EV Charging in 5-15 minutes

A Review of the EVs4ALL Program

Dr. Halle Cheeseman – ARPA-E

CREB - December 9, 2022

Summary – Electric Vehicles for American Low Carbon Living

- ✓ ARPA-E - Transformational, High-Risk Technologies
- ✓ Fast charging is key to solving range anxiety
- ✓ EVs4ALL - Fast charging & better Winter performance
- ✓ EVs4ALL an opportunity to court new chemistries
  - E.g., Mg/Organic batteries & batteries from Trees!
- ✓ We must de-risk beyond LIB Chemistries upfront
- ✓ Battery Development is a long, hard road.

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ARPA-E Leadership Mission:

Energy Efficiency, Energy Independence & GHG emissions reduction

…….and Nuclear Waste reduction & Grid Resilience

If it Works will it Matter?

Since 2009 ARPA-E has provided **$3.06 billion** in R&D funding to more than **1,326 projects**

190 projects have attracted more than **$10.3 billion** in private-sector follow-on funding

131 companies formed by **ARPA-E projects**

25 exits market valuations worth **$21.6 billion** from mergers, acquisitions, and IPOs

270 projects have **partnered with other government agencies** for further development

5,714 peer-reviewed **journal articles** from ARPA-E projects

896 patents issued by U.S. Patent and Trademark Office

288 licenses reported from ARPA-E projects

As of April 2022

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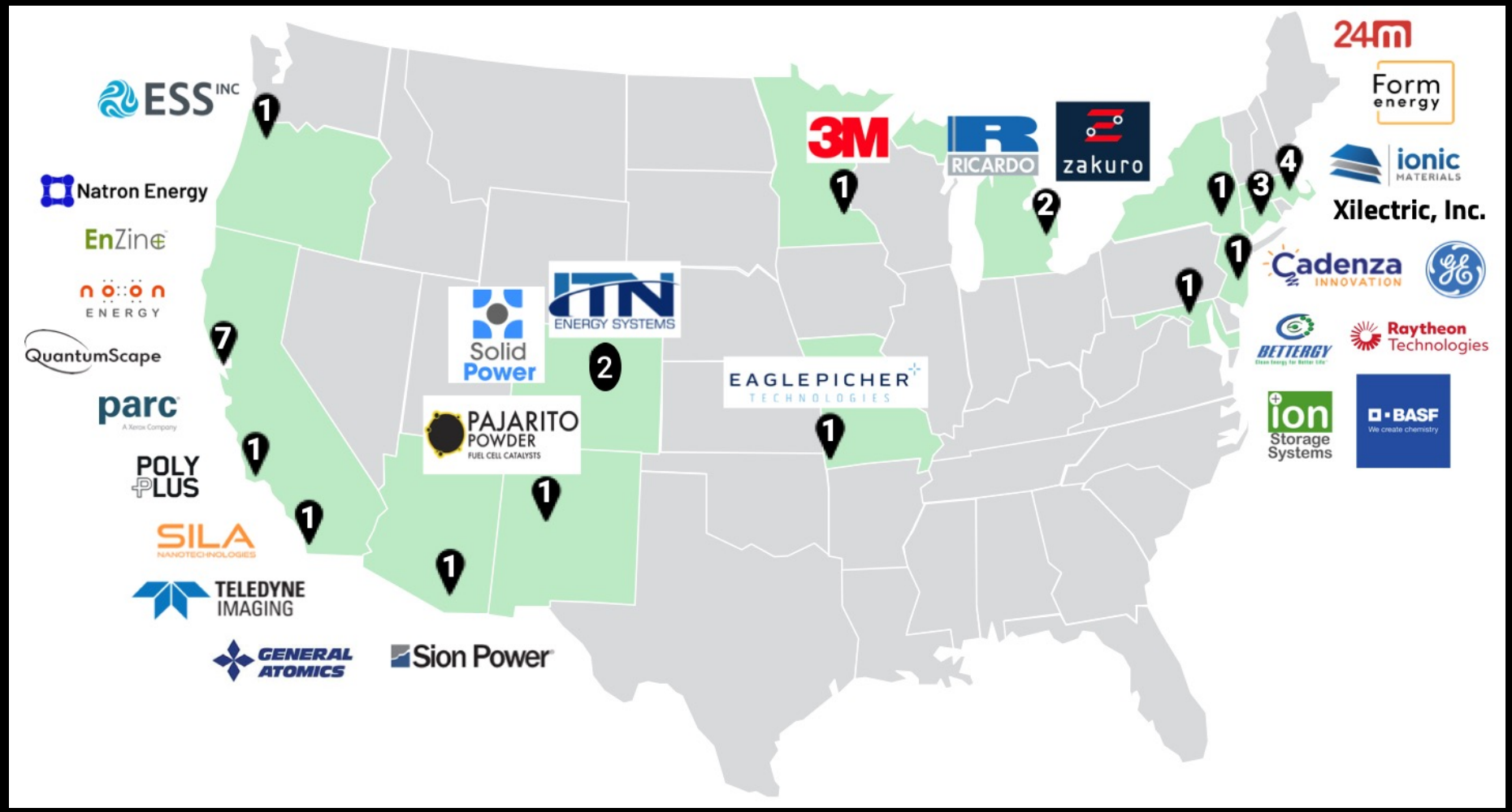
ARPA-E-has funded battery projects for 28 active companies



