

LARGO

+

A LARGE-SCALE
VERTICALLY INTEGRATED
VRFB SYSTEM



+ RENEWABLES INTEGRATION

The **VCHARGE± system** can effectively enable shifting of renewable generated electricity to align with consumer demand by storing a virtually free energy source and delivering clean energy to consumers or businesses when they need it. Additionally, the VCHARGE± system can provide ramp-rate control and frequency response services, smoothing out power fluctuations while providing better alternative response times vs. standard fossil-fuel power generators.



+ UTILITIES / GRID OPTIMIZATION

The **VCHARGE± system** can store energy when electricity lines, substations, and other equipment have excess bandwidth and then discharge to handle peak demands, which allows for delaying or avoiding the upgrade of T&D assets. The VCHARGE± system can also store renewable energy when generation exceeds capacity of transmission infrastructure and discharge energy when generation capacity is low, enabling cyclic renewable generation to fully utilize T&D infrastructure.

+ MICROGRIDS

The **VCHARGE± system** can provide microgrids and island energy systems with a reliable source of clean energy, enabling a full transition away from conventional generation with fossil fuels. VRFBs also provide a source of power for microgrids when access to neighboring grids is unavailable. When combined with solar, the VCHARGE system can be fully charged during peak daylight hours and then discharge at half rated power to deliver 16-hours of power without sacrificing efficiency. A true 24-hour solution.



+ COMMERCIAL AND INDUSTRIAL ENERGY INDEPENDENCE

As the world transitions to a lower carbon future, more and more commercial and industrial businesses are focusing on clean energy integration to meet newly set carbon reduction goals. The VCHARGE± system can enable a full transition away from conventional fossil fuels utilizing long-duration renewable energy storage integration. The **VCHARGE± system** can provide excellent surrogates for balancing and reserves of PV and wind integration for commercial and industrial applications.

+ EV CHARGING INTEGRATION

The **VCHARGE± system** can support renewable energy integration for EV charging stations by reducing grid demands through ultra-fast 350kW charging. Given the demanding profile of EV charging over a typical day, the long-duration discharge cycling with no degradation make our VCHARGE± systems an ideal choice for integration. The inherent non-flammability of the VCHARGE± system allows for installation near occupied structures like vehicle service stations, office parks, or parking garages.



Largo Clean Energy offers customers a vertically integrated VRFB solution.

Unlike our competitors, the **VCHARGE± system** combines industry leading VRFB technology with Largo's world-class, reliable supply of high purity vanadium.



SUPERIOR, MODULAR SYSTEM DESIGN

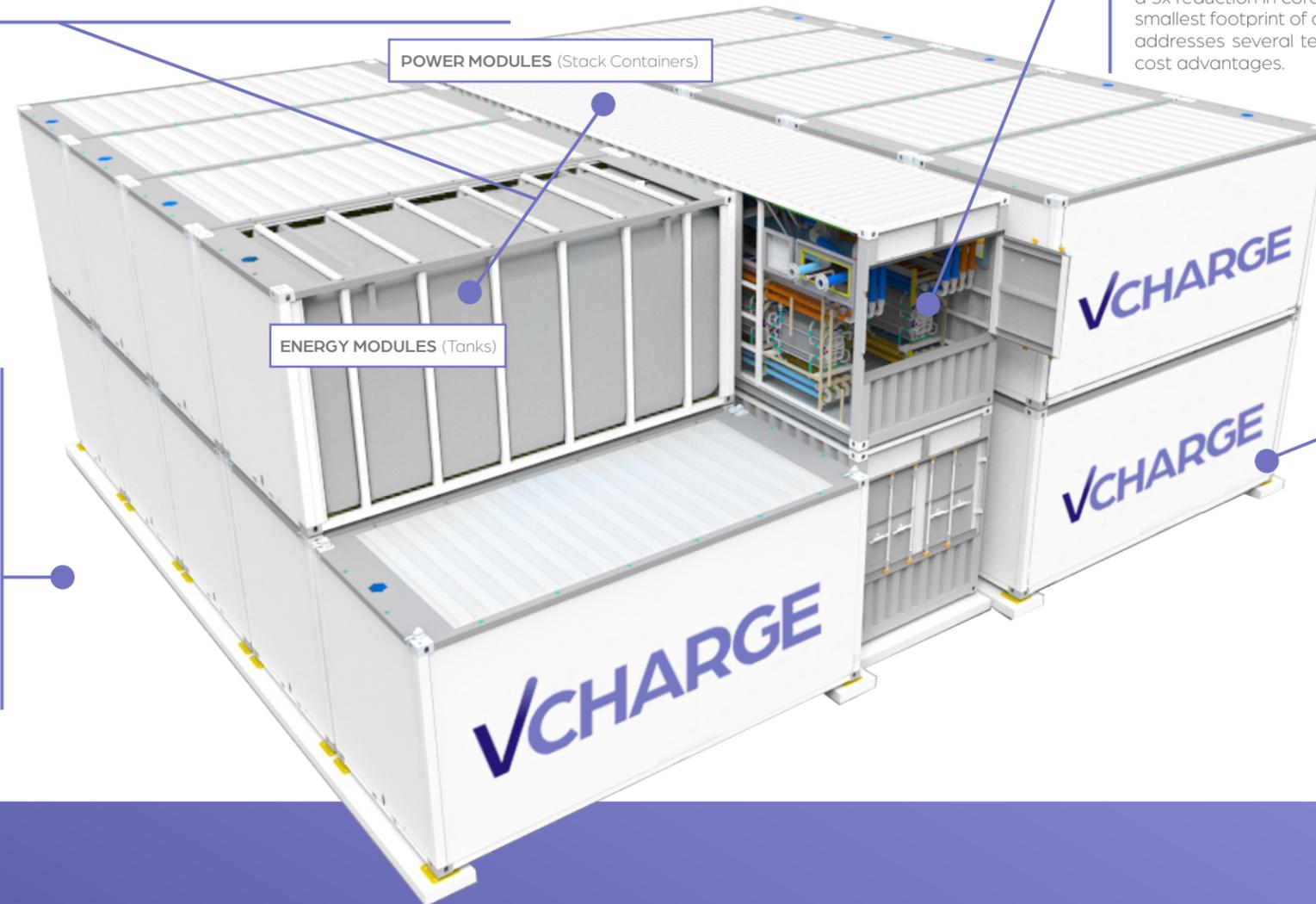
Unlike competing battery technologies, the VCHARGE± system's energy and power modules are housed in separate containers.

