North American Lithium-Ion Battery Supply Chain Database Development – Phase II

Ahmad Pesaran, Vicky Putsche, and Margaret Mann
National Renewable Energy Laboratory

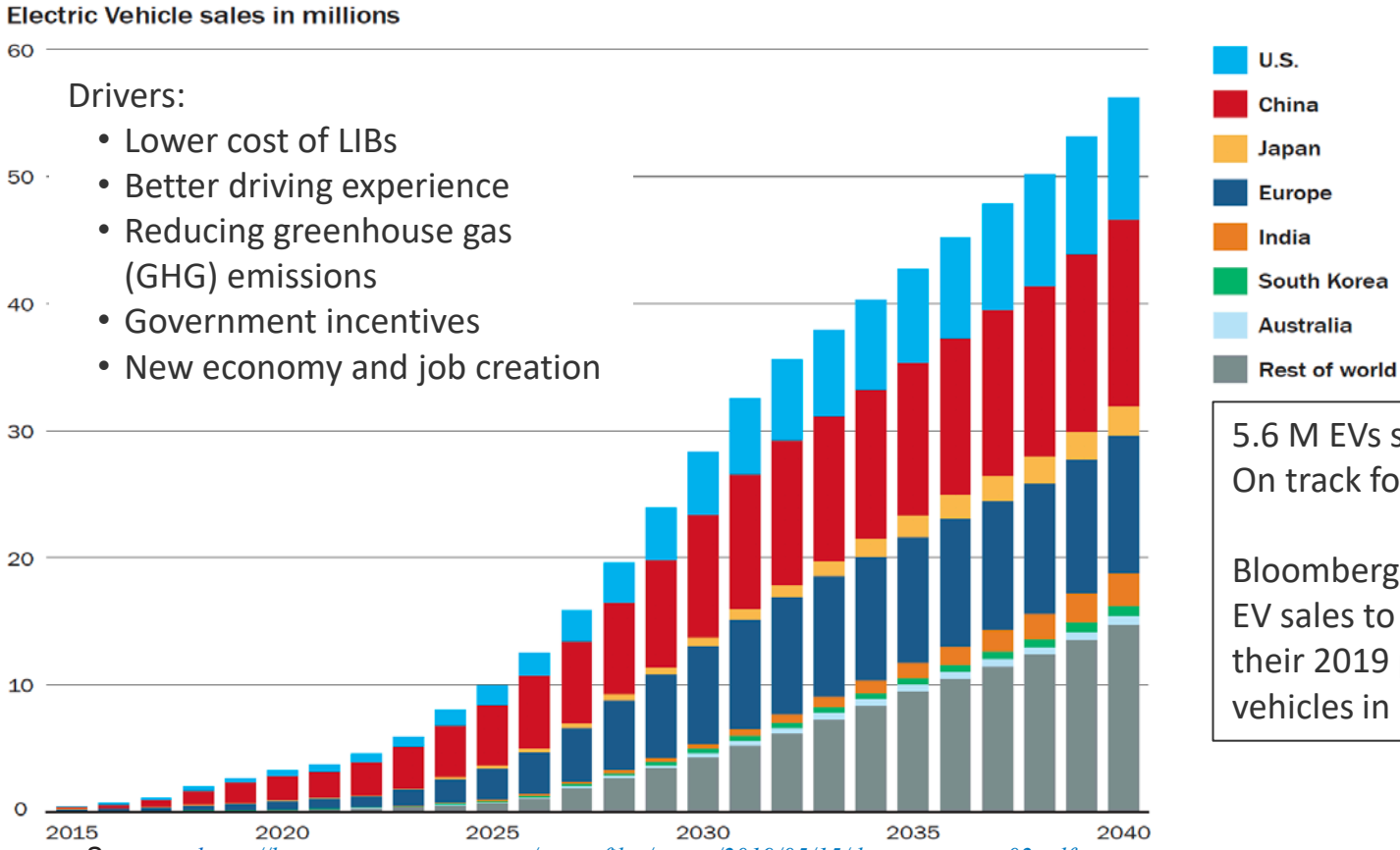
Sponsored by James Greenberger, NAATBatt International

NREL/PR-5700-85610

Summary

- Lithium-ion batteries (LIBs) are used in a wide range of applications, including cell phones, electric vehicles (EVs), and grid storage, and are essential for economic growth and addressing climate change
- However, the significant demand for LIBs has led to supply chain issues for the United States exasperated with China dominance in processing of battery materials and battery production
- To address this concern, NAATBatt International partnered with the National Renewable Energy Laboratory (NREL) to develop a database of companies that mine, process, manufacture, reuse, and recycle batteries in North America
- The purpose of this database is to identify strengths and gaps in the supply chain so that private-government partnerships can develop strategies to create a competitive LIB supply chain in North America
- NREL published the first version of this database in 2021 and the second version in 2022
- The database will be updated every 6 months for the next few years
- This presentation will discuss our approach to collecting data and categorizing various segments and products. We will also provide a summary of the data and present various maps to illustrate the distribution of companies in the database.

EV Adoption Is Faster than Expected



Drivers:

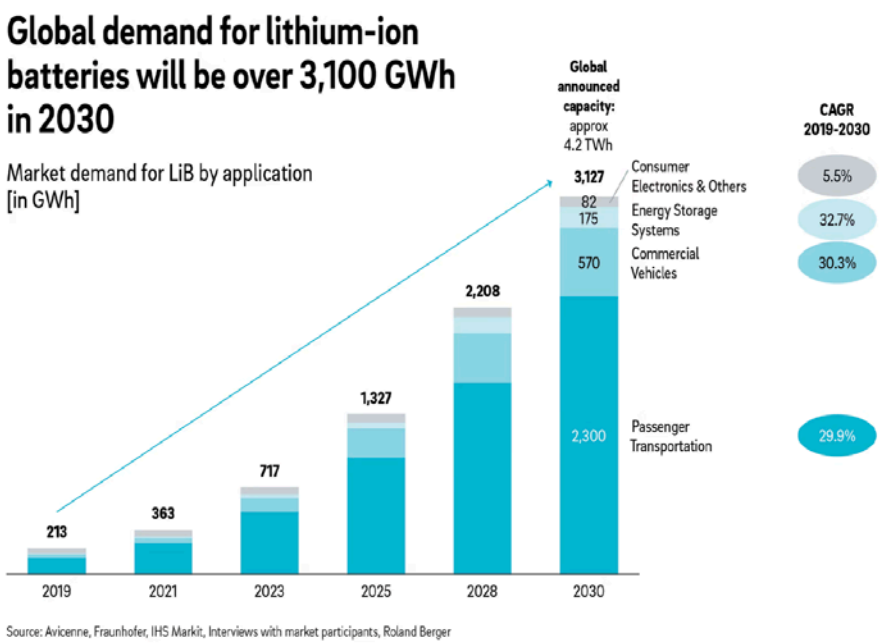
- Lower cost of LIBs
- Better driving experience
- Reducing greenhouse gas (GHG) emissions
- Government incentives
- New economy and job creation

