

Clean energy systems need clean batteries



Energy Storage.
Clean and Simple.

Aquion Energy

- + The world's only manufacturer of safe and sustainable saltwater batteries
- + Products are optimal for stationary, long duration (4+ hr), daily deep cycling applications

- + Spun out of Carnegie Mellon
- + Headquartered in Pittsburgh, PA
- + Manufactured in Westmoreland, PA

Research into sodium ion rechargeable batteries begins

Aquion Energy is founded and spun out of CMU

20+ MWh shipped to date

1980's

2005

2008

2011

Q2 2014

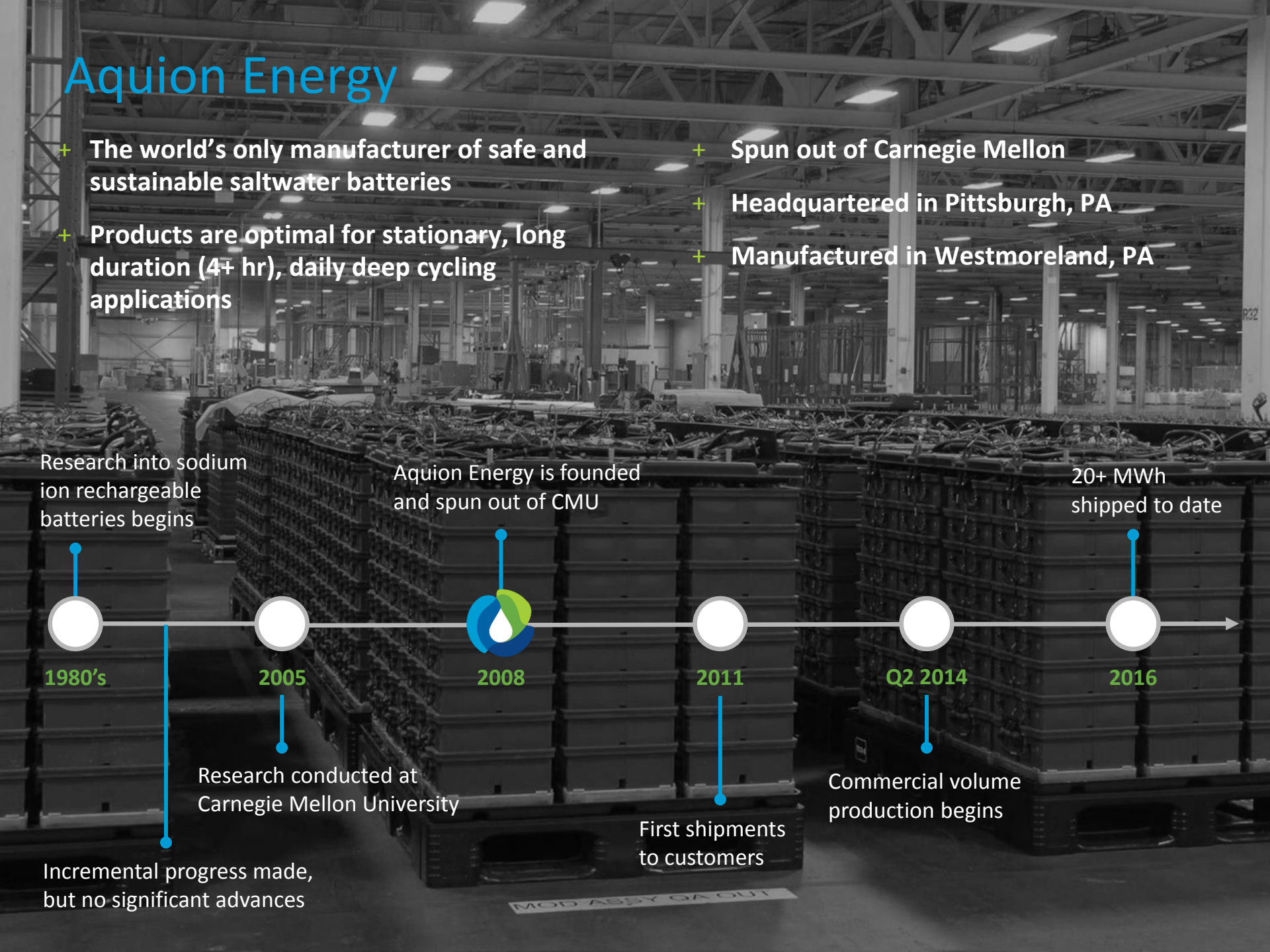
2016

Research conducted at Carnegie Mellon University

First shipments to customers

Commercial volume production begins

Incremental progress made, but no significant advances



The Aspen Battery: What's Inside Matters

Aqueous Hybrid Ion (AHI™) Chemistry

● Poly-ionic system: Na^+ , Li^+ , and H^+ ions all functional in the system

● Neutral pH water-based electrolyte

+ STAINLESS STEEL



Stainless Steel Current Collector

+ BASE OXIDE



Manganese Oxide Cathode

+ COTTON



Synthetic Cotton Separator

+ CARBON

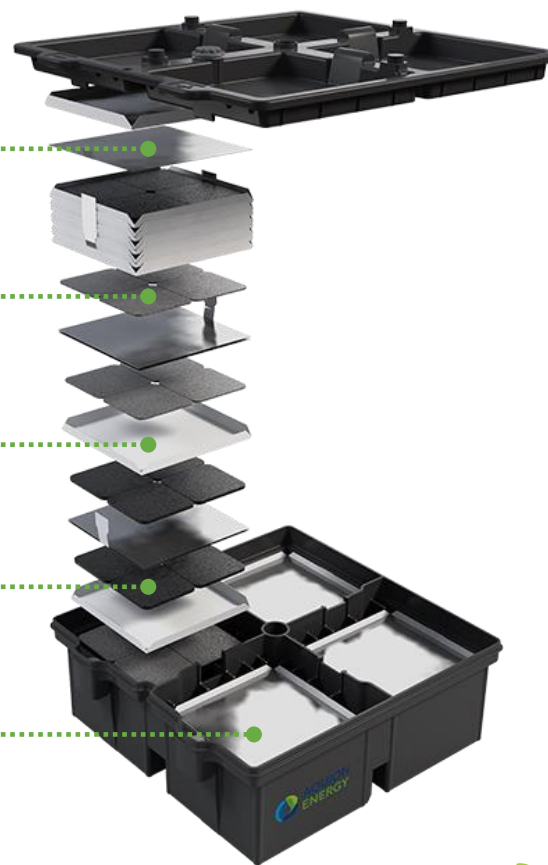


Carbon Titanium Phosphate
Composite Anode

+ SALTWATER



Neutral pH Alkali-ion Electrolyte



Our batteries are different.

How We Stack Up