The VCHARGE± system allows for matching of power and energy to project requirements with a multitude of configurations to suit different site layouts. Our superior containerized system design is easy for global logistics, quick site deployment and future expansion. Our vertical stacking design allows 2x power/energy density in same footprint with significant cost advantages not possible with off-the-shelf tanks.

INNOVATIVE STACK DESIGN & ELECTROLYTE PURIFICATION

The battery stack is the power producing element in the system, converting stored chemical energy into electrical power on discharge.

The VCHARGE± system utilizes the best performing battery cell and stack technology in the industry. The VCHARGE± high performance flow cells enable a 5x reduction in core cell materials leading to significant cost savings and the smallest footprint of any known flow battery. Our patented purification process addresses several technical barriers in typical VRFB systems leading to true cost advantages.



OPTIMIZED CONTROLS FOR HIGH RELIABILITY AND MINIMAL COST

The success of any battery technology is driven by the ability to optimize the performance of the entire system.

The VCHARGE± system's Battery Management System (BMS) is based on decades of VRFB experience and uses proprietary electrolyte optimization and State-of-Charge (SOC) maintenance algorithms. The VCHARGE± system's Energy Management System (EMS) orchestrates a set of battery systems and other distributed energy resources. Our EMS provides a secure web portal to operate the site either locally or remotely and graph historical data and can run independently or integrate with a site level SCADA controller using MESA-2018 standard protocols.

DURABILITY ADVANTAGE

Long-duration applications require technology that can withstand various environmental factors over long periods of time.

The VCHARGE± system's steel container design provides robust protection from weather, UV degradation and vandalism. We have performed extensive material testing to prevent stack degradation in long duration applications which results in significant cost advantages.

Continuous energy storage over a 20+ year life cycle with no degradation.

Our VCHARGE± battery systems use patented battery technology and proprietary vanadium electrolyte processing to provide customers with a fully integrated and cost-competitive renewable energy storage system comprised of power conditioning, system control and thermal management subsystems.

SAFE
NO THERMAL
RUNAWAY RISK

100%
DEPTH OF
DISCHARGE
CAPABILITY

20+
YEARS OF
BATTERY LIFE



+
**INTRINSICALLY
SAFE**

The VCHARGE± system is one of the leading technologies in long-duration energy storage because it is intrinsically safe, with no risk of fire caused by thermal runaway. The VCHARGE± system technology has been proven safe for use in urban applications with proximity to adjacent structures and densely populated areas due to its inherent non-flammability.

Thermal runaway occurs when current flowing through a battery on charge or overcharge causes temperatures to rise, further increasing the current output and temperature, which eventually results in fire. Thermal runaway is a significant risk in solid-state batteries, such as lithium-ion applications.

The electrolyte solution used in the VCHARGE± system is non-volatile, is neither flammable, nor explosive as a result of its high water content, which offers a very high degree of operational safety compared to other battery energy storage systems.

The VCHARGE± system design includes built-in secondary containment systems to ensure environmental safety. The advanced diagnostic and control algorithms used in our battery management system can automatically identify and mitigate safety concerns while remotely notifying the Customer Support Engineering Team who can coordinate necessary repairs.



