Battery Critical Materials Supply Chain Opportunities

June 29, 2020
Assistant Secretary for the Office of Energy Efficiency and Renewable Energy Daniel R. Simmons
Lithium-Ion Battery Critical Materials Challenges related to Electric Vehicles

June 29, 2020

David Howell, VTO
Helena Khazdozian, AMO
Sean Porse, GTO
Samm Gillard, VTO
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

Of the 374 GWh of global Li-ion cell manufacturing, the US capacity was 9% (~34 GWh) in Sept 2019

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.
Global Lithium Ion Cell Production

Li-ion cell manufacturing is strongest in China, the U.S., Asia, and Europe.

China has almost 80% of the current global LIB cell manufacturing capacity (~360 GWh) as well as almost 60% of the 1000 GWh planned and under construction.

The U.S. is the second-largest manufacturer at 9% of current global capacity, with the Tesla-Panasonic plants in Nevada comprising the majority. The U.S. also has 12% of the facilities planned/under construction.

New legislation is driving significant growth in manufacturing in Europe.

Sources: NREL Analysis 2020, BNEF, others
The majority of cobalt is produced in the DRC and is processed in China, for both battery and steel manufacturing. Once cobalt goes to China, very little of it is made available for battery manufacturing elsewhere. Cobalt flowing through the U.S. supply chain primarily comes from steel recycling operations, with a small amount of domestic mining in Michigan and from mine tailings in Missouri.
Lithium trade is similar to cobalt in that China imports the majority of lithium and uses it in its domestic industry. One significant difference, however, is that the supply of lithium is more diverse and most refining companies obtain their supply from numerous sources. There is significant trade among nations except China in the LIB and EV sectors.

The majority of Class 1 nickel is used in metallurgical applications. China’s lithium-ion batteries have lower nickel content than those produced by EU and the U.S.
Lithium Ion Battery Cathode Material Technology

**Critical Materials Content (kg) per 100kWh Battery Pack**

<table>
<thead>
<tr>
<th></th>
<th>NMC622</th>
<th>NMC955</th>
<th>Lithium Metal with Sulfur Cathode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>13</td>
<td>13.7</td>
<td>24.3</td>
</tr>
<tr>
<td>Cobalt</td>
<td>19</td>
<td>~5</td>
<td>0</td>
</tr>
<tr>
<td>Nickel</td>
<td>60</td>
<td>~82</td>
<td>0</td>
</tr>
</tbody>
</table>

Cell specific energy (Wh/kg)

Cobalt Content (for 100 kWh battery pack)

- ~30 kg
- 15-27 kg
- 13-19 kg
- 8-10 kg
- 5 kg
- 0 kg
Worldwide Energy Storage Material Demand
(80M New Sales and 50% Market Penetration by 2045)

EV Market Penetration Assumptions
• 2030: 15%
• 2045: 50%

Lithium Ion Battery Assumptions
• 60 kWh average
• 100% NMC955 (5% cobalt content)

Recycling Assumptions
• 15 Year Vehicle Life
• 100% EV Batteries Recycled

Recycling important for domestic supply

2045 Scenario
over 3% of the world reserve used for new vehicles.

All sources from USGS 2019 Materials Commodity Studies
Worldwide Energy Storage Material Demand
(80M New Sales and 50% Market Penetration by 2045)

EV Market Penetration Assumptions
• 2030: 15%
• 2045: 50%

Lithium Ion Battery Assumptions
• 60 kWh average
• 100% NMC955 (5% cobalt content)

Recycling Assumptions
• 15 Year Vehicle Life
• 100% EV Batteries Recycled

2045 Scenario
2.5% of the world reserve used for new vehicles.

Recycling important for domestic supply

All sources from USGS 2019 Materials Commodity Studies
Worldwide Energy Storage Material Demand
(80M New Sales and 50% Market Penetration by 2045)

EV Market Penetration Assumptions
• 2030: 15%
• 2045: 50%

Lithium Ion Battery Assumptions
• 60 kWh average
• 100% NMC955 (5% cobalt content)

Recycling Assumptions
• 15 Year Vehicle Life
• 100% EV Batteries Recycled

2045 Scenario
1.2% of the world reserve used for new vehicles.

All sources from USGS 2019 Materials Commodity Studies

Recycling important for domestic supply
DOE Battery R&D

Basic Energy Sciences (JCESR, EFRC)
Materials discovery and fundamental research to understand, predict, and control the interactions of matter and energy at the electronic, atomic, and molecular levels.

Vehicle Technologies Office (VTO)
Battery R&D for Electric Vehicles
lithium ion, lithium metal, solid state

Office of Electricity (OE)
Energy Storage for Grid
lithium, sodium, flow, other storage

Advanced Projects Research Agency–Energy (ARPA-E)
“Off-roadmap” Transformational R&D

Geothermal Technologies Office (GTO)
Mineral resources

Advanced Manufacturing Office (AMO)
Support innovative manufacturin
g technology R&D focused on significantly reducing battery and energy storage cost, energy, emissions, and improve performance
### Electric Vehicle Battery R&D

<table>
<thead>
<tr>
<th>Raw Materials Production</th>
<th>Materials R&amp;D and Processing</th>
<th>Cell R&amp;D and Manufacturing</th>
<th>End of Life Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Cathode Powder</td>
<td>Cylindrical Cell</td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>Anode Powder</td>
<td>Pouch Cell</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **EERE GTO**
- **EERE VTO**
- **EERE AMO**
- **Office of Science**

Advanced Manufacturing Office (AMO)

