Natron Energy

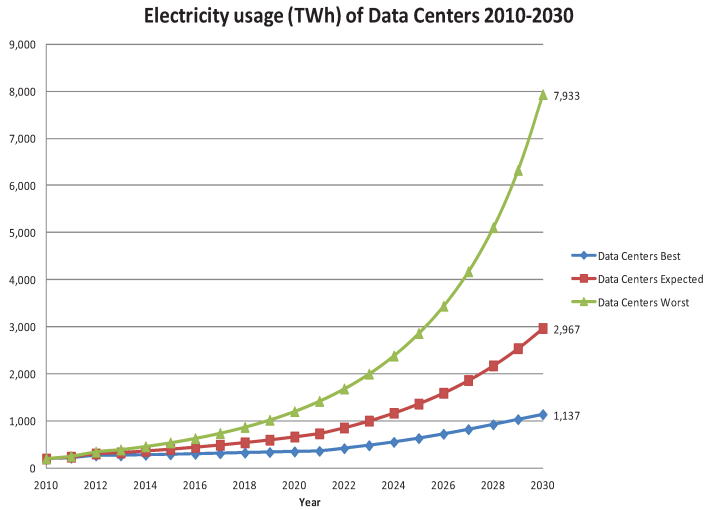
Energy Storage Trends

Data Centers, Edge, and Beyond

Jack Pouchet

Data Center Electrical Energy Consumption – There is an Upper Limit

- 416 Terra Watts[1]
  - 3% Global Electrical Generation
- Cloud Computing alone uses more electricity than all of Japan
- 277 Terra Watts (estimate)[2]
  - Data Communications, Networks, Subsea Cables, Wireless
- Edge? Double Counting?
- HyperScale Data Centers exceed 500[3]