Aquion's Aspen batteries are a safe, environmentally friendly, long-lasting and easy-to-use alternative to lead acid and lithium ion.

They'll give you and your customers a hassle-free experience, peace of mind, and pride in their new clean energy storage system.

Hassle-free



NO MAINTENANCE

Robust Performance



TEMPERATURE
TOLERANT



PSOC
CYCLING TOLERANT



LONG LIFE

Peace of Mind



NON-FLAMMABLE
NON-EXPLOSIVE



TOUCH SAFE



BRONZE



Hassle-Free: Easy to Connect and Safe to Install



- + Aspen batteries are 48V or 24V nominal
- + Safe to install and handle
- + Works with off-the-shelf inverters and charge controllers



- + Use industry-standard MC4 solar connectors
- + Easily connects to PV combiner boxes



NO MAINTENANCE

- + All batteries are sealed, no need to refill
- + No equalization charge required
- + No active management system needed



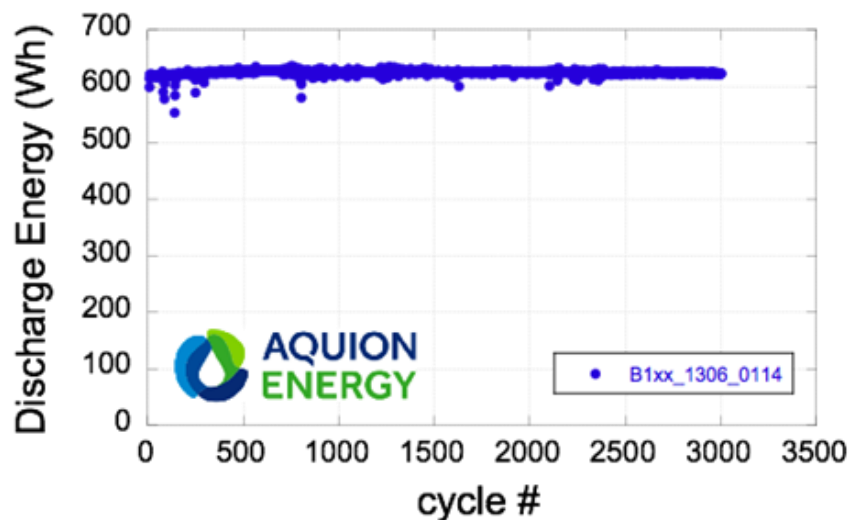
Temperature Tolerance and Daily Cycling

- + Applications testing ongoing, both in-house and at third-party test sites
- + Data from field installations show excellent stability and units continue to meet customer expectations
- + In second year of applications testing; AHI battery out-performs in key stationary applications
- + Full performance at high temperatures (40C) with no compromises in cycle life

