Energy Storage Technology Trends – Implications for Mission Critical Infrastructure

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VP Sales

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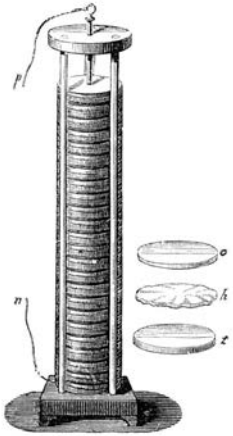
Natron Energy

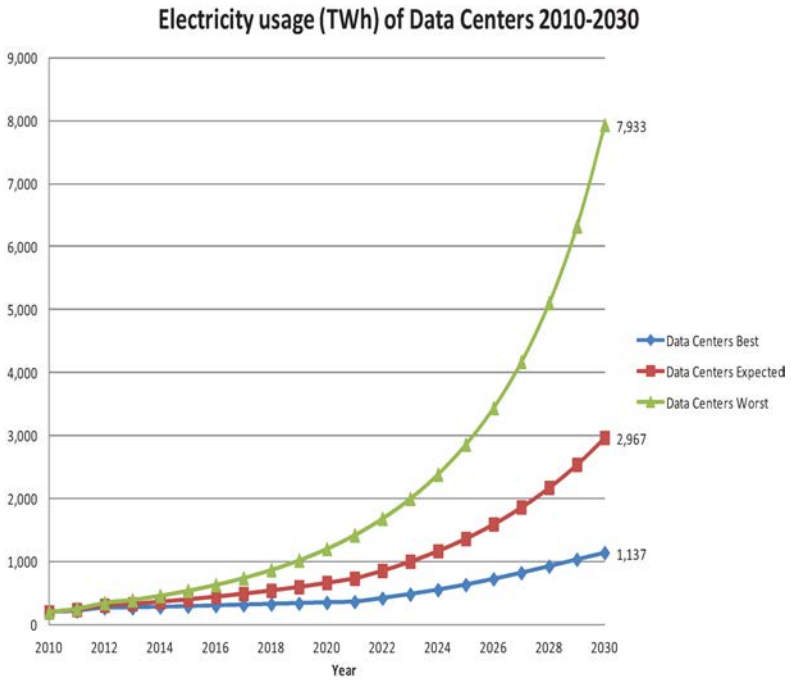
Volta – 220 Years Later

- Data Center energy consumption – driving / forcing new power systems moving beyond energy efficiency alone
- Data Centers – demanding carbon free energy
- Regional / Local energy production: all about renewables
- Innovators exploring on-site generation
- Grid Energy Storage – full of exciting announcements



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]

