Other				0	0	Solar Efficiency on Cloudy Days (percentage)	30% *5*	
Other				0	0	Solar Power Generated on a Cloudy Day	468.0	
Windlass *2*				0	0	Power Drawn from Batteries on a Cloudy Day (Wh)		593.5
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>	Number of Continuous Cloudy Days	2	1,049.8
AC - Equipment powered by an Inverter (Watts)						Sunny Days to Make Up Battery Draw Down		2.4
	Watts	Hours	Hours	AH	AH	<b>5. Battery Capacity Analysis</b>		
Microwave (Watts)	1100	0.1	0.1	10.2	10.2	Scenario 1 - Based on Cloudy Days - with Solar		
Other				0.0	0.0	Ah Drawn from Batteries on Cloudy Days		91.3
Other				0.0	0.0	% of Battery Capacity Useable	50% *6*	161.5
Other				0.0	0.0	Rated Battery Capacity Required (AH)		182.6
Other				0.0	0.0	Rated Battery Capacity (Ah)	120	323.0
<b>Total Amp Hours</b>				<b>10.2</b>	<b>10.2</b>	Number of Batteries Required (in parallel)		1.5
<b>Total Amp Hours Consumed per Day</b>				<b>81.7</b>	<b>176.8</b>	Scenario 2 - Based on Days of Reserve Capacity (no solar)		
Battery Charging Voltage						Number of Days of Reserve Battery Capacity	2	
<b>Total Watt Hours Consumed per Day</b>				<b>1,061.5</b>	<b>2,297.8</b>	% of Battery Capacity Useable	50%	
<b>2. Alternative Power Sources</b>						Rated Battery Capacity Required (AH)		326.6
Alternator	30		2	0	60	Rated Battery Capacity (Ah)	120	467.0
Generator				0	0	Number of Batteries Required (in parallel)		2.7
Other				0	0	<b>6. Summary</b>		
<b>Total Amp Hours</b>				<b>0</b>	<b>60</b>	<b>Net Watt Hours per Day Consumed or Produced</b>		<b>1,061.50</b>
<b>Total Watt Hours Produced per Day</b>				<b>0</b>	<b>780</b>	<b>Custom Marine Products</b>		<b>1,517.80</b>
<b>Net Watt Hours per Day Consumed or Produced</b>								
<b>Custom Marine Products</b>								
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# Sample Power Consumption Worksheet

Appliance	Amps	Hours		Daily AH *1*	
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>

\*1\* AH – Amp Hours

# Sample Power Consumption Worksheet

Appliance DC	Amps	Hours	Hours	Daily AH *1*	Daily AH
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>

**Amp Draw of Each Appliance**

# Sample Power Consumption Worksheet

Appliance DC	Amps	Hours		Daily AH *1*	
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>

**Hours Used of Each Appliance**

# Sample Power Consumption Worksheet

Appliance DC	Amps	Hours		Daily AH *1*	
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>

**Amps X Hours = Daily Amp Hours**

# Sample Power Consumption Worksheet

Appliance DC	Amps	Hours	Hours	Daily AH *1*	Daily AH
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>

**Amps X Hours = Daily Amp Hours**

**AC Power Draw Calculations**

If you know appliance **amp draw**:

$120V \times 9.2 \text{ Amps} = 1,100 \text{ Watts}$

$1,100 \text{ Watts} / 13V = 84.6 \text{ Amp draw DC}$

$84.6 \text{ Amps} \times 1.2 = 101.5 \text{ Amp draw DC}$   
(1.2 inverter inefficiency factor)

If you know appliance **watt draw**:

$1,100 \text{ Watts} / 13V = 84.6 \text{ Amp draw DC}$

$84.6 \text{ Amps} \times 1.2 = 101.5 \text{ Amp draw DC}$   
(1.2 inverter inefficiency factor)

1. Daily Power Consumption Analysis					
Appliance	Amps	Hours		Daily AH *1*	
		At Anchor	On Passage	At Anchor	On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
Windlass *2*				0	0
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>
<b>AC - Equipment powered by an Inverter (Watts)</b>					
Microwave (Watts)	1100	0.1	0.1	10.2	10.2
Other				0.0	0.0
Other				0.0	0.0
<b>Total Amp Hours</b>				<b>10.2</b>	<b>10.2</b>
<b>Total Amp Hours Consumed per Day</b>				<b>81.7</b>	<b>176.8</b>
Battery Charging Voltage			13		
<b>Total Watt Hours Consumed per Day</b>				<b>1,061.5</b>	<b>2,297.8</b>



# Estimate power generation from alternative sources

Total Watt Hours Consumed per Day			1,061.5	2,297.8
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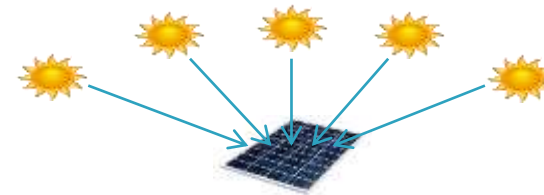
	Amps	Hours At Anchor	Hours On Passage	Daily AH *1* At Anchor	Daily AH On Passage
<b>2. Alternative Power Sources</b>					
Alternator	30		2	0	60
Generator				0	0
Other				0	0
<b>Total Amp Hours</b>				0	60
<b>Total Watt Hours Produced per Day</b>				0	780
<b>Net Watt Hours per Day Consumed or Produced</b>				1,061.50	1,517.80



# Estimate Solar Capacity Needed

	At Anchor	On Passage
<b>Net Watt Hours per Day Consumed or Produced</b>	1,061.50	1,517.80

Note: Average hours of sun per day is based on the sun angle throughout the day.  
 Note: 5 is a good number for horizontal panels, 7 for panels with tilt & rotate



<b>3. Solar Power Requirement Analysis (Full Sun)</b>		At Anchor	On Passage
Average Hours of Sun per Day	5		
Battery Charge Inefficiency Factor	1.2		
<b>Watts of Solar to Replenish Battery Bank Daily</b>		<b>254.8</b>	<b>364.3</b>

Charge efficiency factor –  
 Lead Acid ≈ 1.2, AGM ≈ 1.1 , LiFePO4 ≈ 1.04

**Watts of Solar Power Required**

Watts = Volts x Amps

# Select Solar Panels and Controller

		At Anchor	On Passage
<b>Solar System Design Analysis (MPPT Controller)</b>			
Capacity of Each Solar Panel (Watts)	130		
Number of Solar Panels Required		2.2	3.1
Number of Solar Panels Installed	3		
Minimum Capacity of Solar Controller (Amps)	30.0		
Daily Useable Solar Power in Full Sun (Watt Hrs)	1,560.0		
Daily Power Drawn from Battery Bank (Watt Hrs)		1,061.5	1,517.8
Excess or (Deficit) of Power (Watt Hrs)		498.5	42.2
<b>4. Factor for Cloudy Days</b>			
Solar Efficiency on Cloudy Days (percentage)	30%		
Solar Power Generated on a Cloudy Day	468.0		
Power Drawn from Batteries on a Cloudy Day (Wh)		593.5	1,049.8
Number of Continuous Cloudy Days	2		
Sunny Days to Make Up Battery Draw Down		2.4	49.8

130 x 3 x 5 x .8

1,061.5 - 468.0

1,517.8 - 468.0

593.5 x 2 / 498.5

1,049.8 x 2 / 42.2

Solar efficiency - Partly cloudy ≈ 70%, Mostly cloudy ≈ 50%, Very cloudy ≈ 30%

# Estimate Optimum Size of Battery Bank

5. Battery Capacity Analysis		Amp Hrs	Amp Hrs
		at Anchor	on Passage
<b>Scenario 1 - Based on Cloudy Days - with Solar</b>			
Ah Drawn from Batteries on Cloudy Days		91.3	161.5
% of Battery Capacity Useable	50%	*6*	
Rated Battery Capacity Required (AH)		182.6	323.0
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		1.5	2.7
<b>Scenario 2 - Based on Days of Reserve Capacity (no solar)</b>			
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	50%		
Rated Battery Capacity Required (AH)		326.6	467.0
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		2.7	3.9

$593.5 \times 2 / 13$   
 $1,049.8 \times 2 / 13$

$91.3 \times 50\%$   
 $161.5 \times 50\%$

$182.6 / 120$   
 $323.0 / 120$

$1,061.5 / 13 / 2 \times 50\%$   
 $1,517.8 / 13 / 2 \times 50\%$

\*6\* Useable battery capacity - Lead Acid ≈ 50%, AGM ≈ 60%, LiFePO4 ≈ 95%

# Estimate Optimum Size of Battery Bank

<b>5. Battery Capacity Analysis</b>		<b>Amp Hrs at Anchor</b>	<b>Amp Hrs on Passage</b>
<b>Scenario 1 - Based on Cloudy Days - with Solar</b>			
Ah Drawn from Batteries on Cloudy Days		91.3	161.5
% of Battery Capacity Useable	95%	*6*	
Rated Battery Capacity Required (AH)		<b>96.1</b>	<b>170.0</b>
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		<b>0.8</b>	<b>1.4</b>
<b>Scenario 2 - Based on Days of Reserve Capacity (no solar)</b>			
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	95%		
Rated Battery Capacity Required (AH)		<b>171.9</b>	<b>245.8</b>
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		<b>1.4</b>	<b>2.0</b>

\*6\* Useable battery capacity - Lead Acid ≈ 50%, AGM ≈ 60%, **LiFePO4 ≈ 95%**

# Worksheet for Designing a Solar System Based on Power Consumption

Input fields in Grey

1. Estimate daily power consumption
2. Estimate power generation from alternative sources
3. Estimate solar generation capacity needed
4. Select solar panel(s) and controller – mounting considerations
5. Estimate optimum size of your battery bank

