ACT CV Decarbonization 3rd Edition Advance Preview of Full Study Findings

ACT Research Electrification/Autonomy Staff

ACT Seminar 68

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ACT Research Electrification & Autonomy Team

- Ann Rundle, VP Electrification & Autonomy
- Lydia Vieth, Research Analyst, Electrification & Autonomy

Ann Rundle – VP Electrification & Autonomy

- Strategy, Business Development, Sales Leadership roles 30+ years
  - University of Michigan Engineer, started out in Marine industry
  - 20 years with Eaton - focus in Powertrain technologies
  - 10 years with start-ups & consulting - advanced technologies, li-ion batteries
  - 3 years with FCA (now Stellantis) - head of global electrification strategy PV & CV
- VP Electrification & Autonomy ACT Research
  - Global CV Decarbonization study 2nd edition – 2021
  - N America Autonomous Commercial Vehicle study – 2022
  - Global CV Decarbonization study 3rd edition – 2023

Lydia Vieth – Research Analyst

- Research Analyst, Electrification & Autonomy ACT Research
  - Global CV Decarbonization study 2nd edition – 2021
  - N America Autonomous Commercial Vehicle study – 2022
  - Global CV Decarbonization study 3rd edition – 2023
- Prior work and background in power markets, energy management, and environmental policy

ACT Research CV Decarb Study Scope

Economic & Market Overview

Propulsion Systems Technology

Batteries, Fuel Cell, H2-ICE, Natural Gas, Hybrid

Regulations

Electricity Supply & Charging Infrastructure

Hydrogen Supply & Fueling Infrastructure

Natural Gas Supply & Fueling Infrastructure

Fleet, Operator & User Feedback

Total Cost of Ownership

Regions

- **N AMERICA** (US+CAN)
- **EUROPE**
- **CHINA**

ACT Research CV Decarb Study Sneak Peek

Economic & Market Overview

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Regulations

- **US Federal Regulations**
  - Infrastructure Investment & Jobs Act (Bipartisan Infrastructure Legislation; BIL)
  - Inflation Reduction Act (IRA)
  - US GHG Phase 3 (anticipated)
  - US EPA Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards (EPA Low NOx)
- **CARB Regulations (CARB and states adopting CARB regs)**
  - Heavy Duty Omnibus
  - Advanced Clean Trucks
  - Advanced Clean Fleets
- **Canada**

Regulations: US BIL

- **Batteries**
  - $3 billion for battery processing, manufacturing, recycling, and R&D
- **Hydrogen**
  - $8 billion for regional clean hydrogen hubs where *at least* one with end-use in transportation
  - $1 billion for U.S. clean hydrogen electrolysis program
- **Alternative Fuel Infrastructure**
  - $5 billion to develop nationwide EV charging network (TBD how many DC fast chargers will be part of this)
  - $2.5 billion in grants towards public EV, hydrogen, natural gas, and propane refueling infrastructure