ARPA-E Programs Represented:
BEEST
DAYS
GRIDS
IDEAS
IONICS
OPEN 2009
OPEN 2012
OPEN 2015
OPEN 2018
RANGE
SCALEUP
TINA - SEED

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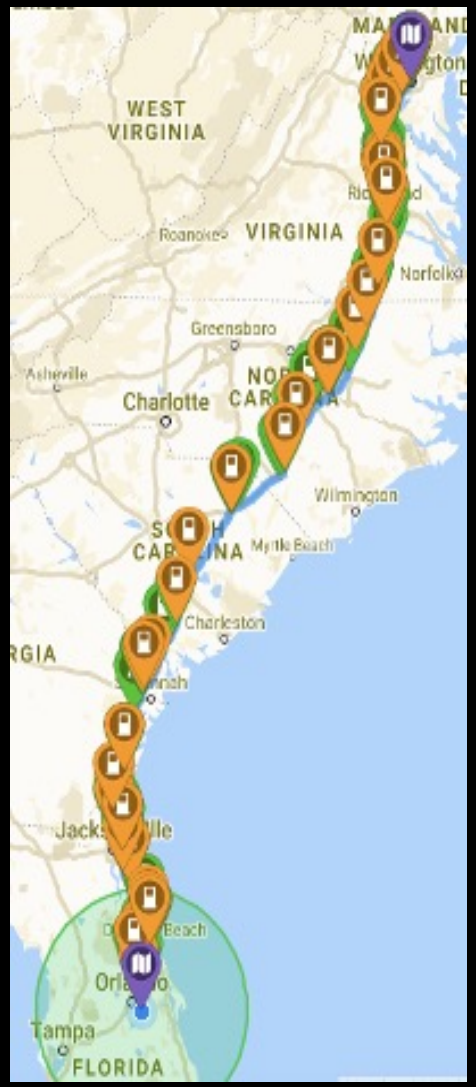
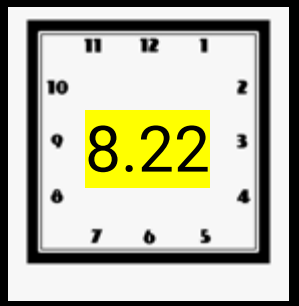
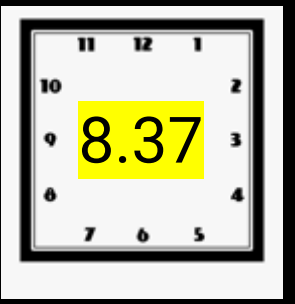
Let's Play a car game – who gets to DC first



Orlando, FL
Departing @ 6.00am

Range	**200 miles**	**400 miles**
Charge Time	**15 mins**	**60 mins**
Battery Energy	**67kWh**	**133kWh**
Vehicle Cost	**$30,000**	**$40,000**





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Assumptions: Base car price = $20,000; Battery Price = $150/kWh; 3 miles = 1kWh
5-minute ramp on 5-minute ramp off, 40 miles min "tank", 80% charge

EVs4ALL ARPA-E Program – eliminating detractors

i) Very Fast Charging for the 37% of Americans who will not have access to home charging

Small Vehicles
>200Wh/kg
5 minute charging

Large Vehicles
>400Wh/kg
15 minute Charging

ii) Improved low temperature performance for the Americans who live in Northern States

Cut low temperature battery performance losses in half

iii) Better Affordability for New Vehicles with Abundant Materials & Range Retention for Used Vehicles.

