

Using Metal-Hydrogen Battery Technology To Drive Down Costs And Decrease Emissions In Operations

September 2022



ENERVENUE

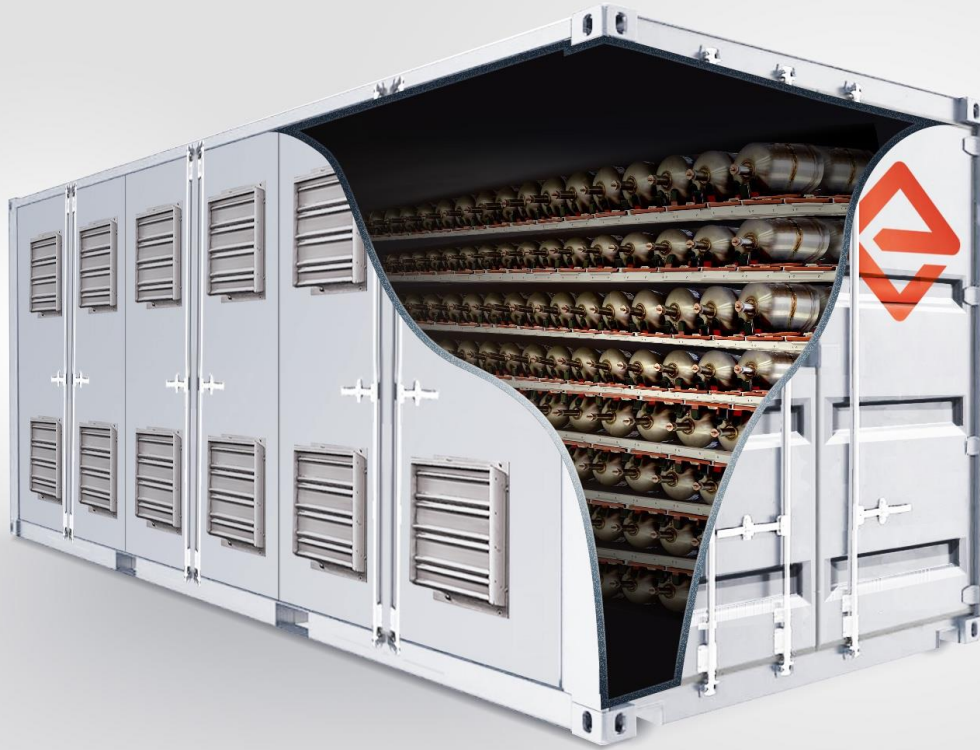
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EnerVenue's Metal-Hydrogen Battery Technology



- **DURABLE** 30,000 cycles, 30 years, 3 cycles/day
- **FLEXIBLE** Fast and slow charge rates
- **SIMPLE** Minimal OPEX with no augmentation
- **SAFE** No fire or thermal runaway risk
- **PROVEN** Refined by NASA and Stanford

Technology Timeline



Mature, proven technology used in outer space applications for 30+ years



Metal-Hydrogen deployed by NASA

- Mars Rover
- Space Station
- Hubble Telescope
- **30+ years**
- **200 million cycles**
- **100,000 charge and discharge cycles**