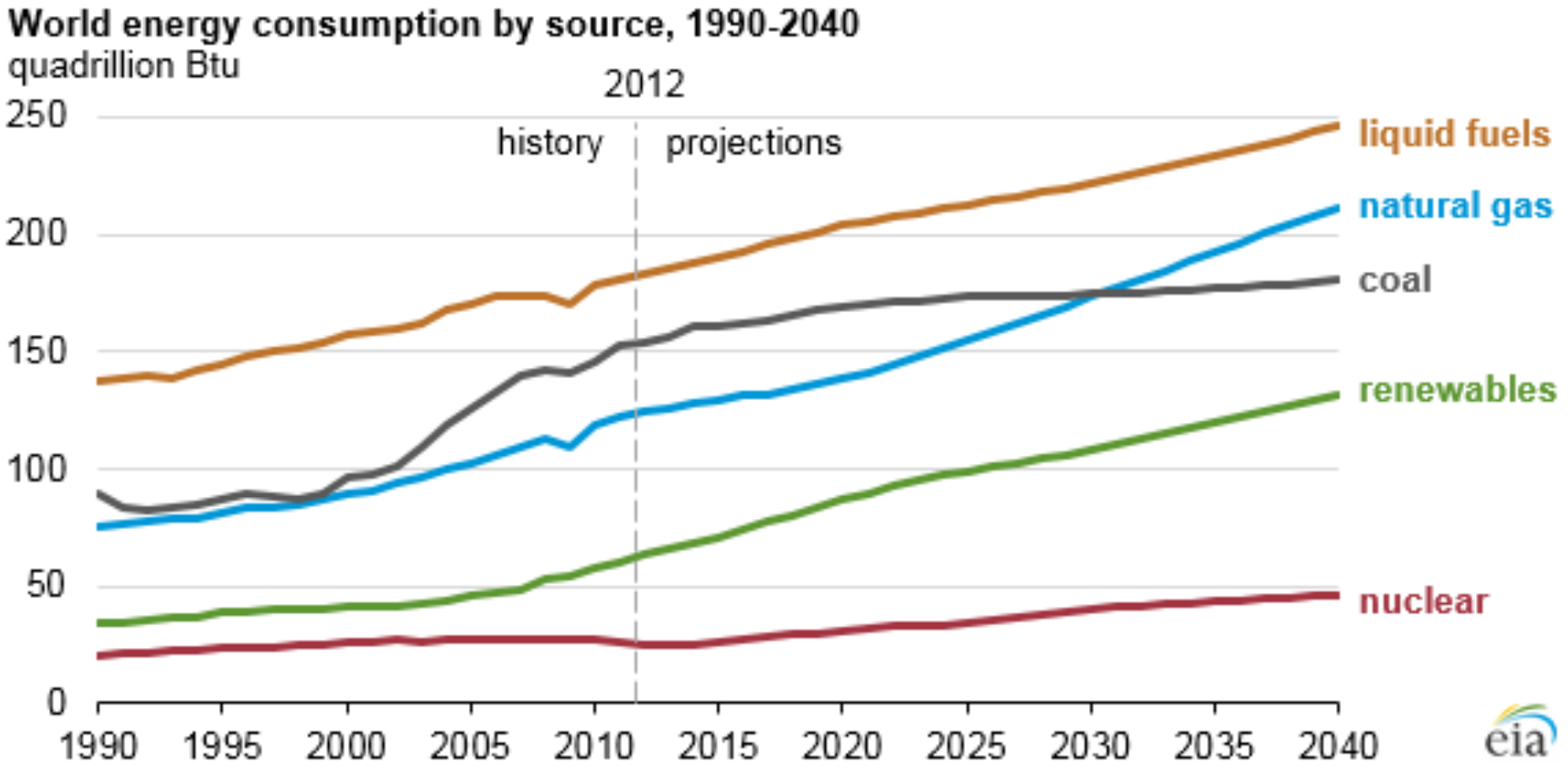


1 https://data-economy.com/the-importance-of-green-data-centres/

2 https://www.hindawi.com/journals/jcnc/2013/897029/

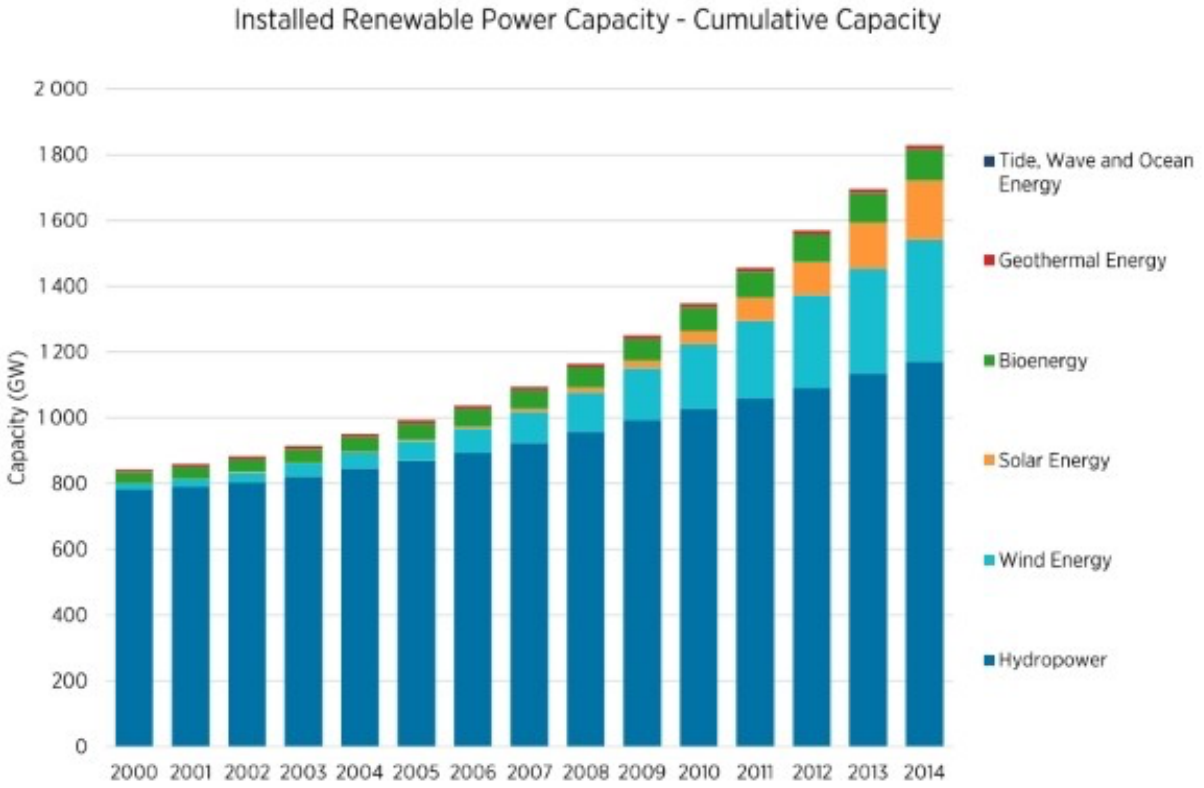
3 https://www.srgresearch.com/articles/hyperscale-data-center-count-passed-500-milestone-q3

Energy Use – All Types, Electrical, Thermal, Mechanical, etc.