- Critical Materials Institute (CMI), a DOE Energy Innovation Hub – Battery R&D
  - Forward-osmosis technology to concentrate lithium chloride and sulfate chemistries for efficient conversion
  - Physical, chemical, and biochemical recycling approaches
  - Supported by cross-cutting R&D efforts like thermodynamic characterization

- Energy Storage Cross-Cut with VTO
  - FY19 FOA: 10 projects with ~$45M total funding to advance battery manufacturing
  - Lithium-ion Battery Recycling Prize (led by VTO)
  - Call for lab-industry partnerships to solve engineering challenges for advanced battery materials and devices

- FY20 Critical Materials FOA
  - Field validation and demonstration
  - Next-generation technologies
Salton Sea Timeline of Mineral Recovery Efforts

1932-54
- CO₂ wells

1960s
- Potash recovery
- Morton Salt/O’Neill pilot project

1965-67
- Chloride Products Inc. CaO₂ recovery plant

1968
- CFE/KCl pilot geothermal brine evaporation pond
- US Bureau of Mines Mineral Recovery Unit

1977
- Unocal line mine pilot

1980s
- DOE Mineral Recovery FOA / Phase I & II

1990s
- Simbol Lithium extraction pilot

2014-16
- Berkshire Hathaway/CaEnergy Zinc plant

2014-15
- Berkshire Hathaway/CaEnergy

2001-04
- Image: Berkshire Hathaway, 2003
EERE seeks to demonstrate added value in regions where geothermal brines can deliver critical elements such as lithium.

Uniting GTO, AMO, and VTO creates clear-path integration from supply to manufacturing to end-market, with improved efficiencies and economics.
R&D to Mitigate Potential Critical Material Impacts

Low/No Cobalt Cathode R&D

- Decrease recycling cost
- Recover critical and high value materials
- Reintroduce recovered materials into the material supply stream

A $5.5 million phased competition over three years

Innovative Ideas for Collection, Storing, and Transporting Discarded Li-Ion Batteries

*Based on: 100 KWh battery pack and NMC622 cathode
Request for Information (RFI)

Battery Critical Materials Supply Chain R&D

- EERE is soliciting feedback from stakeholders on issues related to challenges and opportunities in the upstream and midstream critical materials battery supply chains
- Specifically interested in raw minerals production and refining and processing of cathode materials including cobalt, lithium, and nickel*
  - Future Battery Chemistries and Material Supply
  - Economics and Battery Supply Chain
  - Lithium Powder Processing including Geothermal Brines
  - Cobalt and Nickel Processing
- RFI will inform workshop, tentatively planned for this fall, and inform development of the R&D roadmap as part of implementation of the Federal Strategy

Link to RFI: https://eere-exchange.energy.gov/default.aspx#foaId80854fd9-b498-49e7-b8f0-1f34c55ba3fd
Submit responses by July 31 by 5pm ET to BatteryCriticalMaterialsRFI@ee.doe.gov
Questions should be submitted to BatteryCriticalMaterialsRFI@ee.doe.gov

*Nickel is not a critical mineral commodity on the list published by the Secretary of Interior.
THANK YOU
Questions?
USGS Efforts Impacting Upstream Supply Chain for Critical Minerals in Batteries
Warren Day
Earth Mapping Resources Initiative (Earth MRI)
June 2020
Federal Strategy on Critical Minerals

- **Executive Order 13817**: Of 35 minerals deemed critical (Federal Register, May 18, 2018), the U.S. is 100% reliant on foreign sources for 14 and at least 50% reliant on foreign sources for another 16.

- **Interior Secretarial Order 3359**: Earth MRI data acquisition will target mineral-rich regions, and will also have broad application to energy, groundwater, natural hazards, and other vital geoscience issues.

- USGS tools determine list of Critical Minerals (First version in Federal Register in May 2018).

- **Call to Action In the Federal Strategy (#4)**: Improve Understanding of Domestic Critical Mineral Resources
USGS’s Response to EO 13817 and SO 3359:

Earth MRI: Partnership between USGS and State Geological Surveys to generate state-of-the-art geologic mapping, geophysical surveys, and lidar data for the Nation in areas with critical mineral potential.

Earth MRI Budget
- FY 2019: $9.598M
- FY 2019 State Matching Funds: ~$2.9M from 29 States
- FY 2020: $10.598M
- FY 2020 State Matching Funds: ~$2.2M from 27 States
- Seeking Other Agency Partnerships to leverage funds

Activities
- FY 2019: Focused on rare earth elements
- FY 2020: Focused on rare earth elements and 10 more commodities: Al, Co, graphite, Li, Nb, PGEs, Ta, Sn, Ti, and W
Components of Earth MRI: Geophysics, Geology, Lidar, Data Preservation Coordinated through USGS Mineral Resources Program

75% of Earth MRI Funds for Data Acquisition and Preservation

- **Minerals Resources Program**: Designs and interprets new airborne geophysical surveys in cooperation with State Geological Surveys (~$2.69M in FY20)
- **National Cooperative Geologic Mapping Program**: Funds geologic mapping and geochemistry reconnaissance projects by State Geological Surveys ($2.27M in FY20)
- **National Geospatial Program**: Leverages funds from partners to acquire new lidar data ($1.75M in FY20)
- **National Geologic and Geophysical Data Preservation Program**: Supports State Geological Surveys efforts to preserve and make publicly available critical mineral and borehole data and participate in Earth MRI workshops ($762k in FY20)

<7% of US with adequate coverage

<35% of US with adequate coverage

Existing Geophysical Surveys
- Usable quality

Existing Geological Mapping
- Fine-scale
- Moderate
Status of 3DEP Lidar Surveys

Data are available or in progress for ~70% of the Nation
*includes lidar and Alaska IfSAR