1980s



Stanford Professor Yi Cui refines NASA battery technology

- New materials
- Reduced costs
- New catalyst

2017



EnerVenue spun-out of Stanford's business accelerator

- Long life
- No augmentation
- 99% recyclable

2020

EnerStation

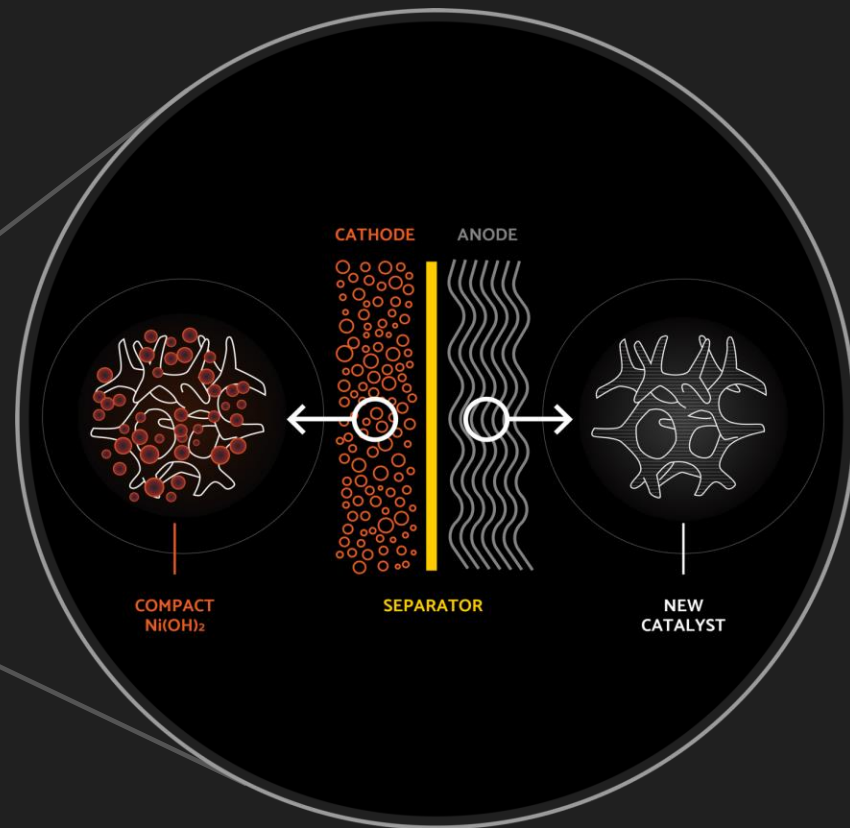
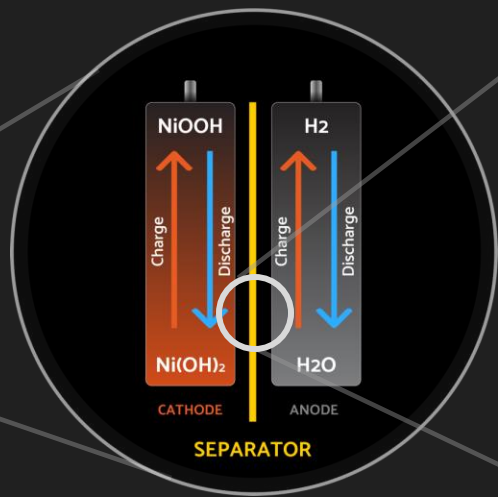
EnerStation Launch

- No heating or AC
- No fire suppression
- Simple utility and C&I solution
- >7GWh customer signed MOUs

2022

EnerVenue Ni-H₂ Battery

30+ years mature technology upgraded with new low-cost earth abundant durable catalyst and design improvements



















Most Durable and Reliable Battery Technology



Ni-H2 batteries can operate in extreme temperatures for 30+ years, offering the longest cycle-life of any battery system

 = Challenge with Lithium-Ion technology

 = Advantage with EnerVenue technology

<p> Li-ion</p> <p>Fire and explosion risk</p>	<p> Li-ion</p> <p>High operating & maintenance expenses</p>	<p> Li-ion</p> <p>Longer duration & dispatch (2-12+ hr charge)</p>	<p> Li-ion</p> <p>Limited cycle life</p>
<p>No thermal runaway risk No fire suppression need</p> 	<p>No augmentation No routine maintenance</p> 	<p>Flexible charge/discharge range C/2 to C/12+</p> 	<p>30+ year lifespan ~30,000 cycles, 3 cycles/day</p> 
<p> Li-ion</p> <p>Restrictions on over-charge and over-discharge</p>	<p> Li-ion</p> <p>Harsh climates: hot deserts & freezing winters</p>	<p> Li-ion</p> <p>Flammable liquids and toxic materials</p>	<p> Li-ion</p> <p>High chemistry, adoption and technology risks</p>
<p>Excellent overcharge, discharge and deep-cycle</p> 	<p>Operate in -30°C to 50°C ambient temperature</p> 	<p>Non-toxic, no lithium, easily sourced</p> 	<p>Proven in 30+ years of use in space applications</p> 