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Worksheet for Designing a Solar System Based on Power Consumption						Input fields in Grey		
<b>1. Daily Power Consumption Analysis</b>						<b>3. Solar Power Requirement Analysis (Full Sun)</b>		
Appliance	Amps	Hours	Hours	Daily AH *1*	Daily AH	Average Hours of Sun per Day	At Anchor	On Passage
DC		At Anchor	On Passage	At Anchor	On Passage	5 *3*		
Refrigeration	5	10	10	50	50	Battery Charge Inefficiency Factor	1.2 *4*	
Radar	4		4	0	6	Watts of Solar to Replenish Battery Bank Daily	254.8	364.3
Computer - Laptop	4	1	10	4	4	<b>Solar System Design Analysis (MPPT Controller)</b>		
Autopilot	4		10	0	40	Capacity of Each Solar Panel (Watts)	130	
Cabin Lights (LED)	1	4		4	0	Number of Solar Panels Required		2.2
Nav/Anchor Lights	0.2	10	10	2	2	Number of Solar Panels Installed	3	
Stereo	1	3	3	3	3	Minimum Capacity of Solar Controller (Amps)	30.0	
VHF Radio	0.5	10	10	5	5	Daily Useable Solar Power in Full Sun (Watt Hrs)	1,560.0	
Instruments	1		8	0	8	Daily Power Drawn from Battery Bank (Watt Hrs)		1,061.5
Pressure Water	6	0.25	0.1	1.5	0.6	Excess or (Deficit) of Power (Watt Hrs)		498.5
Phone Charger	1	2	2	2	2	<b>4. Factor for Cloudy Days</b>		
Other				0	0	Solar Efficiency on Cloudy Days (percentage)	30% *5*	
Other				0	0	Solar Power Generated on a Cloudy Day	468.0	
Windlass *2*				0	0	Power Drawn from Batteries on a Cloudy Day (Wh)		593.5
<b>Total Amp Hours</b>				<b>71.5</b>	<b>166.6</b>	Number of Continuous Cloudy Days	2	1,049.8
AC - Equipment powered by an Inverter (Watts)						Sunny Days to Make Up Battery Draw Down		2.4
	Watts	Hours	Hours	AH	AH	<b>5. Battery Capacity Analysis</b>		
Microwave (Watts)	1100	0.1	0.1	10.2	10.2	<b>Scenario 1 - Based on Cloudy Days - with Solar</b>		
Other				0.0	0.0	Ah Drawn from Batteries on Cloudy Days		91.3
Other				0.0	0.0	% of Battery Capacity Useable	50% *6*	161.5
Other				0.0	0.0	Rated Battery Capacity Required (AH)		182.6
Other				0.0	0.0	Rated Battery Capacity (Ah)	120	323.0
<b>Total Amp Hours</b>				<b>10.2</b>	<b>10.2</b>	Number of Batteries Required (in parallel)		1.5
<b>Total Amp Hours Consumed per Day</b>				<b>81.7</b>	<b>176.8</b>	<b>Scenario 2 - Based on Days of Reserve Capacity (no solar)</b>		
Battery Charging Voltage						Number of Days of Reserve Battery Capacity	2	
<b>Total Watt Hours Consumed per Day</b>				<b>1,061.5</b>	<b>2,297.8</b>	% of Battery Capacity Useable	50%	
<b>2. Alternative Power Sources</b>						Rated Battery Capacity Required (AH)		326.6
Alternator	30		2	0	60	Rated Battery Capacity (Ah)	120	467.0
Generator				0	0	Number of Batteries Required (in parallel)		2.7
Other				0	0	<b>6. Summary</b>		
<b>Total Amp Hours</b>				<b>0</b>	<b>60</b>	<b>Net Watt Hours per Day Consumed or Produced</b>		<b>1,061.50</b>
<b>Total Watt Hours Produced per Day</b>				<b>0</b>	<b>780</b>	<b>Custom Marine Products</b>		<b>1,517.80</b>
<b>Net Watt Hours per Day Consumed or Produced</b>								
<b>Custom Marine Products</b>								
info@custommarineproducts.com 248 705-8337								

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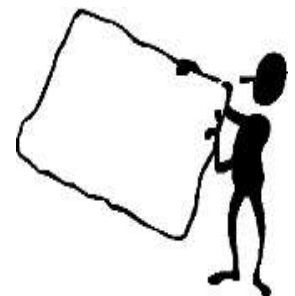
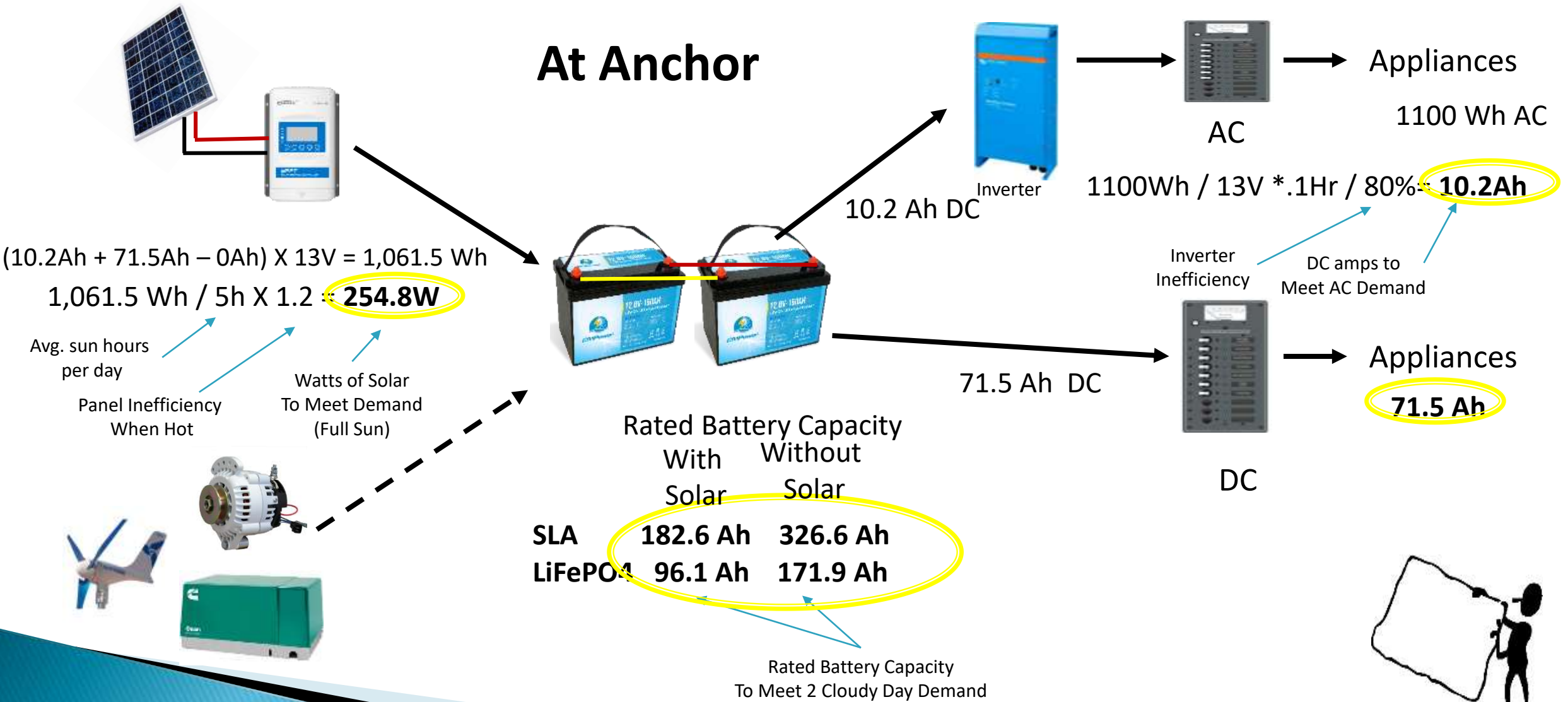
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Available at:  
[custommarineproducts.com](http://custommarineproducts.com)  
 - Handy Info – System Design

\*1\* AH - Amp Hours - Amps of current consumed in one hour.  
 \*2\* Windlass is often not considered because the engine alternator is running when used  
 \*3\* 5 hours avg. is a good estimate for horizontal panels, 7 for panels with tilt & rotate  
 See <http://www.bigfrogmountain.com/SunHoursPerDay.html> for hours in your area.  
 \*4\* Charge efficiency factor - Lead Acid ≈ 1.2, AGM ≈ 1.1, LiFePO4 ≈ 1.04  
 \*5\* Solar efficiency - Partly cloudy ≈ 70%, Mostly cloudy ≈ 50%, Very cloudy ≈ 30%  
 \*6\* Useable battery capacity - Lead Acid ≈ 50%, AGM ≈ 60%, LiFePO4 ≈ 95%

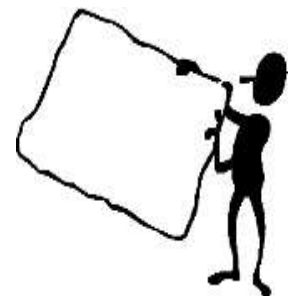
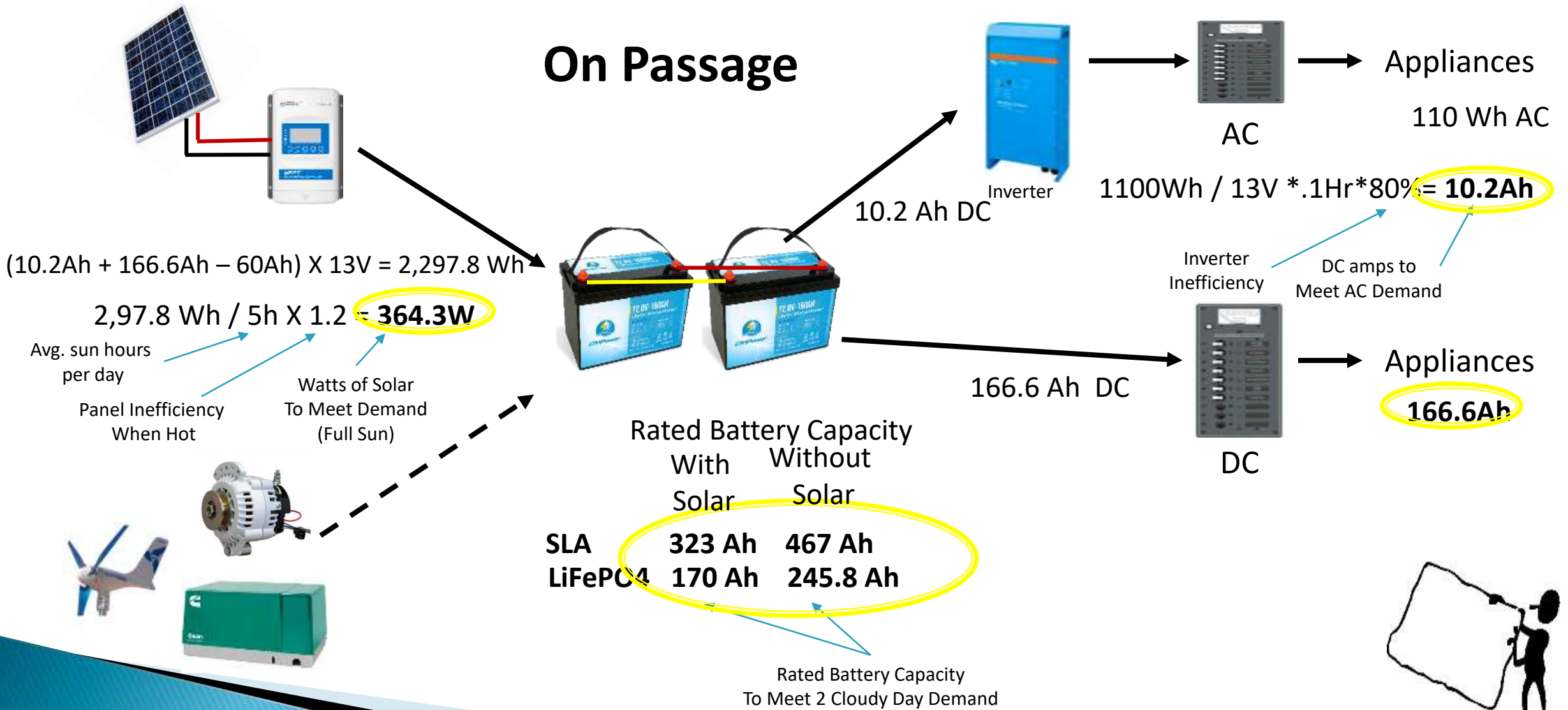
# Designing a Solar System to Meet Your Needs - Findings

## At Anchor



# Designing a Solar System to Meet Your Needs - Findings

## On Passage



# Our Findings

Generate All the Power Needed While at Anchor or on Passage

Power consumption

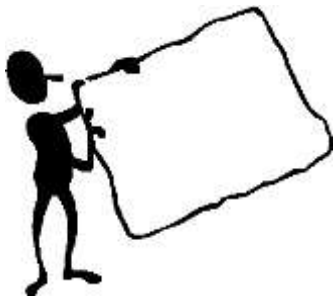
82 to 177 amp hours

Optimum battery capacity

200 to 400 amp hours (lead acid)

Rated panel wattage needed

300 to 550 watts  
(roughly)



Watts = Volts x Amps

## Another Approach

### Solar Capacity Needed Starting with the Battery Bank

#### Findings

Is your current battery bank working for you?