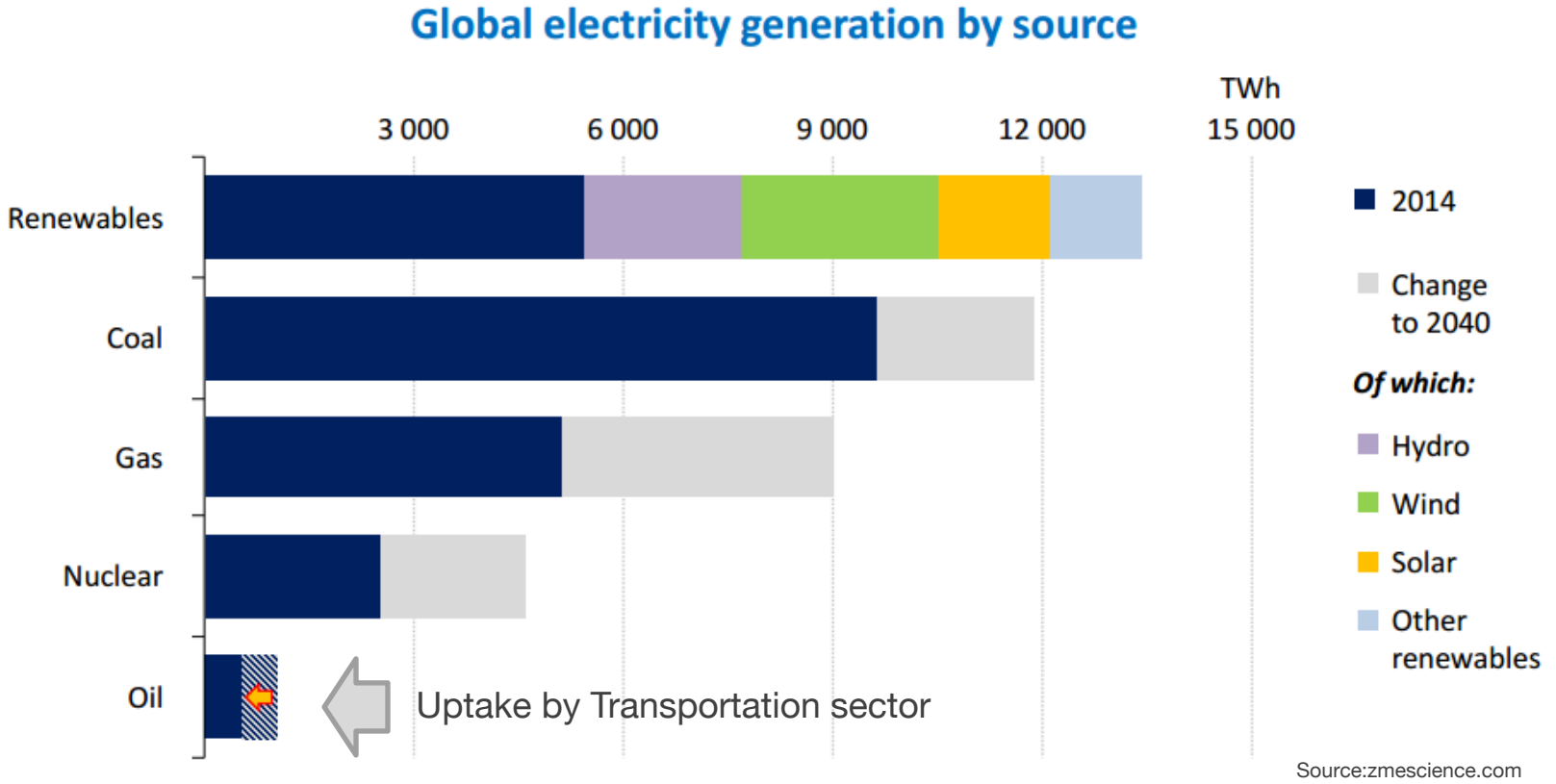


Exponential Growth of Renewables – Not Likely

IRENA
International Renewable Energy Agency



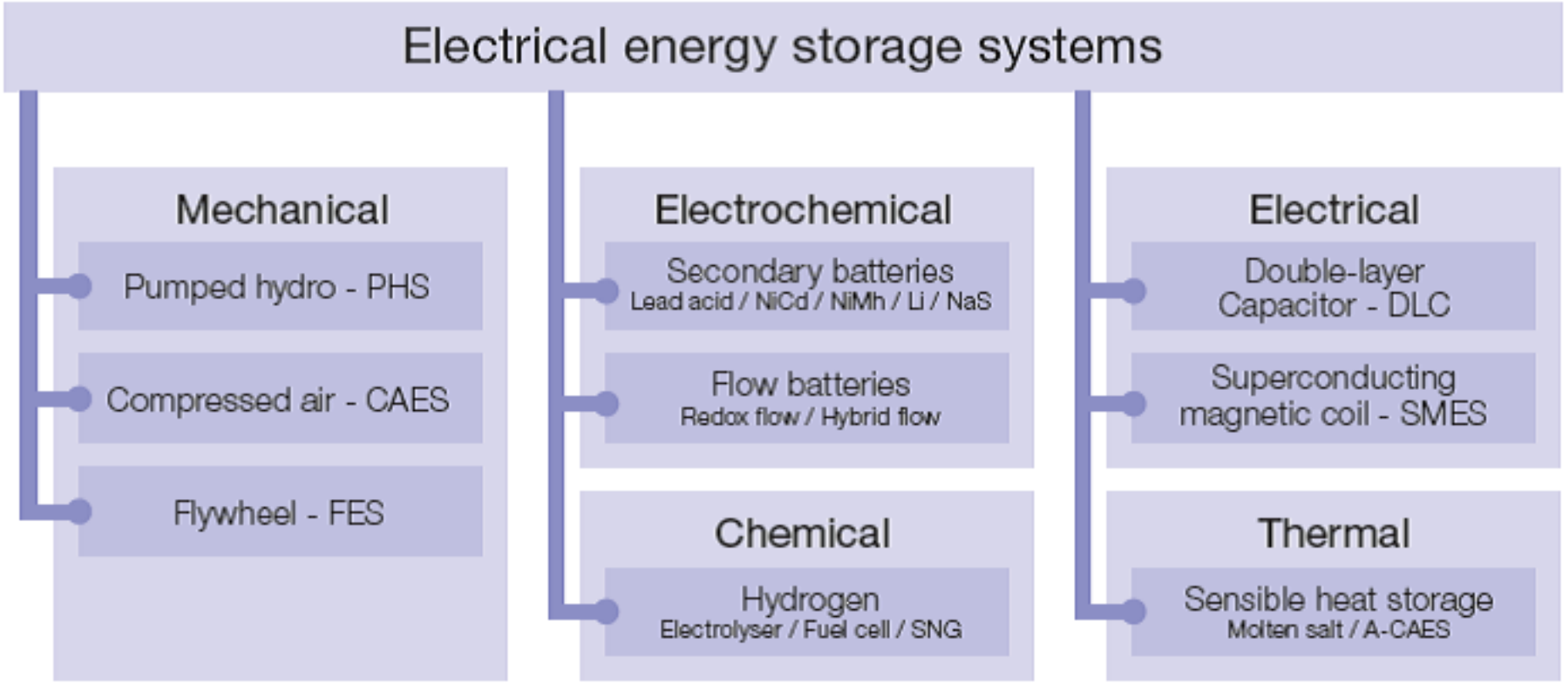
Electricity – Best Chance at a Green Future



Source:zmescience.com

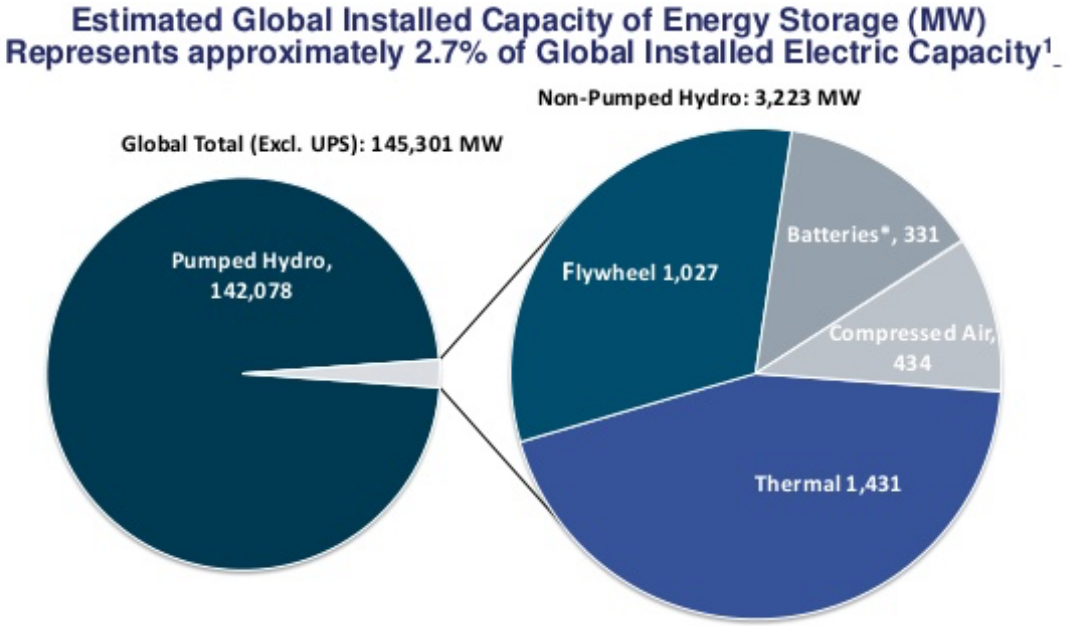
Driven by continued policy support, renewables account for half of additional global generation, overtaking coal around 2030 to become the largest power source