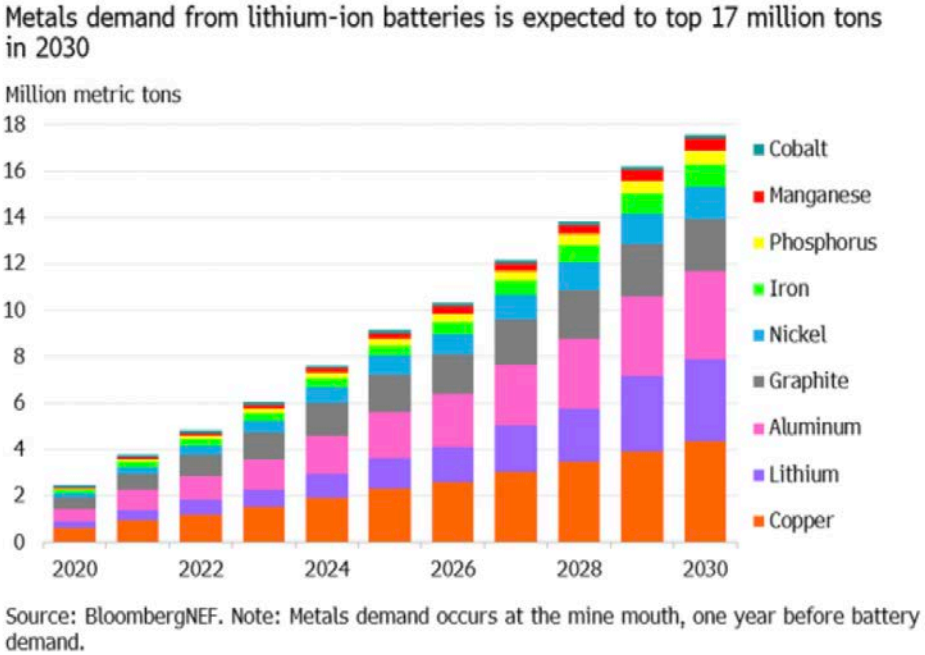
5.6 M EVs sold in 2021
On track for 10 M EV sales in 2022

BloombergNEF is now forecasting EV sales to be 20-30% higher than their 2019 projection (40 M vehicles in 2030)

Source: https://legacy-assets.eenews.net/open_files/assets/2019/05/15/document_ew_02.pdf

Accelerating Demand for LIBs and Key Materials





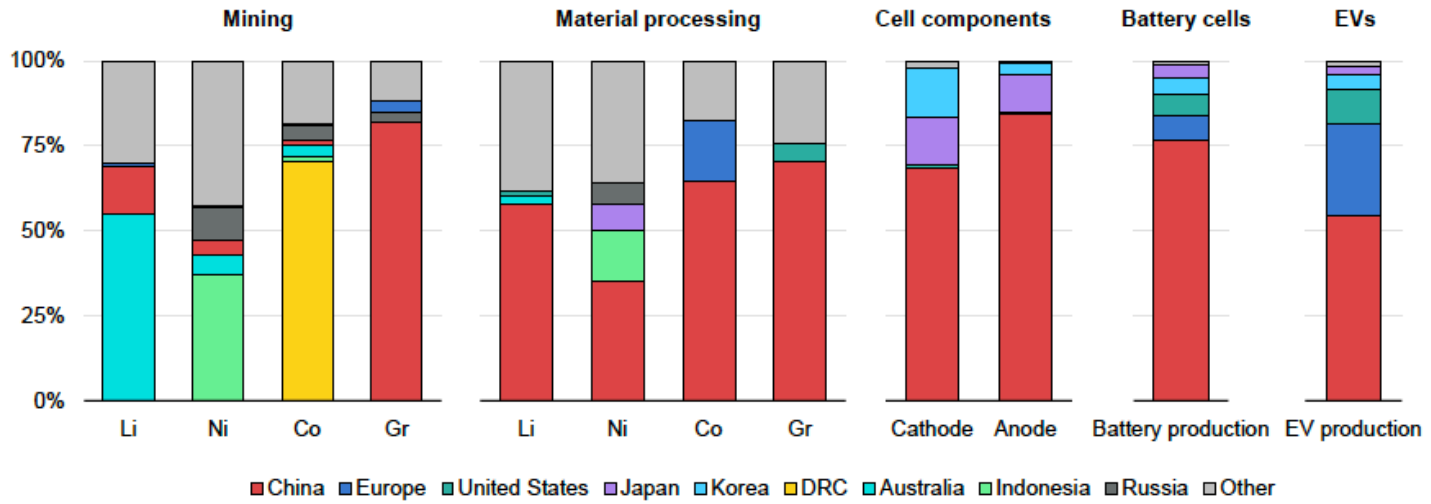
https://www.mynewsdesk.com/rolandberger/pressreleases/rising-demand-for-lithium-ion-batteries-may-lead-to-shortages-in-raw-material-supply-3173780

https://about.bnef.com/blog/race-to-net-zero-the-pressures-of-the-battery-boom-in-five-charts/

Two issues regarding supply chain: 1. Dramatic ram up in demand squeezes the supply regardless of where materials come from, 2. Part of supply chain is further squeezed as productions are limited to a few places

Currently China Dominates the Entire Downstream EV LIB Supply Chain

Source: Global Supply Chains of EV Batteries, July 2022, International Energy Agency https://www.iea.org/reports/global-supply-chains-of-ev-batteries



- China produces 70% of cathode and 85-90% of anode material global production capacity.
- China produces more than 70% of all LIBs

This is a significant concern for many countries, including U.S., that plan to move to EVs.

The Need for Understanding LIB Supply Chain

- In late 2020, NAATBatt, a trade association of companies promoting battery commercialization in North America, committed to better understanding the LIB supply chain landscape
- In April 2021, NAATBatt funded NREL to develop a database of companies that supply goods, equipment, and services to process, manufacture, or recycle high-voltage lithium-ion materials, cells, and battery packs in North America (Phase I)
- The purpose of this project was to:
  - Provide a list of potential suppliers and business partners to NAATBatt
  - Identify where the gaps are in the North American LIB supply chain and inform government agencies to address issues
- Federal Consortium for Advanced Batteries (FCAB) National Blueprint for Lithium Batteries
  - Identified significant LIB supply chain risks create challenges to the U.S. economy, defense, and decarbonization plans
  - Outlined strategies to address this challenge

(https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf).

Phase I – NREL Approach and Data Sources

Public Search

- Internet searches and literature searched
- U.S. and Canada business directories
- Technical and marketing conferences
- Government-supported efforts (USABC, FOA, STTR/SBIR).

Private Searches

- Bloomberg New Energy Finance (BNEF)
- Thomas databases (https://business.thomasnet.com/about)
- Zauba (for trade data: https://www.zauba.com/)
- Market reports and commercial databases.

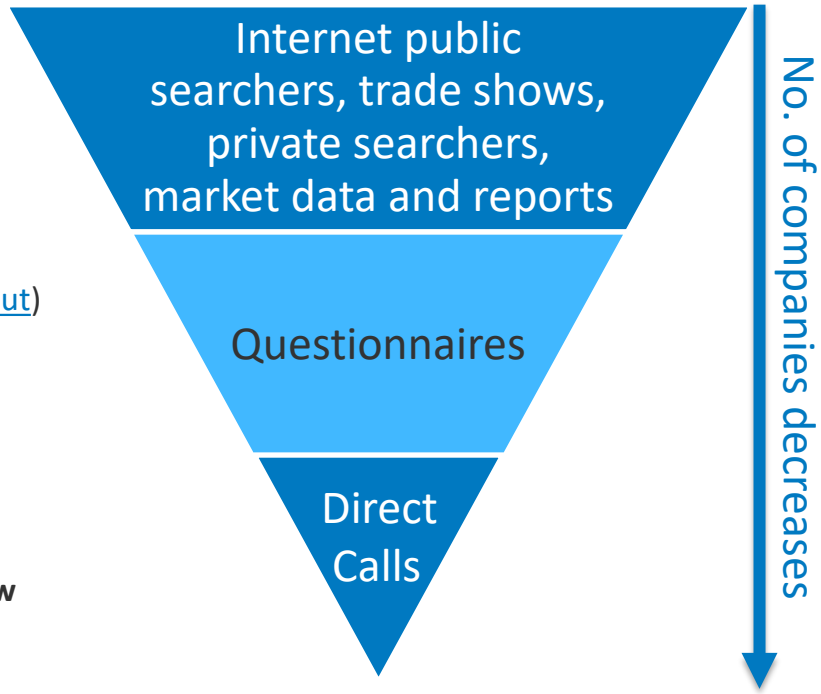
Questionnaire

- Emailed all NAATBatt members and other stakeholders
- Conducted quality check of replies.