Battery type: Lead acid

Battery bank capacity: 240 Ah (Qty 2 120Ah batteries)

Useable battery power: 120 Ah @ 50% draw down

Typical draw down anchored: 40% of battery capacity

#### Calculations

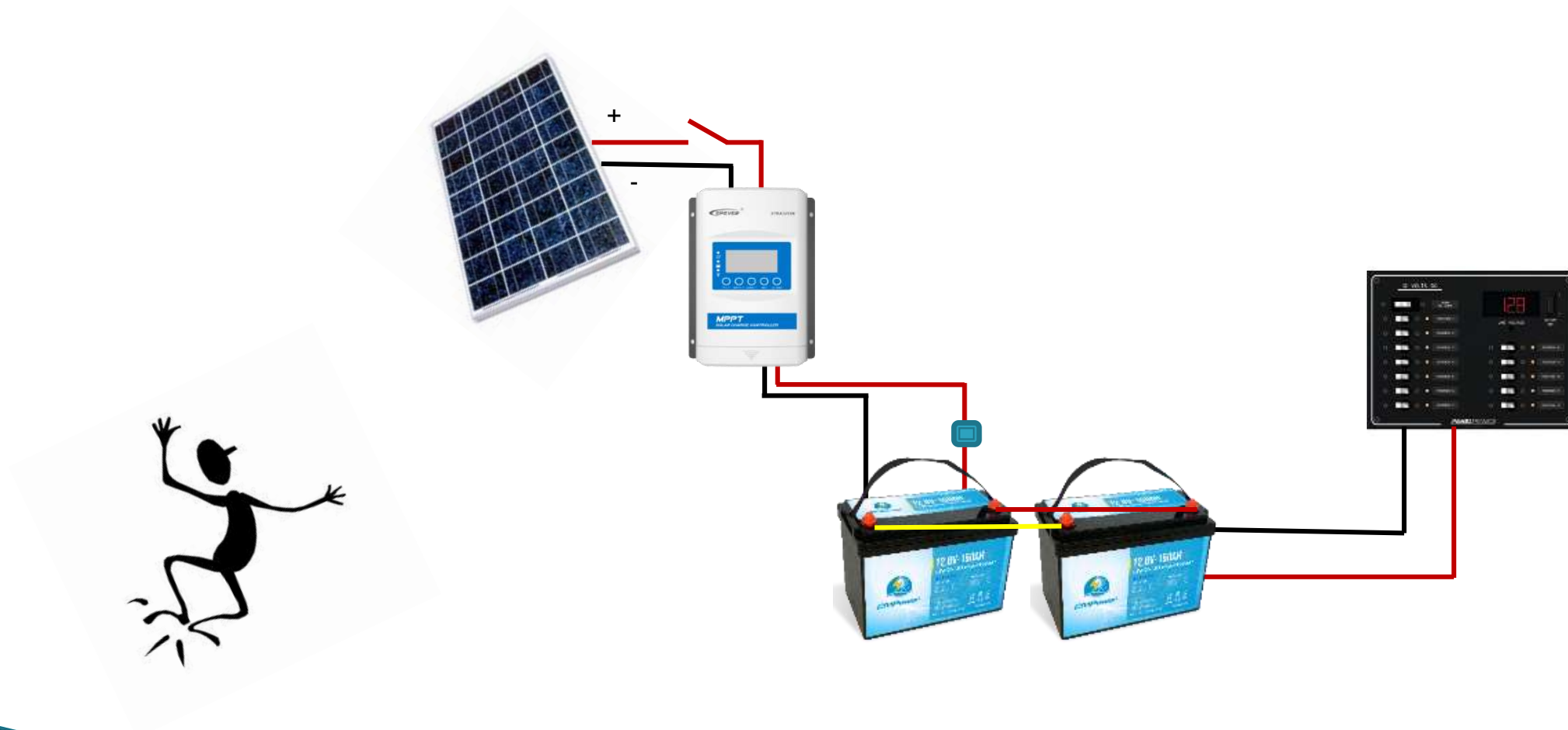
$40\% \times 240 \text{ Ah} = 96 \text{ Amp Hrs}$  used in a 24 hour period

$96 \text{ Ah} \times 12.8 \text{ V} = 1,229 \text{ Watt Hrs}$  used in a 24 hour period

$1,229 \text{ Wh} / 5 \text{ Avg Sun Hrs per day} = 246 \text{ Wh}$

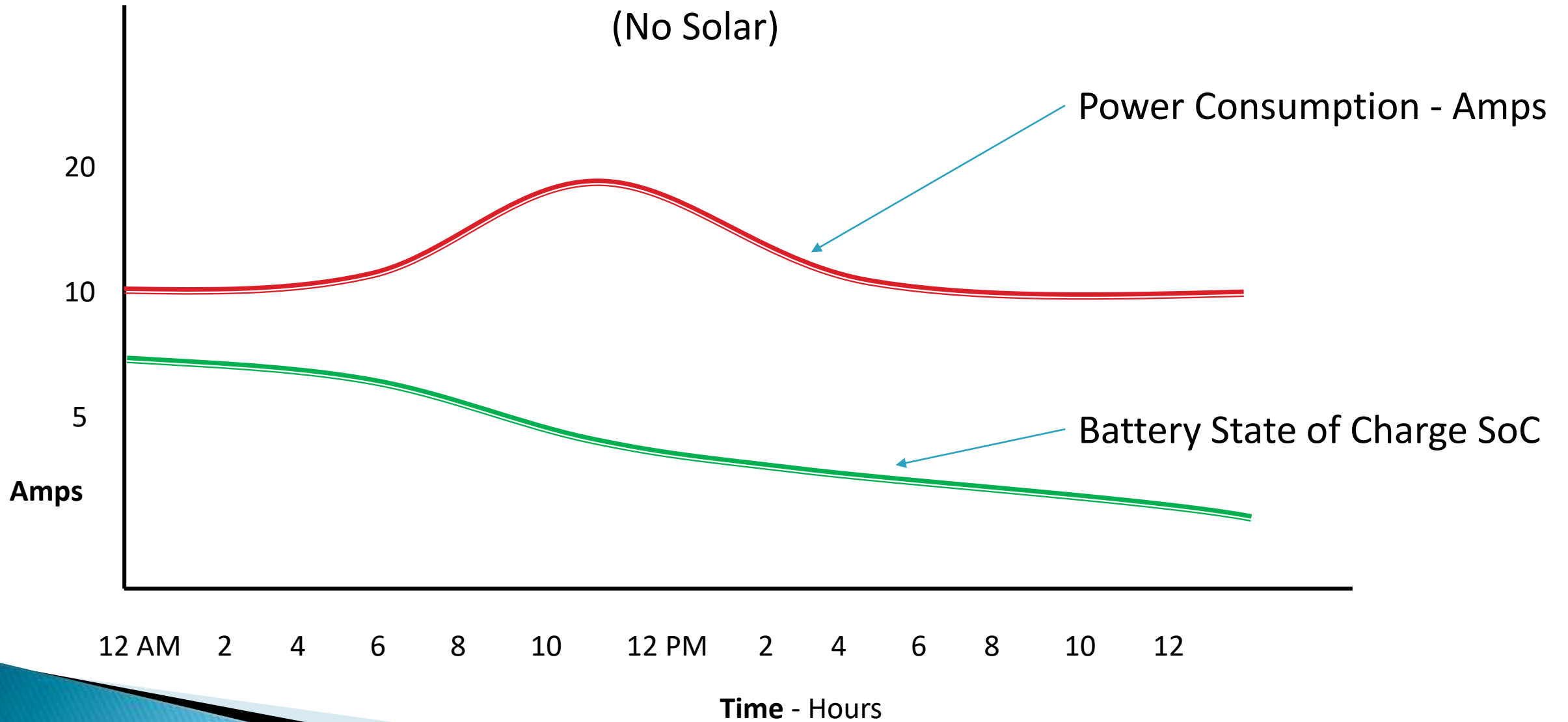
$246 \text{ Wh} \times 1.2 \text{ for inefficiencies} = \mathbf{295 \text{ Watts of solar needed}}$

# A Complete and Balanced Solar Power System



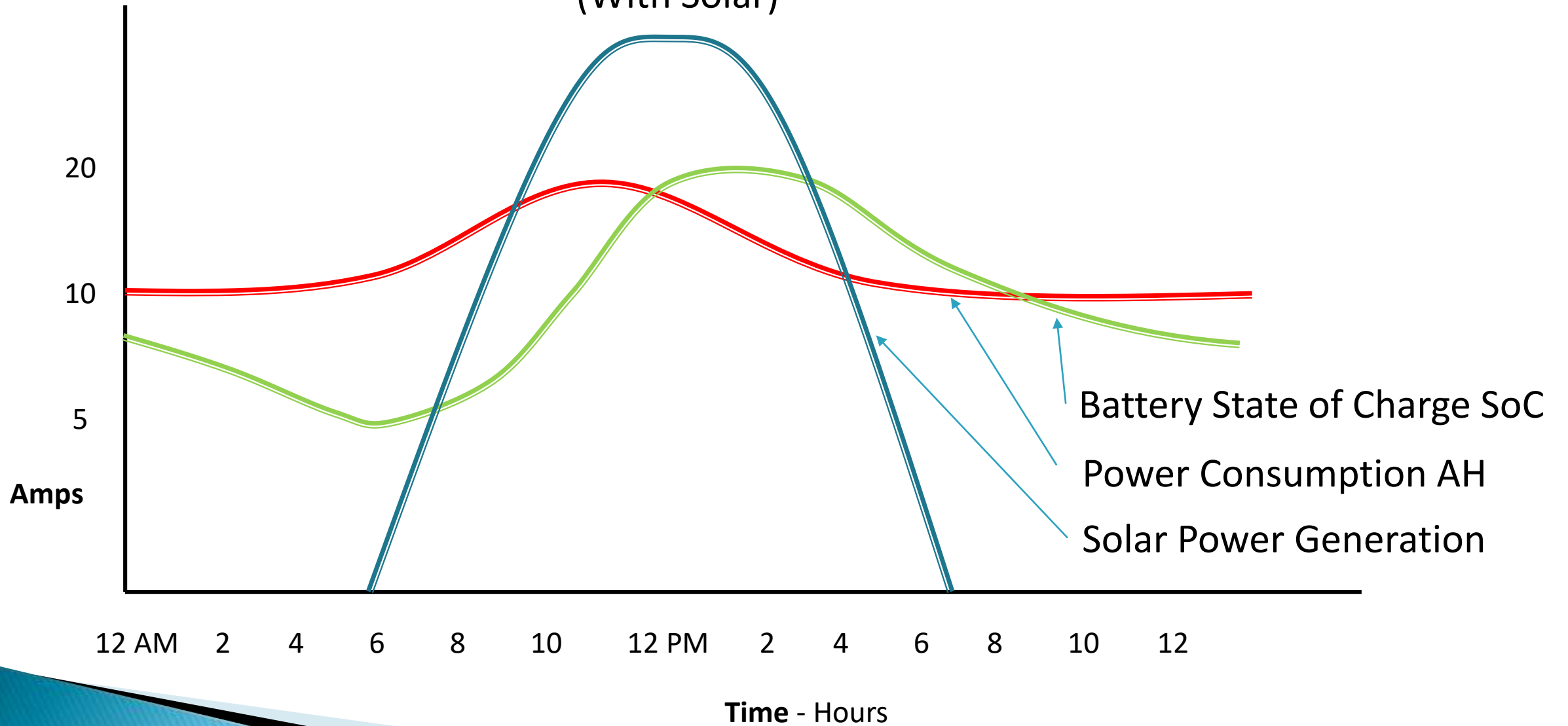
# Effectively Utilize Solar Power in a Balanced System

