

# Lithium Traction Batteries: Chemistry, Composition, and Material Demands

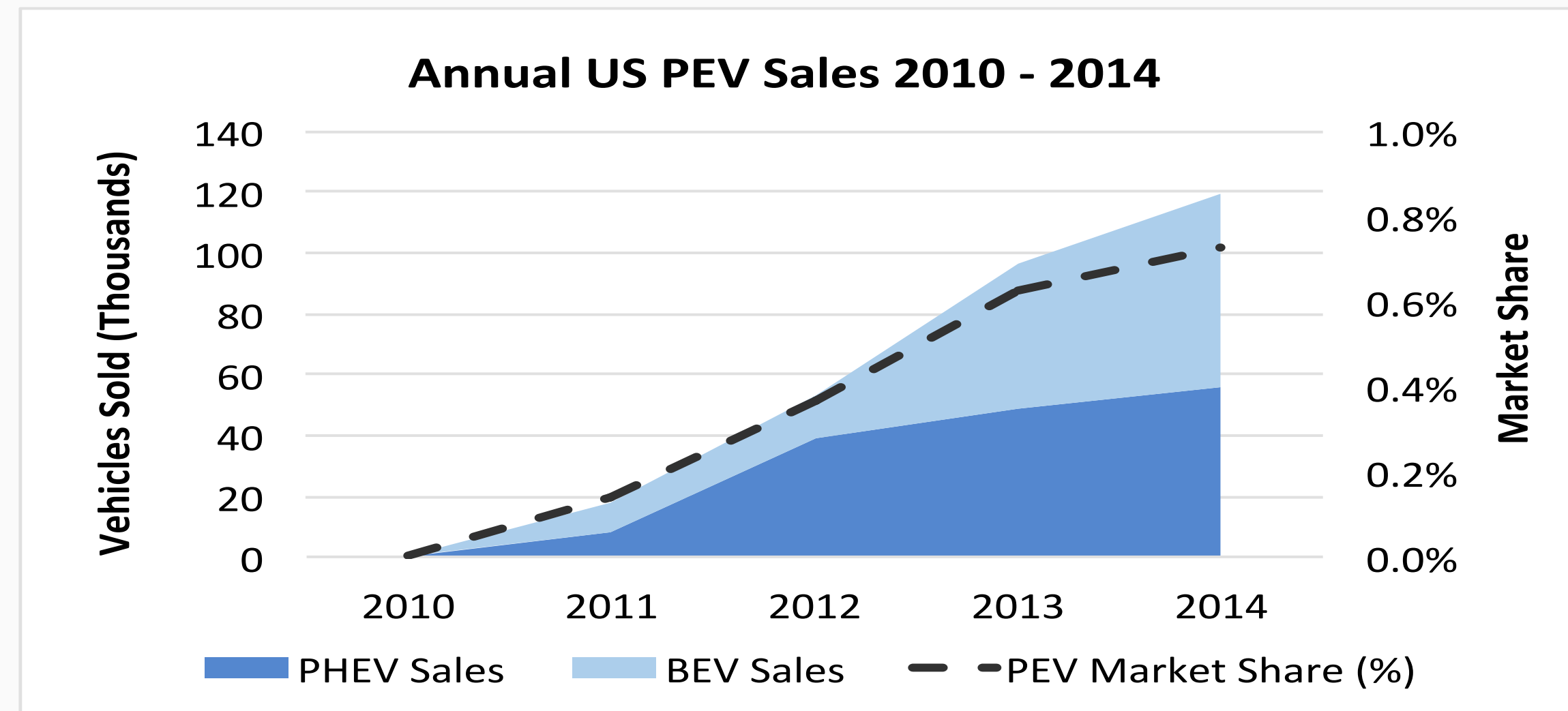


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## Background

A transition to electric vehicles (EVs), including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and plug-in heavy-duty EVs (PHDEVs), is currently underway. Fueled by rapidly decreasing lithium battery prices and supportive policies/incentives, electricity increasingly seems the most viable, near-term, low-carbon, transportation fuel pathway.

