EV Jobs Academy
CAR Electrification Update

18 August, 2022

Our Goals Today

- Provide valuable electrification content to EV Jobs Academy Partners
- Highlight CAR areas of expertise
- Trigger ideas on how CAR can help you

Opportunities in the Battery-Electric Vehicle Value Chain

Mining, Refining, & Processing

Refining & processing can take place anywhere—regardless of point of extraction

R&D, Design, & Engineering

Tied to corporate R&D hubs, national laboratories, & universities

Production

Broad range of parts, components, & vehicles need to be produced—manufacturing skills augment

Charging Network & Grid

Chargers need to be manufactured, planned, deployed, maintained, & repaired

Recycling

End-of-life, mineral reclamation, & conversion for stationary uses—a whole new industry

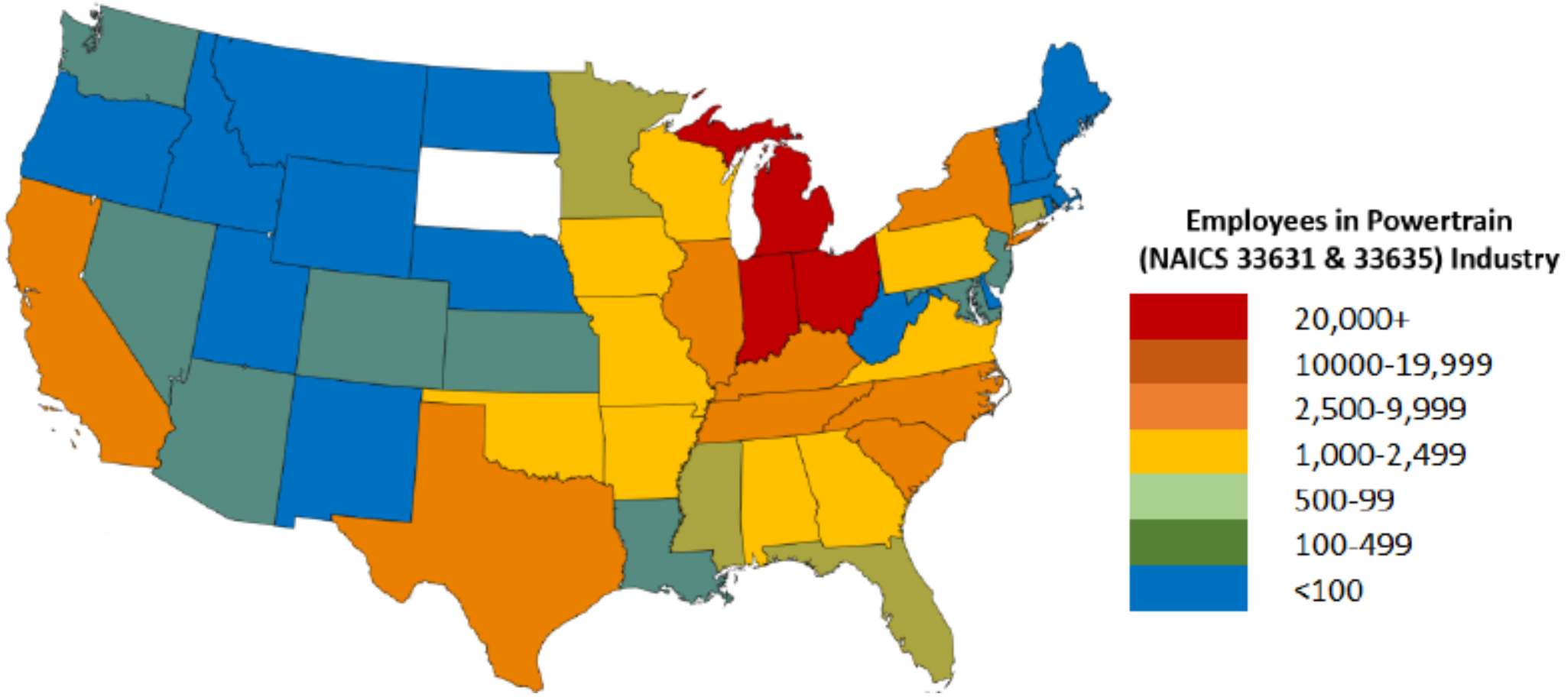
Repair & Maintenance

Service technicians & others who encounter EVs (e.g. first responders) need training

EV Trends

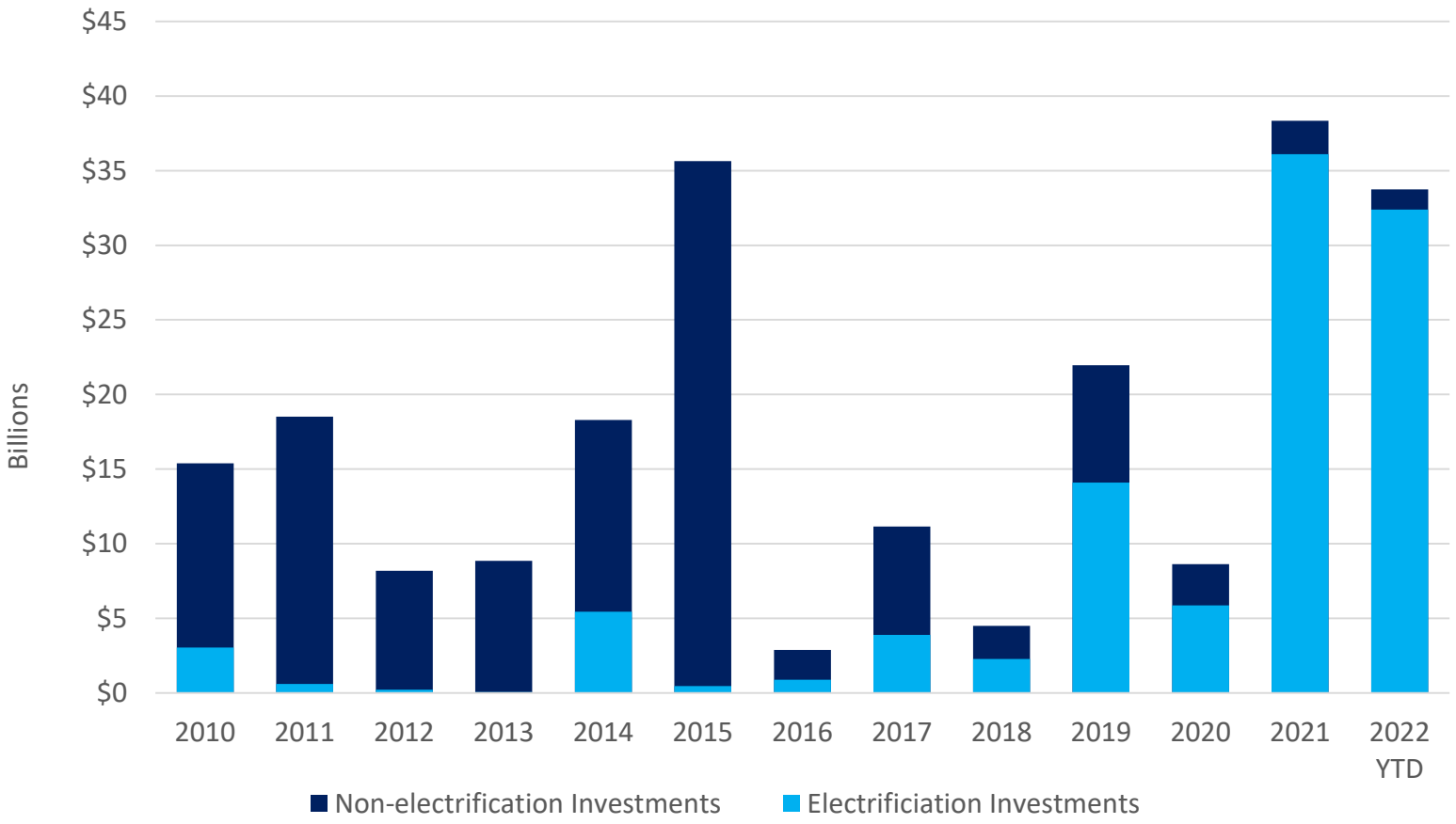
US Powertrain Manufacturing Employment

Indiana, Michigan, and Ohio have much to lose



Source: UAW Research

Announced Automaker EV/Battery Related Investments in NA
2010 to June 2022



The automotive industry has invested heavily in Electrified Vehicle (EV) technology and capacity since 2014. In 2021 and the beginning of 2022, some of the largest investments in the U.S. automotive industry history were announced, totaling to nearly USD 70.0 billion.

