Advanced RV Lithium Batteries

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Introduction

Most people don't really care about the details of their batteries as long as they work. When they are out Glamping (Off-Grid Camping in Style), they want electricity to be just like at home. When the light switch is turned on, the lights should come on.

But, another way of looking at the batteries is that they are like the fuel tank. We can expect the coach to turn when we turn the steering wheel and the coach to stop when the brakes are applied. However, if we don't watch the fuel gage, at some point the coach will refuse to go. RV owners needs to be aware of their batteries just like they are the fuel gage.

In addition, different RV manufacturers are making claims about the capabilities and advantages of battery systems they sell. Some are more informed and/or honest than others. Some knowledge will help the potential buyer sort out these differences. In this discussion, I will be careful to identify information that is published by manufacturers. I have personally measured other battery capabilities; I will share the details of those.

Lithium Batteries in RV's

Lead Acid and their first cousins AGM batteries, have provided electrical power for RV's for many years. But, they could not store enough power to reasonably operate a large load like an air conditioner or provide power for an extended stay off-grid. Lithium's on the other hand, have many advantages. Specifically, they are:

- Lighter
- Store more energy
- Allow faster charging and higher power output
- Allow more and deeper discharge cycles

They have some disadvantages too; they are:

- More expensive
- Require an electronic Battery Management System (BMS) to operate safely
- More limited operating temperature range

For many people today, the advantages outweigh the disadvantages making possible all electric Class-B coaches without the need for an auxiliary generator. This allows owners to travel during the day and park anywhere off grid during the night with full use of lighting, microwave, heat, and in many cases, air conditioning. Air conditioning is the highest load on the battery, so we will discuss it in greater detail later.

Advanced RV Battery Systems

Advanced RV is currently providing three different battery systems. These are:

1. Elite Power Systems Cells with a new customized BMS (Battery Management System). This package has cells that are rated at 800 amp hours at 13 volts. However, the BMS is set to limit the discharge to 640 amp hours to compensate for capacity reduction over the life of the batteries.
2. The Valence Modular Battery System. This system is sold by Valence as a modular system where the number and capacity of battery modules that can be connected allow a variety of configurations. The under-chassis Advanced RV system that is under test has six of the 12 volt 138 amp hour modules for a total capacity of 828 amp hours.
3. The Integrated Volta System. It is unique in that the battery is higher voltage than the others at 52 volts. The system is sold as a totally integrated package where the battery, inverter/charger, alternator, and 52 volt to 12 volt converter are an integrated design. This allows smaller wire to be used to interconnect the components and a higher power alternator. The battery package is self-contained and allows flexible mounting options

These each have different sets of characteristics which will make the choice different for various clients depending on their needs and how they expect to use the coach. We will summarize the differences later.

Battery Management Systems

The Battery Management System (BMS) is something that was not needed in older Lead Acid based batteries. It continuously monitors the voltage of the battery cells, the battery temperature, and the current into and out of the battery. It will disconnect the discharge loads and the chargers if a battery exceeds the temperature or voltage limits for the particular battery and status. In addition, it calculates the state of charge in the battery so that a realistic measure of the amount of energy left in the battery can be presented to the user. All the BMS's that Advanced RV installs communicate with the Silver Leaf coach control system over an industry standard CAN bus. Therefore, the Silver Leaf has a valid State of Charge display.

Battery Capacity

Traditionally, battery capacity was rated in amp hours. Amp Hours is the product of the amps that could be provided times the number of hours it could operate before the voltage dropped to a point where the battery would be damaged. With Lead Acid or AGM batteries, this capacity was much lower if the discharge rate was higher. One of the advantages of Lithium batteries is that the amp hours capacity is much less dependent on the discharge rate; therefore, high current draws from the battery can be used to power higher loads.

The rating of amp hours worked well to describe the capacity difference between battery systems when the batteries all had the same voltage. However, today the batteries are 12, 24 or even 52 volt systems. Since wattage is the product of amps and volts, a higher voltage battery system will provide more usable power, i.e. watt hours, at the same amp hours than a lower voltage system.

