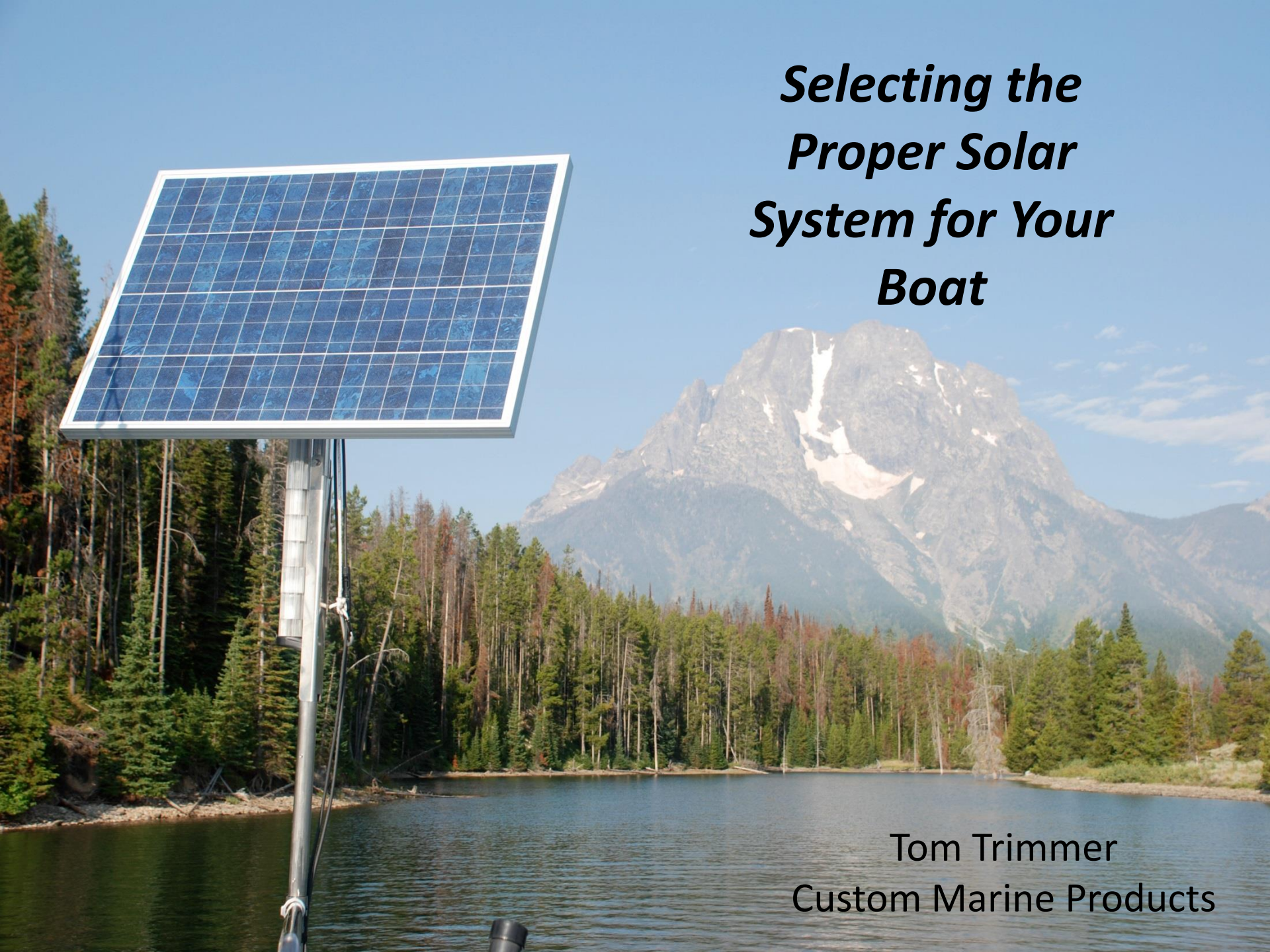
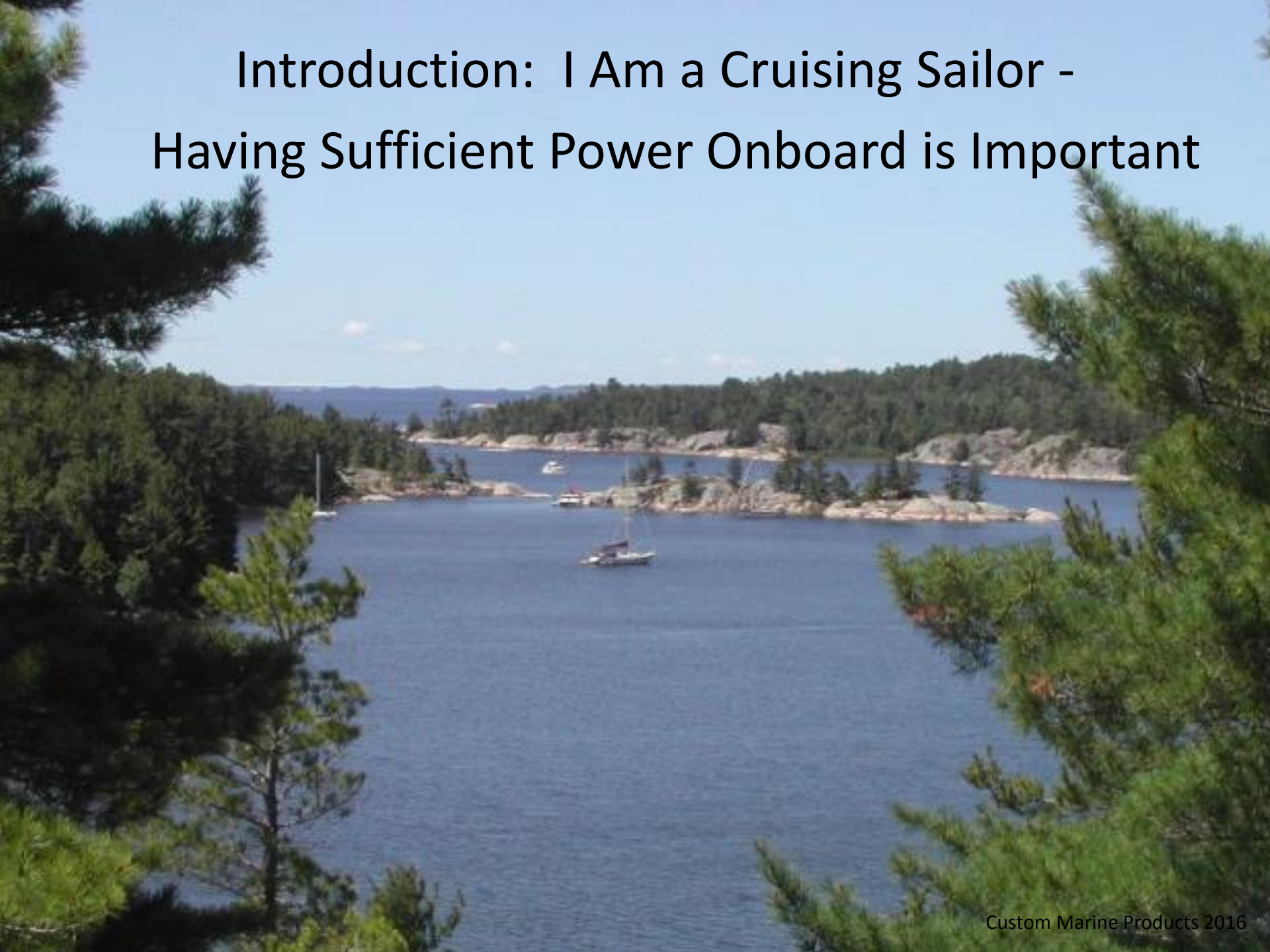


Selecting the Proper Solar System for Your Boat

Tom Trimmer
Custom Marine Products

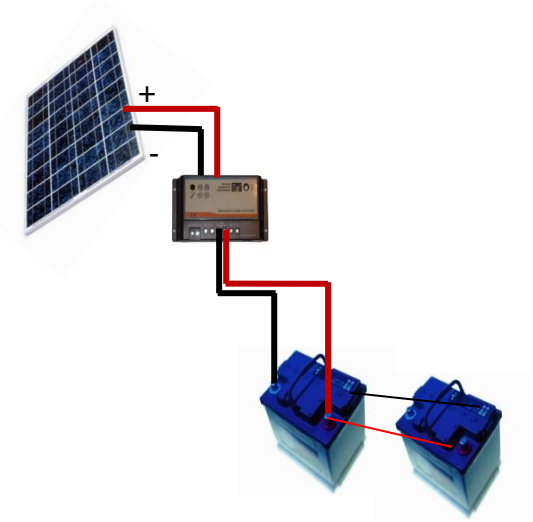
Introduction: I Am a Cruising Sailor - Having Sufficient Power Onboard is Important



Refrigeration started my quest for POWER

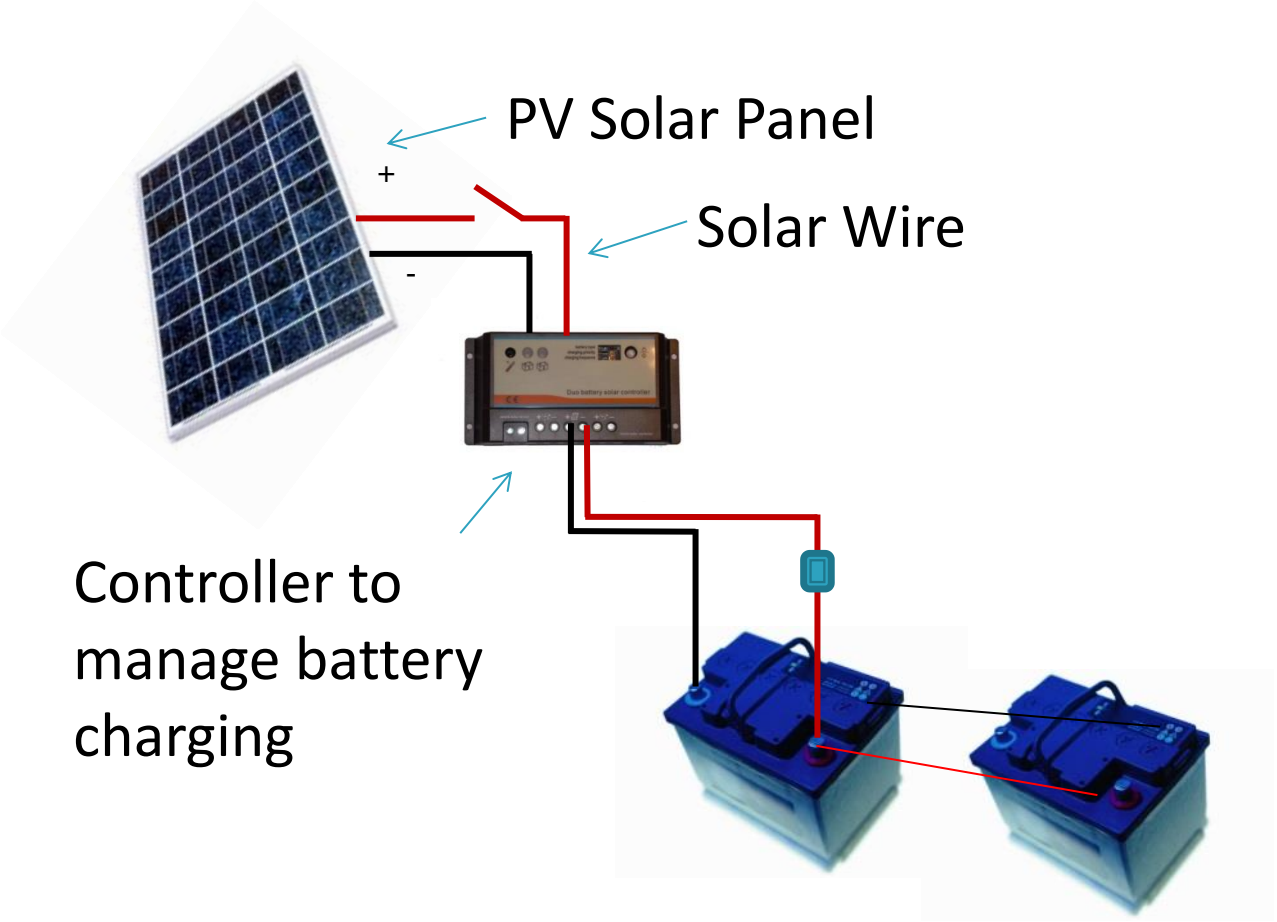
Topics for Discussion

- Introduction to PV solar panels
- Introduction to solar controllers
- What is a balanced solar system?
- Designing your solar system
  - A case study
- Selecting the proper equipment
- Installation ideas
- Q & A



