Sun Xtender Batteries
2009 San Bernardino Road
West Covina, CA 91790 U.S.A.
www.sunxtender.com
Phone 626-813-1234 | Fax 626-813-1235

APPLICATION GUIDE

The following information contains guidelines for sizing a battery system that should provide a reliable energy storage system for stand alone Renewable Energy systems. The primary emphasis is for photovoltaic (PV) systems but other renewable energy source systems would have similar requirements.

Load Calculations

DC Loads

To calculate the *DC Ampere Hours per Day* required to power the system:

DC Load Amps = 1000 x kW ÷ DC System Voltage

Total Daily Load [AH] = DC Load Amps x No. of Operating Hours per Day

> Example:
> For a 0.12 kW DC load at 48 VDC,
> DC Load Amps = 1000 x 0.12kW ÷ 48VDC = 2.5A.
> Total Daily Load = 2.5A x 24 Hours/Day = 60 AH/Day.

For variable DC Loads, establish the duty cycle based on percentages of the daily operations.

(P1% of day at xx Amps) + (P2% of day at yy Amps) + Etc = Total AH Consumed/Day

> Example:
> A system operates at 5A for 70% of the day and 10A for 30% of the day:
> Total Daily Load = (70% X 5A X 24 Hrs) + (30% X 10A X 24 Hrs)
> Total Daily Load = 84 AH + 72 AH = 156 AH/Day.

AC Loads

When an inverter is used to power 120 or 240 VAC appliances, such as pumps, refrigerators, lighting, etc., the AC voltage must be converted to the Battery's DC voltage and the efficiency of the inverter must be considered.

If the inverter AC voltage is 120 VAC and the battery DC voltage is 24 VDC, then the conversion factor is 5.0. For every AC amp drawn there will be 5 times as many DC amps required. Also, the inverter's conversion efficiency from DC to AC is not 100%. There is an internal loss in the inverter which is normally about 10% to 15%. See inverter/charger manufacturer's data for efficiency specifications.

> Example:
> For a 2.4 kW AC Load at 120VAC with a 48VDC battery and Inverter operating at 90% efficiency,
> AC Load = 1000 x 2.4 kW ÷ 120 VAC = 20 Amps @ 120 VAC
> DC Load = 20 Amps AC X 120/48 ÷ 0.90 = 55.6 Amps DC
> Total Daily Load = 55.6 A x 24 Hours/Day = 1,334 AH/Day

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Note: When sizing the battery for non continuous loads, or for larger loads for short periods of time per day, it may not be possible to use the 20, 24 or 120 hr. rate of discharge for the battery's capacity. When discharged at different rates, a battery's capacity will vary. The higher the rate of discharge, the lower the capacity of the battery will be. More detailed calculations are required in these cases.

Days of Autonomy

As everybody knows, the sun does not shine with equal intensity every day, nor does it shine at night and during inclement weather. Cloud cover, rain, snow, etc. diminish the daily insolation (*Insolation* is the amount of solar energy delivered to the earth's surface, measured in W/m^2 or $kWh/m^2/day$. A storage factor must be employed to allow the photovoltaic battery system to operate reliably throughout these periods.

In addition, it is desired to obtain the best service life of the battery by limiting its average daily depth of discharge. This storage factor is commonly referred to as "Number of Days of Battery Autonomy". The number of days is established by evaluating the peak hours of sun per day for the lowest insolation month of the year with the solar array oriented for maximum output during that month.

The minimum number of days that should be considered is 5 days of storage for even the sunniest locations on earth. In these high sun locations there will be days when the sun is obscured and the battery's average depth of discharge should not be more than 20% per day. The recommended days of autonomous storage are shown in the following table:

Table 6-1.

Recommended Days of Storage	
$kWh/m^2/day$	Days of Autonomy
4.5+	5
3.5 to 4.5	6
2.7 to 3.5	7
2.0 to 2.7	8
< 2.0	10 or more

Temperature Considerations

The temperature of the battery is a major factor in sizing a PV system. Battery capacity is reduced in cold temperatures and the battery life is shortened in high temperatures.

It should be realized that the temperature of the battery itself and ambient temperature can be vastly different. While ambient temperatures can change very quickly, battery temperature change is much slower. This is due to the large thermal mass of the battery. It takes time for the

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battery to absorb temperature and it takes time for the battery to relinquish temperature.

The battery's temperature is normally the average temperature for the past 24 hours plus or minus a few degrees. In many systems it can be difficult or impossible to heat or cool the battery and we must take ambient temperature into consideration. A battery that is required to operate continuously at -18ºC (0º F.) will provide about 60% of its capacity. This same battery operated continuously in a 35º C (95º F.) environment will see its life expectancy cut in half.

The earth is a great heat sink which provides enormous insulation in high or low temperatures. By burying the battery in the ground we can increase its capacity at cold ambient temperatures and increase the life of the battery at high ambient temperatures. The battery with only 60% of its capacity at -18ºC (0º F) can be brought up to 85% to 90% capacity by burying it. With life cut in half at 35ºC (95ºF), burying the battery can bring it back to near normal life expectancy.

Battery Sizing

The battery capacity for a PV system can be calculated using the following formula:

Capacity (AH) = Total Daily Load x Days of Autonomy x Design Factor

The Design Factor depends on the battery's average temperature during the coldest time of the year, as discussed above. The following table provides recommended Design Factors at various temperatures.

Table 6-2.

Lowest Battery Temperature Averaged over 24 Hours		Design Factor
Degrees C	Degrees F	
25 or above	77 or above	1.25
20 to 24	68 to 76	1.39
10 to 19	50 to 67	1.43
0 to 9	32 to 49	1.60
-10 to -1	14 to 31	1.84
-20 to -11	-4 to 13	2.23
-30 to -21	-22 to -5	2.84
-40 to -31	-40 to -23	4.17

Example:

For a 48VDC system, Total Daily Load of 30AH, 5 Days of Autonomy, and -8°C is the lowest average temperature, the required battery capacity is as follows:

Battery Capacity = 30 x 5 x 1.84 = 276AH. This requirement could be satisfied with a PVX-2580L, which has a C/120 rating of 305AH. Four of these batteries in series gives 4 x 12VDC = 48VDC.