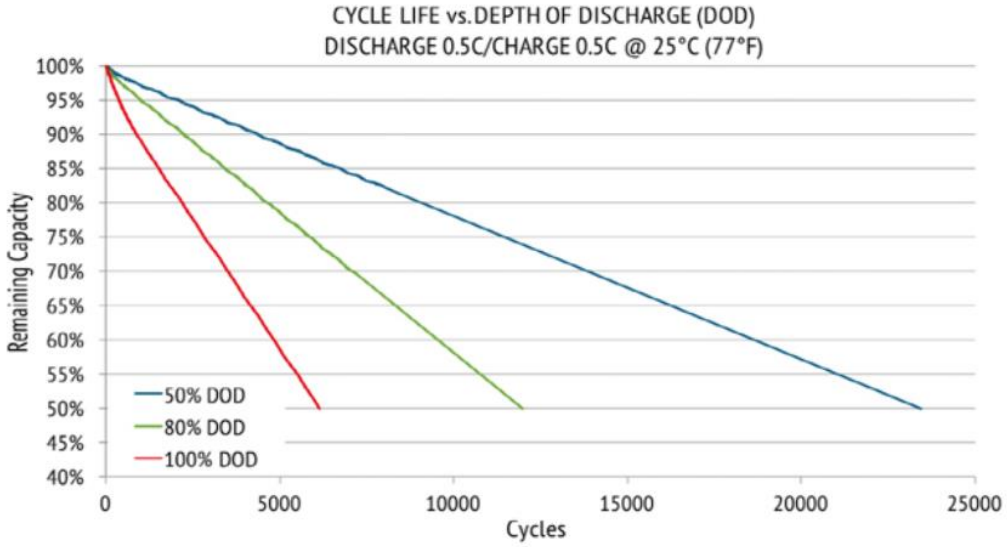
This Solar Battery Technology Beats Lithium

As a company of engineers manufacturing the most efficient battery inverter, we wanted to offer our customers the most cost-effective batteries On and Off Grid. After spending over $200K for R&D battery testing, the results shocked us. Lithium is a newer technology used in many portable applications and has more sex appeal than old lead acid batteries that get 500 cycles (1.4 years) Off Grid and 7 years On Grid. Lithium is expensive, but Lithium Nickel Manganese Cobalt (NMC) can get 4000 cycles (11 yrs) and lithium iron phosphate (LFP) can get 8000 cycles (22 yrs). But we rarely hear about the drawbacks of temperature aging, cycle count hype, and BMS electronics failures which are shortening warranties from Li batt manufacturers. In just 4 years, major advancements in sealed lead acid AGM batteries have increased cycle life 500% to 2500 cycles (7 yrs) with the introduction of carbon to create a partial charge carbon battery (PCC). After all the money and time we spent on Lithium, we found ourselves going back to PCC lead-acid in solar applications because of cost per cycle, 12 yr shelf life reliability, and immunity to temperatures. Interesting times.



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

There are two main types of Lithium: NMC and LFP. Typically, LFP lasts 2-3 times as long as NMC. The above chart from a known USA LFP Lithium manufacturer suggests their battery will last 64 years or more at a typical 50% Depth of Discharge (DoD). It is pretty interesting their warranty is only 7 years (2557 cycles) and it is prorated. Another known USA LFP manufacturer used to spec their battery at 10,000 cycles (27 yrs) @ 80% DoD. Now they spec it at 5,000 cycles (14 yrs) @ 80%. And if the temperature of the battery gets to 32F/0C while charging, the prorated warranty drops from 10 to 5 years or even voided. More on temperature affects later. Another manufacturer of NMC Lithium offers a 10 year prorated warranty but the proration is so steep that they make money if your battery fails and needs replacing at year 5. The specs and marketing materials suggest Lithium lasts 27+ years (10,000 cycles) @ 50% DoD. However, the warranties suggest most last only 7 years for NMC and 14 years for LFP in real world temperature conditions. There are a few exceptions. LFP cells manufactured in Japan come with 8000 cycles (22 yrs) @ 100% DoD data. And batteries using these LFP cells come with 10 year non-prorated warranty.