Slides at: custommarineproducts.com
Support, Manuals & Info

Components of a PV Solar System



A Few things to Know About PV Solar Panels

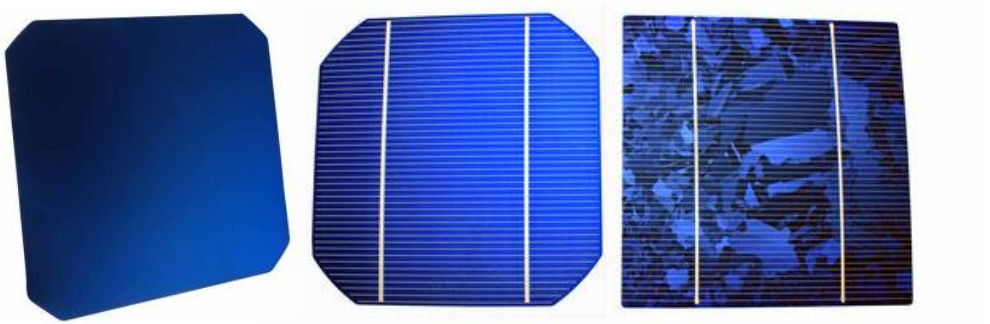
Monocrystalline or Polycrystalline?

Grade A or B or C?

Rigid or Semi-flexible?

Commercial or Marine?

Monocrystalline or Polycrystalline?



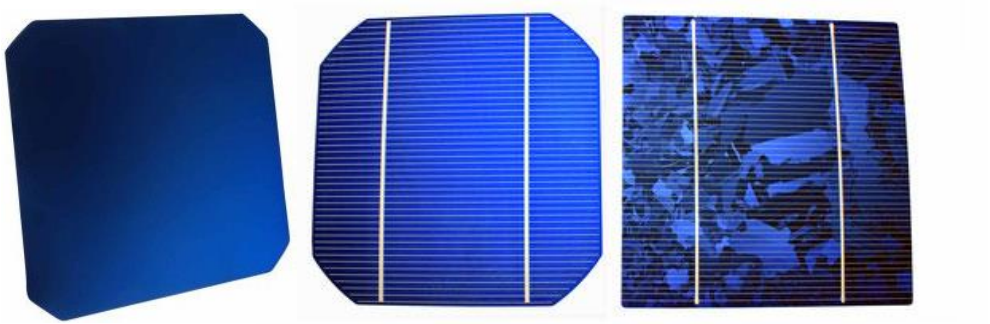
Monocrystalline

- Generally higher efficiency solar cells 15 % to 22%
- Generally higher output than polycrystalline in full sun
- More expensive than polycrystalline

Polycrystalline

- Cell efficiency typically 13% to 16%
- Generally less sensitive to shading and clouds than monocrystalline
- Less expensive that monocrystalline

Monocrystalline or Polycrystalline?



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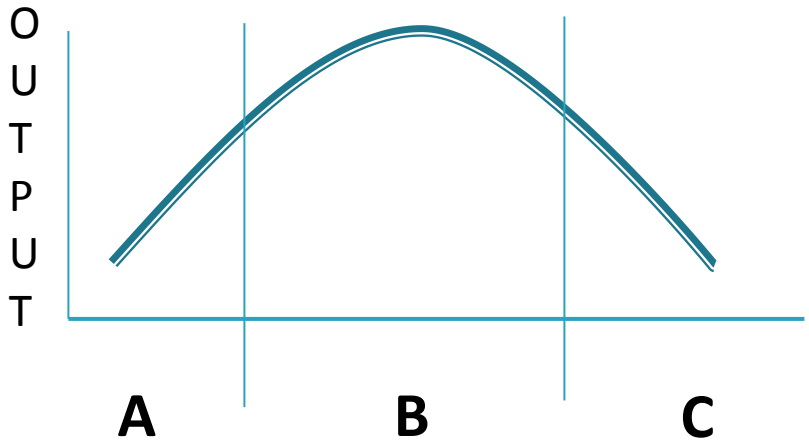
Note: Efficiency of thin-film panels is only 7% - 12%

Grade A or B or C



All solar cells are not created equal

- Cells are graded under a standard artificial light and sorted by 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.**

Rigid or Semi-flexible

New SunPower semi-flexible panel performance is comparable to rigid panels

Rigid panels

- Have a life of at least 15 years - robust
- Excellent for pole and davit mounting

Semi-flexible panels

- Have a life span of at least 7 years
- Excellent for bimini and cabin top mounting
- Light weight
- Can be walked on
- Sensitive to shading
- Expensive

Rigid or Semi-flexible

New SunPower semi-flexible panel performance is comparable to rigid panels

Rigid panels

- Have a life of at least 15 years - robust
- Excellent for pole and davit mounting

Semi-flexible panels

- Have a life span of at least 8 years
- Excellent for bimini and cabin top mounting
- Light weight
- Can be walked on
- Sensitive to shading
- Expensive

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 highest possible output performance – Grade A+ cells
- Output compatible with 12 or 24 volt battery bank systems

Commercial Solar Panel

- Junction box not sealed
- Frames designed for rack mounting
- Output typically 30+ volts
- Panel cells are typically Grade B or B+

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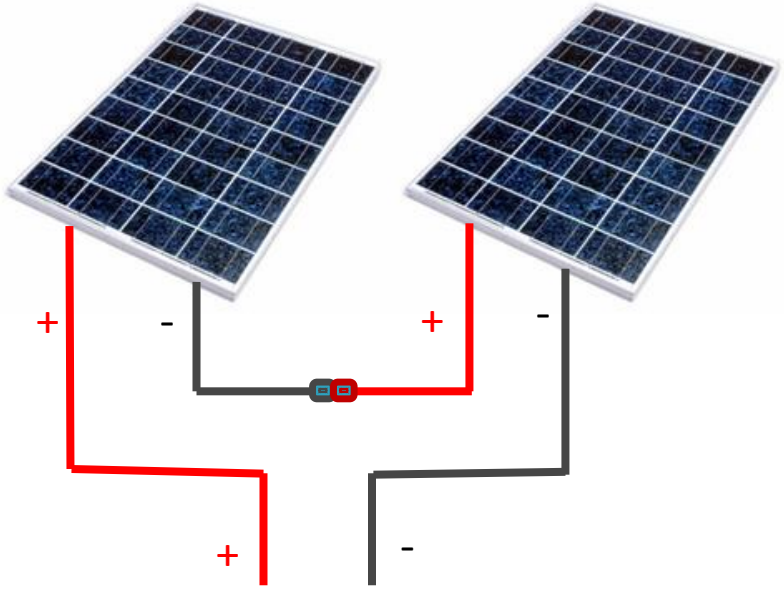
Commercial Solar Panel

- Junction box components not sealed
- Frames designed for rack mounting
- Output typically 30+ volts
- Panel cells are typically Grade B or B+

Wiring Multiple Solar Panels

100 Watt, 18 Volt, 5.6 Amp

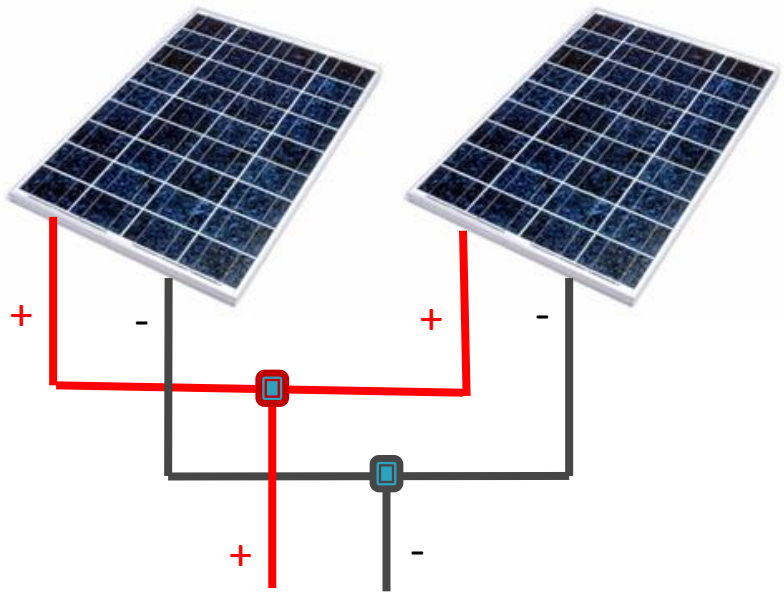
Series



36 Volts

5.6 Amps

Parallel



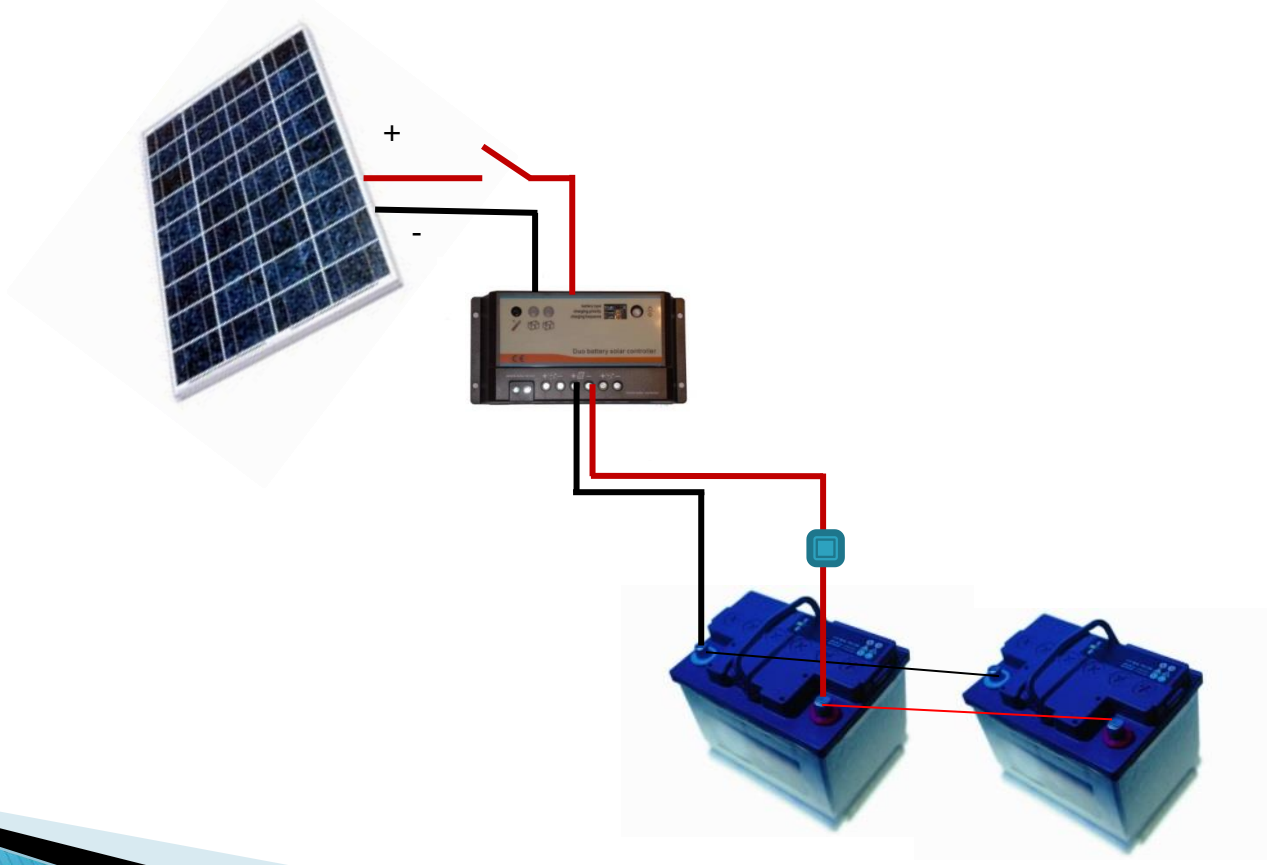
18 Volts

11.1 Amps

A Few Things to Know About Solar Controllers

The purpose of a solar controller is to:

- 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
- Includes float and equalization modes – battery health
- Less expensive than MPPT controllers

(MPPT) Maximum Power Point Tracking

- Excellent for use with commercial solar panels
  (usually above 30 volts)
- Consumes more power than typical PWM controller
- More expensive than PWM controllers
- Reduces voltage to 14 volts and increases amperage
  $Pw = V * I$
- Of little value for panels rated under 20 volts and for small solar arrays (under 200 watts).