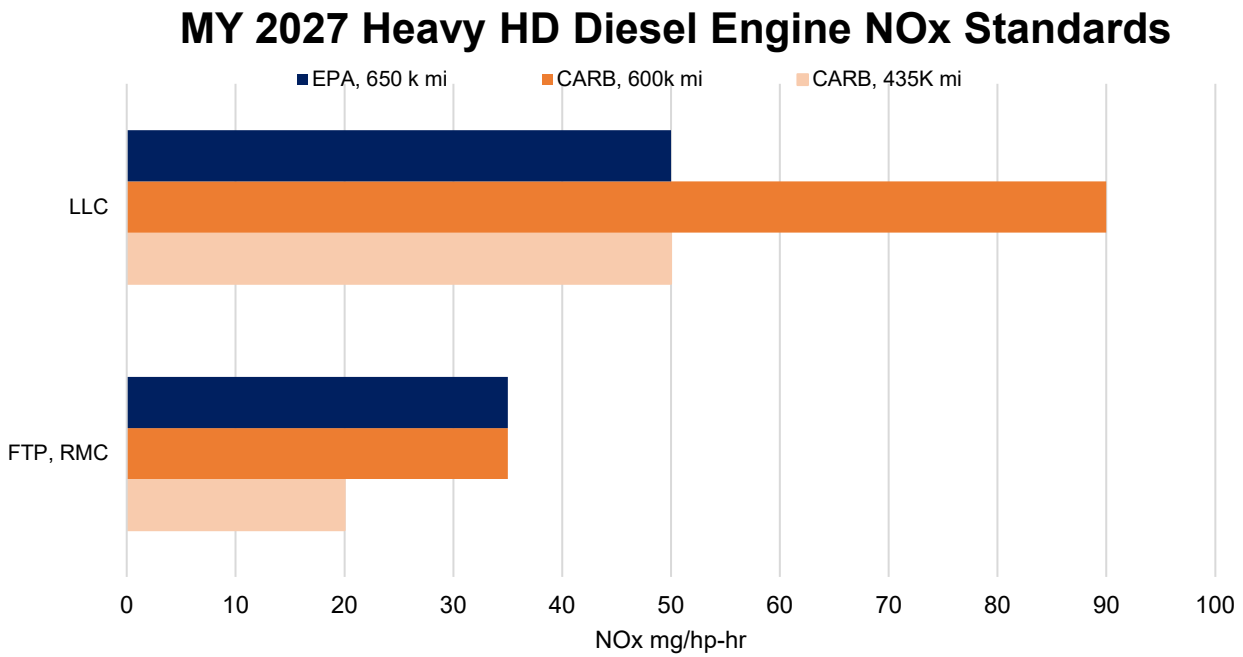
Regulations: US IRA

- **Clean Commercial Vehicles**
  - Up to $40,000 credit per vehicle through 2032
  - BEV, FCEV, even hybrids could qualify (min. 15 kWh battery)
- **Alternative Fuel Refueling Property Credit**
  - Up to 30% of the cost of qualified refueling property (6% if subject to deprecation)
  - Electric, hydrogen, natural gas, ethanol refueling property qualify
- **Advanced Manufacturing Production Credit**
  - Battery cells: $35 multiplied by the capacity of the battery cell
  - Battery modules: $10 multiplied by the capacity of the battery module
- **Credit for Production of Clean Hydrogen**
  - Up to $3.00/kg (subject to inflation adjustment factor) based on lifecycle GHG emissions rate

Regulations: US GHG Phase 3

- Expecting NPRM March 2023
- More stringent GHG standards starting MY 2030
- Consideration of ZEVs