Therefore, a better way to characterize the power storage capacity of a battery is to use its watt hour or kilowatt hour (1000-watt hour) capability. If the voltage was constant, the watt hour capacity would be the product of battery voltage and amp hour capacity.

Watt Hours = (Amp Hours) X (Battery Volts)

(If there are any fellow nerds reading this, they will realize that since the voltage is not constant over the entire discharge cycle, one needs to integrate the product of volts and amps over the discharge cycle to calculate the watt hour capacity of a battery. If the reader did not study calculus, or has forgotten, don't worry, I will avoid too much of this.)

One major advantage of considering watt hours is that it is easier to understand how much of a battery capacity a particular appliance will consume. Microwave ovens are typically 1500 watts. If one is operated for 15 minutes, it would consume 1500 watts for ¼ hour which would be 375 watt hours. Since the inverter will probably have an efficiency of about 80%, this will be about 470 watt hours from the battery.

Later I will compare various battery offerings. I will present both the amp hours and the watt hours.

Temperature Effects

People who live in northern states understand that they need to replace the car-starting batteries every couple of years in the autumn, if they want to count on starting their cars in the winter. In the south, batteries need to be replaced every 2-3 years because they get cooked in the summer heat. The battery life is affected by temperature.

Lithium batteries have even more restrictions on temperature and greater consequences of not following them. The differences between the various Lithium battery offerings also presents major choices for the RV buyer.

The temperature range for charging is usually different from the range for discharging. So, it is not uncommon that the battery can be discharged at a temperature where it cannot be charged.

The two most critical parameters to avoid are storing the battery below its storage temperature and charging the battery below its charge temperature range. The BMS will prevent charging when cold. But, the storage temperature must be handled by battery heaters or winter storage in a controlled environment.

Battery Life

The life of Lithium batteries is usually rated in terms of the number of discharge cycles they can produce. The usual way of stating life is that the battery can be discharged down to 20% state of charge, recharged to 100% and then repeated. The life is usually stated as the number of cycles that can be repeated before the battery capacity falls to 80% of the original capacity. Various manufactures may have other protocols to state life. But, the key point is that they all indicate the capacity is falling slowly from the first cycle.

One nuance in the life measurement is that the testing is performed at room temperature. Any higher or lower temperature will result in a shorter life. But, the battery manufacturers either don't measure the life at different temperatures or don't want to talk about it.

The auto-generation feature in the Advanced RV Silver Leaf control system is programmed to start the chassis engine to charge the battery when the indicated state of charge falls below an operator set level. Since the actual capacity of the battery is changing over life, there needs to be a way to assure the actual state of charge does not fall too low. This is handled by the Volta and Valence BMS systems automatically because they estimate the actual battery capacity at any point in its life and report the percent state of charge accordingly. The Elite system does not have this capability. So Advanced RV sets the capacity in the BMS at 80% of the actual. Therefore, our 800 amp hr system is programmed to be limited to 640 amp hours. This way, the batteries will always provide that capacity.

Battery Capacity

Since various battery manufacturers have different ways of rating their batteries, we gathered the data into one table. In addition, we did a load test on each of the battery systems to demonstrate how long the battery could operate a reasonably large load in addition to the basic load produced by the coach. The load we selected was a 1500 watt space heater. An RV air conditioner uses in the range of 1500 to 1800 watts when the compressor is running. So, this heater is similar to the power requirements of an air conditioner. Since the air conditioners load is dependent on the outside air temperature and other parameters, the heater enables a more consistent test to compare battery systems because it is much more constant.