Energy Storage – Outside the Data Center



Hydro Rules – At Least for Now in Large Part thanks to China

Projects: 145 GW installed - 50 Technologies Represented



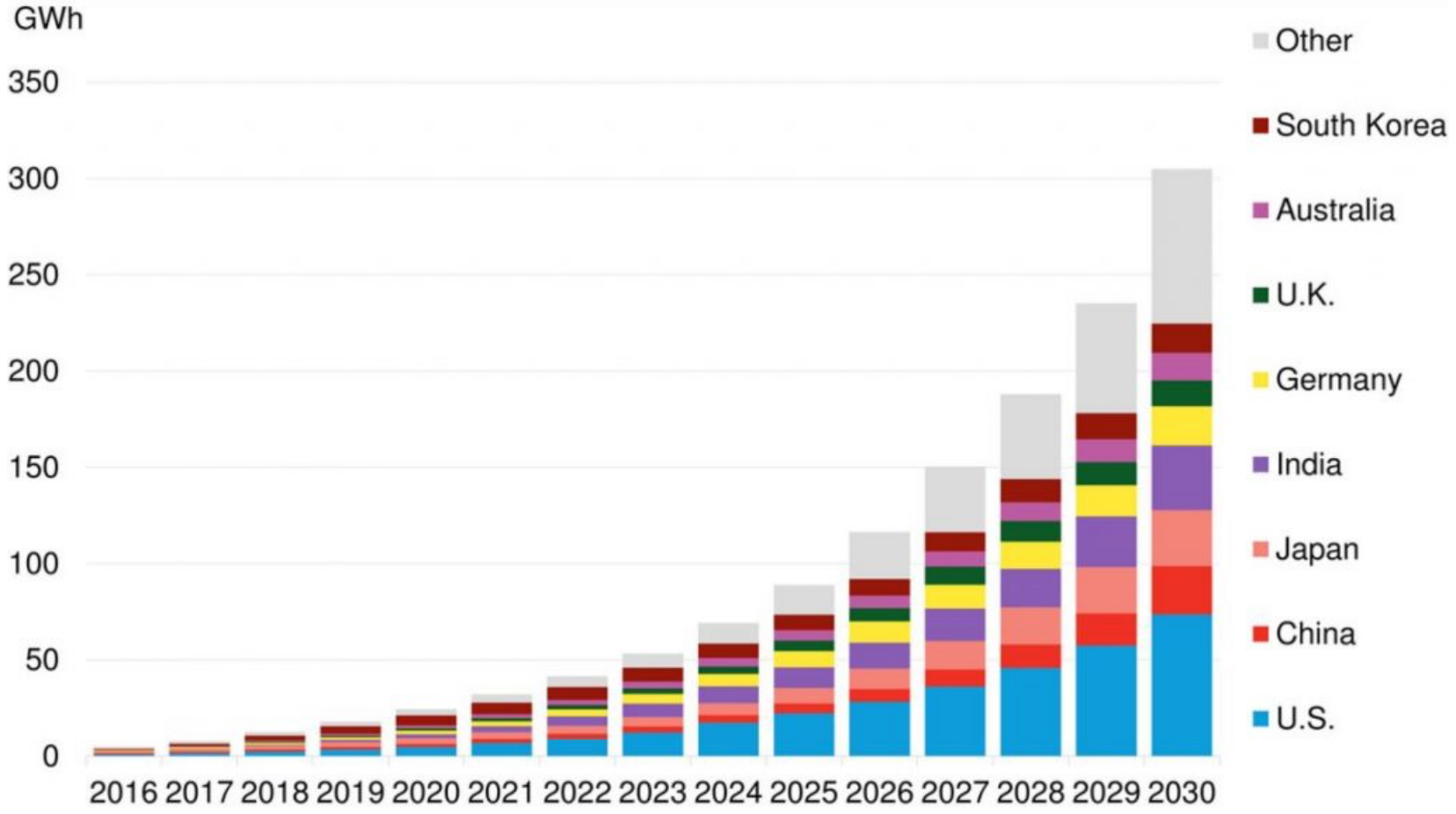
Source: Based on DOE Global Energy Storage Database (http://www.energystorageexchange.org) Est are current as of January 2014

[1]Based on EIA 2010 Total Electricity Installed Capacity Data (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=7)

* Batteries include Flow, Lithium Ion, Sodium Sulfur, Nickel Cadmium, Lead Acid, and Ultra Batteries

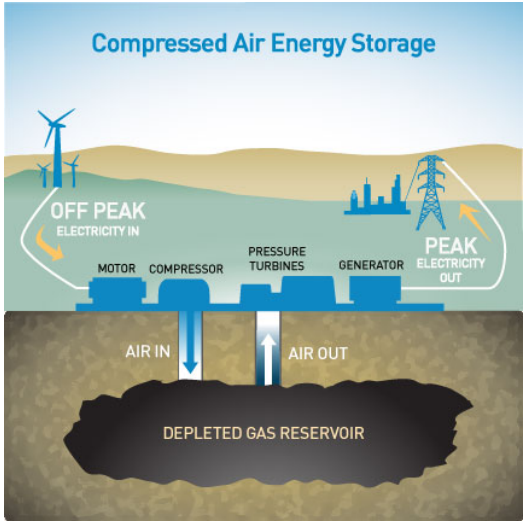
CESA CALIFORNIA ENERGY STORAGE ALLIANCE

Projected Growth of Global Electrical Energy Storage (source BNEF)



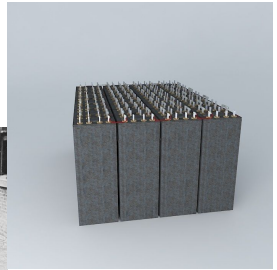
New Energy Storage Systems May Impact Future System Design

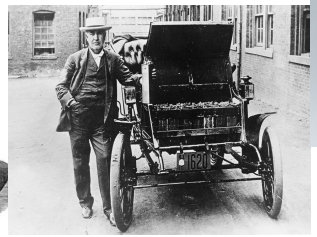
- Internal, On-site, Near-site, Grid
- Old, New, Emerging Platforms
  - Batteries
  - Flywheels / Capacitors
  - Pumped / Compressed
  - Thermal
  - Gravity
- Power, Energy, Volume, Acceleration
  - All Now
  - Some for a While
  - Months / Years
  - Opps, more than you imagined before you knew it