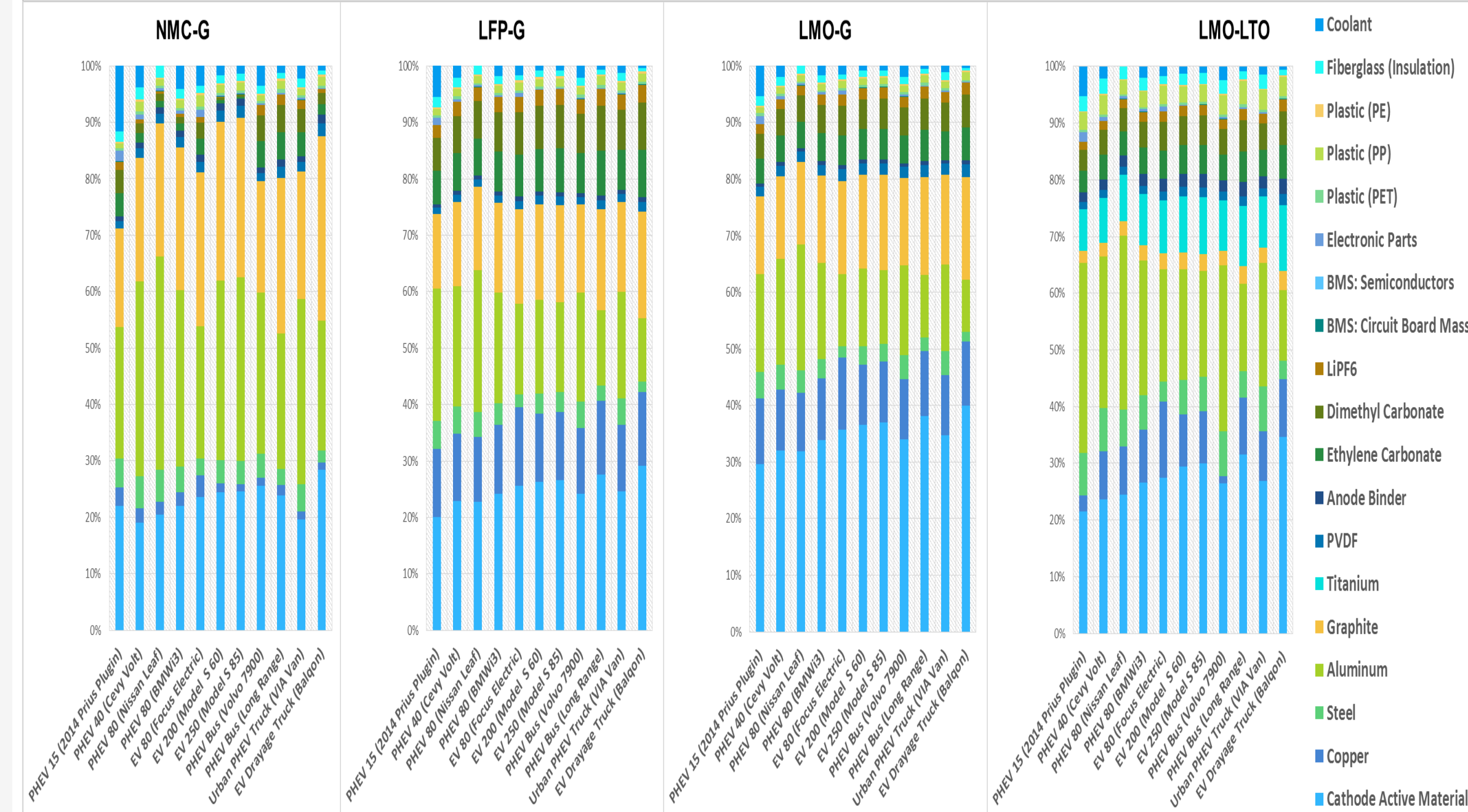


Battery production plays a significant role in the cradle-to-gate impacts of PEV manufacture, and battery life-time and ageing have important impacts on PEV on-road emissions performance. This study lays groundwork for a dynamic assessment of critical energy materials by exploring traction battery composition, production burdens, and material demand.