Digging Deeper:

We went to the manufacturers of the Lithium cells used by these same companies. It turns out they characterize the cells from 3000 to 5000 cycles at 25C/77F and stop. Why? Because it takes approximately 1-3 years to test. The actual production cells are not tested for cycle life and it is typical to stop testing when the remaining Lithium cell capacity drops below 80%. We wondered what happens between 80% capacity and 20%. Some specs above suggest your grandchildren will be using these batteries. We all have real world experience with Lithium NMC in our laptops. How is it that they only last 3-4 years / 1000 cycles? And they don't seem to lose capacity in a linear fashion. They seem to die within weeks/30 cycles.

By Tom Brennan Sol-Ark Engineering Manager September 3, 2018

When you find out Santa isn't real

In addition to our own expensive testing, we purchased a lot of long term Lithium characterization data. We will summarize here, but you can contact us for the detailed data. Heat ages the cells faster, while cold temperatures are very detrimental. If we use real world temperatures and discharge rates, you lose 40-50% of the ideal lab 20C characterization cycles. All large lithium batteries use electronics called a Battery Management System (BMS). In our own testing, we found the BMS to be the weakest link. Off Grid Inverters are hard on the BMS because the peak switching power can be demanding. Some BMS manufacturers did not perform accelerated life testing to assure it would last 10+ years. Because the manufacturers make money on the prorated warranty after 4-5 years, the BMS doesn't have to last more than standard electronics. Many of the Lithium round trip efficiencies are quoted at 100 hour rates instead of the typical 5 to 10 hours that happens in solar. 10 hour rates bring lithium round trip efficiencies to the same levels as other battery technologies.

Improved Lead Acid

There have been several technological leaps in improving lead acid batteries in just 3-4 years. First, they improved paste compounds and pure lead technology to reduce sulfating and go from 600 cycles to 1200 cycles. Then they combined carbon with lead to achieve 2000 to 3000 cycles. The other benefit of carbon coated lead is the ability to prevent sulfating under partial state of charge (PCC) and operate under extreme temperature conditions. There seem to be two types of PCC batteries. Thin plate fast recharge for telecom UPS backup typically get 2000 cycles, while thicker plate solar PCC batteries achieve ~3000 cycles. One PCC manufacturer advertises Pure Lead Carbon. We found pure lead is not needed when using carbon, so this appears to only be a marketing ploy. The only PCC drawback is size and weight.

Conclusions

Lithium batteries are fantastic for portable applications, including cars when you want low weight and size. Standard AGM turned out to be the costliest solution per cycle. Lithium does well, but not for most people who experience some cold. The winner was the AGM PCC that was lower cost of Lithium per cycle, especially if used as backup to the Grid.

	standard AGM	**AGM PCC**	**Lithium NMC**	**Lithium LFP**
10KWh cost range	$1.6K to $2.4K	$2.5K to $3.2K	$5K to $7K	$8K to $12K
10KWh cost Typ	$ 1,800	$ 2,500	$ 6,000	$ 9,000
Off Grid Cycles Typ (50% DOD lab conditions)	600	2800	4000	8000 to 12000
Off Grid Cycles Typ (50% DOD real conditions)	500	2250	2400	4800 to 7200
Off Grid Years Typ (real conditions)	1.4	6.2	6.6	13.2 to 15
On Grid Years Typ	7	12	12	14
Cost per cycle	$ 3.60	$ 1.11	$ 2.50	$ 1.88
Round Trip Efficiency Typ	88%	98%	98%	98%
Benefits	lowest cost UPS backup	Lowest cost/cycle, Partial SOC, Efficiency	Small size, Partial SOC, Efficiency	Small size, Partial SOC, highest cycles, Efficiency
Drawbacks	size, cycles, Partial SOC sulfates battery, >95F reduces cycle count 2X	size, >95F reduces cycle count 2X	<32F reduces cycles 5X, >95F reduces cycles 2X, BMS reliability	<32F reduces cycles 5X, >95F reduces cycles 2X, BMS reliability

