The Ultimate Battery?

Introducing The Terra Bi-Polar Composite Battery

Millions of cycles, safety, reliability, fire resistance and a five-year new- for- old warranty are just a few of the benefits of Terra's Bi-Polar Composite Battery.

Firstly, forget almost everything you know about lead/acid batteries. I've been in this business for over 30 years, brought the World's most accurate battery monitoring technology to market, launched AGM batteries to the mobile power world and delivered critical programmes for the emergency services and military. Trust me, almost everything you know about how lead/acid batteries work and perform does not apply to this technology!

From the outside, the Terra Bi-Polar Composite Battery looks and feels like a regular battery – this means that it will drop in place of a standard battery, requires no charging system modifications, no additional safety measures and can be connected in parallel or series to build up high capacity and/or high voltage battery banks. This is great from an integration and systems engineering perspective.

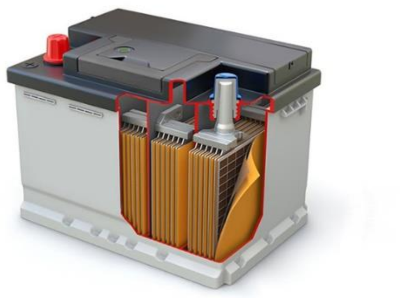
Now look inside a Terra Battery and you will see that there are no similarities to any other lead/acid battery on the market. For a start, plates are oriented on their side (horizontally) and, there are no internal busbars. Place your cell phone nearby and the embedded Bluetooth connected monitor chip starts reporting battery information.

This white paper seeks to introduce those already educated about batteries to this brand-new battery technology.

September 8, 2025

Conventional Lead/Acid

Conventional lead/acid batteries are available in a multitude of formats. Some use thin plates for cranking, thick plates for deep cycle. others use cast grids for longevity, expanded grids for low cost. Then there are variants using AGM technology, Gelled electrolyte, lead-crystal, carbon anodes, carbon-fibre, Thin Plate Pure Lead, etc. Each variant is engineered to achieve a target cost, specific performance and longevity. However, the basic technology is the same: 6 x 2V cells connected in series using heavy lead-alloy busbars with lead-oxide active material pasted on vertically oriented plates. They all work in very much the same way.



Conventional Lead/Acid Battery Technology

Some of these batteries are excellent – even when compared to modern lithium technologies. They are certainly cheaper and safer. But all lead acid batteries following these design and construction features have pretty much topped out on performance and service life. Lead/Acid batteries have a well-established place in the energy storage world and will continue to do so for many years to come.

Today's Power Requirements

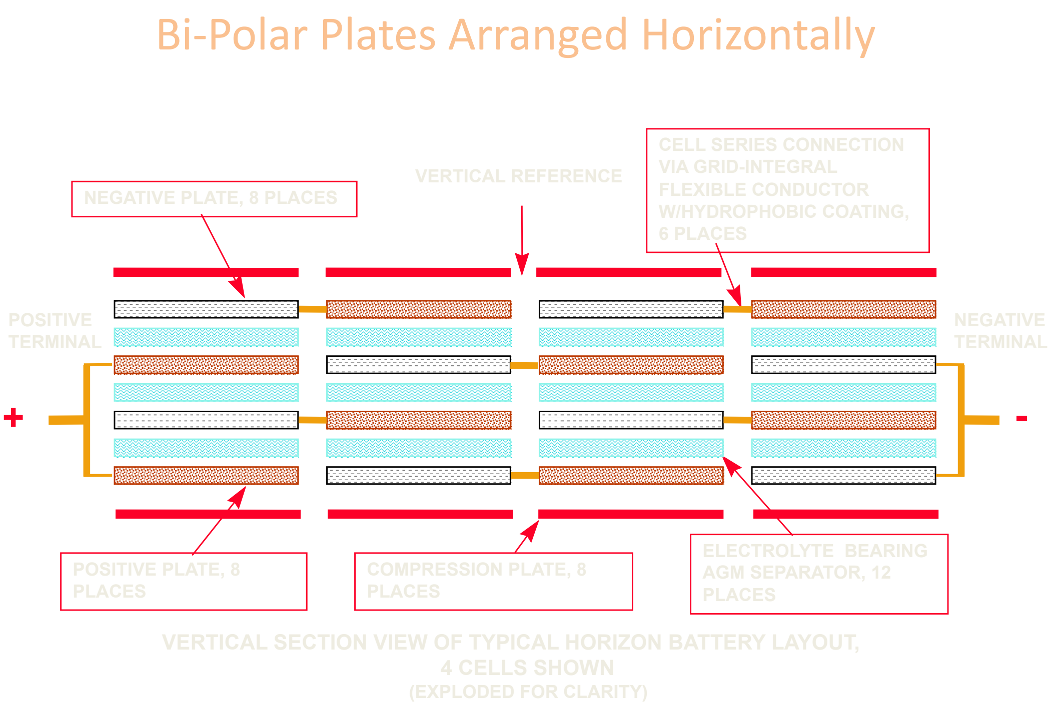
As you may be aware, the global battery industry is rapidly expanding and is expected to continue its current growth rate for the foreseeable future. De-carbonisation is driving this expansion, along with ever increasing power demands. Off-Grid storage, mobile power, back-up power and electrification of everything in general requires a battery that will last a long time in power-hungry service. In other words, the market favours a battery that provides abundant power for lots of cycles.

