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Energy Storage Grand Challenge

Lithium Battery Technology Discussion

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Bi-directional Electricity Storage

What is Bi-directional Electricity storage?

Bi-directional Electricity storage includes local energy storage devices (both for transportation and for the grid) that can store energy, convert to electricity, and then recover or recharge for the same purpose.

Why is this part of the storage portfolio for DOE?

Bi-directional Electricity storage assures the most efficient utilization of generated energy for both the transportation and the utility sectors – by enabling shifting to a desired utilization time from a given energy production time.

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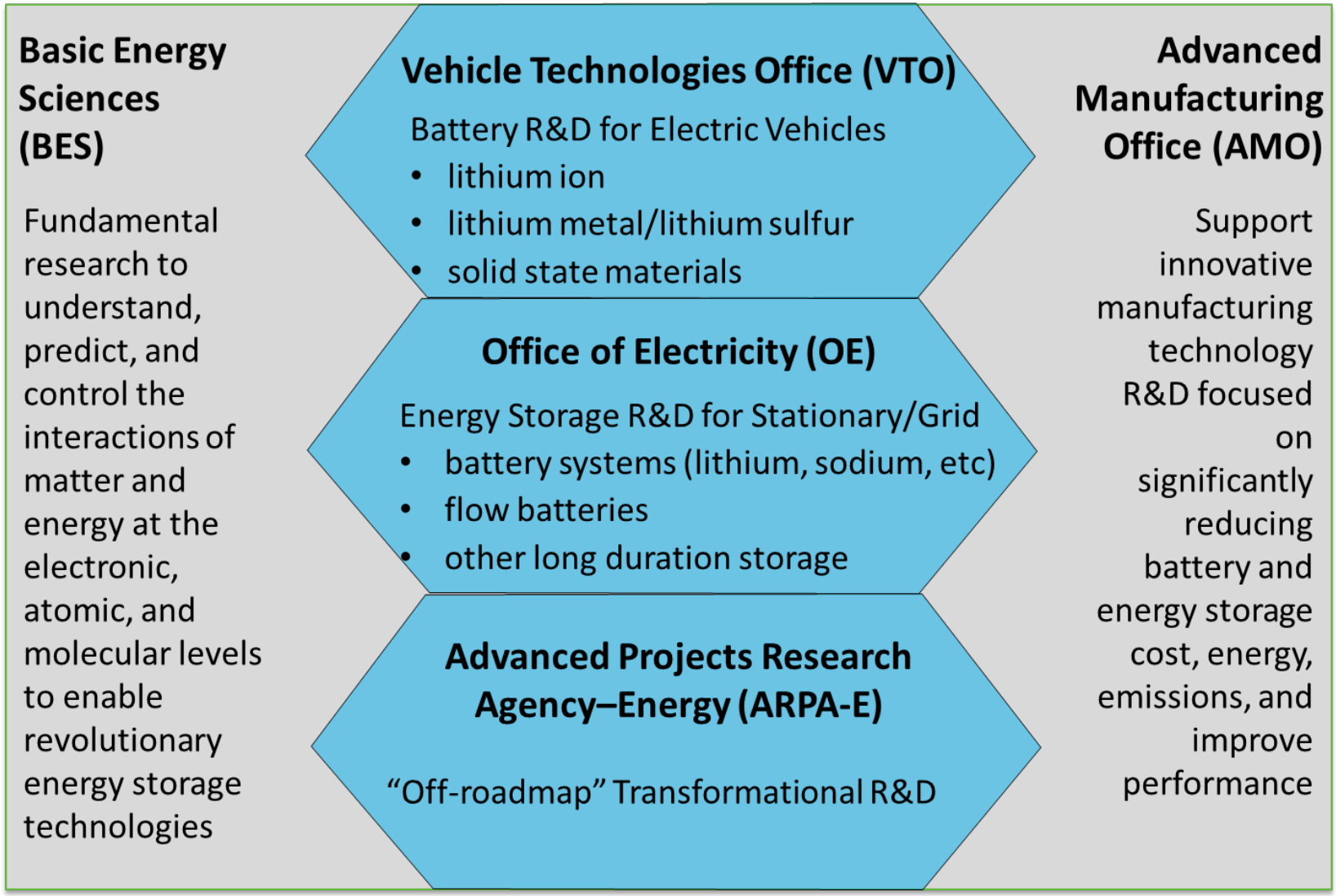
DOE Battery R&D At-a-Glance