Validation from Distinguished Investors




Forbes Sign In Q

Sep 15, 2021, 08:15am EDT | 3,937 views

EnerVenue Closes An Enormous Investment Round In A Great Sign For Grid-Level Storage Technology

 **Erik Kobayashi-Solomon** Contributor 
Sustainability
Investor in climate change adaptation and mitigation businesses



The growing EnerVenue team. CEO Jorg Heinemann is in the front row wearing a blue shirt. CTO Dr. Yi ... [+] ENERVENUE.COM

I introduced EnerVenue to readers of this column in December 2020 and opined that its innovative re-formulation of Metal-Hydrogen batteries were the

“EnerVenue secures \$125 million in Series A funding led by Schlumberger New Energy and Saudi Aramco Energy Ventures.”

[Article link](#)

Schlumberger | New Energy



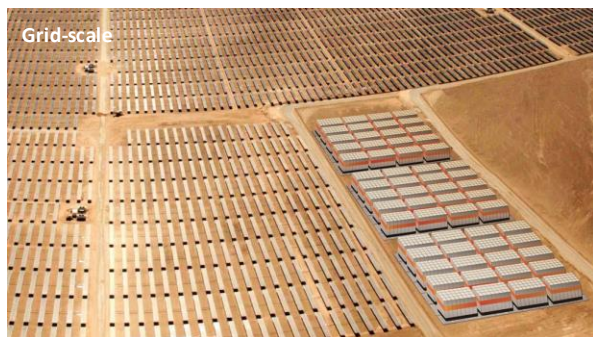
EXPANSION TIMELINE



Target Markets



Traditional energy storage technologies have a role to play in meeting the demands of the energy transition but are limited in their applicability by cost and safety concerns



Grid-scale



Commercial & Industrial (C&I)



Residential

C&I Applications



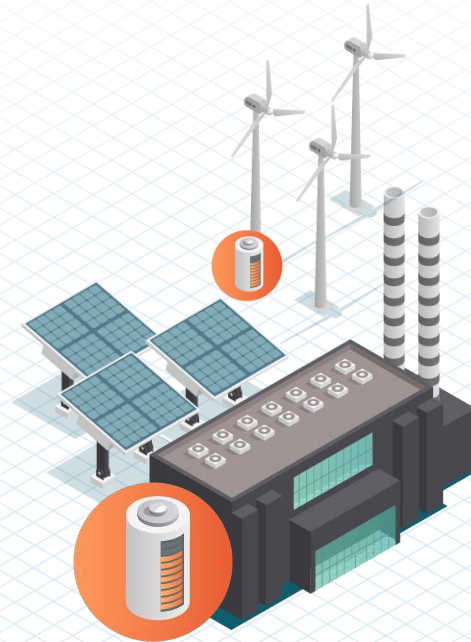
The Swiss Army Knife of battery storage

REDUCE COSTS

- Shift electricity consumption from expensive to lower cost periods
- Generates power locally
- Reduces demand on the grid without disrupting business operations

IMPROVE RESILIENCY

- Provides enough backup power to tackle any grid reliability issues
- Provides backup coverage by leveraging the solar energy stored
- Provides plenty of backup power to tackle any grid imbalances



IMPROVE SUSTAINABILITY

- Harness energy from renewable fuel sources
- Draws more electricity from autonomously generated solar power
- Slashes the amount of energy drawn from the grid

EARN REVENUE

- Grants access to grid services, like Demand Response
- Minimizes the energy curtailment and generates additional revenue streams
- Generates revenue by selling energy surpluses into the energy market