Until now, only two options have been available: high quality, pure lead, thin (or thick) plate AGM batteries and a couple of variants of Lithium-Ion batteries. At the high-quality end, typical cycle rates are around 400-1200 cycles (AGM) or 3000 cycles (Lithium). While Lithium has been reasonably successful in achieving these goals, safety, issues arising from challenging temperature management (especially in rapid charge/discharge cycling & extreme cold/hot environments), and power management complexity in large-capacity energy storage systems cannot be under-estimated.

At the end of the day, the user simply wants reliable delivery of thousands of high-power cycles at the lowest cost/kWh.

Introducing Bi-Polar Batteries

So, what is a bi-polar battery? A bi-polar battery uses a single grid to connect positive and negative plates in adjacent cells in series as shown in the figure below.



Terra Bi-Polar Composite Batteries are arranged completely differently to conventional batteries

This construction departs radically from conventional design practice which stacks individual positive and negative plates together to form a single cell. In conventional batteries positive plates in each cell stack are connected in parallel with a separate casting called a strap. The same connection scheme is used for the negative plates in each cell. Cells are then connected in series with another casting operation to connect negative strap in one cell with the positive strap in the adjacent cell.

In a bi-polar battery, one side of the bipolar plate is positive, the other side is negative. Both plates use the same alloy in the shared grid. There is no secondary casting operations required to connect adjacent cells in series. The only casting operation occurs at each end of the stacked assembly. This operation connects negative plates in the end cell in parallel and positive plates in the cell on the opposite end of the assembly in parallel to form the positive and negative terminals.

This seamless connection between the plates allows electrons to flow quickly through the same low-resistance alloy between positive and negative. Many benefits result from bipolar construction:

- Highest reliability cell-to-cell connectivity
- Lead glass composite material grids reduce lead metal grid content by up to 40%
- Higher specific energy and specific power
- Increased ability to safely absorb and deliver very high charge and discharge current
- No active material shedding because grids are made of creep-proof composite materials that resist stress induced in the grid by volume changes associated with changes in SOC
- No dendrite formation due to uniform current distribution between all plates in each cell

Challenging Manufacture

The concept of a bi-polar battery is not new. In fact, the concept was invented a hundred years ago. However, the barriers to market entry for bi-polar batteries have been the significant challenges arising from producing and assembling bipolar plates into high Voltage batteries. Historical attempts to overcome these challenges have been met with varying degrees of success.