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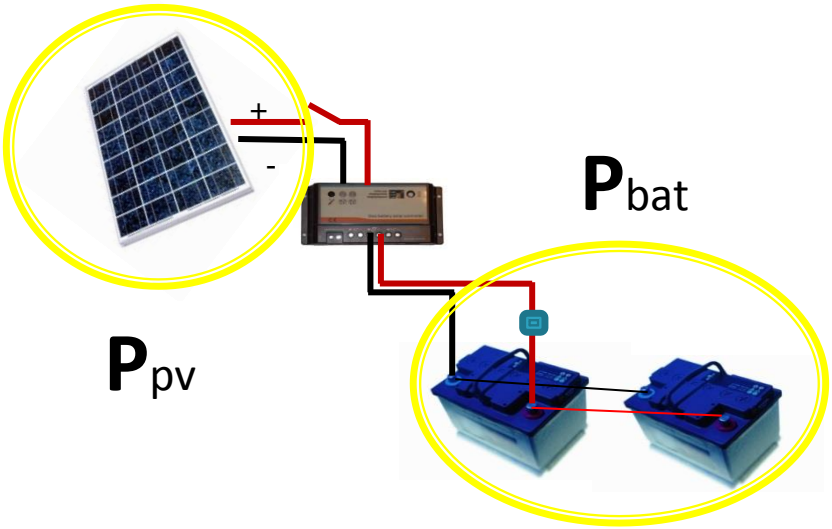
Maximum Power Point Tracking Technology



Input power (**P**pv) = Output power (**P**bat)

200 W = 200 W

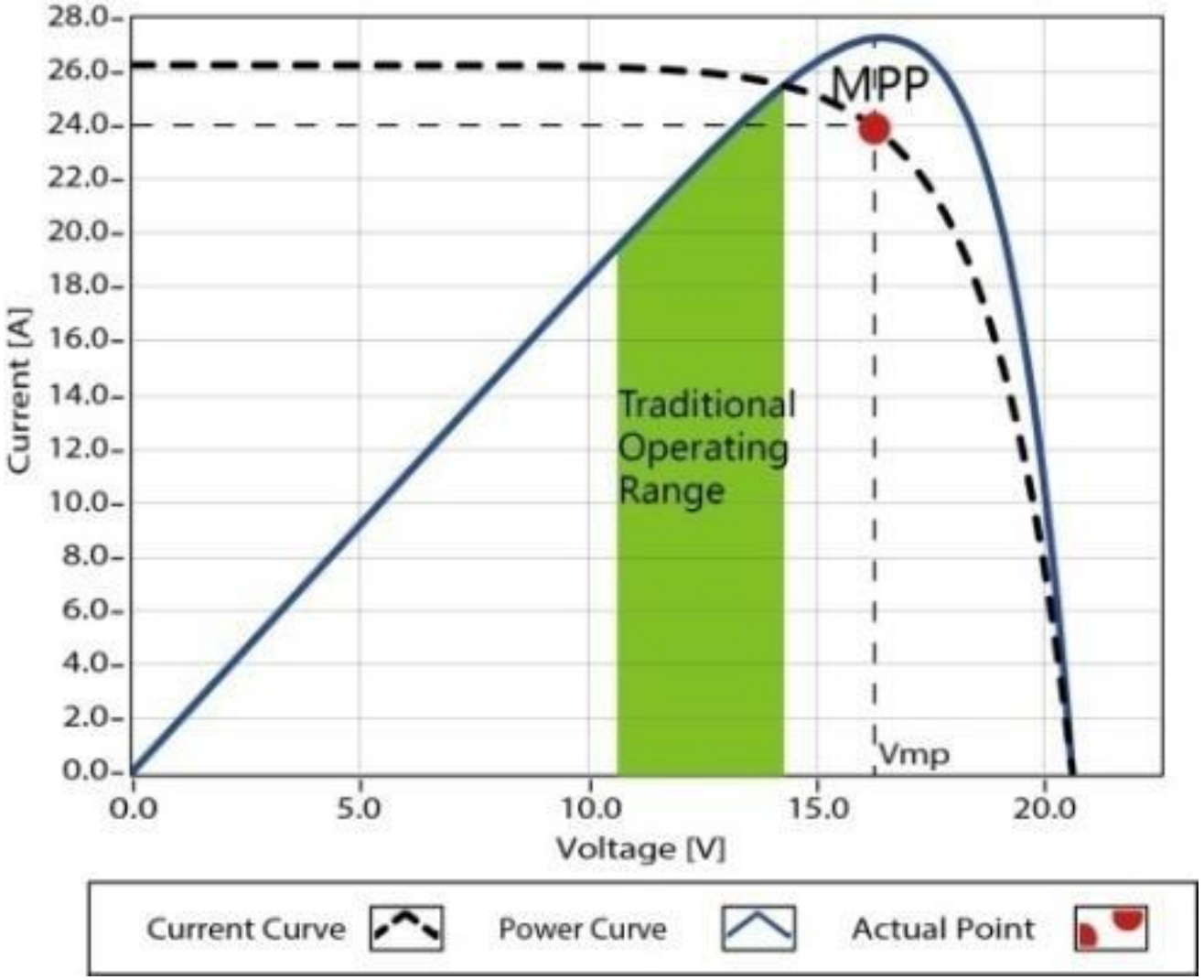
P = V * I

Input Voltage (**V**mpp) * Input Current (**I**pv) = Battery Voltage (**V**bat) * Battery Current (**I**bat)

