DIY MARINE SOLAR & REFRIGERATION

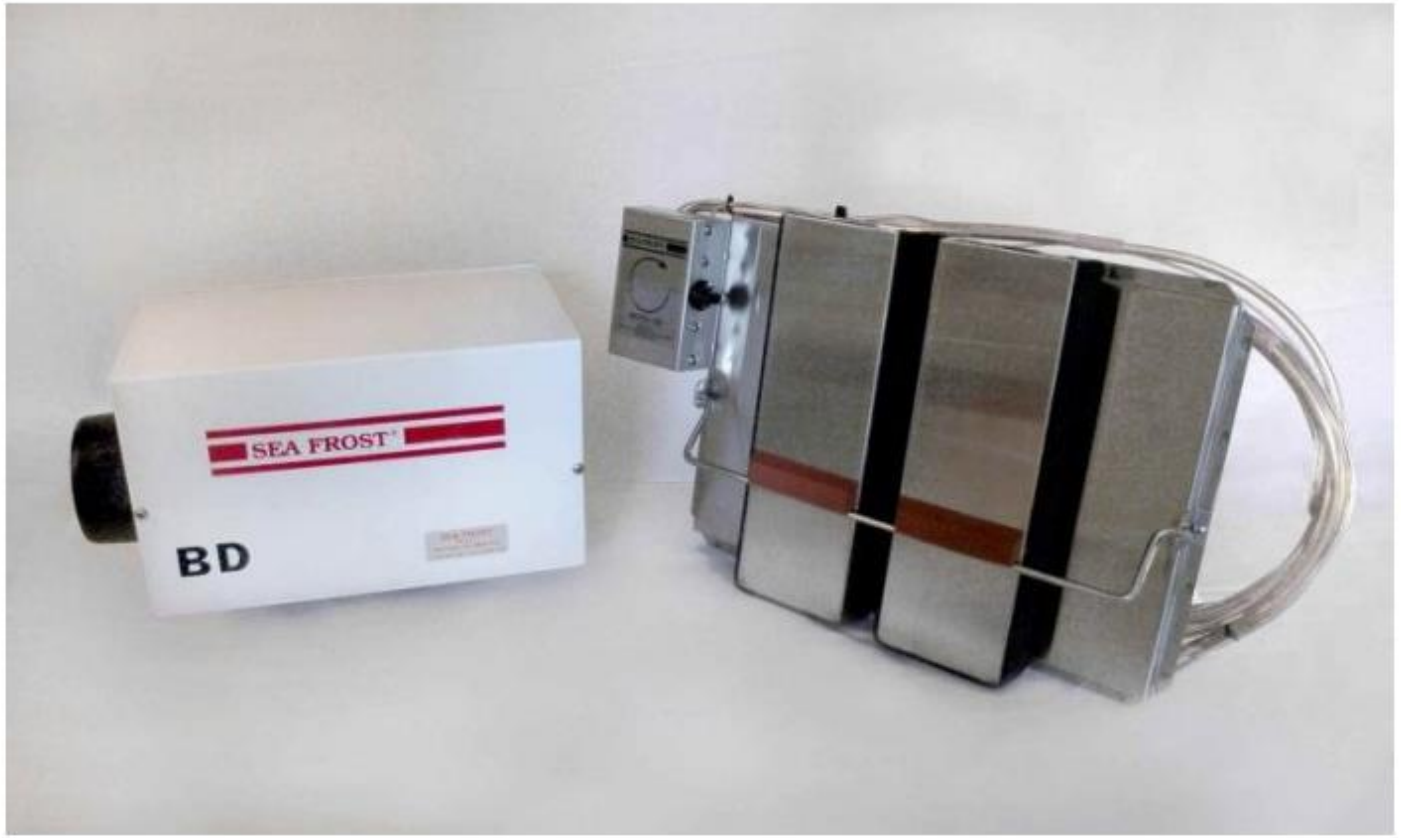
Bernie Coyne
Steve Lee
Len Thibodeau

WHAT ARE WE GOING TO COVER

- Refrigeration replacement
- Solar power from scratch
- Solar power from a kit
- Solar accessories

Oh Honey.
We need refrigeration on the boat!