(No Solar)



# Effectively Utilize Solar Power in a Balanced System

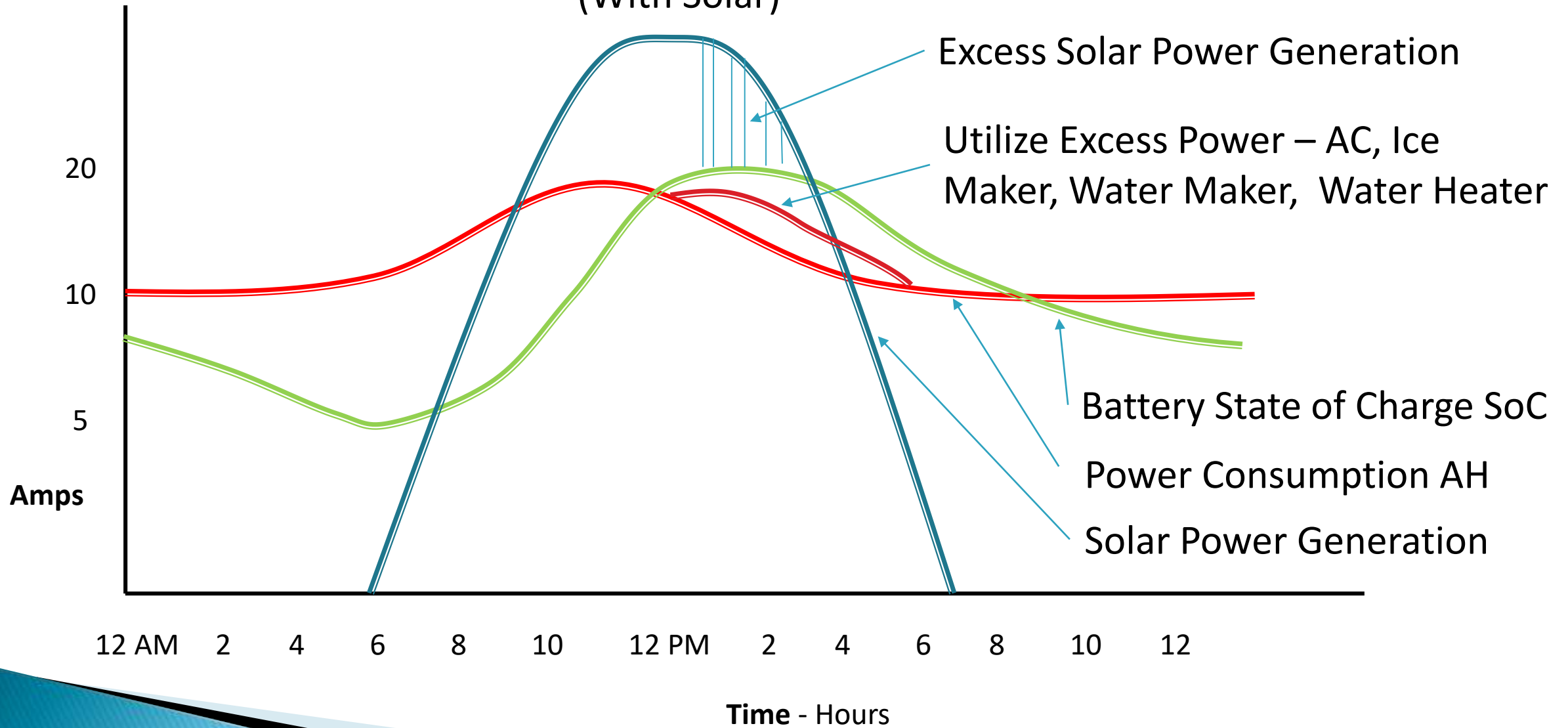
(With Solar)



Battery State of Charge SoC  
Power Consumption AH  
Solar Power Generation

# Effectively Utilize Solar Power in a Balanced System

(With Solar)