Key ARV Battery Electrical Specifications

	Elite with four 200-amp hr. modules	Valance with six U27-12XP modules	Volta 13.5 kwh system
Nominal Voltage	13	13	52
Amp Hr Rated	800	828	Not rated
Amp Hr Measured	640 (limited by the BMS)	875	185
Watt Hour Rated	10400	10600	13500
Initial Watt Hour Measured	8500 (programed by BMS)	11200	9500 +10% promised
1500 Watt heater + coach power run time, hours. Full battery discharge.	4.5	6.1	5.4
Alternator	Delco	Delco	Volta
Alternator Watts at high idle	3100 – 2500	3100 – 2500	5000 to 4000
Approximate Watts for coach and air conditioner	2000	2000	2000

Battery Selection Criteria

The above table describes the electrical capacity of battery systems. When deciding which battery system to purchase, buyers need to consider how they are going to use the coach most of the time.

My wife and I like to explore new areas. As such, we drive for a few hours every day and see what we can find. In the afternoon, we find a place to settle in for the night and have a leisurely evening and following morning. So, we are driving off and on for about 8 hours at the most and then parked for about 16 hours. If we know we will want air conditioning, we find a place to plug in. When we start the engine in the morning, we have used about 2500 watt hours to cook, provide heat and lighting, and provide for other power consumption. So, for us, any of the systems will provide our power needs.

Other people want to dry camp for several days in one place. Just to run the exhaust fan, refrigerator, controls, lighting, etc., will consume at least 3000 watt hours in 24 hours. If they like their music and have one of Advanced RV's high power sound systems, they will use much more. So, they will want the largest capacity system.

Some people want to be able to operate the air conditioner while off grid. Since none of these batteries have the capability of run for extensive periods without recharging, they will want the system with the largest alternator power so that they can maximize the electrical power they can generate and store during high idle charging.

Air Conditioner Run Time

The air conditioner run time is totally dependent on the compressor duty cycle. When the circulation fan is operating but the compressor is not, the air conditioner power is about 10% of what it is when the compressor is running. Despite a competitors claim that a 600 amp hour Lithium system could run an air conditioner for 12 hours, this could only be true if there was only a need for minimal air conditioning.

The 1500 watt space heater test was intended to give an estimate of the air conditioner run time. This would be a condition where the compressor is running much, but not all, of the time and the outside temperature is in the 90's.

AutoGen Feature

If traveling for at least several hours every day or two the auxiliary alternator will charge the batteries

When parked for longer periods, the Advanced RV's have a feature called AutoGen. This is a capability of the Silver Leaf control which monitors the battery state of charge and will start the engine and run at high idle to charge the battery. The system is programmed to run for 110 minutes and then stop. This can be repeated for 5 cycles as limited by the interface to the Mercedes Chassis. Strictly speaking if the engine is manually started with the key, the 5-cycle counter will be reset to zero.

The issue with extensive AutoGen operation is that operating the engine at this power level does not provide sufficiently high exhaust temperature to burn the carbon particles that accumulate in the exhaust filters. Mercedes does not provide a clear statement on the total hours of high idle that can be accumulated before the coach must be driven at highway speeds to burn out the particle filters.

Delco Alternator

The alternator power output is temperature dependent. The power will start out higher and then fall as the alternator itself heats up. In winter, it will maintain a high output longer. The Delco, which is used with the Elite and Valence systems, is capable of producing 2500 to 3100 watts on AutoGen. So, running the AutoGen for 110 minutes will provide enough stored power to run the coach for 1.5- 2 days if reasonable energy

conservation is practiced. The battery charge current will also fall when the battery is closer to the full charged. Since the AutoGen cycle is limited, it is actually better to allow the battery to discharge more and then charge until the charging current falls off. Topping off the battery to 100% on AutoGen is just consuming high idle time without putting much energy into the battery.

The Electrical Specification table displayed above indicates that to run the coach basic power needs and the air conditioner compressor requires about 2000 watts. The Delco can produce 2500-3000 watts at high idle. So, if the air conditioner compressor is running while the AutoGen is running, only 500-1000 watts are available to charge the battery.