Data acquisition investments by all partners, by fiscal year

http://usgs.gov/3DEP/
### List of 35 Critical Mineral Commodities

**Earth MRI Phases 1 and 2 Critical Minerals (in red)**

<table>
<thead>
<tr>
<th>Critical Minerals</th>
<th>Why These?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (bauxite)</td>
<td>US has high net import reliance.</td>
</tr>
<tr>
<td>Antimony</td>
<td>Usage is increasing beyond foreseeable domestic production.</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Focus first on those commodities that, if discovered, may reduce the Nation’s net import reliance.</td>
</tr>
<tr>
<td>Barite</td>
<td>Lower priority given to those commodities for which improvements in recovery and marketing of current supplies can satisfy domestic markets.</td>
</tr>
<tr>
<td>Beryllium</td>
<td></td>
</tr>
<tr>
<td>Bismuth</td>
<td></td>
</tr>
<tr>
<td>Cesium &amp; Rubidium</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td></td>
</tr>
<tr>
<td>Fluorspar</td>
<td></td>
</tr>
<tr>
<td>Gallium</td>
<td></td>
</tr>
<tr>
<td>Germanium</td>
<td></td>
</tr>
<tr>
<td>Graphite (natural)</td>
<td></td>
</tr>
<tr>
<td>Helium</td>
<td></td>
</tr>
<tr>
<td>Indium</td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
</tr>
<tr>
<td>Niobium</td>
<td></td>
</tr>
<tr>
<td>Platinum Group Metals</td>
<td></td>
</tr>
<tr>
<td>Potash</td>
<td></td>
</tr>
<tr>
<td>Rare Earth Elements (REEs)</td>
<td></td>
</tr>
<tr>
<td>Rhenium</td>
<td></td>
</tr>
<tr>
<td>Scandium</td>
<td></td>
</tr>
<tr>
<td>Strontium</td>
<td></td>
</tr>
<tr>
<td>Tantalum</td>
<td></td>
</tr>
<tr>
<td>Tellurium</td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td></td>
</tr>
<tr>
<td>Tungsten</td>
<td></td>
</tr>
<tr>
<td>Uranium</td>
<td></td>
</tr>
<tr>
<td>Vanadium</td>
<td></td>
</tr>
<tr>
<td>Zirconium &amp; Hafnium</td>
<td></td>
</tr>
</tbody>
</table>
List of 35 Critical Mineral Commodities

Preliminary List of Earth MRI Phase 3 Critical Minerals (in blue)

Why these?

- Focus first on those commodities that, if discovered, may reduce the Nation’s net import reliance.
- Lower priority given to those byproduct commodities for which economics of recovery and market forces are most critical factors and supply is not the primary issue.

Note:
- Most of the remaining critical minerals are byproducts of deposits covered in Phases 1-3.
- Need to enhance existing data to include prominent host mineral systems.

Phase 1 and 2 critical mineral commodities in red
Phase 3 critical mineral commodities in blue
**Mineral Systems Approach**

**Example: Porphyry Copper-Molybdenum-Gold System**

![Diagram of Porphyry Copper-Molybdenum-Gold System](image)

<table>
<thead>
<tr>
<th>System Name</th>
<th>Deposit types</th>
<th>Principal Commodities</th>
<th>Critical minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pegmatite</td>
<td>Li, Cs, Ta</td>
<td></td>
<td>Li, Cs, Ta, Be</td>
</tr>
<tr>
<td>Greisen</td>
<td>Mo, W, Sn</td>
<td></td>
<td>W, Sn</td>
</tr>
<tr>
<td>S-R-V Tungsten</td>
<td>W</td>
<td></td>
<td>W, Bi, Mn</td>
</tr>
<tr>
<td>Porphyry/Skarn</td>
<td>Mo, W, Sn</td>
<td></td>
<td>W, Re, Bi</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porphyry/Skarn Copper</td>
<td>Cu, Ag, Au, Mo</td>
<td></td>
<td>PGE, Te, Re, Bi, U</td>
</tr>
<tr>
<td>Polymetallic</td>
<td>Cu, Zn, Pb, Ag, Au</td>
<td></td>
<td>Mn, Ge, Ga, In, Bi, Sb, As, W, Te</td>
</tr>
<tr>
<td>Sulfide S-R-V-IS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal Disseminated</td>
<td>Ag, Au</td>
<td></td>
<td>Sb, As</td>
</tr>
<tr>
<td>Ag-Au</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High sulfidation</td>
<td>Cu, Ag, Au</td>
<td></td>
<td>As, Sb, Te, Bi, Sn, Ga</td>
</tr>
<tr>
<td>Au-Ag</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithocap Alunite</td>
<td>Al2O3, K2SO4, H2SO4</td>
<td></td>
<td>Al2O3, K2SO4, Ga</td>
</tr>
<tr>
<td>Lithocap Kaolinite</td>
<td>Kaolin</td>
<td></td>
<td>Ga</td>
</tr>
</tbody>
</table>

Abbreviations: S skarn, R replacement, V vein, IS intermediate sulfidation.
Earth MRI Phase 2 Focus Areas

Areas Identified workshops with 38 State Geological Surveys in Fall 2019

Earth MRI Phase 2 Critical Minerals

- Aluminum
- Cobalt
- Graphite (natural)
- Lithium
- Niobium
- Platinum group elements
- Rare earth elements (also FY19 focus)
- Tantalum
- Tin
- Titanium
- Tungsten
FY19 & FY20 Project Areas For Phase 1 & 2 Critical Mineral Commodities
(Aluminum, cobalt, graphite (natural), lithium, niobium, platinum group metals, rare earth elements, tantalum, tin, titanium, and tungsten)
FY19 & FY20 Project Areas For Phase 1 & 2 Critical Mineral Commodities
(Aluminum, cobalt, graphite (natural), lithium, niobium, platinum group metals, rare earth elements, tantalum, tin, titanium, and tungsten)
# New FY20 Funded Earth MRI Projects

