

# Natron Energy

Energy Storage Trends  
Data Centers, Edge, and Beyond

Jack Pouchet

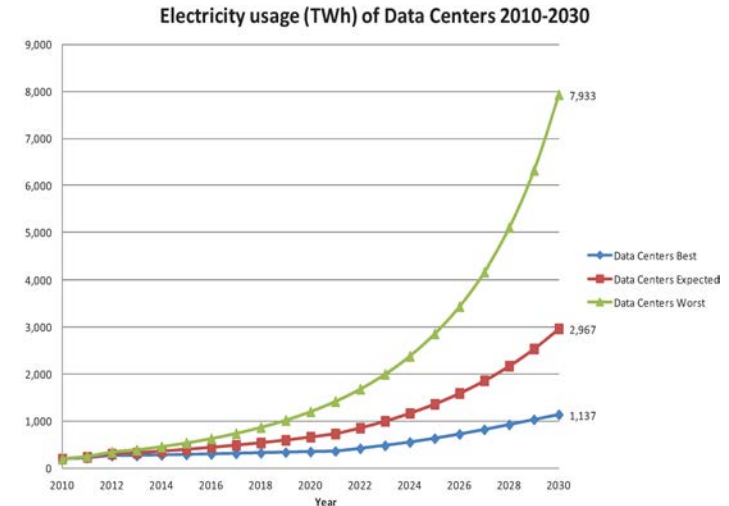
# Data Center Electrical Energy Consumption – There is an Upper Limit

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

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

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

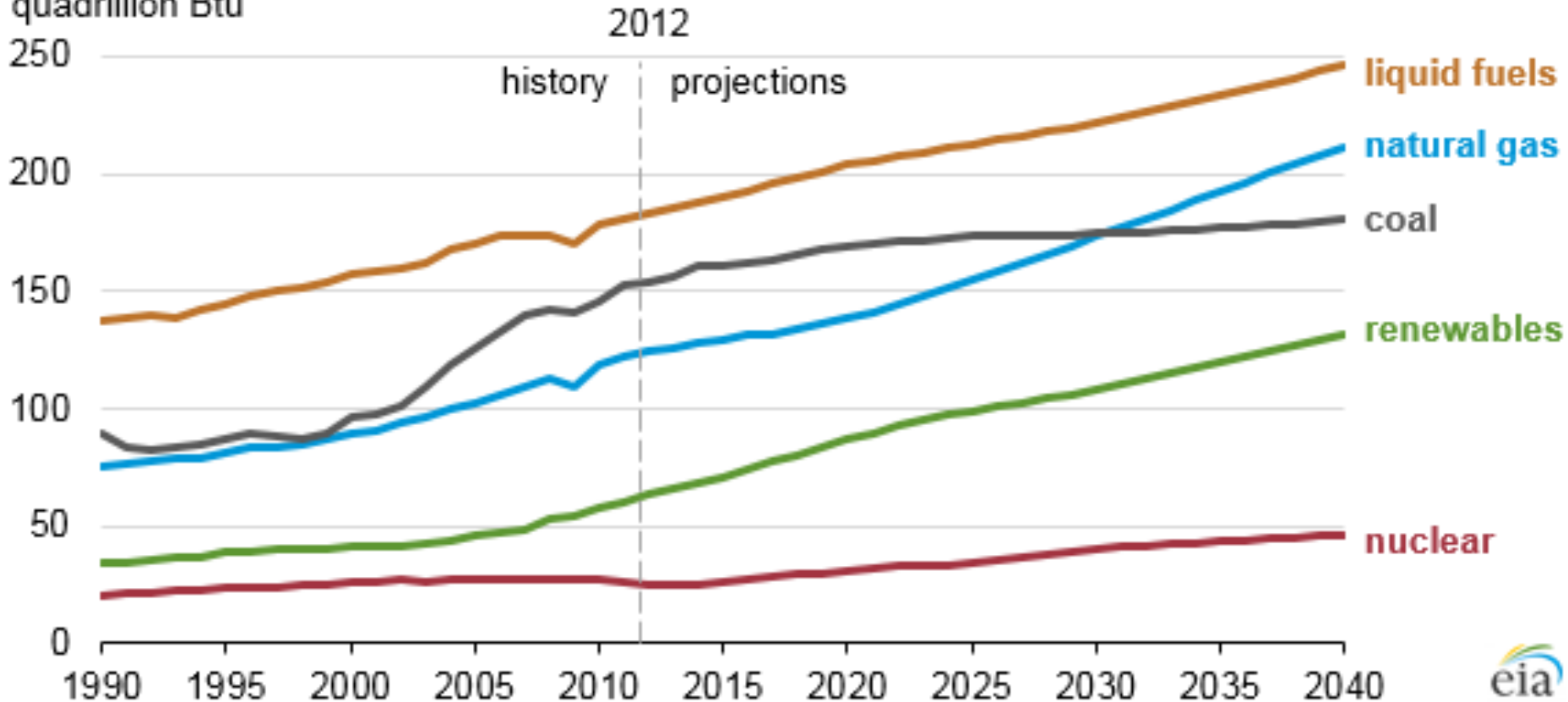
<sup>3</sup> <https://www.srgresearch.com/articles/hyperscale-data-center-count-passed-500-milestone-q3>