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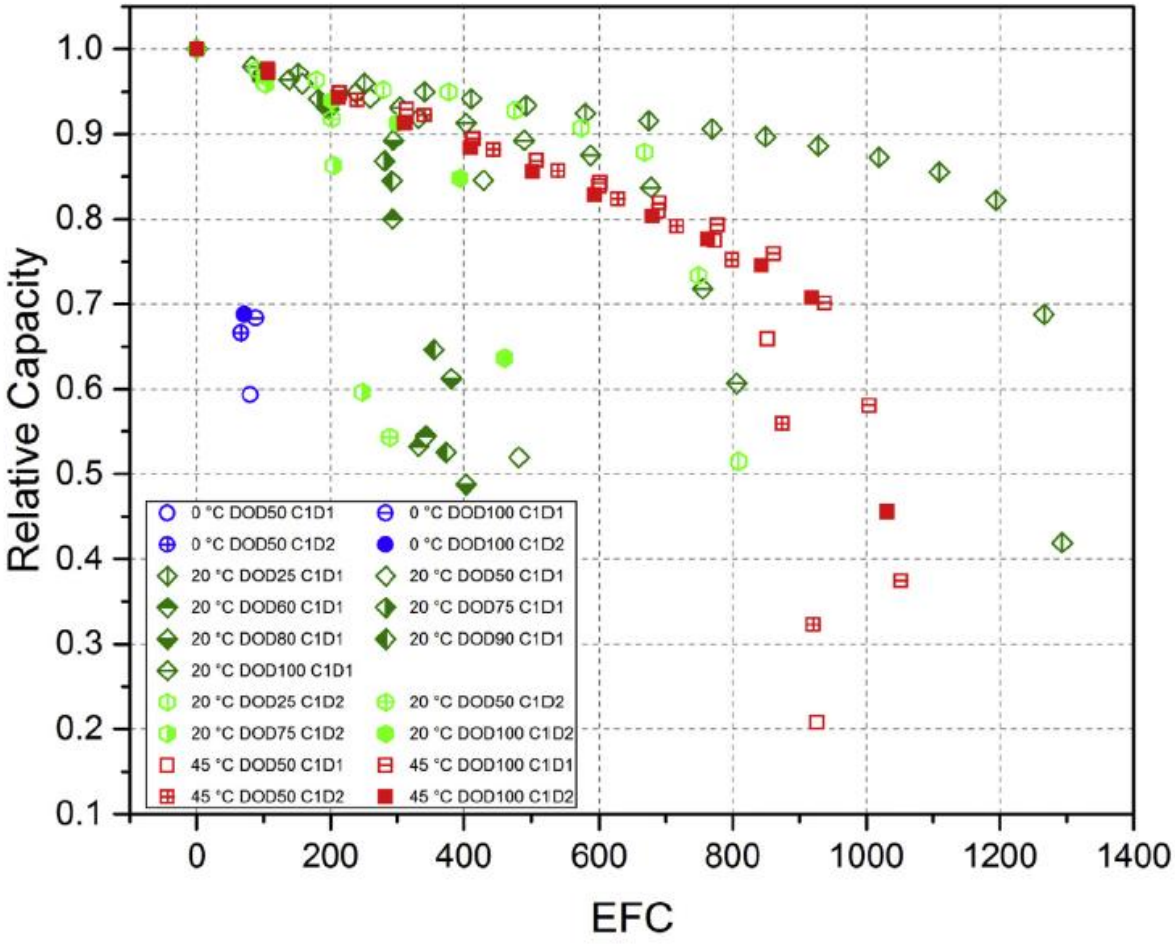
Not Part of the Article, Research Data Only

Different Lithium batteries show different specs for charge efficiency because some are using 10h and some 100h. Most solar battery charging is done in 6-10 hours.

Table 2. Efficiencies of batteries from different manufacturers at different charge durations

Charge duration	Manufac-turer A	Manufac-turer B	Manufac-turer C	Manufac-turer D	Manufac-turer E	Manufac-turer F
2 h	92%	93%	92%	90%	87%	92%
10 h	97%	97%	96%	96%	95%	97%
100 h	99%	99%	99%	99%	99%	99%

This 2017 NMC test chart shows the longest life (Effective Full Cycles) is when they are only discharged 25% and at 20C. ~5000 cycles at 25% DoD. At 50% DoD, cycle counts dropped between 800 and 1600, for an average of 1200 @ 50% DoD. Notice when Lithium is used near 0C, the number of cycles drop to ~100. Also notice that after the capacity drops below 90/80/70%, Lithium capacity quickly drops to zero.