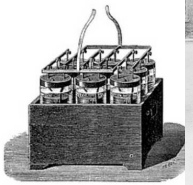


Batteries Remain the Most Practical Solution for Short Duration Applications

Cycles



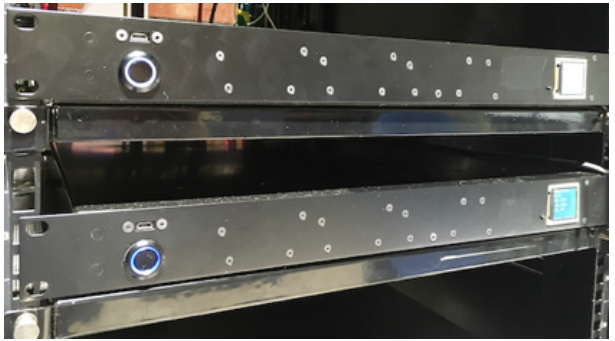




Density

Introduction to Natron Energy

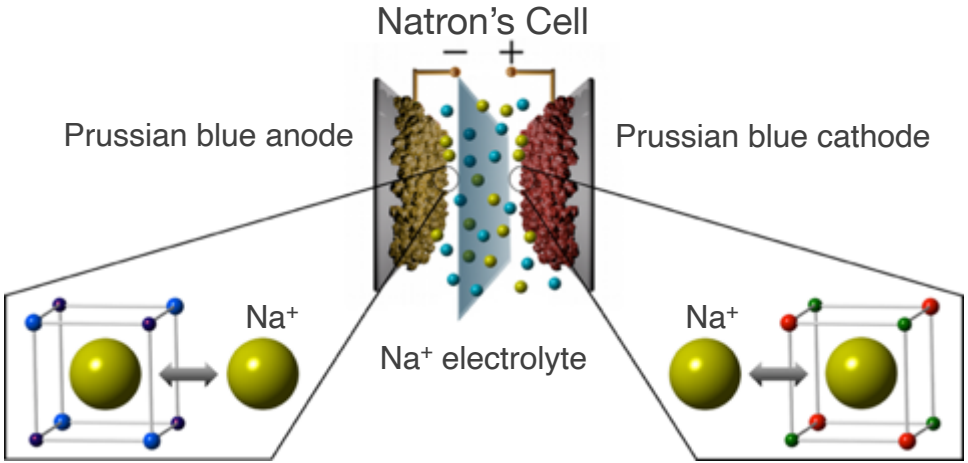
- Company:
  - Founded in 2012 as a Stanford spin out.
  - $38 M raised to date, from investors including Chevron, Khosla Ventures, and Prelude Ventures.
  - Won two ARPA-E grants totaling $4.6M (3% acceptance rate).
  - 50 employees based in Santa Clara, CA.
- Product:
  - High power, long life, safe, rack mounted battery packs.
  - New cell chemistry: Prussian blue electrodes / sodium-ion electrolyte.
- Status:
  - Customer validation in Data Center markets complete, transitioning to commercial supply.
  - UL Recognition core battery cell
  - UL Listing 1U battery pending
  - January 2020 product launch
  - Large Battery Cabinet (300kW) – POC Q4 2020




CHARGING
ONLY

A Unique Prussian Blue Battery Cell

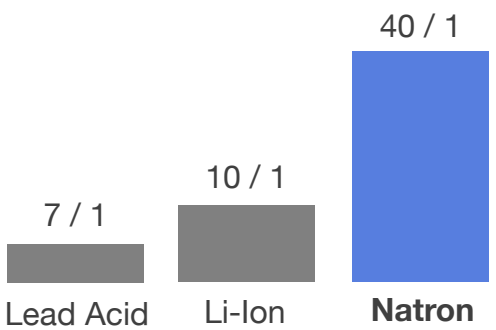
- Prussian blue pigment electrodes store sodium ions.
- Zero-strain charge storage for 10x faster cycling and longer life.
- Dramatically lower cost than Li-ion materials.
- No Rare Earth metals or giant holes in the ground.
- Drop-in to existing pigment plants and Li-ion manufacturing lines.



Natron Energy: A High Power, Long Life, Safe Battery

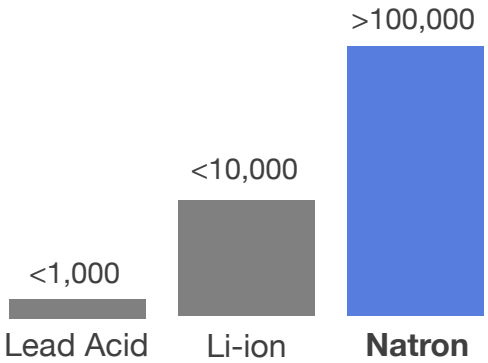
High Power

Max Sustained Power per Energy (W/Wh)



Long Life

Deep Discharge Cycle Life



Safe and Fault Tolerant

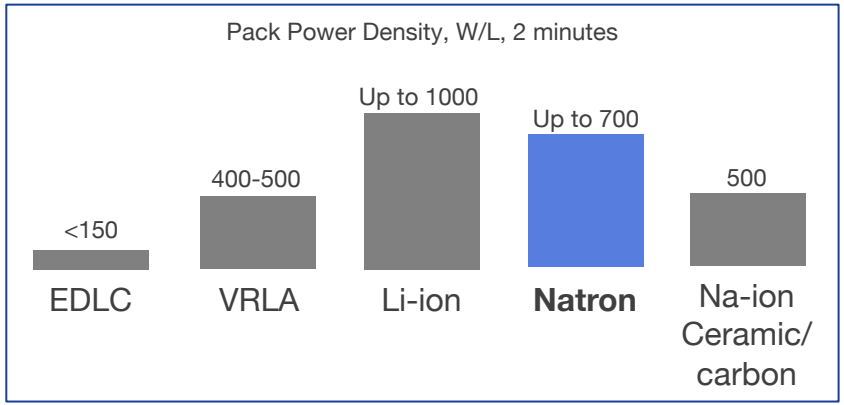
No Fire or Explosion During

	Lead Acid	Li-Ion	Natron
Heating	✓	✗	✓
Overcharge	✗	✗	✓
Short Circuit	✗	✗	✓
Nail Penetration	✓	✓	✓

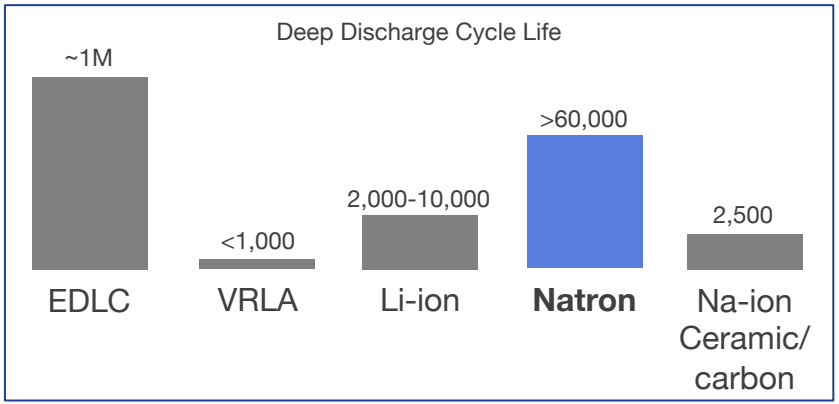
Battery Power / Cycle Life Characteristics

Note: EDLC = ultracapacitor

Pack Power Density



Cycle Life



Prussian Blue sodium-ion delivers more instantaneous to 5-minute power per Unit volume at significantly lower cost than ultracaps, better TCO than Li-ion