Volta Alternator

The biggest advantage of the Volta system is the alternator power output. Volta rates the alternator at 6000 watts. But, that is while driving. The more important parameter is the power output at high idle which we have measured at 4000-5000 watts. Once again, the output is temperature dependent. This alternator allows the operation of the air conditioner and puts more than 2000 watts into the battery at the same time.

Battery Temperature Considerations

In addition to the electrical performance of the battery system, the limitations placed on the battery by temperature need to be considered. The following table has the critical temperatures for the Advanced RV battery systems as well as the Xantrex/Lithionics system that is now being sold in other Class B's as well as the Calb Lithium cells. Calb is a popular reasonably high-end producer of batteries.

Battery Temperature Limits (all in deg F)

	Elite	Valence	Volta	Xantrex Lithonics	Calb
Chemistry	Lithium Iron Phosphate	Lithium Iron Magnesium Phosphate	Lithium Nickel Manganese Cobalt	Lithium Iron Phosphate	Lithium Iron Phosphate
Cell Manufacturer	Elite's Chinese Parent	Valence	Farasis	NA	Calb
Max Cell Temp	150	140	135	140	130
Max Charge Temp	NA	113	116	113	113
Min Charge Temp	32	32	37	32	32
Min Discharge Temp	-4	14	-4	-4	-4
Max Storage	100	122	113	113/77	113/77
Min Storage	-4	-40	-40	-4	-4
4-6 Month Storage	-4	-40	-4	-4	-4

Battery Temperature Discussion

The first thing to notice is that the various systems have a lot in common, as well as some notable differences.

1. None can be charged if the cell temperature is around freezing or below.
2. They all have similar high temperature limits
3. All except Volta and Valance will be damaged if they are allowed to get colder than minus 4F.
4. The recreant published Volta specification is that it should be stored above -4F for long periods. But, Advanced RV has been assured that they can take excursions to minus 40F for short periods.

5. We have been assured by Valence that their modules can be stored at -40F for 4-6 months.

The low temperature operating limits are not a real problem in that all the systems that are sold by Advanced RV have internal heaters and insulation, which maintain the battery temperature in operating range when the ambient temperature is well below freezing. The potential cold issues involve winter storage.