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

## World energy consumption by source, 1990-2040

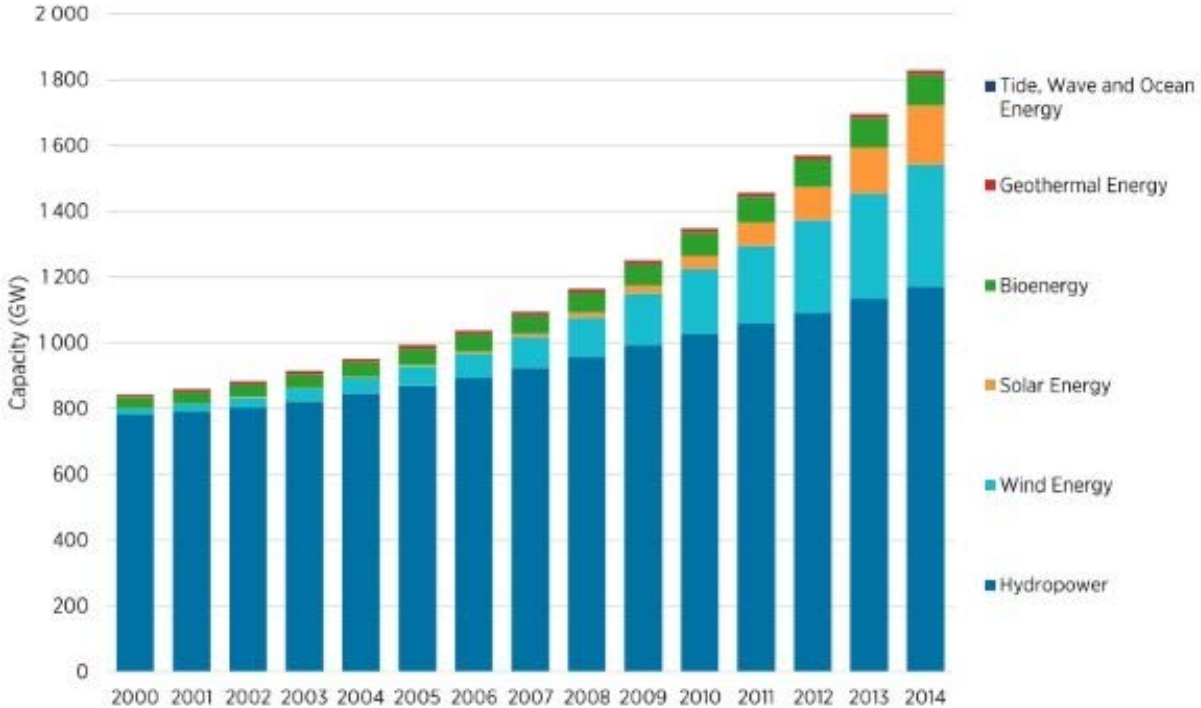
quadrillion Btu



# Exponential Growth of Renewables – Not Likely

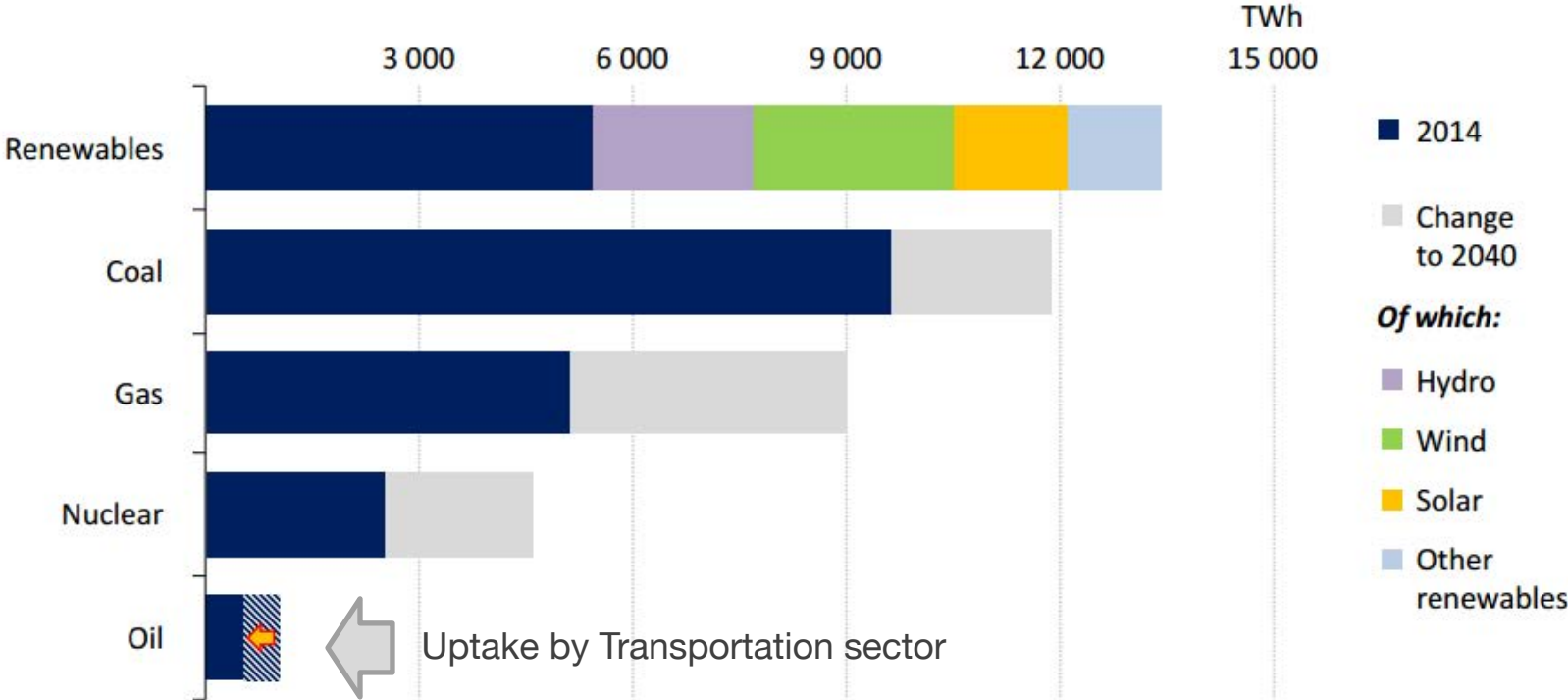


Installed Renewable Power Capacity - Cumulative Capacity



# Electricity – Best Chance at a Green Future

## Global electricity generation by source



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

## Electrical energy storage systems

### Mechanical

Pumped hydro - PHS

Compressed air - CAES

Flywheel - FES

### Electrochemical

Secondary batteries  
Lead acid / NiCd / NiMH / Li / NaS

Flow batteries  
Redox flow / Hybrid flow

### Chemical

Hydrogen  
Electrolyser / Fuel cell / SNG

### Electrical

Double-layer  
Capacitor - DLC

Superconducting  
magnetic coil - SMES

### Thermal

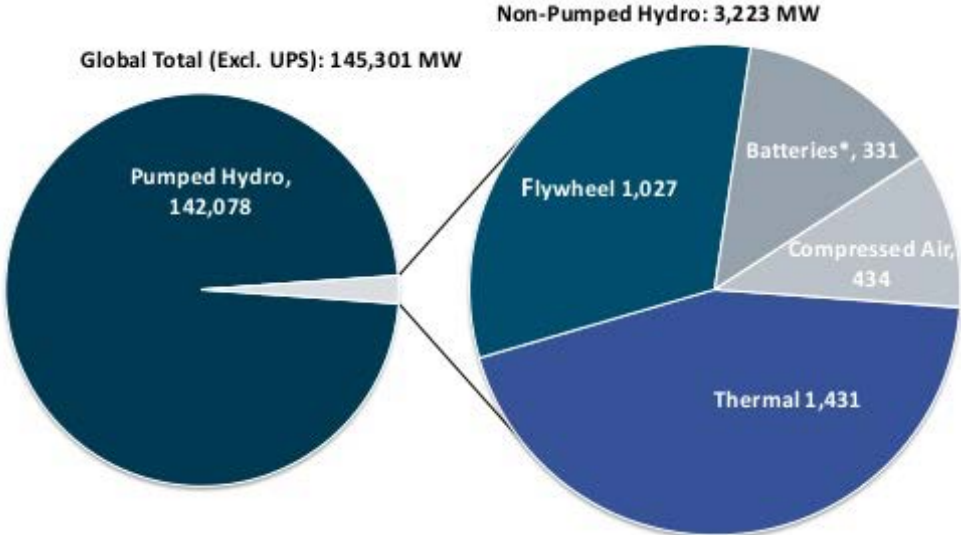
Sensible heat storage  
Molten salt / A-CAES



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

## Projects: 145 GW installed - 50 Technologies Represented

Estimated Global Installed Capacity of Energy Storage (MW)  
Represents approximately 2.7% of Global Installed Electric Capacity<sup>1</sup>