Note: Diesel = 300W/L unlimited discharge period

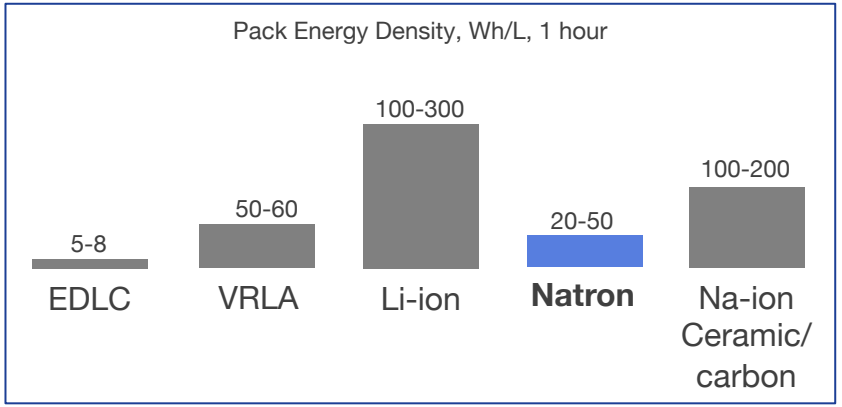
Safety – Density Trade Offs

Note: EDLC = ultracapacitor

Superior Safety

	EDLC	Lead Acid	Li-Ion	**Natron**	Na-Ion Ceramic/ Carbon
Low fire risk	✓	✓	×	✓	✓
No acid	✓	×	✓	✓	✓
No heavy metals	✓	×	✓	✓	✓

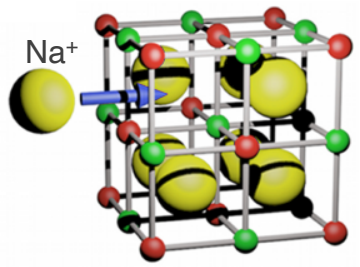
Energy Density

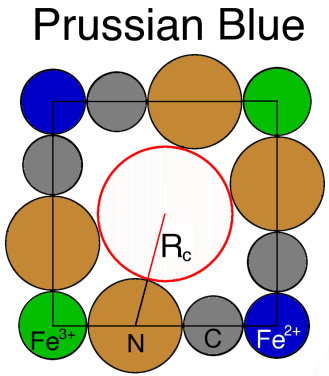


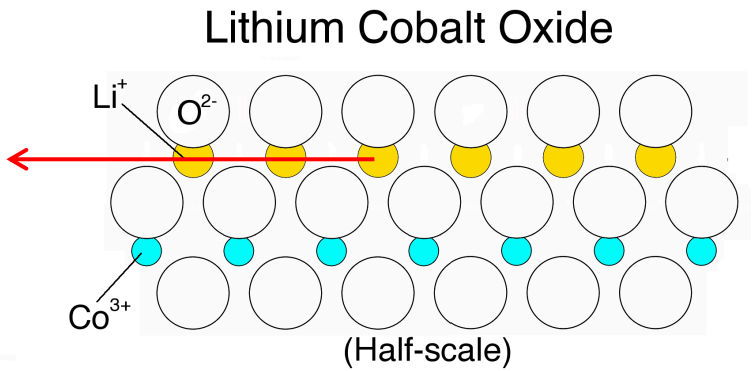
Prussian Blue Na-ion Considered non-flammable, no thermal runaway condition by UL
Core battery cell UL Recognized

Comparison of Charge Storage: Prussian blues vs. Li-ion

Prussian blues: storage sites are larger than sodium ions.







Prussian Blue
Channel radius: R_c = 1.6 Å

Larger than Na+ = 1.12 Å

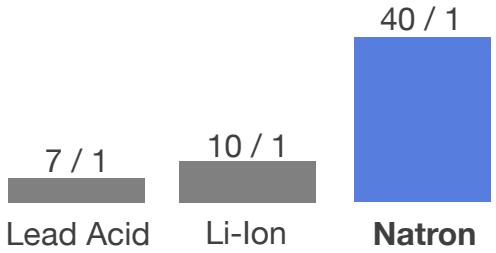
$LiCoO_2$:
Channel radius: R_c = 0.43 Å

Smaller than Li+ = 0.6-0.7 Å

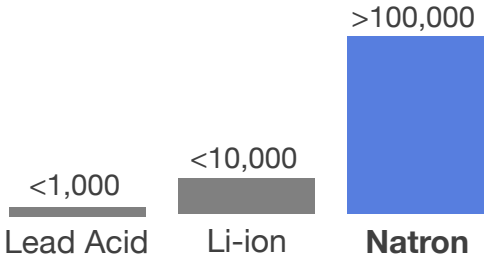
Mission Critical Power article – *Is Battery Technology on the Verge of a Blue Period?*
https://issuu.com/energymagazines/docs/mcp_june_2019_digital_issue/36

Prussian Blue Battery: High Power, Long Life, Safe, Fully De-risked

4x Higher Max Power-to-Energy Ratio



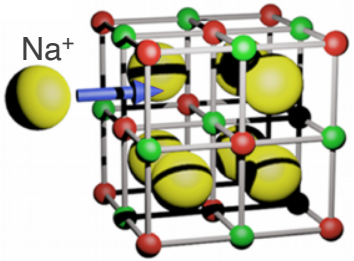
10x Longer Deep Discharge Cycle Life



Nonflammable During Failure and Abuse

	Lead Acid	Li-Ion	Natron
Heating	✓	✗	✓
Overcharge	✗	✗	✓
Short Circuit	✗	✗	✓
Nail Penetration	✓	✓	✓