- **<$75/kWh versus SOA $120/kWh**
- **Cut battery degradation losses in half**

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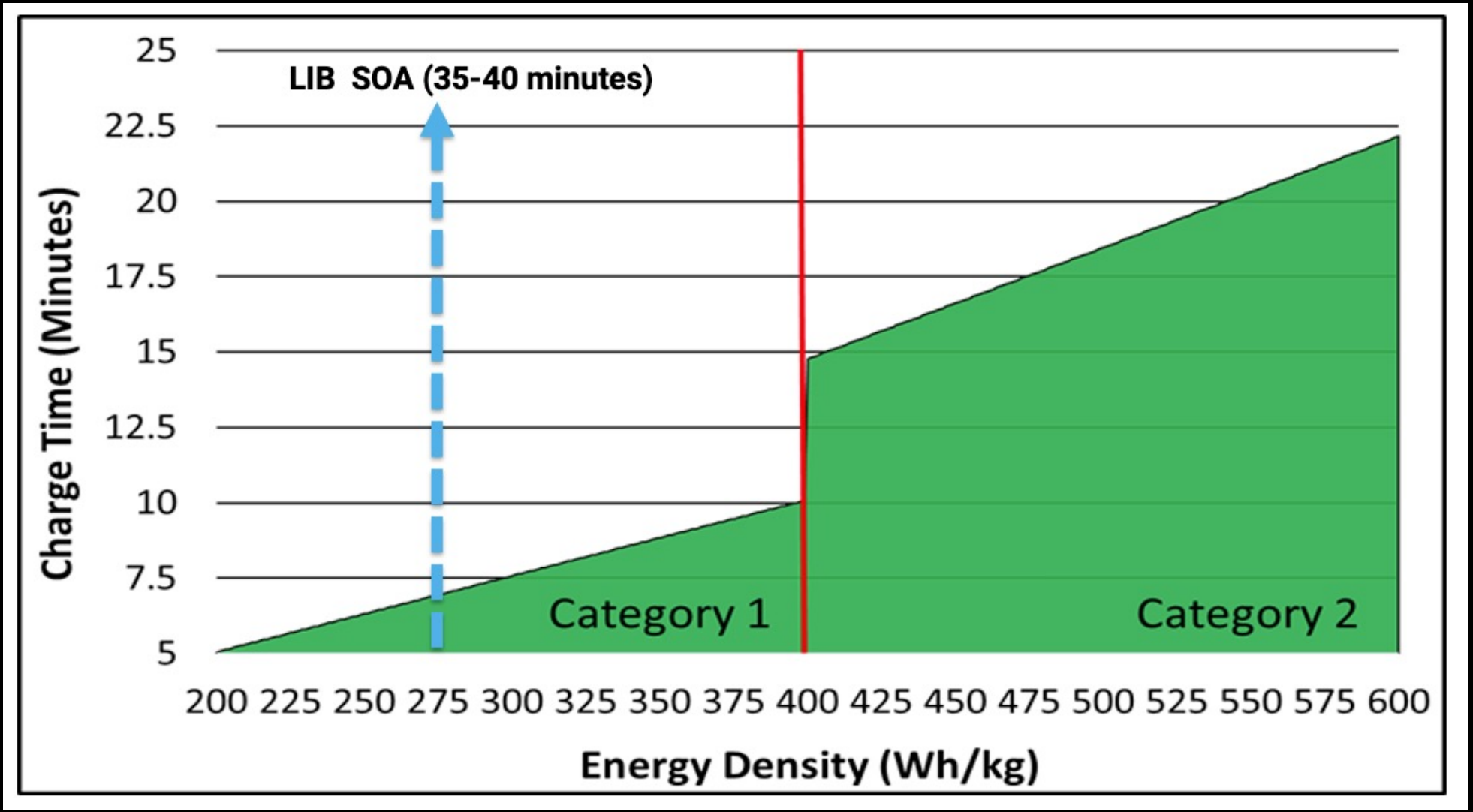
New Technologies must be Safety Assured & de-risked upfront

EVs4ALL Categories 1 and 2 – Summary



EVs4ALL: Technical Performance Targets (Categories 1 and 2)

Table. Primary cell performance metrics for the EVs4ALL program (Categories 1 and 2).