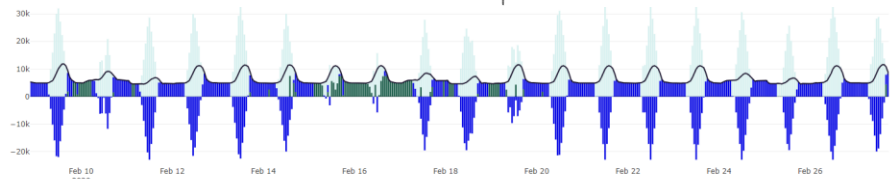
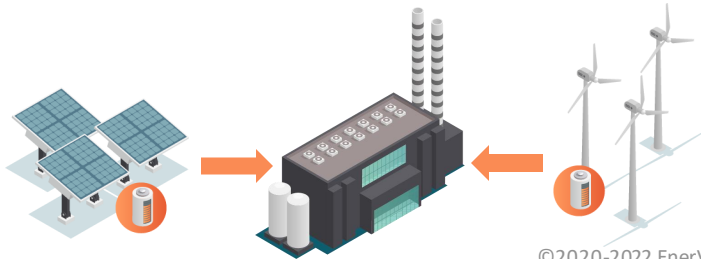
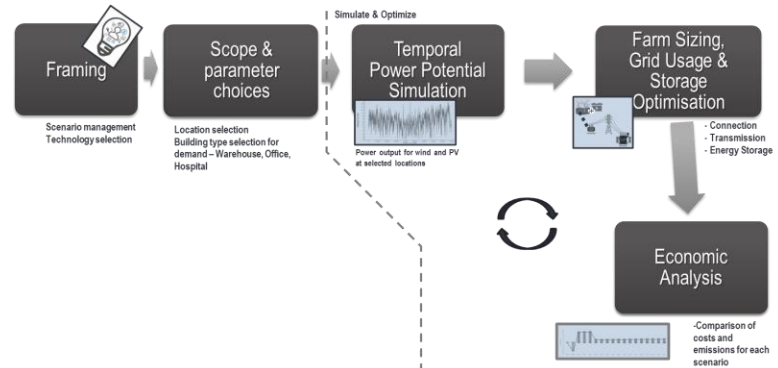
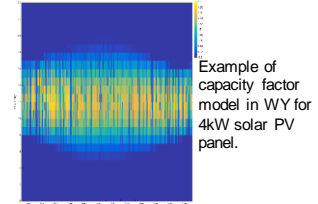
Schlumberger Energy and Emissions Modeling



Challenge: To model commercial and industrial facilities' energy usage to determine which onsite energy generation and storage technologies, lithium-ion or EnerVenue's metal-hydrogen, yielded the best result while also reducing carbon emissions.

Solution: Schlumberger New Energy developed an optimization algorithm, *New Energy Screening Tool* (NEST), to consider carbon emission and financial impact by evaluating real-world electricity usage data.

- NEST looks at solar PV and wind capacity factors from real-world data from National Renewable Energy Lab (NREL) database
- Optimization algorithm accounts for grid electricity prices and optimizes for the lowest cost system and lowest emissions at any given time
- CAPEX and OPEX of each technology is analyzed based on usage



Example 1 – Hospital

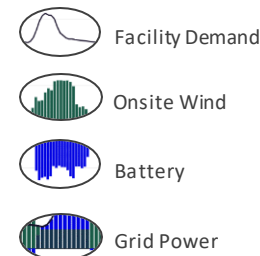
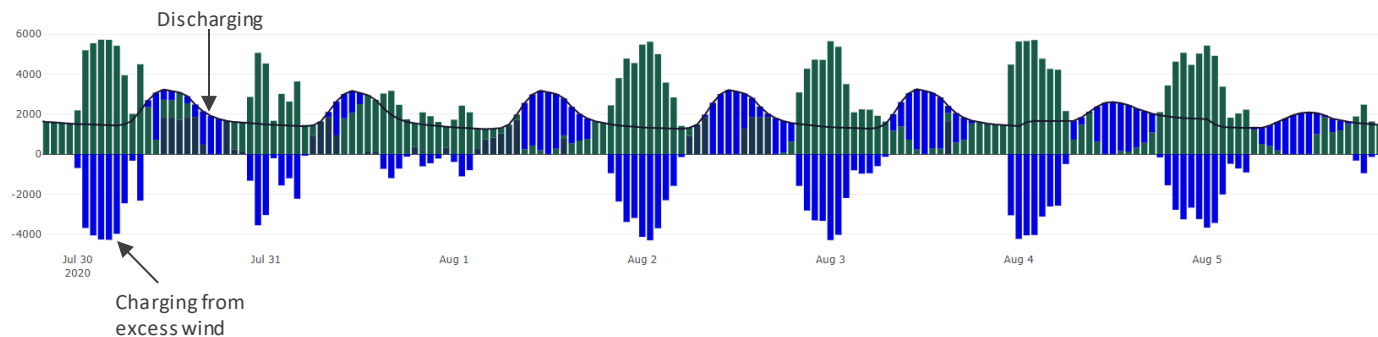
Using NREL energy usage data with Schlumberger’s NEST optimization algorithm shows carbon emissions reductions and overall lifecycle costs of various renewable technologies