Regulations: EPA Low NOx/CARB HD Omnibus



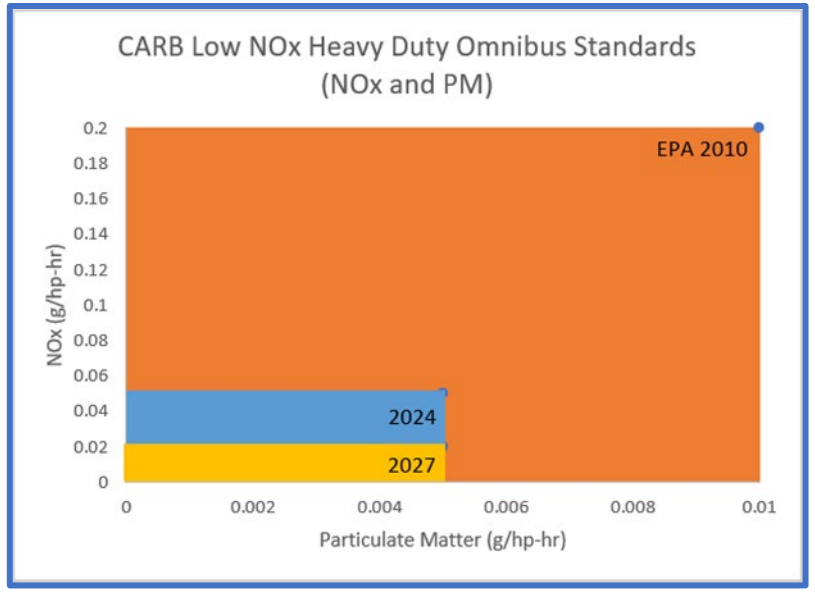
EPA: 1 step in 2027

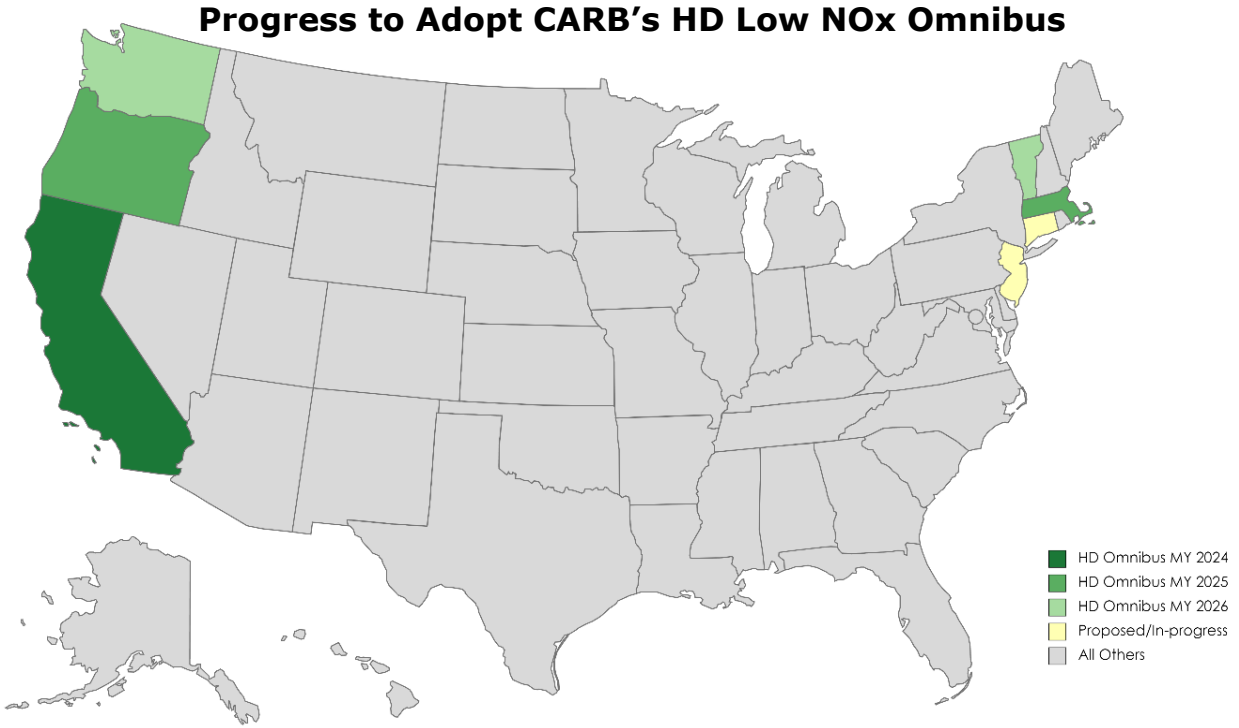
CARB: 3 steps: 2024, 2027, & 2031

- **CARB's main concerns with EPA 2027 Low NOx:**
  - EPA temperature adjustment for off-cycle NOx standards when temperature is less than 77 degrees F
  - EPA interim NOx compliance allowance for in-use testing 15 mg/hp-hr

Regulations: EPA Low NOx /CARB HD Omnibus

- **CARB HD OMNIBUS low-NOx Regulations:**
  - **2024MY = 75% reduction in NOx**
  - **2027MY = 90% reduction in NOx**
  - **2031MY = extended Useful Life & Warranty**





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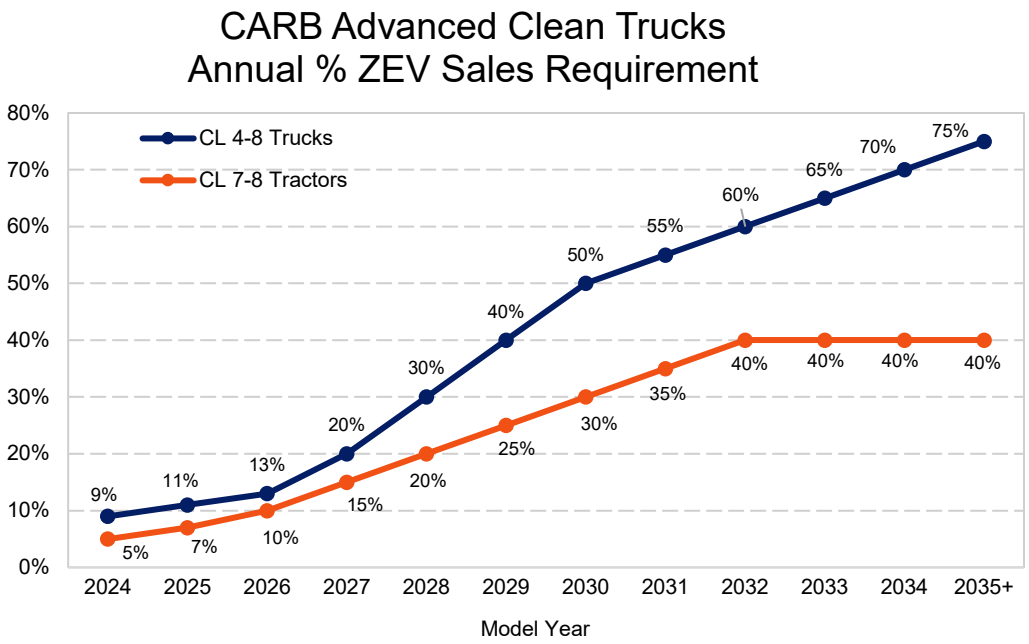
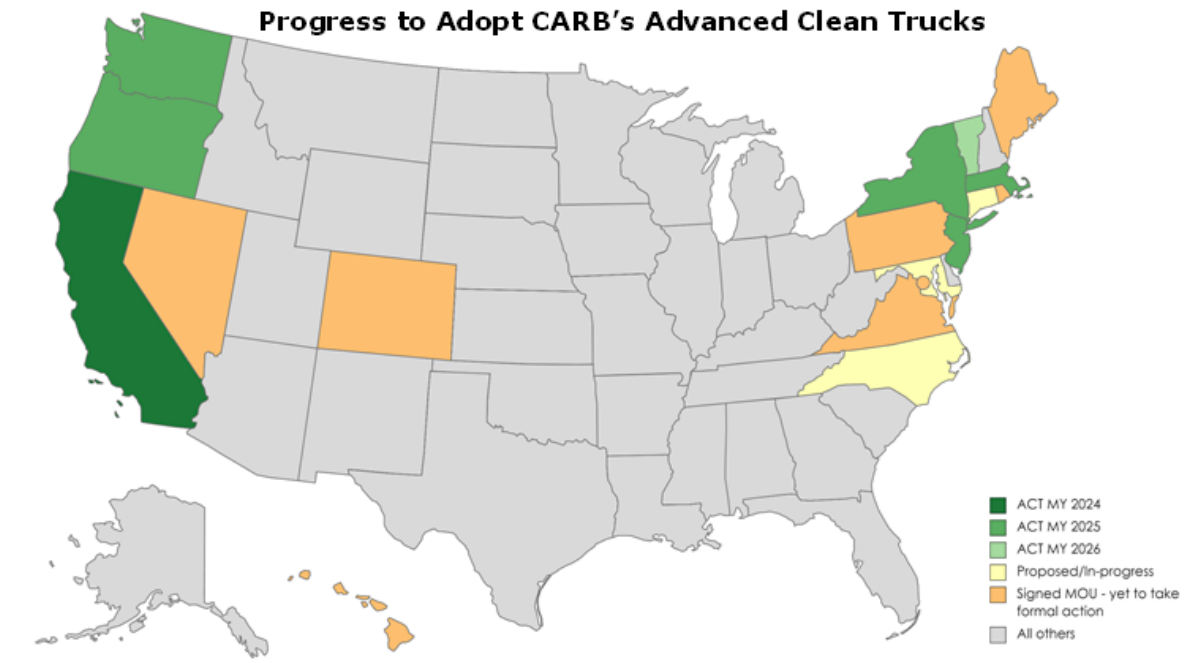
California, Washington, Oregon, Massachusetts, & Vermont have adopted HD Low NOx Omnibus