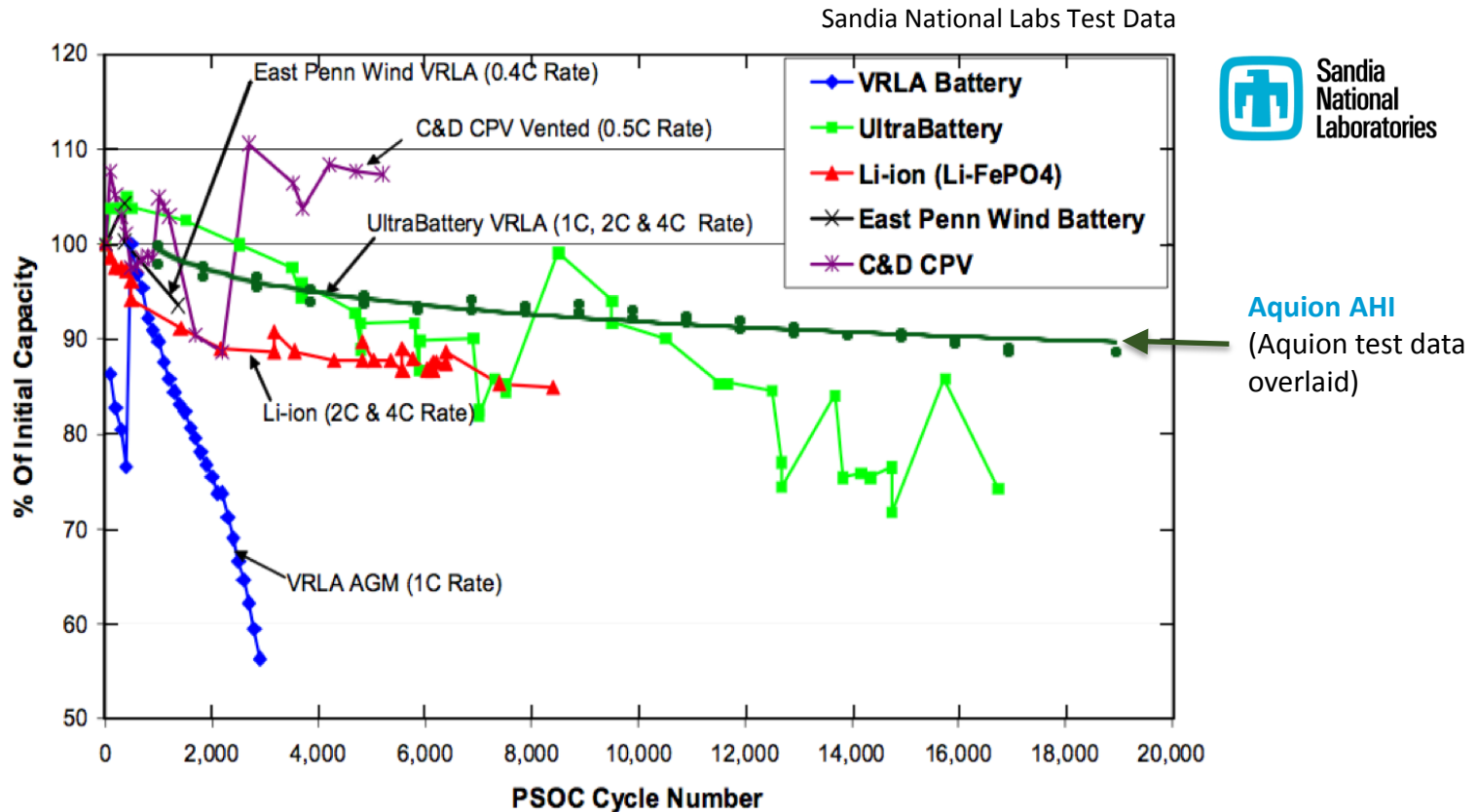


LONG LIFE

Stable Daily Energy Delivered,
2.5 Years, >3000 Cycles



Partial State of Charge Comparison Plot



- + Aquion AHI battery tested at continuous 40°C, all other tests at room temperature
- + Much faster degradation expected from all competitors at 40°C
- + Charge/discharge rate for AHI battery was $\sim C/2$

Touch Safe: Easy to Handle and Install



- + Aspen batteries are sealed and completely touch-safe
- + Don't require special enclosures
- + No special protective equipment
- + Use industry-standard MC4 solar connectors



Other Battery Chemistries Pose Great Safety Risks



Smoky Fire Prompts Evacuations; Batteries for Wind-power System In Flames

PENINSULA DAILY NEWS

Boeing Warns Passenger Airlines That Carrying Bulk Shipments of Lithium Batteries Can Cause Major Fires Onboard

INTERNATIONAL BUSINESS TIMES



"This is a very dangerous environment to fight a fire in," explained Capt. Terry Seelig of the Honolulu Fire Department. ... Firefighters faced thick smoke, toxic fumes and other hazards.