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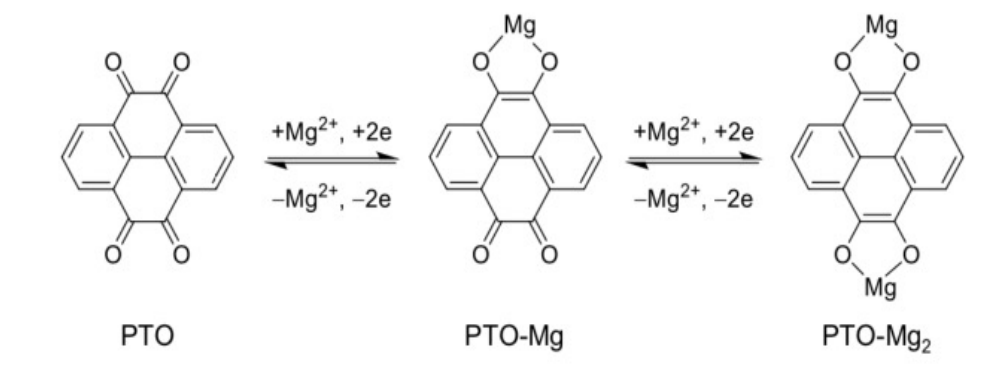
	Cell-Level Performance Metrics*	**Category 1 (*High Power*)**	**Category 2 (*High Energy*)**
1	Gravimetric Energy Density (Wh/kg)	**≥ 200**	**≥ 400**
2	Volumetric Energy Density (Wh/L)	≥ 500	≥ 900
3	Charge Power/Acceptance (kW/kg)	**≥ 1.9**	**≥ 1.3**
4	(%) Performance Loss per °C [≤ 30° C to -20° C]	≤ 0.3	≤ 0.4
5	Cycle Life – 90% of initial capacity (80% SOC swing)	≥ 1500	≥ 750
6	Cell Cost Target ($/kWh)	≤ 60	≤ 60

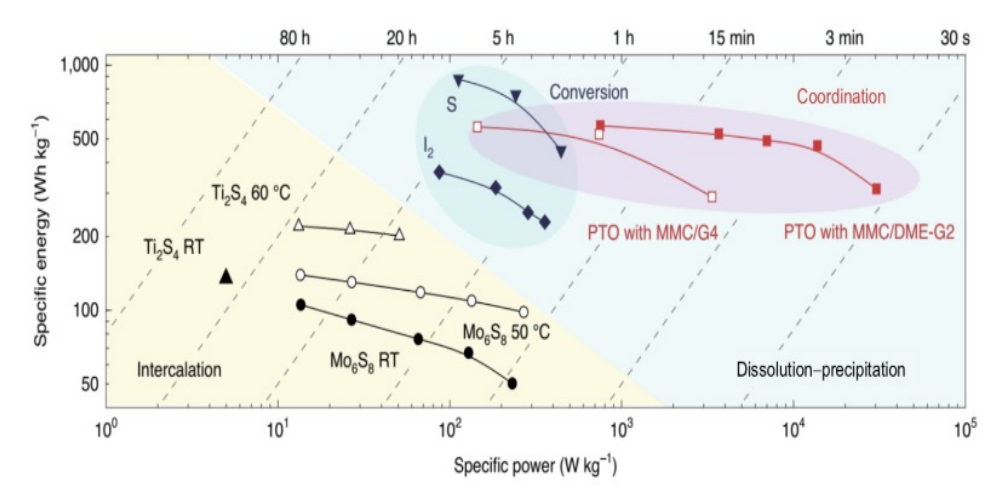
EVs4ALL Technical Categories of Interest (Categories 1 and 2)