Regulations: Advanced Clean Trucks



Source: CARB, ACT Research Co. Copyright 2023



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California, Washington, Oregon, Massachusetts, New Jersey, New York, & Vermont have adopted ACT

MOU signed by add'l 9 States & District of Columbia & Quebec

Regulations: CARB Advanced Clean Fleets

- **High Priority Fleets**
  - Entity or entities operating under common ownership or control w/ $50m or more in gross annual revenue
  - Fleet owner (or combination of fleets operated under common ownership and control) that owns, operates, directs 50 or more vehicles in the total fleet
  - Federal government agency
  - Starting 2024 all vehicles added must be ZEV and ICE removed at end of UL
  - **OR** opt-in to ZEV Milestones Option:

Percentage of vehicles that must be ZEVs	10%	25%	50%	75%	100%
Milestone Group 1: Box trucks, vans, buses with two axles, yard tractors, light-duty package delivery vehicles	2025	2028	2031	2033	2035 and beyond
Milestone Group 2: Work trucks, day cab tractors, buses with three axles	2027	2030	2033	2036	2039 and beyond
Milestone Group 3: Sleeper cab tractors and specialty vehicles	2030	2033	2036	2039	2042 and beyond

- **Drayage**
  - 2024 only ZEV may be added and legacy vehicles removed from service at end of UL
  - By 2035 all drayage trucks ZEV
- **State & Local Government Fleets**
  - 2024-26 50% of purchases must be ZEV
  - 2027+ 100% purchases ZEV
- **ZEV Sales Requirement**
  - 100% M-HD Vehicles Sales ZEV starting 2040

- Pending adoption, still in CARB regulatory process

Regulations: Canada Summary

- **Typically follow U.S. emissions standards**
- **Clean Fuel Regulations**
  - Credits issued to makers of low carbon fuels like ethanol and biodiesel (similar to CA's LCFS)
- **Action Plan for Clean On-Road Transportation**
  - Target of 35% M-HD CV sales ZEV by 2030
  - Gov't to develop regulation to require 100% sales ZEV by 2040 (based on feasibility by vehicle type)