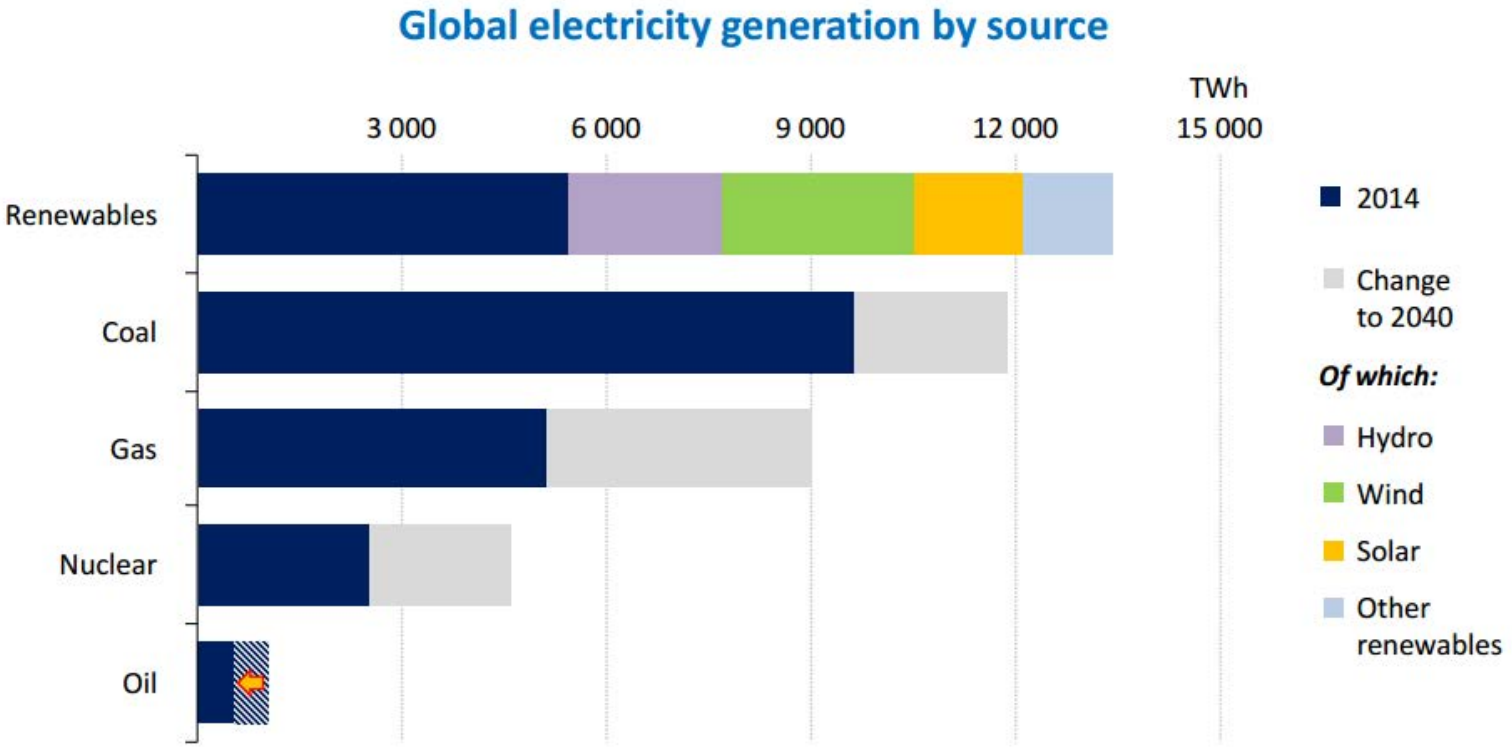


[1] https://data-economy.com/the-importance-of-green-data-centres/

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

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

Electricity – Best Chance at a Green



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

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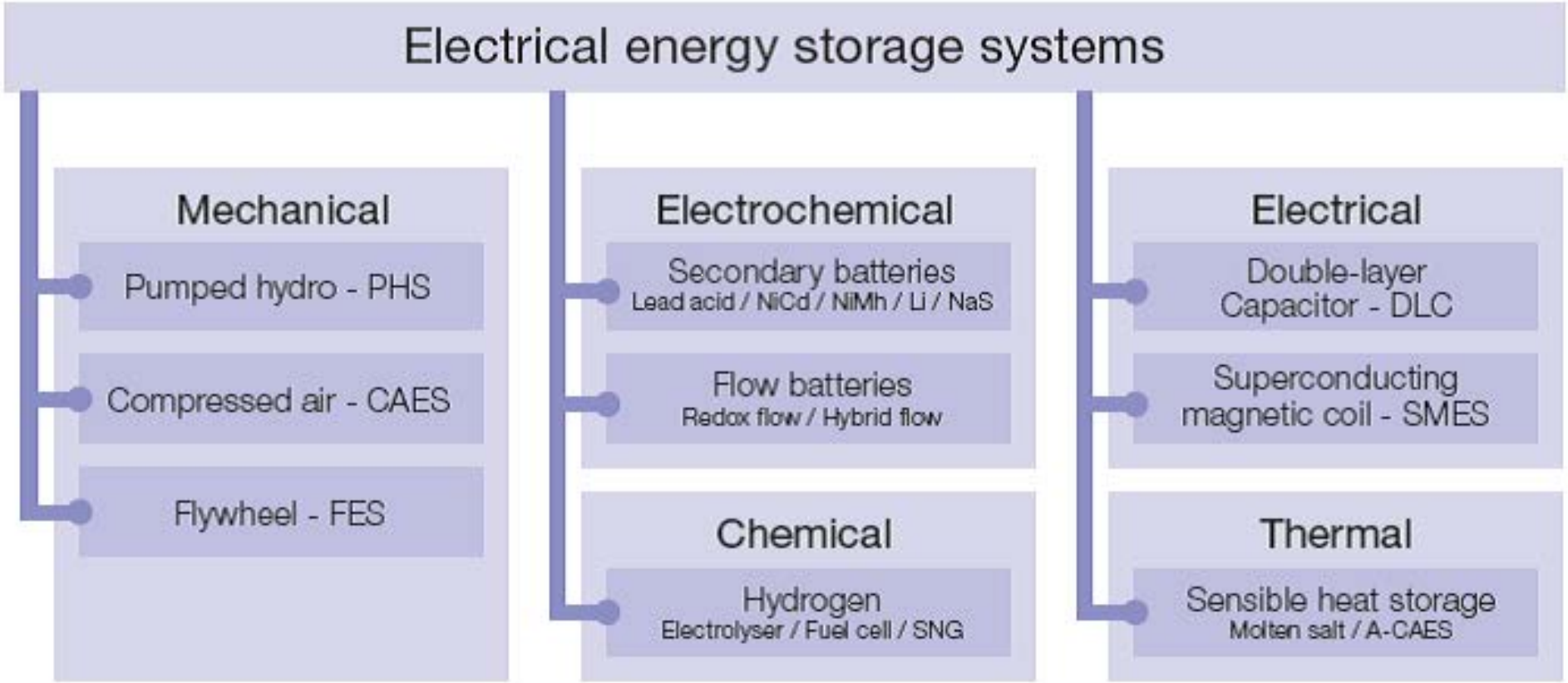
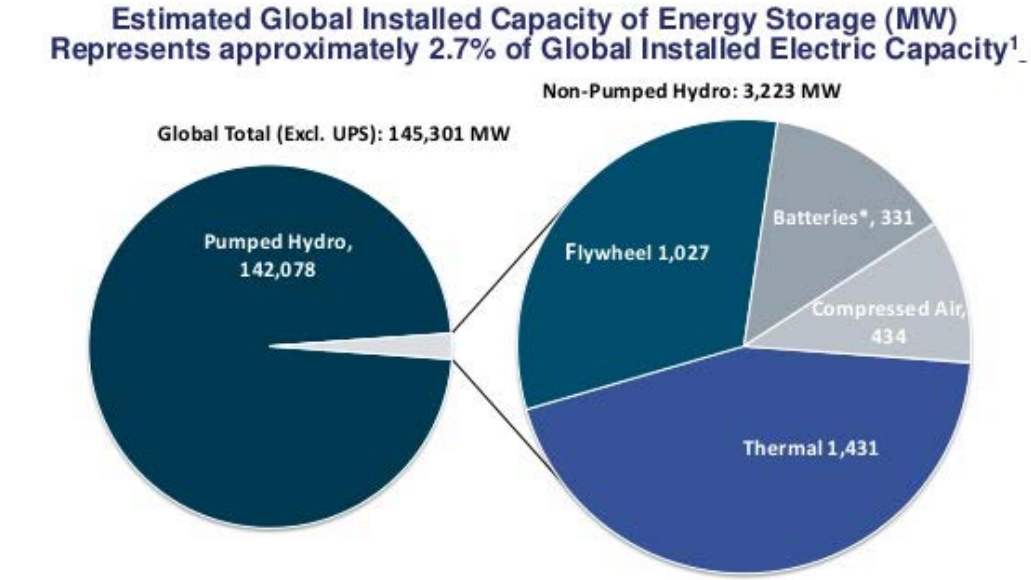
Grid Stability / Availability Require