1) Ford: Blue Oval City and Blue Oval SK, USD 11.4 billion total

2) Rivian: Georgia assembly plant, USD 5 billion total

3) Hyundai-Kia: for EVs, and hydrogen fueling infrastructure, USD 7.4 billion

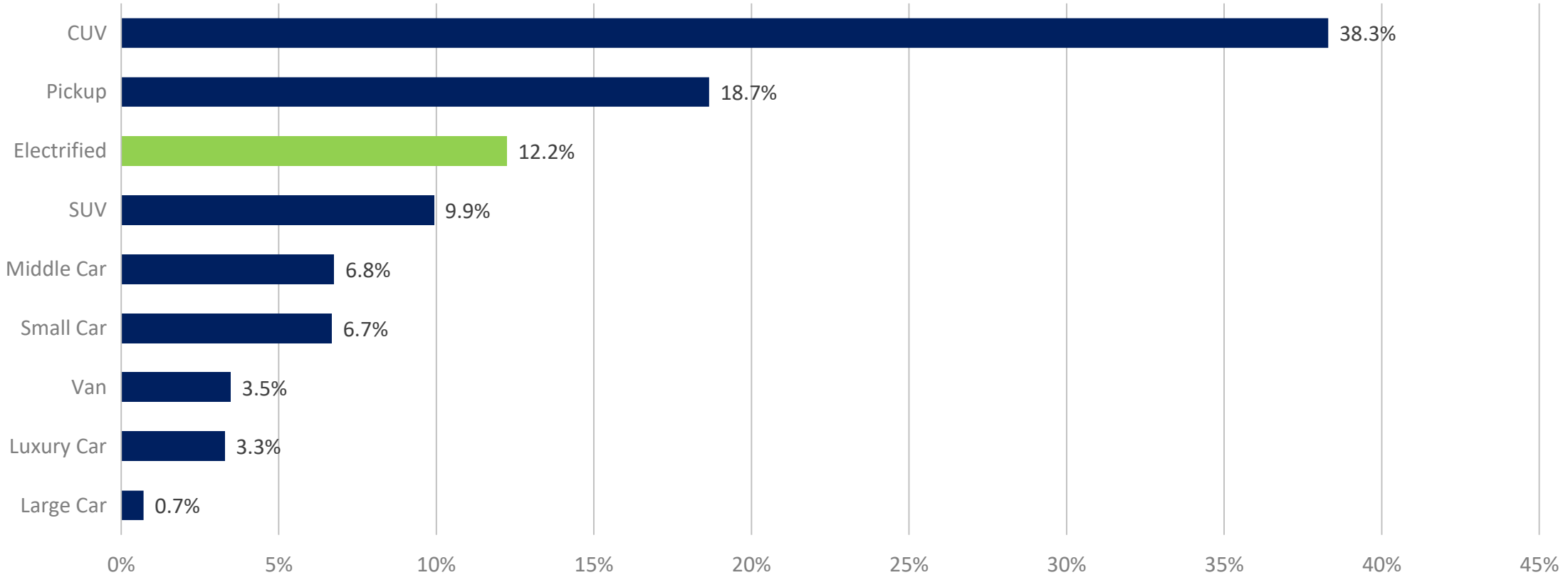
4) Stellantis and LG Energy joint venture battery manufacturing facility in Windsor, Canada, CAD 5.0 billion (USD 4.1 billion)

Source: CAR Book of Deals Database

Electrified vehicles take up 12.2% of the LV market

Market Share: Segment Breakdown

U.S. Light Vehicle Sales 2022 YTD Through July



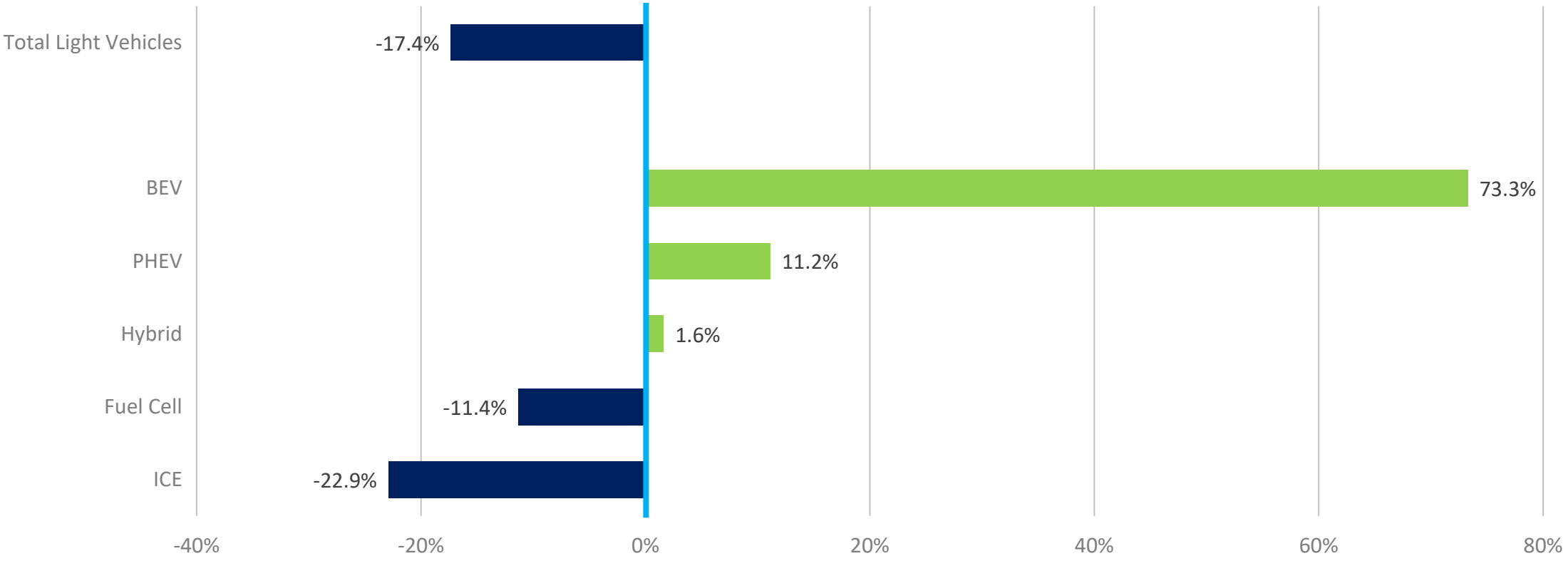
Note: Electrified Segment consists of BEVs, HEVs and PHEVs; all other segments are sales exclusive of Hybrid models

Source: Wards Automotive Reports and CAR Research

Electrified vehicles see a massive increase in year-to-date sales since last year

Segment Breakdown: U.S. Light Vehicles Sales Percent Change

2022 YTD vs. 2021 YTD Through July



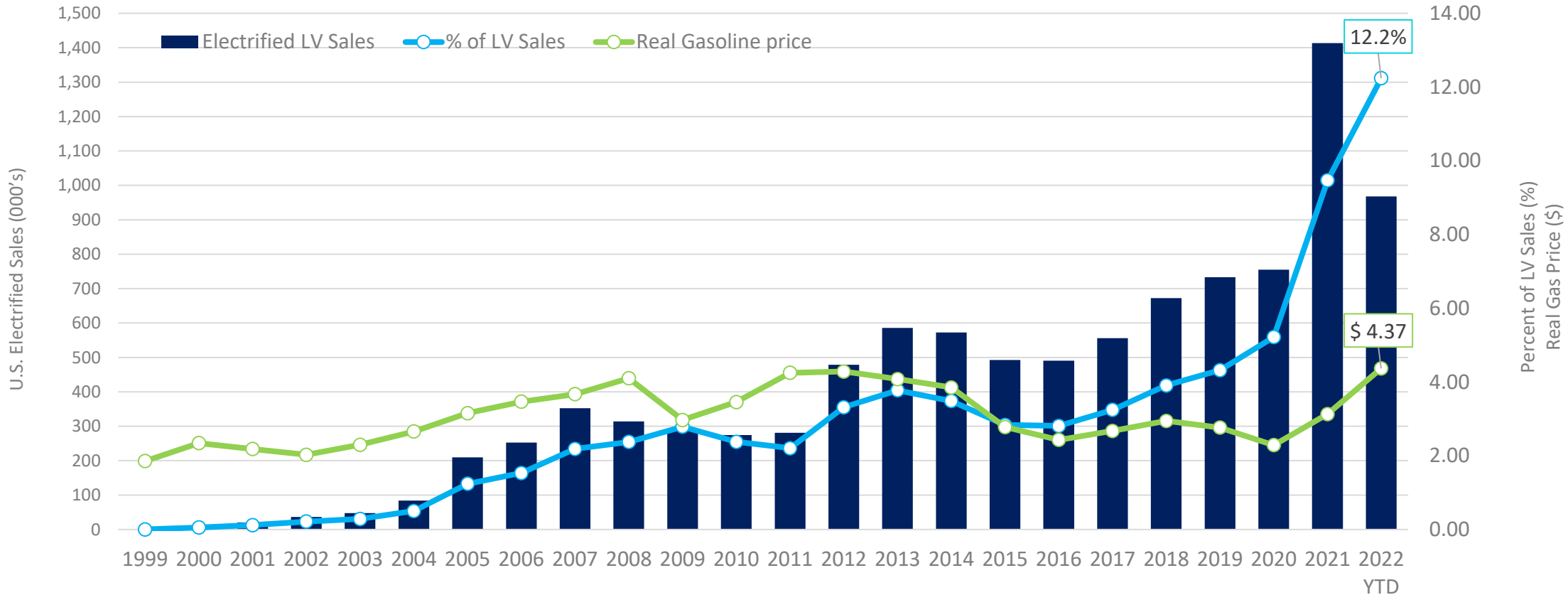
Note: All other segments are sales exclusive of Hybrid models

Source: Wards Automotive Reports and CAR Research

U.S. electrified vehicle sales no longer rise & fall with the real price of gasoline

U.S. Electrified Light Vehicle Sales & Market Share

1999 – 2022 July YTD



Note: Electrified vehicles consist of BEV, HEV, Fuel Cell, and PHEV

Source: Wards Automotive Reports (from 2010 and on), HybridCars.com and CAR Research

What matters to U.S. consumers?

