Save $$$$ on Batteries

by Tom Brennan Engineering Manager

- How many batteries per appliance
- Different types, efficiency, cost per cycle, where to install
  - Traditional: Wet, Gel, AGM, Nickel Iron
  - Newer: Li Polymer, Li NCM, Li LFP, Carbon AGM
- Lithium Battery Management System (BMS): advantages/drawbacks
- Warranties: read the fine print
- How to size battery bank
  - Depth of Discharge vs. lifespan
- How Smart Load Management reduces battery size ~10% on Grid and 20-30% Off Grid

Sol-Ark®

Energy Insurance for your family

- Mission:
  - A Veteran owned engineering company dedicated to helping families be less dependent on our vulnerable Power Grid in an affordable way
- No customer returns in 6 years of business
- Sol-Ark 8K: most efficient & affordable Solar Storage inverter in the world

ees AWARD 2019 FINALIST

VETERAN OWNED BUSINESS

THE ENERGY AWARDS 18
Sol-Ark 8K: Renewable Energy Technology of 2018
FINALIST

S&P GLOBAL PLATTS
GLOBAL ENERGY AWARDS
2018 FINALIST

THE ENERGY AWARDS 18
Sol-Ark 8K: Home Energy Product of 2018
FINALIST

How much power do you need?

=

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300 Watt Panel

12V 110Ah

300W x 5 “full” sun hours = 1.5KWh

12V x 110Ah = 1.3KWh

+ consuming 2000 calories / person

Power Needs

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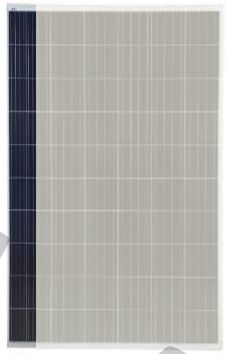

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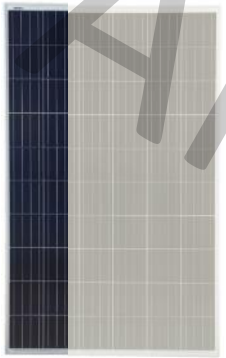

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Power Needs

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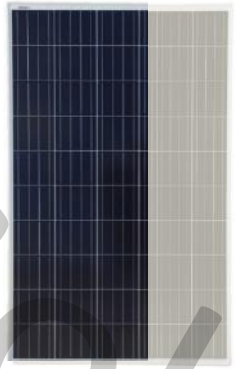

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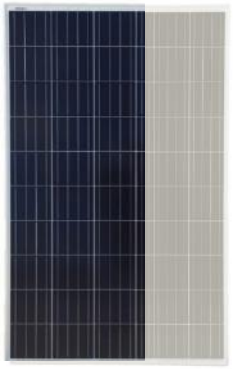

Power Needs

=  × 2

=  × 6

=  × 9

=  × 36

Traditional Batteries

	Nickel Iron	Lead Acid (thick plate)	
		Wet	AGM
Round Trip Efficiency	65%	80%	88%
Round Trip Losses w/ Sol-Ark	35%	20%	12%
10KWh Cost (MSRP)	$9,300	$1,600	$1,800
Off Grid Real World Cycles 50% DoD	8,000	1300	750
Off Grid Years @ 50% DoD	21.9	3.6	2.1
On Grid Years	25	9	7
Cost Per KWh Cycle	$0.23	$0.25	$0.48
Cost of Oversizing 10KW PV @ $4/W	$14,000	$8,000	$4,800

GEL like AGM but ~9 yrs
On Grid but limited charge rates

Traditional Batteries

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Cost of Oversizing 10KW PV @ $4/W	$14,000	$8,000	$4,800

Lead Acid Tip:
Don't go by battery Ah rating.
Compare by weight.

Drawbacks:
Batt Round Trip Losses
+ 7-20% in electronics
Venting
Anticorrosive spray
Overfill / Underfill
Can freeze if discharged

Drawbacks:
Cost per cycle

Traditional Batteries

	Nickel Iron	Lead Acid (thick plate)	
		Wet	AGM
Round Trip Efficiency	65%	80%	88%
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Cost of Oversizing 10KW PV @ $4/W	$14,000	$8,000	$4,800

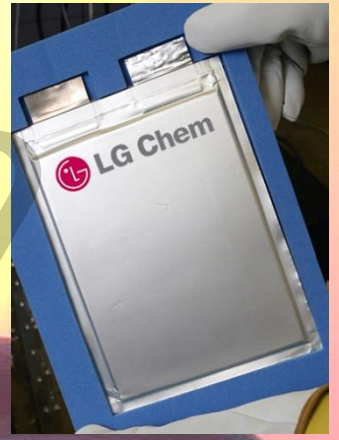
Good for Emergency Backup

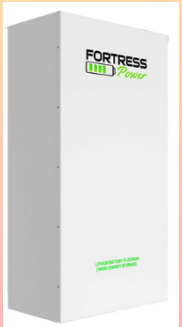
AGM Example #2

$2400
1200x80% = 950
2.6
7
$0.51
$4,800

New Battery Comparison

	Lead Acid (thick plate)		Lithium		
	AGM	Carbon AGM	Li Polymer	LiOn / NMC	LFP
Round Trip Efficiency	88%	94%	98%	98%	98%
Round Trip Losses w/ Sol-Ark	12%	2%	2%	2%	2%
10KWh Cost (MSRP)	$1,800	$2,100	$4,500	$6,500	$8,500
Off Grid Real World Cycles 50% DoD	750	2400	1500	3000	6000
Off Grid Years @ 50% DoD	2.1	6.6	4.1	8.2	16.4
On Grid Years	7	12	9	12	15
Cost Per KWh Cycle	$0.48	$0.18	$0.60	$0.43	$0.28
Cost of Oversizing 10KW PV @ $4/W	$4,800	$800	$800	$800	$800



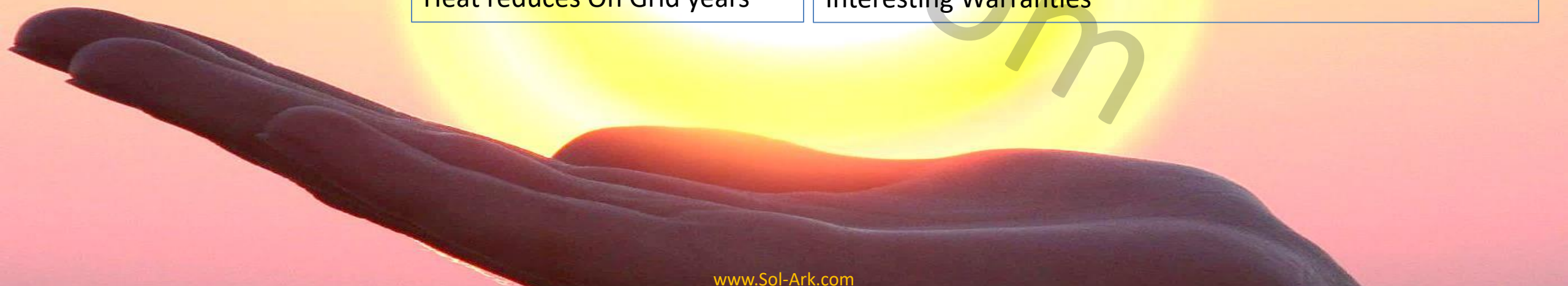


New Battery Comparison

	Lead Acid	Lithium	
	Carbon AGM	**LiOn / NMC**	**LFP**
Round Trip Efficiency	94%	98%	98%
Round Trip Losses w/ Sol-Ark	2%	2%	2%
10KWh Cost (MSRP)	$2,100	$6,500	$8,500
Off Grid Real World Cycles 50% DoD	2400	3000	6000
Off Grid Years @ 50% DoD	6.6	8.2	16.4
On Grid Years	12	12	15
Cost Per KWh Cycle	$0.18	$0.43	$0.28
Cost of Oversizing 10KW PV @ $4/W	$800	$800	$800