18	*	11.1	=	14	* 14.3
36	*	5.6	=	14	* 14.3

At 100% conversion efficiency

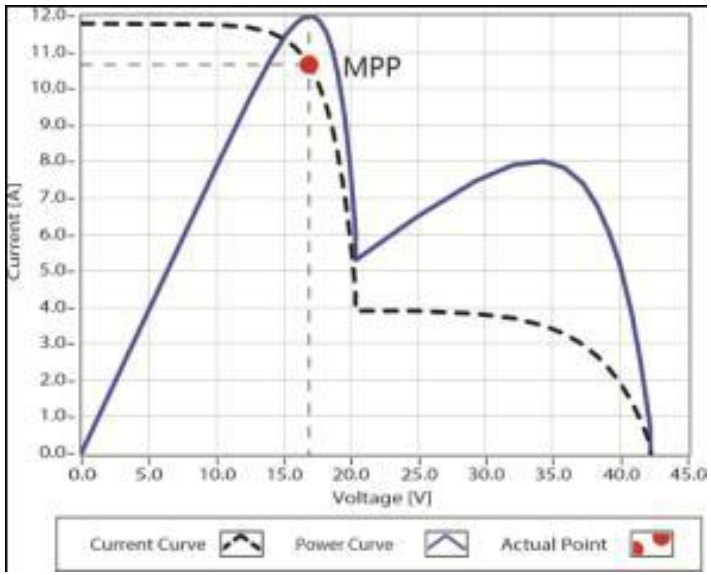
Maximum Power Point Curve

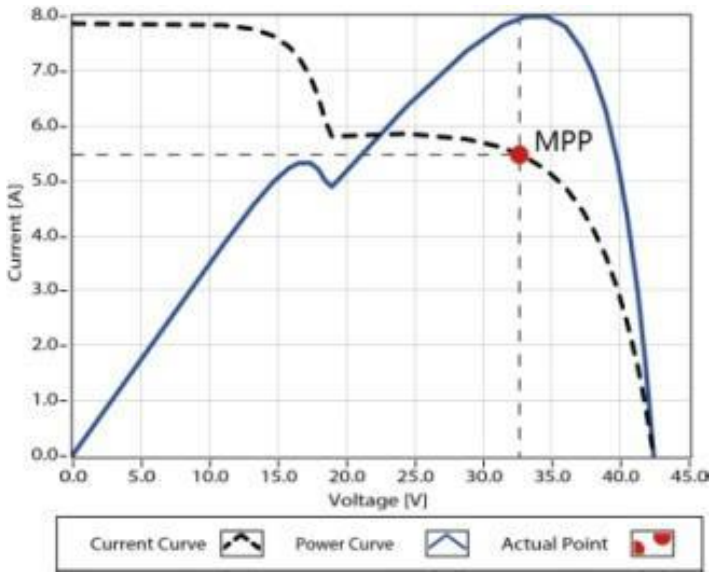


EP Solar

Maximum Power Point Tracking Technology

Impact of Shading

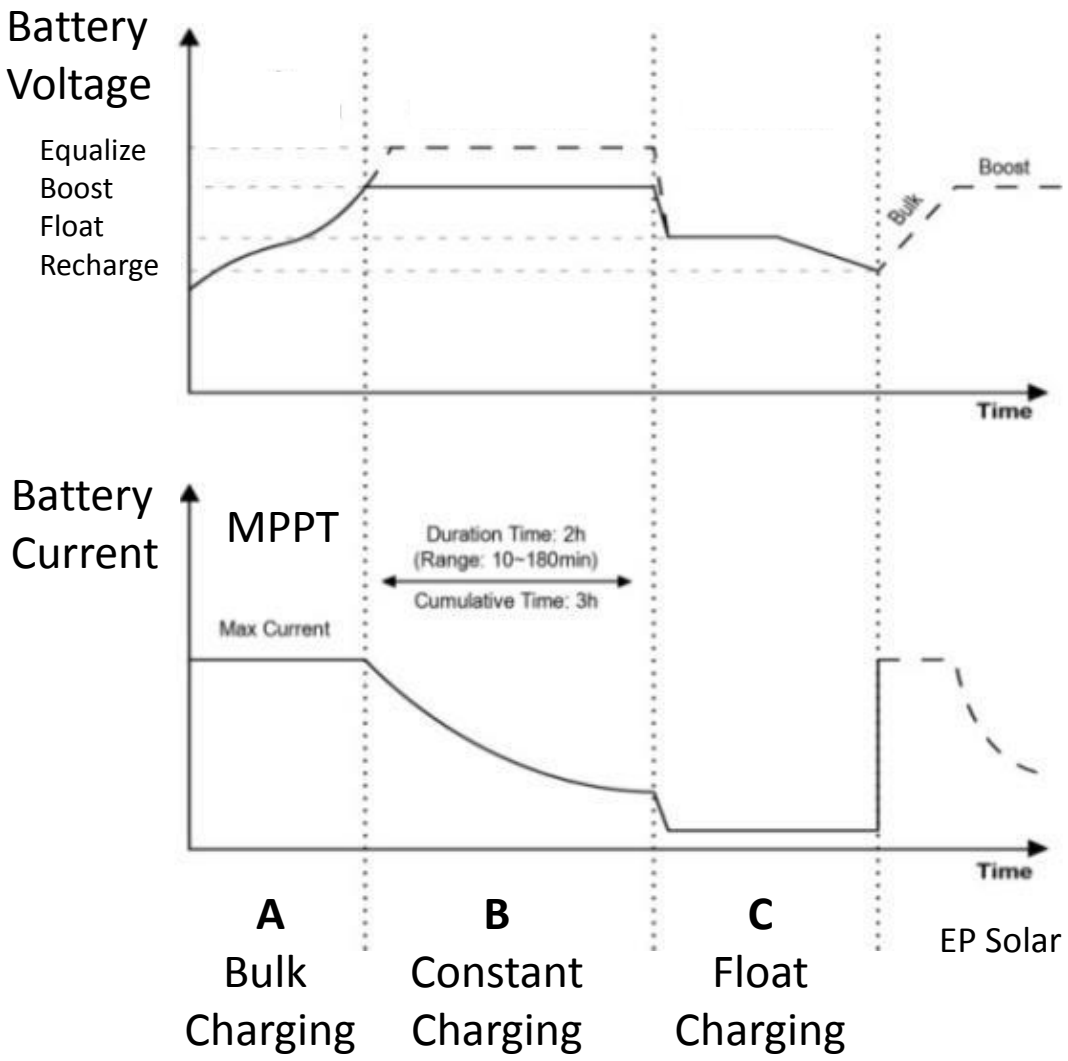




EP Solar

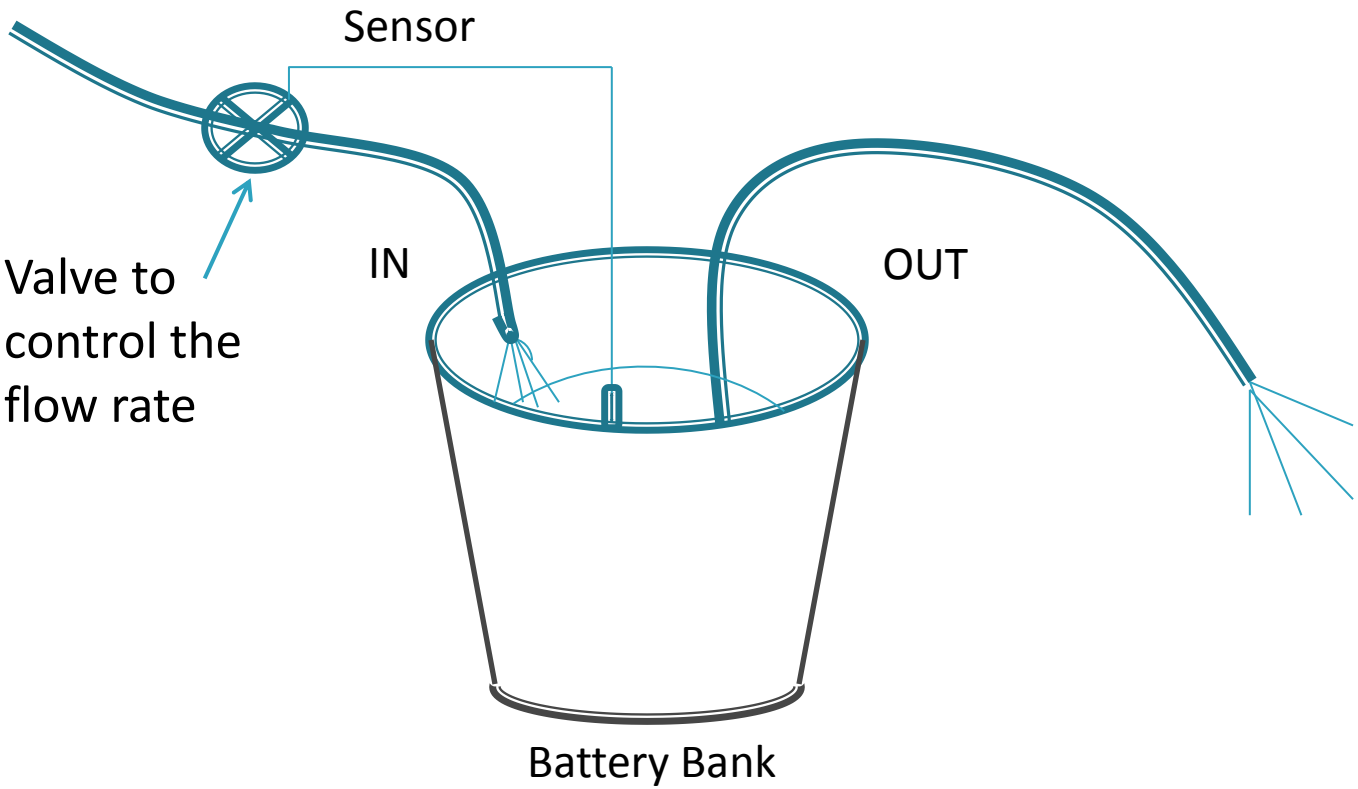
Multi - MPP

Battery Charging Stage Curve



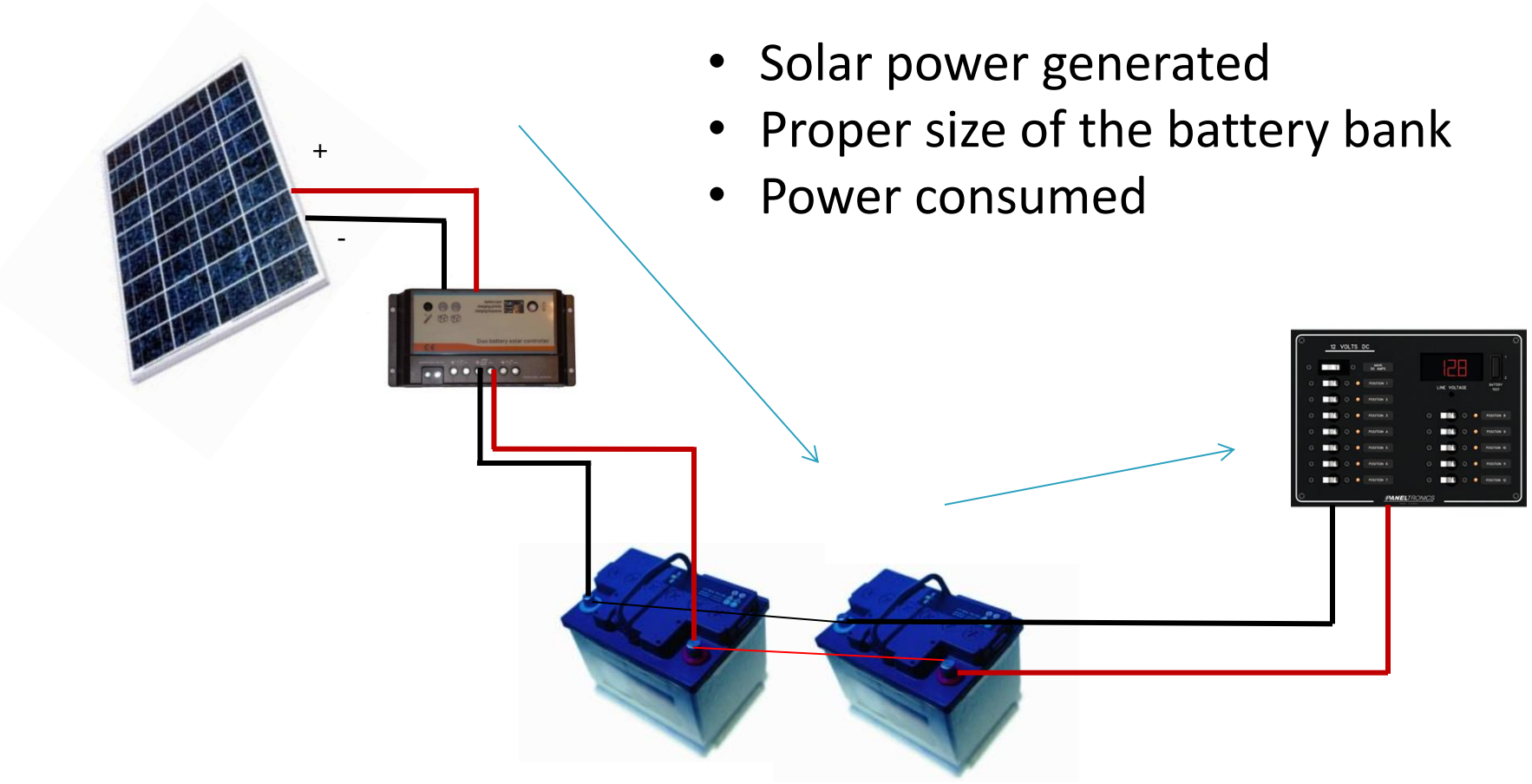
A Balanced System

- Water in
- Size of the bucket
- Water consumed



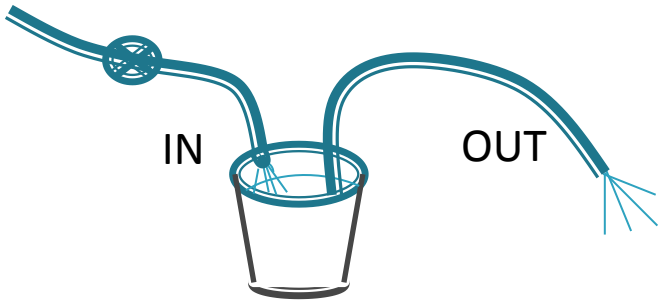
A Balanced System

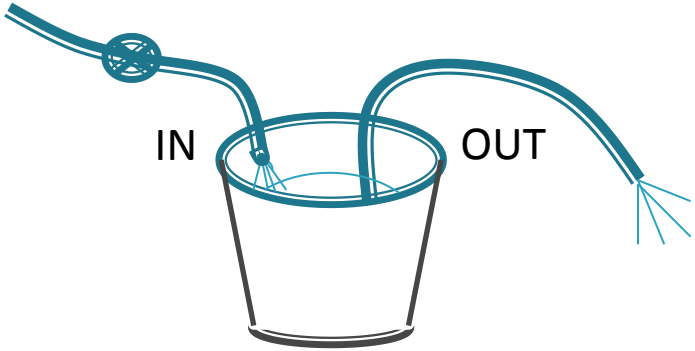
- Solar power generated
- Proper size of the battery bank
- Power consumed