- Cylindrical, Pouch or Prismatic cells Cells 2.0V – 5.5V
- Anode materials based on alkali or alkaline earth metals
- Oxide-based anodes
- Three-dimensional anode architectures
- Coatings on separators, cathodes and/or anodes
- No/low cobalt and no/low nickel-content cathodes
- Electrolyte agnostic. Safety is the overriding requirement
- New battery technologies that can be manufactured using existing processes

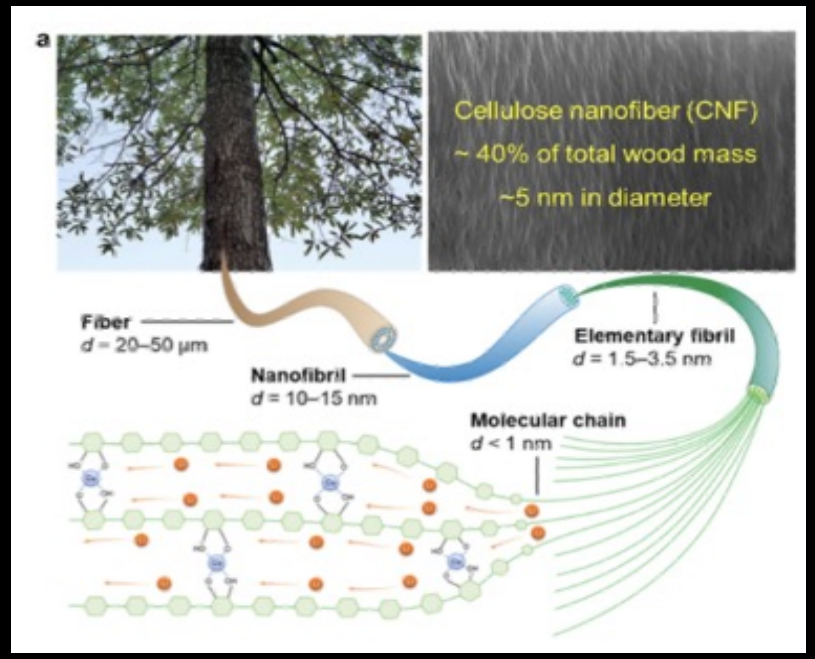
Examples of Beyond LIB Technologies – ARPA-E OPEN 2021 Awards

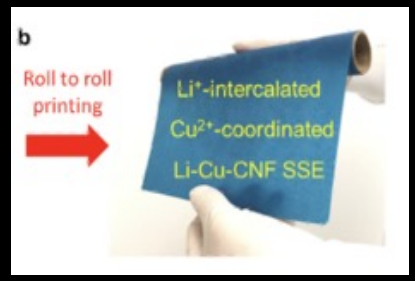
Magnesium – Organic Cathode, University of Houston. PI: Yan Yao

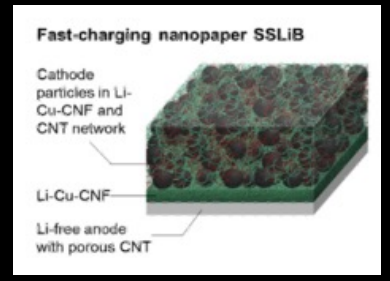




Cellulosic Nano Fibers ASSB – University of Maryland, PI: L. Hu



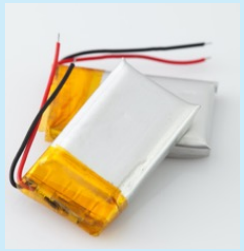
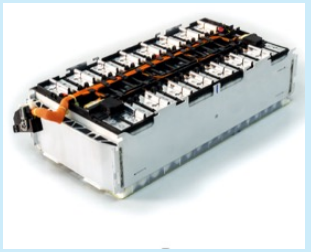
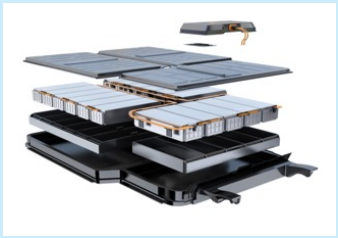




An ARPA-E Project is a beginning & batteries take a long time

Design Scale-up



Stack pressure, Safety, Degradation, gassing, poisoning, flammability, swelling, balancing, corrosion, sealing……..