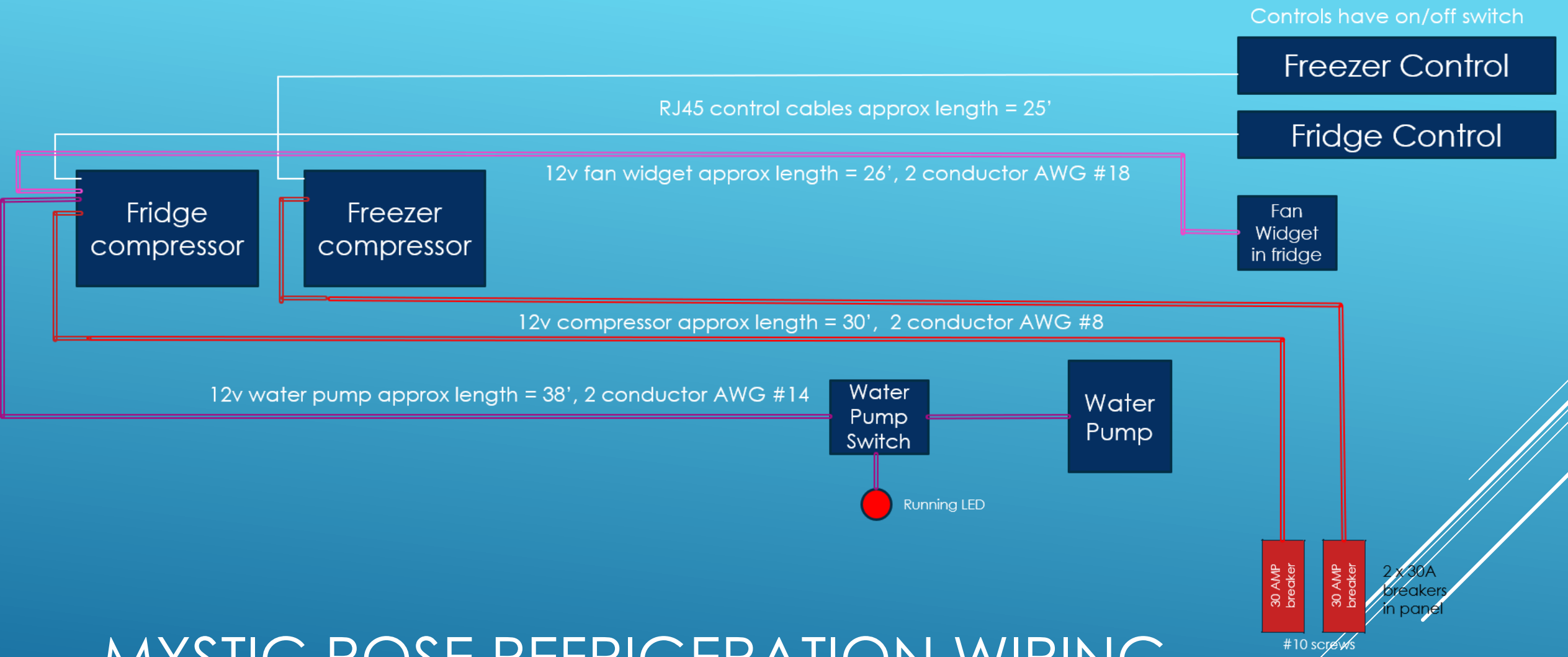
BD Systems



Sea Frost's BD is well-suited for boats with adequate battery banks and charging equipment. Thermostatic operation maintains the cold plate at even temperatures. The thin direct evaporator cold plate requires minimal box space. Dockside, the system operates through the boat's battery charger.

OUT WITH THE OLD SEAFROST

IN WITH THE NEW SEAFROST



MYSTIC ROSE REFRIGERATION WIRING

WHY SOLAR

- Ability to leave refrigeration on while boat unattended at anchor or mooring for several days
- Reduce engine/genset use
  - 110v refrigeration required 2x daily genset run for 1+ hr each time
  - Reduce noise
  - Save fuel
- Solar charging occurs during daylight hours even on overcast, foggy or rainy days
- More peace and quiet!

WIND GENERATORS VS SOLAR

- Wind generation Pros
  - Can put out a lot of power in winds > 10 knots (eg Caribbean)
  - Can produce 24x7 day and night

- Wind generation Cons
  - Requires 6 knots minimum to work
  - Some can be fairly noisy
  - High winds can be dangerous
  - Moving parts require routine maintenance

DETERMINE YOUR ELECTRIC LOAD

BATTERY MONITORS

- Great way to know what is really going on with your batteries and solar panels
- Real-time rate of charge or discharge
- AH's consumed
- Exact voltage and state of charge
- Digital displays provides more accurate readings

AGM BATTERY STATE OF CHARGE	
Level	Voltage
100%	13.00V
90%	12.75V
80%	12.50V
70%	12.30V
60%	12.15V
50%	12.05V
40%	11.95V
30%	11.81V
20%	11.66V
10%	11.51V
0%	10.50V

Xantrex
- 2 bank monitoring on Mystic Rose
- No longer in production

Victron Energy
- Single bank monitor on Breakaway & Salacia
- $169


Victron energy
P1
-Battery
079-08/03
+B1
+B2 Start
P5
C2
P4
-Load

Battery monitor

Fig. 1

Shunt

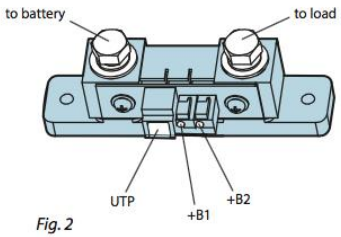


Fig. 2

Wiring diagrams

Connect the negative pole of the battery last!

BMV-700
BMV-702 configured for *STARTER/AUXILIARY*-battery monitoring.

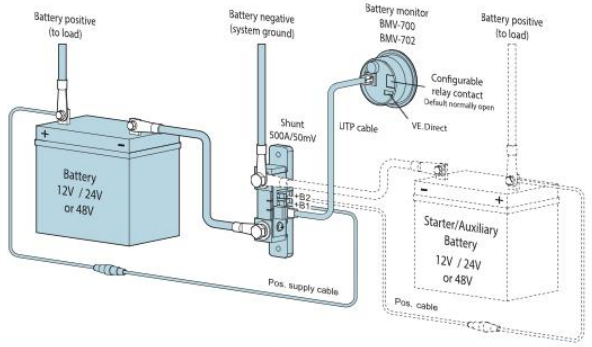


Fig. 3

BMV-702 configured for battery *TEMPERATURE* monitoring

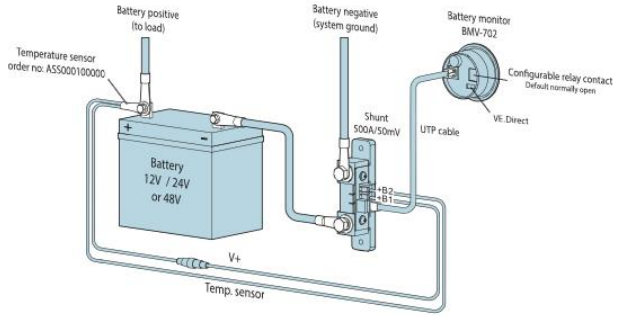


Fig. 4

quick installation guide **Connect the negative pole of the battery last!**

HOW MUCH POWER DO YOU NEED

Power
Watts = Amps x Volts

MYSTIC ROSE – BERNIE COYNE

System load calculation worksheet for Mystic Rose

AC loads	Watts x	Hrs/Day x	Watts/day	Notes
laptop	135	12	1620	max rated AC power adapter is 135W
microwave	700	0.5	350	
Total			1970	
Add inverter loss			2266	
Total AC AH/day			**189**	
DC loads	**Watts x**	**Hrs/Day x**	**Watts/day**	**Notes**
tv/pc monitor	37	12	444	
cabin lights 20w	20	18	360	20w/halogen light;
refrigeration & freezer	66	12	792	92w max; 66w medium; assume running half the time
autopilot	60	4	240	ST 7000+ electric autopilot with type 2 long linear drive motor (48w-72w)
windlass	1600	0.2	320	Lewmar Concept v4
elec winch	2400	0.1	240	2 x primary
anchor light	2	12	24	
instruments	8.64	6	52	12 x Raymarine ST60; 60ma avg each
cell phone charger	12	9	108	
internet router	6	24	144	
TOTAL			2724	
Total DC AH/day			**227**	
Total AH/day			416	
Mystic Rose House Batteries				
	210A AGM x 2		420	
	100A AGM x 2		200	
	Total		**620**	
	Useable		310	