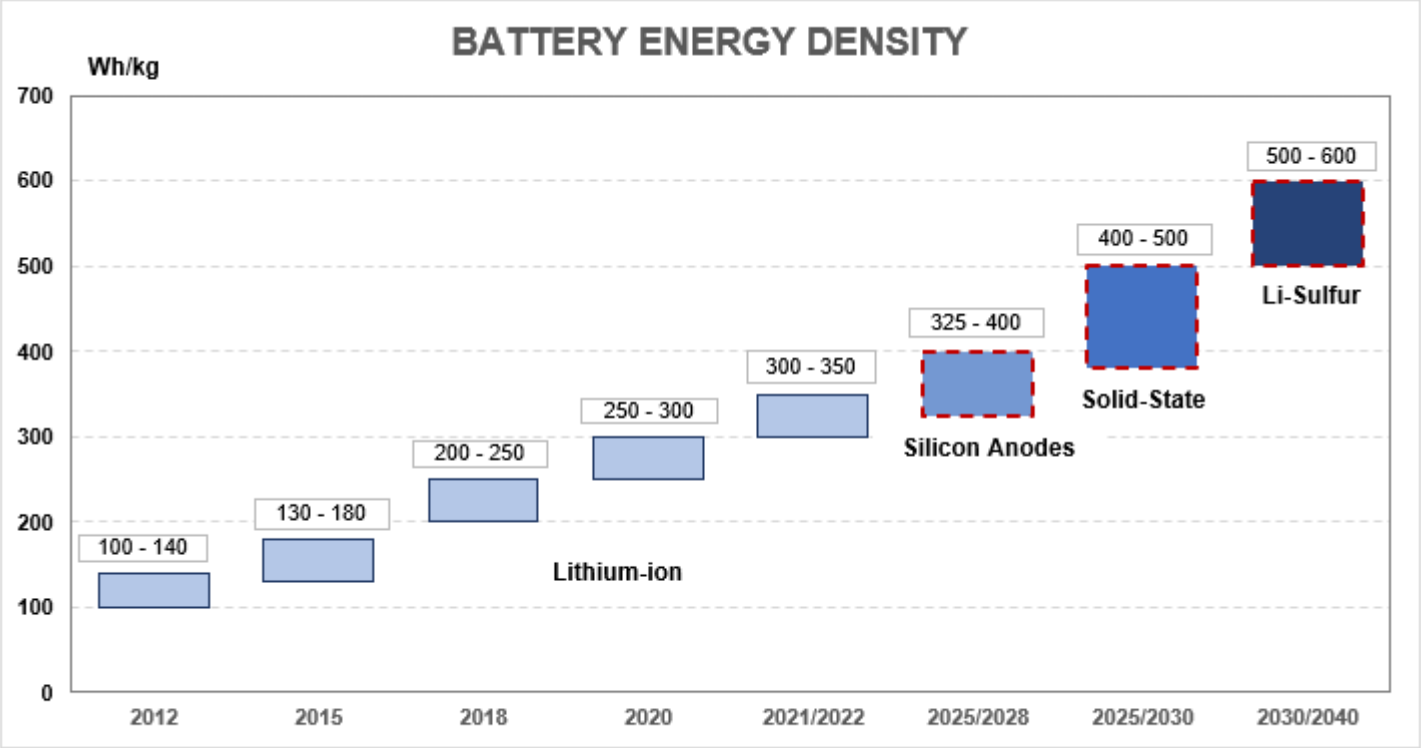
Batteries: Technology, Supply, Costs

- **Technology**: What is the timing and impact of advancements?
- **Supply of Raw Materials**: Will we have enough Lithium? Cobalt? Nickel?
- **Supply of Battery Cells**: Will there be enough gigafactories to support the combined demand of all market segments?
- **Costs**: Will cell and pack costs continue to decrease, or have we bottomed out?

Technology: Battery Energy Density

Advancements in battery energy density continue to improve:

- ✓ Silicon-rich anodes should be a viable technology by 2025/28
- ✓ Solid State continues to advance towards commercialization
- ✓ Li-Sulfur should commercialize sooner than anticipated