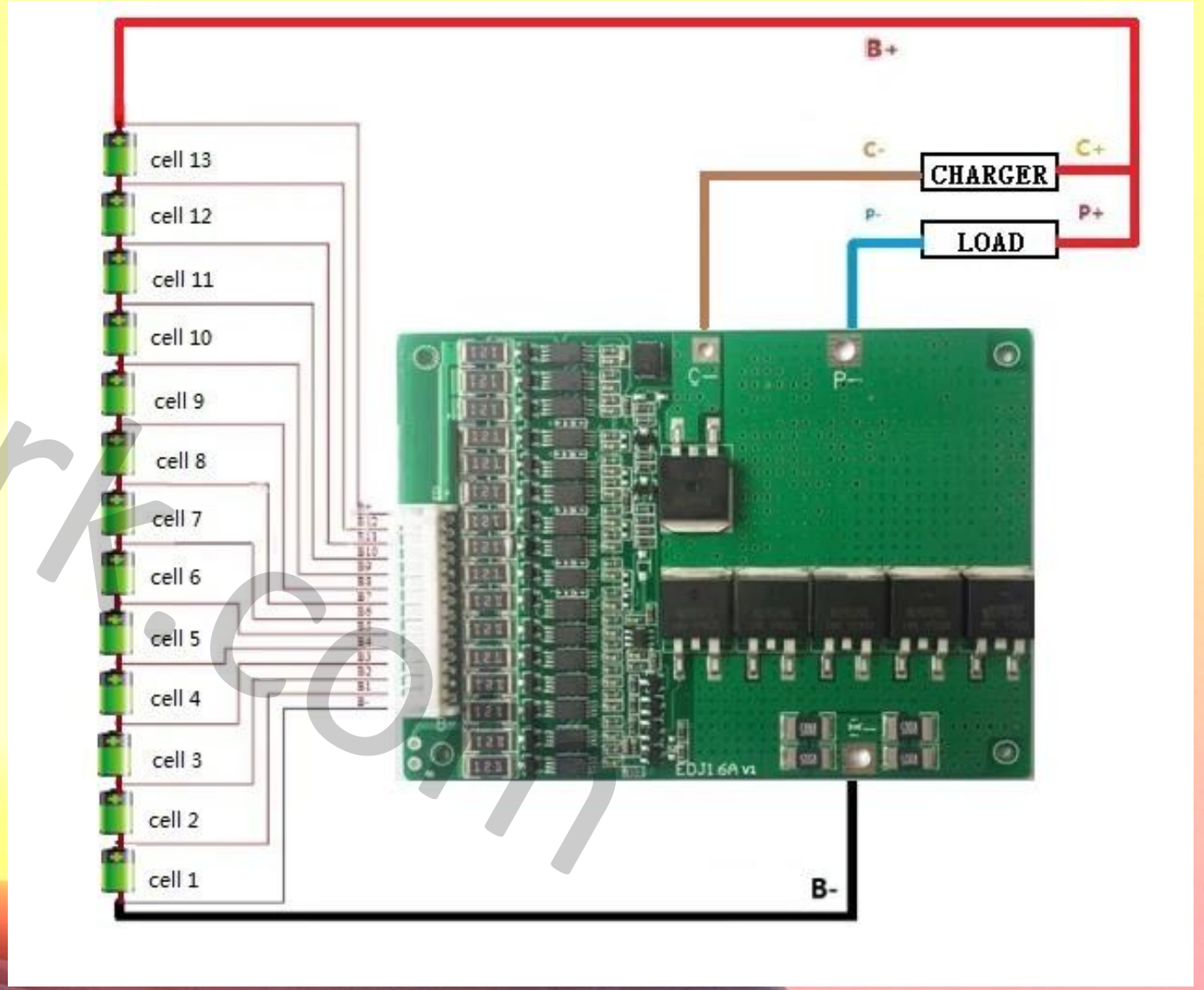
Drawbacks:
Can over discharge (no BMS – but can use inverter)
Heat reduces On Grid years

Drawbacks:
BMS reliability
Temperatures near 32F/0C
Interesting Warranties



Lithium Battery Management System (BMS)

- BMS required for:
  - Balancing cells
    - LFP = definitely need
    - NMC = likely need
  - Protecting from over charging, discharging, shorts (& thermal runaway)
    - Inverter can help
- BMS good for:
  - Measuring % SOC, Temp
  - Communication to Inverter



Lithium BMS Types

Active (MOSFET Based)

- Most FET's easily damaged by: Inverter connection (charging caps), ESD
- Most shut down due to peak currents
- Not all are bad. A few are built well.

Passive (Relay Based)

- Replaces FET's with Relay
- More expensive but very reliable

Other Good Things to look for

- Continuous Amps? 150A-200A
- Surge Amps? 500A for 5-10s
- Peak Amps? 1000A
- Precharge: Inverter Capacitors
- ESD testing
- HALT: Highly Accelerated Life Testing (85C/85%)

Battery Warranties = The Wild West

LG Chem Battery: StorEdge / SunnyBoy / Huawei

LG Chem RESU10H

- 9.8KWh NMC (9.3KWh usable)
- MSRP Price = ~$7K

(NMC Chemistry ~3000 cycles @ 50% DOD)

- 380V External, 50V internal
  - DC/DC Efficiency = 94.5% → 11% losses excluding NCM & Inverter