Requires ~ 416AH/day

BREAKAWAY POWER SYSTEMS ANALYSIS WHEN CRUISING						
		house voltage	12	avg hrs	daily	power
Power use, maximum		amps	watts	per day	watts	amp-hrs
	navigation equipment	10	120	6	720	60
	radar	3	36	6	216	18
	running lights	1	12	1	12	1
	refrigerator	5	60	12	360	30
	cabin lites	1	12	3	36	3
	water pump	7	84	0.5	42	3.5
	stereo	2	24	5	120	10
	Total power required				1506	126
Battery capacity, house in amp-hrs		315				157.5

BREAKAWAY POWER SYSTEMS ANALYSIS WHEN ON MOORING						
		house voltage	12	avg hrs	daily	power
Power use, maximum		amps	watts	per day	watts	amp-hrs
	navigation equipment	10	120	0	0	0
	radar	3	36	0	0	0
	running lites	4	48	0	0	0
	refrigerator	5	60	12	720	15
	cabin lites	3	36	4	144	12
	water pump	7	84	0.5	42	3.5
	stereo	2	24	5	120	10
	Total power required				1026	41
Battery capacity, house in amp-hrs		315				157.5

BREAKAWAY – LEN THIBODEAU

Requires ~ 126AH/day

SALCIA – STEVE LEE

SALACIA							
EQUIPMENT	AMPS	HRS.	RUNNING	HRS.	CRUISING	HRS.	ANCHOR
Autopilot	2.4	24	57.6	5	12		0
ChartPlotter	2.6	12	31.2		0		0
Radar-Stby	4.4	10	44	5	22		0
Radar- Trx	6.4	2	12.8	5	32		0
Binnacle light	0.11	10	1.1	0	0		0
Running lights	0.2	10	2	0	0		0
Steaming Light	0.75	0	0	0	0		0
TriColor	0.18	0	0	0	0		0
Anchor light	0.17	0	0	10	1.7		0
Cabin Lights	0.1	1	0.1	4	0.4	5	0.5
pressure water	11	0.1	1.1	0.3	3.3	0.25	2.8
VHF radio-standby	0.2	24	4.8	0.5	0.1	0.5	0.1
Refridgeration	2	24	48	24	48	24	48
STEREO	1	0	0	2	2	1	1
TOTAL AMP HOURS	**31.51**		**202.7**		**121.5**		**52.4**

Requires ~ 121AH/day

FIND SPACES ON YOUR BOAT
FIND PANELS WITH SUFFICIENT OUTPUT
FIND PANELS THAT FIT

MYSTIC ROSE

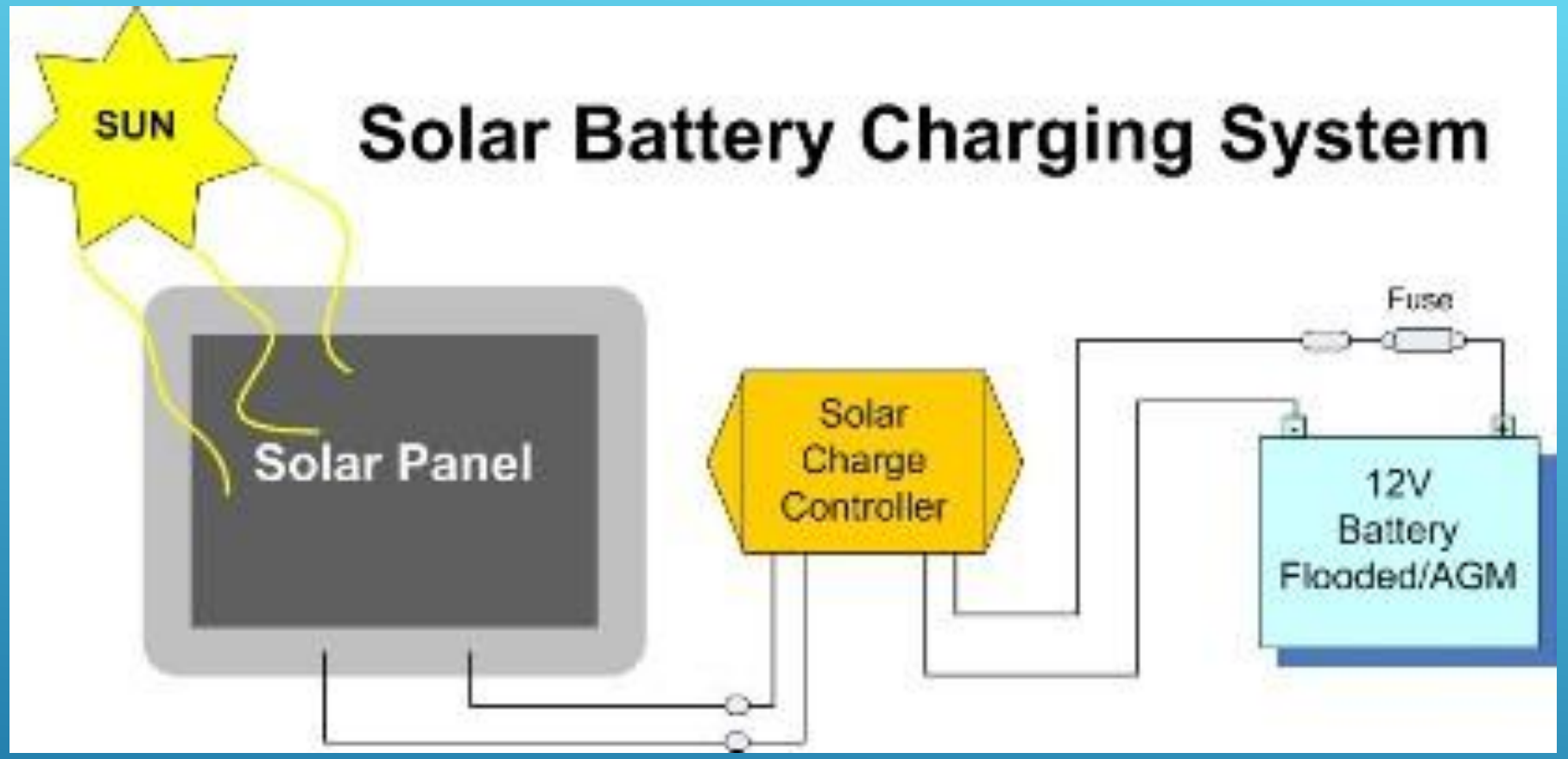
- ALLPOWERS 4x 100w flexible panels with Sunpower cells
- 400w total, 200AH/day
- No generator use required while cruising and using refrigeration and freezer (but did include some motor-sailing charging)
- On mooring batteries were always full (no refrigeration running)