Cold Temperature Storage Requirements

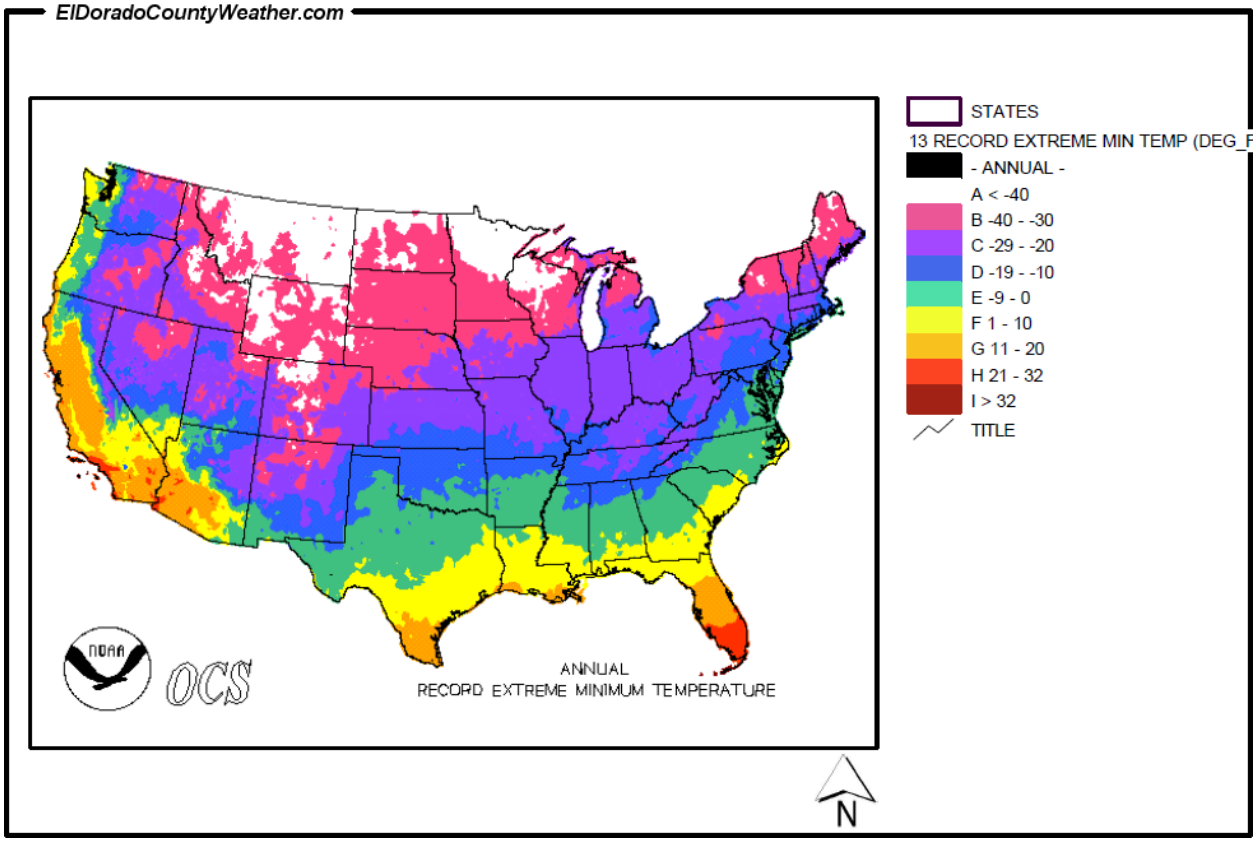
These coaches can always be winter stored in a heated garage or with continuous power to supply power for the battery heaters. If they are winter stored outside, the local environment needs to be considered.

Xantrex and Lithionics are marketing a battery, inverter, alternator system that is being introduced by several major RV manufacturers. Lithionics markets a similar battery system for use in golf carts. Here is what Lithionics says about winter storage in the operator's manual.

"The ePower must be kept between -4°F and 149°F at all times. The recommended temperature range is between 32°F and 100°F for optimal life time. Exposing the ePower battery to temperatures below -4°F will cause the battery to freeze. Such damage is not covered by warranty. The ePower batteries freezing temperature does not change with the state of charge like it does with lead acid batteries."