Na^+ Storage in Proprietary Prussian Blue Electrodes

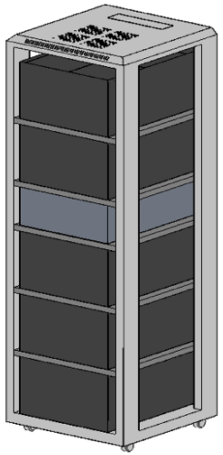


12 patents issued

Data Center Sales Begin Q1 2020

Rack-mounted battery
4kW for 2 minutes

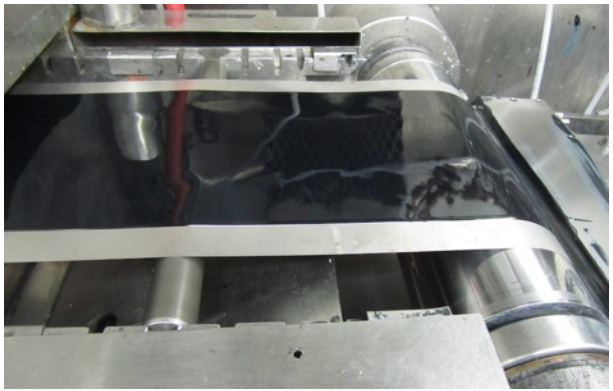
BlueRack
300kW
Q4 2020



Industry Standard Electrode Processing and Cell Assembly

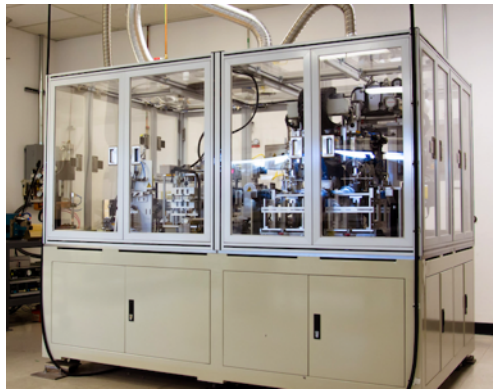
- Prussian blue batteries can be manufactured in any Li-ion plant using stock equipment.
- Electrodes: slurry coating and drying, calendering, slitting/punching.
- Pouch cell assembly: stacking, welding, electrolyte fill, sealing.
- Natron is scaling production through existing manufacturers. No new plants.

Slurry Electrode Coating

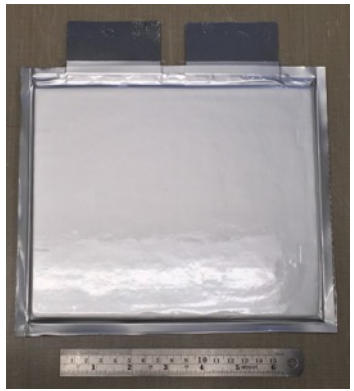


Calendering

Cell Stacking

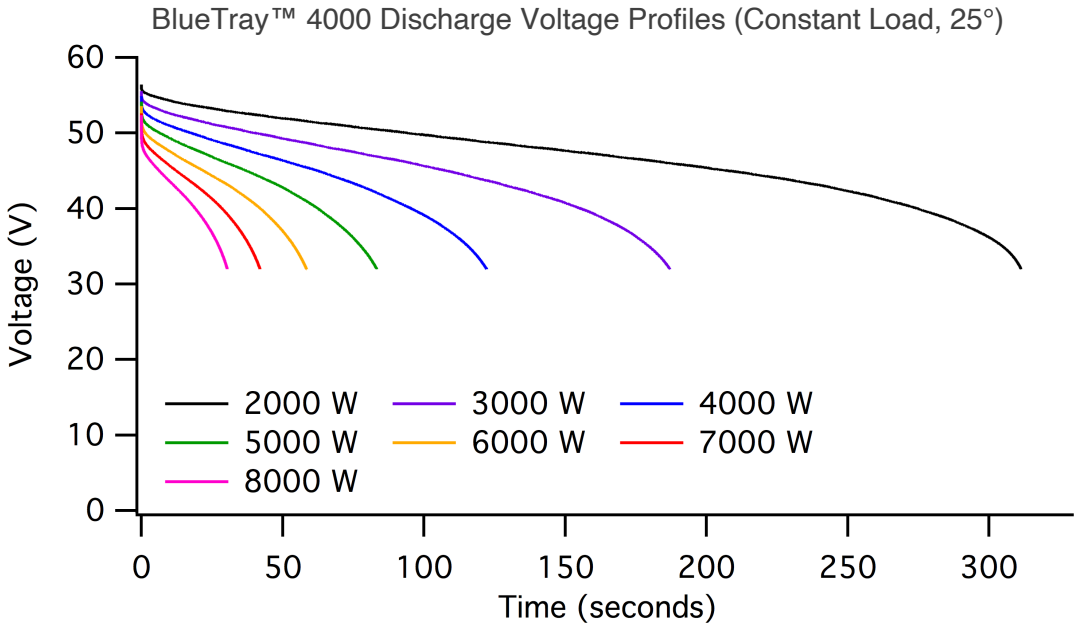


Pouch Cell



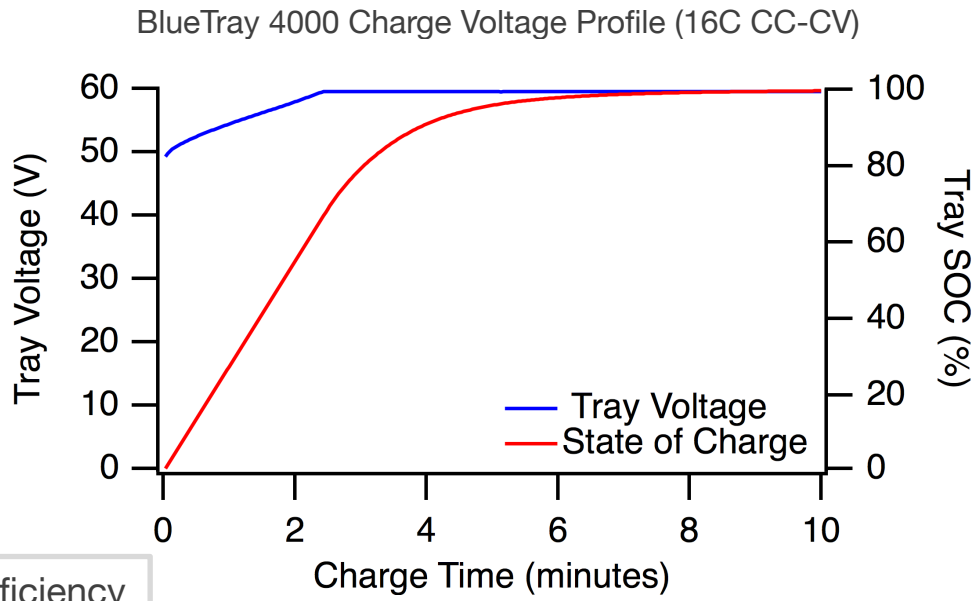
Full Discharge As Fast As 30 Seconds

- Natron's battery has half the internal resistance per energy of lead acid.
- This allows a much higher fraction of total energy to be delivered during rapid discharge.
- 70% of rated energy is delivered during 2 minute discharge at 4kW.
- 33% of rated energy is delivered during 30 second discharge at 8kW.