17 Hillsboro Workers Sent to Hospitals After Batteries Overheat, Release Acid Fumes at Business

The Oregonian

Aspen Batteries are Non-flammable and Non-explosive



NON-FLAMMABLE
NON-EXPLOSIVE

- + Aspen batteries are water-based and possess a very low fire hazard
- + Passed UL 1973 flame propagation testing
- + Comparable to any standard appliance
- + Inherently safe chemistry, not capable of thermal runaway

Aquion Energy
MGA Test: Q12307

Flame Propagation Test
30 Minute Exposure

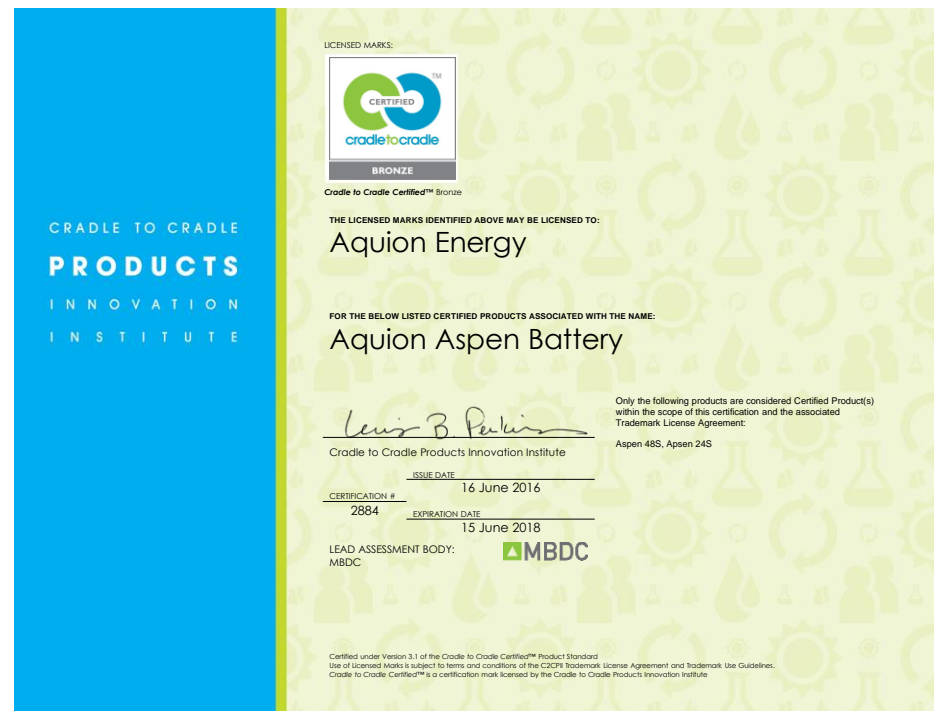
MGA Research Corp.
Outdoor Test Range
August 8, 2012

View this on our YouTube channel - <http://bit.ly/1T43QIN>

World's Only Cradle to Cradle Certified™ Battery

- + Aquion's batteries are the first in the world to be Cradle to Cradle Certified™
- + Cradle to Cradle is an independent certification organization that ensures our batteries contain **no toxic components** and uses only **sustainable manufacturing processes**

Aquion Aspen Battery



Products: Flexible, Scalable Energy Storage

ASPEN BATTERIES

Aspen 48S



- + ~2 kWh
- + 48V nominal
- + Standard building block for flexible system design

Aspen 48M



- + ~26 kWh
- + 48V nominal
- + 12 stacks in parallel
- + Pre-wired and forklift-ready for easy deployment

Aspen 24S



- + ~83 Ah
- + Nominal 24V output
- + Ideal for small off-grid solar applications, such as LED lighting

BATTERY MONITORING SYSTEM

- + Monitors current, voltage, temperature, state of charge



AQUION ENGINEERING SUPPORT

- + Compatibility, controls and system sizing



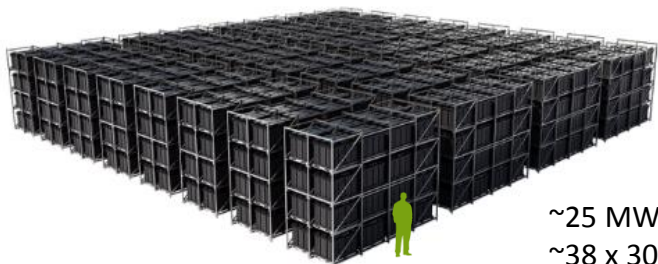
Bulk Energy Storage Configurations

HIGH-DENSITY RACKING

- + Industry-standard racking accommodates Aspen 48M batteries
- + Scalable for wide range of interior configurations
- + Simple interface
- + Available with several off-the-shelf grid capable PCS Systems



16 x Aspen 48M
~400 kWh system
~5.3 x 2.4 x 2.5 m



~25 MWh system
~38 x 30 x 5 m

CONTAINERIZED SYSTEMS

- + Containerized systems available through integration partners
- + Accommodates Aspen 48M batteries, 2 rows high



Integrated Energy Storage Systems

AQUION GLOBAL PARTNERS

- + Partners provide sales, design, integration and installation of full systems including Aspen batteries coupled with typical 3rd party equipment (inverters, controls, solar/wind, gensets, racking, enclosures)