## Geologic Mapping Projects (~$2.27M*)

<table>
<thead>
<tr>
<th>State</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>Yukon-Tanana Upland, east-central AK</td>
</tr>
<tr>
<td>Arizona</td>
<td>Lithium resources in the Big Sandy Valley and environs</td>
</tr>
<tr>
<td>Colorado</td>
<td>Wet Mountains carbonatites</td>
</tr>
<tr>
<td>Florida</td>
<td>Heavy mineral sand deposits in northern Florida</td>
</tr>
<tr>
<td>Maine</td>
<td>Lithium-, cesium-, niobium-, tantalum-bearing pegmatites</td>
</tr>
<tr>
<td>Missouri</td>
<td>Proterozoic of Eastern St. Francois Mountains</td>
</tr>
<tr>
<td>Montana</td>
<td>Bull Mountain</td>
</tr>
<tr>
<td>New Mexico</td>
<td>Trans-Pecos Tertiary alkaline rocks, TX-NM</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Cornwall-type Magnetite Skarns, Mesozoic Basins</td>
</tr>
<tr>
<td>Texas</td>
<td>Trans-Pecos Tertiary alkaline rocks, TX-NM</td>
</tr>
<tr>
<td>Utah</td>
<td>Gold Hill mining district</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Central Laramie Range</td>
</tr>
</tbody>
</table>

*Includes geochemistry reconnaissance projects and geochemistry support
New FY20 Funded Earth MRI Projects

<table>
<thead>
<tr>
<th>Regional Geophysical Surveys (~$2.69M)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State(s)</strong></td>
</tr>
<tr>
<td>Alaska</td>
</tr>
<tr>
<td>Colorado</td>
</tr>
<tr>
<td>Minnesota</td>
</tr>
<tr>
<td>Missouri-Illinois</td>
</tr>
<tr>
<td>Texas-New Mexico</td>
</tr>
<tr>
<td>Virginia-North Carolina</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geochemistry Reconnaissance Projects (~$476k)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State</strong></td>
</tr>
<tr>
<td>Indiana</td>
</tr>
<tr>
<td>Illinois</td>
</tr>
<tr>
<td>West Virginia</td>
</tr>
<tr>
<td>Kentucky</td>
</tr>
</tbody>
</table>
Devonian Phosphates Geochemistry Reconnaissance Projects

The Issues
- Rare earth element enrichment seen in Upper Devonian phosphatic sediments over a vast region of Eastern and Central US (Emsbo and others, 2015, 2016).
- Could represent a major resource for REEs for the Nation!
- High risk-high reward situation
- Need to lower the risks with reconnaissance effort

The Challenges
- How extensive is REE enrichment? Regional variability? Stratigraphic control?
- Limited resources—Need to determine if and where appropriate to concentrate future studies.
- Not practical to set up 12-15 Cooperative Agreements for single topic with uncertain outcome.
Devonian Phosphates Geochemistry Reconnaissance Projects

The Approach

• Set up reconnaissance projects to evaluate regional geochemical, geographic, and stratigraphic variabilities and gain insights on geologic processes controlling REE enrichment in sedimentary phosphate units.

• Indiana (lead) and Illinois (partner) Geological Surveys will work across the region with other States and Devonian experts to evaluate.

• Projects: total $200k with $36k geochemistry budget (~1,200 samples)

• Appreciate help and cooperation from other State Surveys!

• 2 year study generating database for sample characterization and geochemistry and summary report.

• Use information gathered to evaluate if, where, and how much to devote resources for follow-up studies.

• Will guide possible future project scoping.
Middle to Upper Pennsylvanian Underclays Projects

The Issues
- Pennsylvanian-aged coal-bearing units known to host underclay deposits over vast area of US.
- Known to have elevated Al, Li, and REEs.
- Could represent a major resource for REEs for the Nation!
- High risk-high reward situation
- Need to lower the risks with reconnaissance effort

The Challenges
- How extensive is lithium and REE enrichment? Regional variability? Stratigraphic control?
- Limited resources—Need to determine if and where appropriate to concentrate future studies.
- Not practical to set up >10 Cooperative Agreements for single topic with uncertain outcome.
Middle to Upper Pennsylvanian Underclays Projects

The Approach

• Set up reconnaissance projects to evaluate regional geochemical, geographic, and stratigraphic variabilities.
• West Virginia (lead) and Kentucky (partner) Geological Surveys will work across the region with other States.
• Projects: total $200k with $36k geochemistry budget (~1,200 samples).
• Appreciate help and cooperation from other State Surveys!
• 2 year study generating database summary report.
• Use information to evaluate if, where, and how much to devote resources for follow-up studies.
• Engaging with DOE for opportunities to cooperate.
High Resolution Magnetic Anomaly Map
Earth MRI Geophysical Survey

The new airborne survey maps igneous centers such as Hicks Dome, Coefield anomaly, and Omaha Dome as well as several new centers.

Hicks Dome
- is a breccia complex with several critical minerals including fluorite-barite-titanium-niobium-beryllium-thorium-rare earth elements-yttrium
- It sits within the Illinois-Kentucky fluorspar district, which is a major source of domestic fluorite and significant amounts of lead, zinc, barite, cadmium, and germanium.
- Mineralization at Hicks Dome is thought to be related to igneous rocks at depth.

The new airborne survey has identified anomalies and dikes associated with the known igneous centers and importantly, has identified several new igneous centers that were not previously known.