Hydro Rules!

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

4

CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

Note:

Excludes UPS / Data Centers

3-Phase / MW sites

1.1 – 1.3 x Capacity

Batteries (Lead)

Generators (Diesel)

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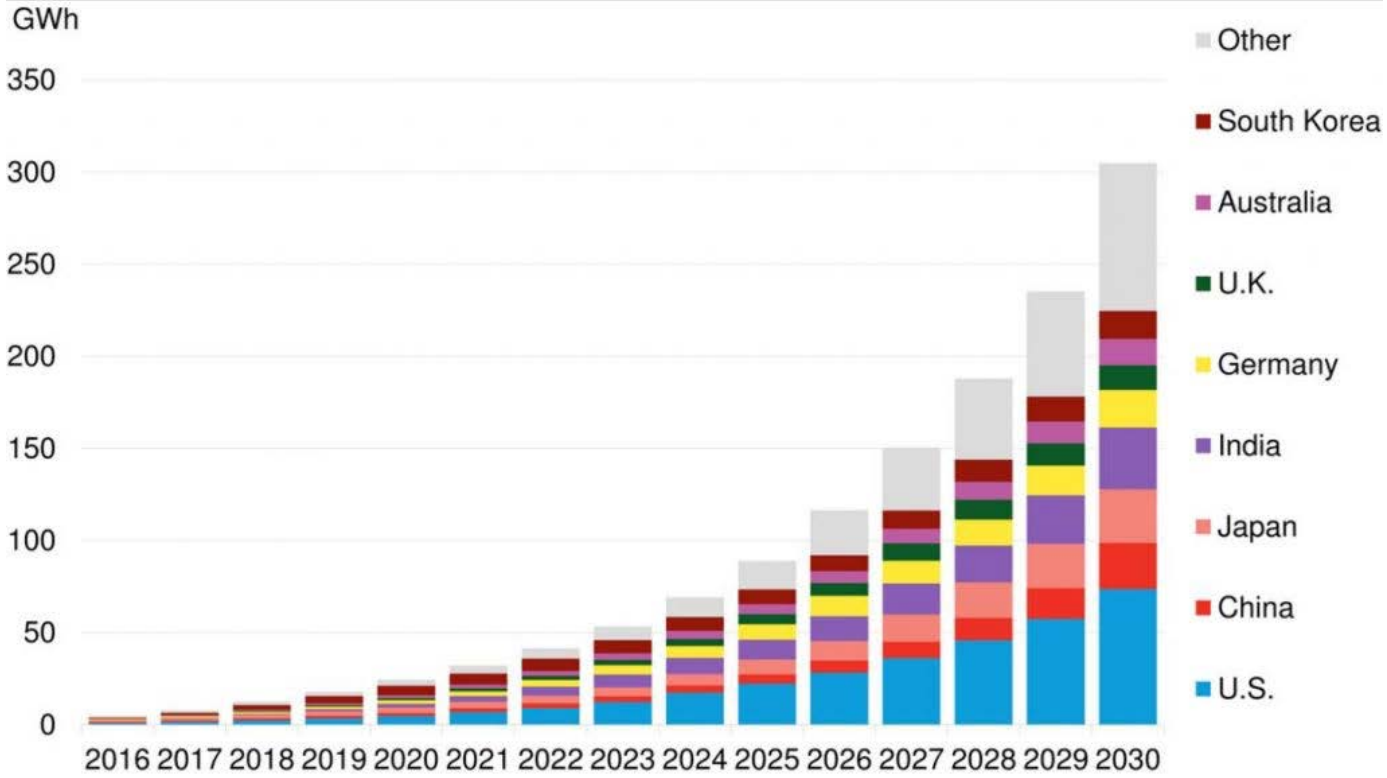
Projected Growth of Global Electrical Energy Storage



>75% Hydro

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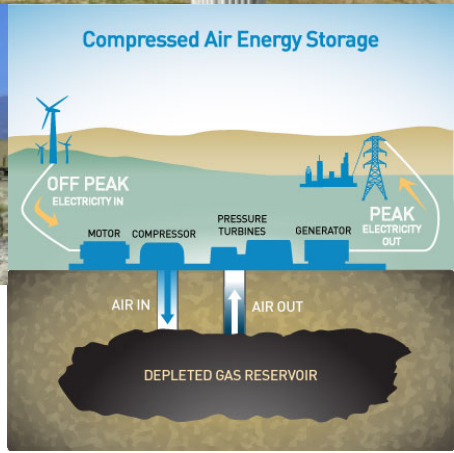
New Systems / Technologies Emerging