Excess Solar Power Generation

Utilize Excess Power – AC, Ice Maker, Water Maker, Water Heater

Battery State of Charge SoC

Power Consumption AH

Solar Power Generation

Amps

Time - Hours

12 AM 2 4 6 8 10 12 PM 2 4 6 8 10 12

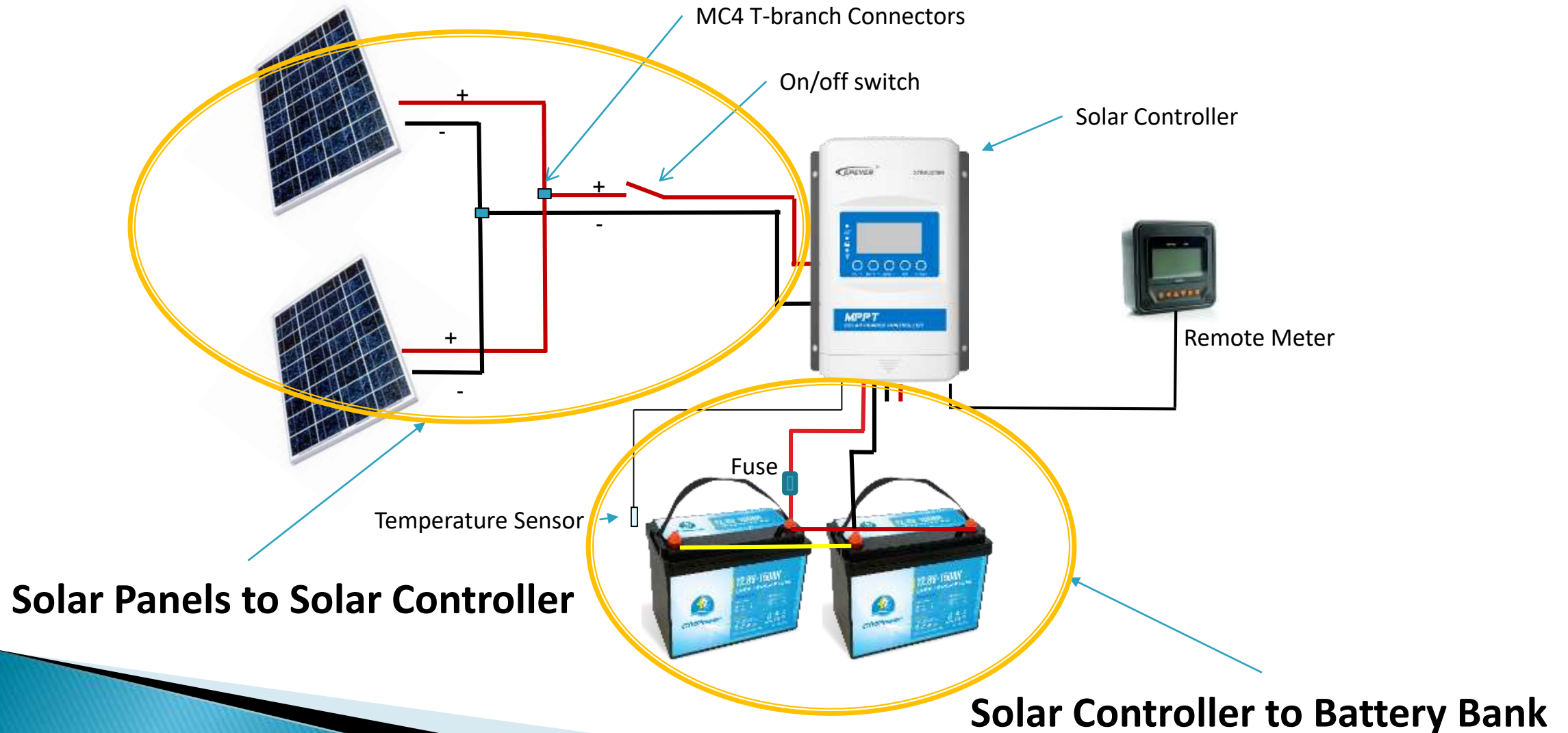


# Marine Solar System Installation and Wiring Considerations



**CMIPower**

# Marine Solar System Installation and Wiring Considerations

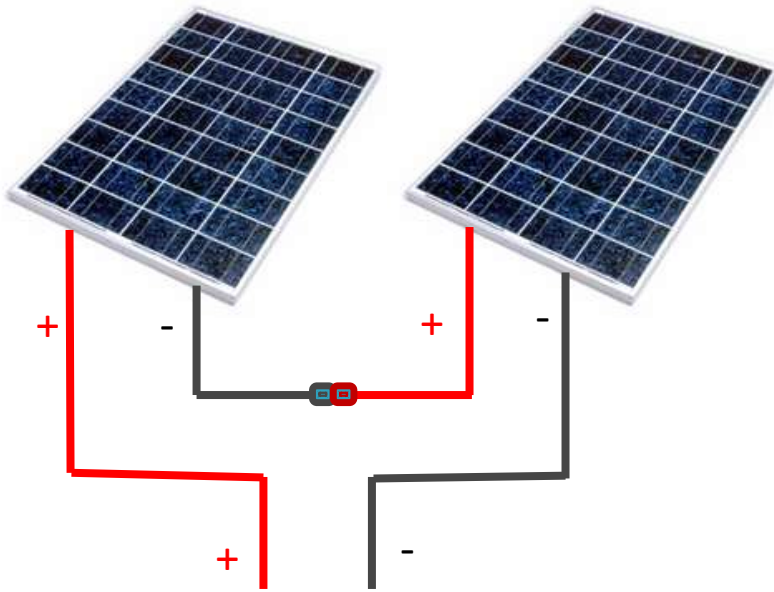


# Wiring Multiple Solar Panels

100 Watt, 18 Volt, 5.6 Amp

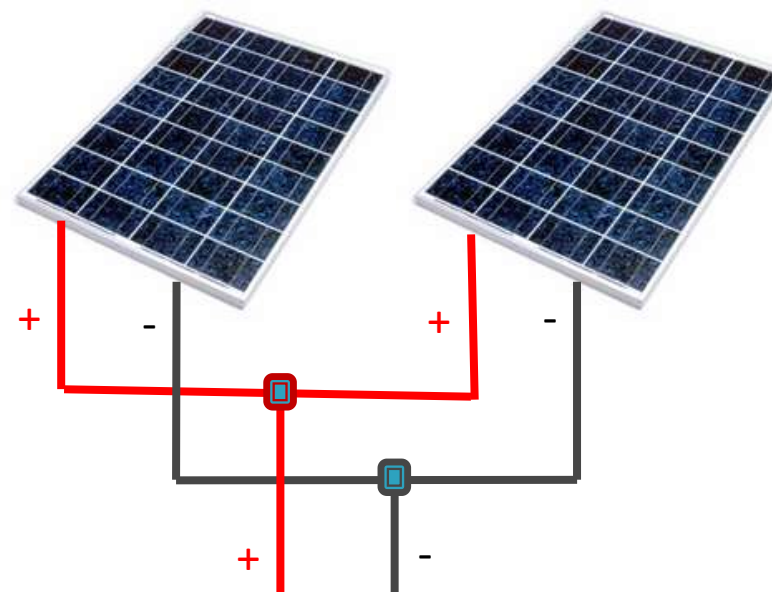
Generally Recommended

## Series

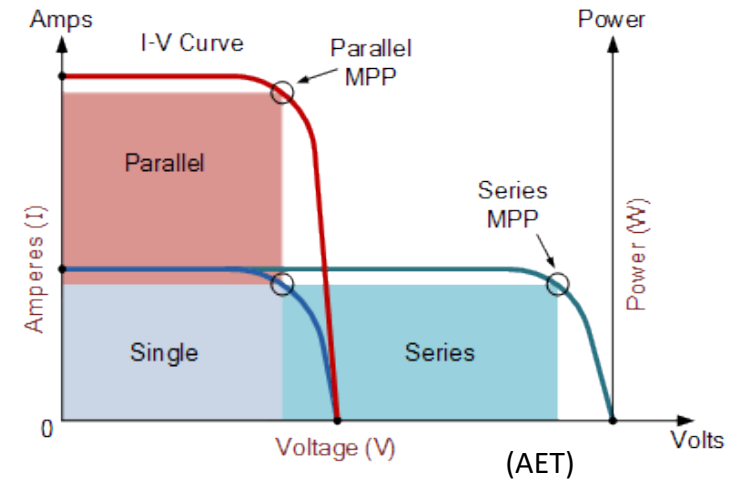


**36 Volts**  
**5.6 Amps**

## Parallel



**18 Volts**  
**11.1 Amps**



# Wiring Solar Panels in Parallel

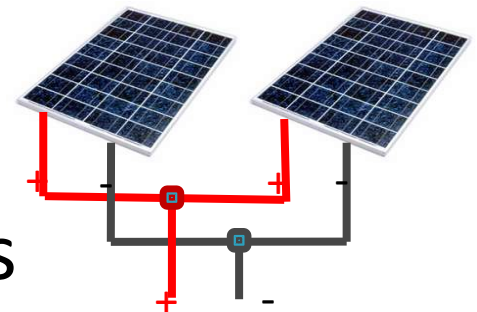
Pros –

- The **voltage** from the solar array to the controller is **lower** than in a series configuration so the controller operates more efficiently to bring the voltage down to what the battery bank requires. (More power stored)
- If one panel is shaded, the higher output of the other panels is not hindered. (If the panels have proper diodes built in)

Cons –

- The **amperage** from the solar array to the controller is **higher** than in a series configuration so the wire size must be larger.

**18 Volts**  
**11.1 Amps**



# Wiring Solar Panels in Series

Pros –

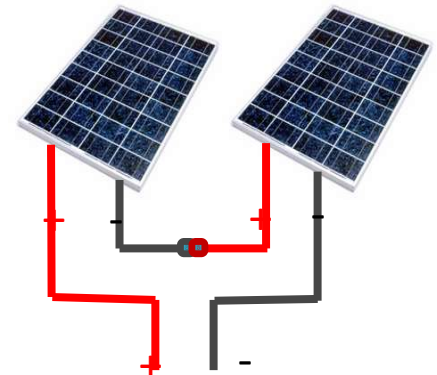
- The **amperage** from the solar array to the controller is **lower** than in a parallel configuration so the wire size can be smaller.

Cons –

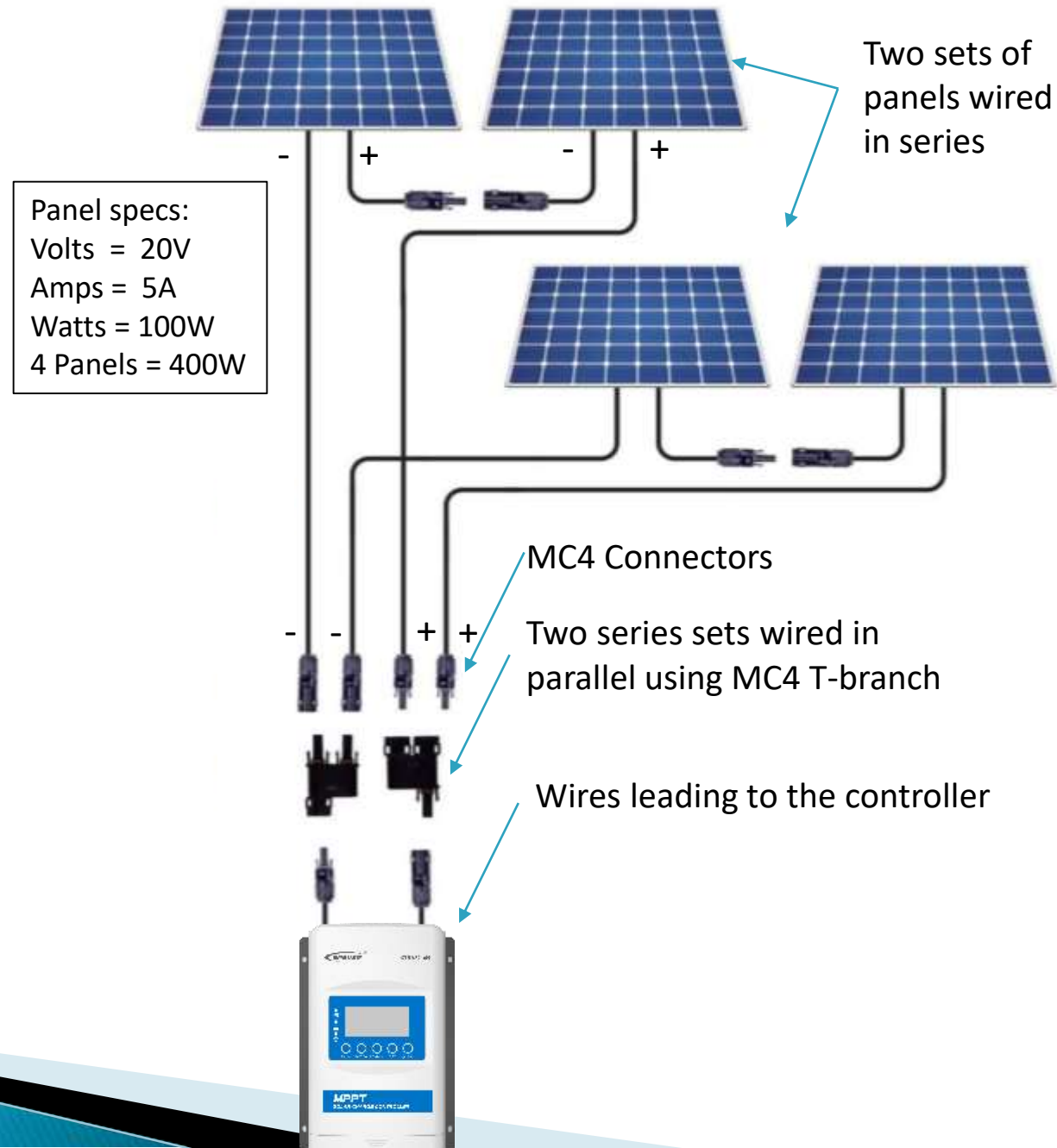
- The **voltage** from the solar array to the controller is **higher** than in a parallel configuration so the controller operates less efficiently to bring the voltage down to what the battery bank requires.
- If one panel is shaded, the output of the entire solar array is significantly reduced.

If in doubt and you have limited shading, try both configurations to see which provides the maximum watt hours per day.

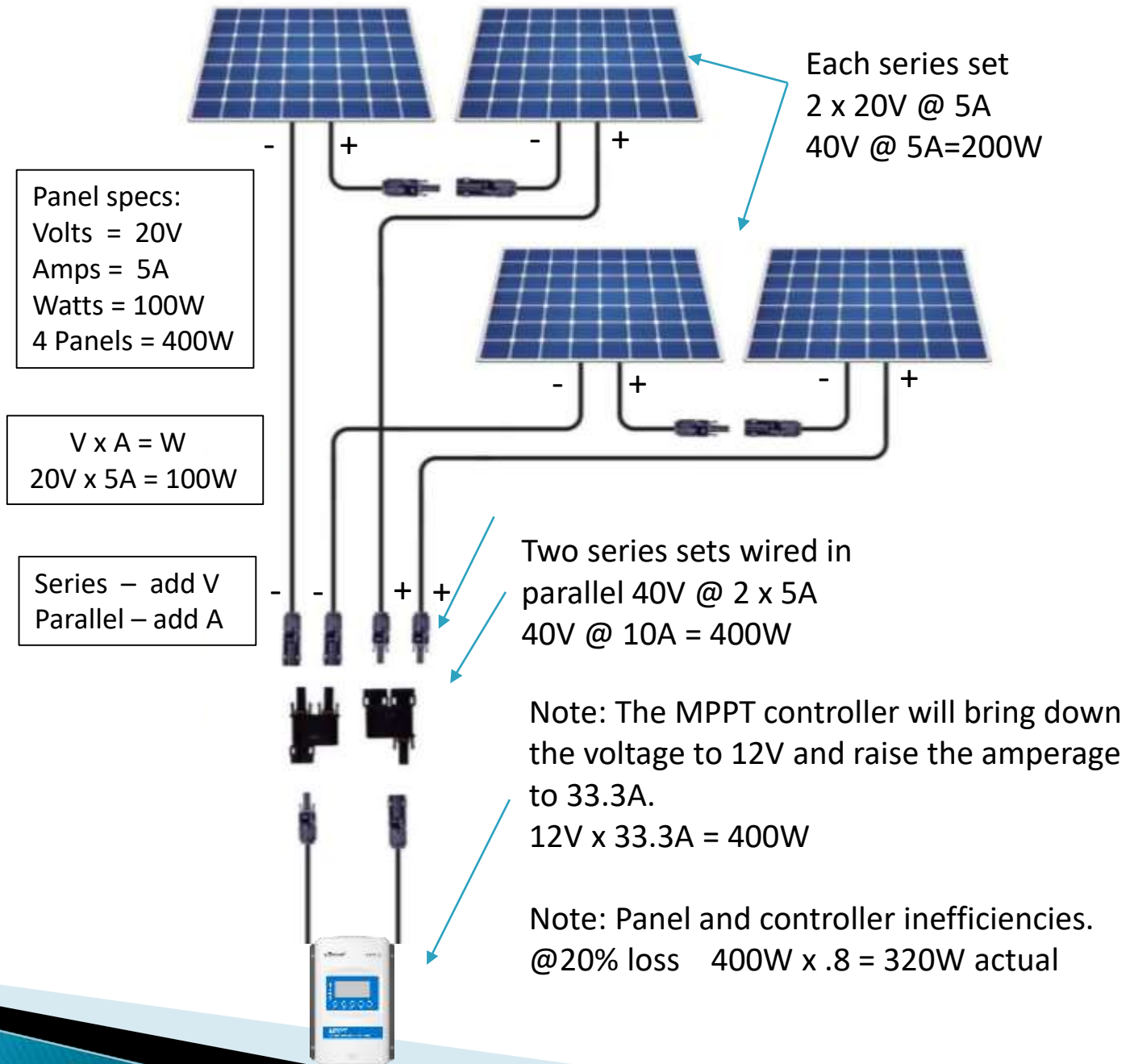
**36 Volts**  
**5.6 Amps**



# Four 100 W solar panels – 2 in series, 2 series sets in parallel



# Four 100 W solar panels – 2 in series, 2 series sets in parallel



# Solar Wire Specifications

Use marine solar wire to connect the solar panels to the solar controller.