Interviews with Select Stakeholders

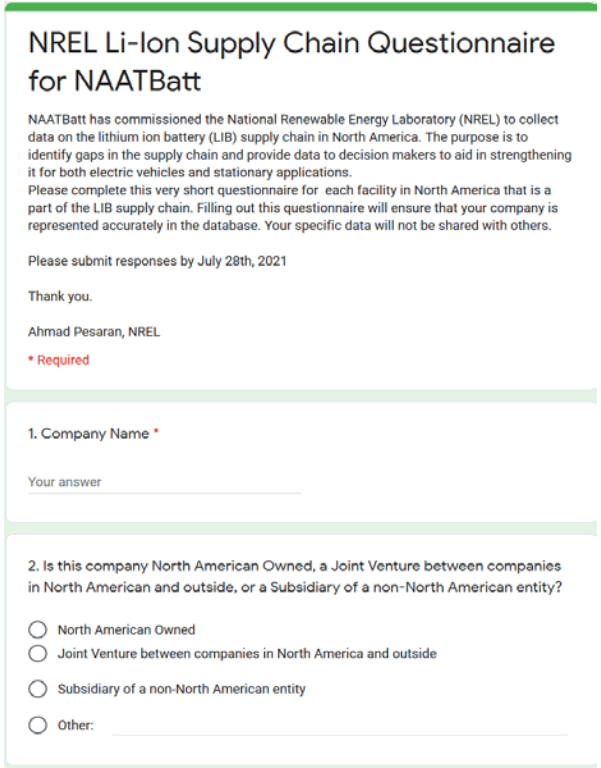
Frequent progress review meetings with NAATBatt Technical Review Committee

- Obtained insight
- Clarification on terminology.



Phase I – Questionnaires and Interviews

- **Questionnaire**
  - Sent to all current NAATBatt members
  - Sent to approximately 600 others
  - Received >150 responses
  - Researched responses for quality check
- **Interviews**
  - Contacted companies with missing or confusing data



NREL Li-Ion Supply Chain Questionnaire for NAATBatt

NAATBatt has commissioned the National Renewable Energy Laboratory (NREL) to collect data on the lithium ion battery (LIB) supply chain in North America. The purpose is to identify gaps in the supply chain and provide data to decision makers to aid in strengthening it for both electric vehicles and stationary applications.
Please complete this very short questionnaire for each facility in North America that is a part of the LIB supply chain. Filling out this questionnaire will ensure that your company is represented accurately in the database. Your specific data will not be shared with others.

Please submit responses by July 28th, 2021

Thank you.

Ahmad Pesaran, NREL

* Required

1. Company Name *

Your answer

2. Is this company North American Owned, a Joint Venture between companies in North American and outside, or a Subsidiary of a non-North American entity?

- North American Owned
- Joint Venture between companies in North America and outside
- Subsidiary of a non-North American entity
- Other:

Phase I – Building the LIB Supply Chain Database

- NREL completed the first phase and developed the LIB Supply Chain Database in the Excel framework, including:
  - Most companies doing business in materials, cells, packs, and end-of-life (EOL) management with a manufacturing facility in North America
  - List of companies engaged in li-ion battery modeling, distribution, service and repair, logistics, and research and development (R&D).
- NREL collected information on the size of the workforce and production volumes but did not include this in the first version of the database for source clarifications
- NREL released the database on September 15, 2021. NAATBatt announced its release to the public on The Battery Show https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html
- More than 500 unique users have downloaded the database
- NREL and NAATBatt continued to publicize the availability of the database, e.g., at International Battery Seminar in March 2022.

Phase II - Improving and Expanding the Database

- Realizing LIB Supply Chain Database development should be an ongoing effort, NAATBatt funded NREL in May 2022 to initiate Phase II
  - Demand for LIB is growing and new companies are forming
  - The LIB market is competitive and evolving fast
  - Some information (e.g., production capacity) is not always publicly available, and companies may not want to share this
  - We know that we must have missed things
  - New companies and facilities will constantly be coming online
  - Impact of the Bipartisan Infrastructure Bill and Department of Energy Funding Opportunity Announcement for developing battery supply chain
- In Phase II, we will regularly update information from existing companies in the database and add information about new companies.

Phase II – Updated Database Released in August 2022

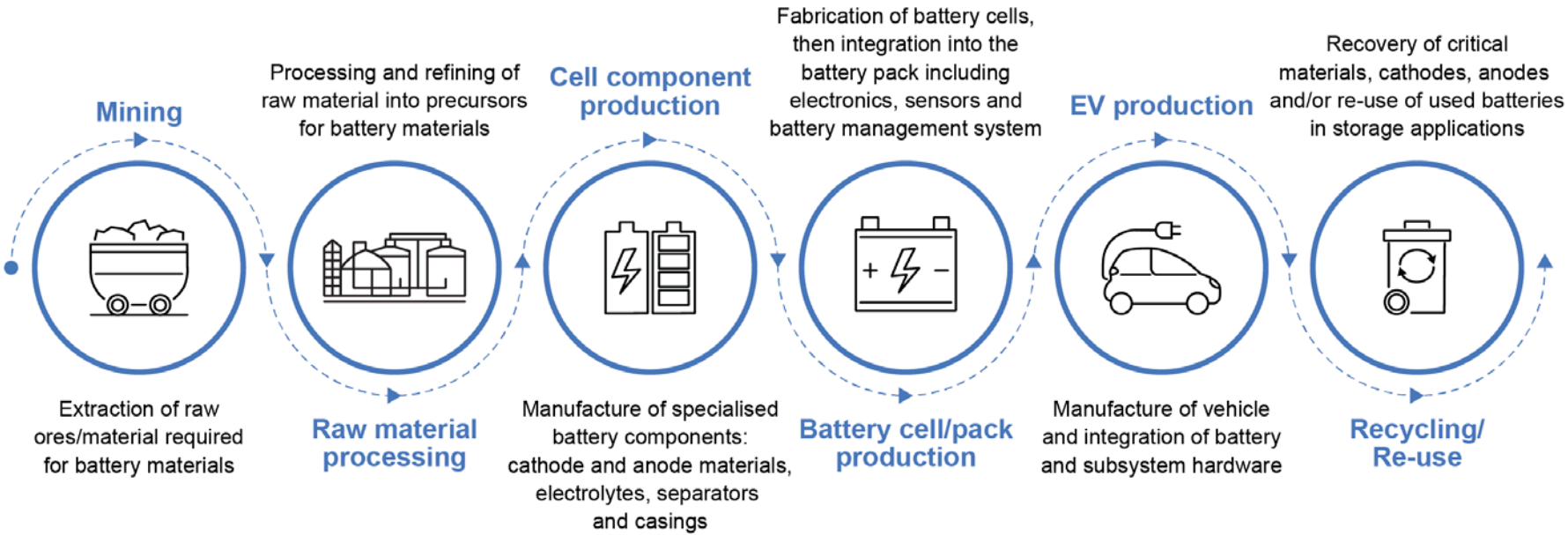
The updated database was released on August 10, 2022, at the NAATBatt Battery Recycling Workshop. This update includes:

- Almost 50 new facilities and 40 new companies added
- Facility workforce and production capacities added from public sources
  - Over 60% of facility workforce values
  - Almost 50% of production values for manufacturing and EOL segments
- Numerous name changes/mergers, including:
  - Ascend Elements (formerly Battery Resourcers)
  - Cirba Solutions (formed from Battery Solutions, Heritage Recycling, Retrieve Technologies)
  - Anovion (from Armsted Graphite Materials affiliates and Pyrotek Battery Materials Division)
- New Gigafactory Details/Announcements
  - Tesla in Texas locations
  - LG/GM in Michigan, Ohio, and Tennessee
- Corrected information based on feedback on the last version
- Added improved searching capability and mapping capabilities.

More than 600 unique users have downloaded the latest version of the database.