Warranty

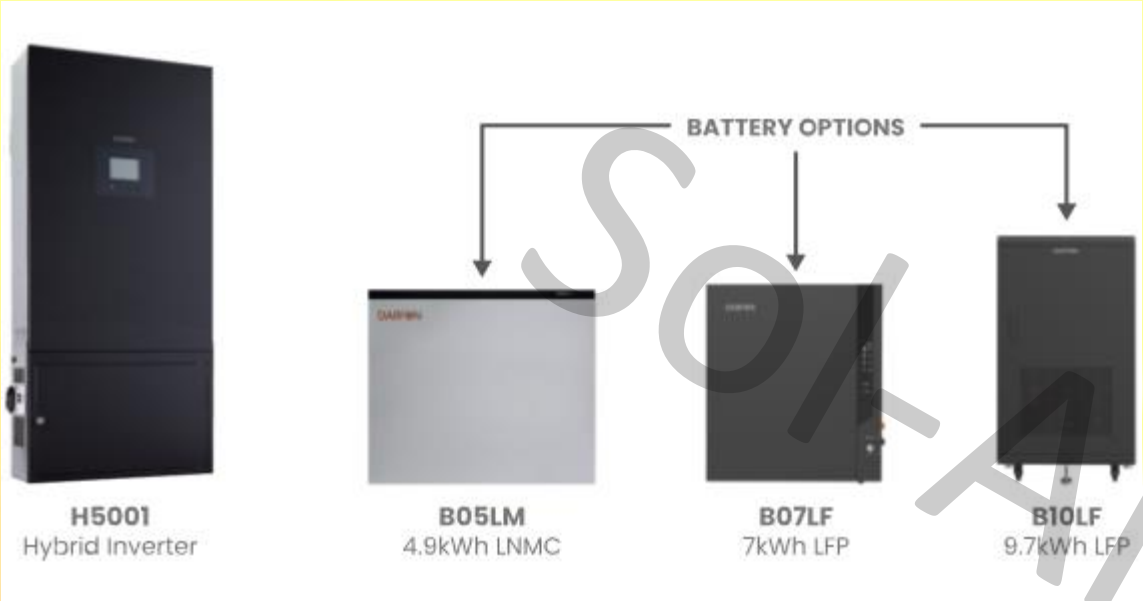
- Temp: 14 ~ 113F (-10 ~ 45C)
- 60% of capacity after 10 years
- They cover you for 6-7 years

- Compensation Scheme -

CLASS I : 100% of the purchase price from the initial installation date to 24th month
CLASS II : 72% of the purchase price from 25th to 36th month
CLASS III : 58% of the purchase price from 37th to 48th month
CLASS IV : 44% of the purchase price from 49th to 60th month
CLASS V : 30% of the purchase price from 61st to 72nd month
CLASS VI : 16% of the purchase price from 73rd to 84th month
CLASS VII : 6% of the purchase price from 85th to 96th month
CLASS VIII: 4% of the purchase price from 97th to 108th month
CLASS IX : 2% of the purchase price from 109th to 120th month
No warranty of performance will be provided from the 121st month

Warranty: 10-year product warranty, the LG Chem is also covered by warranty for 3,180 cycles and the amount that is repaid upon failure is dependent on how

Darfon Batteries: Started with NCM, now LFP



- Price & Warranty = No info
- Manufacturers learning LFP is far better and safer than NMC for solar cycling
- Non Ideal lab conditions cycles are:
  - NMC Chemistry ~3000 cycles @ 50% DOD
  - LFP Chemistry ~6000 cycles @ 50% DOD

BATTERY SPECIFICATIONS	B05LM	B07LF	B10LF
Capacity@ 25°C	4.88kWh (95.4Ah)	7kWh (136.8Ah)	9.68kWh (201.6Ah)
Battery Chemistry	Lithium Nickel Manganese Cobalt	Lithium Ferrite Phosphate	Lithium Ferrite Phosphate
Nominal Voltage	51.1V	51.2V	48V
Continuous Charge Current	44A	100A	100A
Continuous Discharge Current	44A	136A	200A
Cycle Life [80%DOD, @25°C]	2500 Cycles	> 60% capacity @ 6000 cycles	> 60% capacity @ 6000 cycles
Scalable	Up to 2 units (Master Box Required)	Up to 4 units	Up to 3 units
Product Weight	45.2kg (99.6 lbs)	88kg (194 lbs)	180kg (396.8 lbs)
Min. Cold Charge Temperature	0°C (32°F)	0°C (32°F)	0°C (32°F)

Sonnen

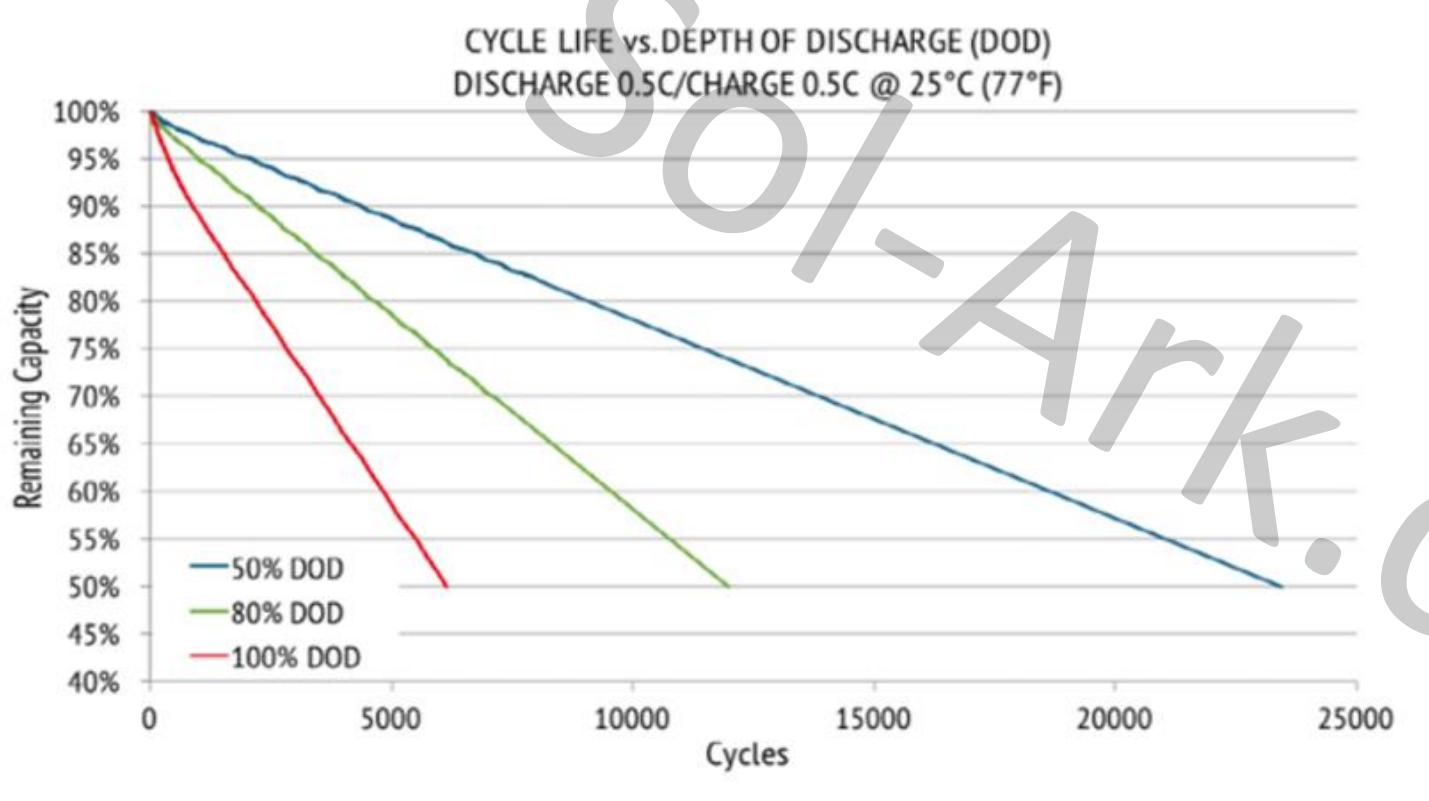
- ECO-16 16KWh LFP
- MSRP Price = **$24K**
- Includes Radian 8K inverter
- AC coupling losses are:
  - 3% + 15% + 7% = **25% loss** PV to Batt to AC

Warranty

- Temp: 14 ~ 113F (-10 ~ 45C)
- 10 years (even 5yr Radian Inverter)

RELion LFP

Does Lithium Last 23,500+ Cycles = 64 years?