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RoundTable Discussions on Lithium Batteries

The U.S. Department of Energy

RoundTable Discussion

"Ensuring United States Domestic Battery Manufacturing Competitiveness"

SEPTEMBER 25, 2019 | NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, CO

Roundtable #1

Battery Manufacturing

18 Industry Participants

Electrode Production, Cell Fabrication, Manufacturing Equipment

1. Projected Market Growth
2. World & USA Manufacturing Landscape
3. Manufacturing Processes & Technology

Q&A and Discussion

"Made in America: Opportunities and Barriers"

Roundtable #2

Battery Materials Supply Chain

20 Industry Participants

Raw Materials Supply/Battery Materials Production

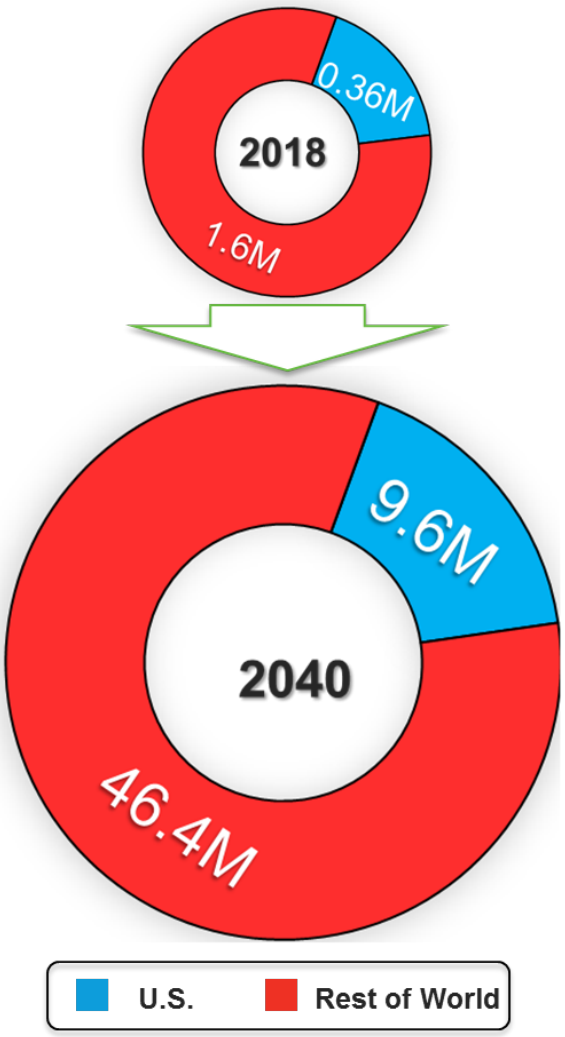
1. Raw Materials Sources and Supply
2. Battery Materials Supply Chain
3. Current Recycling Industry

Q&A and Discussion

"Technology and Market Opportunities"