Making Batteries for EVs Requires Several Stages

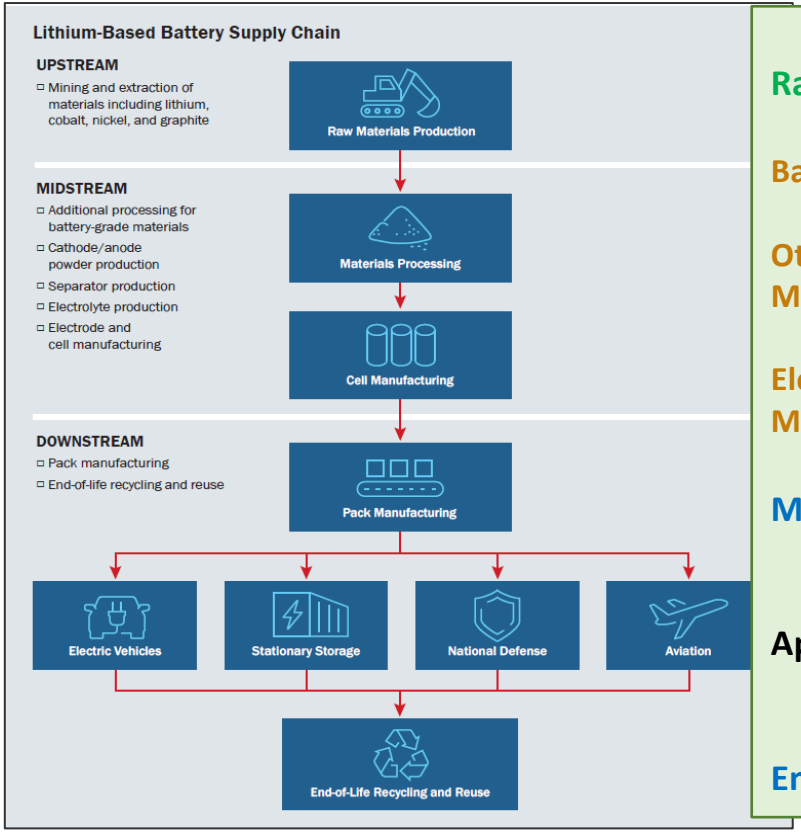
Global Supply Chains of EV Batteries, July 2022, International Energy Agency https://www.iea.org/reports/global-supply-chains-of-ev-batteries



Using proper terminologies accepted by most stakeholders is essential. There are various segments/companies in each stage.

Segments in the Database Consistent with FCAB Blueprint

FCAB National Blueprint for Lithium Batteries 2021-2030



NAATBatt/NREL Database 2021

Raw Materials

Battery Grade Materials

Other Battery Components and Materials

Electrode and Cell Manufacturing

Module/Pack Manufacturing

Applications

End of Life Management

- **Manufacturing Supply Chain**
  - Raw Materials
  - Battery Grade Materials
  - Other Battery Components and Materials
  - Electrode and Cell Manufacturing
  - Module/Pack Manufacturing
- **EOL Supply Chain**
- **Other Segment Supply Chains**
  - Equipment
  - Service
  - R&D
  - Modeling and Software
  - Distributors

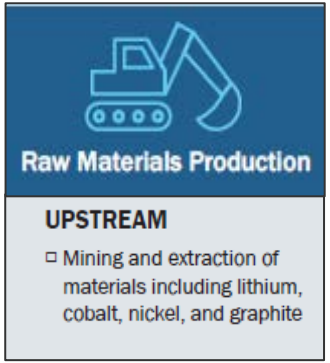
Database Statistics as of August 2022

Supply Chain Segment	US		Canada		Other		Total	
	Companies	*Facilities*	Companies	*Facilities*	Companies	*Facilities*	Companies	*Facilities*
Raw Material Manufacturing	4	*7*	11	*16*	3	*4*	**18**	***27***
Battery Grade Component Manufacturing	21	*31*	6	*7*	5	*5*	**32**	***43***
Other Battery Components and Materials Manufacturing	20	*22*	1	*1*	1	*1*	**22**	***24***
Electrode and Cells Manufacturing	30	*35*	4	*4*	0	*2*	***34***	***41***
Modules and Packs Manufacturing	95	*109*	9	*10*	2	*6*	**106**	***125***
End of Life/Recycling	37	*49*	6	*6*	0	*0*	**43**	**55**
Equipment Manufacturing	28	*30*	1	*1*	3	*2*	**32**	***33***
R&D	88	*96*	9	*9*	3	*3*	**100**	***108***
Service and Repair	58	*60*	4	*0*	0	*4*	**62**	***64***
Modeling	15	*15*	1	*1*	1	*1*	**17**	***17***
Distributors	3	*3*	1	1	0	*0*	**4**	***4***
Totals	**399**	***457***	**53**	***56***	**18**	***28***	**470**	***541***

*Companies are counted more than once if they are active in multiple sections of the supply chain and/or have multiple products

Example of a Segment: Raw Materials - Upstream

- RawMatl Spreadsheet
- Mining and extraction of cathode and anode materials and initial processing (e.g., concentrating) of those materials
- Other component raw materials are not included.



Example

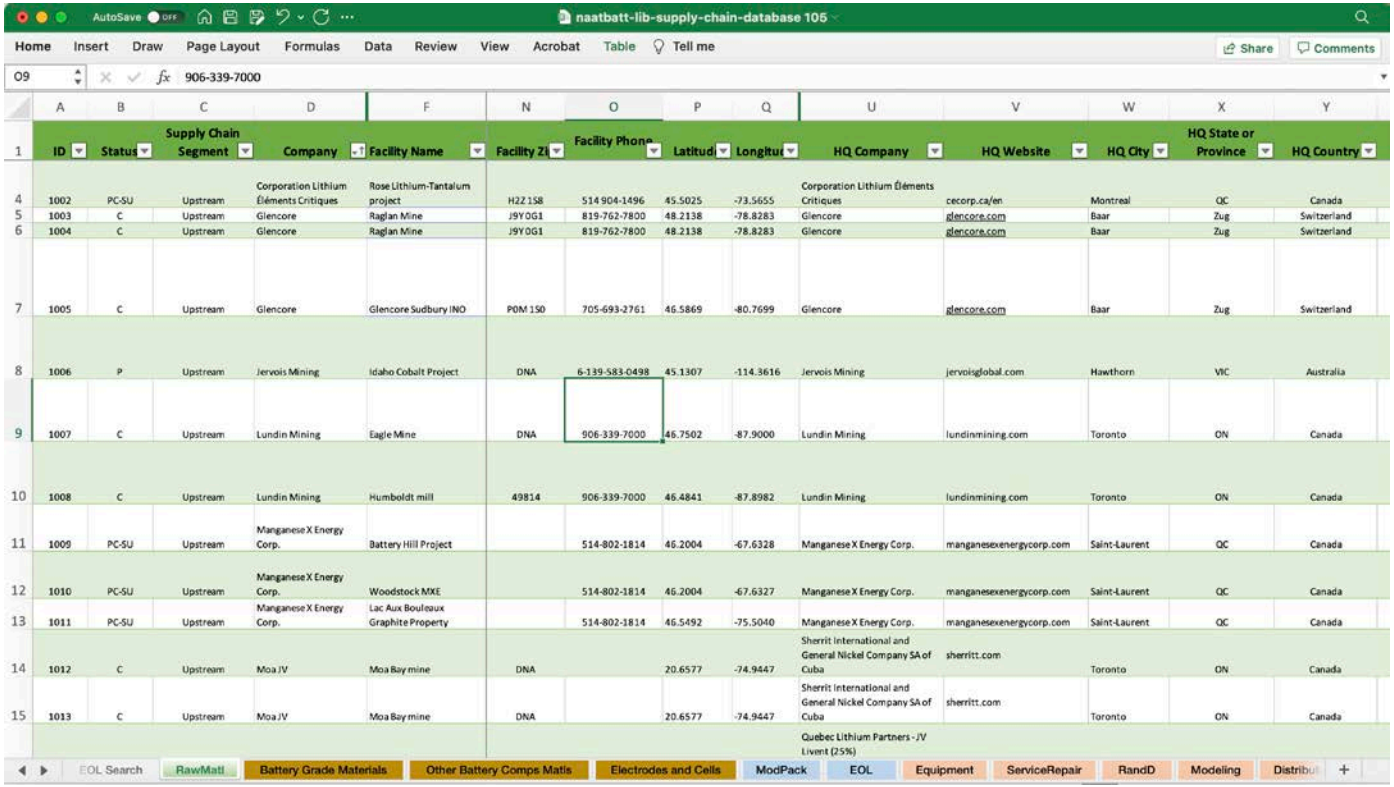
RAW MATERIALS				
Company	**Facililty**	**Location**	**Product Type**	**Product**
Vale Canada Ltd	Sudbury Basin	Copper Cliff, ON	Cathode raw materials	Co concentrates
Glencore	Raglan Mine	Rouyn-Noranda, QC	Cathode raw materials	Ni concentrates
Albemarle	Silver Peak Phase I	Silver Peak, NV	Cathode raw materials	Li concentrates/ salts
Nouveau Monde Graphite	Advanced Materials Plant (Planned)	Becancour, QC	Anode raw materials	Graphite ore/ concentrate