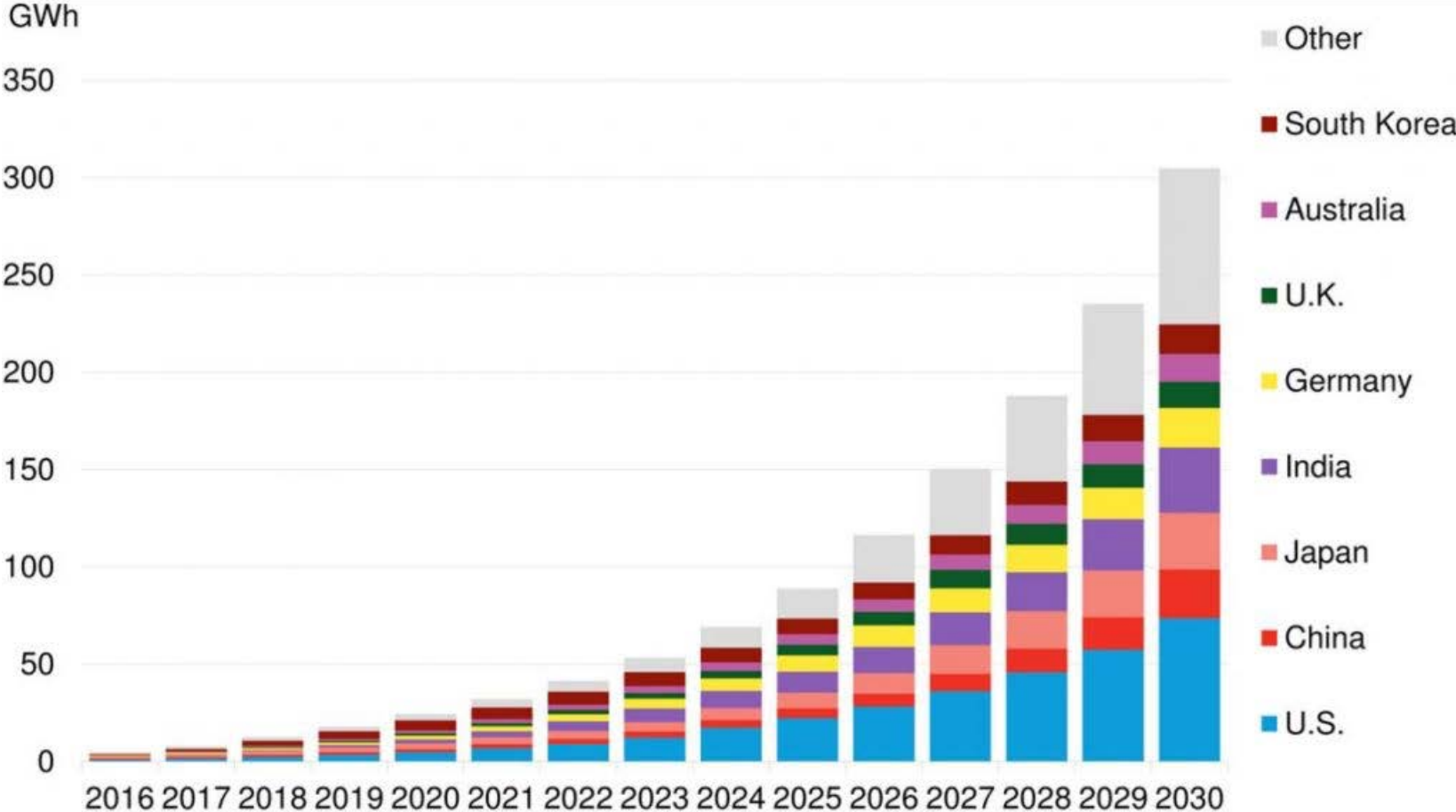


Source: Based on DOE Global Energy Storage Database (<http://www.energystorageexchange.org>) Est are current as of January 2014

<sup>1</sup>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

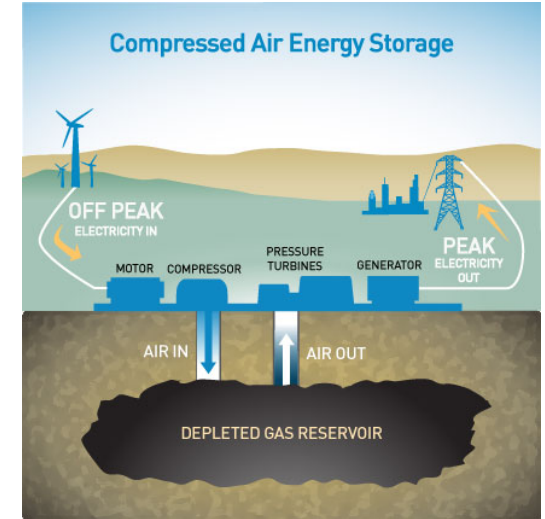
# Projected Growth of Global Electrical Energy Storage (source BNEF)





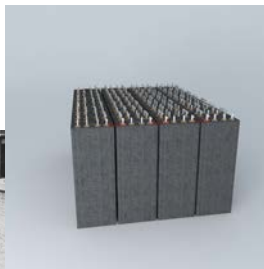
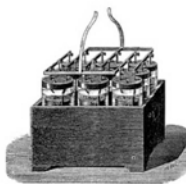
# New Energy Storage Systems May Impact Future System Design