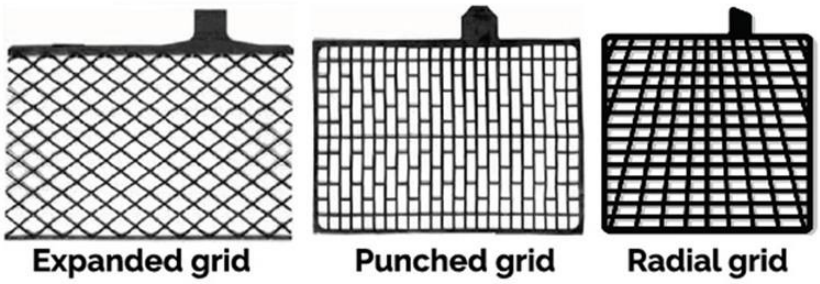
The Terra Supreme Battery manufacturing system has overcome these challenges by introducing innovative and unique manufacturing processes available with Manufacturing 4.0 technology[1].

It starts by taking a strand of extremely strong fibreglass and coating it with pure lead. This gives the composite wire extreme strength (up to 6x stronger than steel) with excellent conductive properties. This wire is then woven into a mesh matting to form the basis of the battery's grid. The virtually indestructible composite mesh provides a strong, dimensionally stable foundation for the battery's active material.

Busbar Free Construction

As you will be aware, conventional battery plates have a tab that it is welded to tabs of like polarity plates in the same cell. Cells are connected in series using busbars. Busbars are a significant weak-point for a lead/acid battery – in fact, the higher end manufacturers have invested significantly in improving them with 'over the partition' busbars and those that are locked in place with epoxy to prevent movement (movement causes physical stress on the plates and promotes shedding of active material). Furthermore, there is one place of entry and exit for current which makes part of the plate work 'harder' than other parts (again, practices such as radial patterned grids have been introduced to spread the current path and mitigate overheating). This is also the reason why a standard lead/acid Group 31 battery has a general maximum current of 800-1200 amps.

[1] Manufacturing 4.0 is the employment of ultra-modern manufacturing techniques that combine Ai, Robotics, Machine to Machine Communication to ensure rapid construction of complex items with almost non-existent variance between serial produced products.



Standard battery plates – expanded used in low-cost automotive applications, punched/cast grids are used in high quality AGM batteries. Radial Grids are used to draw uniform current across the grid in cranking applications.

Terra Bi-Polar Composite Batteries do not have a busbar. At each end of the woven grid are free wires – 50 in total. These are individually connected to a single metal piece that acts as a current collector. As each grid has 50 individual points of connection, current delivery (or absorption) is uniform and there is no hefty busbar to transmit vibration across the cells. This allows a Terra Battery to deliver massive amounts of current – >2750A in fact – over double that of a conventional battery.

By comparison, the wire mesh plate of a Terra Bi-Polar Composite Battery – there are 50 points of connection for each grid for uniform power absorption/delivery. This allows more than double the cranking amps and significantly reduced charging times.

Removal of Failure Modes

Conventional Lead/Acid batteries have several failure modes. These are generally:

- Shedding of active material – through vibration, poor construction, high current load/charging. Expansion of conventional positive grids fractures the positive active material, isolating much of the central portion of each active material pellet, disconnecting it from the grid. Since such material is no longer connected to its deformed grid it is no longer capable of storing charge.
- Stratification – this is layering of the battery acid (and it does also occur in AGM batteries), with weak acid at the top of the battery and strong acid at the bottom. As stratification imbalances the chemical reactions within a cell, it helps promote sulfation and dendrite growth.
- Sulfation – this is build-up of non-conductive material on the plates, typically caused by leaving the battery at a low state of charge for a long period of time
- Dendrite Growth – Dendrites are small needle-like structures attached to the negative plates of conventional lead acid batteries. Dendrites form because of uneven distribution of current between the positive and negative plates of a cell. Uneven current distribution over the surface of conventional plates is caused primarily by the tab used on each grid to conduct current in and out of the plate.

  During a discharge cycle, the negative plate dissolves in proportion to the current density throughout the plate. This is not a perfectly uniform process because of the single tab grid design. Therefore, each negative plate ends up with an unevenly distributed amount of conductive material on its grid. During recharge, lead precipitates out of solution on the negative grid unevenly, resulting in different path lengths in the electrolyte between positive and negative plate surfaces.