- 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: Still the Most Practical

Cycles

Density

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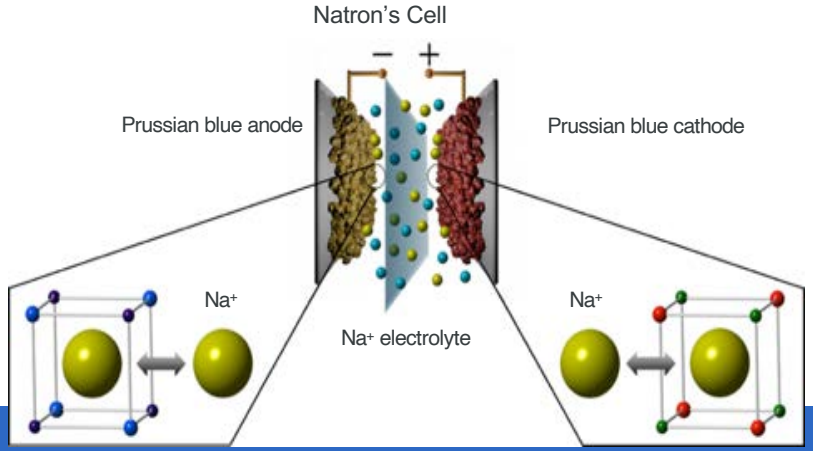
Introduction to Natron Energy

- Company:
  - Founded in 2012 as a Stanford spin out
  - > $70 M raised to date, from investors including ABB, 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:
  - Ramping commercial production
  - UL Recognition core battery cell – 9540A (Nonflammable, no thermal runaway) 1973, NFPA855
  - UL 1973 Listing 1U battery July
  - Software Defined Power Platform shipping now
  - Large Battery Cabinet (300kW) – 2021

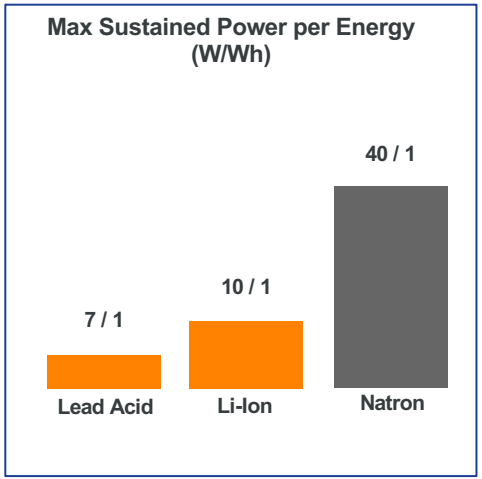
Unique Prussian Blue Battery Cell

- Prussian blue pigment electrodes store sodium ions
- Zero-strain charge storage for 10x faster cycling and longer life
- Extremely low internal impedance
- 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