1

Cost Parity→
Makes consumers indifferent to propulsion system

2

Utility Parity→
A vehicle to fit their needs & take them where they need to go

3

Convenience Parity→
Does not require extra time or planning to use

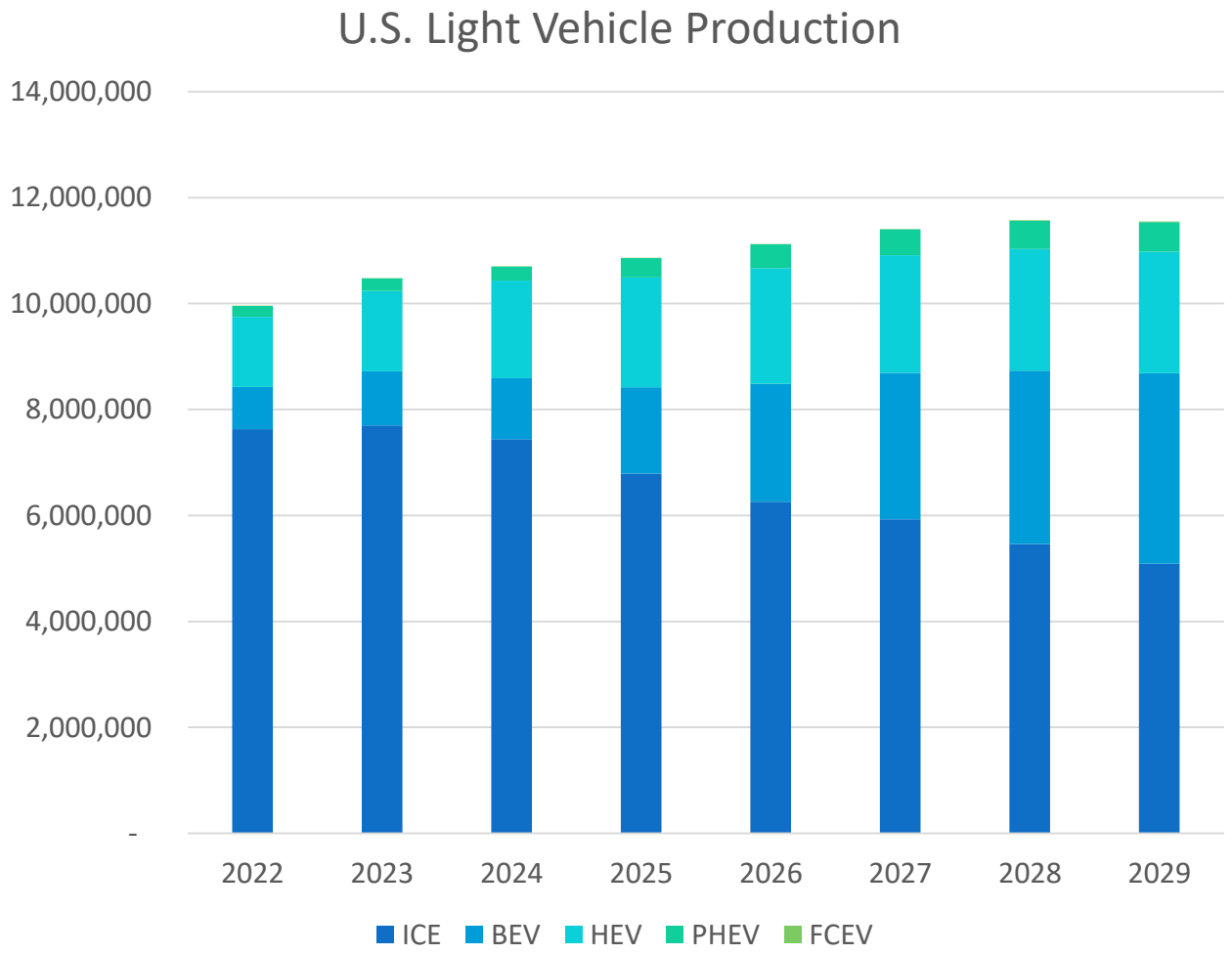
Product is Coming to Market

Key segments are about to be filled

Source: Ford Media

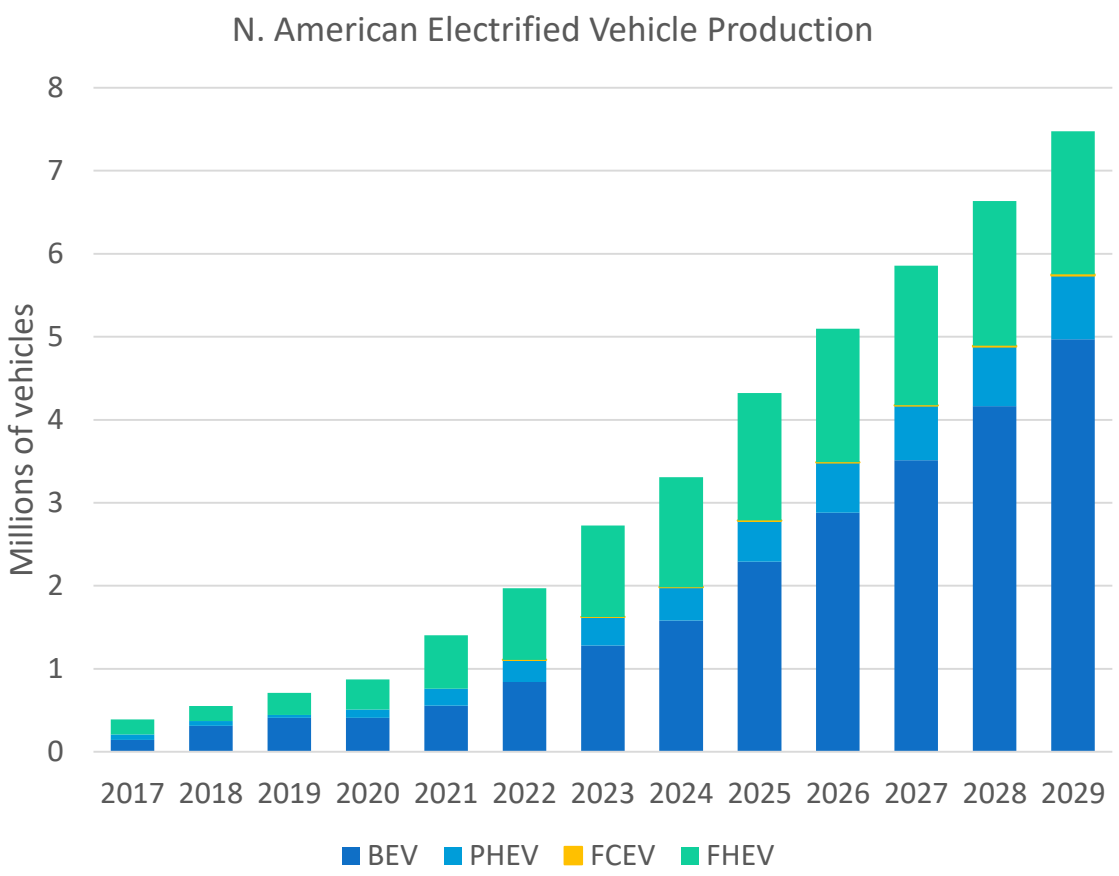
Source: General Motors Media

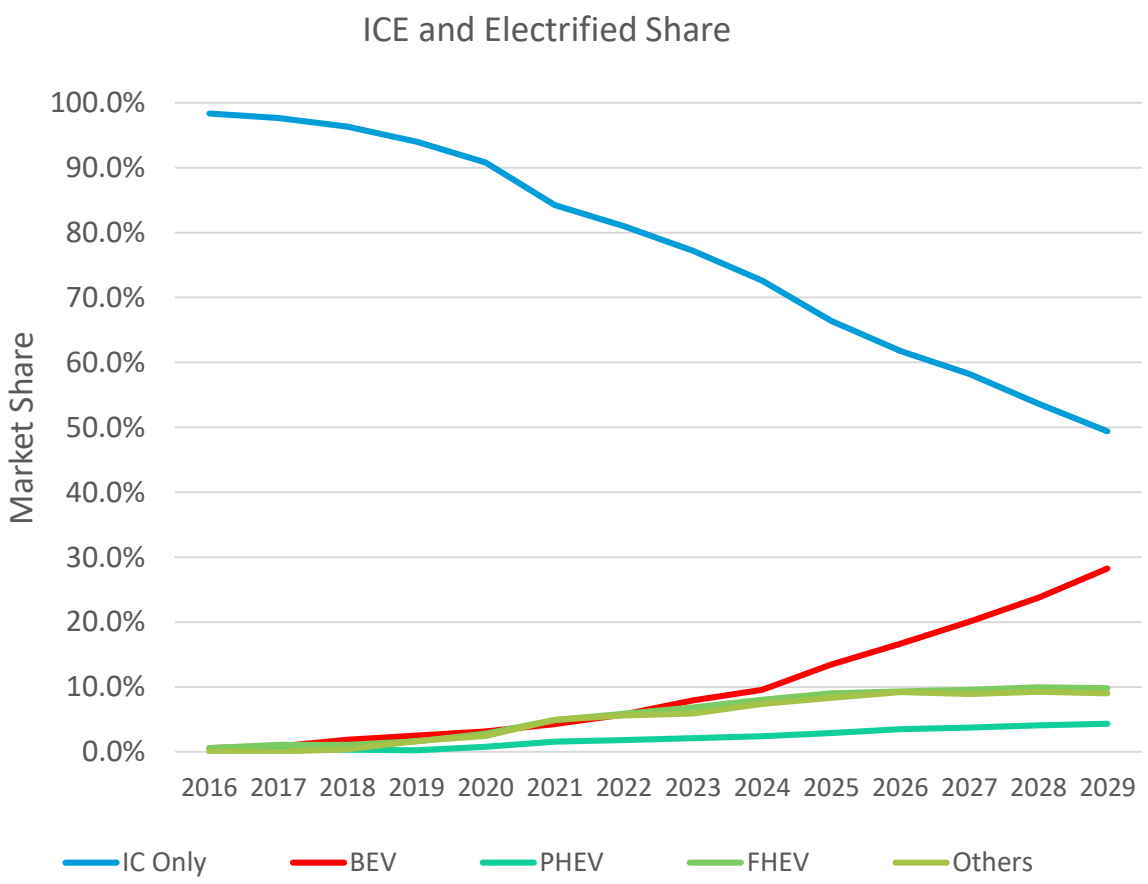
U.S. Light Vehicle Production By Powertrain Technologies 2022 – 2029