- Like all marine grade wire, solar wire should be tinned to prevent corrosion.
- High strand count is important. It should be >50 strands
  - More flexible
  - Won't fracture from boat vibration
  - Less resistance – lower voltage drop
- Most quality solar wire is single conductor with two layers of insulation.
- AWG #10 solar wire is ¼" (6mm) in diameter and adequate for smaller marine installations. AWG #8 solar wire (10mm) is appropriate for larger installations.



# Wire Size

Number 10 or 8 gauge high strand count tinned solar wire is generally adequate for most marine solar systems.

**2% Voltage Drop Chart For 12 volt Systems**

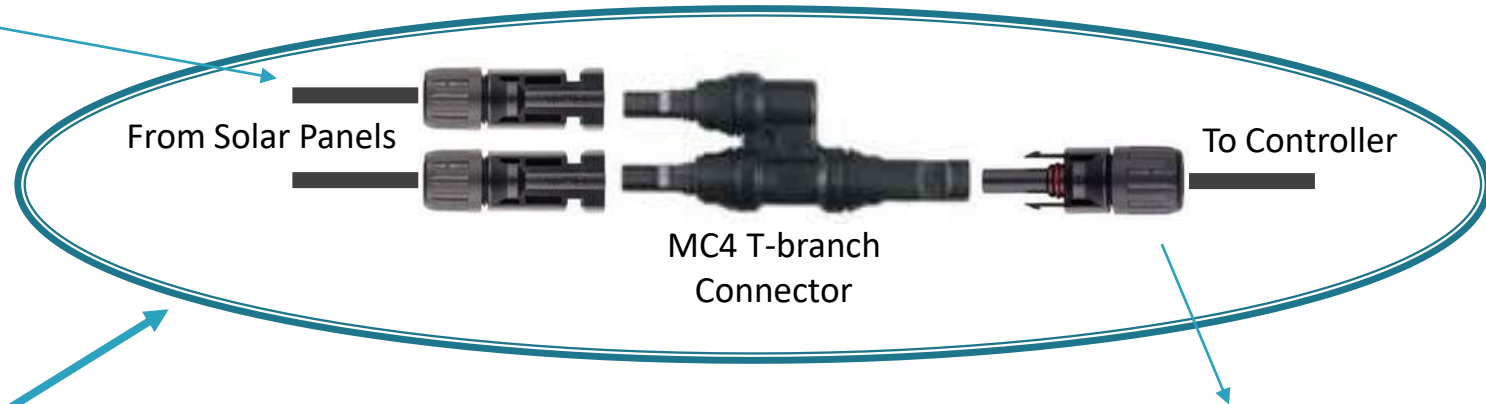
Maximum distance in feet of various gauge two conductor copper wire from power source to load for 2% voltage drop in a 12 volt system. Do not exceed the 2% drop for wire between PV modules and batteries. A 4 to 5% loss is acceptable between batteries and lighting circuits in most cases, however the cost of the next larger wire size is usually insignificant and increases efficiency.

Amps	#14	#12	#10	#8	#6	#4	#2	#1/0	#2/0	#4/0
1	45	70	115	180	290	456	720			
2	22.5	35	57.5	90	145	228	360	580	720	1060
4	10	17.5	27.5	45	72.5	114	180	290	360	580
6	7.5	12	17.5	30	47.5	75	120	193	243	380
8	5.5	8.5	11.5	22.5	35.5	57	90	145	180	290
10	4.5	7	11.5	18	28.5	45.5	72.5	115	145	230
15	3	4.5	7	12	19	30	48	76.5	96	150
20	2	3.5	5.5	9	14.5	22.5	36	57.5	72.5	116
25	1.8	2.8	4.5	7	11.5	18	29	46	58	92
30	1.5	2.4	3.5	6	9.5	15	24	38.5	48.5	77
40			2.8	4.5	7	11.5	18	29	36	56
50			2.3	3.5	5.5	9	14.5	23	29	46
100					2.9	4.6	7.2	11.5	14.5	23
150							4.8	7.7	9.7	15
200							3.6	5.8	7.3	11



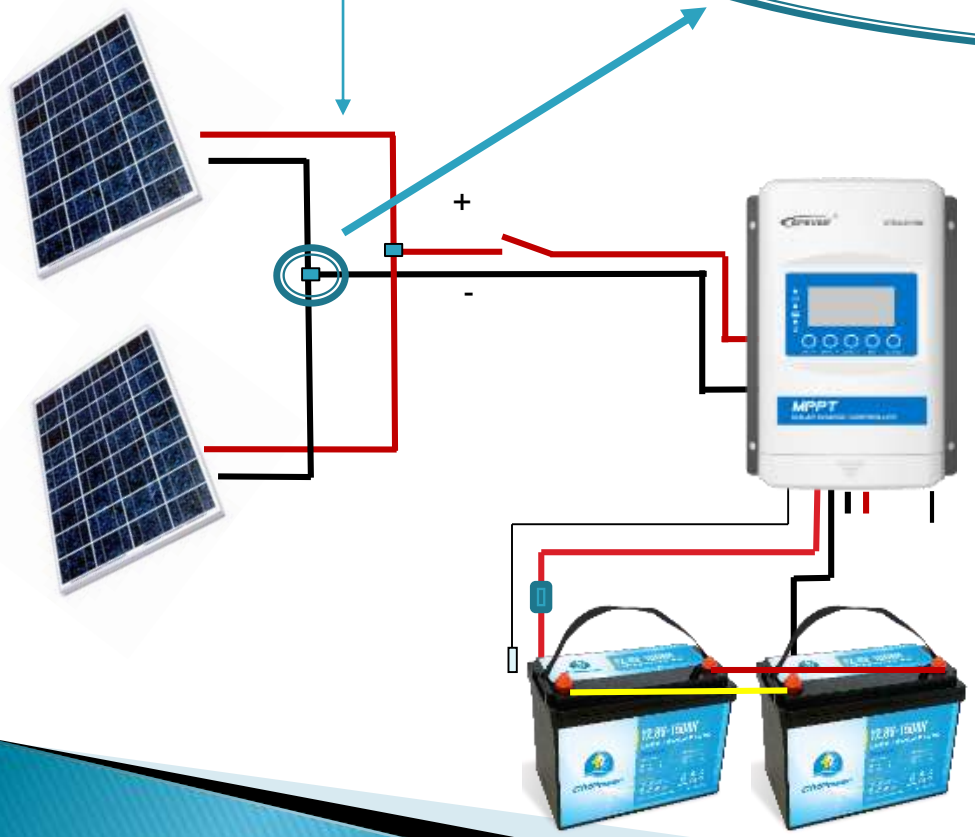
# MC4 Solar Connectors

Most *CMPower* solar panels include three foot pigtails with MC4 connectors pre-installed.



Note: *CMPower* wire coil provided in a solar kit includes a male and female MC4 connector pre-installed on each wire end. Coils are typically 50 or 60 feet in length.

Cut the coil in half and there are two 25 or 30 foot lengths to run from the solar panels to the solar controller. Thus, no crimping tool is required. Excess wire can be used to connect the solar controller to the battery bank.



# MC4 Solar Connectors

- MC4 connectors are waterproof.
- MC4 connectors seal around solar wire.
- MC4 connectors enable easy connecting and disconnecting of solar panels.
- MC4 T-branch connectors are used to wire solar panels in parallel.
- A special crimping tool is required to install connectors.



MC4 Male & Female Connectors

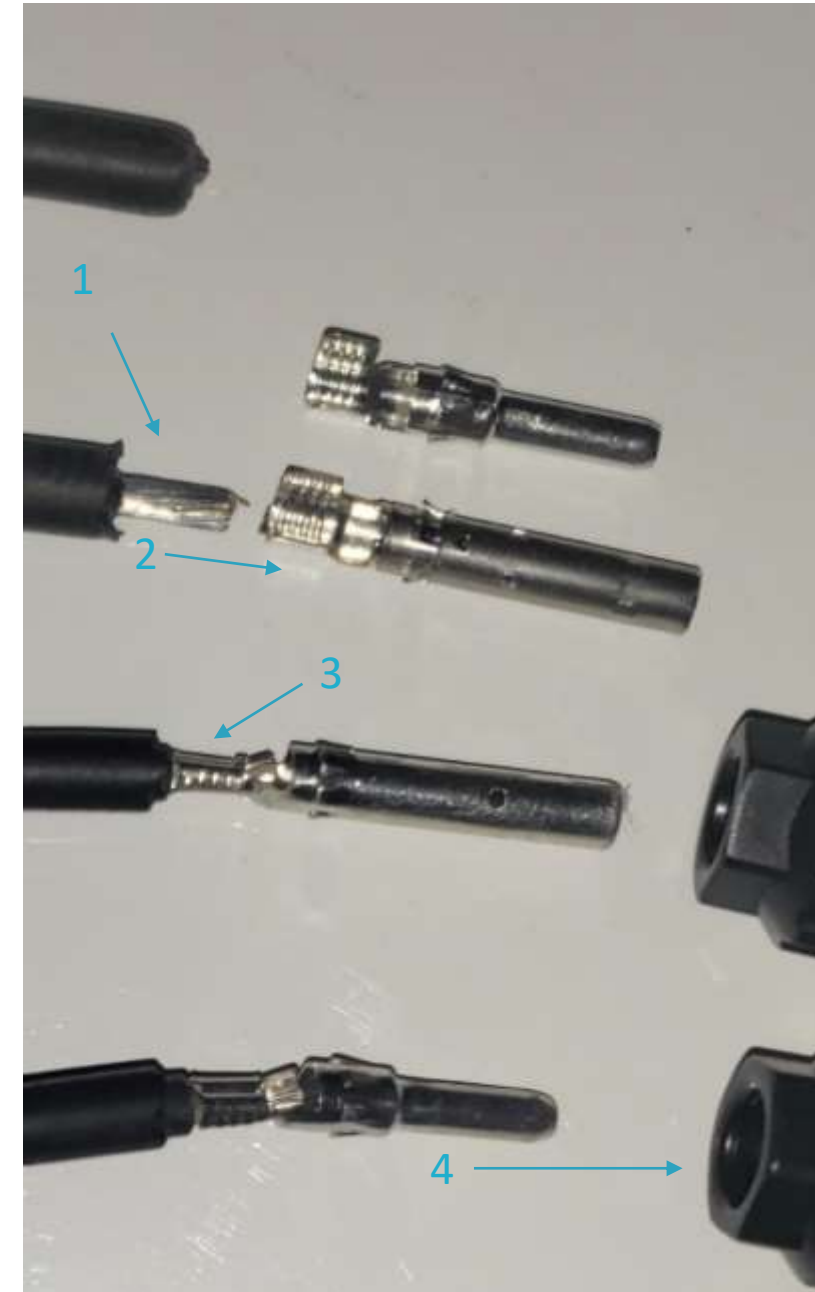


MC4 Male & Female T-branch Connectors are Used to Wire Multiple Solar Panels in Parallel