Sizing Your Battery Bank

Battery capacity is measured in Amp Hours





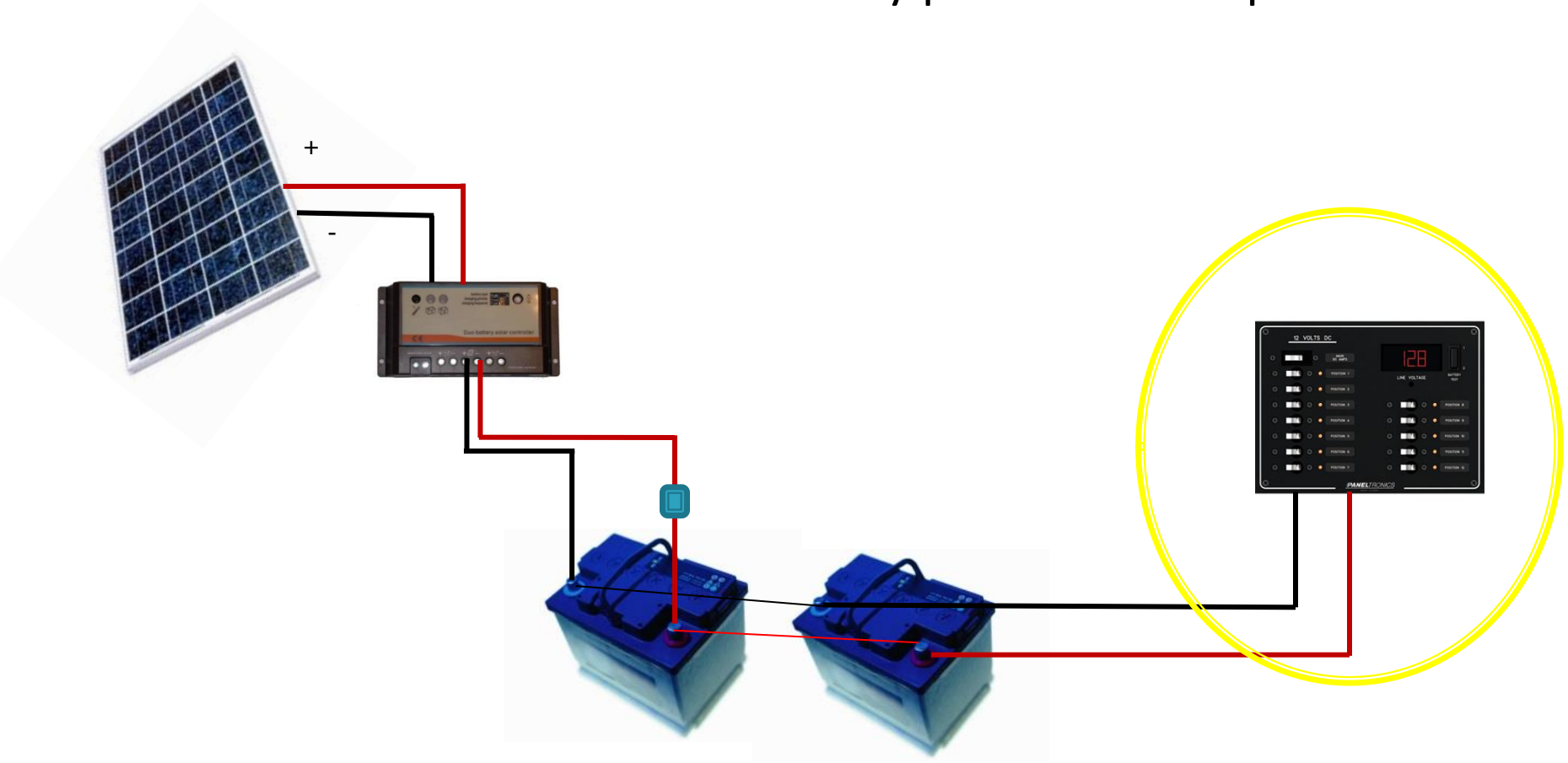
A limited capacity battery bank

- Unable to store all the power your solar panel produces
- 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 hours

Designing a Solar System to Meet Your Needs

1. Determine daily power consumption



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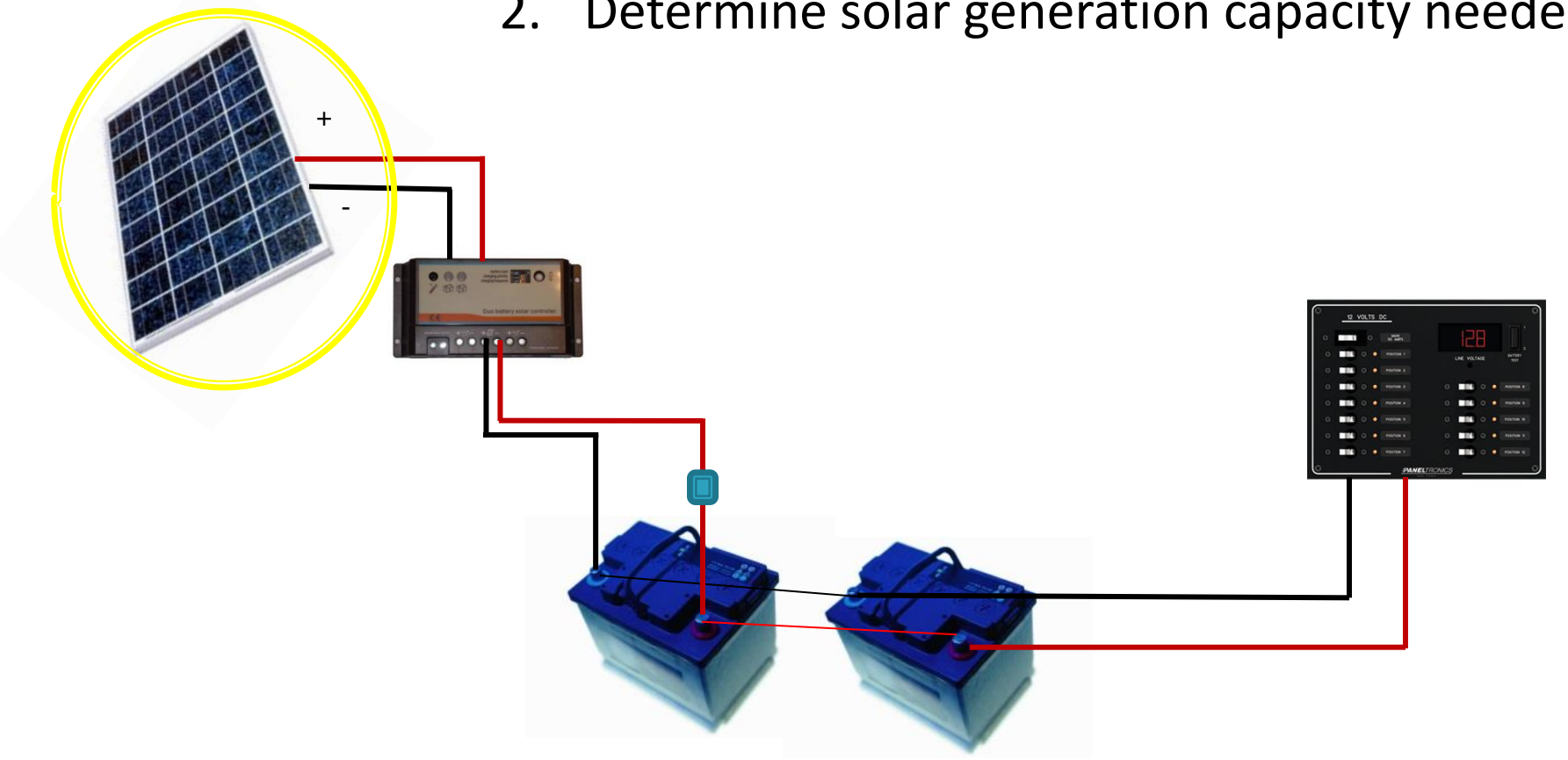
Designing a Solar System to Meet Your Needs

1. Determine daily power consumption
2. Determine solar generation capacity needed



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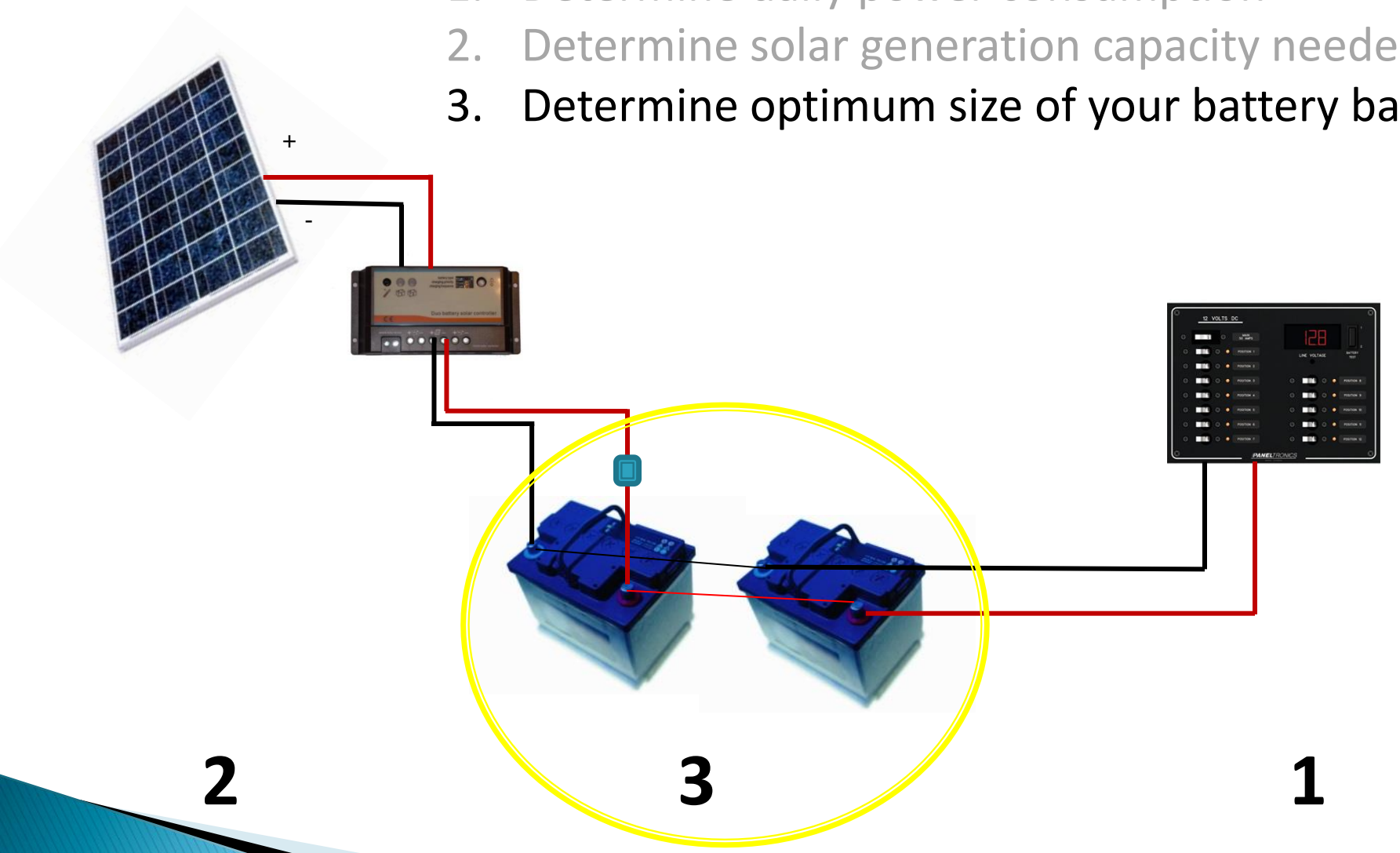
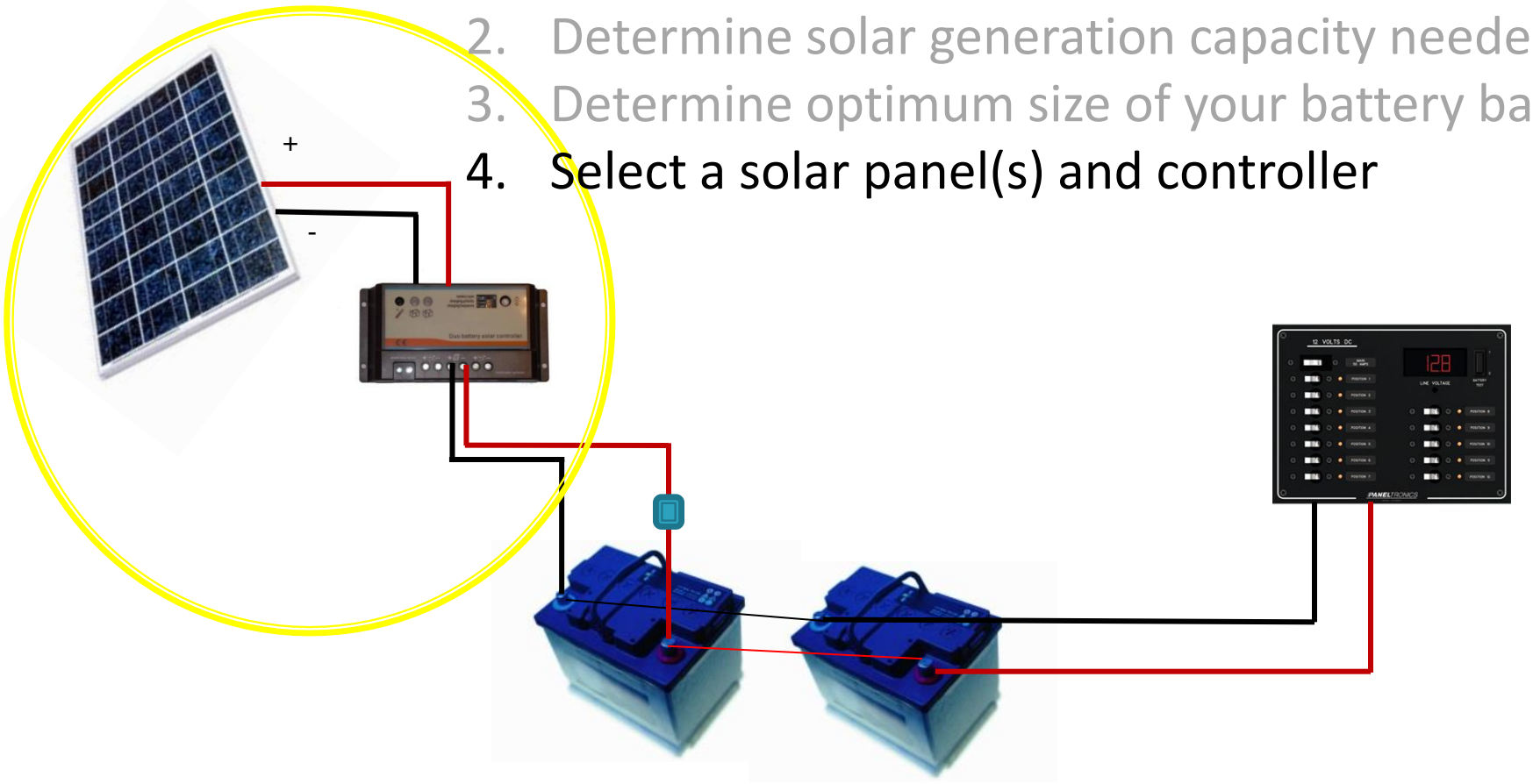
Designing a Solar System to Meet Your Needs