ASPEN INTEGRATED SYSTEMS



Residential/Telco Scale



C&I or Microgrid Scale



Utility/IPP Scale

Aspen Battery Specifications

Aspen 48S-2.2



- + ~2 kWh
- + 48V nominal
- + Standard building block for flexible system design

ASPEN 48S OPERATION & PERFORMANCE

Nominal Energy	2.2 kWh
Operating Temp Range*	-5 to 40° C
Round Trip DC Efficiency	~90% at 20 hour discharge, 30° C
Voltage Range	40 to 59.5 V
Charge/Discharge Modes	CC, CP, CV

PHYSICAL CHARACTERISTICS

Height	935 mm	36.8 in
Width	330 mm	13.0 in
Depth	310 mm	12.2 in
Weight	118 kg	260 lbs

Aspen 48M-25.9



- + ~26 kWh
- + 48V nominal
- + 12 stacks in parallel
- + Pre-wired and forklift-ready for easy deployment

ASPEN 48M OPERATION & PERFORMANCE

Nominal Energy	25.9 kWh
Operating Temp Range*	-5 to 40° C
Round Trip DC Efficiency	~90% at 20 hour discharge, 30° C
Voltage Range	40 to 59.5 V
Charge/Discharge Modes	CC, CP, CV

PHYSICAL CHARACTERISTICS

Height	1,159 mm	45.6 in
Width	1,321 mm	52.0 in
Depth	1,016 mm	40.0 in
Weight	1,504 kg	3,309 lbs

Aspen 24S-83



- + ~83 Ah
- + 24V nominal
- + Ideal for small off-grid solar applications, such as LED lighting

ASPEN 24S OPERATION & PERFORMANCE

Nominal Energy	83 Ah
Operating Temp Range*	-5 to 40° C
Round Trip DC Efficiency	~90% at 20 hour discharge, 30° C
Voltage Range	20 to 29.7 V
Charge/Discharge Modes	CC, CP, CV

PHYSICAL CHARACTERISTICS

Height	935 mm	36.8 in
Width	330 mm	13.0 in
Depth	310 mm	12.2 in
Weight	118 kg	260 lbs

Aquion Energy Storage Markets

APPLICATIONS

STORAGE BENEFITS

RESIDENTIAL SOLAR



- + Solar Self-Consumption
- + Provide Backup Power and Islanding
- + Time of Use Optimization
- + Demand Charge Reduction

- + Store and consume all the solar you generate
- + Control energy costs and demand charges
- + Resiliency and critical power during grid outages

OFF-GRID AND MICROGRIDS



- + Diesel Reduction
- + Islanding with Renewable Generation
- + Critical Power

- + Manage intermittency and ensure stability
- + Reduce reliance on fossil fuels
- + Store energy for later use to enable islanding and independence

C&I ENERGY MANAGEMENT



- + Demand Response
- + Power Quality
- + Peak Shaving
- + Self-Consumption

- + Control energy costs
- + Avoid peak power demand charges
- + Store energy generated on-site to maximize use of renewables

Competition Overview

LEAD ACID

High Quality 2V Cells



- + Lowest \$/kWh capX price
- + Chemistry is well known
- + Worldwide manufacturers and distribution
- Limited cycle life, heavily life compromised by partial state of charge
- Requires costly maintenance
- Environmental challenge
- Low temperature tolerance

Lead acid is a stagnant chemistry – very little projected improvement in performance or cost.

LITHIUM ION

Tesla Style, 18650 cells



- + Higher Power/Energy Ratio
- + Potentially lower \$/kWh
- + Small size provides packaging flexibility
- + Strong brand recognition
- Poor 100% DoD cycle life
- Safety concerns
- Requires thermal and cell to cell active management
- High system complexity
- Poor temperature tolerance

Automotive style lithium ion 18650 cells are at the limit of performance and cost down. Future 18650 cells will be similar to products today.

LITHIUM ION

High Power LFP ESS Style



- + Perceived to be a more stable and safe chemistry
- + Higher power to energy ratio performance
- + Strong brand names / bankable
- Utilizes flammable organic solvent electrolyte
- Requires thermal and cell to cell active management
- Higher cell costs

More chemistries are being optimized for full DoD cycling and large companies are playing in the space. The cost floor is higher than 18650's and AHL.

Off-Grid Residential System, California, USA

PROBLEM

- + Owners of a luxury ranch in a pristine, remote area in Jenner, California need continuous access to reliable power but are located outside of the utility's service territory
- + Cost to extend grid power would have been >\$250K
- + Diesel generator generates noise and pollution, requires fuel transport

SOLUTION

- + Implement a microgrid using solar + batteries with small backup generator
- + Power residence entirely from solar power
- + Quiet, clean, sustainable
- + Saves over 6 metric tons of CO₂ emissions annually, an additional 2 metric tons from the guest house