- 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

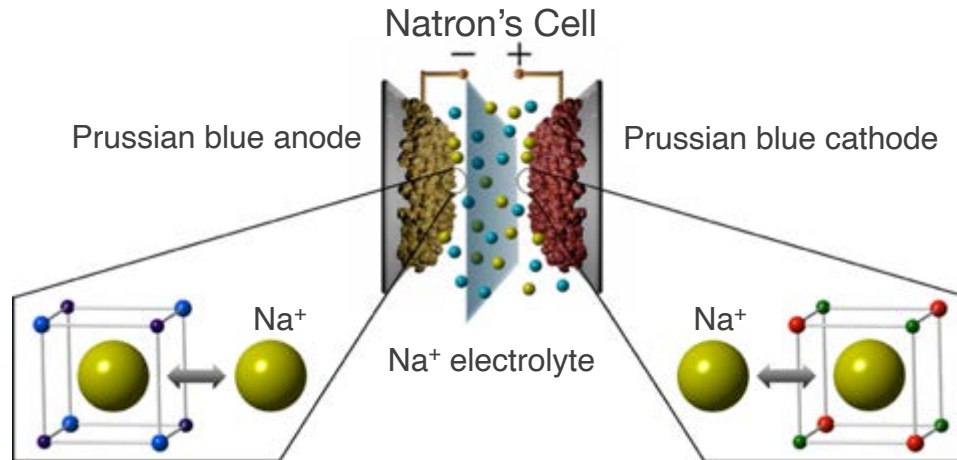




CHARGING  
ONLY

# A Unique Prussian Blue Battery Cell

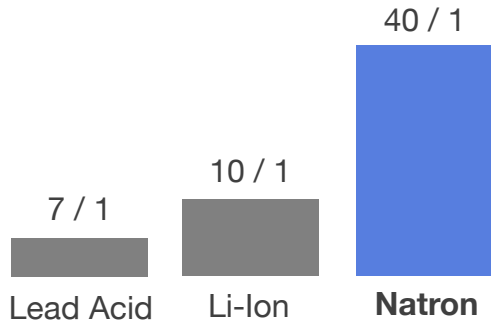
- Prussian blue pigment electrodes store sodium ions.
- Zero-strain charge storage for 10x faster cycling and longer life.
- Dramatically lower cost than Li-ion materials.
- No Rare Earth metals or giant holes in the ground.
- Drop-in to existing pigment plants and Li-ion manufacturing lines.



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

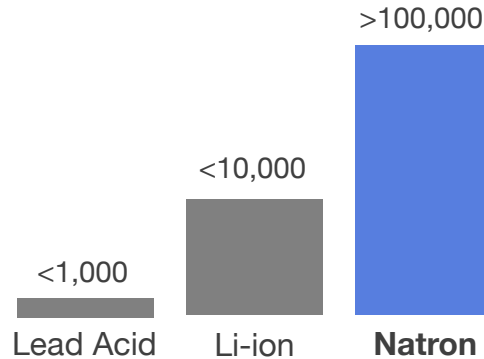
## High Power

Max Sustained Power per Energy (W/Wh)



## Long Life

Deep Discharge Cycle Life



## Safe and Fault Tolerant

No Fire or Explosion During

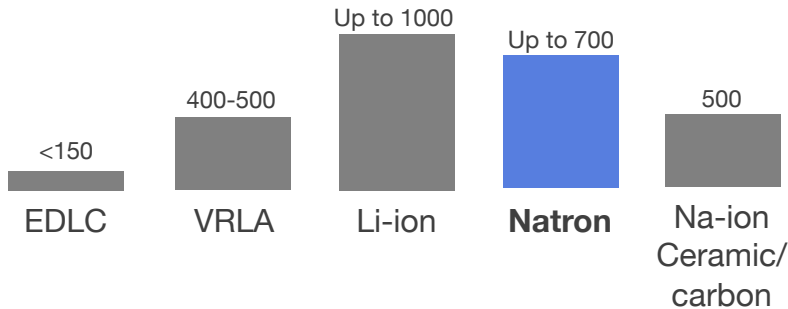
Heating	✓	✗	✓
Overcharge	✗	✗	✓
Short Circuit	✗	✗	✓
Nail Penetration	✓	✓	✓
	Lead Acid	Li-Ion	Natron

# Battery Power / Cycle Life Characteristics

Note: EDLC = ultracapacitor

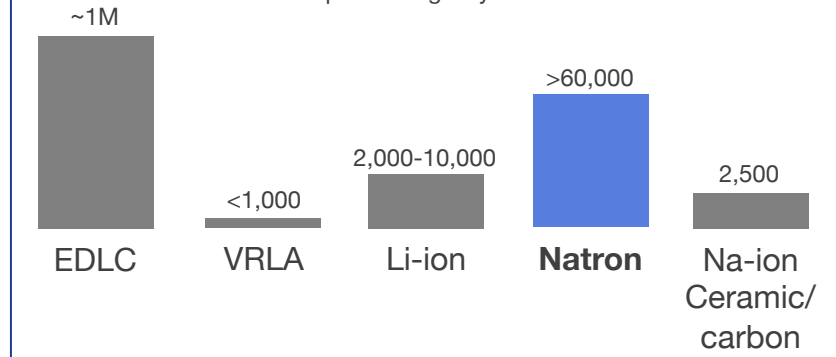
## Pack Power Density

Pack Power Density, W/L, 2 minutes



## Cycle Life

Deep Discharge 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





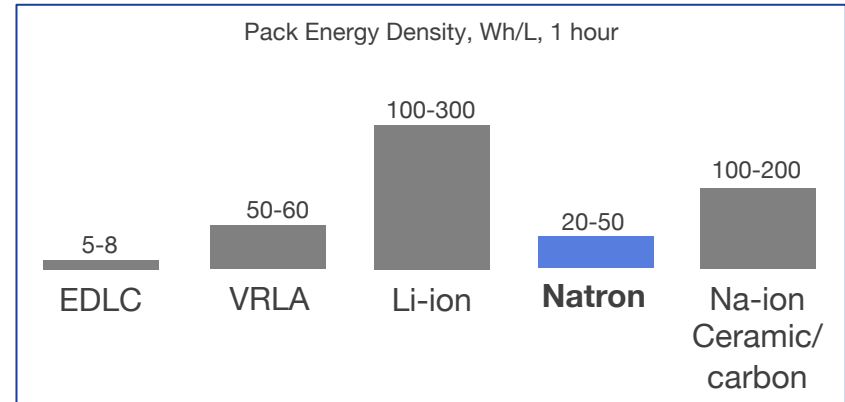
# Safety – Density Trade Offs

Note: EDLC = ultracapacitor

## Superior Safety

Low fire risk	✓	✓	✗	✓	✓
No acid	✓	✗	✓	✓	✓
No heavy metals	✓	✗	✓	✓	✓
	EDLC	Lead Acid	Li-ion	<b>Natron</b>	Na-ion Ceramic/ Carbon