1. Determine daily power consumption
2. Determine solar generation capacity needed
3. Determine optimum size of your battery bank



Designing a Solar System to Meet Your Needs

1. Determine daily power consumption
2. Determine solar generation capacity needed
3. Determine optimum size of your battery bank
4. Select a solar panel(s) and controller



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Our Case Study Boat

Sample Power Consumption Worksheet

	Amps	Hours at Anchor	Hours on Passage	Daily AH at Anchor	Daily AH on Passage
Refrigeration	5	6	6	30	30
Radar	4		4	0	16
Computer - Laptop	4	1	8	4	32
Autopilot	1.5		8	0	12
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	8	8	4	4
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
				50.5	**109.6**

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Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
				50.5	**109.6**

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Computer - Laptop	4	1	8	4	32
Autopilot	1.5		8	0	12
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	8	8	4	4
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
				50.5	**109.6**

Step 1

	Amps	Hours at Anchor	Hours on Passage	Daily AH at Anchor	Daily AH on Passage
Refrigeration	5	6	6	30	30
Radar	4		4	0	16
Computer - Laptop	4	1	8	4	32
Autopilot	1.5		8	0	12
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	8	8	4	4
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
				50.5	**109.6**
Equipment going through an Inverter (Multiply by 1.2 for inverter inefficiency)					
Microwave	80	0.1		9.6	0
Windlass				0	0
Other				0	0
Other				0	0
				9.6	**0**
Total Amp Hours Consumed per Day				**60.1**	**109.6**

Determine Solar Capacity Needed

Total Amp Hours Consumed per Day		**60.1**	**109.6**
Average Hours of Sun per Day	5		
Note: 5 is a good number for panels mounted horizontal, 7 for panels tilted and rotated.			
Rated Panel Amperage Needed (Immp)		**12.0**	**21.9**
Panel Rated Voltage (Vmmp)	18		
Rated Panel Wattage Required (Watts)		216.4	394.6

Watts = Volts X Amps

Determine Solar Capacity Needed

Total Amp Hours Consumed per Day		**60.1**	**109.6**
Average Hours of Sun per Day	7		
Note: 5 is a good number for panels mounted horizontal, 7 for panels tilted and rotated.			
Rated Panel Amperage Needed (Immp)		**8.6**	**15.7**
Panel Rated Voltage (Vmmp)	18		
Rated Panel Wattage Required (Watts)		154.5	281.8

Our Case Study Boat

Sample Power Consumption Worksheet

	Amps	Hours at Anchor	Hours on Passage	Daily AH at Anchor	Daily AH on Passage
Refrigeration	5	6	6	30	30
Radar	4		4	0	16
Computer - Laptop	4	1	8	4	32
Autopilot	1.5		8	0	12
Cabin Lights (LED)	1	4		4	0
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Other				0	0
Other				0	0
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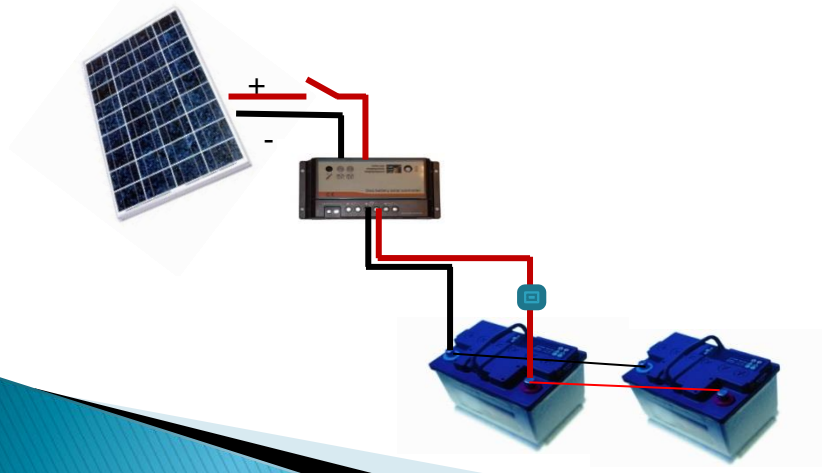
Equipment going through an Inverter (Multiply by 1.2 for inverter inefficiency)					
Microwave	80	0.1		9.6	0
Windlass				0	0
Other				0	0
Other				0	0
				9.6	**0**
Total Amp Hours Consumed per Day				**60.1**	**109.6**
AH - Amp Hours - Amps of current consumed in an hour					
Windlass is often not considered because engine alternator is running when used					
Average Hours of Sun per Day			5		
Note: 5 is a good number for panels mounted horizontal,					
7 for panels tilted and rotated.					
Rated Panel Amperage Needed (Immp)				**12.0**	**21.9**
Panel Rated Voltage (Vmmp)			18		
Rated Panel Wattage Required (Watts)				216.4	394.6

Available at
custommarineproducts.com
- Support
  - Manuals & Info

Battery Bank Capacity in our Example

		At Anchor	On Passage
Total Amp Hours Consumed per Day		**60.1**	**109.6**

Amp hours consumed per day		60	110
Days to run on batteries only	X	2	1.5
Amp hours required		120	165
Use 50% of battery bank capacity X 2			
Battery bank capacity needed (amp hours)		**240**	**330**



Note: You can use 50% of your battery bank capacity and keep your bank healthy.

Our Findings

Power consumption	60 to 110 amp hours
Optimum battery capacity	240 to 320 amp hours
Rated panel amperage needed	12 to 22 amps @ 5 hours sun avg. 8.6 to 16 amps @ 7 hours sun avg.
Rated panel wattage needed	216 to 395 watts

Watts = Volts X Amps

What Do You Want to Achieve with Your Solar System?

(Another Way to Analyze Your Solar Requirements)

1. Keep the batteries charged while on a mooring.

2. Supplement current power generation capability.
   (Run my engine less to charge the batteries)

3. Generate all the power needed while at anchor.

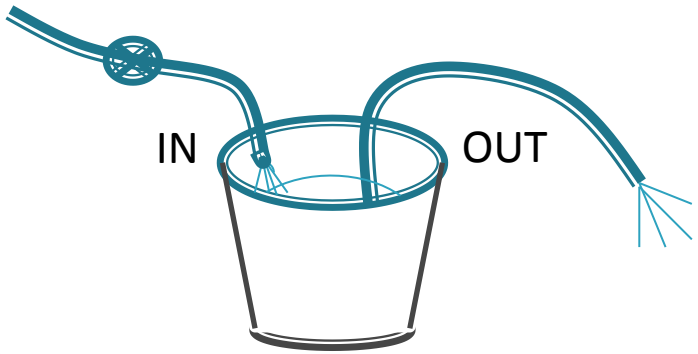
4. Generate all the power needed on passage and at anchor.

What Do You Want to Achieve with Your Solar System?

1. Keep the batteries charged while on a mooring

- Nothing running but bilge pump - 30-50 watt panel
- Refrigeration 30 amp hours – 110 watt panel

- PWM controller



What Do You Want to Achieve with Your Solar System?

2. Supplement current power generation capability at anchor (Run my engine every 3 days to charge the batteries)

Power consumed	60	AH/day
Days at anchor	X 3	Days
Amp hrs. needed	= 180	AH

What Do You Want to Achieve with Your Solar System?

2. Supplement current power generation capability at anchor (Run my engine every 3 days to charge the batteries)

Power consumed	60	AH/day
Days at anchor	X 3	Days
Amp hrs. needed	= 180	AH
Battery capacity @40%	- 96	AH
Amp hr. deficit	= 84	AH
Amp hr. deficit per day	= 28	AH

What Do You Want to Achieve with Your Solar System?

2. Supplement current power generation capability at anchor (Run my engine every 3 days to charge the batteries)

Power consumed	60	AH/day
Days at anchor	X 3	Days
Amp hrs. needed	= 180	AH
Battery capacity @40%	- 96	AH
Amp hr. deficit	= 84	AH
Amp hr. deficit per day	= 28	AH
Hours of sun	/ 5	Hrs
Solar amps needed	= 5.6	Amps
Solar panel voltage	X 18	Volts
Solar Panel capacity	= **100**	Watts

What Do You Want to Achieve with Your Solar System?

2. Supplement current power generation capability at anchor (Run my engine every 3 days to charge the batteries)

Power consumed	60	70	AH/day
Days at anchor	X 3	3	Days
Amp hrs. needed	= 180	210	AH
Battery capacity @50%	- 120	120	AH
Amp hr. deficit	= 60	90	AH
Amp hr. deficit per day	= 20	30	AH
Hours of sun	/ 5	4	Hrs
Solar amps needed	= 4	7.5	Amps
Solar panel voltage	X 18	18	Volts
Solar Panel capacity	= **72**	**135**	Watts

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Variables

What Do You Want to Achieve with Your Solar System?

3. Generate all the power needed while at anchor for an extended period of time

Power consumed	60	60	AH/day
Days at anchor	X 3	1	Days
Amp hrs. needed	= 180	60	AH
Battery capacity @50%	- 120	120	AH
Amp hr. deficit	= 60	60	AH
Amp hr. deficit per day	= 20	60	AH
Hours of sun	/ 5	5	Hrs
Solar amps needed	= 4	12	Amps
Solar panel voltage	X 18	18	Volts
Solar Panel capacity	= **72**	**216**	Watts

What Do You Want to Achieve with Your Solar System?

3. Generate all the power needed while at anchor for an extended period of time (Our Case Study Boat)

Power consumed	60	60	AH/day
Days at anchor	X 3	1	Days
Amp hrs. needed	= 180	60	AH
Battery capacity @50%	- 120	120	AH
Amp hr. deficit	= 60	60	AH
Amp hr. deficit per day	= 20	60	AH
Hours of sun	/ 5	7	Hrs
Solar amps needed	= 4	8.6	Amps
Solar panel voltage	X 18	18	Volts
Solar Panel capacity	= **72**	**154**	Watts

What Do You Want to Achieve with Your Solar System?