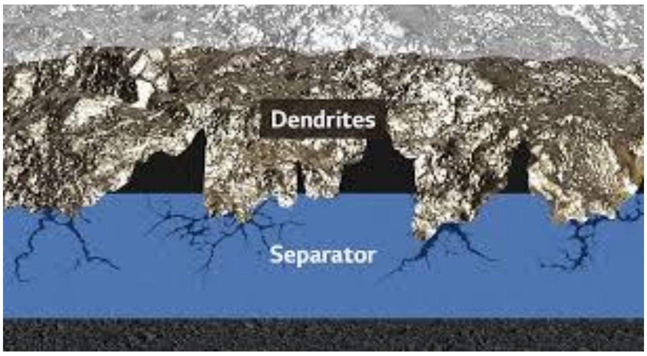
  Since current always finds the path of least resistance, short paths between positive and negative plates carry the largest fraction of current during charge and discharge of the cell. During charge, the largest currents deposit disproportionately large amounts of lead -- Dendrites --at the shortest-path locations on the negative plate surface.

  TSB bipolar grids provide uniform current distribution which eliminates uneven dissolution and precipitation of lead during cycling service.

Shedding of active material is the #1 killer of lead/acid batteries

Battery Stratification is where acid sits in layers of increasing strength

Sulfated plates – deposits of non-conductive lead sulfate crystals on the positive and negative plates. This is caused by leaving a battery in a discharged condition. It is irreversible and renders lead/acid batteries useless.



Dendrite growth is caused by partial dissolving and re-formation of the negative plate during a charge and discharge cycle. Stratification and a non-uniform plate surface promote dendrite growth.

A Terra Bi-Polar Composite Battery is not affected by these failure modes:

- By providing over 90% more surface area for adhesion (by using a woven matting foundation for the grid), removal of the inter-connecting busbar (that transmits vibration) and the overall superior strength (6x stronger than steel) of the wire composite construction, shedding of active material is removed.
- The cells within a Terra Battery are not arranged vertically. They are arranged horizontally. This eliminates stratification – completely.
- Due to the elimination of stratification, Dendrite growth is removed and localized uneven sulfation is eliminated.
- Removal of stratification virtually eliminates sulfation.
- Pure Lead materials provide maximum corrosion resistance and long cycle life.
- A Terra Battery can be recovered from extended storage at low voltage – making them much more resistant to battery abuse and the harshest operating conditions.

Dual Use

Conventional batteries (both lithium and lead/acid) must be designed and manufactured specifically for an application – usually cranking (engine start) or for deep cycle use. This is achieved by varying the concentration of acid, plate thickness and plate design.

Terra Bi-Polar Composite Batteries are unique because they are designed to operate in any application. Furthermore, they will outperform both lead and lithium in either:

<u>Cranking:</u>

Due to the use of pure lead, robust grids and the 1500 individual cell connections, Terra Batteries develop significantly more cranking amps of a standard battery. The Group 31 Terra Battery will provide more CCA (SAE Cold Cranking Amps) than a 4D (215Ah) TPPL Odyssey – on a 24V truck (where two are connected in Series), this would equate to a space saving of 41% and weight saving of over 147 pounds (66.8 Kg).

Deep Cycling:

Deep Cycle Batteries are all about the number of cycles from fully charged down to a certain level (usually 50%).

Battery Make	Type	Battery Life 50% Cycles	80% Cycles
Terra	Bi-Polar Composite	>4000	2000
Fullriver DC115-12	Pure Lead Thick Plate	1350	800
Odyssey 2150	Pure Lead TPPL	800	400
Victron Smart	Lithium	5000	2500*

**Note that cycle life is dependent on temperature (stated at 25 degrees C) and charge/recharge voltages and current at C2/C3 limits.*

A Terra Bi-Polar Composite Battery dramatically outperforms all other lead/acid technologies. It also provides the same cyclic ability as lithium cells without the limitations around temperature, charge rate etc (the number of cycles available from lithium varies dramatically where temperature extremes exist).

PSOC – Millions of Cycles

PSOC stands for Partial State of Charge Cycles. If you cycle the battery below 55% State of Charge, the Terra Battery will provide millions of cycles. The is unparalleled in any other battery technology.