Source: LMC Automotive, July 2022

Electrified Vehicle Production to Grow Rapidly

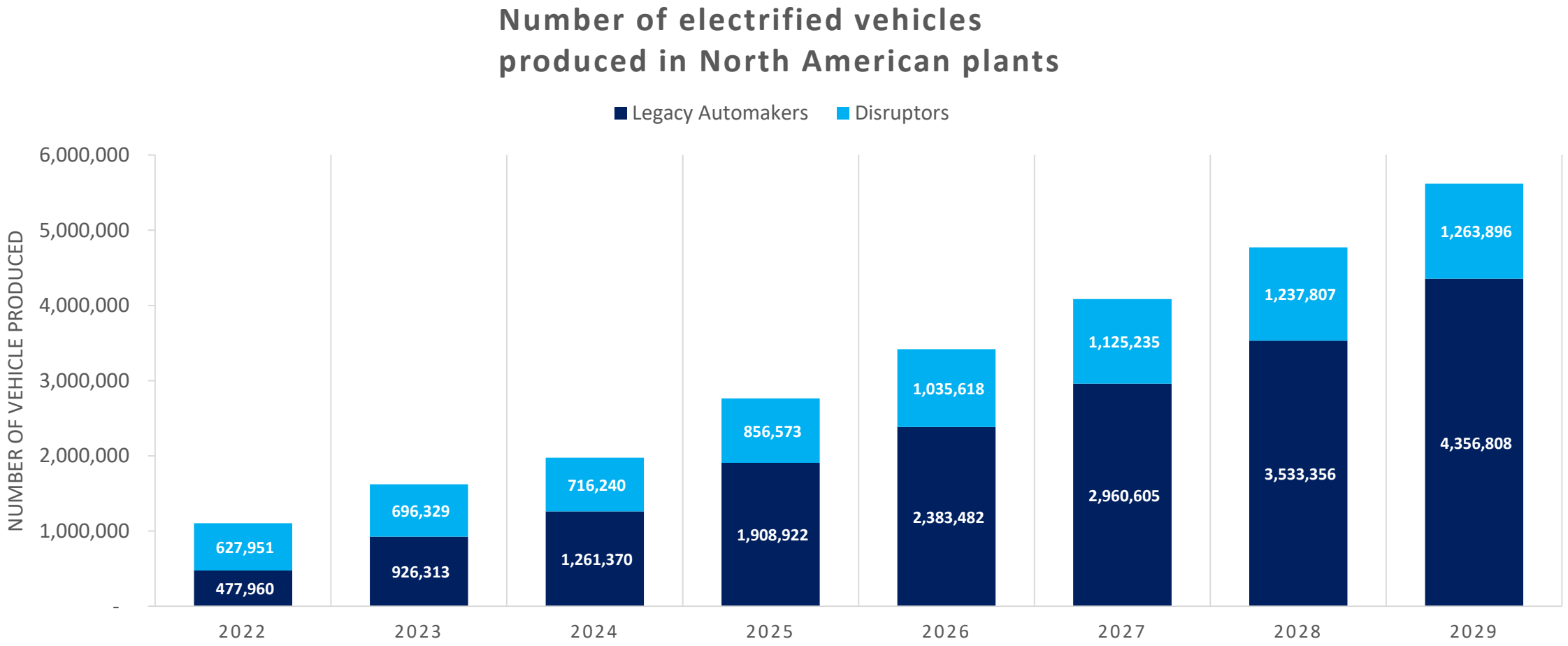




Source: LMC Automotive

Legacy Automakers' EV Production Will Surpass Disruptors By 2023

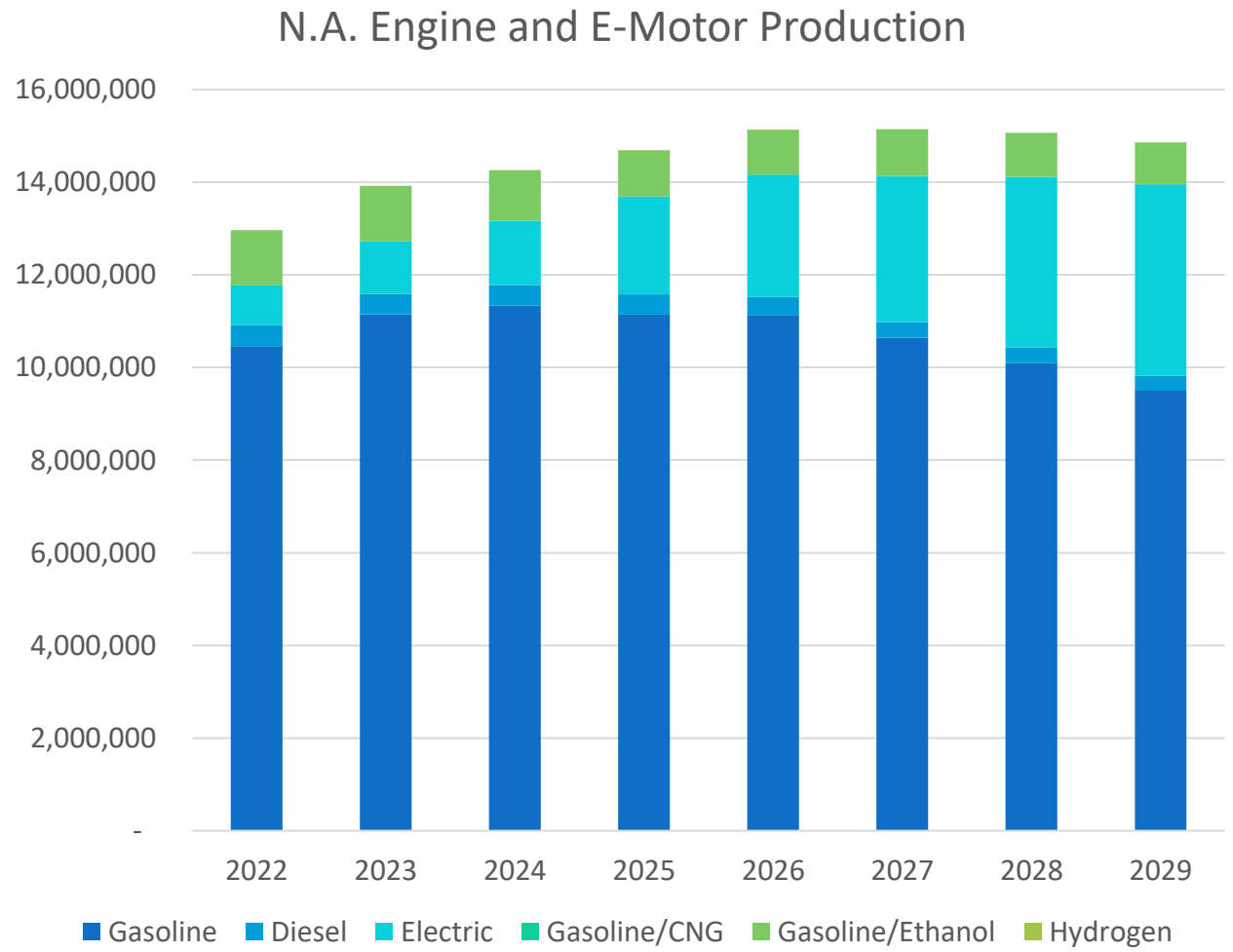
2022–2029 forecast



**Electric Vehicle (EV) includes: BEV, PHEV, and FCEV*

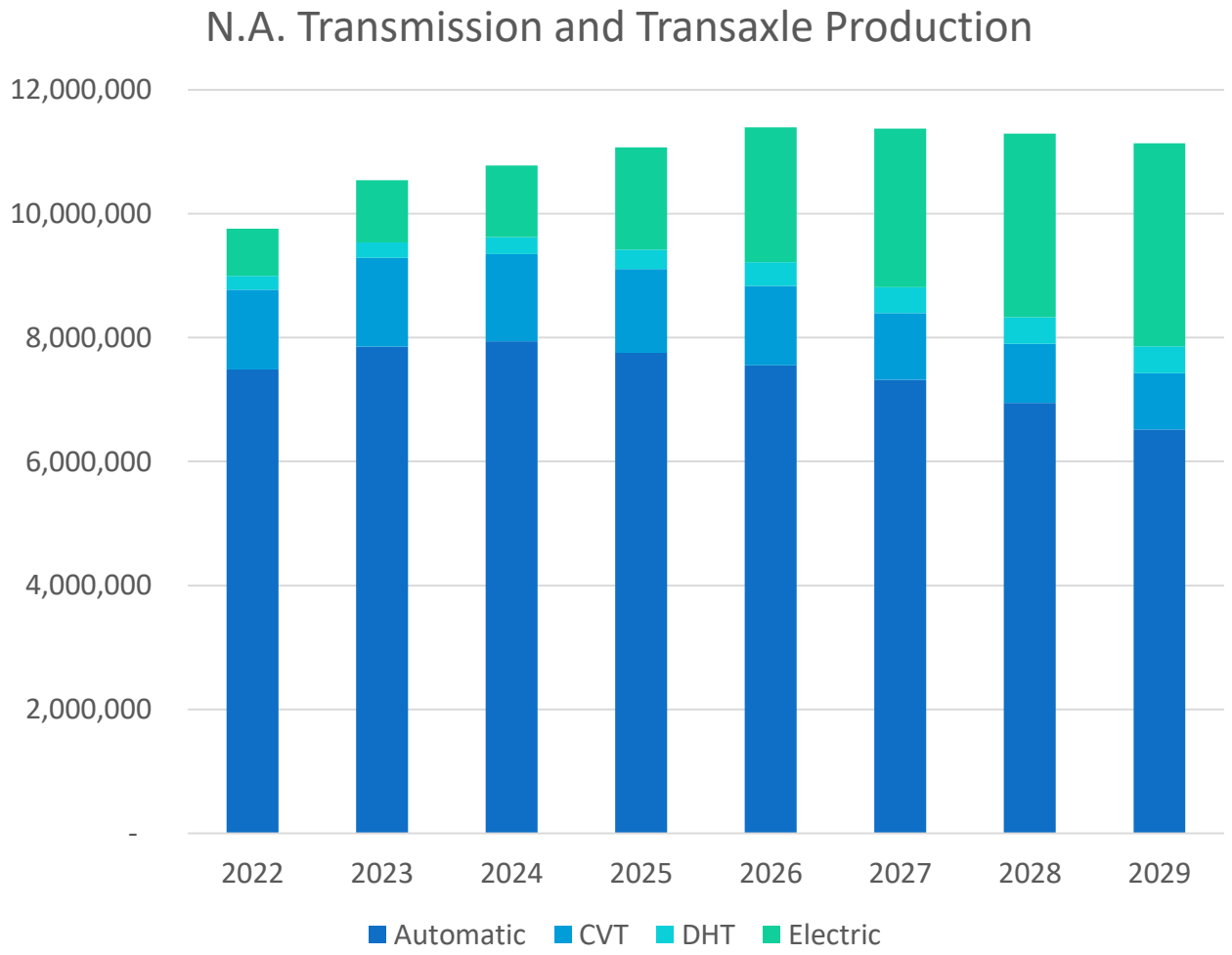
Source: LMC Automotive, Q1 2022

N.A. Engine and E-Motor Production By Fuel Type 2022 – 2029



Source: LMC Automotive, July 2022

N.A. Transmission and Transaxle Production By Type 2022 – 2029



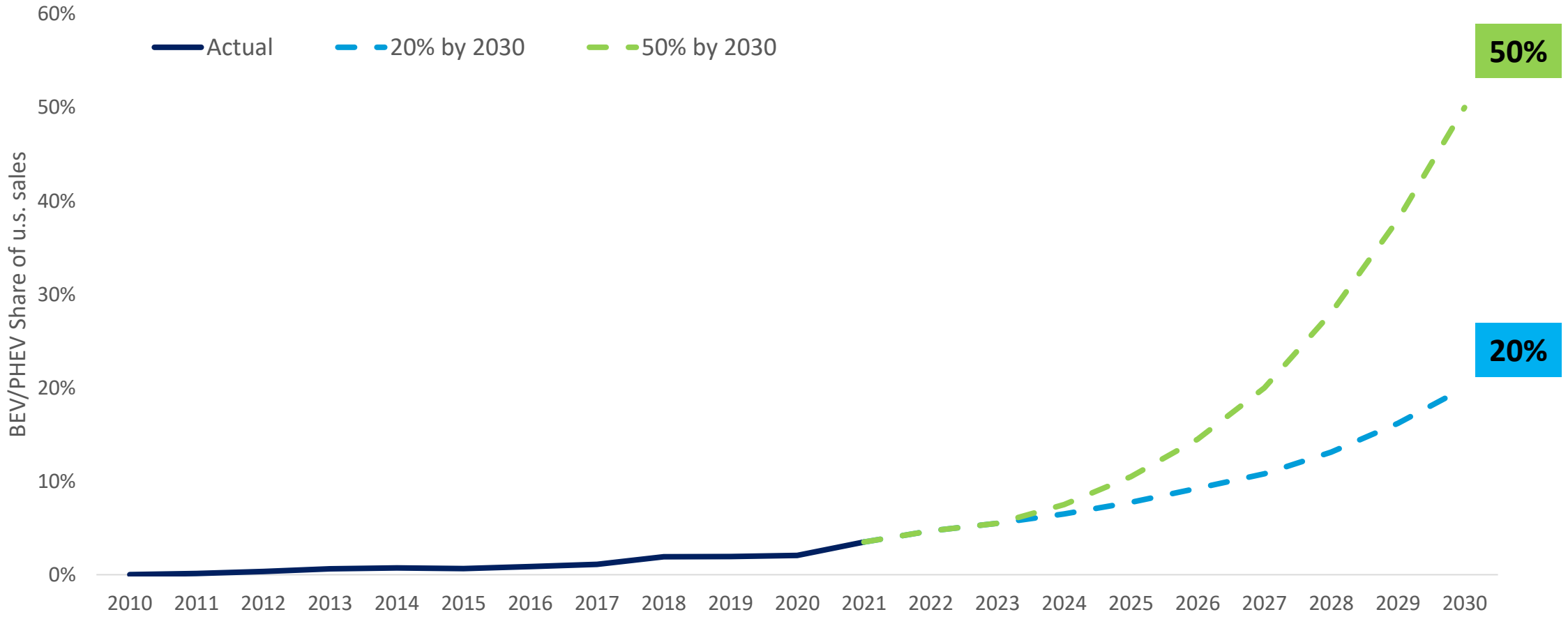
Source: LMC Automotive, July 2022

"They're a vision of the future that is now beginning to happen — a future of the automobile industry that is electric. Battery electric, plug-in, hybrid electric, fuel cell electric — it's electric, and there's no turning back. The question is whether we'll lead or fall behind in the race for the future."

–President Joseph R. Biden, Jr.
5 August 2021

A long way to go to get to net zero by 2050

BEV & PHEV U.S. Market Share 2010-2021 YTD; 2021-2030 projected



Source: Ward's Automotive Reports (from 2010 & on), HybridCars.com & CAR Research

Inflation Reduction Act (IRA): Implications and Opportunities for Michigan

- Balance of policy supporting electrification and North American manufacturing
- The resulting anticipated growth in U.S. EV supply chain is an opportunity for existing Michigan companies and for the attraction of new firms to the state
  - Near-term: expand existing supply base
  - Medium and Long-term: cathode production (no plants currently exist in North America)
- Battery content requirements likely biggest source of opportunity for Michigan
  - 2024: 40% of content from NA or Free Trade Agreement (FTA) countries
  - 2029: 100% of content from NA or Free Trade Agreement (FTA) countries
  - Long-term content requirements will be challenging for automakers without substantial additional investment in localized North American supply chain (only Tesla, GM, and Ford have publicly announced plans so far for cathode manufacturing in North America)

EV Projections and Sales

(20221-2025)