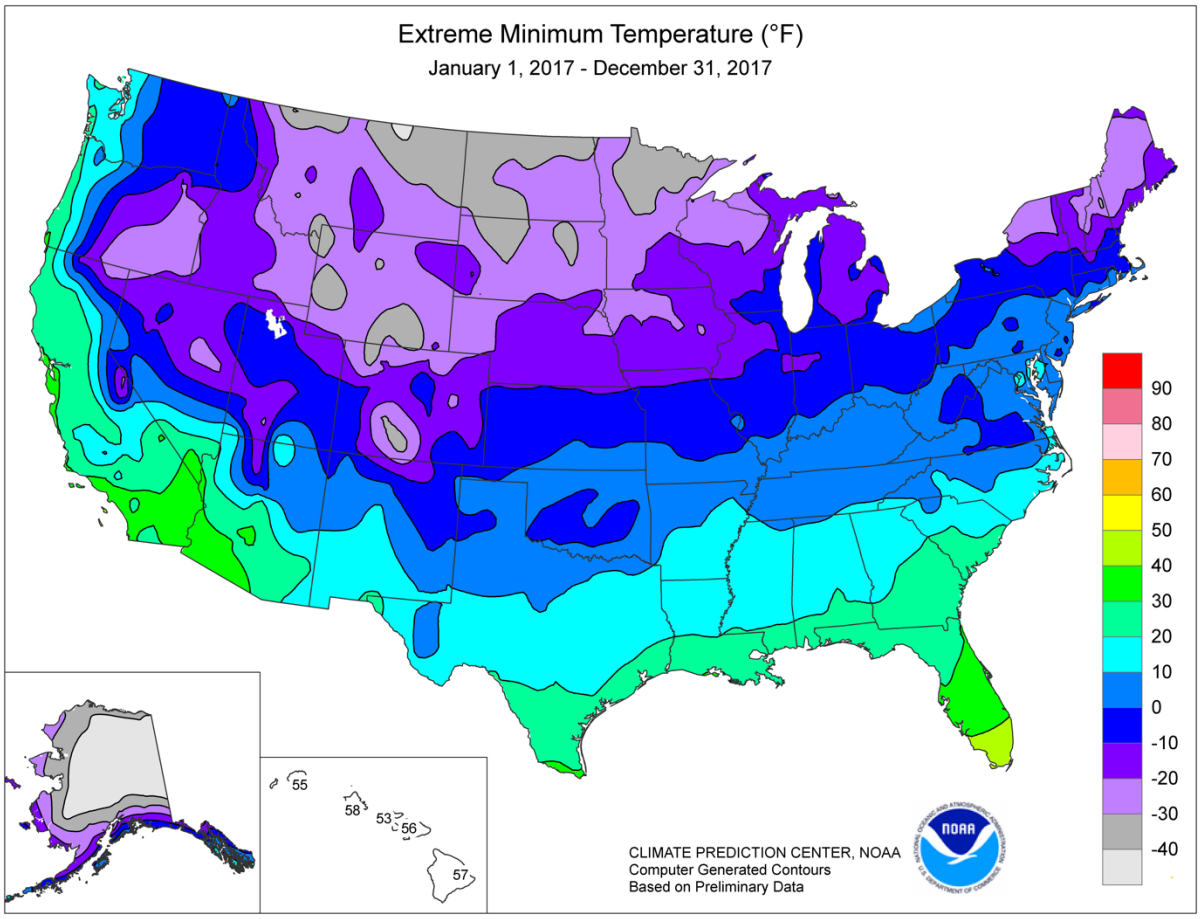
This is typical for the Lithium Iron Phosphate batteries. This brings up the question of what the actual temperature expectations are for cold weather in the US.

The following map shows the extreme cold temperature distribution in the continental US for the 30-year period 1965 to 1995. This is the coldest temperature recorded in each area during the period. This is an extreme case but does show how far South temperatures that could damage a Lithium Iron Phosphate extend.