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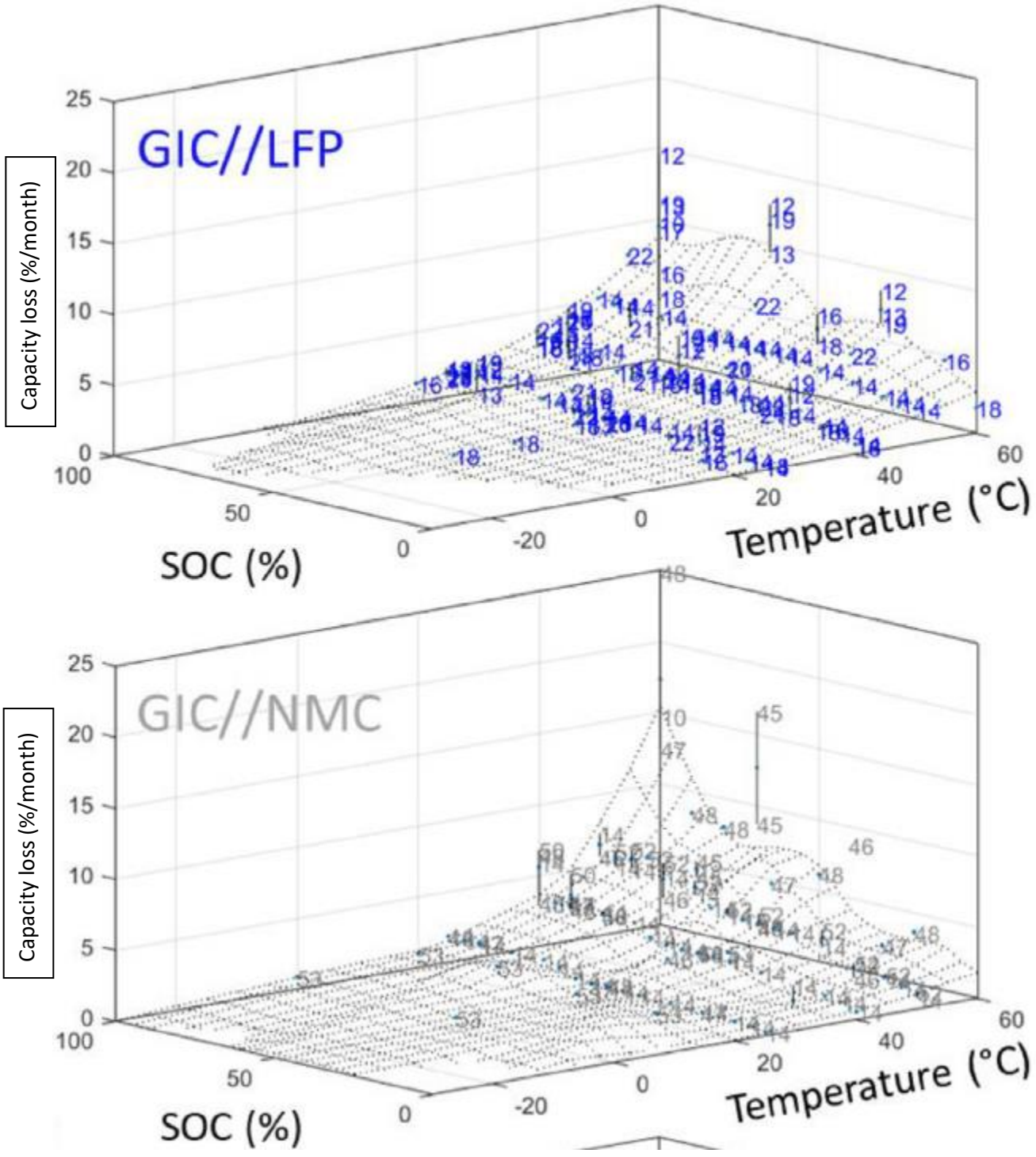
Lithium batteries lose their capacity as they age. Both Lithium and Lead Acid batteries lose cycles at higher temperatures. Assuming 20C temperature and 50% DoD, Lithium capacity will drop between 0.5% and 1.5% per month. Suggesting 8 to 12 year life span when used.



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