BREAKAWAY

- Kyocera 2 x 65w fixed panels above bimini
- Go Power Solar Flex100w flexible panel on dodger
- 230w total, 115AH/day
- Powered everything including refrigeration for entire season without running generator

SALACIA

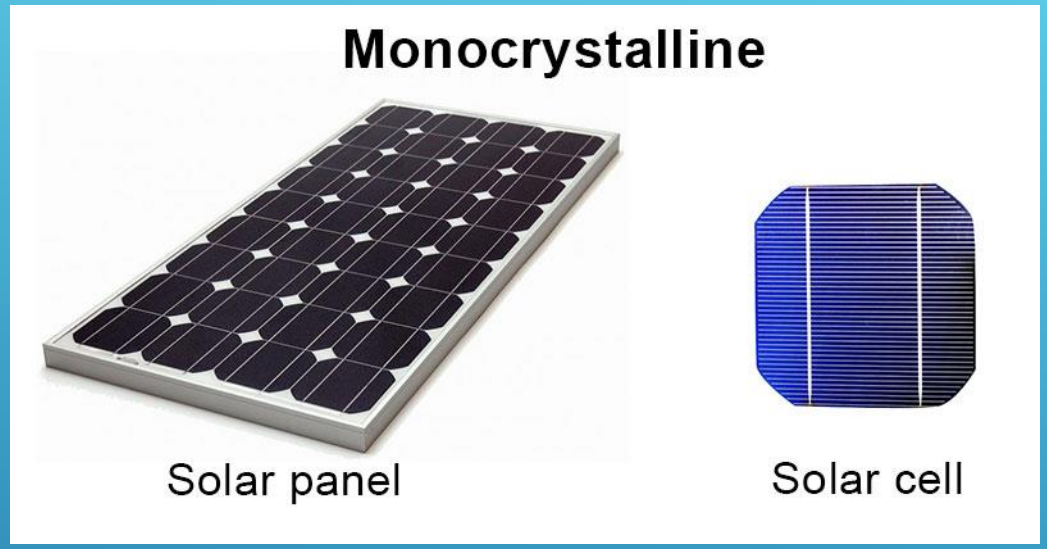
- HamiltonFerris SolarFlexx 2x 50w panels on dodger
- 46AH/day



HOW TO BUILD A SOLAR SYSTEM

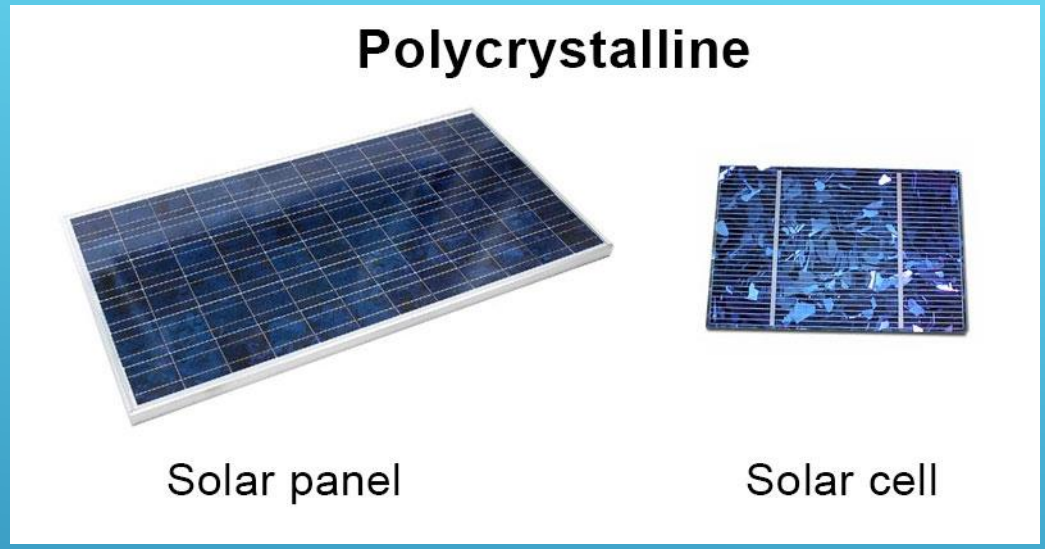
SOLAR PANEL CELL TYPES

Monocrystalline Cells ☑



- 15-21% efficient
- Slightly higher cost (eg Renogy 100w $140)
- Smallest area
- Perform better in low light
- Rounded edges
- Solid dark blue/black
- Sunpower cells most popular