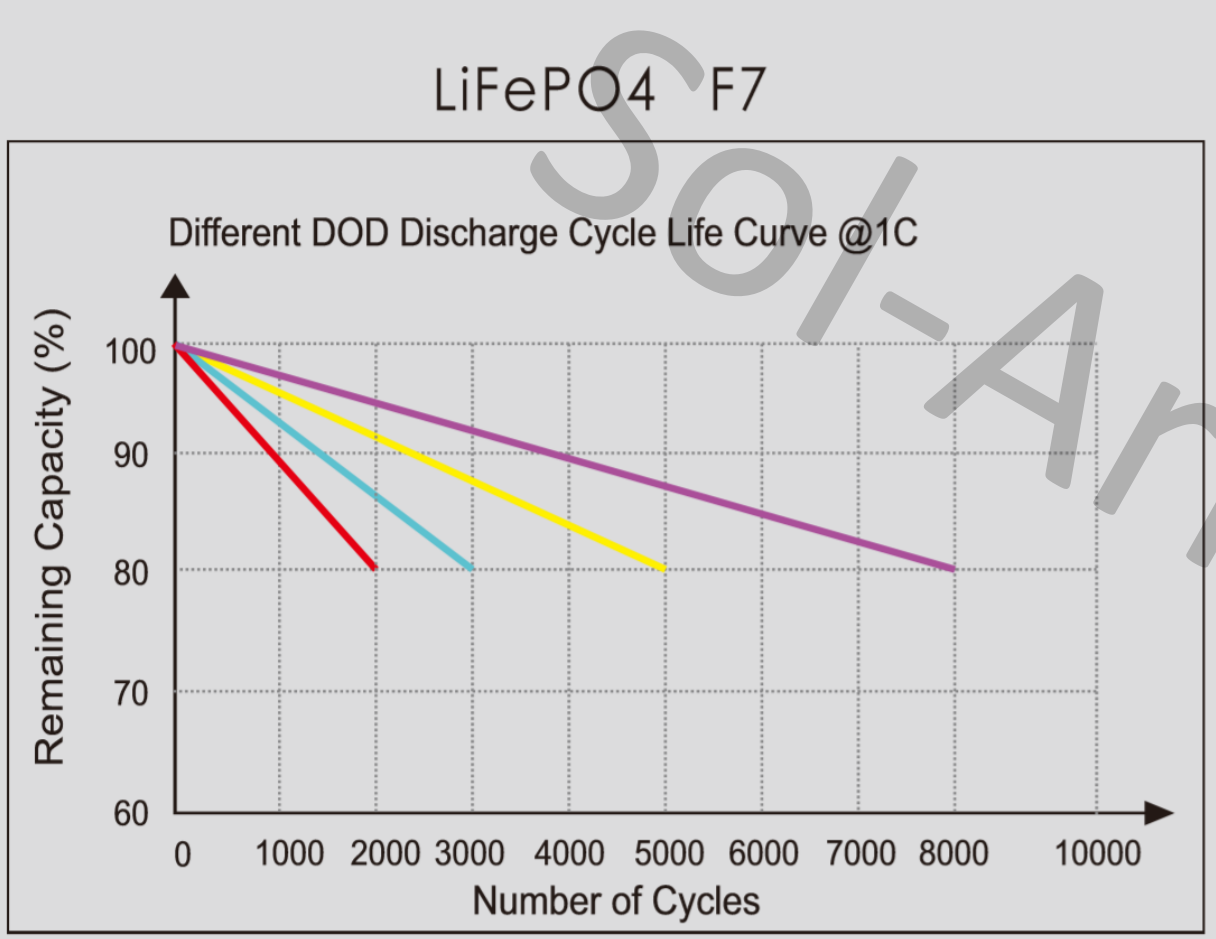


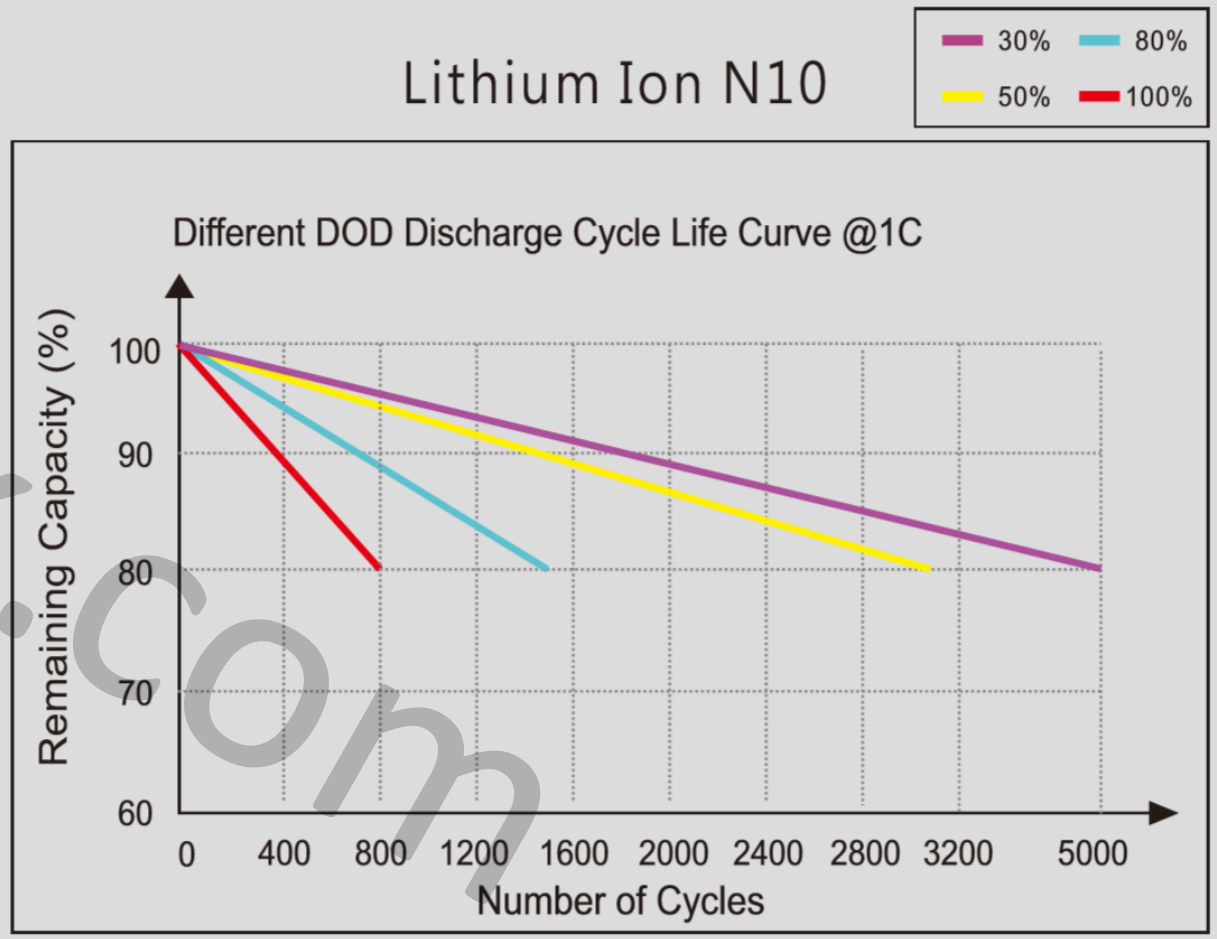
- 15.4KWh 51.2V 300Ah LFP
- MSRP Price = $13.3K
- BMS 200A (250A 4s)