RAW MATERIALS SUPPLY CHAIN	
Product Type	**Product**
Anode raw materials (crude)	Brine
	Li carbonate - crude
	Graphite ore/ concentrates
	Spodumene
	Other
Cathode raw materials (crude)	Brine
	Co concentrates
	Co ore
	Li carbonate - crude
	Li clay
	Li concentrates/salts
	Mn concentrates
	Mn ore
	Ni concentrates
	Ni ore
	Spodumene
	Other

Accessing NAATBatt LIB SC Database

https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html

An Example Screenshot of the Database



naatbatt-lib-supply-chain-database 105

Home Insert Draw Page Layout Formulas Data Review View Acrobat Table Tell me Share Comments

O9 906-339-7000

	A	B	C	D	F	N	O	P	Q	U	V	W	X	Y
1	ID	Status	Supply Chain Segment	Company	Facility Name	Facility Zi	Facility Phone	Latitud	Longitu	HQ Company	HQ Website	HQ City	HQ State or Province	HQ Country
4	1002	PC-SU	Upstream	Corporation Lithium Éléments Critiques	Rose Lithium-Tantalum project	H2Z 1S8	514 904-1496	45.5025	-73.5655	Corporation Lithium Éléments Critiques	cecorp.ca/en	Montreal	QC	Canada
5	1003	C	Upstream	Glencore	Raglan Mine	J9Y 0G1	819-762-7800	48.2138	-78.8283	Glencore	glencore.com	Baar	Zug	Switzerland
6	1004	C	Upstream	Glencore	Raglan Mine	J9Y 0G1	819-762-7800	48.2138	-78.8283	Glencore	glencore.com	Baar	Zug	Switzerland
7	1005	C	Upstream	Glencore	Glencore Sudbury INO	P0M 1S0	705-693-2761	46.5869	-80.7699	Glencore	glencore.com	Baar	Zug	Switzerland
8	1006	P	Upstream	Jervois Mining	Idaho Cobalt Project	DNA	6-139-583-0498	45.1307	-114.3616	Jervois Mining	jervoisglobal.com	Hawthorn	VIC	Australia
9	1007	C	Upstream	Lundin Mining	Eagle Mine	DNA	906-339-7000	46.7502	-87.9000	Lundin Mining	lundinmining.com	Toronto	ON	Canada
10	1008	C	Upstream	Lundin Mining	Humboldt mill	49814	906-339-7000	46.4841	-87.8982	Lundin Mining	lundinmining.com	Toronto	ON	Canada
11	1009	PC-SU	Upstream	Manganese X Energy Corp.	Battery Hill Project		514-802-1814	46.2004	-67.6328	Manganese X Energy Corp.	manganesexenergycorp.com	Saint-Laurent	QC	Canada
12	1010	PC-SU	Upstream	Manganese X Energy Corp.	Woodstock MXE		514-802-1814	46.2004	-67.6327	Manganese X Energy Corp.	manganesexenergycorp.com	Saint-Laurent	QC	Canada
13	1011	PC-SU	Upstream	Manganese X Energy Corp.	Lac Aux Bouleaux Graphite Property		514-802-1814	46.5492	-75.5040	Manganese X Energy Corp.	manganesexenergycorp.com	Saint-Laurent	QC	Canada
14	1012	C	Upstream	Moa JV	Moa Bay mine	DNA		20.6577	-74.9447	Sherrit International and General Nickel Company SA of Cuba	sherritt.com	Toronto	ON	Canada
15	1013	C	Upstream	Moa JV	Moa Bay mine	DNA		20.6577	-74.9447	Sherrit International and General Nickel Company SA of Cuba	sherritt.com	Toronto	ON	Canada
										Quebec Lithium Partners - JV Livent (25%)				

EOL Search | RawMatl | Battery Grade Materials | Other Battery Comps Matls | Electrodes and Cells | ModPack | EOL | Equipment | ServiceRepair | RandD | Modeling | Distribu | +

rials | Other Battery Comps Matls | Electrodes and Cells | ModPack | EOL

Easier Search Capabilities Added in Recent Database

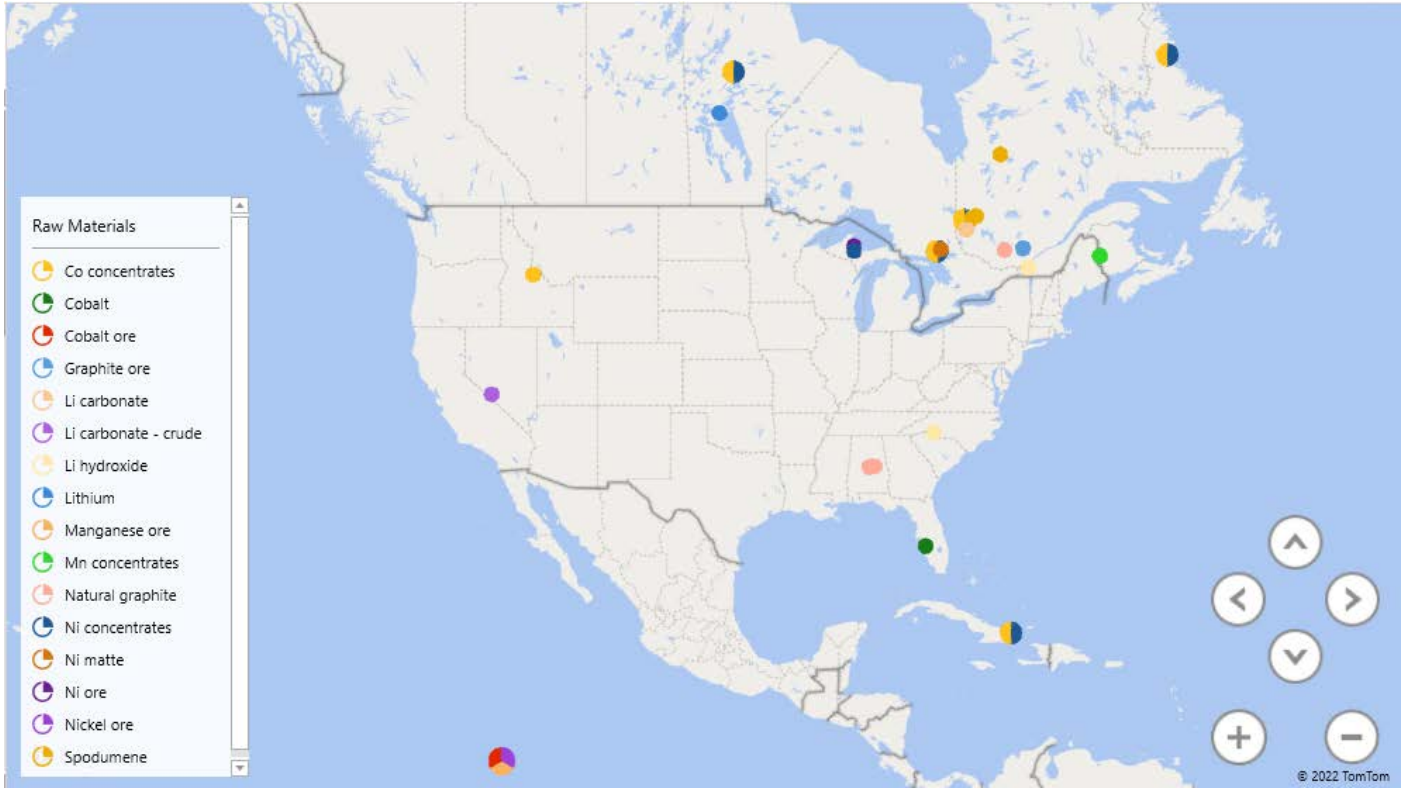
Directions:	1. Select the **Search Type** (*Company, Product, State*) in the yellow box next to **Search Type**.						
	2. Enter the full or partial name of a the selected **Search Type** in the 2nd yellow box and hit Enter	**No. of Records:**	0				