Polycrystalline Cells



- Slightly less expensive (eg Renogy 100w $120)
- 13-16% efficient
- Larger area
- Exact rectangular shape
- Speckled blue

RIGID

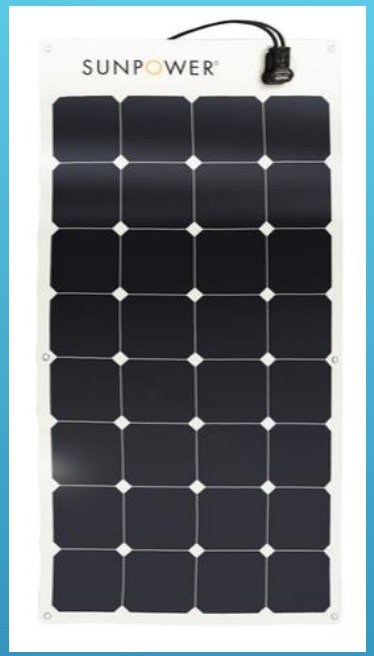
12 Volt Monocrystalline Solar Panel

Example:
- Renogy 100 Watt
- 100W, 16V, 6.25A
- Dimensions 47”x20”x 1¼”
- 16.5 lbs
- $140

- Less expensive
- Heavier requiring more complex, permanent and visible mounting
- Best for davit or rail installations
- Slightly more efficient per given area

FLEXIBLE

12 Volt Monocrystalline Solar Panel



Example:
- Renogy 100 Watt
- 100W, 17.5V , 5.8A
- Dimensions 47”x21”x 1/16”
- 4.4 lbs
- $300

- More expensive
- Much lighter
- Simpler mounting (Velcro or snaps on canvas)
- More stealthy less visibile
- Can be setup temporarily and portable
- Some are non-skid and can be walked on
- Bend to contours up to 30º
- Slightly less efficient
- Not as rugged
- Require good ventilation

RIGID VS FLEXIBLE PANELS

HOW MUCH POWER DOES A SOLAR PANEL PRODUCE

- 100 watt panel generates 100W per hr in direct full sunlight
- Assuming 6hrs direct full sunlight per day
- Potentially100W x 6hrs = 600W / 12 V = 50AH
- Likely less

Ohm's Law
Volts =
Amps x Ohms

Power
Watts =
Amps x Volts

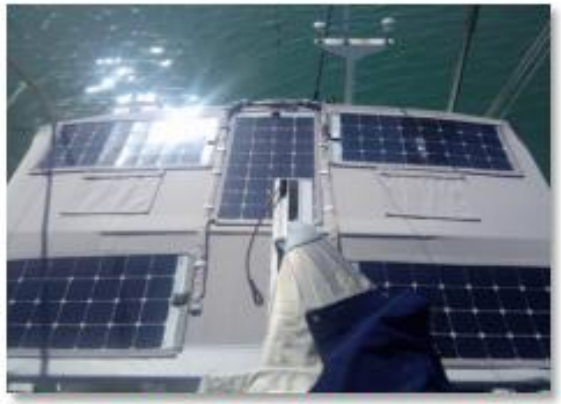
SELECTING SOLAR PANELS

- Power and physical size varies by brand – typically 50w, 100w, 150w
- Re panel specs, use working/operating/rated values, not short circuit or open circuit values
- Think about where shadows may fall – partial shading can reduce power by 80% (boom, radar pole, mast, etc…)
- Pick your mounting areas and figure out what size panels fit best to meet your power needs
- Some solar is better than none
- More panels are better

SOLBIAN

FREEDOM POWERED BY THE SUN

OceanPlanet Energy
72 Front Street Bath, ME 04530
Phone# 207-370-9112
www.oceanplanetenergy.com
info@oceanplanetenergy.com



Semi-Flexible & 1/16" thick: perfect for canvas installation

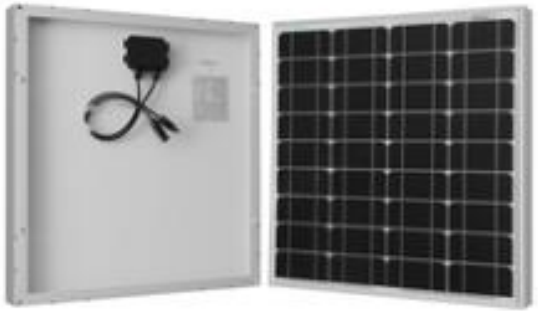
Available in a variety sizes, shapes & efficiencies

Highest Power, Lightest Weight

Highest Output SP Series using SunPower cells with up to 23% cell efficiency, the most powerful flexible solar panels

Model #	SP52L	SP52Q	SP64	SP78	SP104	SP118L	SP118Q	SP130	SP144
Length	44" /1109mm	24" /601mm	29" /728mm	33.7"/855mm	44"/1109mm	49"/1236mm	33.7"/855mm	54"1363mm	59"/1490mm
Width	11.7"/292mm	21.7"/546mm	21.7"/546mm	21.7"/546mm	21.7"/546mm	21.7"/546mm	31.5"/800mm	21.7"/546mm	21.7"/546mm
Weight	1.8 lbs.	1.8 lbs.	2 lbs.	2.3 lbs.	3.1 lbs.	3.5lbs.	3.5lbs.	3.7 lbs.	4.2 lbs.
Power	52 W	52 W	64 W	78W	104 W	118W	118W	130 W	144 W
Panel V (Vmp)	9.1V	9.1V	11V	13.7V	18.2V	20.7V	20.7V	22.8V	25.3V
Max I to 12V battery	4.3A	4.3A	5.3A	6.5A	8.7A	9.8A	9.8A	10.8A	12A
Est. Sunny Day Yield	13-20Ahs/day	13-20Ahs/day	16-24Ahs/day	20-30Ahs/day	26-40Ahs/day	30-45Ahs/day	30-45Ahs/day	33-50Ahs/day	36-55Ahs/day
Price	**$529**	**$529**	**$649**	**$789**	**$1049**	**$1189**	**$1189**	**$1299**	**$1449**