Warranty

- 7 years: 3yr + 4yr prorated
- Temp: 32 ~ 113F (0 ~ 45C)
- Void if “Product was undersized for the application”

Lithium Manufacturer (good) Example





Panasonic: Pika

- 20.3KWh NMC (usable 15.9KWh 78% DOD)
- MSRP Price = $15K
- 380V External, 50V internal
  - DC/DC Efficiency = 96.5% → 7% losses excluding NCM & Inverter
- You cannot change battery/inverter setup, only factory

Warranty

- 10 years
- Connect to Internet
  - Why must it always be internet connected?
- How are they delivering 10 years from 8 year NMC?
  - Are they reducing capacity to extend life?
    - Doubt: they upsized by 22%

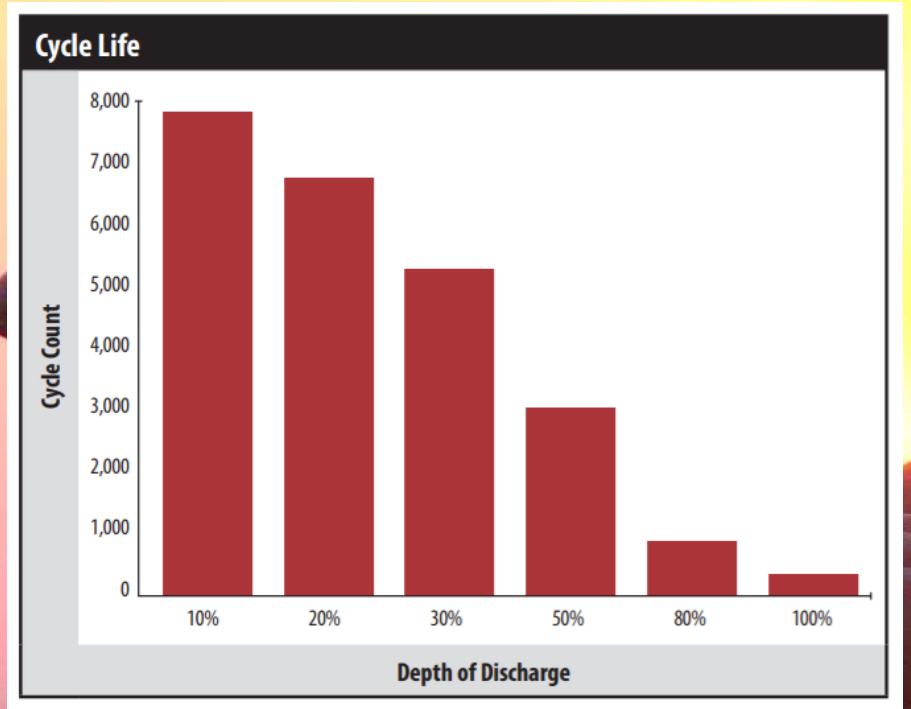
Tesla

- 14KWh x 2 = 28KWh NMC (27KWh usable)
- MSRP Price = $7K + $7K + $5K? = $19K
  - Lowest quotes seen ~$25K (maybe short supply)
- 10KW / 14KWpk inverter built in

Warranty

- 70% of capacity after 10 years
- Connect to Internet or shuts down after 48hours
- How are they delivering 10 years from 8 year NMC?
  - Why is past detailed usage data is erased?
  - Why must it always be internet connected?
  - Are they reducing capacity to extend life? (Apple does)

Outback EnergyCell 200PLC (Pure Lead Carbon AGM)



- 12V x 178Ah x 4 = 8.5KWh
- MSRP Price = ~$2.6K
  - 130lbs
- ~3000 cycles @ 50% DOD
  - Need to derate ~20% for non-ideal real world conditions = ~2400 cycles
- Thick Plate Carbon AGM handles partial state of charge well

Warranty

- 70% of capacity after 6 years
- Void:
  - Average temp >86F for 30days
  - Discharge lower than 12.3V / 49.2V = 35% DOD

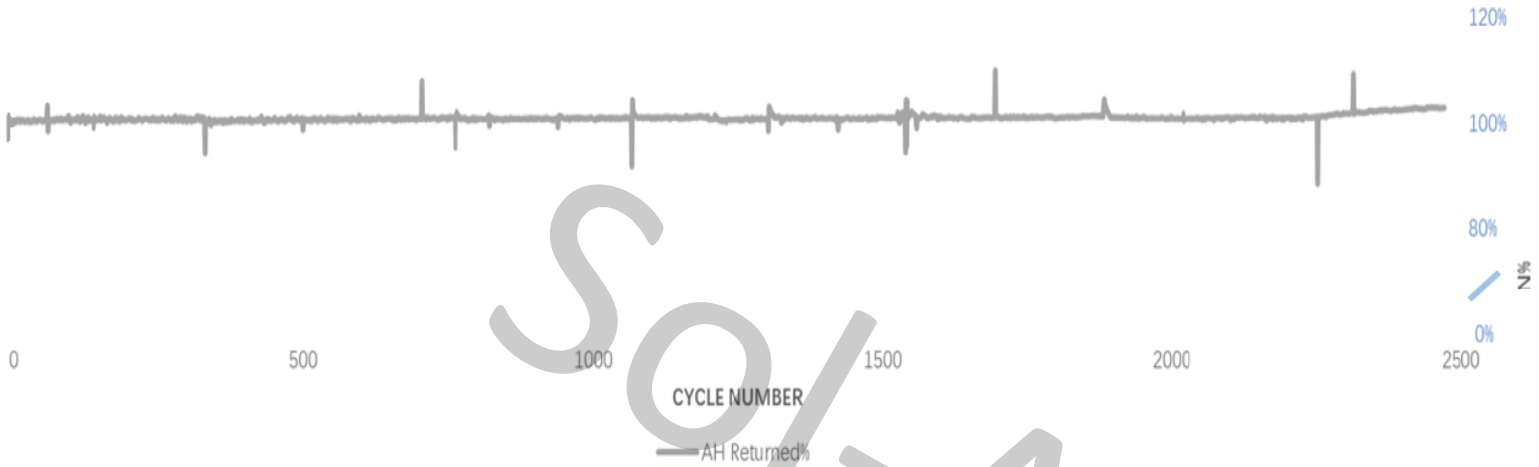
Sol-Ark PCC-230 (Partial Charge Carbon AGM)