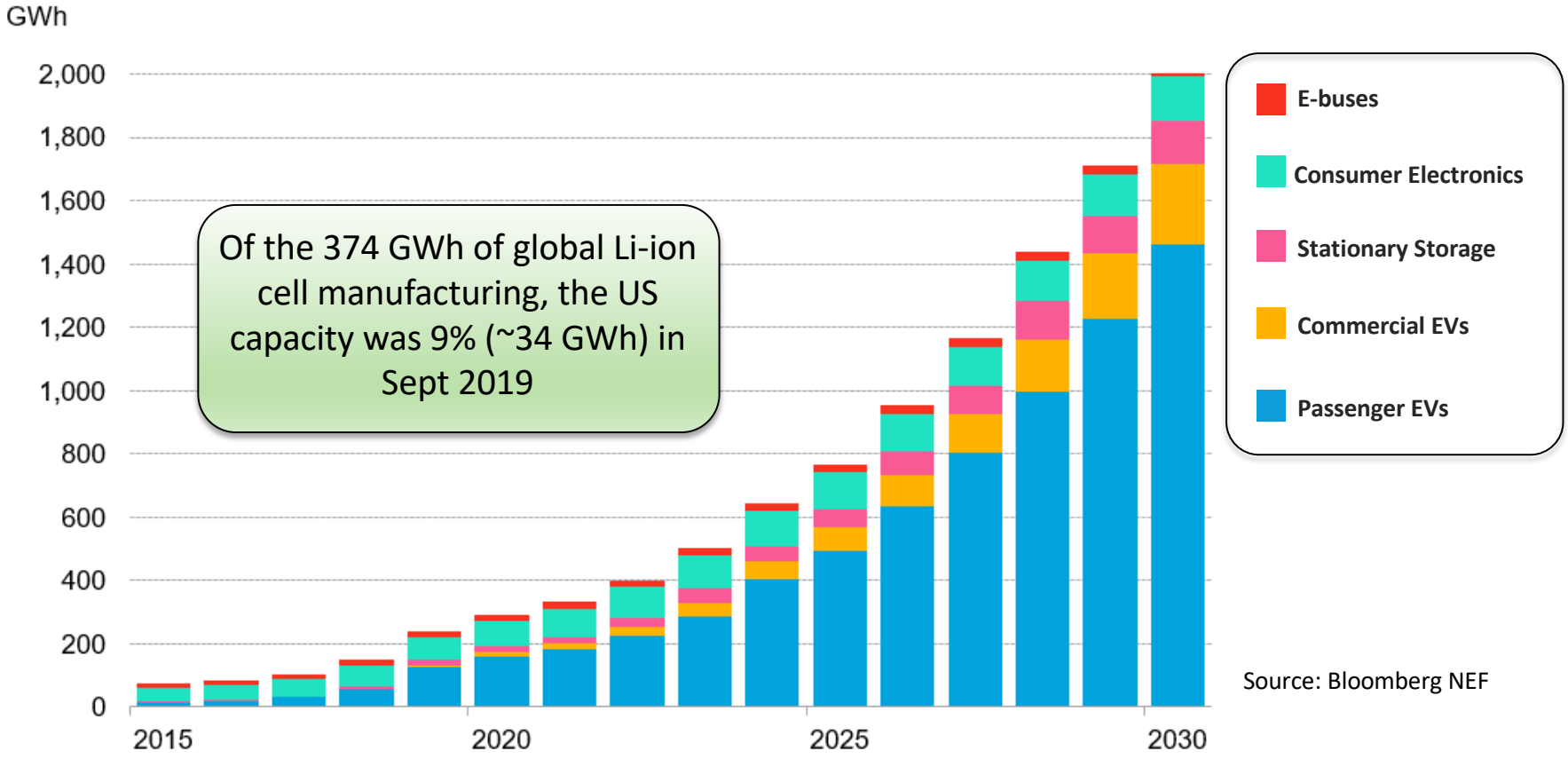
Anticipated Rise in Electric Vehicle Purchases

- **Global projection of annual passenger EV sales is 56M EVs in 2040[1]**
  - 17% (~9.6M EVs) of those sales will be in the US market
  - 9.6M EV's equates to approximately a $100 billion battery market
- **2018 markets[2] of similar size:**
  - Smart phones ($79 billion)
  - Gas stations ($110 billion)
  - Passenger Car/auto manufacturing ($112 billion)



[1]Source: Bloomberg NEF Long-Term Electric Vehicle Outlook 2019
[2]Source: IBIS World, Market Size Statistics - United States 2018 NAICS Reports

EVs will dominate the demand for Li-ion batteries



Source: Bloomberg NEF

Lithium Battery development and production is a strategic imperative for the US, both as part of the clean energy transition and as a key component for the competitiveness of the US automotive industry

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RoundTable Key Recommendations and Next Steps