RENOGY

Renogy 150 Watt 12 Volt Monocrystalline Solar Panel	Renogy 50 Watt 12 Volt Monocrystalline Solar Panel	SunPower® Flexible 100 Watt Monocrystalline Solar Panel	Renogy 100 Watt 12 Volt Monocrystalline Solar Panel (Slim Design)
			
$189.99	$79.99	$299.99	$139.99

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ALLPOWERS

ALLPOWERS Solar Panel 100W 18V 12V Bendable Flexible Solar Charger SunPower Solar Module with MC4 for RV, Boat, Cabin, Tent, Car, Trailer, 12v Battery or Any Other Irregular Surface

4.3 out of 5 stars | 282 customer reviews | 269 answered questions

Price: $179.99 & **FREE Shipping**. Details

Buy 1, get a discount on selected products 7 Applicable Promotion(s)

In Stock.

Want it Tuesday, Jan. 9? Order within **2 hrs 13 mins** and choose **Two-Day Shipping** at checkout. Details

Sold by ALLPOWERSDirect and Fulfilled by Amazon. Gift-wrap available.

Color: **18V100W**


$6.59

$7.99

$8.79

$89.99

50W


$179.99

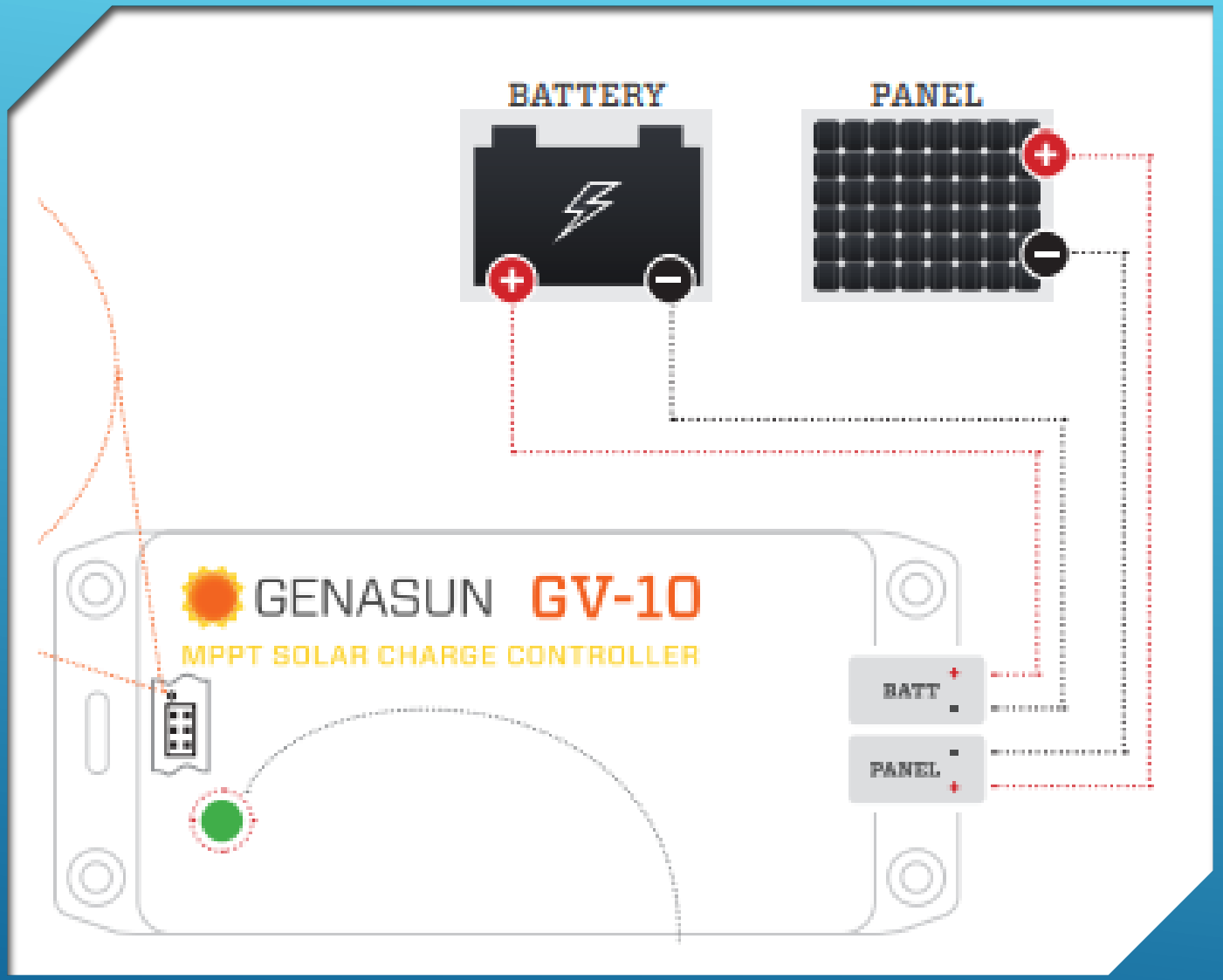
$18.99

$34.99

HAMILTONFERRIS

Power for Boat, Home & RV since 1975

Model	Approx. A/Hr/Day	Package	Panel	Panel Size / ea.	Price
SolarFlexx 30W	30 Watt	Panel only	SF 30W	21.6" x 15.0"	$299.00
SolarFlexx 55W	55 Watt, NEW 2018	Panel only	SF 55W	22.1 x 22.0"	$399.00
SolarFlexx 110W	110 Watt, NEW 2018	Panel only	SF 110W	41.8 x 21.4"	$699.00
SF-400-4P	400 Watt 184A/Hr/Day	Live Aboard Serious Power	4x 100W	41.8 x 21.4"	$3699.00
SF-300-3P	300 Watt 138A/Hr/Day	Extended Cruising	3x 100W	41.8 x 21.4"	$2599.00
SF-200-2S	200 Watt 92A/Hr/Day	Full Time Fridge Use	2x 100W	41.8 x 21.4"	$1799.00
SF-100-1	100 Watt 46A/Hr/Day	Weekend Fridge Use	1x 100W	41.8 x 21.4"	$1099.00
SF-100-2S	100 Watt 46A/Hr/Day	Weekend Space Saver	2x 50W	22.1 x 24.6"	$1139.00
SF-50-1	50 Watt 23A/Hr/Day	House Bank Maintainer	1x 50W	22.1 x 24.6"	$659.00