# Installing MC4 Connectors

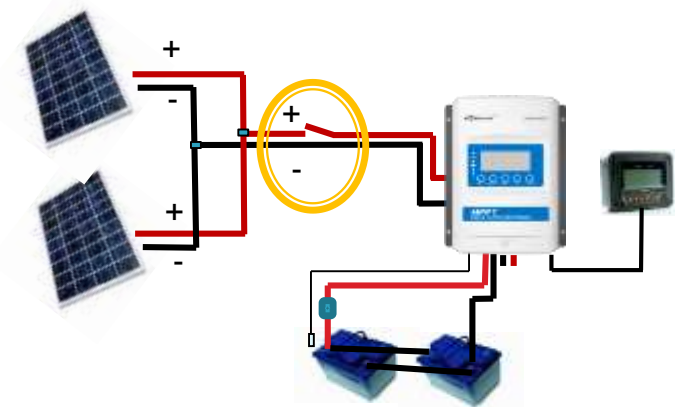
1. Strip wire back 3/8 " or 1 cm.
2. Place the wire in the metal insert between the two tabs.
3. Use an MC4 crimping tool to fold the tabs onto the bare wire.
4. Insert the metal insert into the MC4 connector until the insert tabs lock into the MC4 connector. Note which insert to place into which connector.
5. Use spanners or wrenches to tighten the barrel onto the connector making a waterproof seal.



# Turning a Solar System On and Off

- We recommend inserting a switch or breaker in the positive wire between the solar array and the controller to turn the solar system on and off.
- Why? To prevent the alternator and shore power charge controller from prematurely going into float mode.
- The alternator may sense a higher than actual battery voltage due to the solar controller voltage and thus sense the battery bank is in a higher state of charge and prematurely go into float mode reducing the output of the alternator.
  - If this occurs, use the switch to shut down the solar system and gain the full output power from the alternator or shore charger.
  - This only occurs with some charging devices under certain conditions.

Note: Any DC on/off switch with sufficient rated capacity will do.

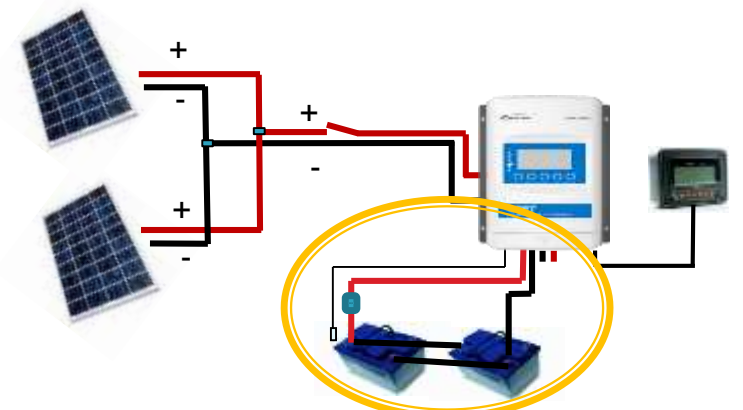


# Wiring the Solar Controller to the Battery Bank

- **Wiring** – Position the Controller close to the battery bank.
  - Unless there is a battery monitor, the negative wire from the controller should attach to the negative bus or the negative terminal on the battery. The positive wire should go directly to the battery.
- **Wire Size** – Adequate size wire is critical.

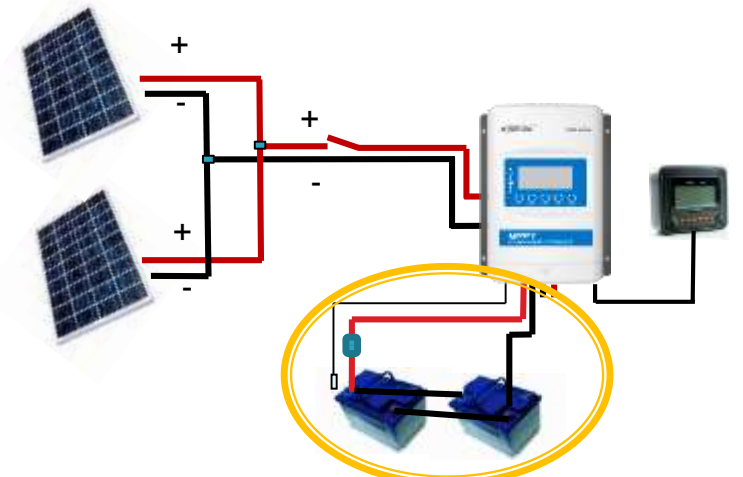
Solar array watts / boat voltage = amps going through the wire.  $240 \text{ watts} / 12\text{V} = 20\text{A}$
- **Fuse** - Per ABYC standards, the positive wire leading to the battery bank should be fused roughly 10 amps above the rated capacity of the solar controller.

- **Always check to be sure the + and – wires are the correct polarity before inserting into the controller.**



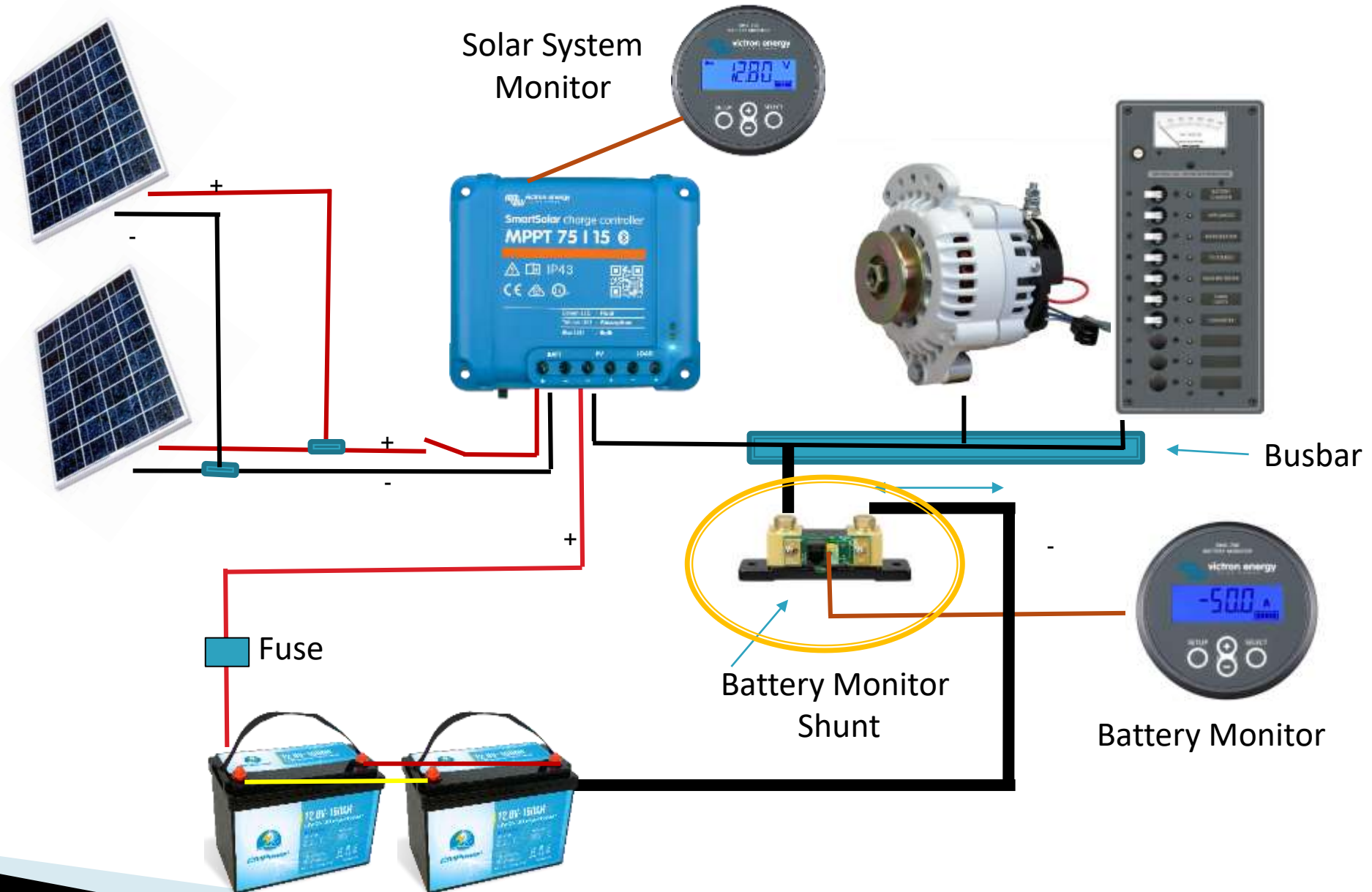
# Wiring the Solar Controller to the Battery Bank

- **Load function** - The LOAD function available on some controllers is not used for marine applications. Ignore it. LOAD is primarily used to control lighting systems.
- **Temperature sensor** - The temperature sensor should be attached to the side or top of a battery. If the battery heats up, the controller cuts back on the power supplied. A temperature sensor is not necessary for LiFePO4 batteries or for small systems with solar arrays under 150 watts.
- **Connection sequence** - The solar controller is powered by the battery bank, not the solar panels. Thus, **the solar controller should be attached to the battery bank first and then to the solar panel array.**