Case Study – Lithium Vs Terra

In the last 10 years, lithium-ion batteries have been promoted as the replacement for lead acid. For sure, when discussing conventional technology, they are lighter, have greater energy density (so are smaller) and provide 2-3 times the amounts of cycles. However, there are limitations. Let's compare lithium vs a Terra Installation:

For this, study, we are using the published manufacturer's data of the Victron Lithium Smart LFP12.8/100.

BMS Limitations

Due to their internal chemistry, a lithium battery can only discharge and recharge at a certain level. The level is dynamic – it changes according to temperature; So, make sure that you are comparing "apples with apples".

In normal operation (quoted to be 25°C/ 77°F), you can discharge the lithium battery at 200A. However, the recommended limit is 100A. This is because the limit reduces as the battery heats up. As you discharge the battery, heat is generated. Therefore, to run a 1500-watt inverter, continuously (137.5A) for half an hour, you will need two batteries in parallel as the heat reduces the current deliverable from the battery. Therefore, the argument of a 70% space saving is somewhat redundant in this case. If you are rapidly discharging and recharging a lithium battery, the internal heat builds up quickly – hence the much-reduced recommended limits.

During charging, the limitations are 200A maximum, less than 50A recommended – again for the same reasons regarding temperature. Therefore, you will have to fit a DC-DC charger if you wish to recharge from a conventional alternator. With a limitation of 50A, the argument for rapid recharging is again somewhat irrelevant when many vehicles are now fitted with 150A alternators.

By comparison, with Terra Bi Polar Composite Batteries, there is no current limitation of either charging or discharging and are not dependent on temperature.

Temperature Limitations

The temperature limitations of the Smart lithium battery are: During Discharge: 5-50°C/41-122°F), Charging -20 to 50°C/-4 to 122°F. Therefore, you cannot mount the batteries in a hot engine room environment or in a compartment that may get too cold. This may be a problem on a vehicle where underslung or under hood are the only practical installation sites. With Terra, the batteries will operate from -40°C/-40°F to 60°C/140°F so can be mounted almost anywhere.

Cycle Life

The cycle life of the lithium and Terra Bi-Polar Composite Battery are virtually identical, both returning >4000 cycles at 50% Depth of Discharge and 2500/2000 at 80%. However, note that the lithium rating is provided at a steady 25°C (their ideal ambient temp), outside of this the numbers reduce.

Environmental & Safety

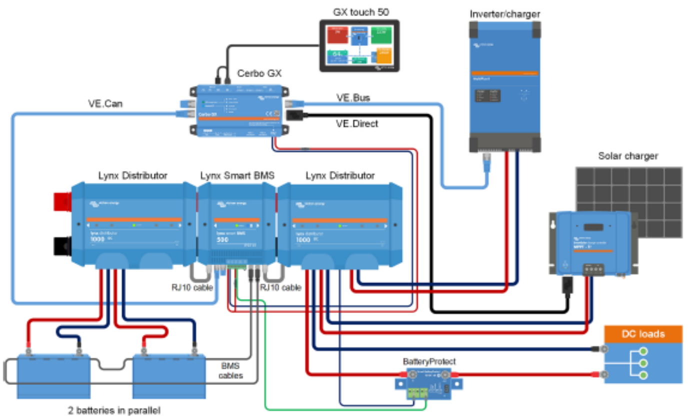
There are known significant environmental problems with the extraction of lithium for batteries and their recyclability. Safety is a known problem too with many insurance companies specifically excluding lithium battery risks from their policies. Terra Batteries are already part of the existing lead/acid recycling process (lead/acid batteries are the most recycled consumer product in the world) and are classified as non-hazardous goods (they can be transported by conventional air-cargo for example).

Weight

The only true benefit of the lithium battery at this point is weight. The Terra Battery weighs 68 pounds (30.8Kg). The Lithium Battery weighs 31 pounds (14Kg). However, do remember that due to current (amps) limitations, where a dual lithium install is needed and where a single Terra Battery could achieve the same mission, the Terra installation weight would be virtually identical.