Key:
Pending projection in DARK TEXT
Abandoned Promise in GREY TEXT
Successful projection in BLUE TEXT

2021

Audi
80,000 EV sold
Ford
Mache E sells over 27,000
GM
Chevy sold over 20,000 EVs
Kia
Over 8,000 EVs sold
Jaguar
i-Pace sold 9,970
Mercedes
99,000 EVs sold
Rivian
Delivered and sold around 1,000 EVs
Tesla
936k EVs delivered
VW
263K BEVs delivered
Volvo
25K BEVs sold

2022

Ford
Projecting at least a 25% growth in EV revenue and several new models
Previously projected 16 BEVs by this year
GM
Six-fold increase in EV truck and SUV production
Kia
Will introduce 2 EV models a year
Mercedes
Early projection said entire lineup will be electrified by this time
Nissan
Originally projected 7 models by this time and 1M sales a year
Rivian
Target of 25,000 Units for year
Tesla
Projecting over 1.4M EVs delivered
Produce 1.5M EVs
VW
Target of 700,000 EV sales

2023

GM
400k EVs delivered
In 2017, projected 20 all-electric models by this time
Ford
600k EVs produced
Kia
2 EV models will be released
Nissan
Electrified vehicles to be 60% of sales in Japan, 23% in China, and 50% in Europe
1 million units by 2023
Solely introducing EVs in Europe
Stellantis
First Jeep EV released
Volvo
US lineup fully electrified
VW
Ability to produce 1M EVs/year in China

2024

Honda
First EV SUV Available
VW
ID.Buzz release
Stellantis
All new launches in US will included BEV alternative
BEVs only luxury in Europe
Audi
20 EV models
800k electrified sales
BMW
25% of Chinese sales to be EV
9 EV models and 2M produced
Ford
Have sold a total of 1M EVs
GM
30 models by this time
40% of the US entries will be EVs
Will have production capacity to build 1M EVs in NA
Hyundai
Introduce 44 electrified models and sell 1.67M sales
11 BEVs 500k EV sales
Kia
20% of sales in Euro, NA, and Korea will be EVs
16 electrified cars
11 BEVs
Mercedes
50% of sales to be electrified
Originally aimed to offer all electrified models
Nissan
15 BEV models
Stellantis
Ram 1500 EV released
Toyota
Six EV models by this time
70 electrified models globally
VW
Originally planned to launch 30 BEVs and to account for 20-25% of sales this time
Cupra will launch 3 BEVs
Volvo
50% of sales to be to EVs