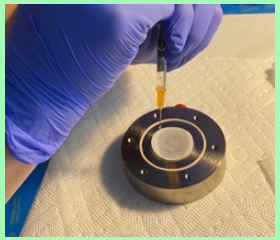
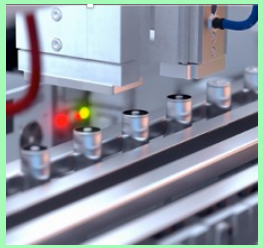
Material Scale-Up





Purity, packing, settling, separation, clumping, grain structure, dusting, sticking, contamination, moisture……..

Process Scale-Up


Storage, blending, consolidating, drying, curing, ageing, welding, inserting, folding. Filling, closing…

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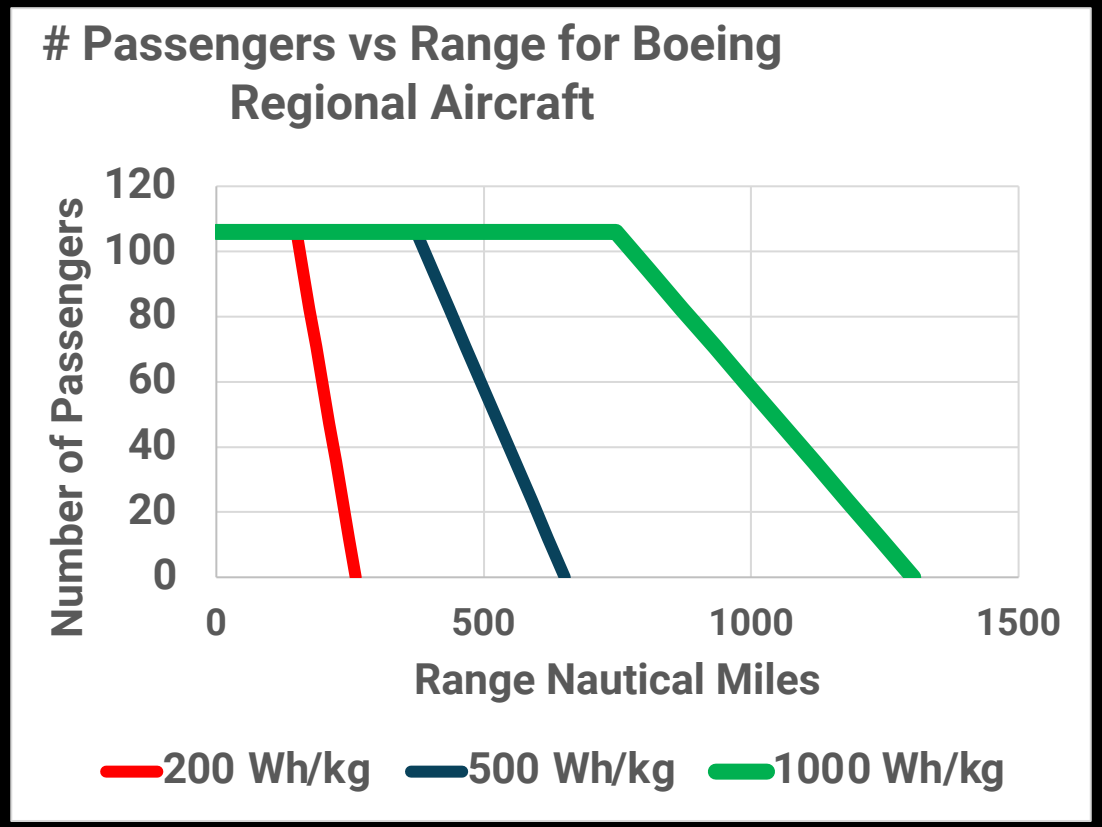
Battery 1K (1000Wh/Kg) – Transformational for Transportation



Metals as Fuels/Anodes

Lithium	Aluminum	Magnesium
11.1kWh/Kg	8.4kWh/Kg	6.1kWh/Kg
		
Li_2O = 5.2kWh/Kg.	Al_2O_3= 4.3kWh/Kg	MgO = 2.8kWh/Kg

19% Required for 1K

23% Required for 1K

36% Required for 1K

How do we package these metals to deliver 1000Wh/Kg – Battery 1K

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EVs4ALL – Solving for key EV purchase detractors

Thank You for Listening

Halle.Cheeseman@hq.doe.gov

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