These features have potential for similar critical metal mineralization as Hicks Dome.

McCafferty and Brown (2020), [https://doi.org/10.5066/P9R05B0M](https://doi.org/10.5066/P9R05B0M)
New Earth MRI Products

Released Spring 2020:
McCafferty and Brown (2020), Airborne magnetic and radiometric survey, southeastern Illinois, western Kentucky, and southern Indiana, 2019, https://doi.org/10.5066/P9R05B0M.
Dicken and Hammarstrom (2020), GIS for focus areas of potential domestic resources of 11 critical minerals—aluminum, cobalt, graphite, lithium, niobium, platinum group elements, rare earth elements, tantalum, tin, titanium, and tungsten, https://doi.org/10.5066/P95CO8LR.

In the pipeline:
McCafferty and others (in review), Airborne magnetic and radiometric survey, northern Arkansas, ScienceBase data release.
Americans Love Lithium

But How Should We Mine it in the 21st Century?

Alex Grant
Principal, Jade Cove Partners
agtjadecove.com
www.jadecove.com/research
alexjadecove

US Department of Energy
29 June 2020
Why Americans Love Lithium
1. Americans love how EVs don’t need gas, oil changes, transmission fluids, coolants, & other smelly, explosive, & expensive chemicals. Driving an EV is like driving an iPhone.
2. Americans love paying less for repairs. Fewer moving parts means less maintenance.
3. Americans love to stop paying gasoline bills. American electrons are cheaper energy.
4. Americans love computer-controlled, autonomous vehicles, which work better as electric.
5. Americans love warp drive acceleration of electric motors compared to ICE motors.
6. Americans love that EVs barely make any noise. Quiet cities are less stressful.
7. Americans love that EVs don’t emit NO\textsubscript{x}, SO\textsubscript{x}, and particulate emissions, which currently cause 53,000 premature American deaths every year from ICE vehicles alone.
8. Americans love transparent air in their cities so they can see the faraway mountains.
9. Americans love how EVs are 3x more energy efficient than ICE vehicles.
10. Americans love using homegrown electrons to power their vehicles.
Lithium Packs Light (on Neutrons and Protons) and We Are Practically Swimming in Electrons

It’s the best way to store energy for almost all ground transport.

Period.
EV Demand is Lithium Chemical Demand

The profound impact of the megafactories on raw material demand

Assuming a 100% utilisation rate, these are the numbers...

- Graphite anodes in batteries 2018 = 170,000 tonnes
- Graphite anodes in batteries 2028 = 2.22m tonnes
- Lithium in batteries 2018 = 150,000 tonnes
- Lithium in batteries 2028 = 1.48m tonnes
- Nickel in batteries 2028 = 82,000 tonnes
- Nickel in batteries 2028 = 1.19m tonnes
- Cobalt in batteries 2028 = 58,000 tonnes
- Cobalt in batteries 2028 = 365,000 tonnes

Source: Benchmark Mineral Intelligence

Tesla Vehicle Sales ( Deliveries )
Europe and China: Off to the Races

The entire planet is rapidly mobilizing lithium-ion battery supply chain strategies as we speak because Europe, China, and other governments understand that their citizens also love lithium... What about the US?
Lithium-Ion Battery Supply Chain Overview
In the Ground: The Types of Lithium Natural Resources

<table>
<thead>
<tr>
<th>Pegmatites</th>
<th>Sedimentary Deposits</th>
<th>Brines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spodumene</td>
<td>Smectites</td>
<td>Salaris</td>
</tr>
<tr>
<td>Lepidolite</td>
<td>Illites</td>
<td>Oilfield/Continental</td>
</tr>
<tr>
<td>Petalite</td>
<td>Jadarite</td>
<td>Geothermal</td>
</tr>
<tr>
<td>Zinnwaldite</td>
<td>Searlesite</td>
<td>Ocean</td>
</tr>
<tr>
<td>Amblygonite</td>
<td><em>Combinations &amp; Others</em></td>
<td></td>
</tr>
<tr>
<td>Eucryptite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zabuyelite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Bradshaw
From Ground to Garage: The Lithium Atom’s Journey

1. Lithium Deposit to Concentrate
2. Lithium Processing to Battery Chemical
3. Cathode Manufacturing
4. Lithium-Ion Cell Manufacturing
5. Battery Pack & EV Manufacturing
6. EV Market
# Global State of Play Today

## Simplified Map of Significant Participation in the Current, Global Lithium-Ion Battery Supply Chain – June 2020

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
</tr>
<tr>
<td>North Carolina</td>
<td></td>
<td>[Active]</td>
<td></td>
<td></td>
<td>[Active]</td>
<td></td>
</tr>
<tr>
<td>Alberta</td>
<td></td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quebec</td>
<td></td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>[Active]</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>[Active]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **Active:** Existing participation in the jurisdiction.
- **Aspiring:** Efforts or plans to develop participation in the jurisdiction.
- **Upstream** and **Downstream** indicate the direction of participation in the supply chain.
- (*) Either commercial or political efforts exist to develop the activity within the jurisdiction (some more realistic than others).
- Note: This map is not intended to be comprehensive.
Rules of Thumb for LIB Supply Chain Industrial Policymaking

From *So, You Want to Make Batteries Too?* (by Grant, Hersh, & Berry), with Payne Institute at the Colorado School of Mines and Institute of the Americas, June 2020

A Framework for Developing Lithium-Ion Battery Supply Chain Industrial Strategy

1. **If your jurisdiction does not participate in a LIB supply chain, and you have a resource but no EV market or EV manufacturing, incentivize upstream activity.**