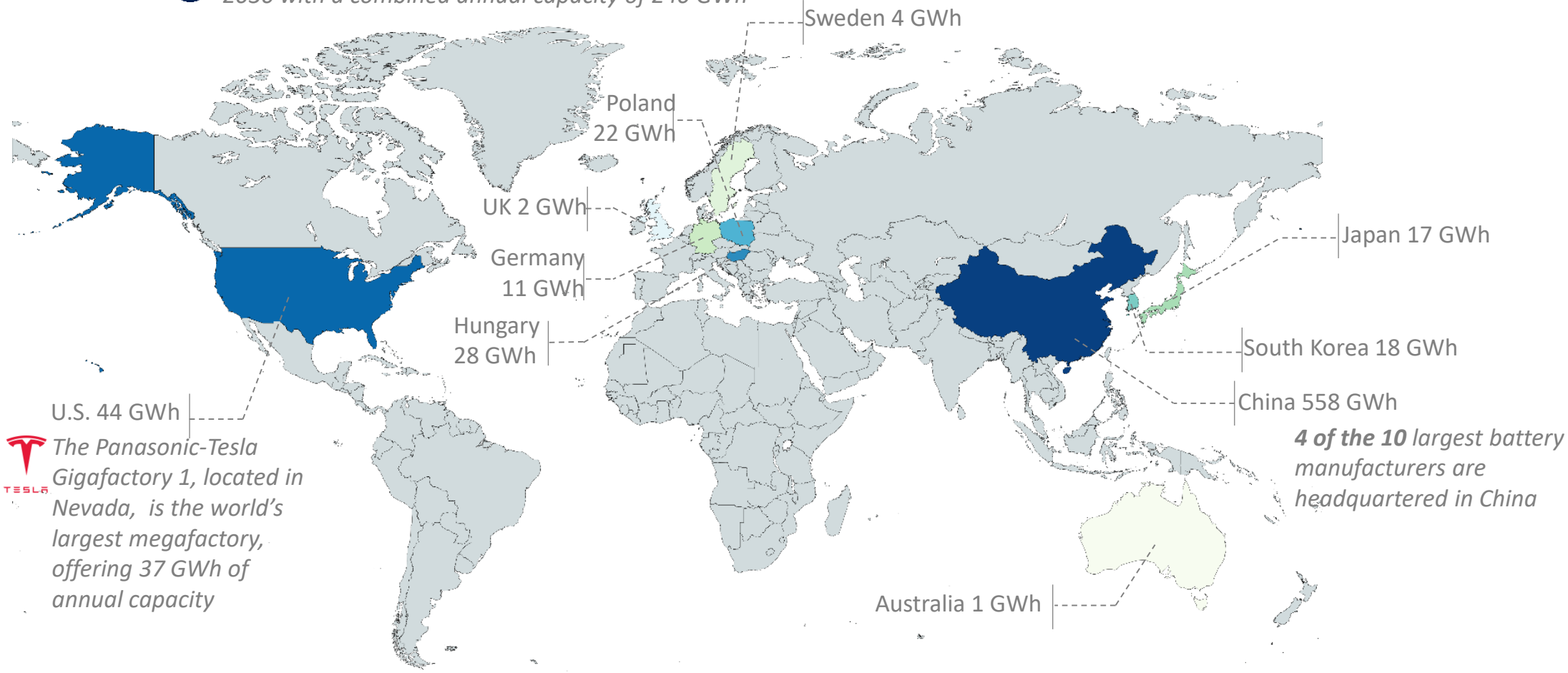
2025

Source: Center for Automotive Research (CAR). Last updated 2022.7.22.

The Top Ten Countries for EV Battery Production

EV Battery Manufacturing Capacity, by Region

Volkswagen plans to build 6 factories in Europe by 2030 with a combined annual capacity of 240 GWh



The Panasonic-Tesla Gigafactory 1, located in Nevada, is the world's largest megafactory, offering 37 GWh of annual capacity

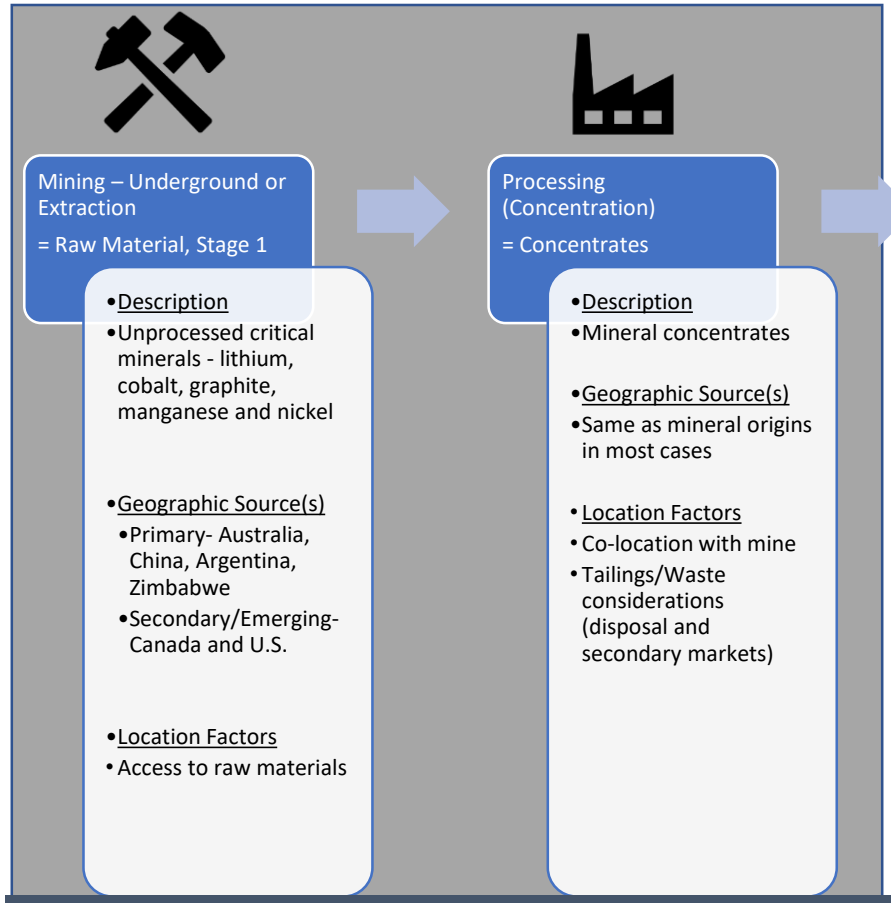
***4 of the 10** largest battery manufacturers are headquartered in China*

Source: S&P Global Market Intelligence, 2021

EV Critical Minerals – Supply Chain

Upstream Materials – Value Chain

Current pathways to market for critical minerals



Mining – Underground or Extraction

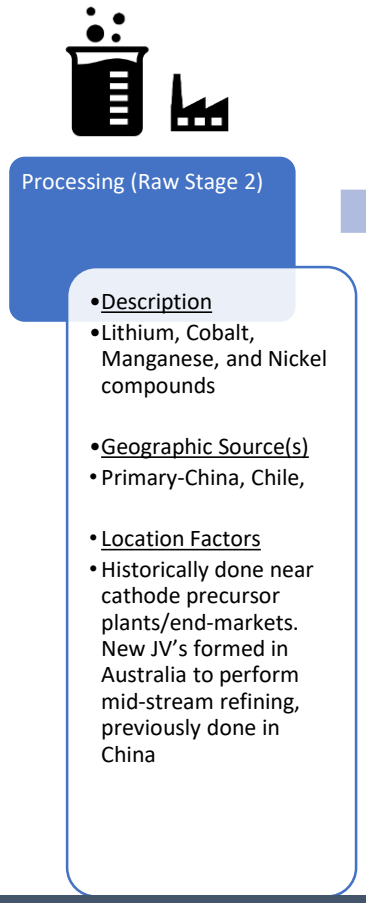
= Raw Material, Stage 1

- Description
- Unprocessed critical minerals - lithium, cobalt, graphite, manganese and nickel
- Geographic Source(s)
  - Primary- Australia, China, Argentina, Zimbabwe
  - Secondary/Emerging- Canada and U.S.
- Location Factors
- Access to raw materials

Processing (Concentration)

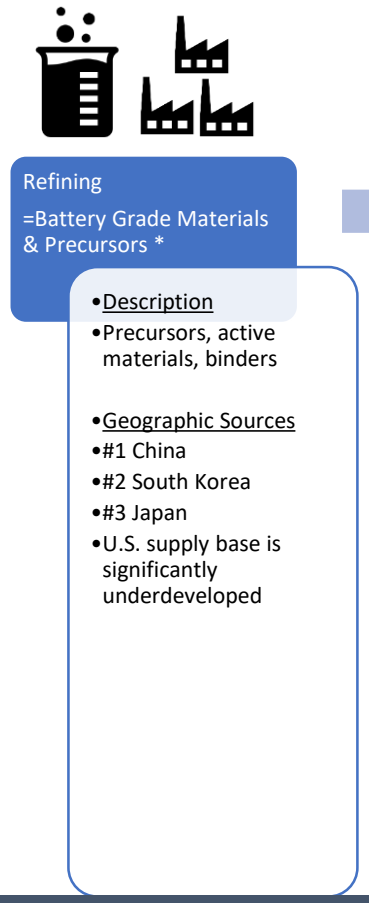
= Concentrates

- Description
- Mineral concentrates
- Geographic Source(s)
- Same as mineral origins in most cases
- Location Factors
- Co-location with mine
- Tailings/Waste considerations (disposal and secondary markets)



Processing (Raw Stage 2)

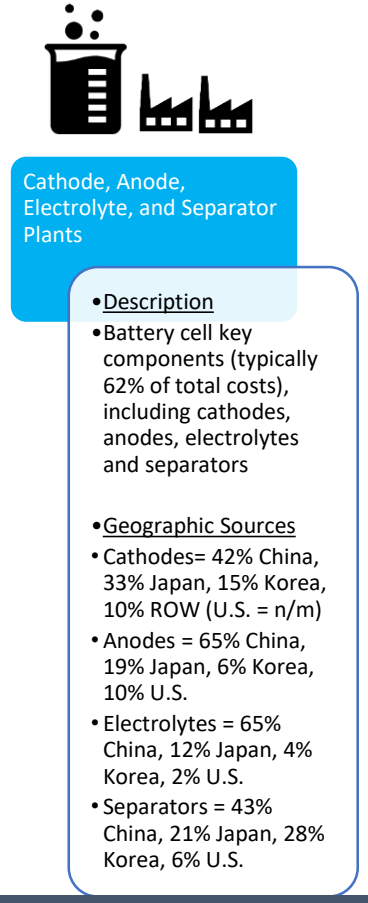
- Description
- Lithium, Cobalt, Manganese, and Nickel compounds
- Geographic Source(s)
- Primary-China, Chile,
- Location Factors
- Historically done near cathode precursor plants/end-markets. New JV's formed in Australia to perform mid-stream refining, previously done in China



Refining

=Battery Grade Materials & Precursors *

- Description
- Precursors, active materials, binders
- Geographic Sources
- #1 China
- #2 South Korea
- #3 Japan
- U.S. supply base is significantly underdeveloped



Cathode, Anode, Electrolyte, and Separator Plants

- Description
- Battery cell key components (typically 62% of total costs), including cathodes, anodes, electrolytes and separators
- Geographic Sources
- Cathodes= 42% China, 33% Japan, 15% Korea, 10% ROW (U.S. = n/m)
- Anodes = 65% China, 19% Japan, 6% Korea, 10% U.S.
- Electrolytes = 65% China, 12% Japan, 4% Korea, 2% U.S.
- Separators = 43% China, 21% Japan, 28% Korea, 6% U.S.