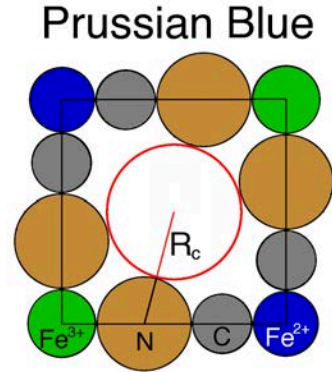
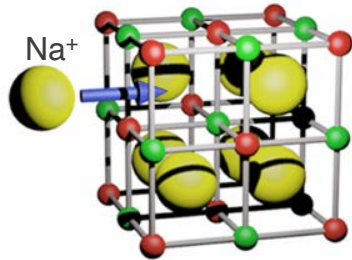
## Energy Density



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

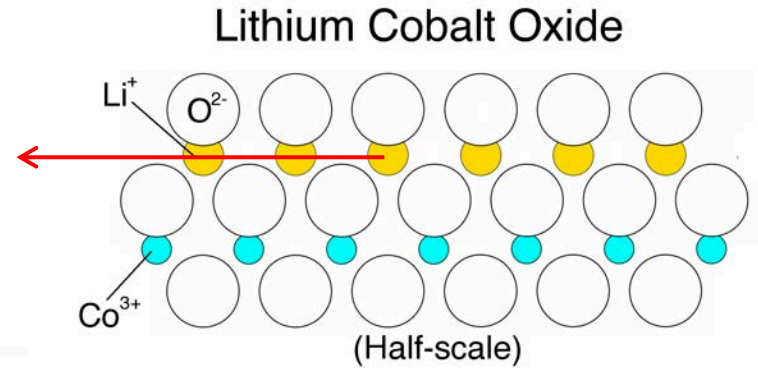
# Comparison of Charge Storage: Prussian blues vs. Li-ion

Prussian blues: storage sites are larger than sodium ions.



Prussian Blue  
Channel radius:  $R_c = 1.6 \text{ \AA}$

Larger than  $\text{Na}^+ = 1.12 \text{ \AA}$



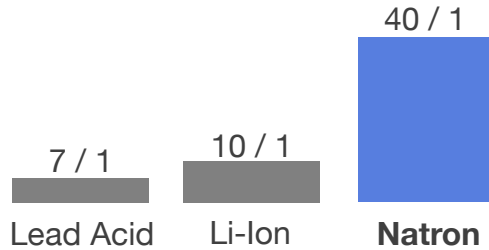
$\text{LiCoO}_2$ :  
Channel radius:  $R_c = 0.43 \text{ \AA}$

Smaller than  $\text{Li}^+ = 0.6\text{-}0.7 \text{ \AA}$

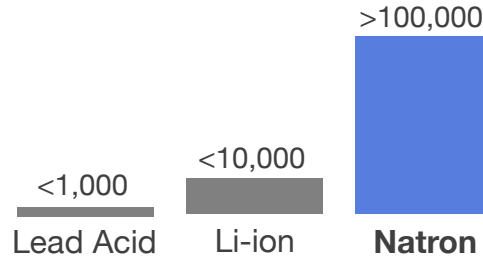
Mission Critical Power article – *Is Battery Technology on the Verge of a Blue Period?*  
[https://issuu.com/energymagazines/docs/mcp\\_june\\_2019\\_digital\\_issue/36](https://issuu.com/energymagazines/docs/mcp_june_2019_digital_issue/36)