2. **If your jurisdiction does not participate in a LIB supply chain, and you have an EV market or historic vehicle manufacturing but no significant resources, incentivize downstream activity.**

3. **If your jurisdiction already produces lithium concentrates from a resource but not battery chemicals, incentivize processing to battery chemical production. Don't incentivize activity any further downstream unless you have an EV market.**

4. **If your jurisdiction has an EV market or EV manufacturing, move upstream one step at a time. Stop at processing to make battery chemicals if you have no significant resources, or go all the way upstream if you have resources.**

5. **To build a resilient LIB supply chain, build partnerships with jurisdictions who have complimentary positions in a LIB supply chain so that you can vertically integrate as a team.**
Where Does The US Stand?
Large-Scale Cathode Manufacturing in the US: Coming Soon?
The Broader Opportunity

- More Tesla Gigafactories (Texas/Oklahoma (?) Gigafactory)
- Other EV manufacturers setting up shop from Arizona to Massachusetts
- European EV manufacturing
The US is Rich in Lithium Resources

The Western Sedimentary Lithium Projects – October 2019

<table>
<thead>
<tr>
<th>Pegmatites</th>
<th>Sedimentary Deposits</th>
<th>Brines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spodumene</td>
<td>Smoother</td>
<td>Salars</td>
</tr>
<tr>
<td>Legipalite</td>
<td>Ilite</td>
<td>Oilfield/Continental</td>
</tr>
<tr>
<td>Petalite</td>
<td>Jadellite</td>
<td>Geothermal</td>
</tr>
<tr>
<td>Zinnwaldite</td>
<td>Seionite</td>
<td>Ocean</td>
</tr>
<tr>
<td>Apiterite</td>
<td>Combinations &amp; Others</td>
<td></td>
</tr>
<tr>
<td>Eucryptite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zabuyelite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

And don’t forget the Carolinas’ Tin-Spodumene Belt

North American Brownfield Lithium Brine Potential Opportunities – November 2019

1. Leduc Formation (oil)
2. Great Salt Lake Region (Mg metal, MgCl₂, NaCl, K₂SO₄, other salts)
3. Mojave Desert (H₂SO₄, Na₂SO₄, other salts)
4. Salton Sea (geothermal power)
5. Bakken Shale (oil)
6. Paradox Basin (oil)
7. Marcellus Shale (oil)
8. Smacker Formation (oil, Br₂, CaCl₂)
And Leading in New Extraction Technologies

Direct Lithium Extraction (DLE) is used in Argentina and China, but originally developed by Dow Chemical for American oilfield brines.

Minimize costs of production by:
- Minimizing energy consumption
- Minimizing reagent consumption
- Minimizing water consumption
- Minimizing waste production
It’s The American Way!

2010

2020
What’s
The Plan?
We Need to Think Big

Capital markets are failing to write big checks and accept longer payback periods to build chemical plants ("WeWork Syndrome").

Let’s use US federal government funding mechanisms to fund the construction of three lithium projects (to start):
1. One spodumene project
2. One sediment project
3. One DLE brine project

We should take a portfolio approach to build on the USA’s lithium processing expertise for the next generation. If we can develop a diversity of types of resources, we will be faced with a diversity of technical challenges and develop a diversity of technical skills in solving those problems.
1. Permitting Should be Accelerated
It takes 2-5 years to permit a new mine in Canada or Australia, ex-British colonies settled by miners from the UK who kept their extractive industries alive. In the US, it can take upwards of 10 years. Set up a task force?

2. Environmental Impact Acceptance Should Remain Strict
All extraction operations have environmental impacts, and the government decides if proposed impacts are acceptable or not. The US could simultaneously accelerate permitting while maintaining high standards for waste disposal, water consumption, and other parameters (Where will soluble sulfate waste products go?).

3. Expertise in Lithium Processing Can Help Achieve American Strategic Goals (At Home & Abroad)
On top of leveraging our historic experience in lithium extraction and processing, countries around the world will benefit from cooperating with American companies to build their LIB supply chains too.

4. The American Scientific Machine Should be Unleashed on Mineral Processing Challenges
The US national lab and university system hosts some of the most brilliant scientists and engineers on the planet. But they do not understand mineral project development or know what the right problems to work on are (ex. electrochemical lithium extraction from geothermal brines is a bad idea that just won’t die).
How Can I Help, DOE?
Americans Love Lithium

But How Should We Mine it in the 21st Century?

Alex Grant
Principal, Jade Cove Partners
ag@jadecove.com
www.jadecove.com/research
alexjadecove

US Department of Energy
29 June 2020
Manufacturing of Battery Critical Materials

Dr. Kenan Sahin
Founder and President, CAMX Power

June 29, 2020

CAMX Power
35 Hartwell Avenue
Lexington, MA
02421-3102

www.camxpower.com

© 2020 CAMX Power LLC
Manufacturing of Battery Critical Materials

Three Major Li-ion Battery Markets

- Industrial Stationary: Evolving market, ~20% CAGR
- Transportation: Rapidly growing market, ~30% CAGR
- Electronic Devices: Mature market, ~5% CAGR

Source: AVICENNE Energy 2019
Manufacturing of Battery Critical Materials

Global Lithium-ion Battery Market (GWh)

- Other
- Industrial Stationary
- Transportation
- Electronic Devices

Source: AVICENNE Energy 2019
Anatomy of a Li-ion Battery Cell

**Pouch Cell**
- Positive Lead
- Negative Lead
- Anode
- Cathode
- Separator
- Filled with liquid electrolyte

**Cylindrical Cell**
- Positive Lead
- Negative Lead
- Separator
- Filled with liquid electrolyte
- Anode
- Cathode

Source: [https://www.teijin.com/rd/technology/separator/](https://www.teijin.com/rd/technology/separator/)
Manufacturing of Battery Critical Materials

Contributions to Cell Cost

50-65% of cathode cost is raw material cost

Source: Benchmark Mineral Intelligence 2020
Lithium and Metals Comprise 65% of the NMC811 Cathode Cost

- Lithium, 26%
- Nickel, 30%
- Cobalt, 9%
- Processing and Labor, 29%
- Manganese, 1%
- Energy & Consumables, 5%

Transportation cost of cathode from the source to the cell production site is not included.
How to achieve cost reduction across the supply/manufacturing chain?