SYSTEM OVERVIEW

Batteries

Aquion Energy
M-Line Modules
100 kWh, 48 V

Battery Inverter

SMA Sunny Island

Solar Array

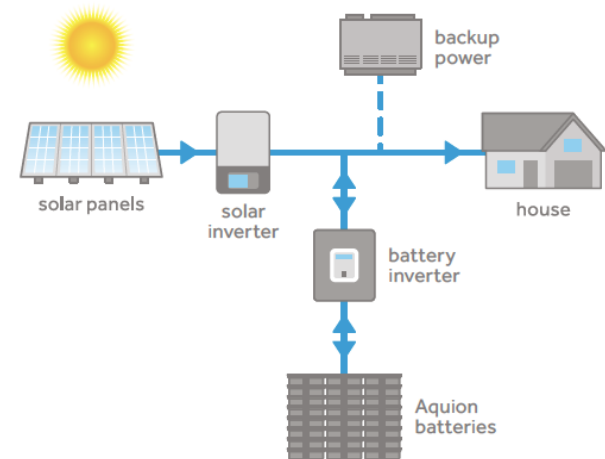
16 kW

Solar Inverter

SMA Sunny Boy

Backup Power

Diesel generator



Solar Microgrid, Hawaii, USA

PROBLEM

- + Large off-grid private microgrid on Island of Hawaii, located in state park land alongside pristine coast where they can't run power lines
- + Powered entirely by propane generators; want to reduce fossil fuel use
- + Needs clean, reliable power to meet the load requirements of the estate



SOLUTION

- + Implemented a solar + batteries microgrid with a small backup generator, 23 kW avg load, 42 kW peak load
- + Batteries charge from solar during the day and discharge overnight – 8 hour charge/16 hour discharge
- + Residence is powered entirely from solar, expected to reduce fossil fuel usage by 97% and eliminate over 35 metric tons of CO₂ emissions annually

SYSTEM OVERVIEW

Batteries

Aquion Energy
M-Line Modules
1 MWh, 48 V

Battery Inverter

SMA Sunny Island

Charge Controller

Midnite Solar Classic

Solar Array

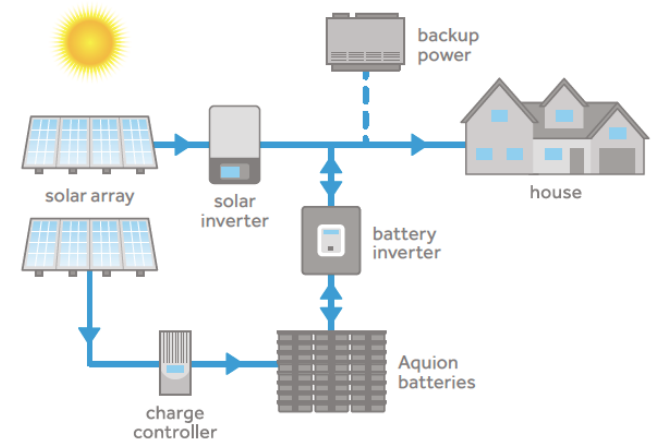
172 kW

Solar Inverter

SMA Sunny Boy

Backup Power

Propane generator



Off-Grid LED Lighting Microgrid, Thailand

PROBLEM

- + 23.5 kilometer bicycling track at the Suvarnabhumi Bangkok Airport can only be used during daylight hours
- + Want to increase the usability of the track by adding lighting
- + Costly to run electricity to all of the off-grid lights surrounding the track

SOLUTION

- + Over 700 independent off-grid systems – each with solar-powered LED lights and an Aquion battery
- + Sky Lane is the first airport-based track to allow nighttime riding
- + Sky Lane's estimated 14,000 cyclists per week can now use the facility during nighttime hours.



SYSTEM OVERVIEW

Each of the 700+ systems consists of:

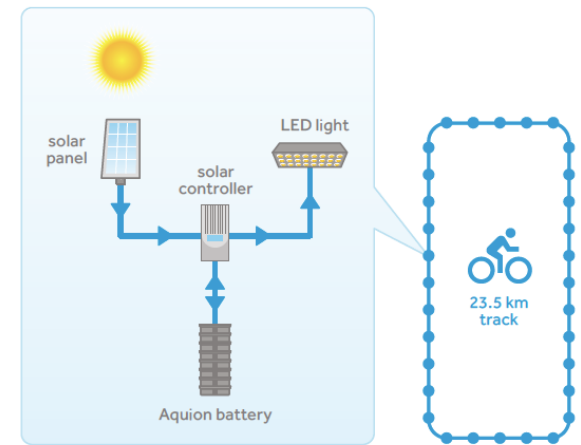
Battery

Aquion Energy
S-Line Battery
2.4 kWh, 24 V

Solar Controller

LED Light
60 watt

Solar Panel
240 watt



Zero Emission Solar + Storage System: American Samoa

PROBLEM

- + Nearly 100% dependent on imported petroleum fuels
- + Extremely remote, susceptible to natural disasters
- + No interconnections
- + High electricity tariffs
- + N-2 reliability criterion