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

4x Higher Max  
Power-to-Energy Ratio



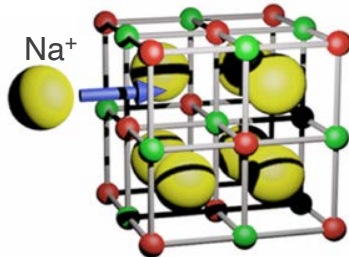
10x Longer Deep Discharge  
Cycle Life



Nonflammable During  
Failure and Abuse

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

Na<sup>+</sup> Storage in Proprietary  
Prussian Blue Electrodes



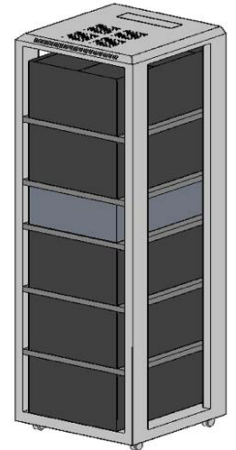
12 patents issued

Data Center Sales  
Begin Q1 2020



Rack-mounted battery  
4kW for 2 minutes

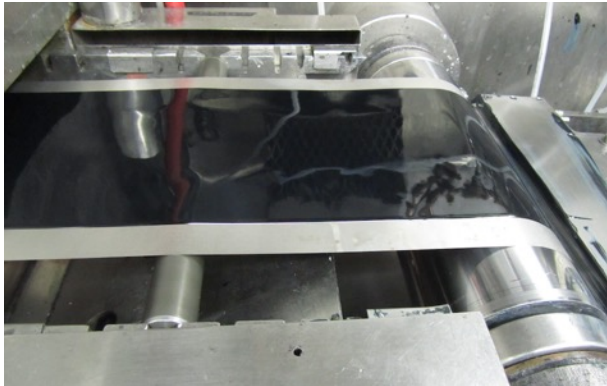
BlueRack  
300kW  
Q4 2020



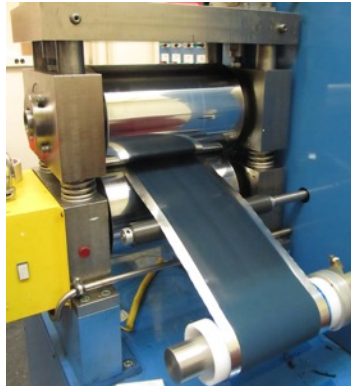
# Industry Standard Electrode Processing and Cell Assembly