- Hospital use case - Texas, USA
- NEST model evaluates how onsite wind and solar PV generation paired with a battery energy storage system would help reduce need for grid power while also reducing CO₂ emissions



Energy Usage Plot Example With Wind And Battery Storage

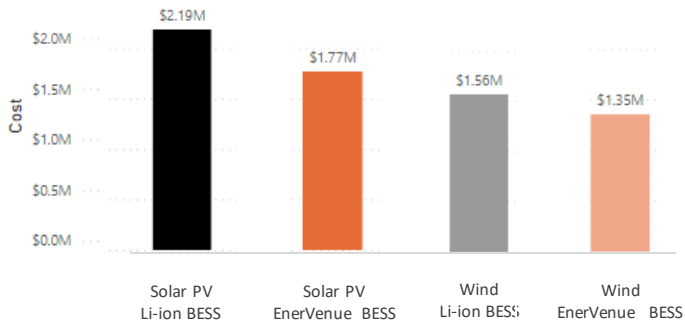


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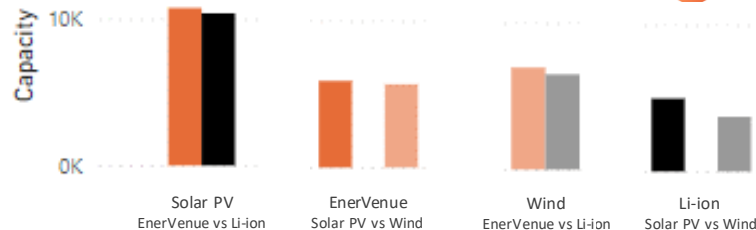
NEST evaluation output of different renewable energy and battery technologies



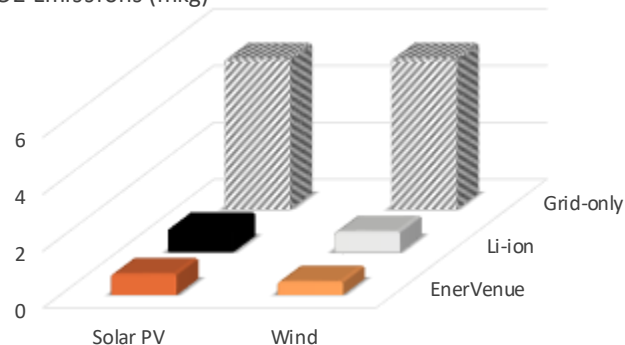
Total Lifecycle Cost Comparison (CAPEX + OPEX)
Annualized over 25 yr life



Capacity (kW) Comparison



CO2 Emissions (mkg)



- Solar and wind systems paired with EnerVenue batteries results in 19% and 14%, respectively, lower lifecycle costs compared to those systems paired with lithium-ion batteries
 - Due to EnerVenue's longer life, no augmentation, ability to cycle more times, less maintenance