Search		**Results**								
Select Search Type (dropdown list):	Product	**ID**	**Status**	**Company**	**Facility Name**	**Facility City**	**Facility State or Province**	**Facility Country**	**Product or Service Type**	**Product or Service**
Product										
Note:	If a company is in the EOL sector (e.g. recycling), use the **EOL Search** sheet instead									

Database Mapping Capabilities

Guide to Creating Maps is Included in the Map Instruction Sheet

Example: Raw Materials Companies in North America, August 2022

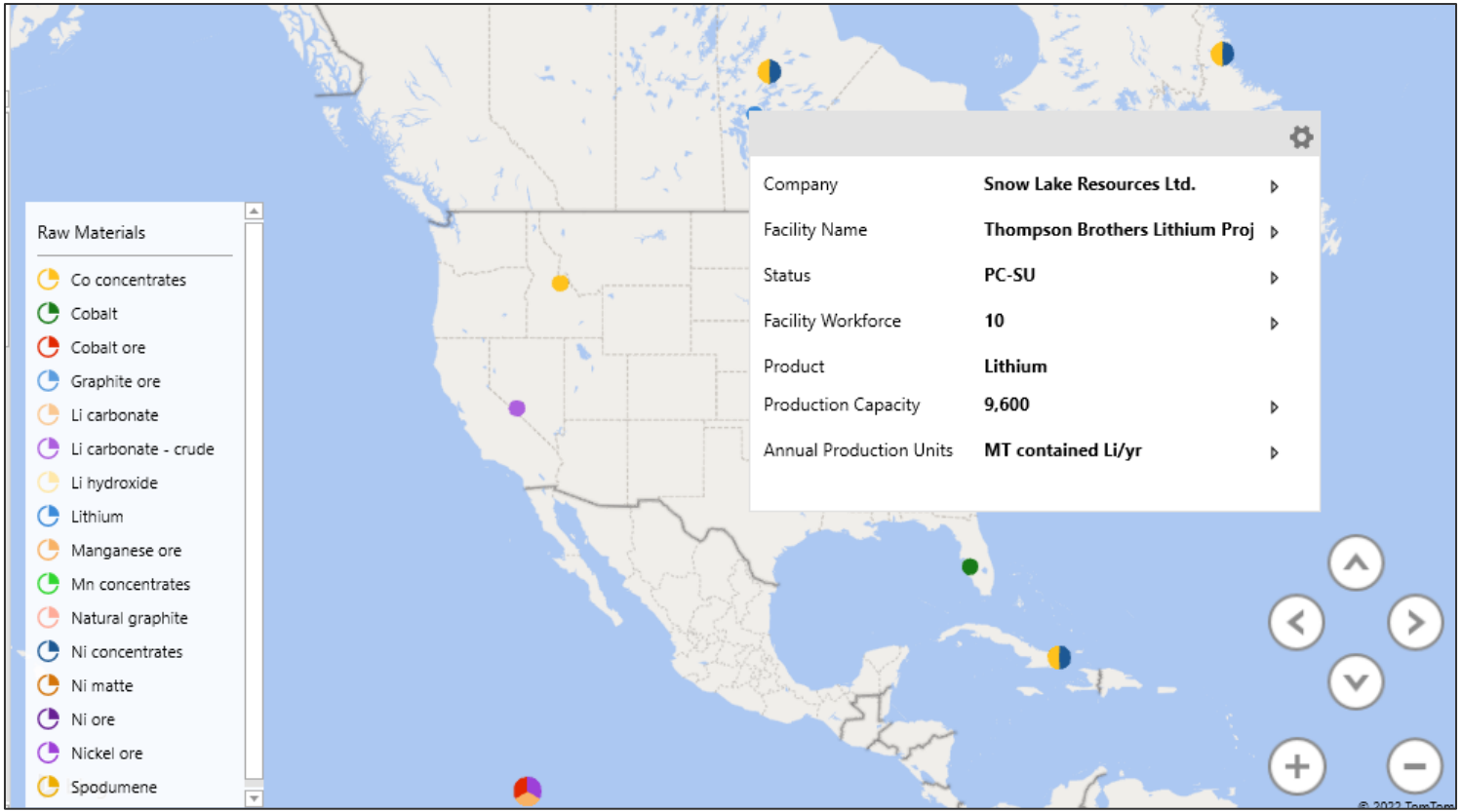


Symbols:

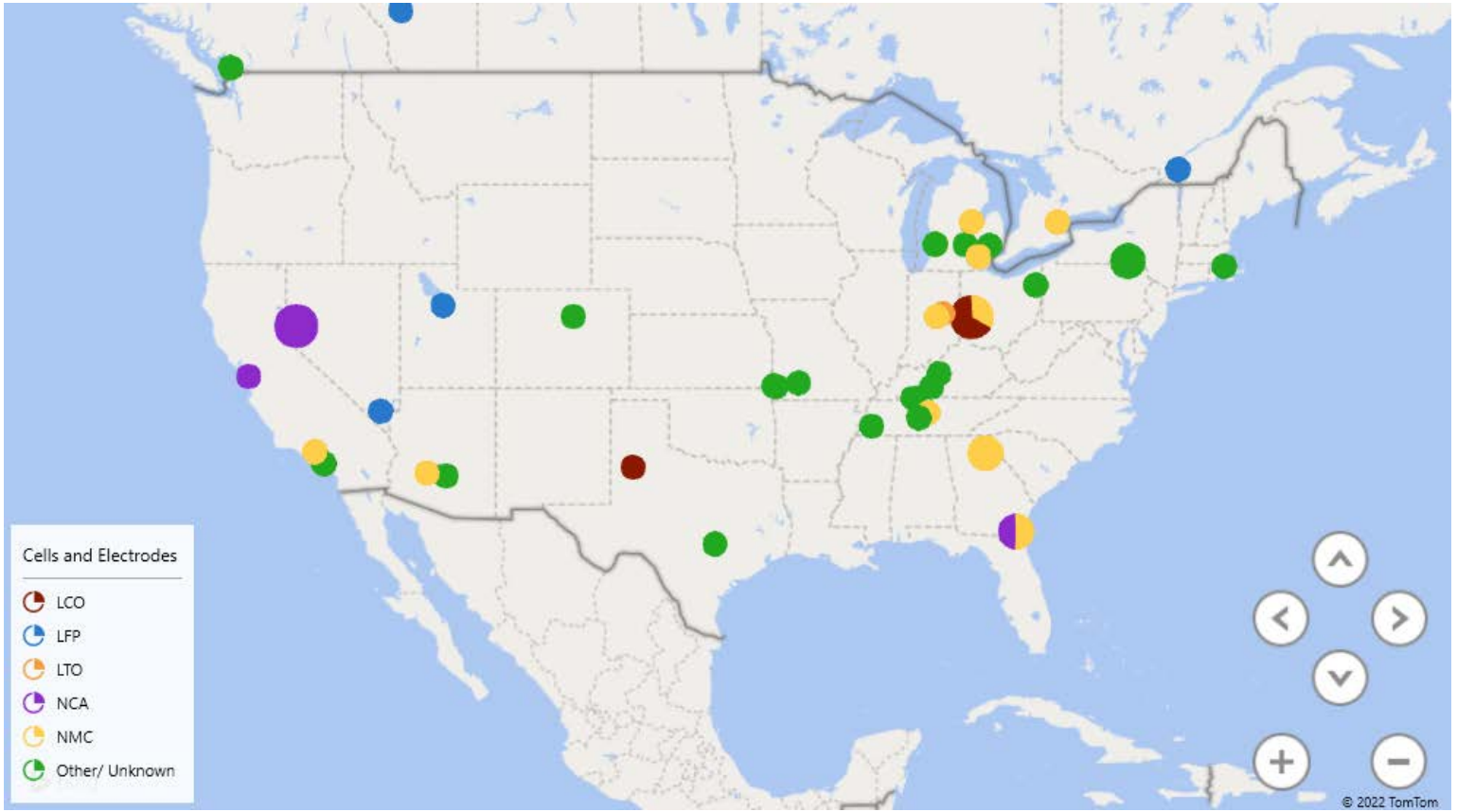
- Size of the circle indicates annual production
- Color indicates product type