- 12V x 230Ah x 4 = 11KWh
- MSRP Price = $2.6K ($650 each)
  - 160lbs
- ~2400 real world cycles @ 50% DOD
- Thick Plate Carbon AGM handles partial state of charge well
- Charge/Discharge: 140A continuous & 230A peak

Warranty

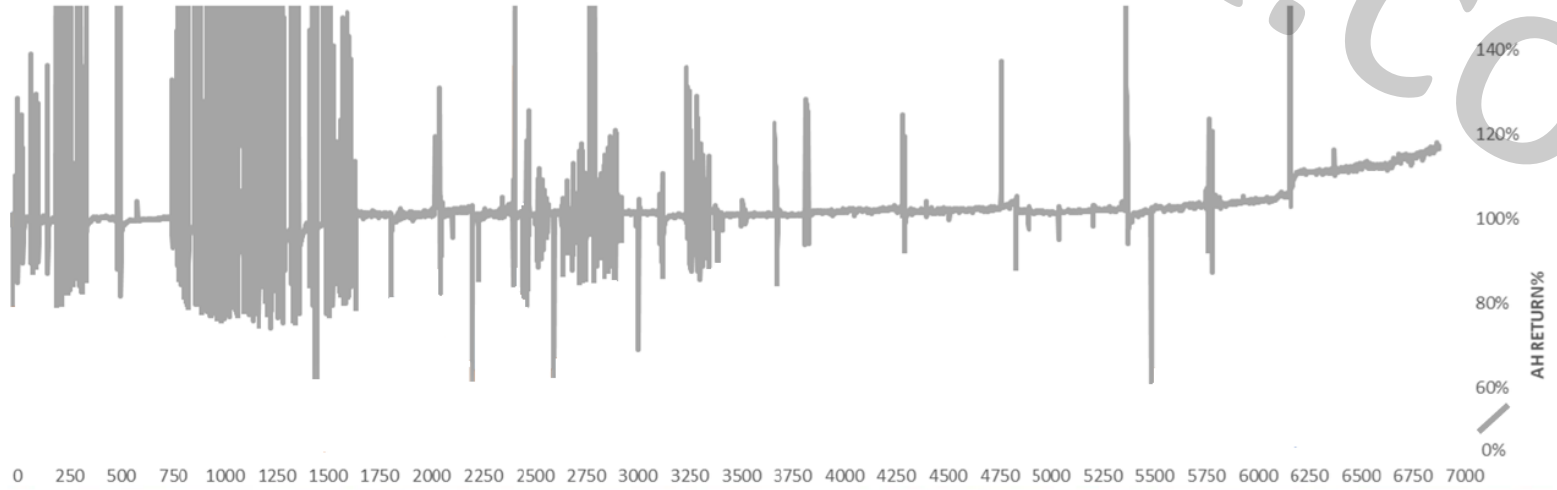
- 5 years: 3yr + 2yr prorated (online monitoring)

AH Input / AH Output



99% round trip efficiency is maintained for over 2300 cycles.

Energy Input / Energy Output vs. Cycles



The batteries recover their efficiency after being heavily used and undercharged for the first 1700 cycles.

PCC Battery Efficiency = 99%

PCC Battery Efficiency
to 6200 cycles

Battery Summary

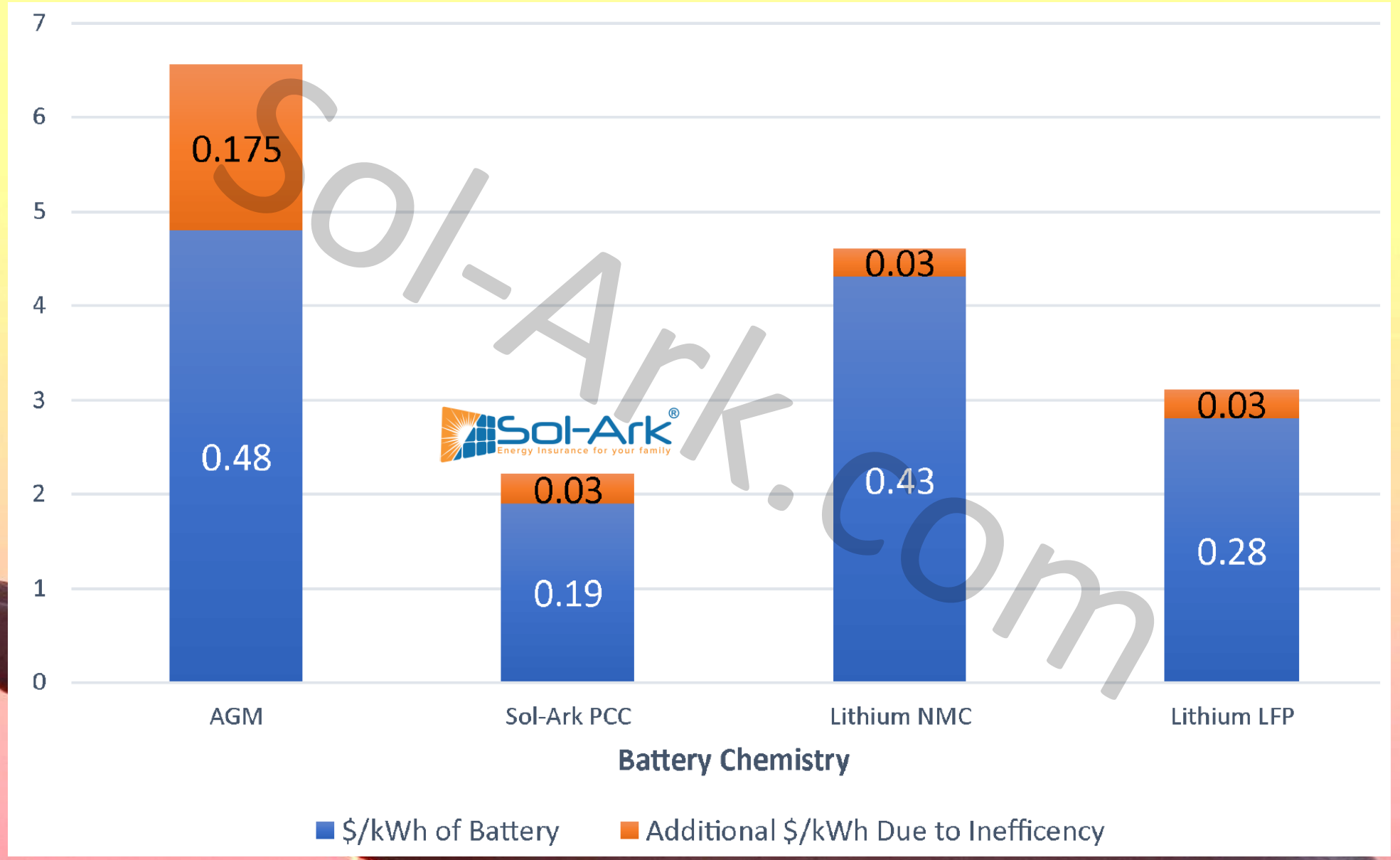
	Nickel Iron	Lead Acid (thick plate)			Lithium		
		Wet	AGM	Carbon AGM	Li Polymer	LiOn / NMC	LFP
Round Trip Efficiency	65%	80%	88%	94%	98%	98%	98%
Round Trip Losses w/ Sol-Ark	35%	20%	12%	2%	2%	2%	2%
10KWh Cost (MSRP)	$9,300	$1,600	$1,800	$2,100	$4,500	$6,500	$8,500
Off Grid Real World Cycles 50% DoD	8,000	1300	750	2400	1500	3000	6000
Off Grid Years @ 50% DoD	21.9	3.6	2.1	6.6	4.1	8.2	16.4
On Grid Years	25	9	7	12	9	12	15
Cost Per KWh Cycle	$0.23	$0.25	$0.48	$0.18	$0.60	$0.43	$0.28
Cost of Oversizing 10KW PV @ $4/W	$14,000	$8,000	$4,800	$800	$800	$800	$800