Based on the roundtable discussion and the various takeaways listed above, six action items emerged where DOE can help maintain and expand US leadership in batteries:

1. **Continually evaluate the R&D portfolio to drive cost and charge times toward VTO targets.**
   - ❑ Battery manufacturing will occur in the US as demand for EV's increase.
   - ❑ Demand increase is critically tied to ensuring that EV's achieve cost parity with gasoline cars and can be recharged at rates on parity with gasoline refueling.
   - ❑ DOE will continue to work with the OEM's to examine the key bottlenecks for consumer adoption, translate this to the materials R&D needs, and adjust the R&D scope as needed to address the changing landscape.
   - ❑ DOE should continue materials R&D that takes material availability into consideration.

RoundTable Key Recommendations and Next Steps

2. Examine different approaches to bridge the "prototype to pilot" scaling challenge.
   - ❑ Scaling, from a lab-scale prototype to the pilot scale, is time consuming and expensive, sometimes taking as much as a decade.
   - ❑ Solving this issue could lead to next-generation manufacturing approaches, protected by a strong IP portfolio, resulting in US manufacturing.
   - ❑ DOE will determine to what extend existing National Lab facilities can be adapted to help industry accelerate technology maturation.
   - ❑ DOE will consider assembling the capabilities at the labs into a single portal to aid companies to match technologies to facilities.
   - ❑ DOE will examine new approaches for using existing facilities and capabilities across the Labs and possibly provide funding to support R&D and Industry CRADAs for proof-of-concept scaling projects

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RoundTable Key Recommendations and Next Steps

3. **Examine different approaches to link materials companies, cell manufacturers, OEMs *etc.* to ensure better connectivity.**
   - Innovation ecosystems, with links between the different players across the value chain, provide a means of accelerating the adoption of new technology.
   - DOE will continue working with industry consortiums and trade groups and invigorate the efforts to ensure connectivity between the various parts of the ecosystem.
   - Some specific activities include;
     - Sponsor meetings to shed light on emerging trends in innovative battery technologies and the implications for different parts of the manufacturing value chain
     - organize workshops to brainstorm manufacturing challenges in specific parts of the value chain and identify common bottlenecks
     - organize end-use focused workshops to link future application needs to the gaps in the value chain (link transportation and stationary sectors)

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RoundTable Key Recommendations and Next Steps

4. Work with USGS to develop the R&D needs related to material extraction and determine approaches to further develop a local mining and extraction industry.
   - ❑ The increasing dependence the US has on other countries for raw materials suggests that a comprehensive approach is needed to ensure that supply chain risks are minimized/eliminated.
   - ❑ While DOE already supports a variety of programs related to decreasing the dependence on critical materials, less emphasis has been placed on methods to extract battery-grade materials from US mines.
   - ❑ DOE will work with USGS to hold a workshop related to battery materials supply and determine the opportunities and gaps in this space.

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RoundTable Key Recommendations and Next Steps

5. **Work with universities, Labs, and industry to develop the workforce needed for the growing battery manufacturing industry.**
   - ❑ As the US manufacturing industry grows, the needs for a trained workforce will continue to increase. The lack of talent can be an impediment to rapid innovation and long term competitiveness.
   - ❑ A few different approaches will be considered including;
     - ❑ working with Universities initiate a dedicated curriculum on battery manufacturing
     - ❑ linking with Community Colleges to develop skilled workforce
     - ❑ linking with research societies, such as the Electrochemical Society, to offer short courses related to manufacturing
     - ❑ working with the National Labs to allow summer student internships to work at scale-up facilities
     - ❑ Supporting industry internships focused on manufacturing,
     - ❑ partnering with the Department of Labor, Veterans Affairs, or DoD Institutes.

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RoundTable Key Recommendations and Next Steps

6. **Determine the applicability of the DOE loan program to aid scale-up of lower TRL innovations and other potential policy incentives.**
   - ❑ While the National Labs may help in scaling from prototype to pilot scale, more is needed.
   - ❑ Specifically, companies need multi-year funding to validate and nurture lab-established technologies and develop it to a stage where the process can be implemented in the large scale.
   - ❑ The DOE loan program should work closely with the battery industry to determine the applicability of funding such ideas while minimizing the risk to the taxpayer.
   - ❑ Another avenue could be to explore the possibility of reinstating the IRS Section 48C Advanced Energy Manufacturing Tax Credit Program (MTC) for battery manufacturing.