- Significant economies of scale in the supply and procurement of critical metals.
- Significant economies of scale in plant size and the production of materials and cells.
- Reduced transportation costs through vertical integration and co-location of facilities.
## Global EV and Battery Cathode Markets

<table>
<thead>
<tr>
<th>Year</th>
<th>Global EV Sales</th>
<th>Global EV Market ($)</th>
<th>Global Li-ion EV Cathode Market ($)</th>
<th>Global Li-ion EV Cathode Market (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>~2 MM</td>
<td>~$80 B</td>
<td>~$5 B</td>
<td>~200,000 tons</td>
</tr>
<tr>
<td>2025</td>
<td>~10 MM</td>
<td>~$400 B</td>
<td>~$25 B</td>
<td>~1,000,000 tons</td>
</tr>
<tr>
<td>2030</td>
<td>~25 MM</td>
<td>~$1 TN</td>
<td>~$65 B</td>
<td>~2,500,000 tons</td>
</tr>
<tr>
<td>2035</td>
<td>~50 MM</td>
<td>~$2 TN</td>
<td>~$130 B</td>
<td>~5,000,000 tons</td>
</tr>
</tbody>
</table>

Assumption: 300 mile EV range → ~ 100 kg cathode/EV → ~$ 2,500 cathode/EV
~$ 40,000 / EV

Source: Bloomberg New Energy Finance Electric Vehicle Outlook 2020
How much of this market do we want supplied domestically?

- Li-ion batteries are strategic products that are widely used by critical infrastructure sectors (e.g., defense, energy, emergency services).
- The cathode material drives the cost and performance of Li-ion batteries.
- High-nickel cathode material is key to high performance Li-ion batteries, especially for EVs.
# US EV and Battery Cathode Markets

<table>
<thead>
<tr>
<th>Year</th>
<th>US EV Sales</th>
<th>US EV Market ($)</th>
<th>US Li-ion EV Cathode Market ($)</th>
<th>US Li-ion EV Cathode Market (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>~0.3 MM</td>
<td>~$12 B</td>
<td>~$1 B</td>
<td>~30,000 tons</td>
</tr>
<tr>
<td>2025</td>
<td>~1.5 MM</td>
<td>~$60 B</td>
<td>~$4 B</td>
<td>~150,000 tons</td>
</tr>
<tr>
<td>2030</td>
<td>~4 MM</td>
<td>~$150 B</td>
<td>~$10 B</td>
<td>~400,000 tons</td>
</tr>
<tr>
<td>2035</td>
<td>~8 MM</td>
<td>~$300 B</td>
<td>~$20 B</td>
<td>~750,000 tons</td>
</tr>
</tbody>
</table>

Assuming 15% of Global Market

- The cathode market for electronic devices and industrial stationary storage
- The large supply of cathode material for the current DoD electrification program

Source: Bloomberg New Energy Finance Electric Vehicle Outlook 2020
What would it take to have cathode production in the US in 2025?

- **CAPEX**
  - 150,000 tons by 2025 increasing to 400,000 tons by 2030
  - At 10,000 metric tons/year per cathode plant → ~ 15 cathode plants by 2025
  - At ~ $50 MM CAPEX per cathode plant → Less than ~ $1 B investment to make cathode in USA
  - For at least a $5 B US cathode market per year (allowing for DoD, stationary, and electronics)
What else is necessary for US cathode manufacturing in addition to CAPEX and demand?

- Intellectual Property: Lacking in the US
- Deep Cathode Synthesis Expertise: Lacking at industrial scale in the US for high-nickel
- Deep Cell Design Expertise: Lacking at industrial scale in the US for high-nickel

Manufacturing of Battery Critical Materials
Manufacturing of Battery Critical Materials

Deep cell design knowledge is required for precise component control.

There are multiple choices for each component.
2019 Li-ion Battery Patent Landscape

Top 5 Patent Offices (2019)
- China (8,063)
- Japan (1,870)
- European Union (2,185)
- United States (3,871)
- Korea (1,544)

Top 5 Assignees (2019)
- LG Chem (Korea) 40%
- Toyota (Japan) 24%
- Samsung (Korea) 19%
- Sumitomo (Japan) 9%
- Toshiba (Japan) 8%

Source: LexisNexis
Manufacturing of Battery Critical Materials

• Key cathode active materials were invented in the USA.
• The compositional patents have either expired or will soon expire.
• Key processing patents of these materials are held by foreign companies.

Current Cathode Material Market Share

- NMC (41%)
- LFP (34%)
- LMO (5%)
- NCA (9%)
- LCO (11%)

Source: AVICENNE Energy 2019
CAMX has global composition IP in high nickel classes

CAMX has deep cell design expertise (multiple ongoing DoD demonstration programs)

CAMX has a functioning industrial pilot plant in Massachusetts

About CAMX
Manufacturing of Battery Critical Materials

- The CAMX-invented GEMX™ cathode platform is based on engineering grain boundaries to overcome the problems associated with high-nickel, low-cobalt cathode materials.

- The GEMX™ cathode platform applies to all high-nickel materials, in particular NCA, NMC, and LNO.