Example 2 – Large Office

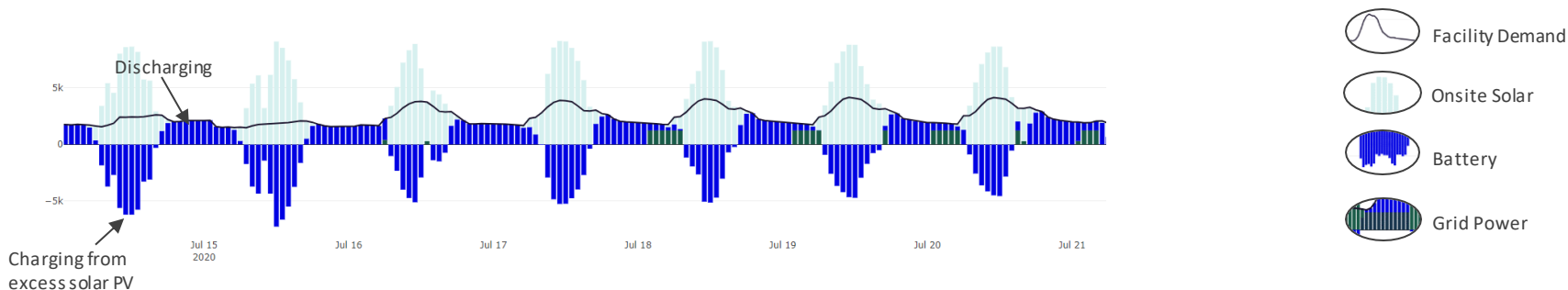
Using NREL energy usage data with Schlumberger's NEST optimization algorithm shows carbon emissions reductions and overall lifecycle costs of various renewable technologies



- Office use case – Arizona, USA
- NEST model evaluates how onsite wind and solar PV generation paired with a battery energy storage system would help reduce need for grid power while also reducing CO₂ emissions



Energy Usage Plot Example With Solar PV And Battery Storage

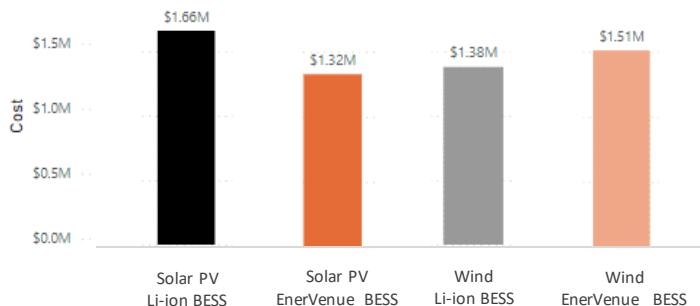


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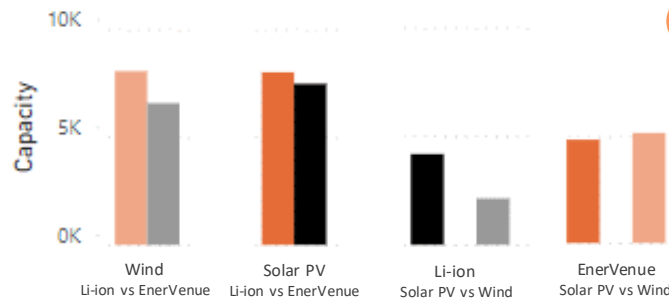
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Total Lifecycle Cost Comparison (CAPEX + OPEX)
Annualized over 25 yr life

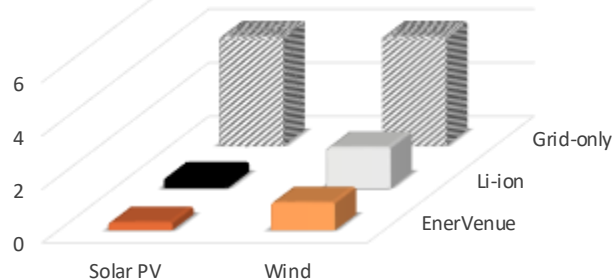


Capacity (kW) Comparison



- Solar systems paired with EnerVenue batteries in this example results in ~20% lower lifecycle costs compared to those systems paired with lithium-ion batteries
 - Due to EnerVenue's longer life, no augmentation, ability to cycle more times, less maintenance
- EnerVenue batteries paired with Wind is showing higher leveled cost
 - Because the NEST algorithm is optimizing for as little grid usage as possible with the maximum carbon reduction possible.

CO2 Emissions (mkg)





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Thank You!

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