Maps Allow Data Drill-Down for More Information

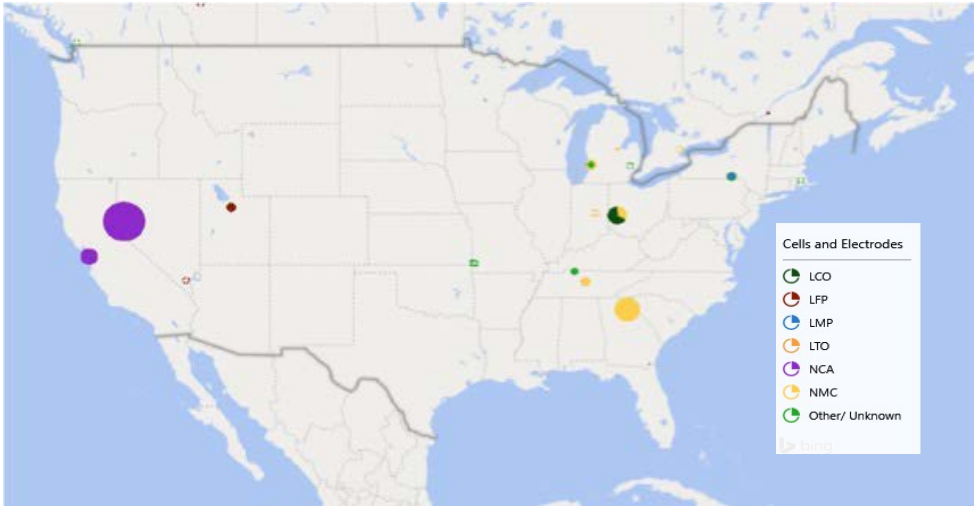
Example: Raw Materials Companies in North America, August 2022



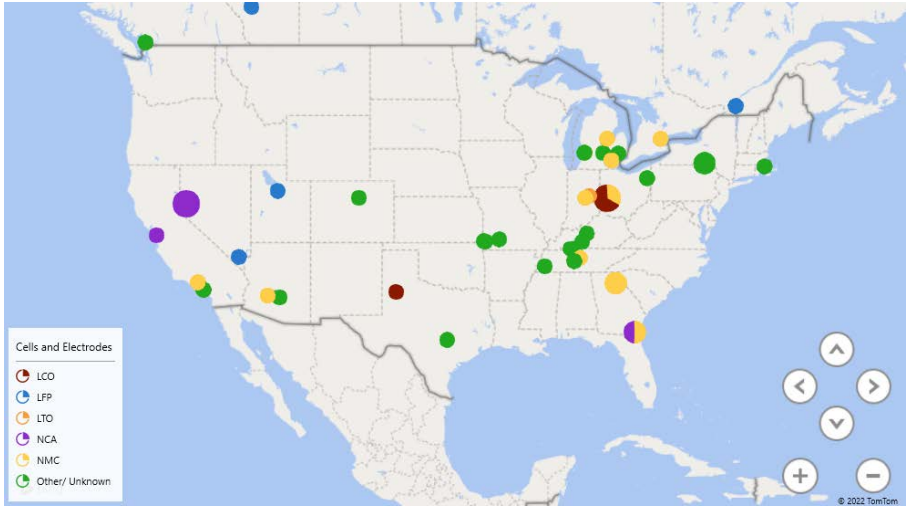
Cells & Electrodes Manufacturing Companies (2022)



Cells and Electrodes Manufacturing 2021 vs 2022



September 2021

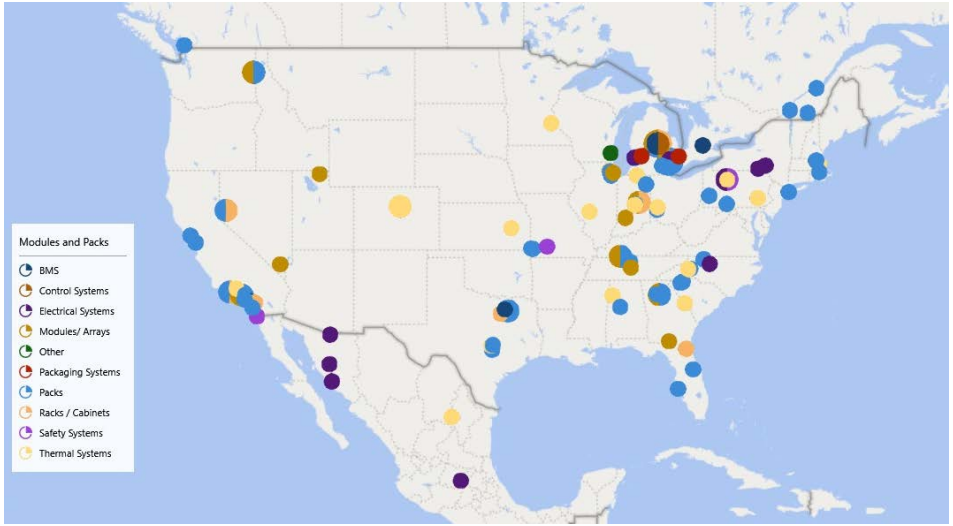


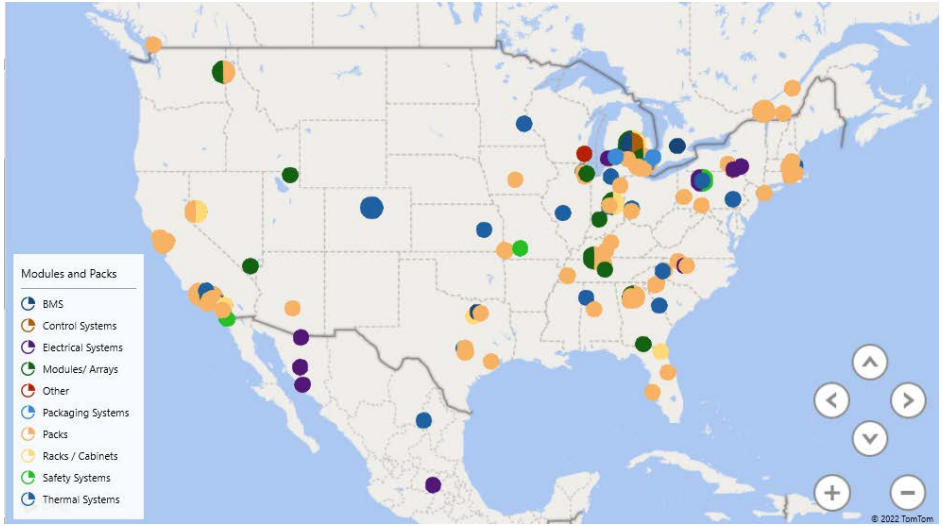
August 2022

Significant growth in # and capacity

Please note that scale difference between 2022 and 2021 maps does not indicate reduction of capacity.