SOLUTION

- + Existing diesel-powered stationary genset replaced
- + Reducing annual emissions of Nox by 7.57 tons
- + Reducing carbon monoxide by 1.48 tons
- + Reducing carbon dioxide by 832 tons
- + Reducing 284,000 liters of diesel fuel annually



SYSTEM OVERVIEW

Batteries

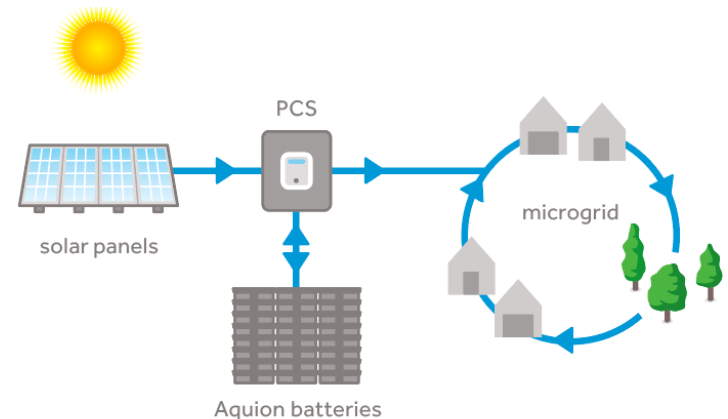
Aquion Energy
M-Line Modules,
1.25MWh

Power Control Electronics

Princeton Power

Solar Array

250 kW



Hybrid Microgrid Organic Farm and Winery, California

PROBLEM

- + Stone Edge Farm has a goal of seeing how far below zero carbon emissions they can go
- + Looking for innovative technologies to run an organic farm and winery with clean energy sources
- + Needs clean, safe, and reliable energy storage for storing on-site solar

SOLUTION

- + 350 kWh high-voltage containerized energy storage solution
- + 23 kW solar array on-site charges batteries during the day, and they discharge overnight to carry loads
- + Solar + battery system integrated in microgrid to help meet carbon emissions reduction goals



SYSTEM OVERVIEW

Batteries

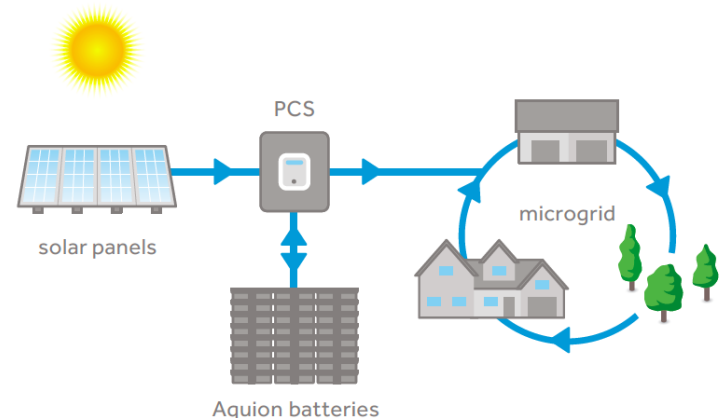
Aquion Energy
M-Line Modules
350 kWh

Power Control

Electronics
Ideal Power
Solutions

Solar Array

32 kW



Solar Farm Baseload Shifting, Salinas, Puerto Rico

PROBLEM

- + Sonnedix 16 MW Horizon Energy solar farm needs to power overnight loads of buildings and equipment
- + Grid electricity in Puerto Rico is expensive and solar farm doesn't want to purchase power from the grid when they are producing it at a cheaper rate
- + Solar farm wants access to power during non-solar producing times

SOLUTION

- + 1.25 MWh of Aquion batteries provides energy storage for on-demand solar
- + Dedicated 250 kW solar array charges batteries during daylight hours
- + Aquion batteries provide 100% of overnight operation energy requirements for solar farm
- + Solar farm does not need to purchase grid power



SYSTEM OVERVIEW

Batteries

Aquion Energy
M-Line Modules,
1.25 MWh

Power Control Electronics

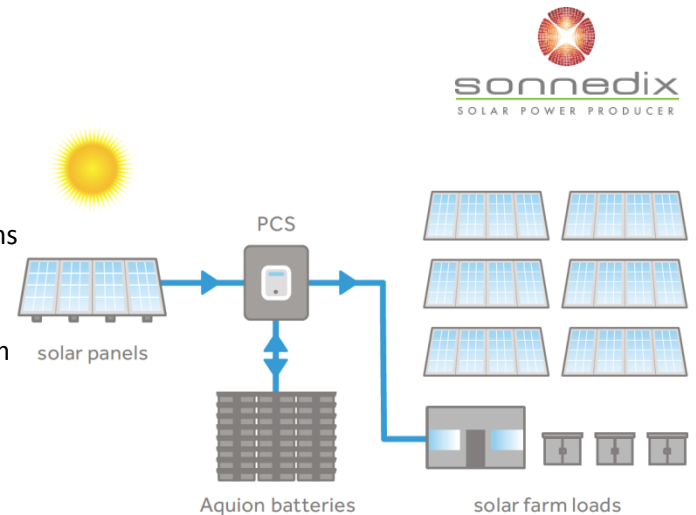
FlexGen Power Systems
Multi-Port Inverter