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**VERTICALLY
INTEGRATED**

The VCHARGE± system is a large-scale, vertically integrated vanadium redox flow battery system in the world.

The VRFB is well-known for its technical and economic merits, but a fundamental issue that plagues most VRFB deployment projects is the secure and reliable supply of high purity vanadium.

Largo Clean Energy solves this problem by combining industry leading VRFB technology with Largo's world-class supply of high purity vanadium.

All of the major components of the VCHARGE± system can be readily disassembled and processed individually.

There are no major safety concerns during battery operations. The refurbishment of specific components, including electrolyte, can be readily used in another battery system or the contained vanadium can be readily separated from the electrolyte.

This is a major challenge with lithium-ion battery systems. Inventions are required to make recycling practical within these battery systems and this becomes an even greater problem which needs to be addressed with grid-scale systems.

Under our electrolyte lease agreement, Largo Clean Energy will safely remove and recycle the electrolyte solution from the customer site at end of life at no cost to the customer.



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**FULLY
RECYCLABLE**

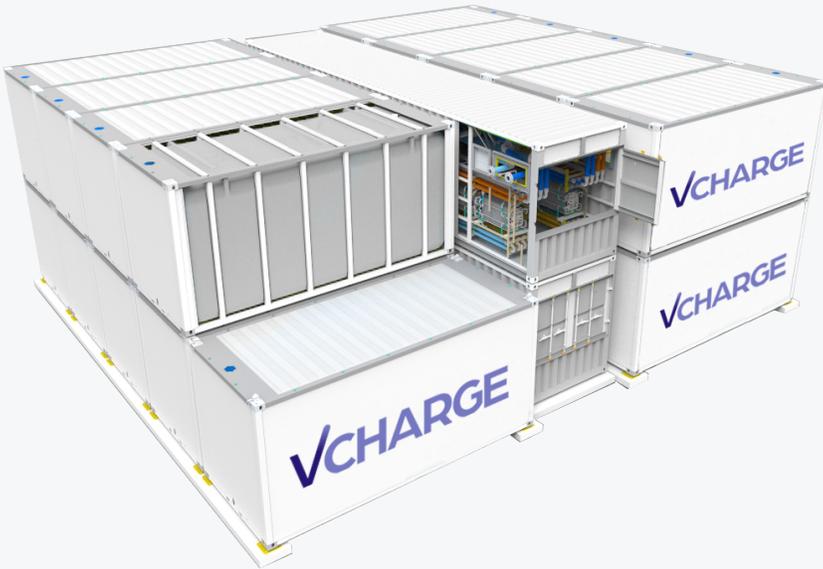
The VCHARGE± system has proven durability with unlimited cycles and no capacity loss with use or time.

The VCHARGE± system technology has undergone extensive accelerated life testing. This testing has demonstrated that stack efficiency can be maintained for 40+ years with no loss in performance over the equivalent of 20+ years of daily cycles.

Real world testing of the VCHARGE± system has resulted in >48,000 hours of operation and >3,800 cycles with no loss in system efficiency or capacity. Our extensive material testing is essential in preventing stack degradation in long-duration applications which substantially lowers operation and maintenance costs.



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**PROVEN, LONG-DURATION
ADVANTAGE**



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- Safe with no thermal runaway fire risk
- Most advanced VRFB technologies
- Fully recyclable
- Unmatched power density
- Long-duration discharge capability
- Proven grid-scale durability

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	VCHARGE± ₆	VCHARGE± ₈	VCHARGE± ₁₀
Power Rating	1,000 kW or 1,200 kW		
Energy Rating	6,000 kWh	8,000 kWh	10,000 kWh
Discharge Duration @ 1000kW	6.0 h	8.0 h	10.0 h
Discharge Duration @ 1200kW	5.0 h	6.7 h	8.3 h
Usable Capacity (Depth of Discharge)	100%		
DC Efficiency	78%		
AC Efficiency	68%		
DC Voltage	500–800VDC Operating Range		
System Life	20 Years (unlimited cycles)		
Response Time	< 1 second with electrolyte pumps ON / < 1 minute with electrolyte pumps OFF		
DC Footprint	132 m ² / 1,417 ft ²	166 m ² / 1,782 ft ²	200 m ² / 2,148 ft ²
Ambient Operating Temperature	-40°C to +45°C / -40°F to 113°F		
Ambient Relative Humidity	0 to 100%		
Installation	Outdoor		
Enclosure Rating	NEMA 3R+		
Certifications	UL 1973 and UL 9540		



This paper has been certified to meet the environmental and social standards of the Forest Stewardship Council® (FSC®) and comes from responsibly managed forests and/ or verified recycled sources.

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1640 Boro Place, 4th Floor, Suite 504, McLean, VA 22102 USA
 sales@largoinc.com | +1 571 491 7827 | www.largoinc.com