SOLAR CHARGE CONTROLLERS

- Essential to optimize battery charging and prevent overcharging
- Multi-stage charging profile (bulk, absorption, float)
- MPPT (Maximum Power Point Tracking) vs PWM (Pulse Width Modulation) types
- Ideally use one controller per panel which eliminates one panel bringing down overall output
- Some can boost low voltage panels (remember batteries require up to 14v to charge)

Genasun $65-$175

Blue Sky Energy $180-$199

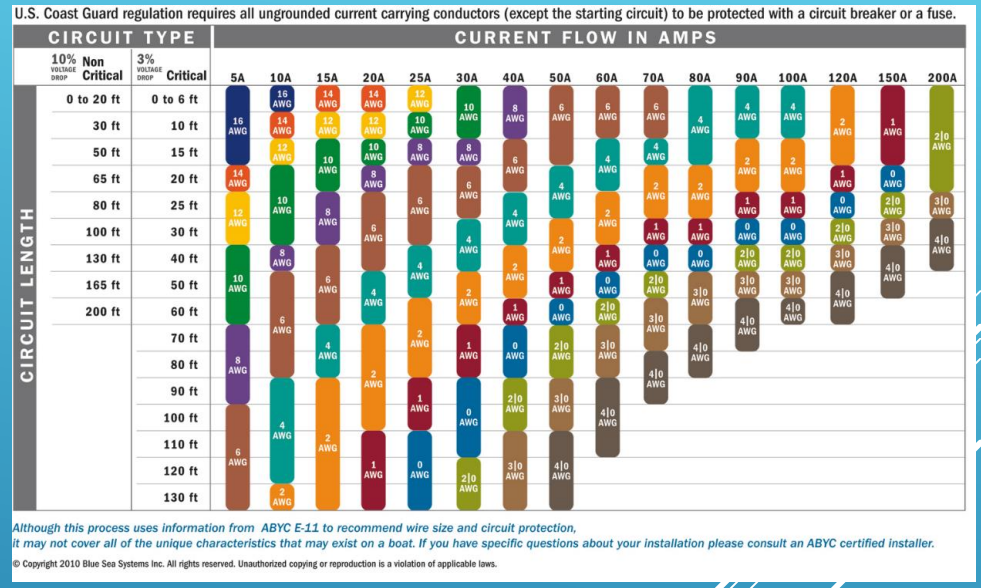
Western Co. $207-$460

Victron BlueSolar $139-$381

POPULAR MPPT CONTROLLERS

WIRE SIZING

- **Panel voltage and wire size**
  - For a given wattage panel, higher voltage panels have lower current and can therefore use thinner gauge wire (W = A x V)
  - Useful fact for long wire runs from panels to controller(s)
- **Choosing the optimal wire gauge**
  - The longer the run the higher the loss or voltage drop (remember the run length is measured as a round trip)
  - Good West Marine article: https://www.westmarine.com/WestAdvisor/Marine-Wire-Size-And-Ampacity
  - ABYC recommends max 3% voltage drop
  - Most wire size tables are for 12 or 24 volt only, so need a calculator for solar panel runs
    - Web: http://wiresizecalculator.net/
    - App: WireSizer for Apple: http://www.wiresizer.com/



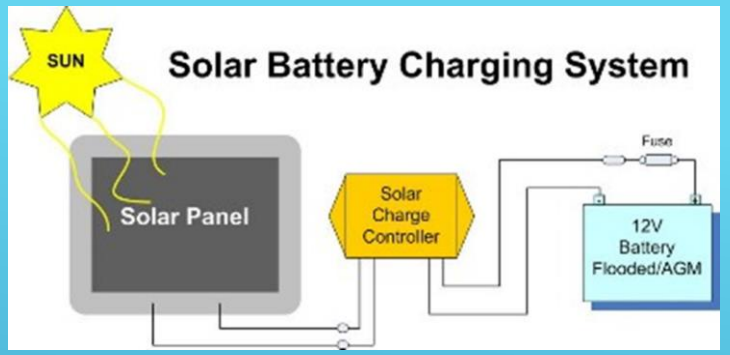
U.S. Coast Guard regulation requires all ungrounded current carrying conductors (except the starting circuit) to be protected with a circuit breaker or a fuse.

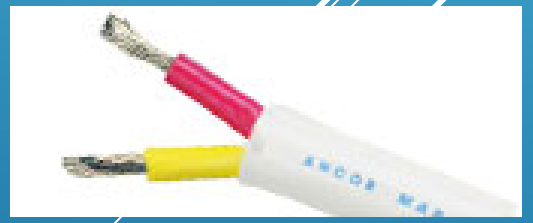
CIRCUIT TYPE			CURRENT FLOW IN AMPS														
CIRCUIT LENGTH	10% VOLTAGE DROP Non Critical	3% VOLTAGE DROP Critical	5A	10A	15A	20A	25A	30A	40A	50A	60A	70A	80A	90A	100A	120A	150A	200A
	0 to 20 ft	0 to 6 ft	16 AWG	16 AWG	14 AWG	14 AWG	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	1 AWG	2|0 AWG
	30 ft	10 ft	14 AWG	14 AWG	12 AWG	12 AWG	10 AWG	8 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	0 AWG	3|0 AWG
	50 ft	15 ft	14 AWG	12 AWG	10 AWG	10 AWG	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	2|0 AWG	4|0 AWG
	65 ft	20 ft	12 AWG	10 AWG	8 AWG	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	0 AWG	2|0 AWG	3|0 AWG	
	80 ft	25 ft	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	0 AWG	2|0 AWG	3|0 AWG	4|0 AWG
	100 ft	30 ft	10 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	0 AWG	2|0 AWG	2|0 AWG	3|0 AWG	4|0 AWG	
	130 ft	40 ft	10 AWG	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG	3|0 AWG	3|0 AWG	4|0 AWG	4|0 AWG	
	165 ft	50 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG	4|0 AWG	4|0 AWG	4|0 AWG			
	200 ft	60 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG	4|0 AWG					
		70 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG						
		80 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG						
		90 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	4|0 AWG						
		100 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	4|0 AWG						
		110 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	4|0 AWG						
		120 ft	8 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	4|0 AWG						
		130 ft	8 AWG	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2|0 AWG	3|0 AWG	4|0 AWG							