- The GEMX™ cathode platform is protected by granted patents worldwide.

<table>
<thead>
<tr>
<th>gNCA™</th>
<th>gNMC™</th>
<th>gLNO™</th>
</tr>
</thead>
<tbody>
<tr>
<td>gNCA™ with &lt; 6 mol % Co demonstrated to have same performance as conventional NCA with 15 mol % Co</td>
<td>gNMC™ with 10 mol % Co demonstrated to have superior performance compared to commercial NMC(811)</td>
<td>gLNO™ has best combination of capacity and life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 210 mAh/g at C/5 rate</td>
</tr>
</tbody>
</table>

Patents are valid beyond 2030
The GEMX™ Cathode Platform in the Market

- Recently Samsung **HAS ACQUIRED** a global license to the GEMX™ cathode platform.

- Samsung is already selling cells with GEMX™ equivalent cathode material in the US and internationally.

- Samsung and a Korean partner are adding a 150,000 ton capacity to an existing 30,000 ton plant in South Korea to be completed by 2023.

- CAMX believes a significant fraction of this capacity will be dedicated to gNCA™ and gNMC™ equivalent cathode materials.
The GEMX™ Cathode Platform in the Market

- In 2016, Johnson Matthey (JM) licensed CAMX’s original high nickel cathode platform (CAM-7®), and in less than a year after significant technology transfer from CAMX, built a pilot plant to produce eLNO™ (JM's branding).

- In 2018, JM licensed CAMX’s GEMX™ cathode platform.

- In 2016, BASF also licensed CAMX’s original high nickel cathode platform.

- Conversations with additional licensees are ongoing.

Source: Johnson Matthey
Manufacturing of Battery Critical Materials

CAMX Business Model

Early Stage Technologies (Internal and External Sources)

CAMX Technology Processing

Low-Rate Initial Production at CAMX

Technologies and Products for Rapid Adoption by Manufacturers

Partnering with High-Volume Manufacturers

- De-Risked
- Scaled-up
- IP-Protected

- Accelerated Growth
- Shortened Time to Market & Profitability
- Lower Risk & Cost
- CAMX Staff Engageable for Interactive Technology Transfer
Manufacturing of Battery Critical Materials

- It is strategically important and economically viable to have cathode production in the US.
- The investment required is modest compared to the size of the market and its strategic importance.
- CAMX is well-poised to partner with domestic companies for rapid creation of a domestic cathode supply chain for US and international markets.

For inquiries info@camxpower.com
Questions?
Debt Capital for Commercial Deployment

Potential opportunities through LPO’s automotive and innovative energy programs

Aaron Trent, Origination
Battery Critical Materials Supply Chain Opportunities – Virtual Workshop
June 29, 2020
Financing Energy Infrastructure

NOW AVAILABLE: MORE THAN $40 BILLION IN LOAN & LOAN GUARANTEE AUTHORITY

**TITLE 17 INNOVATIVE ENERGY LOAN GUARANTEE PROGRAM**

- **ADVANCED FOSSIL ENERGY**
  - $8.5 Billion
  - ($2 Billion conditionally committed to Lake Charles Methanol)

- **ADVANCED NUCLEAR ENERGY**
  - $8.8 Billion
  - ($2 Billion specifically for Front End)

- **RENEWABLE ENERGY & EFFICIENT ENERGY**
  - Up to $4.5 Billion

---

**TRIBAL ENERGY LOAN GUARANTEE PROGRAM**

- **Up to $2 Billion**
  - In Partial Loan Guarantees

- **ADVANCED TECHNOLOGY VEHICLES MANUFACTURING LOAN PROGRAM**
  - **$17.7 Billion**

  - All-of-the-above energy projects benefiting tribal economies

  - Domestic manufacturing of light-duty vehicles & eligible components
Advanced Technology Vehicles Manufacturing (ATVM) Loan Program

Key Benefits

⚡ Very low cost debt (U.S. Treasury rates, minimal fees)
⚡ Flexible loan structures (corporate, project, structured corporate)
⚡ Qualifying investments include automotive supply chain (e.g., battery cell and cell component) manufacturing

Important Considerations/Requirements

⚡ Use of funds: Capital investments – typically construction and/or procurement of equipment – in U.S. manufacturing (also certain engineering integration costs)
⚡ Legal restriction to manufacturing vs. mining/extraction
⚡ Designed for and installed in light-duty vehicles (LDVs) that meet a certain fuel economy threshold (most/all BEVs qualify)
⚡ Transaction credit profile

Other Useful Information (all LPO programs)

⚡ Recommended size: $50+ mm
⚡ When to reach out: 6-12+ mos. prior to spend/capex
Title 17 Innovative Energy Loan Program

Key Benefits

⚡ Access to debt capital for first-time commercialization of new technology
⚡ Flexible loan structures (corporate, project, structured corporate)
⚡ Long-term partner – from development through construction and operation
⚡ No limitation to automotive/LDVs or manufacturing
⚡ Sample project: more energy-efficient mining, processing, recycling etc.

Important Considerations/Requirements

⚡ Located in the U.S.
⚡ New or significantly improved ("innovative") technology
⚡ GHG benefits (reduce, avoid or sequester) on lifecycle basis
⚡ Cost of funds not subsidized / based on credit profile
⚡ Use of funds: Costs directly related to design, engineering, financing, construction, startup and commissioning
Potential Applicants

- Potential applicants are encouraged to contact DOE staff and request a pre-application consultation to learn more about our process and requirements.

For Questions or to Request a Consultation

- lpo@hq.doe.gov or 202-586-8336

Learn More

- Visit our website: energy.gov/lpo
THANK YOU