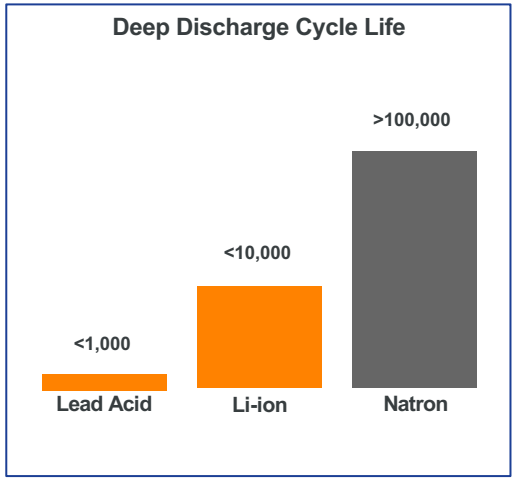


A High Power, Long Life, Safe Battery

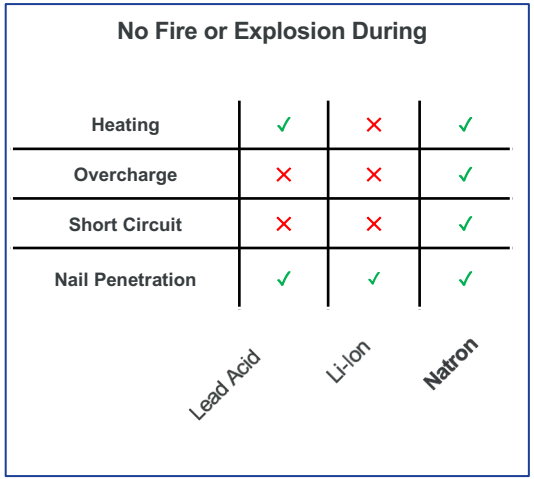
High Power



Long Life



Safe and Fault Tolerant



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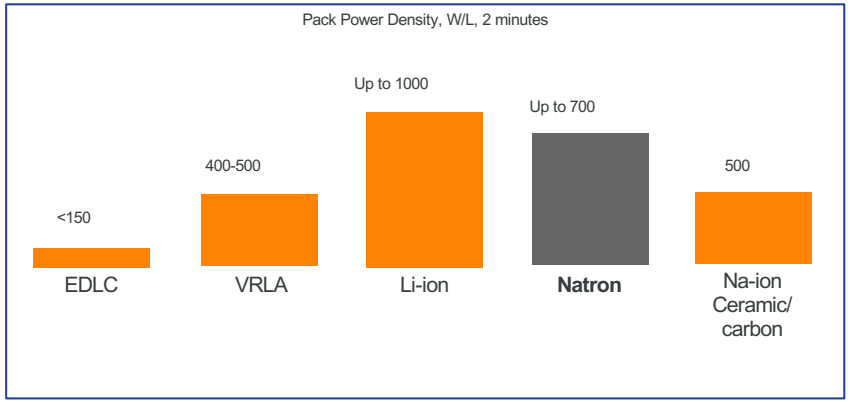
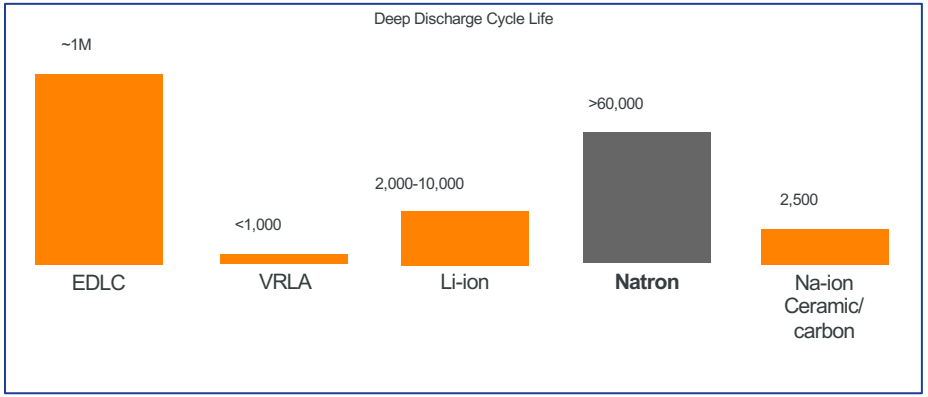
Battery Power / Life Cycle

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

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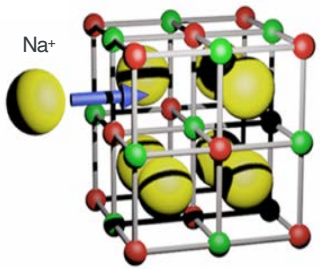
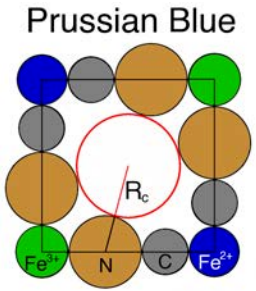
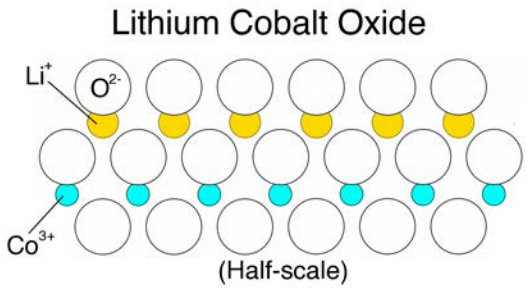
Na-ion / Li-ion Comparison

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

Na-ion ½ internal resistance of any Lithium chemistry

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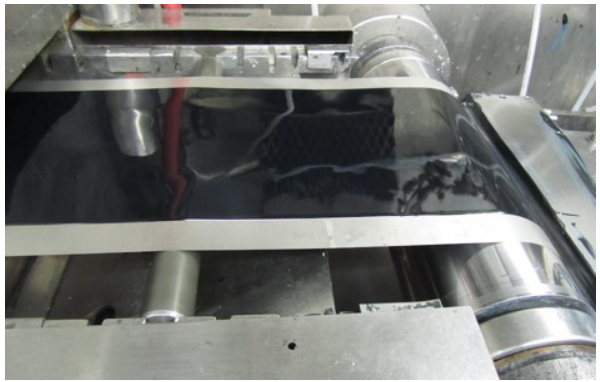
Industry Standard Manufacturing