Full Recharge As Fast As 8 Minutes

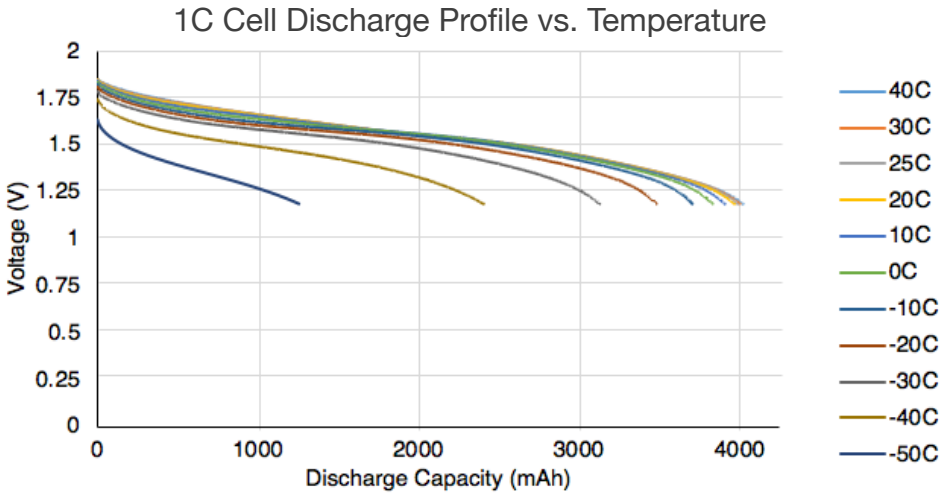
- Natron's tray has unique charge acceptance ability: 0-99% SOC in 8 minutes.
  - 0-70% SOC during 16C recharge lasting 2.5 minutes.
  - 70-99% SOC during constant voltage hold lasting 6 minutes.

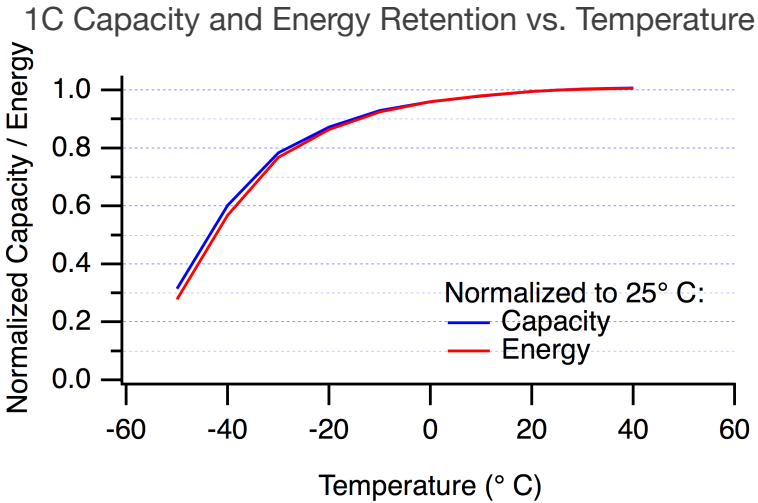


96 - 98% round-trip efficiency

Wide Operating Temperature Range: -50° to +50° C

- 96% of cell energy available during 1C discharge at 0° C.
- 76% of cell energy available at -30° C.





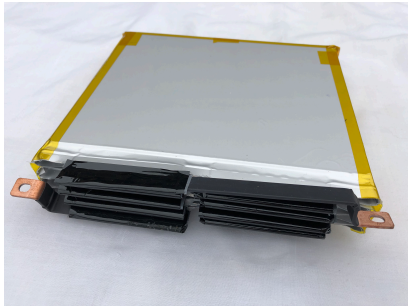
We Won't Dig or Build Our Way to 1,000 TWh with Lithium Alone

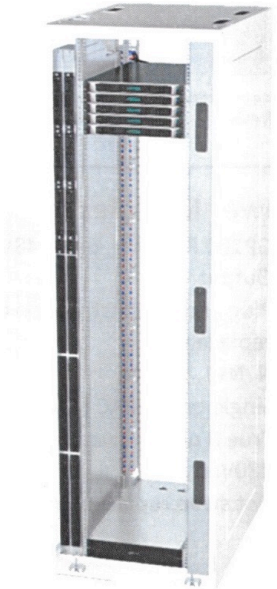
Greenpeace doesn't like Tar Sands just wait until they focus-in on Lithium and Rare Earth Metal extraction and processing

Chemistry World article: A Battery worth its Salt - https://www.chemistryworld.com/features/a-battery-technology-worth-its-salt/3010966.article#/

On-Site Energy Storage Design Considerations for Data Center, Telecom

- Battery is no longer the weakest link
- Ensure Rectifier, Inverter, Wire, Breakers fit power profile
- Think Power over time not total available Energy
- Core battery module – nonflammable, no thermal runaway
- Internal N+1 redundancy at reduced run time





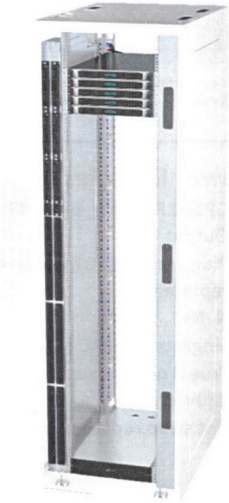
- Lead is NOT Dead!
- Lithium is here to stay, properly deployed for right application
- Diesel, still your best friend for hours to days of operation

Natron Exploring Software Defined Power with Strategic Partners

- Frequent high-power, high cycle-rate applications
- All within White Space – AHJ /UL / NFPA / Insurance concerns with Lithium
- 48V DC to backplane – OCP-like applications
- 48V DC to bi-directional inverter (s) for 230V AC operation
- Real-time peak power capping
- Extra Power Capacity (billable) for Client peak loads

VPS
Virtual Power Systems

- Proof-of-Concept units shipping end-of-year
- Public availability anticipated Q1 2020



Next Steps

- Come visit when you are in the Bay Area
  - We are one exit up 101 from the SJC airport
  - New fab operations are now live
- Participate in our 300kW+ cabinet development and testing
- Explore the merits of Software Defined Power for Peak Shaving, Storage, behind-the-meter applications

- Call, email anytime with questions, wild ideas, data & demo requests

Thank you

Jack Pouchet

+1 949.351.8142

jack@natron.energy

www.natron.energy

Twitter: @JackPouchet

LinkedIn: https://www.linkedin.com/in/jack-pouchet-aa569a/

Mission Critical Power article: https://issuu.com/energymagazines/docs/mcp_june_2019_digital_issue/36

Software Defined Power: https://natron.energy/wp-content/uploads/2019/09/VPS_Natron_Press-Release_09_23_2019_NatronRev.pdf

EV Fast Charging: https://natron.energy/wp-content/uploads/2019/09/Natron_CEC_Press_2019.pdf