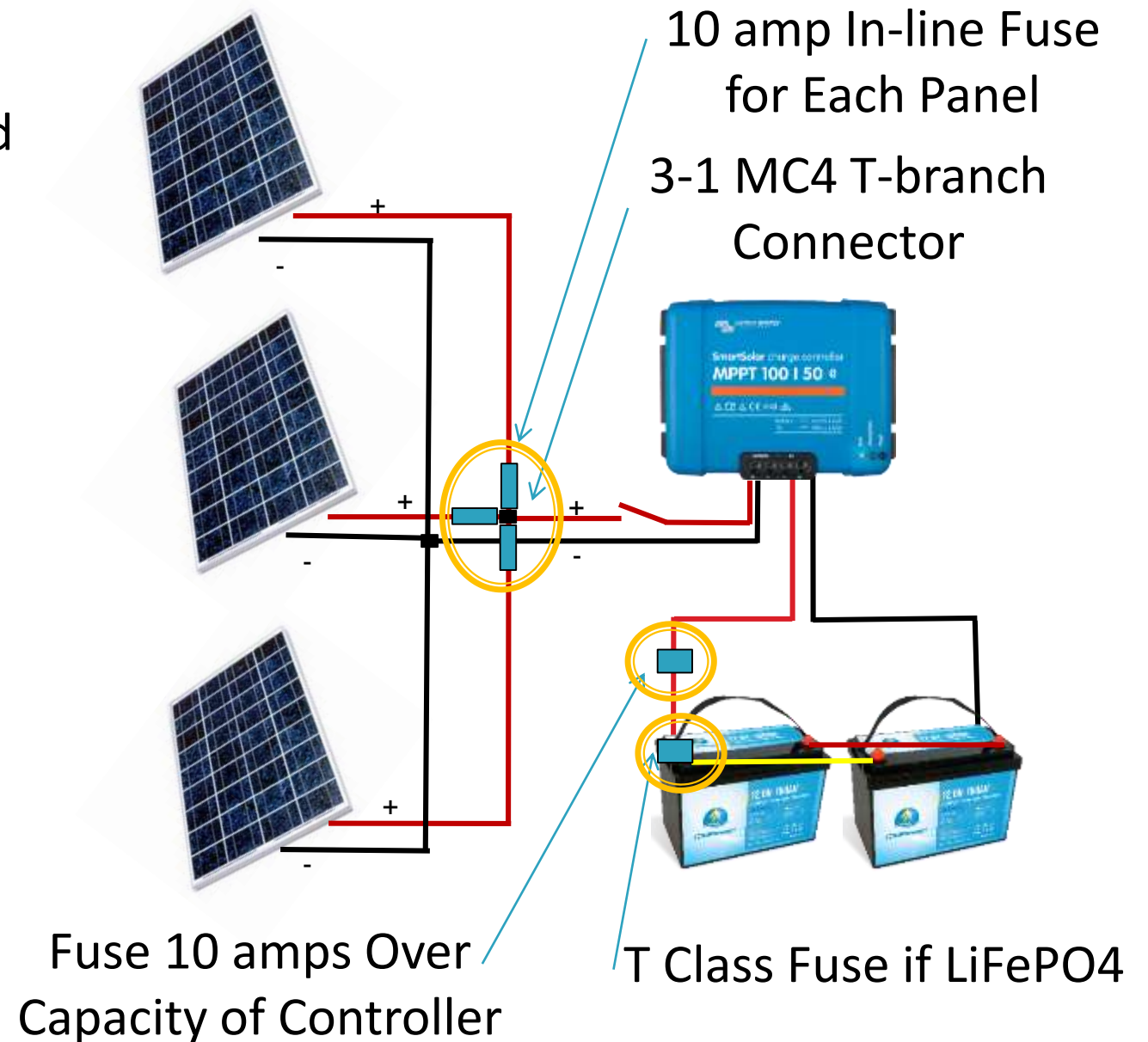
# Wiring a Solar Controller with a Battery Monitor

- Most battery monitors require a shunt.
- The negative wire from the controller is attached to the house/charging side of the shunt.
- The positive wire from the controller is attached to the positive battery bank terminal and fused.



# Overview - System Fuse Considerations

- If the solar array has more than two solar panels, a 10 -15 amp fuse should be placed in the positive line for each panel. If MC4 connectors are used, an in-line MC4 fuse holder works well.
- There should be a fuse between the controller and the battery bank 10 amps greater than the capacity rating of the controller.
- All positive wires connected to the battery bank should be fused.
- A T- Class fuse should be used if LiFePO4 Batteries.



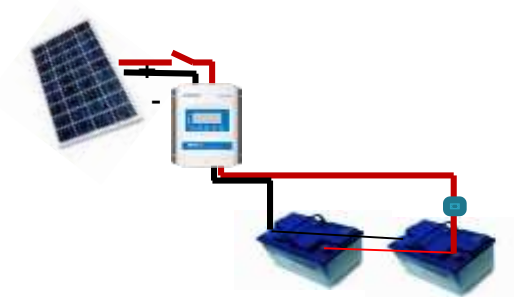
# Trouble Shooting

## **Meter shows voltage but zero amps from the solar panel –**

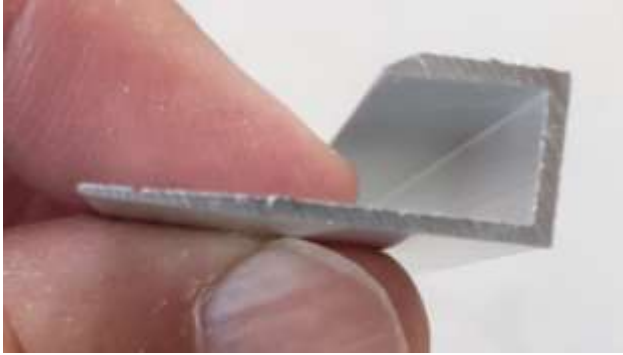
- The controller is likely not getting power from the battery.
- Check the battery connection and the fuse between the battery and the controller.
- Measure the voltage of the battery wires at the controller.
- If all looks good, measure the voltage and amperage at the panel pigtails.
- Reboot the controller

## **The solar panels are not producing the full amount of rated power –**

- The power output of a solar panel decreases as the panel heats up.
- The batteries may be at full charge so the controller is cutting back the solar power.
- There may be a loose or defective connection in the MC4 connectors or the wiring between the solar panels and the solar controller

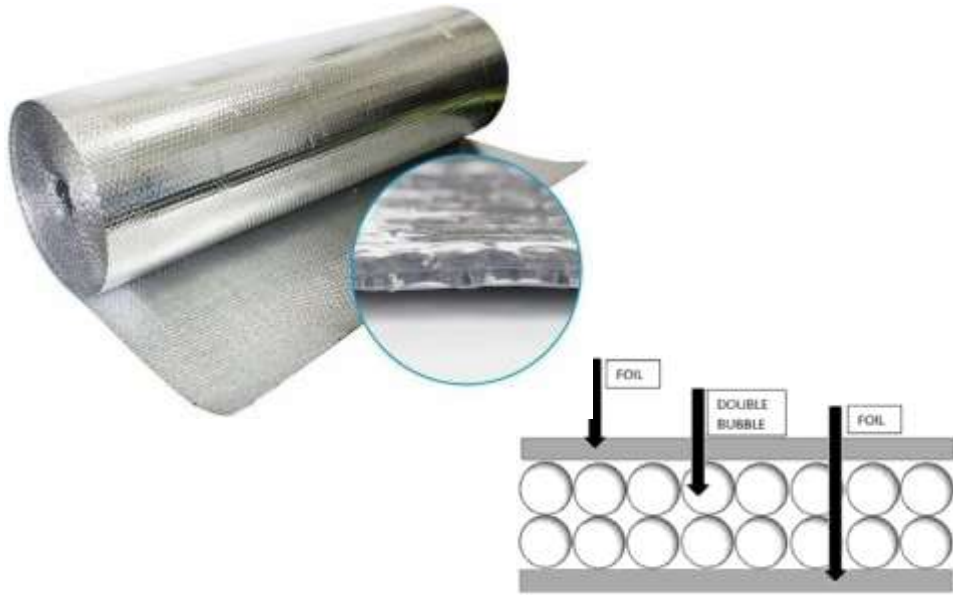


# Mounting Semi-Rigid Walk-on Panels with a “J” Channel



# Heat Dissipation for Flexible and Semi-rigid Solar Panels

A panel can reach 150+ degrees Fahrenheit in direct sun on a warm day. Material between the solar panel and the canvas bimini or boat deck can effectively dissipate heat.

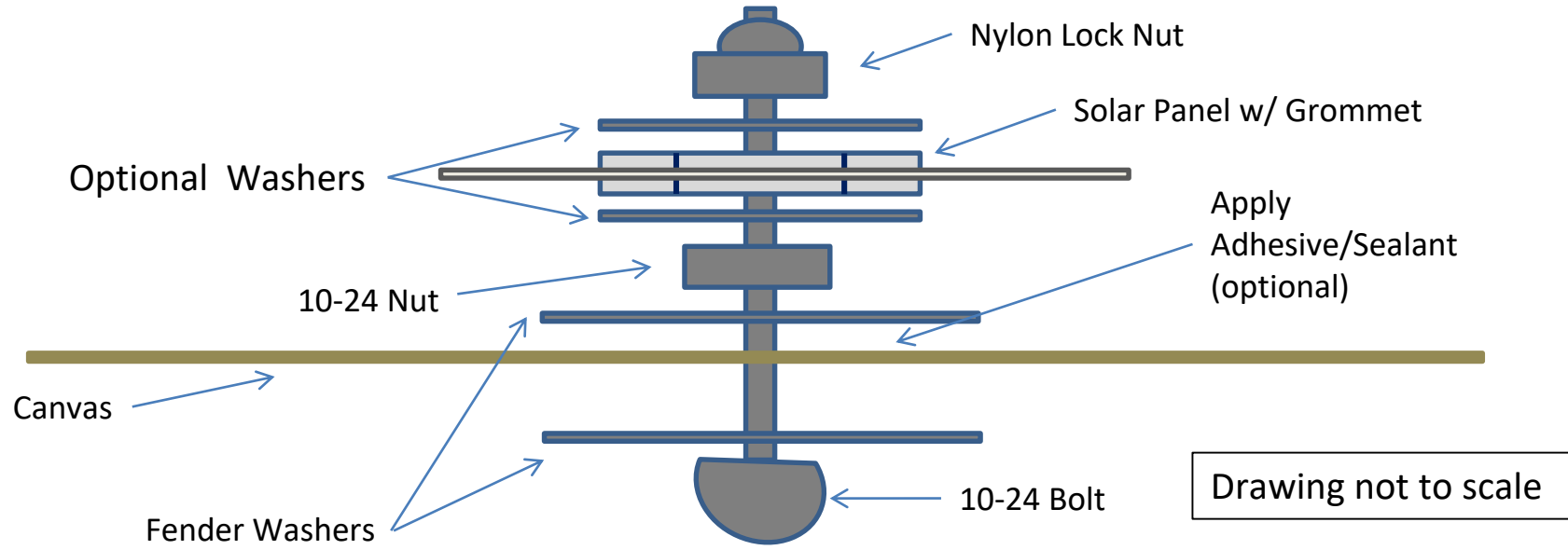


**Reflectix Insulation**



**Twin Wall Polycarbonate**  
4mm, 6mm, 8mm

# Flexible Solar Panel Canvas Mounting Kit Assembly



Punch hole with hot tool



Insert bolt with washer



Apply optional adhesive  
Secure washer with nut



Place washer and  
panel grommet on bolt



Place washer  
and tighten lock nut



Below is contact information should you have questions or comments.

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**CMIPower**



*Selecting the  
Proper Solar  
System for Your  
Boat*

**Q & A**

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