4. Generate all the power needed while on passage and at anchor for an extended period of time

Power consumed	60	110	AH/day
Days at anchor	X 3	1	Days
Amp hrs. needed	= 180	110	AH
Battery capacity @50%	- 120	120	AH
Amp hr. deficit	= 60	110	AH
Amp hr. deficit per day	= 20	110	AH
Hours of sun	/ 5	5	Hrs
Solar amps needed	= 4	22	Amps
Solar panel voltage	X 18	18	Volts
Solar Panel capacity	= **72**	**396**	Watts

What Do You Want to Achieve with Your Solar System?

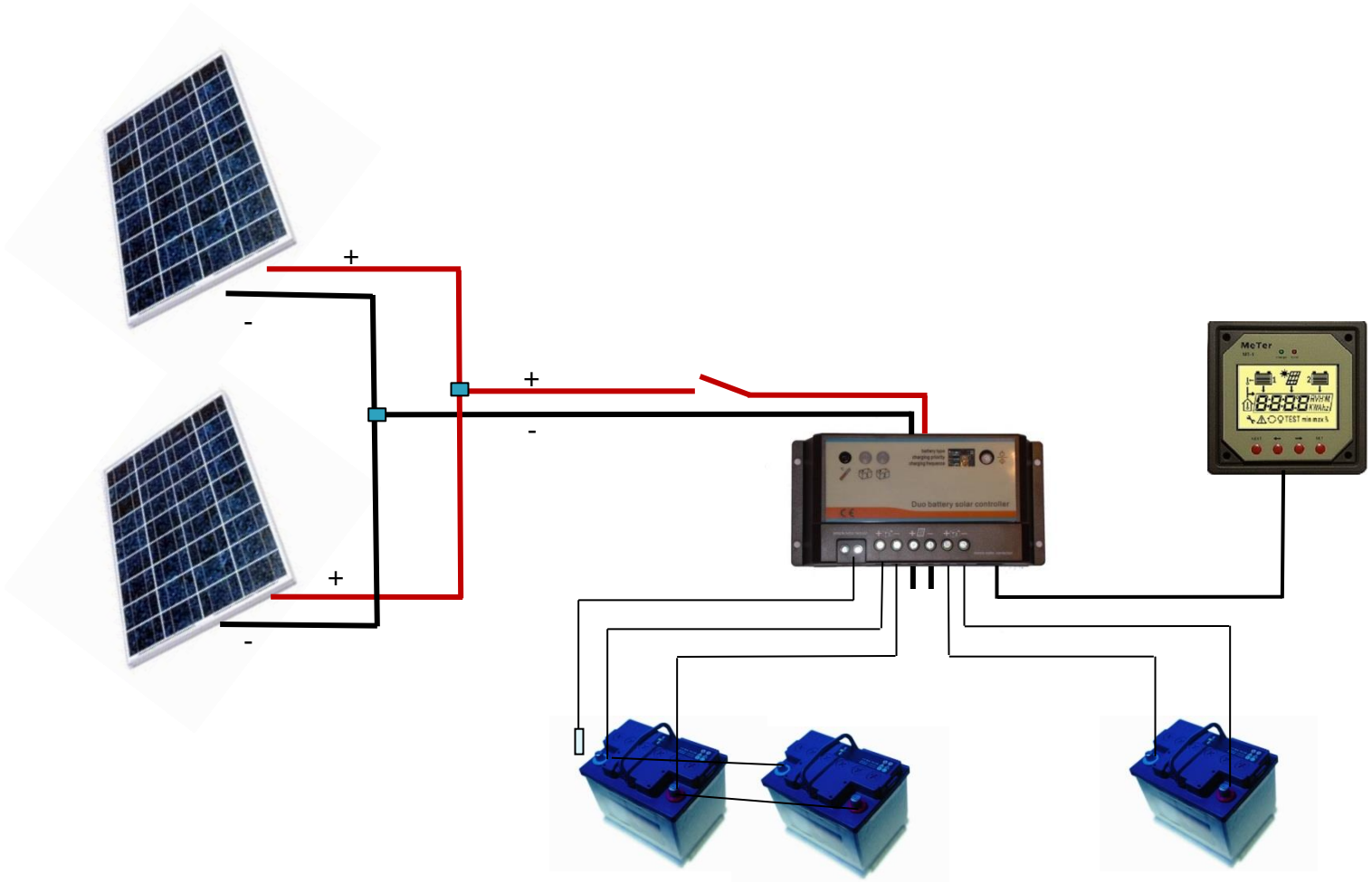
	Solar Panel Capacity	Solar Controller Capacity
1. Keep the batteries charged while on a mooring	**50 Watts**	**3 Amps**
2. Supplement current power generation capability	**100 Watts**	**6 Amps**
3. Generate all the power needed while at anchor	**216 Watts**	**12 Amps**
4. Generate all the power needed on passage and at anchor	**396 Watts**	**22 Amps**

Controller Selection

Under 200 Watts PWM

Over 200 Watts MPPT or PWM

A Complete and Balanced Solar Power System



Solar Panel Installation Ideas

Semi-Flexible Solar Panels

- Canvas biminis
- Hard tops

Rigid Solar Panels

- Canvas biminis
- Hard tops
- Top-of-pole systems
- Dinghy davits

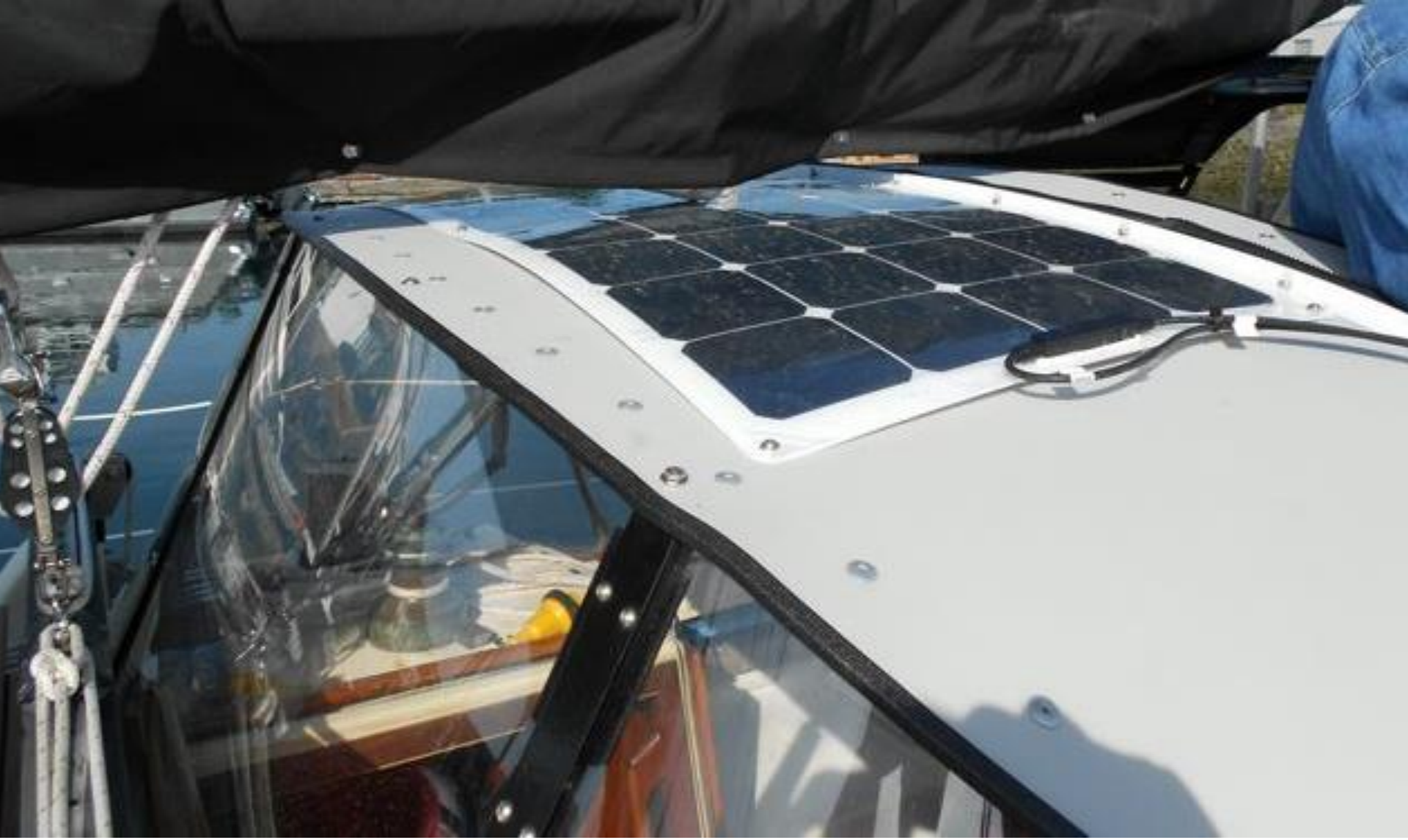
See **Gallery of Installations** at custommarineproducts.com for more ideas.

100 Watt Semi-flexible Panels Zippered On

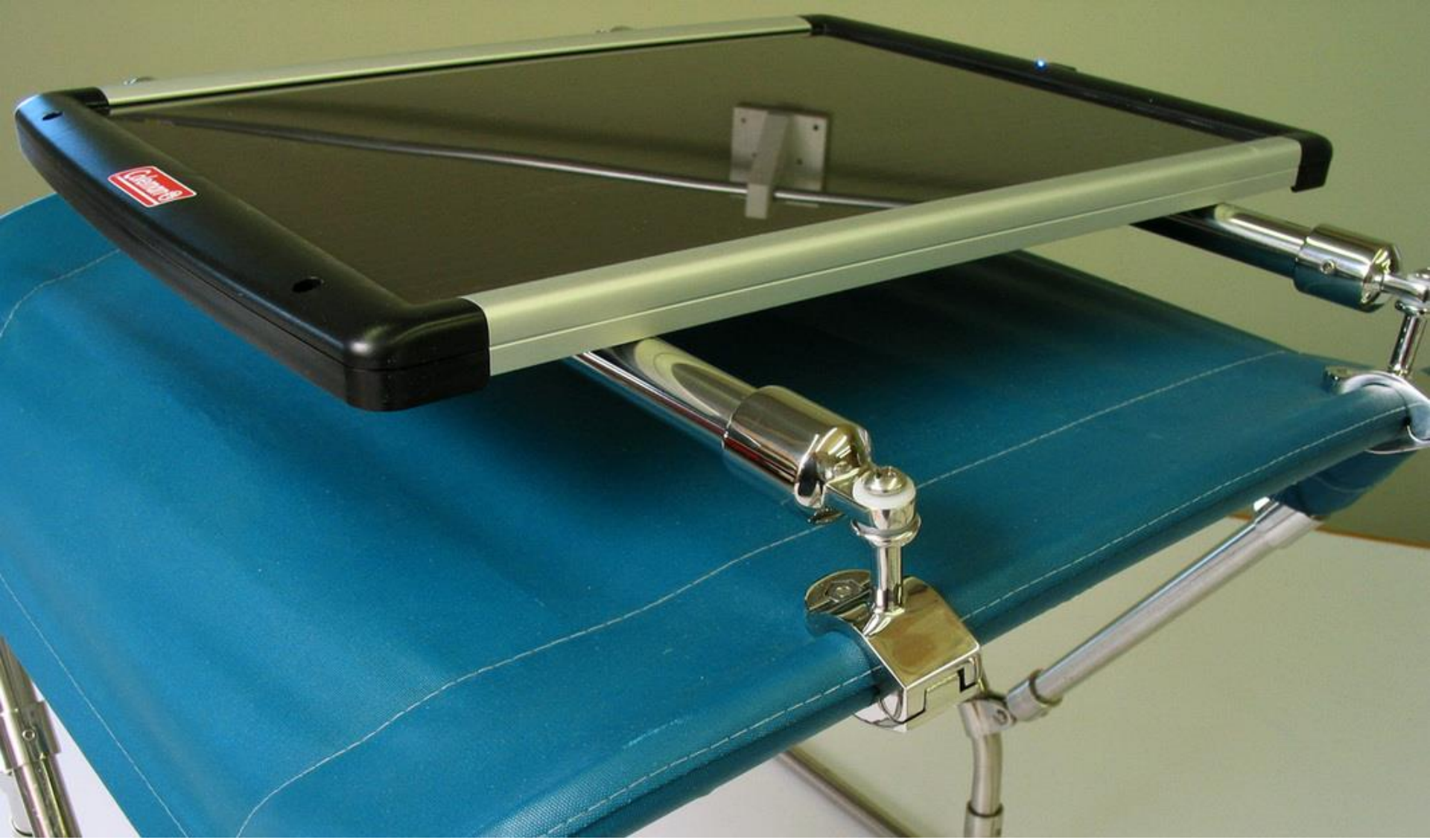
Two 50 Watt Semi-flexible Panels Bolted On