Solar Array

250 kW (separate from
16 MW solar farm)

Site Controller

Geli's EOS – Energy
Operating System



Global Shipments and Installations

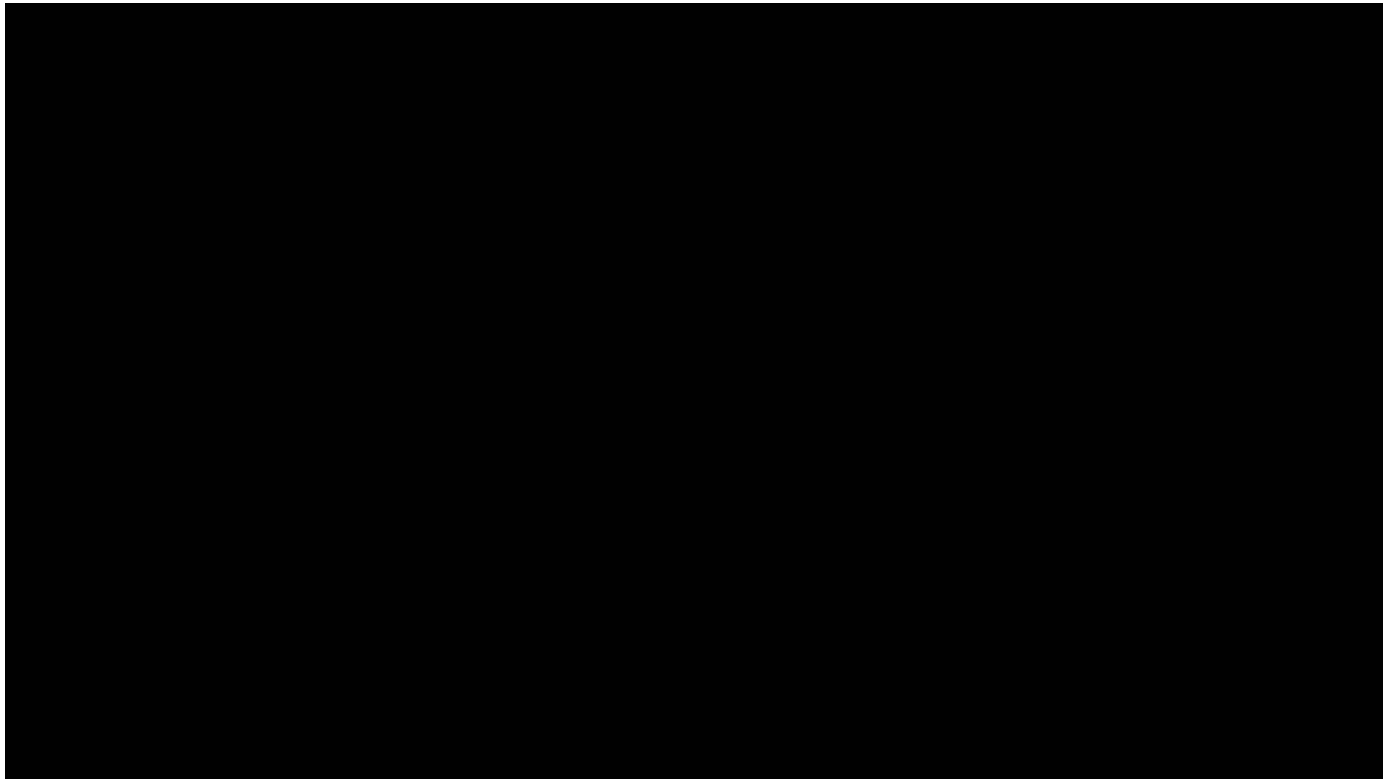
GLOBALLY MORE THAN 20 MWh OF BATTERIES DELIVERED TO OVER 100 SITES



Large Scale Manufacturing Overview - Video



All of our products are
manufactured in Pennsylvania



View this video at <https://www.youtube.com/watch?v=aANBtotnsLI>

Aquion In The News

MIT Technology
Review
50 Smartest
Companies 2016



ees Award for
Innovation in Energy
Storage Technology
2015



Fast Company
World's Top 10 Most
Innovative Companies
of 2015 in Energy



LEMELSON-MIT
Celebrating invention, inspiring youth

Jay Whitacre wins
Lemelson-MIT Award
2015

Popular Science
Best of What's New
Innovation of the Year
2014



Global Cleantech 100
Top 100 Company
2014



"Priorities for
Jumpstarting the
U.S. Industrial
Economy"

**Harvard
Business
Review**

"Does Mars have
the answer to
storing energy?"



GIGAOM
"12 energy storage
startups to watch in 2015"

The background of the slide is a deep blue, textured image that resembles an underwater scene with light rays filtering through the water. The text is white and positioned in the upper left quadrant.

Thank You

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