Modules and Packs Manufacturing Companies





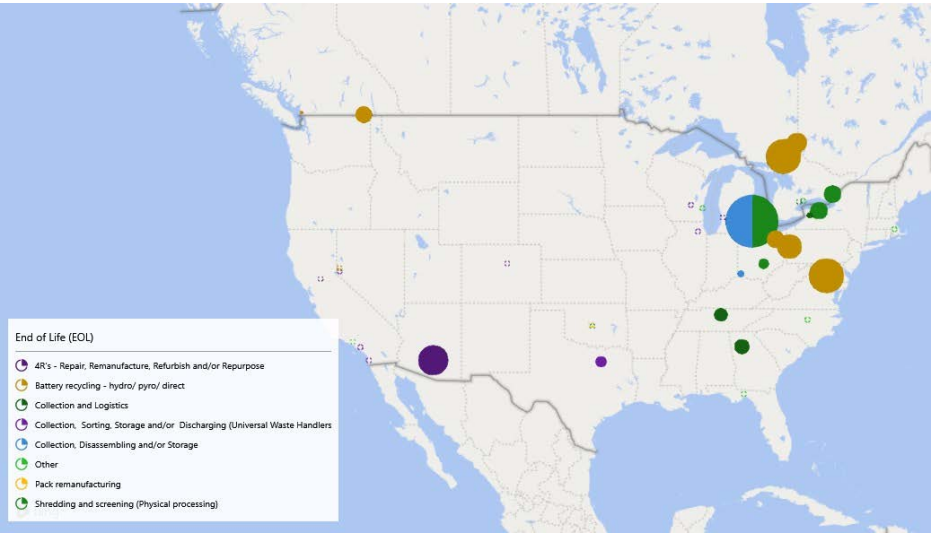
September 2021

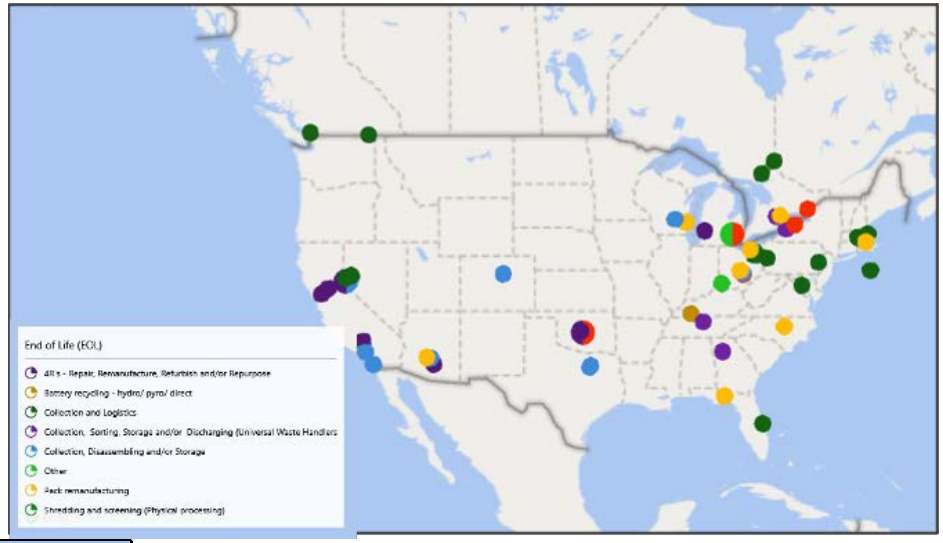
August 2022

Significant growth in # and capacity

Please note that scale difference between 2022 and 2021 maps does not indicate reduction of capacity.

End of Life Management Companies (2nd Life and Recycling)





EOL FACILITIES
4R's - Repair, Remanufacture, Refurbish and/or Repurpose
Battery material refining
Battery recycling - hydro/ pyro/ direct
Collection and Logistics
Collection, Disassembling and/or Storage
(Universal Waste Handlers)
Shredding and screening (Physical processing)
Other

September 2021

August 2022

Significant growth in # and capacity

Please note that scale difference between 2022 and 2021 maps does not indicate reduction of capacity.

Updates of December 7, 2022 Release

- Addition of or modification of 10 companies in the database from requests to LIB.SupplyChain@nrel.gov
- Addition of all projects funded through DE-FOA 2678- *Battery Materials Processing and Battery Manufacturing* and DE-FOA-2680 *Electric Drive Vehicle Battery Recycle and Second Life Applications*
- Revision of R&D supply chain segment
  - Only firms focusing on R&D for revenue are included
  - Pre-commercial start-ups were moved to their supply chain segment, even if they are still in the R&D stage
- More than 600 facility and 519 company listings are included*

*Companies are counted more than once if they are active in multiple sections of the supply chain and/or have multiple products

U.S. Government Investments and Polices to Accelerate LIB Supply Chain Development

Bipartisan Infrastructure Law (2021):

- $2.8B Battery Materials Processing and Battery Manufacturing Recycling (20 projects) developing https://www.energy.gov/sites/default/files/2022-11/DOE%20BIL%20Battery%20FOA-2678%20Selectee%20Fact%20Sheets.pdf
  - Battery-grade lithium, graphite, nickel, iron phosphate cathodes
  - Lithium electrolyte salt, separators, and PDVF binder
  - Battery-grade silicon anodes, pre-lithiation, and lithium anode
  - Cathodes from minerals or recycled batteries
- $74 M Battery Recycling and Second Life Applications support research and development of 10 projects
  - Advanced Materials Separation, Scale-Up, and Reintegration for Lithium-Ion Battery Recycling for the Battery Supply Chain and
  - Second Life Scale-Up Demonstration Projects.

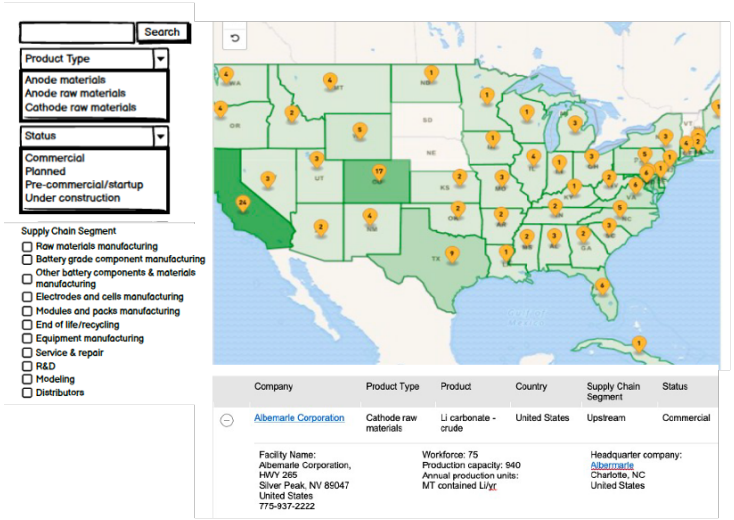
  https://www.energy.gov/sites/default/files/2022-11/Recycling%20and%20Second-Use%20Selections%20Factsheets%2011-16.pdf

Inflation Reduction Act (2022): https://afdc.energy.gov/laws/409

- Will provide subsidies to only battery EVs that are assembled in North America and contain more than a certain percentage of core minerals extracted in the friendly regions.

NAATBatt LIB Supply Chain Moving Forward

- LIB market is evolving fast with new companies and facilities coming online more often
- Bipartisan Infrastructure Law and Inflation Reduction Act provide investments and policies will increase domestic supply chain
- We will update the database at least every 6 months (next release about February 2023)
- We intend to move from the Excel framework to a more user-friendly, searchable online database
- Please provide us feedback on improving the database, correcting, updating, and adding information by email to us at LIB.SupplyChain@nrel.gov



Acknowledgments:
Funding for this work was provided by NAATBatt International. NREL authors thank James Greenberger, Executive Director of NAATBatt for providing insights needed to conduct this project and appreciate valuable feedback provided by NAATBatt Review Committee.

Thank You!

www.nrel.gov

Ahmad Pesaran ahmad.pesaran@nrel.gov

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.