- 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

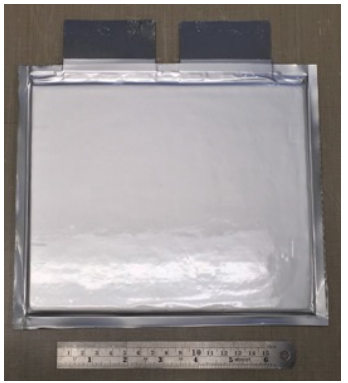
Slurry Electrode Coating



Calendering

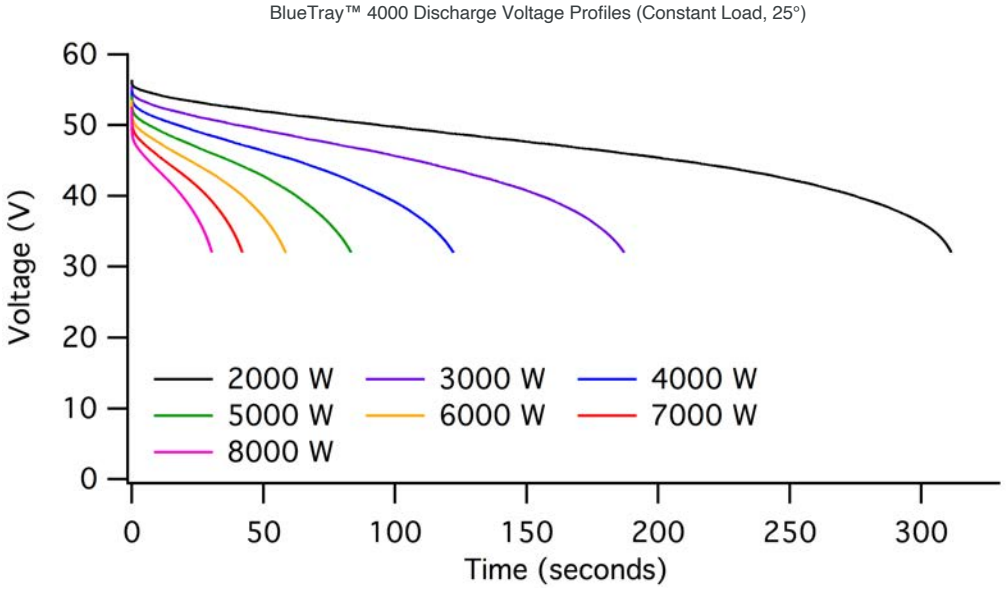
Cell Stacking

Pouch Cell



Unique Performance Characteristics

- 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.

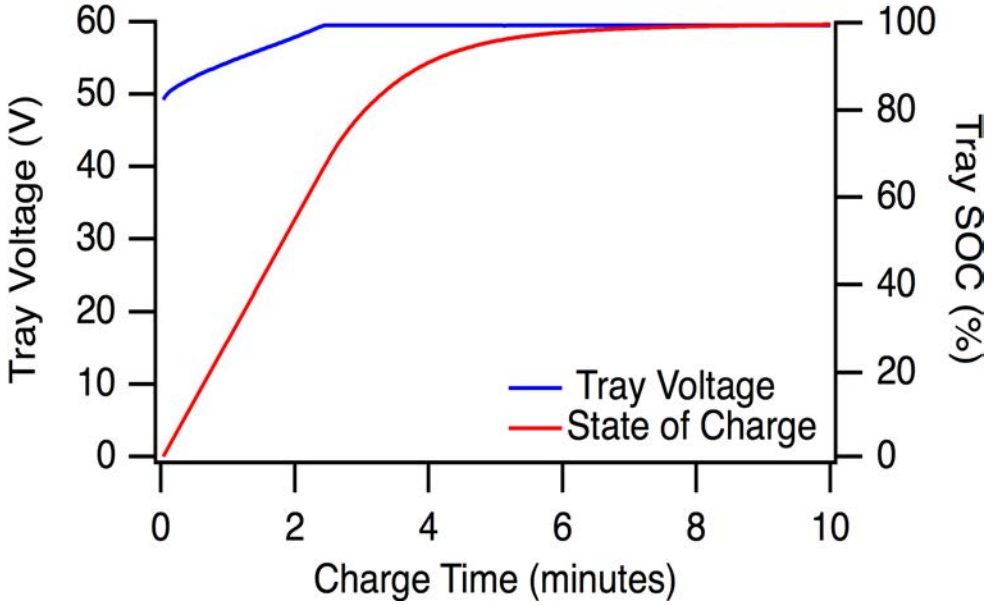


High Availability & Efficiency

- 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

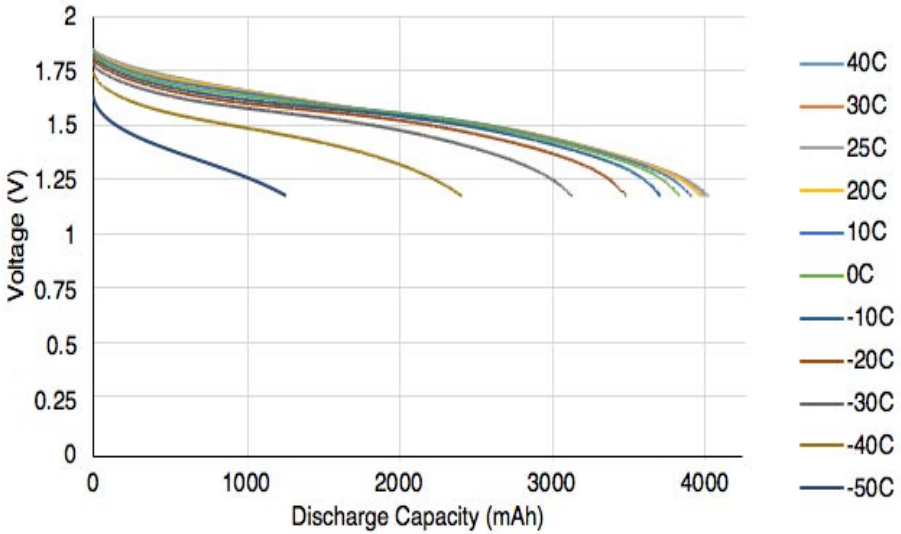
BlueTray 4000 Charge Voltage Profile (16C CC-CV)