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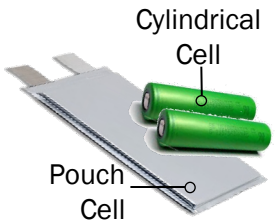
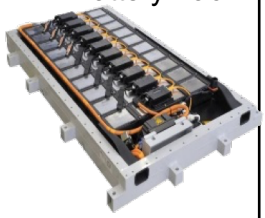
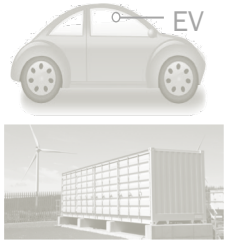
Key Actions Towards Lithium Battery Technology Advances

Raw Materials Production	Materials R&D and Processing	Cell R&D and Manufacturing	Pack Manufacturing	EV Manufacturing And Grid Storage	End of Life Recycling
					
• Bolster domestic supply chain • Eliminate or Reduce the use critical materials • Recover and reuse	• Develop disruptive active materials • Develop revolutionary processes • Support scale up	• Develop disruptive cell manufacturing methods • Novel cell designs to enable faster cell assembly • Enable production of leap-frog battery tech	• Foster automation • Quality control, diagnostic testing. • Design for recyclability and second use	ESGC Policy and Valuation Activities	• Strategies to capture spent Li-ion • Reduce recycling costs • Increase material recovery rates • Processes to reintroduce materials into supply chain

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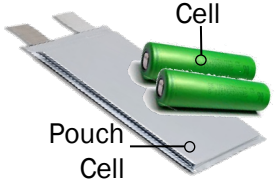
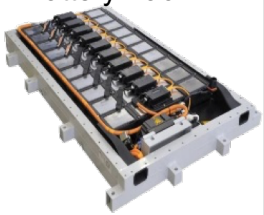
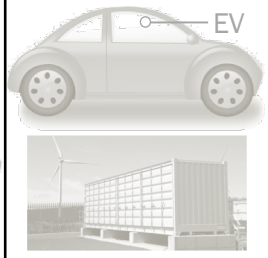
DOE's Ongoing Work Related to Lithium Battery Development

Raw Materials Production	Materials R&D and Processing	Cell R&D and Manufacturing	Pack Manufacturing	EV Manufacturing And Grid Storage	End of Life Recycling
 Lithium, Cobalt, Nickel, Graphite	 Cathode Powder; Anode Powder	 Cylindrical Cell; Pouch Cell	 Battery Pack	 EV	
CMI	Low-No Cobalt Cathode MERF @ Argonne NATIONAL LABORATORY SEISta Silicon Electrolyte Inerface Stabilization BATTERY 500 CONSORTIUM IONICS JCESR/EFRCs	USABC UNITED STATES ADVANCED BATTERY CONSORTIUM LLC XCEL eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries CAMP @ Argonne NATIONAL LABORATORY BMF @ OAK RIDGE ABF @ Pacific Northwest NATIONAL LABORATORY BATTERY 500 CONSORTIUM AMO/VTO FOA	DEPARTMENT OF ENERGY · LPO Loan Programs Office Office of Electricity		ReCell ADVANCED BATTERY RECYCLING AMERICAN MADE BATTERY RECYCLING PRIZE U.S. DEPARTMENT OF ENERGY

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Lithium Battery Strategy Under Development

Position US domestic battery materials, cell, and pack manufacturers to dominate the growing and critically important battery technology market.

- secure **access** to **raw materials** and discover alternates for critical materials
- support domestic **battery material discovery, development, and processing**
- bolster domestic **electrode, cell, and component manufacturing** at scale
- promote domestic **pack manufacturing** at scale
- enable domestic **end of life and critical materials recycling** at scale

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Thank You!