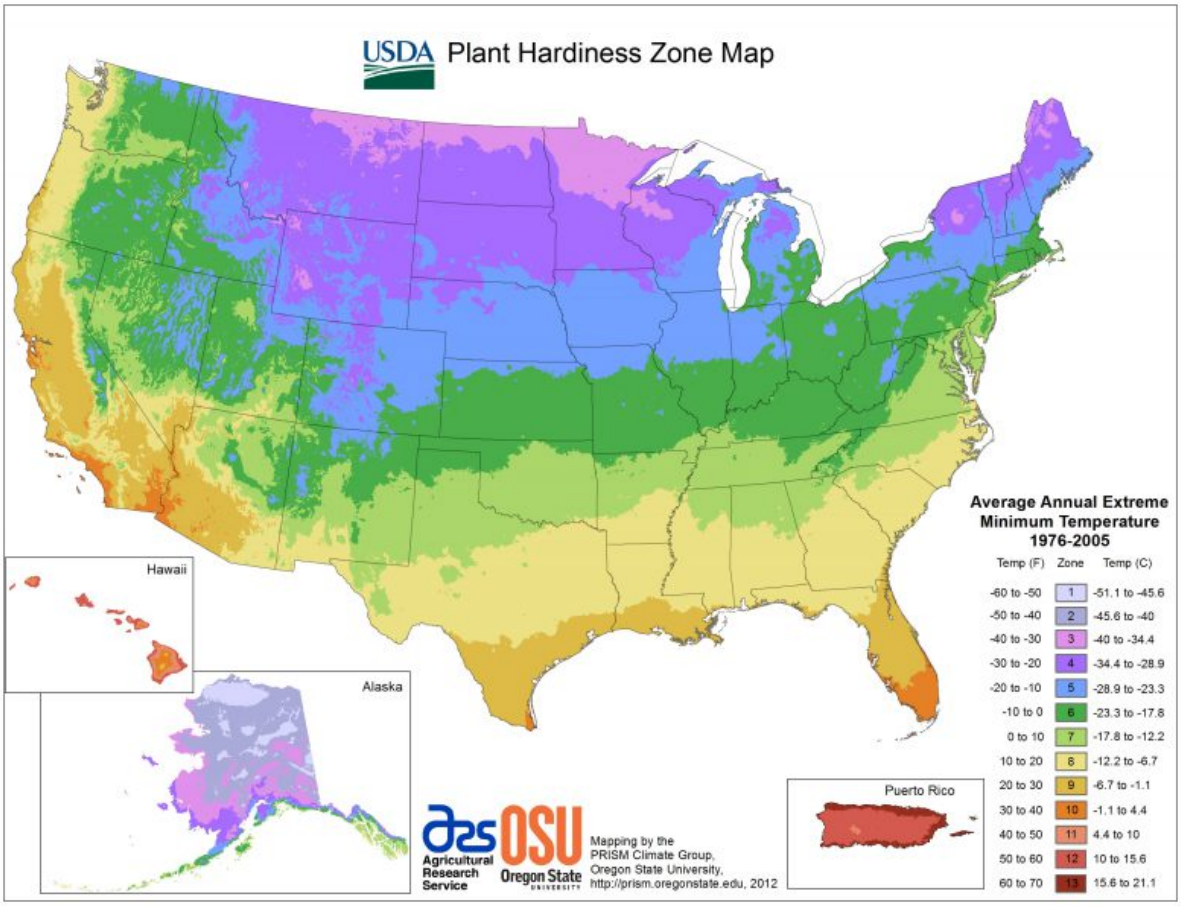


While the extreme for a 30-year period may not be representative of what one should expect in the future, it does show that the extreme cold temperatures in northern Minnesota and parts of the Western states get below -40F. From personal experience, I know that people who live in those places will be prepared for the cold.

The following map shows the record cold temperatures for the year 2017.



The USDA has a similar map for the average annual extreme cold for 1976 through 2005. This map is the average of the annual minimum temperatures over the time frame.



These maps for extreme cold temperature, the average annual cold temperature for a recent period or the coldest temperatures for the last year, all indicate that if the coach is to be stored in the Northern 1/2 to 2/3's of the US, it requires the battery systems either:

1. Be one that can be stored cold or,
2. be stored in a heated garage or,
3. have continuous electrical shore power for the battery heaters.

Winter Storage Summary

The Advanced RV Elite system is the same as the Xantrex/Lithionics system. The battery itself needs to be protected so its temperature does not fall below -4F.

The Volta system can be allowed to get down to -40F for some period of time. Volta's engineering manager says that their battery will not be damaged by an excursion to -40F. But, Volta is not able to provide a specification on how many times or for how long.

The Valence battery specifies that it can be cold stored at -40F. No qualifications are necessary.

Advanced RV Lithium Battery Systems Offerings

Elite

The Elite battery system will be the lowest cost and will provide the energy storage requirements for most users. The Advanced RV coaches that have been delivered for the last 3 years have these battery cells with an older BMS and have provided the off-grid power that we are noted for and is now being copied by other RV manufacturers. Cold storage will need to be considered.

Valence

The Valence system will provide the highest stored energy and will allow cold storage in most of the entire lower 48 states.

Volta

The Volta has a higher power alternator. Therefore, it can recharge the batteries with shorter high idle periods which will allow longer dry camping periods and/or air conditioner operation. It has better cold tolerance than the Elite but not as good as the Valence. It is lighter weight than the other systems and allows smaller gage wiring.