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

Slurry Electrode Coating



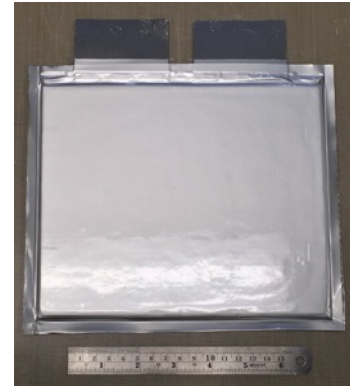
Calendering



Cell Stacking

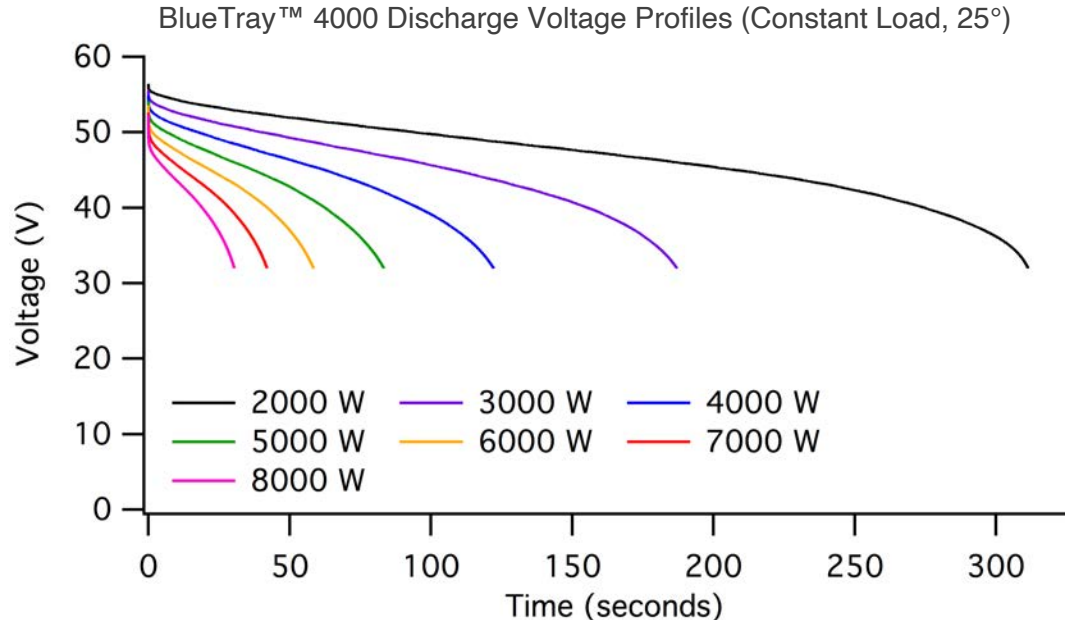


Pouch Cell



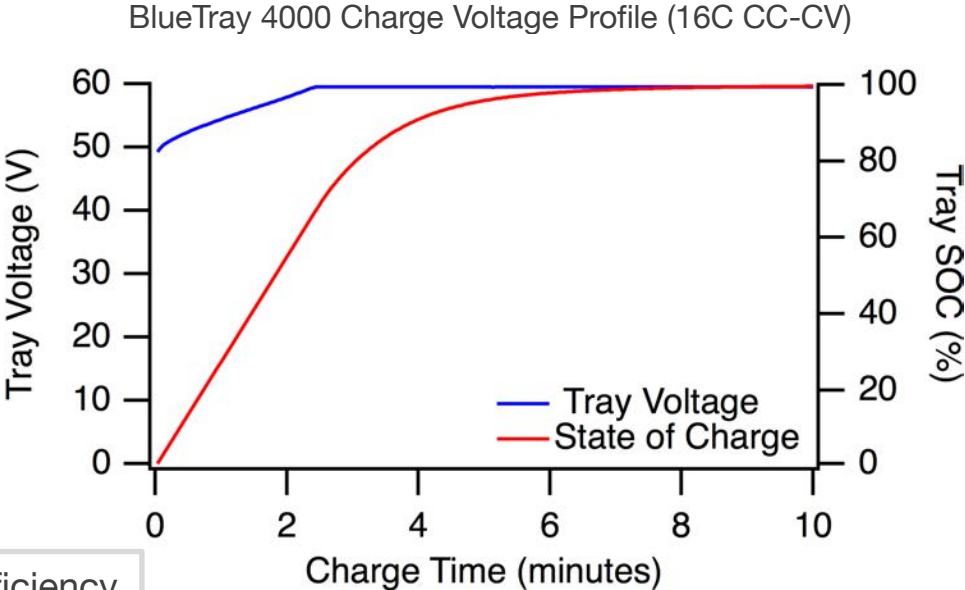
## Full Discharge As Fast As 30 Seconds

- 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

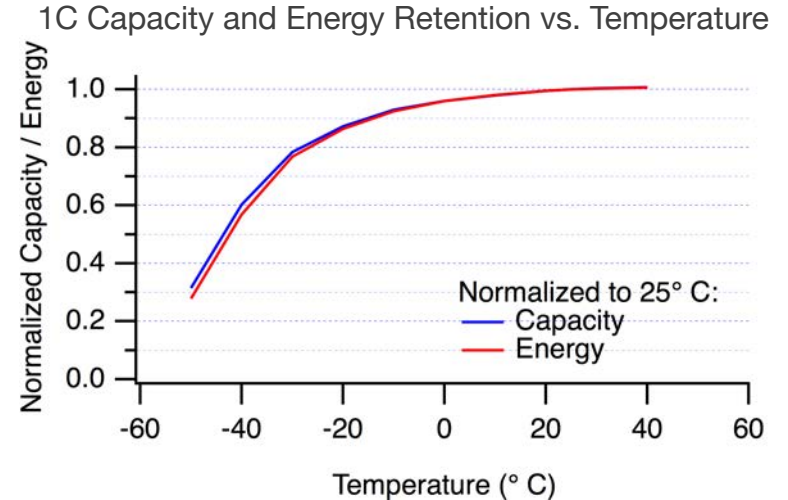
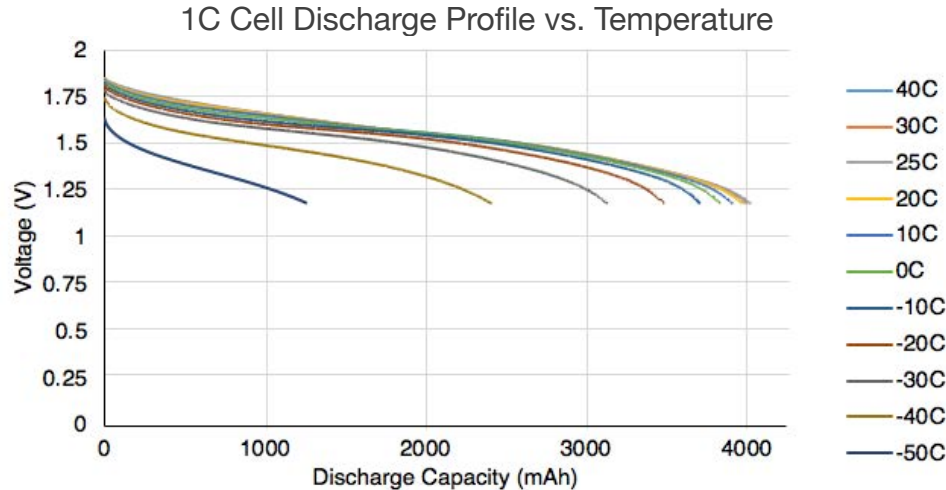
- Natron’s tray has unique charge acceptance ability: 0-99% SOC in 8 minutes.
  - 0-70% SOC during 16C recharge lasting 2.5 minutes.
  - 70-99% SOC during constant voltage hold lasting 6 minutes.



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

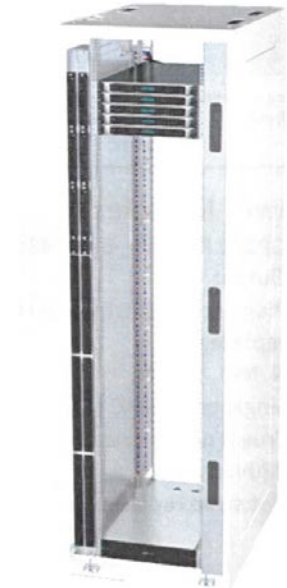


Greenpeace doesn't like Tar Sands just wait until they focus-  
in on Lithium and Rare Earth Metal extraction and processing

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

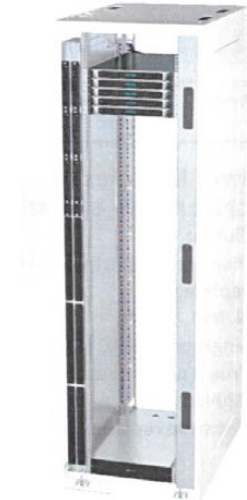
# On-Site Energy Storage Design Considerations for Data Center, Telecom

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



## Next Steps

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- 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

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Thank you

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Mission Critical Power article: [https://issuu.com/energymagazines/docs/mcp\\_june\\_2019\\_digital\\_issue/36](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](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](https://natron.energy/wp-content/uploads/2019/09/Natron_CEC_Press_2019.pdf)