Lithium, cobalt, nickel, manganese, and graphite are all in short supply, globally. Mines can take 5-13 years to bring online, whereas processing and refining can take 18-24 months to establish. Processing and refining are expected to follow similar localization trends as battery cell assembly.

*Source: U.S. International Trade Commission, FCAB National Blueprint for Lithium Batteries (June 2021), and CAR analysis. Simplified for illustration purposes. Not exhaustive. Grey box denotes trend to co-locate initial processing states with mines and extraction points. * Separate and unique supply chains associated with each. n/m = Non-material*

Upstream Materials
Key Trends

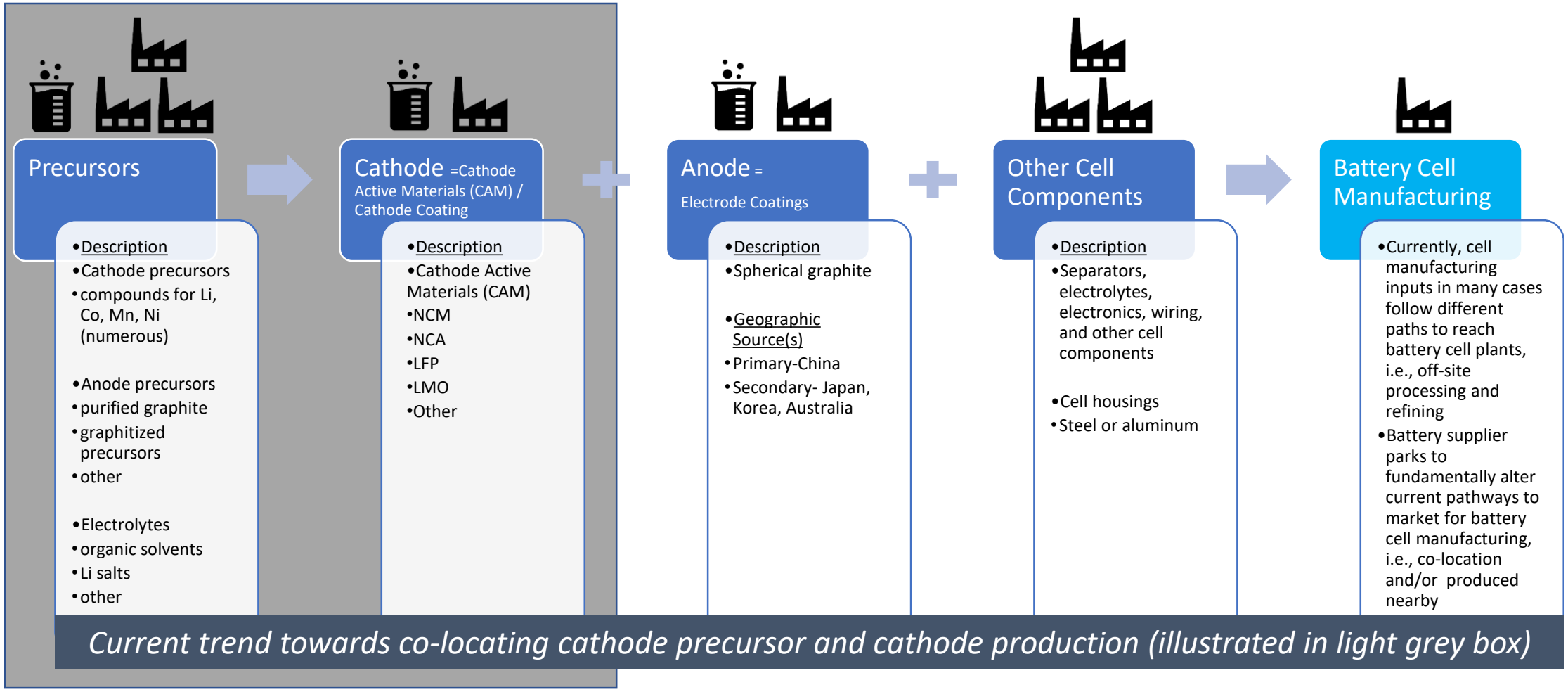
Raw Materials	Securing sufficient access to support forecast BEV demand	Global capacity for key raw materials, and related processing, remains concentrated in China* (e.g. 82% electrolyte salts, 66% electrolyte solution, 65% anodes), which poses supply chain risk, according to battery companies.
		Demand for raw materials is expected to grow globally, led by BEV sales in Europe and China, which are currently forecast to outpace North America through 2030.
		Despite a push to localize cell manufacturing and mining, battery companies say that the U.S. will still likely be dependent on imports for 60% of raw materials requirements by 2030.
	Reducing cobalt & graphite content	Automakers are seeking to reduce use of cobalt within current and next generation li-ion cells for performance and cost reasons, due to overall scarcity.
		Battery companies are pushing to replace graphite long term with silicon for performance and cost reasons, although timing remains uncertain.
		Nickel will become increasingly important to replace cobalt in the near-term and silicon may replace graphite (anodes) in next gen batteries, assuming no significant tech breakthrough with graphene before 2025. However, Nickel may decline long-term with increased Manganese usage.
	Localizing raw materials processing	Localized raw materials processing will become important long-term to insure global competitiveness of domestic battery companies, according to battery companies.
		The practice of localized processing is already prevalent in China, but not in North America because of previously insufficient demand.
		Additional vertical integration will be also required in order to compete globally as economies of scale become increasingly important to achieve future battery cost-reduction targets.

*Source: *U.S. International Trade Commission, Executive Briefing on Trade, February 2021 & CAR analysis*

EV Battery Supply Chain

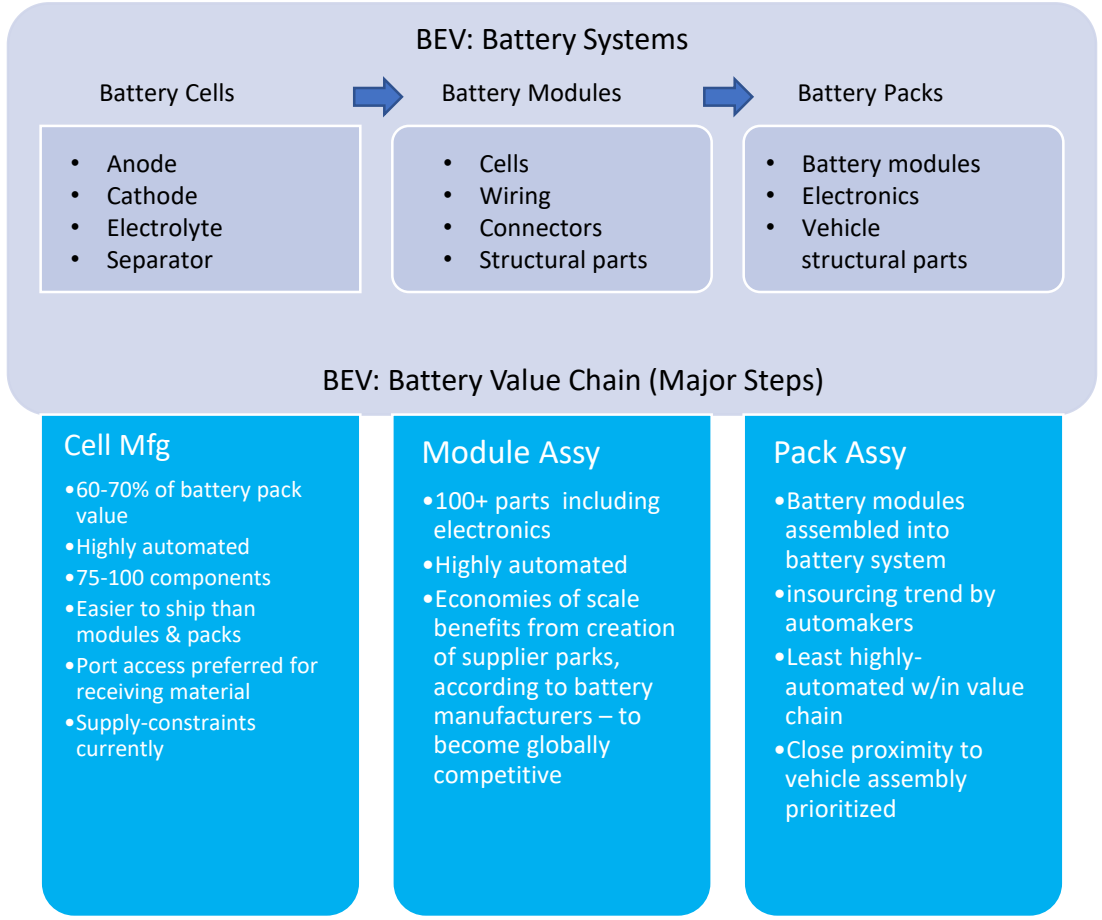
Midstream – Value Chain

Current pathways to market



Source: CAR analysis. For illustration purposes. Not exhaustive.