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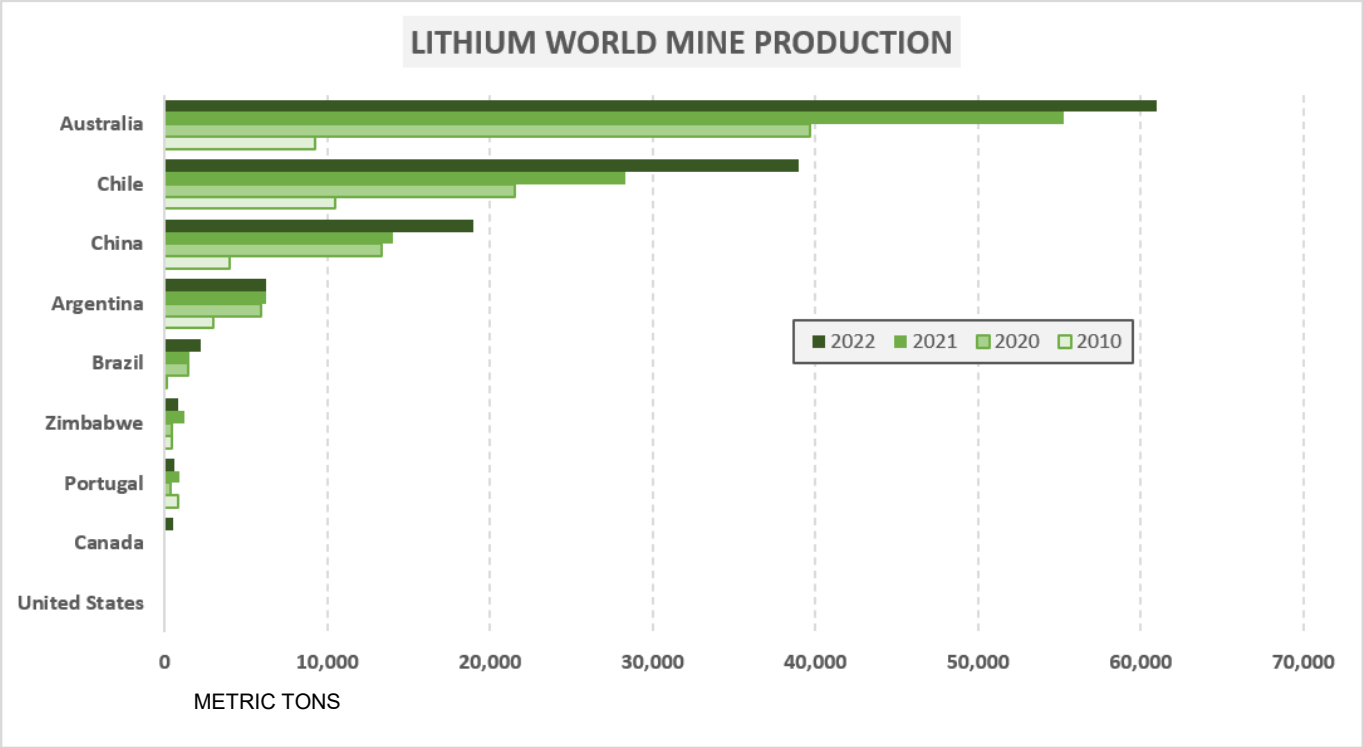
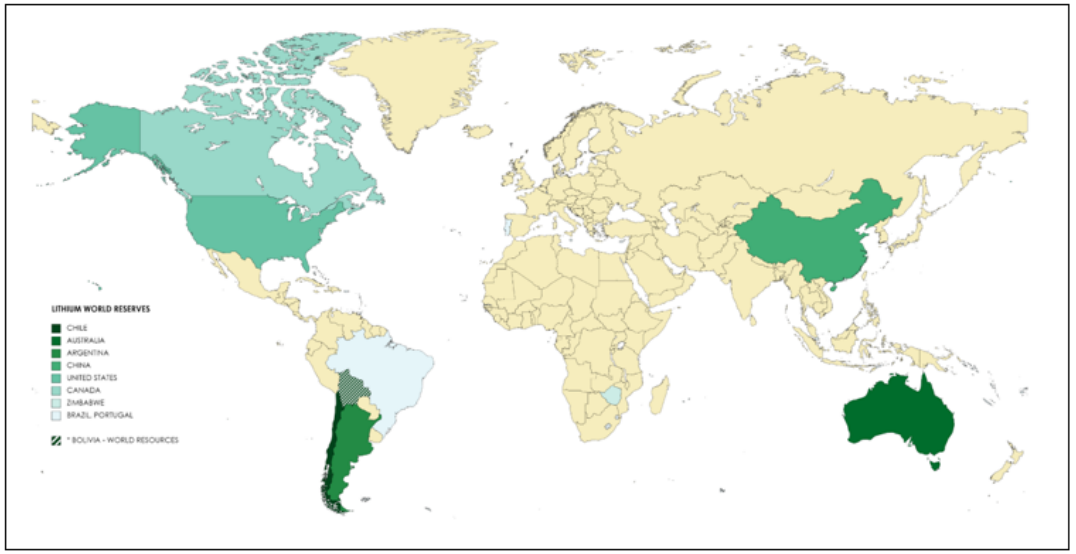
Batteries: Raw Material Supply Considerations

Significant programs to expand extraction & processing:

- ✓ Lithium extraction in 2022 = 130Mil MT … 20% increase over 2021
- ✓ World Reserves = 26Mil MT … add'l 3Mil identified in 2022
- ✓ World Resources ~ 98Mil … 12Mil reside in USA



LITHIUM WORLD RESERVES

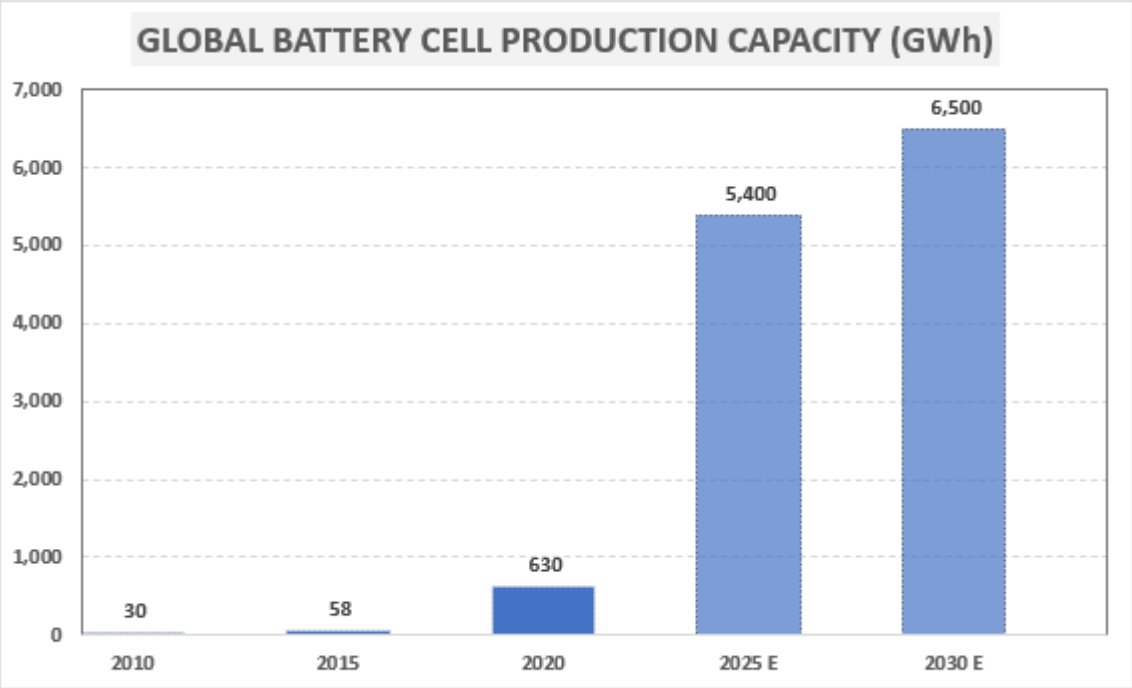


Batteries: Battery Capacity Supply Consideration

METRIC TONS

Significant activity underway to expand cell manufacturing capacity:

- ✓ Cell manufacturing grew ~ 11X 2020 to 2015
- ✓ Cell manufacturing anticipated to expand ~ 9X by 2025
- ✓ BIL & IRA provide significant $$ support to grow US cell manufacturing



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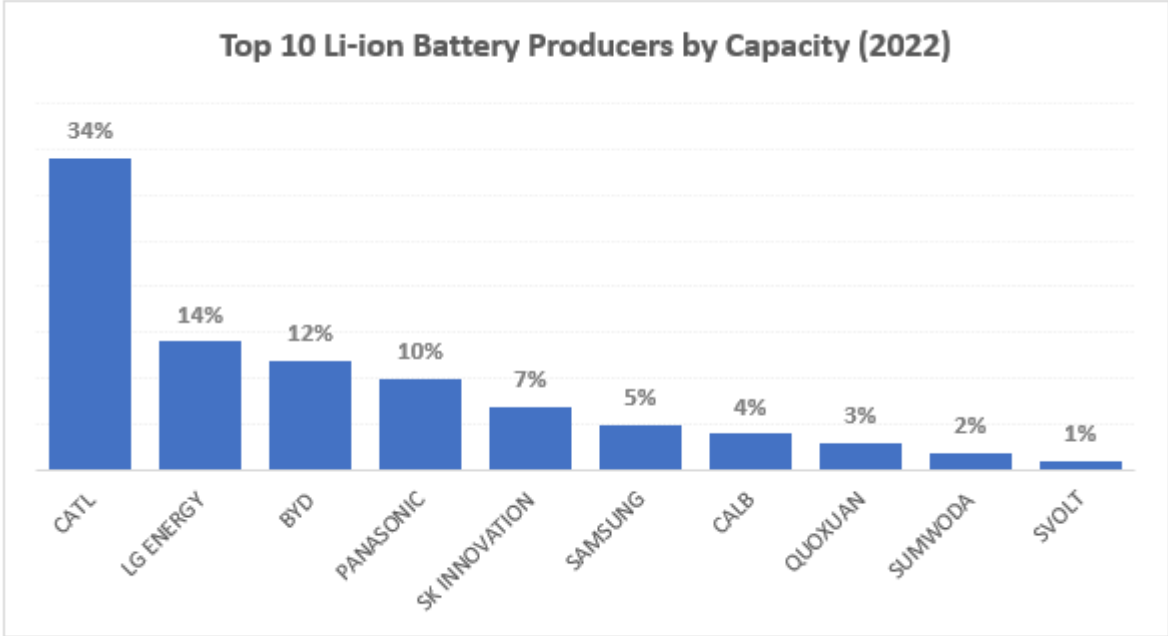