Good for Emergency Backup

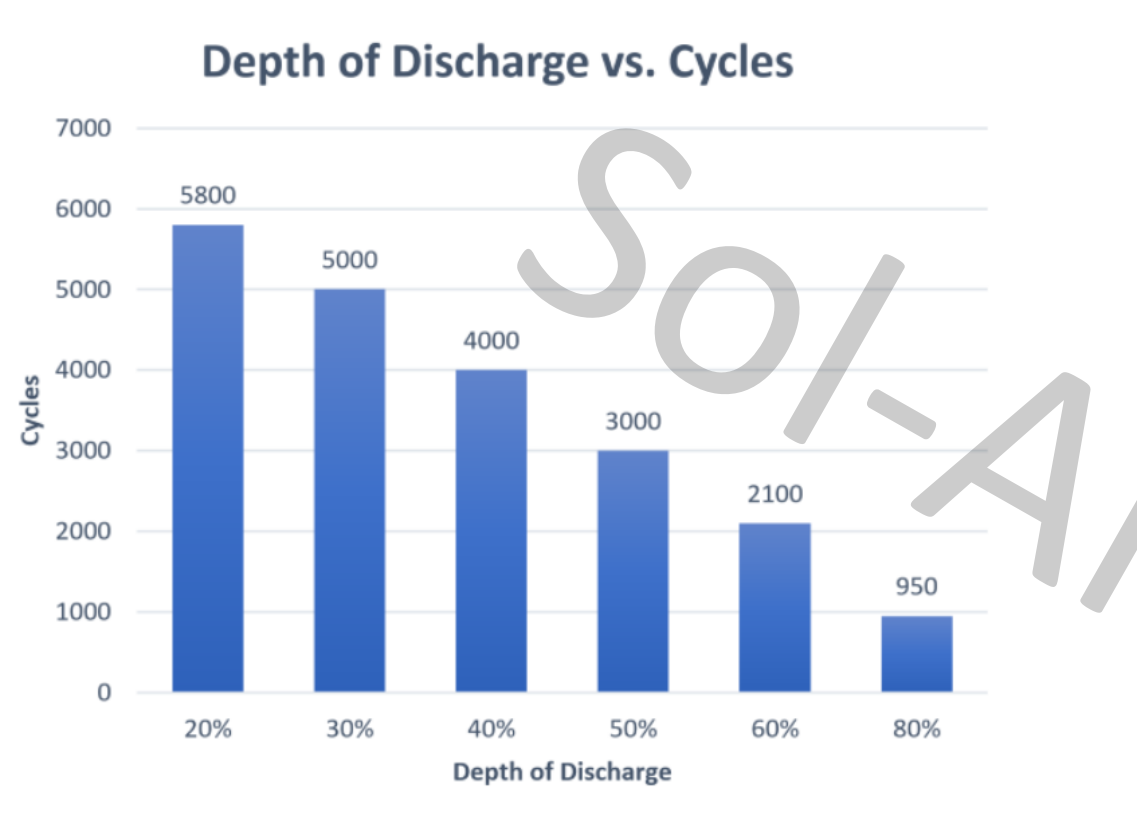
Good for Daily Cycling

Good for Daily Cycling

Battery Chemistry Cost Comparison



Sizing batteries given Depth of Discharge (DOD)