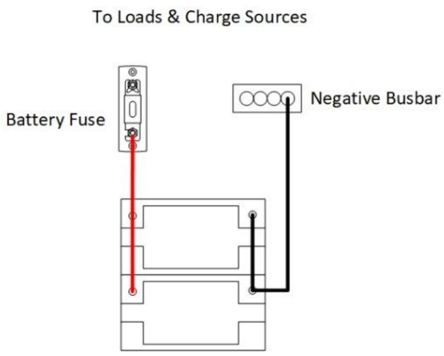
System Complexity

The suggested system diagram for the Smart Lithium battery is below:



Ignore the Inverter/Charger, Cerbo GX & Solar Panel with Regulator – these are added on items. As mentioned previously, you will also need a DC-DC Charger if you wish to recharge from a vehicle alternator.

The equivalent Terra install looks like this:



We have included a main battery fuse and busbar. The batteries can be charged from an existing conventional split charging system.

A lithium system is significantly more complicated than an equivalent Terra Install. Overall reliability should be considered too. With a significant amount of electronics required to make the lithium system operate correctly, their reliability in harsh environments and those with high vibration should be considered – a single broken communications cable for example will shut down the entire system.

The World's Most Advanced Lead Acid Battery Factory

High quality manufacture and exacting techniques are required in the production of Terra Batteries. The new factory in Albion, Indiana, USA is the World's Most Advanced lead/acid battery factory.

The purpose build 112'000 square foot plant uses state-of-the-art automation and robotics to ensure that each battery is produced to a consistent quality and performance. With over $50m invested, the plant can operate 24 hours a day and produces up to 180'000 batteries per year. A planned expansion of the plant will allow production to double.

Advanced robotics and Manufacturing 4.0 Techniques are employed at Terra Supreme Battery to ensure rapid yet highest quality manufacture in what is today's most advanced lead/acid battery factory.

Terra Battery Models

The Terra Bi-Polar Composite Battery is initially available in a Group 31 Case as a 12V, 105Ah mono-bloc. These can be linked in series/parallel for greater voltages and capacities. The standard product is designed for cranking, motive, deep-cycle, off-grid and standby power applications.

Terra Group 31 Bi Polar Composite Battery

Terra eBM™

Terra is fitted with eBM™ – an embedded battery monitor that records and reports battery usage and status via Bluetooth to your smart phone or tablet. As well as tracking battery Voltage, temperature and state of charge %, you can monitor an unlimited number of batteries in the same installation and check or expedite any warranty or battery change-out requirements.

Terra eBMTM provides battery monitoring information on your smart phone or tablet

Conclusion

Terra Bi-Polar Composite batteries set a new standard for both lead/acid and lithium technologies in the cranking, standby, mobile, marine, off-grid, solar and trucking markets – in fact, wherever a standard lead/acid or lithium battery is currently fitted. They will outperform and outlast anything on the market. They should not be confused or grouped with conventional lead/acid batteries and really inhabit a completely new advanced battery technology group.

Could The Terra Bi-Polar Composite Battery be the ultimate battery? With lithium not being the 'silver bullet' everyone hoped it would be and conventional lead/acid technology topping out; Until there is a marked shift in technology, it certainly seems that way!

	Terra Battery	Odyssey ODX-AGM31M	Fullriver DC115-12	Victron Smart 12.8/100
Technology	Bi-Polar Lead Composite	Lead/Acid AGM	Lead/Acid AGM	Lithium-Ion Phosphate
Cranking Performance:				
CCA	1200A	1150A	760A	N/a
MCA	1800A	1370A	910A	N/a
Deep Cycle Performance				
Max Charge Current	N/a	N/a	N/a	<50A Recommended
Max Discharge Current	N/a	N/a	N/a	<100A Recommended
Cycles to 50% DoD	>4000	800	1000	5000*

Cycles to 80% DoD	2000	400	600	2500*
PSOC Cycles	>15 million	Not Reported	Not Reported	Not Reported
Weight	68lbs / 30.8Kg	77.8 lbs / 35.3Kg	72.1 lbs / 32.7 Kg	30.8 lbs / 14 Kg

*At 25°C

For Further Information

For further information please contact:

Terra Supreme Battery - North America
1563 E State Road 8
Albion, IN 46701
United States of America
www.terrasupremebattery.com
T: +1 260-636-6618
E: sales@terrasupremebattery.com

Terra Supreme Battery Website: https://terrasupremebattery.com/