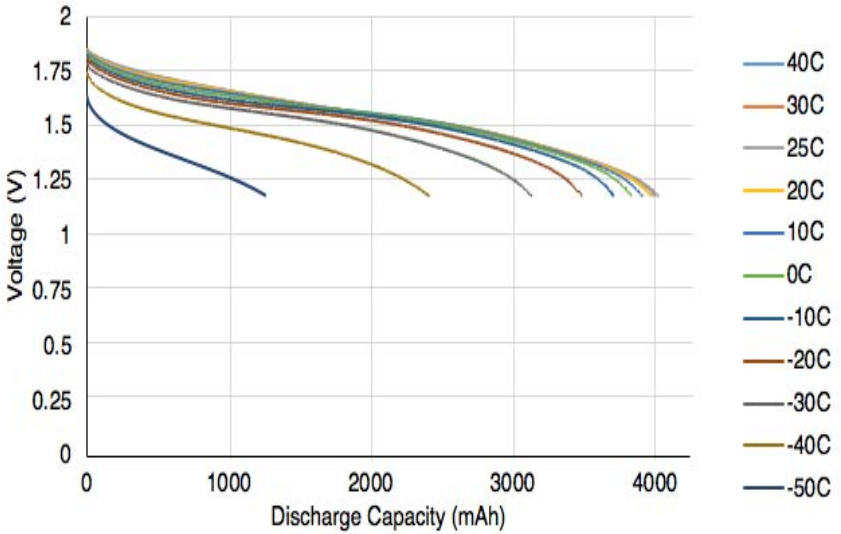
Wide Operating Range

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

1C Cell Discharge Profile vs. Temperature



1C Cell Discharge Profile vs. Temperature



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Opportunities

- OCP R 3.0 – migrating to 48V DC
- Telecom, Fiber, networks
- Edge
- Software Defined Power
- Traditional Bridging with new redundancy architectures
- Grid Services – behind the meter peak shaving
- Grid Service – revenue based: frequency, voltage, DR, etc

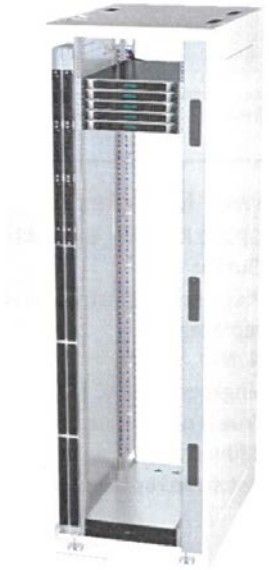


ABB Edge Cabinet

Increased Power Density
Power Density Improvements at the Cabinet

up to 48KW per Cabinet
Pay-As-You-Grow Cabinet Power
Increased White Space Utilization

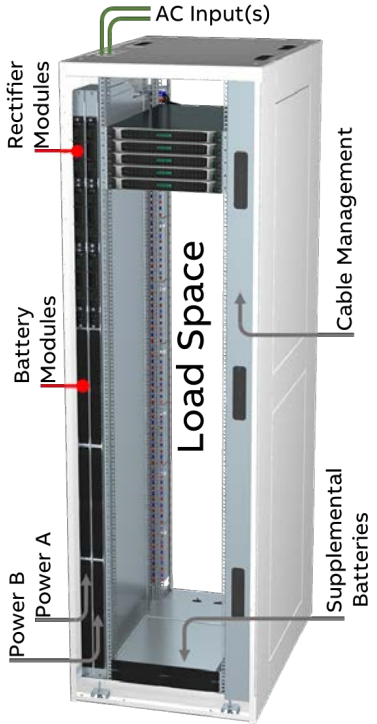
up to 30%+

Reduced Capital Cost
Eliminates Traditional Power Room
Minimizes Battery Cost
Reduces Infrastructure Costs

up to 25%

Reduced Operating Cost
Efficiency Maximized
Losses Minimized
Reduced Utility Cost (energy savings)
Minimal Maintenance Costs

3 Phase AC input
No phase balancing required
Twist and Lock connection



Easy Installation
Rapid Installation and Turn Up
Simplify Upgrades and Expansions
Twist and Lock AC Connection

Plug and Play Modules
Rectifiers, Batteries and Controllers
Hot Swappable, Plug and Play

Easy Maintenance
Modules Self Identify with problems
Hot Swap, Plug and Play replacement

Improved Reliability
Dual System (N + N) Redundancy
Flexible Redundancy levels
Improved Availability / Reliability
Fault Domain Minimized to Single Cabinet

Energy Storage Design Considerations

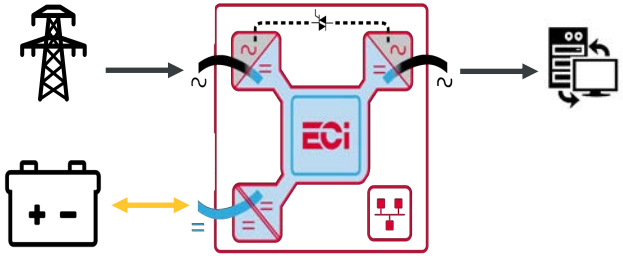
- Battery is no longer the weakest link
- Ensure Rectifier, Inverter, Wire, Breakers fit power profile
- Think Power over time not total available Energy
- Core battery module – nonflammable, no thermal runaway
- Internal N+1 redundancy at reduced run time

- Lead is NOT Dead!
- Lithium is here to stay, EVs anyway
- Diesel, still your best friend for hours to days of operation

Software Defined Power / Energy Augmentation

- Sodium-ion, NFPA 855 compliant suitable for White Space
- Localized energy storage, peak power capping / augmenting
- Extending life of current UPS / power infrastructure