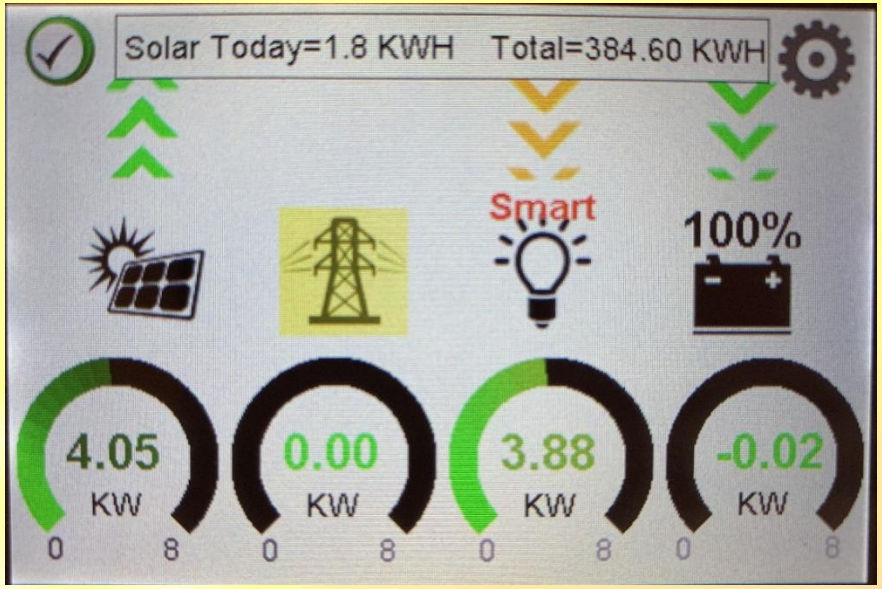


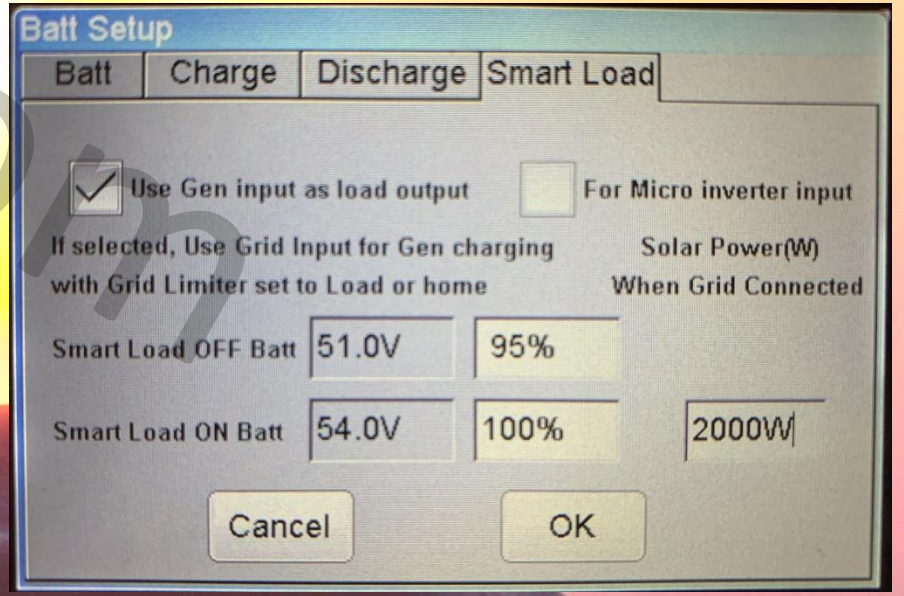
- There is an online sizing tool
  https://www.sol-ark.com/customize-8k-system/
- Battery Backup Applications
  - Rarely cycles so 80% DOD is fine
  - Typical: 11KWh $2.6K
  - Large: 22KWh $5.2K
- Time of Use Applications
  - 50% DOD ~7 years with Grid as backup
  - Min: 22KWh to 44KWh
- Off Grid
  - 30% DOD ~10 years with Gen as backup
  - Max: 22KWh to 44KWh $5.2K/$10.4K

Example Batt Overnight Usage

Freezer = 0.5KWh	Lights = 0.2KWh
Fridge = 1KWh	Fan = 1KWh
Furnace Fan = 7KWh	12,000BTU A/C = 12KWh

Sol-Ark 8K Smart Load: Reduces Batt size 10-30%





Storage Inverter Battery Efficiency Comparison

Stop by our Booth: B5

Brand & Model	Sol-Ark 8K	Pika X7600 + 4xS2500	SolarEdge 7600A + 32xP400	Darfon 2xH5001	Schneider XW6848 + 2xMPPT80	Sonnen ECO-16 + String Inv	Tesla 2x Powerwall2 + String Inv
MSRP Price	$6,500	$6,500	$5,500	$6,500	$8,500	$28,500	$29,000
Inverter Continous Power	9KW (8KW)	7.6KW	7.6KW (Batt=5KW)	2x5.5KW	6.8KW	8KW	2x5KW
Off Grid Inverter Power peak (5s)	20KW	12KW	6.6KW	13KW	12KW	12KW	14KW
PV to Batt Efficiency @ 65%	97.5%	92.0%	91.0%	91.0%	96.0%	82.0%	92.5%
AC to Batt Efficiency @ 65%	96.0%	93.0%	91.0%	90.0%	91.5%	85.0%	95.0%
Batt to AC Efficiency @ 65%	95.5%	93.0%	88.0%	90.0%	92.5%	93.0%	95.0%
Off Grid or Time of Use PV -> Batt -> AC *Losses* @ 65%	7%	15%	21%	19%	12%	25%	13%
Battery Bank	optional 24KWh +$5K	380V 20.3KWh +$15K	380V 9.8KWh +$7K	optional 20KWh +$11K	26KWh +$7.2K	included 16KWh LFP	included 26.4KWh
UPS Grid Failure Transfer Time	2ms	1000ms	2000ms	20ms	8ms	16ms	2000ms
Warranty electronics	5/10 yr	10 yr	12/20/25 yr	5/10 yr	5 yr	10 yr	10 yr

Storage Inverter Comparison: Off Grid & Time of Use

Brand & Model	Sol-Ark 8K	Outback Skybox SBX5048	Pika X7600 + 4xS2500	SolarEdge 7600A + 32xP400	Darfon 2xH5001	Outback Radian FPR-8048A	Schneider XWPro6.8 + 2xMPPT80	Sonnen ECO-16 + String Inv	Magnum 2x4448PAE +16xGT500	Tesla 2x Powerwall2 + String Inv
MSRP Price	$6,500	$6,500	$6,500	$5,500	$6,500	$9,000	$8,700	$28,500	$12,000	$29,000
Inverter Continous Power	9KW (8KW)	5KW	7.6KW	7.6KW (Batt=5KW)	2x5.5KW	8KW	6.8KW	8KW	2x4KW	2x5KW
Off Grid Inverter Power peak (5s)	20KW	5KW	12KW	6.6KW	13KW	12KW	12KW	12KW	17KW	14KW
System Idle Power	60W	140W			200W	76W	48W	60W	58W	78W
AC to DC Charger	185A	100A	6.7KW	5KW	120A	115A	140A	115A	120A	N/A
User Interface	color touch	color touch	Text	Text	Text	Text	Text	color touch	Text	X
PV to Batt Efficiency @ 65%	97.5%	81.0%	92.0%	91.0%	91.0%	97.5%	96.0%	82.0%	80.5%	92.5%
AC to Batt Efficiency @ 65%	96.0%	80.0%	93.0%	91.0%	90.0%	85.0%	91.5%	85.0%	85.0%	95.0%
Batt to AC Efficiency @ 65%	95.5%	94.5%	93.0%	88.0%	90.0%	93.0%	92.5%	93.0%	91.0%	95.0%
On Grid PV to AC Efficiency @ 65%	96.5%	94.0%	95.5%	96.5%	95.5%	90.2%	88.5%	97.0%	95.5%	97.0%
Off Grid or Time of Use PV -> Batt -> AC *Losses* @ 65%	7%	24%	15%	21%	19%	10%	12%	25%	30%	13%
Battery Bank	optional 24KWh +$5K	26KWh +$7.2K	380V 20.3KWh +$15K	380V 9.8KWh +$7K	optional 20KWh +$11K	26KWh +$7.2K	26KWh +$7.2K	included 16KWh LFP	26KWh +$7.2K	included 26.4KWh
UPS Grid Failure Transfer Time	4ms	20ms	1000ms	2000ms	20ms	8ms	8ms	100ms	16ms	2000ms
EMP/Solar Flare Hardened to >100KV/m	optional +$1.2K	X	X	X	X	X	X	X	X	X
Low Cost Easy Install	✓	✓	X	X	✓	X	X	X	X	X
Warranty electronics	5/10 yr	5/10 yr	10 yr	12/20/25 yr	5/10 yr	5/10 yr	5 yr	10 yr	5 yr / 25yr	10 yr
NEC UL1699B Arc Fault	✓	✓	✓	✓	X	✓	X	✓	✓	✓
AC Coupling to Micro/String Inverters	✓	X	X	✓	X	✓	✓	✓	✓	✓
Parallel Stacking	X	✓	X	X	✓	✓	✓	X	✓	✓
UL1741SA/Rule 21 & 14H (Grid Sell only)	✓	✓	✓	✓	✓	✓	✓	✓	X	X