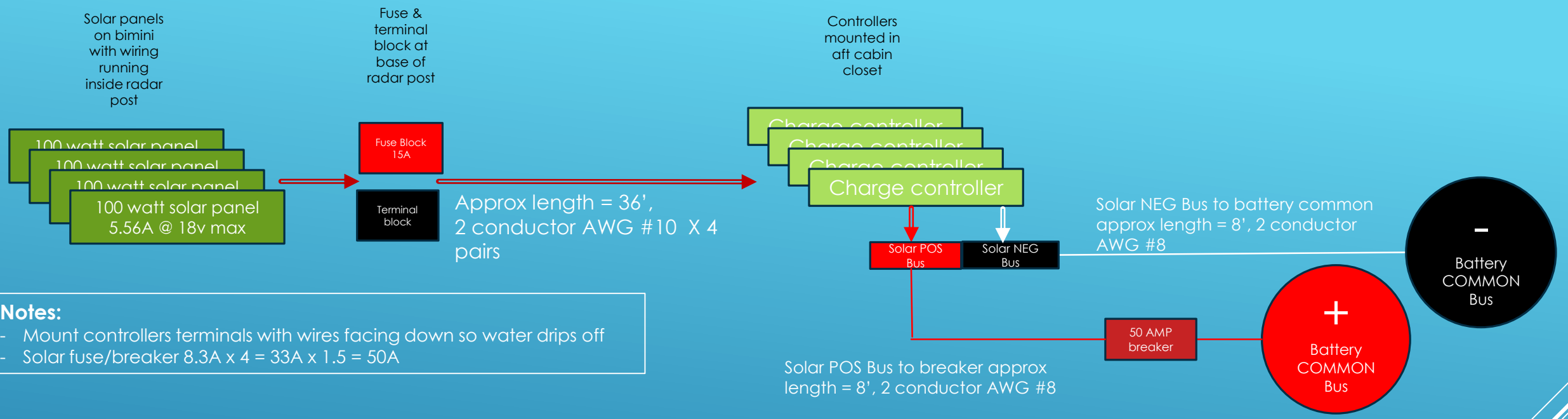
Although this process uses information from ABYC E-11 to recommend wire size and circuit protection, it may not cover all of the unique characteristics that may exist on a boat. If you have specific questions about your installation please consult an ABYC certified installer.

CONNECTING EVERYTHING & DISCONNECTING

- **Fuses protect the wire**
  - Sized 1.5 x max expected amps
  - Protect positive lead at each end of wire
- **MC4 connectors**
  - Industry standard plug and socket for connecting solar panels
  - Waterproof design using o-ring seals
  - Special crimping tool required
  - Disconnect tool required
- **Wire**
  - Use Ancor marine grade tinned wire: red &yellow "safety" duplex cable
  - Use waterproof heat-shrink crimp terminals







Notes:
- Mount controllers terminals with wires facing down so water drips off
- Solar fuse/breaker 8.3A x 4 = 33A x 1.5 = 50A

4 Solar Panels	Length	Length x 2	Volts	Amps	WireSizer app	CharlieWing tables	Min CM from Charlie Wang	CM AWG based on table
Solar panels to controllers	36	72	18	5.56	10	8	7,969	10
Controllers to buses	8	16	12	33	8	8	15,767	8
Buses to battery	8	16	12	33	8	8	15,767	8

AWG	Min CM for AWG
18	1,620
16	2,580
14	4,110
13	6,530
10	10,380
8	16,510
6	26,240

MYSTIC ROSE WIRING & FUSES

MYSTIC ROSE INSTALLATION

Take a pic of fuse block base of radar post

SALACIA INSTALLATION

SALACIA INSTALLATION

SALACIA INSTALLATION

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SALACIA INSTALLATION

- **Parts:**
  - Solar panels: 4 x $180 = $720
  - Controllers: 4 x $100 = $400
  - Wire, terminals, fuse blocks: $350
  - Canvas work - velcro strips to bimini and panels: $500
- **Total Parts:** $1970
- **Personal Labor:** 40 hrs

COSTS FOR MYSTIC ROSE INSTALLATION

COSTS FOR SALACIA INSTALLATION

- **Parts:**
  - Solar panels, wiring, cable clam, regulator = $1,252
  - Battery Monitor = $169
  - Canvas work - velcro strips to dodger and panels: $450
- **Total Parts:** $1871
- **Personal Labor:** hrs = Endless

- Mystic Rose experimenting with 2x 50w panels on shrinkwrap to charge batteries during winter
- Considering adding 2x 50w to bimini this spring

WHAT'S NEXT

REFERENCES

- **BruceSchwab Energy Systems:** https://www.bruceschwab.com/solar-power/
- **Renogy solar panels:** https://www.renogy.com/
- **Victron battery monitors and controllers:** https://www.victronenergy.com/battery-monitors
- **HamiltonFerris:** http://www.hamiltonferris.com/categories/Solar_Power/6
- **Genasun controllers:** https://genasun.com/
- **Seafrost refrigeration:** http://seafrost.com/
- **Ancor wire and terminals:** http://www.ancorproducts.com

- **PDF of this presentation**: http://bit.ly/BWSC-DIYSolar