Midstream
Trends & Analysis



Key Trends:

- Localization of supply chain – battery cell assembly to become center of ecosystem
- Vertical integration of cell manufacturing, module assembly, including raw materials processing, and end-of-life recycling solutions
- Joint ventures/alliances will play important role across the value chain
- Supplier parks may become key to help reduce system costs longer term

Source: U.S. International Trade Commission, Executive Briefing on Trade, February 2021 & CAR analysis

Battery Component Manufacturing

Current pathways to market – Cells through Battery Packs

Cell Manufacturing

- Cells (3 types, numerous chemistries)
- Electrode Materials
  - Anode (5 types)
  - Cathode (16 types)
  - Electrolyte (Solid/Liquid)
  - Separators
  - Current Collectors
  - Tapes
  - Additives
- Equipment (14 types)
- Services (5 total)

Battery Module Assembly

- Cells (Li-ion)
  - Cylindrical
  - Prismatic
  - Pouch
- Mechanicals
  - Thermal Systems
  - Heat Sinks
  - Thermal Pad/Gap Filler
  - Bus Bars(LV & HV)
- Electricals
  - LV / HV Interconnects
- Safety Technology
  - Fuse Links
  - Thermal Runway Mitigation
- Assembly Equipment
- Services

Battery Pack Assembly

- Battery Packs / Module Components
  - Mechanicals
    - Thermal (5)
  - Electricals
  - Battery Management Systems (5)
  - Connectors (Current/Voltage)
  - Safety (5)
  - Voltage Converters
    - DC/DC
    - AC/DC
- Assembly Equipment (2 Categories)
  - EOL Testing
  - DC Charging
- Automakers (if actively engaged)

End-of-Life / Recycling

- Recycler - Inputs
  - Cells
  - Module
  - Black Mass
  - Shredded Materials
- Recycler - Outputs
  - Black Mass
  - Sulfates/Hydroxides
  - Cathode Materials
  - Cathode Precursors
  - Cells
- Services
  - Transporters (certified)
  - Remanufacturers
  - Test / Evaluation
  - Brokers (commodity)
  - Auto Auctions (EV)
  - HazMat Packaging (certified)

Battery component manufacturing at scale is largely new to North America

Source: CAR analysis

Battery Supplier Park – Tesla Example

Tesla Giga Texas in Austin, TX

Image: Phase 1 = vehicle assembly. Unmarked includes battery cell production for vehicles and stationary power. Planned battery cathode facility = 150 acres

- Giga Austin is among the company's five plants globally in process, with another rumored to follow in Indonesia (to be announced)
- Construction – 2020 to unknown (cathode plant plans pending zoning approval)
- Total Investment – USD 10 Billion planned
- Size – 2,518 acre site (987 acres used to-date)
- Employment – 20,000 planned
- Co-located onsite including captive battery supply
  - Model Y, Cybertruck and van vehicle assembly (planned)
  - Battery cells to packs assembly and conversion (currently for Model Y and stationary power products planned)
  - Battery grade materials production, e.g., cathodes and anodes (planned)
- If goals achieved, Tesla's Giga Austin plant would become among largest plants in world for vehicle assembly and related battery production (on par with largest examples in China)
- Other Tesla vehicle assembly plants have battery suppliers co-located onsite or nearby
  - Berlin, Shanghai (includes recycling onsite; CATL's cell assembly plant within 3 miles)

Source: Torque News, 4 February 2022

Battery Supplier Parks – Emerging Business Model

BYD in Xiangyang, Hubei (China) Example

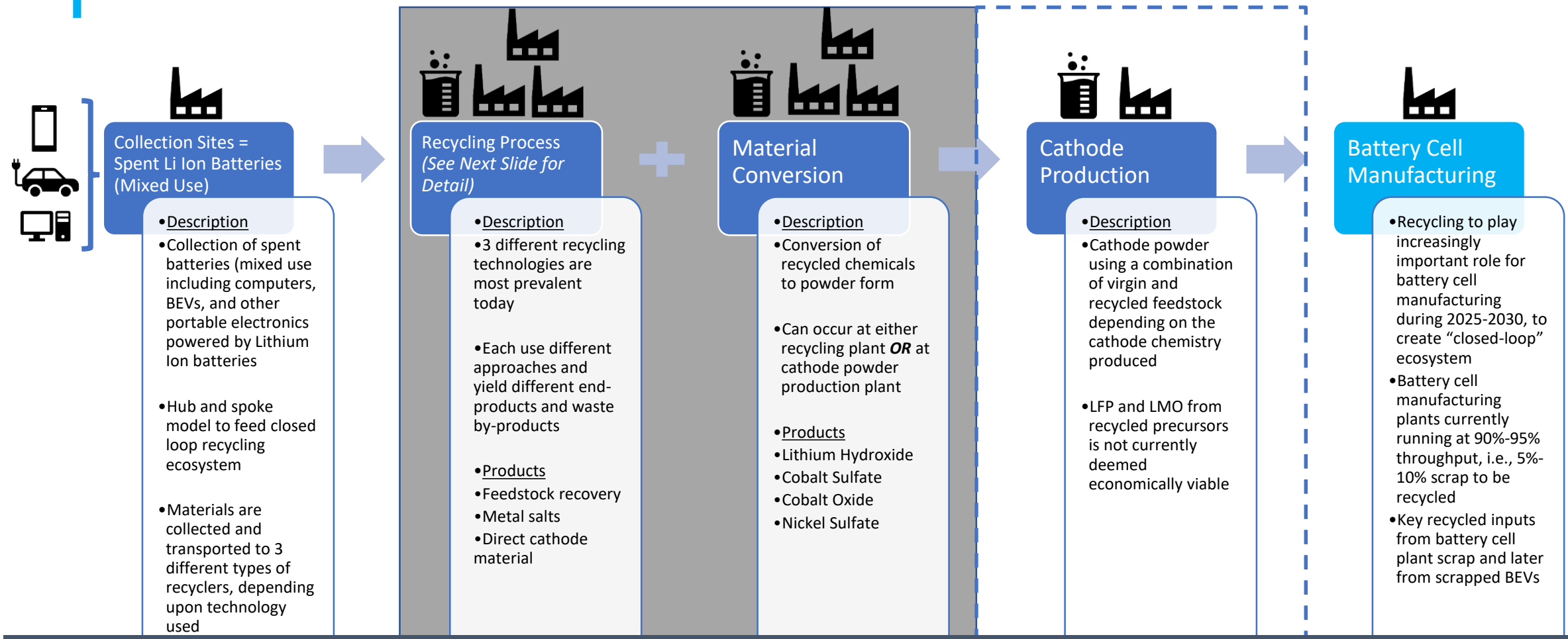
- Construction – 2022 to 2025 estimated
- Total Investment – 10 Billion RMB (USD 1.6 Billion) for Phase 1
- Size and Capacity – 824 acre, 30 Gwh
- Employment – 10,000
- BYD Suppliers co-located
  - Phase 1 = cell assembly, modules (BYD)
  - Phase 2 = suppliers of cathodes, anodes, copper foil, aluminum foil, separators, electrolyte, and structural components
  - Phase 3 = suppliers of electric motors, ECU's, HVAC, wiring harnesses
- Batteries supplied to BYD for its vehicles produced nearby
- Estimated annual output of 300,000 EVs

Source: Company reports and CAR research

EV Recycling

Downstream – Value Chain

Current pathways to market



Current trend towards vertical integration (illustrated in light grey box) , expanding to cathodes in some cases (dotted line)

Source: CAR analysis. For illustration purposes. Not exhaustive..

Downstream – Value Chain

Li-Cycle Example

- Through a hub-and-spoke model, Li-Cycle's central recycling facility is in Rochester, NY, with smaller facilities in Ontario and building new recycling centers in Tuscaloosa, AL, Warren, OH, and Gilbert, AZ.
- Univar Solutions Inc. will be an anchor battery feed supply customer for the new Alabama facility.
- Li-Cycle's Warren, OH location will be co-located with Ultium Cells.
- Southeastern U.S. is emerging as a critical region for the lithium-ion battery supply chain, as battery manufacturers and OEMs establish operations in the region, it will lead to the generation of significant quantities of battery manufacturing scrap and end-of-life batteries available for recycling.

Source: NAATBatt, CAR analysis, Li-Cycle Investor presentations

Supplier Restructuring – Traditional Powertrain

Restructuring the Propulsion Supply Base

Important USD-Content Implications for Suppliers

ICE Example @ USD 39,100 MSRP Passenger Car

Major Systems Affected by Transitioning to BEV	Est-USD Impact per Vehicle
Axles, driveshafts & auxiliary components (Reduced complexity)	↓ 300
Exhaust system (Eliminated)	↓ 575
Fuel system (Eliminated)	↓ 650
Transmission including clutches, planetary gears & torque converter (eliminated & replaced with electric drive unit & electric motor(s). 1 electric motor illustrated, but up to 4 possible.	↓ 525 net
Engine (Eliminated)	↓ 4,850
Power electronics & high-voltage electrical architecture (Added)	2,650
Battery pack (Added)	11,150
Other systems affected include body structures (increased content), audio/infotainment (upgraded), braking (upgraded), climate control/HVAC (upgraded)	1,875

Insourcing Risk by Automakers

Source: BofA Global Research, Intellicosting LLC , Wolfe Research, & CAR analysis (May 2022); Note- For illustrative purposes & figures rounded. to the nearest USD25 Light trucks & performance models could differ significantly.

Restructuring the Propulsion Supply Base
Key Trends

Investment shifting from traditional ICE development to BEV

- No new transmissions are currently under development, according to suppliers interviewed
- Current ICEs & transmissions are viewed as last generation
- Vertical integration of select BEV driveline systems by automakers to put pressure on traditional suppliers to to adapt their growth strategies (at least currently)

Restructuring the Propulsion Supply Base
Key Trends – Growth Strategies

Will force powertrain suppliers (along with automakers) to pursue dua

- Vehicle manufacturers & Tier 1 suppliers will harvest investments in existing technology & manufacturing assets, while increasing investment in BEV systems
- Tier 2-3 suppliers are most vulnerable, however, because some will not be able to make the necessary BEV investments
- Will force some to seek diversification by pursuing alternative markets

** Based upon interview findings, as of 3 March, 2021, & assumes mid-point of $-content per vehicle of typical BEV & hybrid automatic transmissions, excludes AWD vehicle configurations*

Thank You

CENTER FOR AUTOMOTIVE RESEARCH