Four 100 Watt Semi-flexible Panels Sewn On

Two 110 Watt Semi-flexible Panels Bolted On



110 Watt Semi-flexible Panel Bolted on
or Attached with VHB Double Sided Tape



Gemini Mounting Bracket

Two Panels on a Bimini Mounted Frame

130 Watt Panel Rotated on a Bar

Two Rigid Panels Cantilevered

130 Watt Rigid Panel on a Ranger Tug 32

Two 275 Watt Panels on the Pilot House of a Nordic Tug 37

Custom MarineProducts 2016

Four 100 Watt Rigid Panels on a Nordic Tug 32

160 Watt Panel on a Pole with Outboard Motor Crane Tilt and Rotate

130 Watt Panel on a Pole Mount – Morgan 38

Two 90 Watt Panels
Pole Mounted

Two 100 Watt Panels
Rotatable On Dinghy Davits

Selecting the Proper Solar System for Your Boat

Q & A

Tom Trimmer
Custom Marine Products

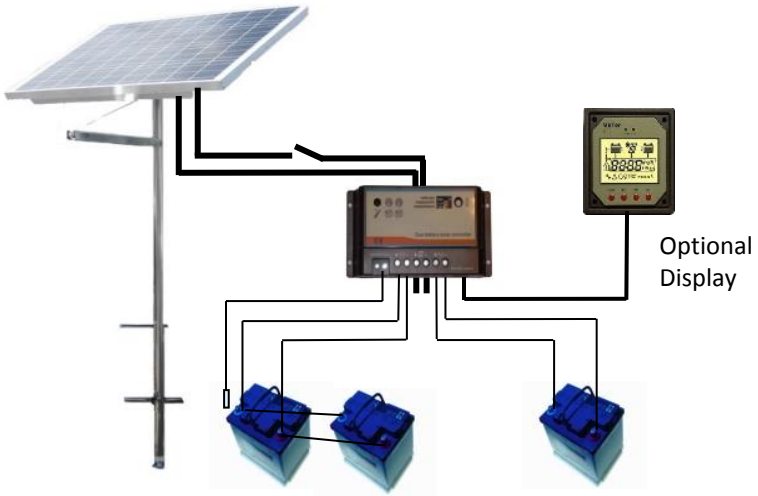
Complete top-of-pole solar panel kits contain everything you need to install solar power on your boat.

High Performance Marine Solar Panel

+

High Efficiency Dual Output Solar Controller and Solar Wire

+



Complete Kit

Batteries Not Included

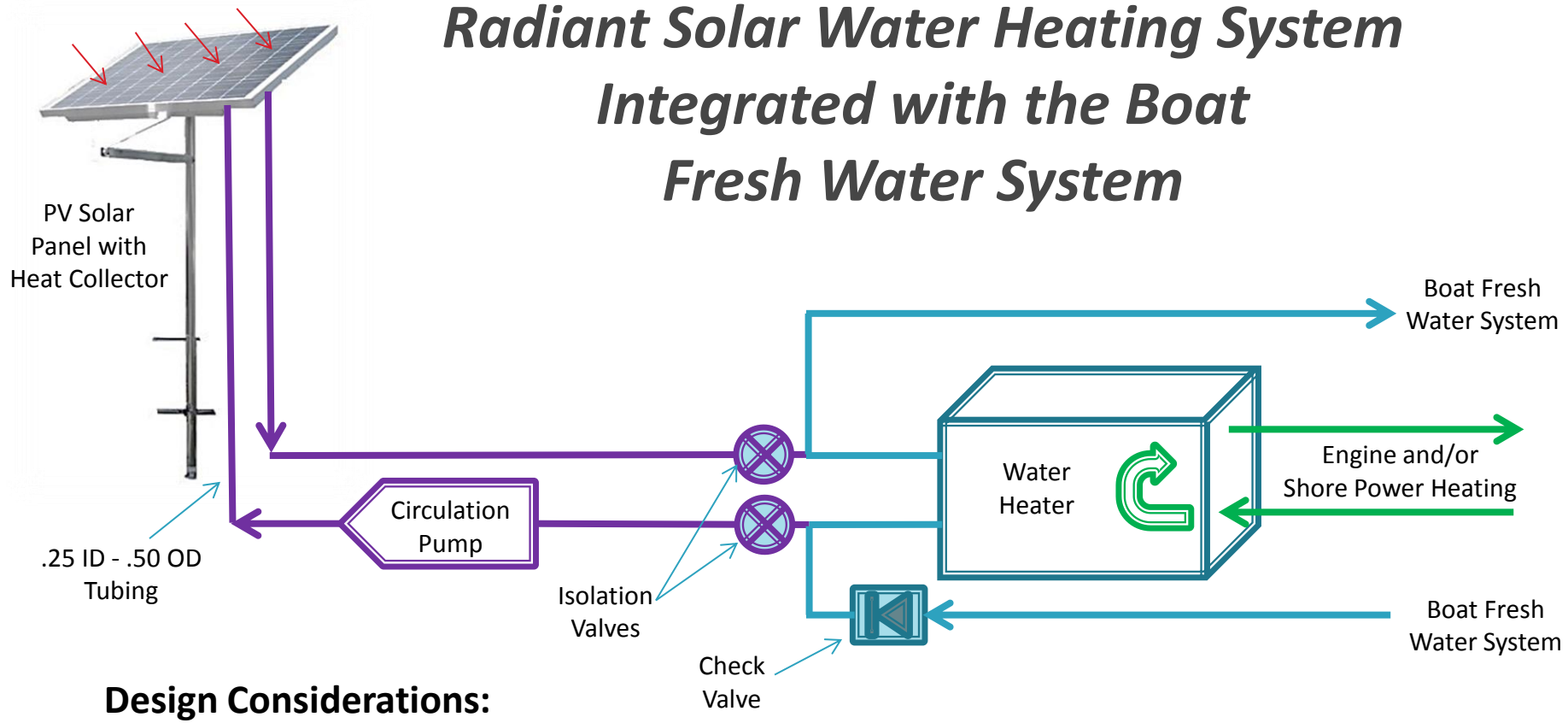
Tilt and Rotate Mounting Hardware for Optimum Sun Angle

Use Your Solar Panel to Heat Water on Your Boat

Install our unique heat collector on the back of your solar panel and use the **sun's radiant energy** to heat water for showers and dish washing.

- You no longer need to run your engine at anchor to heat water.
- Solar heater can be integrated directly into your boat's water system.
- Highly efficient circulating pump moves water from the solar heat collector to your water heater.
- Kits are available for all CMP panels and many other brands.
- Kits include: heat collector, insulation, panel backing, pump, tubing.
- Easy DIY installation.
- Heat water to 115° F+.

Radiant Solar Water Heating System Integrated with the Boat Fresh Water System



Design Considerations:

1. Heat collector is mounted behind the solar panel.
2. Boat water heater is used for storage of warmed water.
3. Circulation pump can be turned on and off manually.
4. Solar panel is tilted and rotated for maximum heating efficiency.

Existing water system
Existing water heating
Solar water heating

High Performance Marine PV Solar Panel Specifications

Model	Maximum Power Watts Wp	Cell Type	Open Circuit Voltage Voc	Short Circuit Current Isc	Maximum Voltage Vmp	Maximum Power Current Imp	Efficiency %	Cell Make	Panel Size Inches	Weight lbs.	Amp Hrs per Day @6 Hrs Sun
Semi-flexible											
CMP21050F	50	Mono	20.8	3.1	17.6	2.8	20.4	SunPower	20.9x21.7	3.3	16.8
CMP21100F	100	Mono	21.3	6.0	17.6	5.7	20.4	SunPower	21.3x41.3	5.5	34.2
CMP21110F	110	Mono	21.6	6.8	17.6	6.3	20.4	SunPower	22x47.2	6.6	37.8
Rigid											
CMP21100P	100	Poly	21.6	6.2	17.5	5.7	16.7	Q Cell	26.4x39.4	18.0	34.3
CMP21105M	105	Mono	21.6	6.5	17.5	6.0	17.9	Bosch	26.4x39.4	18.0	36.0
CMP21120S	120	Mono	24.0	6.5	20.0	6.0	21.0	SunPower	26.8x41.3	19.0	* 45.0
CMP21130M	130	Mono	21.6	7.9	18.0	7.3	17.8	Bosch	31.5x49	24.0	43.8
CMP21150P	150	Poly	21.9	9.2	17.6	8.5	17.1	Q Cell	39x39.5	26.5	51.0
CMP21160M	160	Mono	21.6	9.9	17.5	9.1	18.4	Bosch	39x39.5	26.5	54.6
CMP21200S	200	Mono	26.4	12.0	17.6	11.4	21.0	SunPower	41.3x41.3	28.0	68.4

All marine solar panels have a 10 year warranty.

* With MPPT Controller

Semi-flexible SunPower Cells

Rigid Polycrystalline

Rigid Monocrystalline

Solar Panel Power Requirement Worksheet

Power Consumption Analysis					
	Amps	Hours at Anchor	Hours on Passage	Daily AH at Anchor	Daily AH on Passage
Refrigeration	5	6	6	30	30
Radar	4		4	0	16
Computer - Laptop	4	1	8	4	32
Autopilot	1.5		8	0	12
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	8	8	4	4
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
				50.5	**109.6**
Equipment going through an Inverter (Multiply by 1.2 for inverter inefficiency)					
Microwave	80	0.1		9.6	0
Windlass				0	0
Other				0	0
Other				0	0
				9.6	**0**
Total Amp Hours Consumed per Day				**60.1**	**109.6**

Solar Panel Capacity (Watts) Calculation				
	Scenarios			
	A	B	C	D
Power Consumed per Day	30	60	60	110
Days at Anchor	1	3	3	1
Amp Hrs Needed	30	180	180	110
Battery Bank Rated Amp Hrs.	240	240	240	240
Battery Draw Down %	0%	40%	0%	0%
Battery Amps Drawn	-	96	-	-
Amp Hr. Deficit	30	84	180	110
Amp Hr. Deficit per Day	30	28	60	110
Hours of Sun	5.0	5.0	5.0	7.0
Solar Panel Amps(Imp) Needed	6.0	5.6	12.0	15.7
Solar Panel Voltage (Vmp)	18.0	18.0	18.0	22.0
Solar Panel Watts Needed				
With PWM Controller	**108**	**101**	**216**	**346**
With MPPT Controller	**90**	**84**	**180**	**236**

A. On a mooring with refrigeration
B. 3 days at anchor supplement with 40% of battery capacity
C. 3 days at anchor no battery supplement
D. All power from solar with max power usage

1. Determine your daily power consumption
2. Assess your battery capacity
3. Calculate solar amps needed
4. Calculate solar watts needed
5. Select solar panel(s) and controller