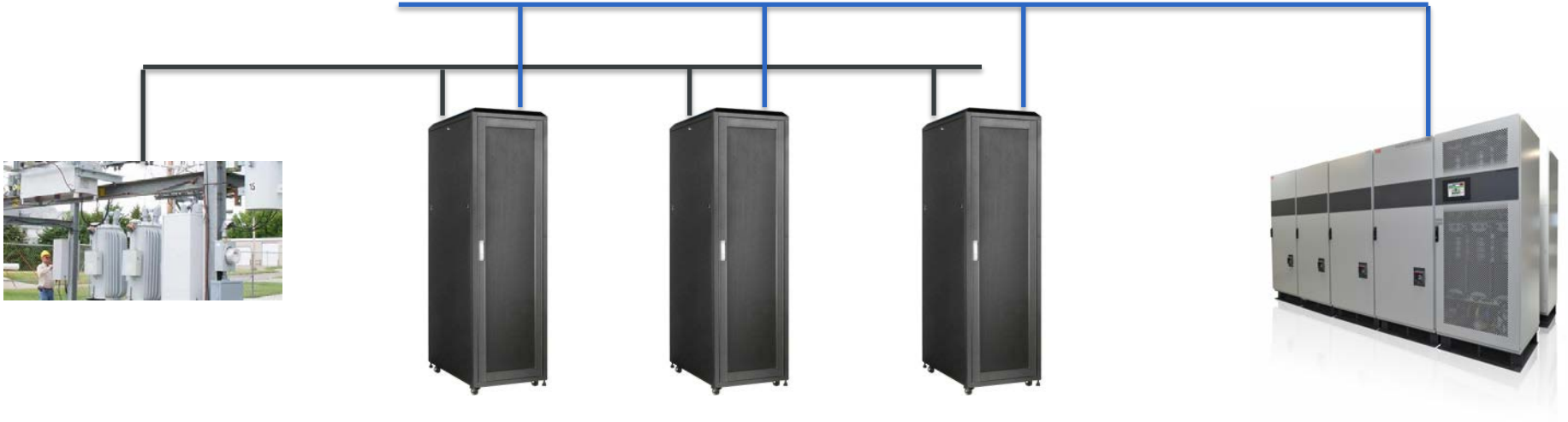
4 – 20 kW power block



MW+ multi-mode Power / Energy system

10 – 80 kW power rack

Managing Peak Loads

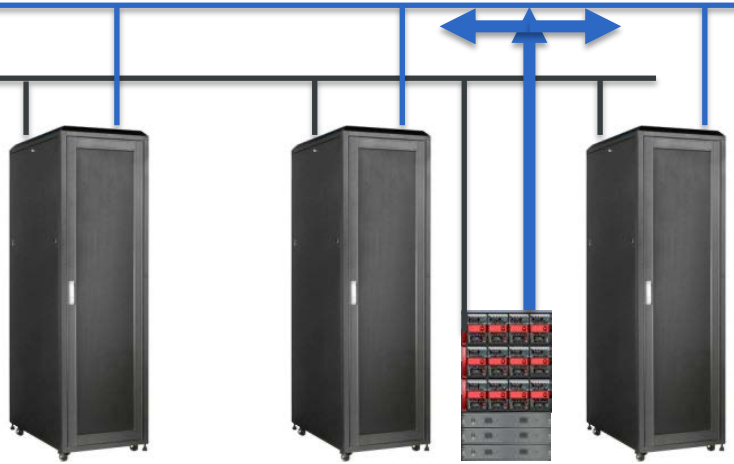


1 MW UPS = 100 10kW cabinets

Real World = 125, 150? Cabinets

Peak Demand Charges – not good!

Expand Capacity & Eliminate Peaks



In Rack Battery / Inverter Power Blocks
Inject Energy as needed behind the breaker
Add energy/power capacity on-the-fly
Peak Power capping

New revenue streams
1 to 5 minute peak charge to clients
OPEX improvements

OCP Data Center Deployment

- Recently deployed at H5 Data Centers Phoenix campus
- Forced Physics DCT high-density innovative cooling IT stack
- Backup power via Natron Energy 1U batteries

H5 DATA CENTERS

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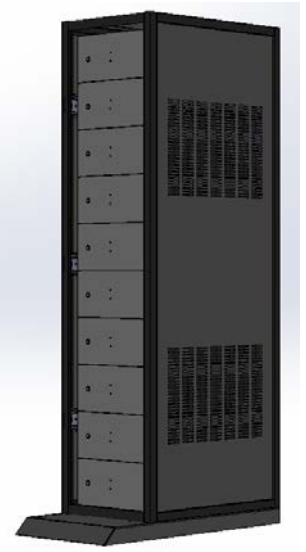
New Battery Plant Configurations

- High Peak Power capacity eliminates need for N+1 (N+ many)
- 52U standard IT cabinet form factor 1000mm deep
- High power cabinets: 1,600 kVA 2 MVA UPS power blocks
  - Fewer strings
  - Higher per cabinet standard power
  - Significantly higher Peak Power capacity
- 300kW per cabinet ‘nominal’, 3-minute discharge EOL rating
- 400kW+ peak, 90-second discharge EOL rating
- 4 cabinets to make 1,200 kW power block
- Fail One – 3 remaining cabinets make 1,200kW @ 90-seconds



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

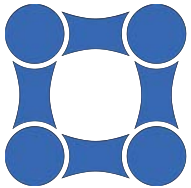
Greenpeace doesn’t like Tar Sands just wait until they focus-in on Lithium and Rare Earth Metal extraction and processing

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

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
- Shipping 1U products today
- Shipping Software Defined Power systems with VPS
- Edge and Telecom applications available
- 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!

Questions/Comments?

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