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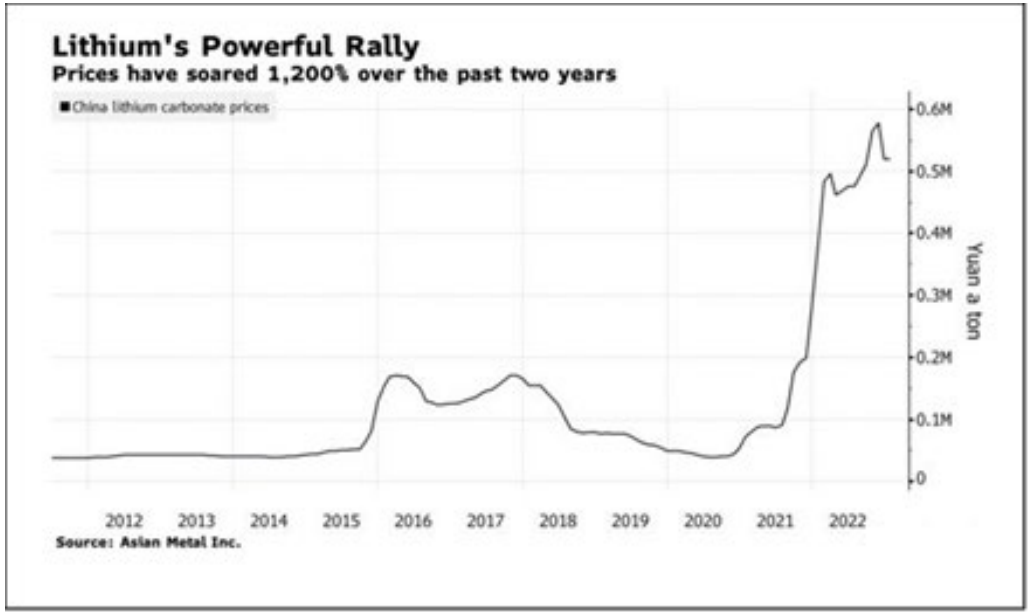
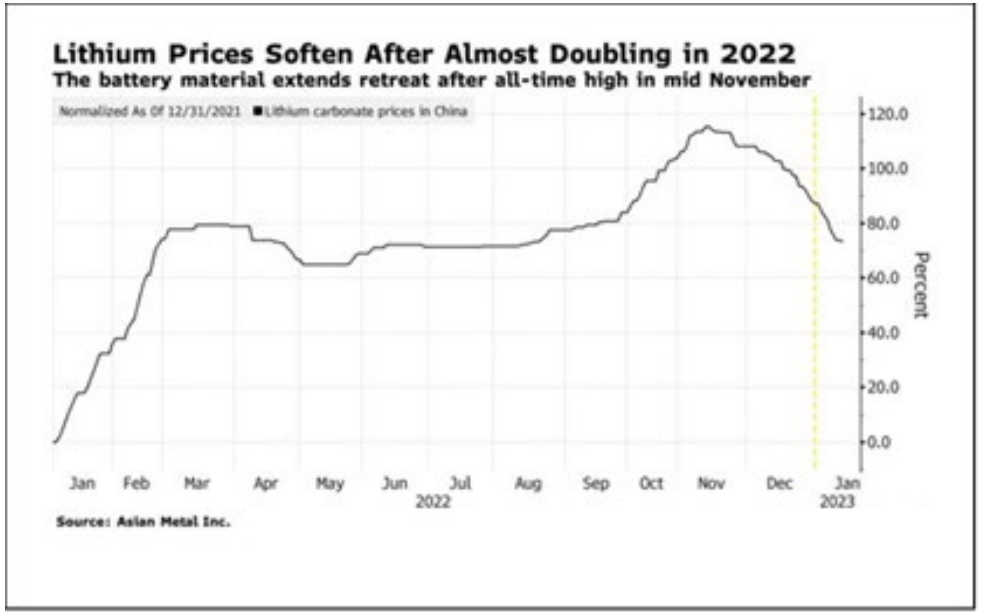
Batteries: Cost Considerations

Long-term downward cost curves impacted by raw materials:

- ✓ Lithium prices spiked in 2022 as a result of supply constraints
- ✓ Nickel prices spike in MAR2022 due to a market “short” and have dropped
- ✓ Shift in mix saw increased utilization of cheaper LFP chemistry





EV Charging & H2 Fueling Infrastructure

- BIL provides $5B for network of public EV fast chargers installed across major highways/freight corridors National Electric Vehicle Infrastructure program (NEVI) administered by DOT
  - 75,000 miles of US national highway system
  - Standards include adoption of CCS
- FHWA to launch $2.5B Charging & Fueling Infrastructure (CFI) discretionary grant program over five years 1st tranche of $700M
- DOE providing $7.4M to fund 7 projects to develop MH/HD EV charging & H2 fueling infrastructure

EV Charging & H2 Fueling Infrastructure …

- **DOE providing $7.4M to develop MH/HD EV charging & H2 fueling infrastructure**
  - ***East Coast Commercial ZEV Corridor***: I-95 corridor Georgia to New Jersey (CalStart)
  - ***MD-HD ZEV Infrastructure Planning w Focus on I-80 Corridor***: two-phase MD-HD EV Charging & H2 Fueling Plan for Midwest I-80 corridor between Illinois, Indiana, Ohio … goal to serve 30% of the MD/HD fleet by 2035 (Cummins)
  - ***Houston to Los Angeles (H2LA) I-10 Hydrogen Corridor Project***: develop a plan for investment ready H2 fueling network Houston-LA, including the Texas Triangle region (GTI Energy)
  - ***First to Last Mile: Creating an Integrated Goods Movement Charging Network around the I-710 Corridor***: Infrastructure solutions at industrial facilities in SoCal I-710 corridor (LA CleanTech Incubator)
  - ***San Francisco & Bay Area MD/HD Electrification Roadmap***: Roadmap for charging infrastructure for drayage, regional haul, & long haul in the Bay Area (Rocky Mountain Institute)
  - ***Northwest Electric Highway Study***: Forecast EV charging demand on freight corridors across 9 NE states from Maine to Pennsylvania (National Grid)
  - ***Wasatch Front Multi-Modal Corridor Electrification Plan – Great Salt Lake City Region***: Develop action plan to improve air quality in underserved communities impacted by MD/HD traffic in greater Salt Lake City region (Utah State University)

Conclusion

- Significant changes over the last two years since ACT published CV Decarbonization 2nd edition study
- **Regulations**:
  - Completely new: BIL and IRA
  - Revised/Finalized: US EPA 2027 Low-NOx, CARB Advanced Clean Truck & HD Omnibus
  - In-Process: CARB Advanced Clean Fleets, US GHG Phase 3
- **Batteries**: Technology, Supply, Costs
- **EV & H2 Infrastructure**

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