## Battery LCA and Material Analysis

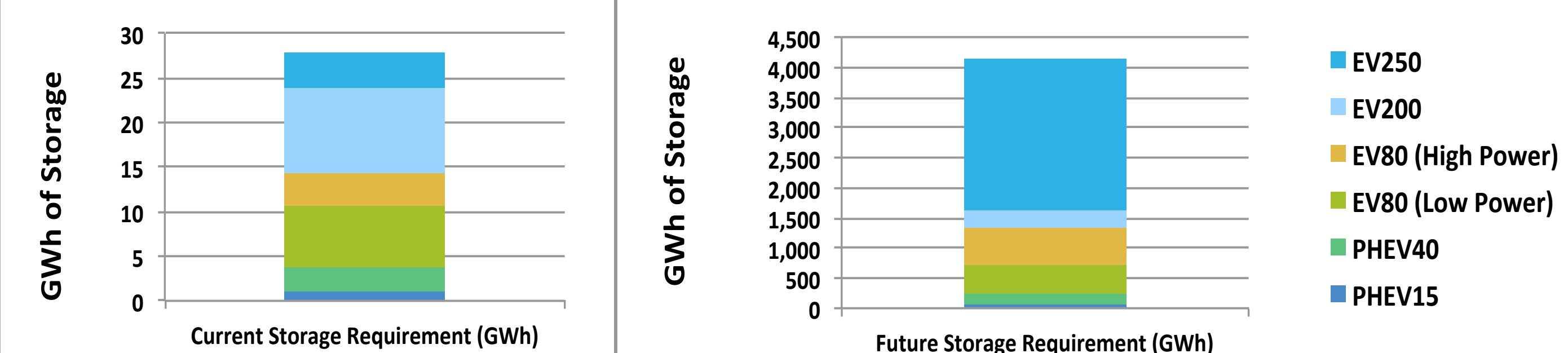
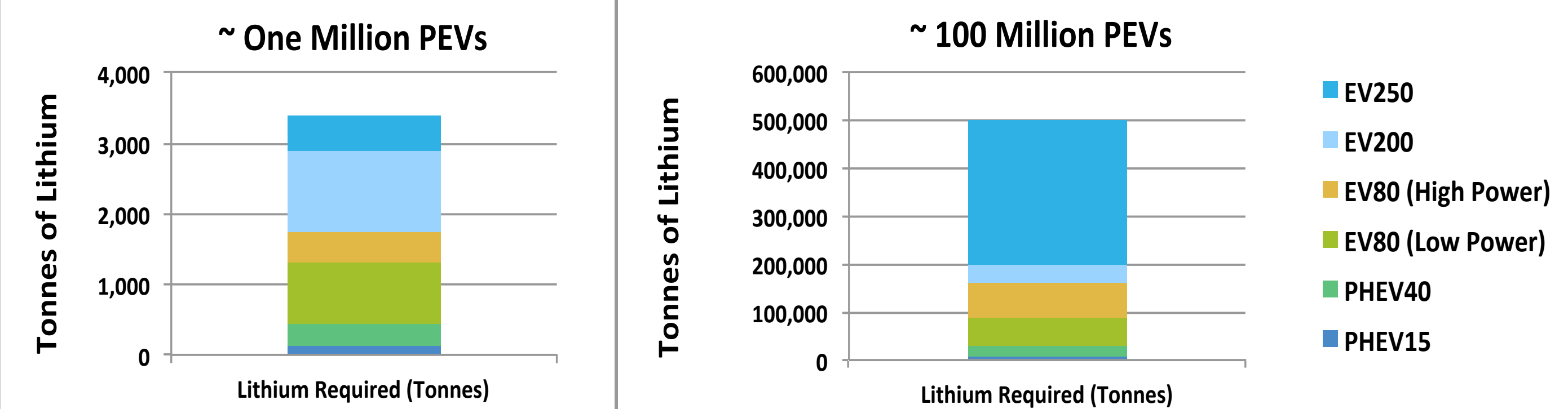
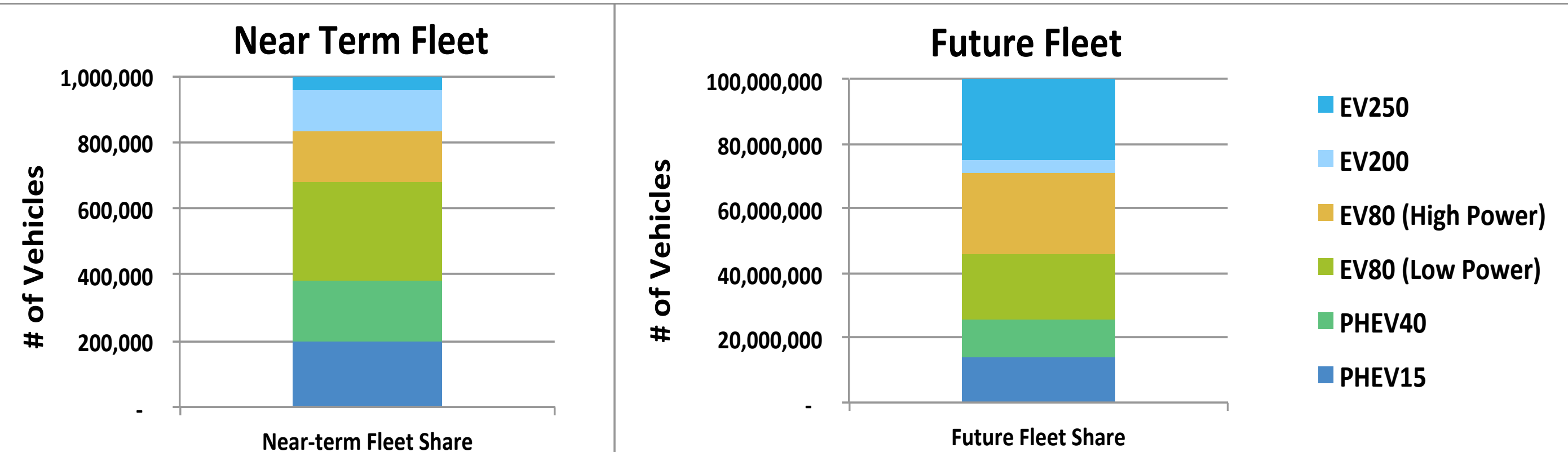
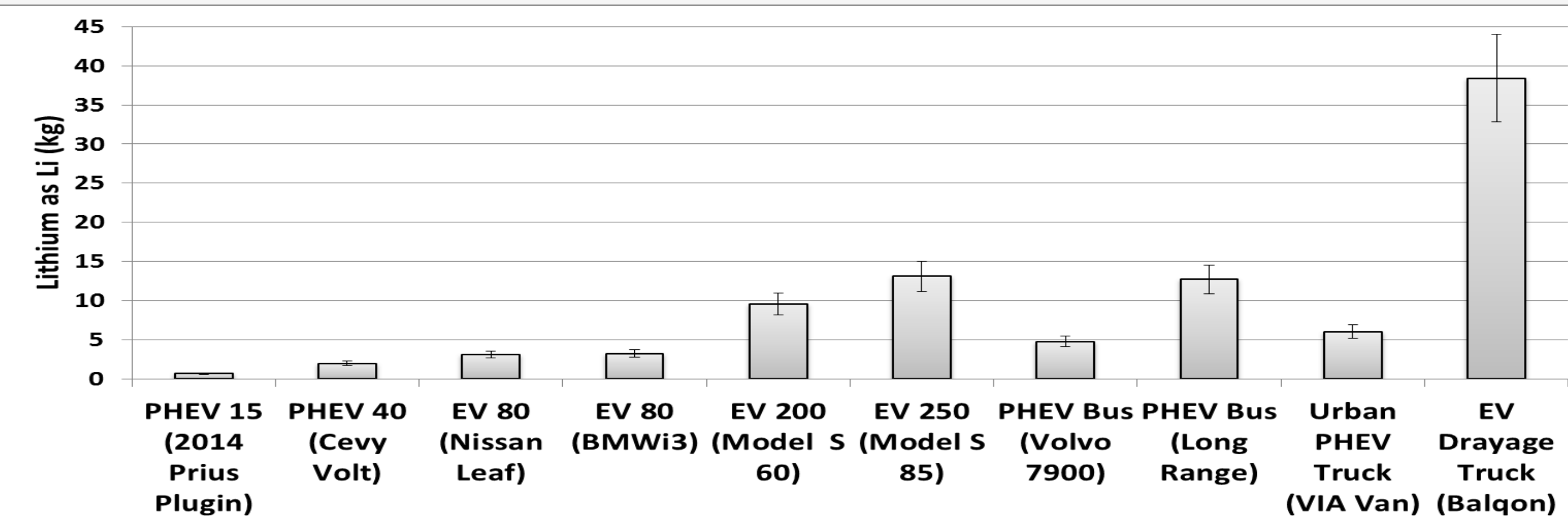
Several Lithium chemistries are being applied across PEV technologies. Due to the range of performance characteristics for these cathode arrangements, it seems unlikely any one cathode will dominate in the near term, suggesting a continued mixed chemistry wastestream with different reuse capacities.

Battery Name	LFP	LMO (Spinel)-Graphite	Spinel-TiO	NMC
Cathode	LiFePO <sub>4</sub>	LiMn <sub>2</sub> O <sub>4</sub>	LiMn <sub>2</sub> O <sub>4</sub>	Li(Ni <sub>0.37</sub> , Co <sub>0.37</sub> , Mn <sub>0.36</sub> )O <sub>2</sub>
Anode	Graphite	Graphite	Li <sub>4</sub> Ti <sub>5</sub> O <sub>12</sub>	Graphite
High Energy Density (Wh/kg)	90-115	100-120	60-150	75-170
Cycle Life (>80% DOD)	>3000	1000	>5000	2000-3000

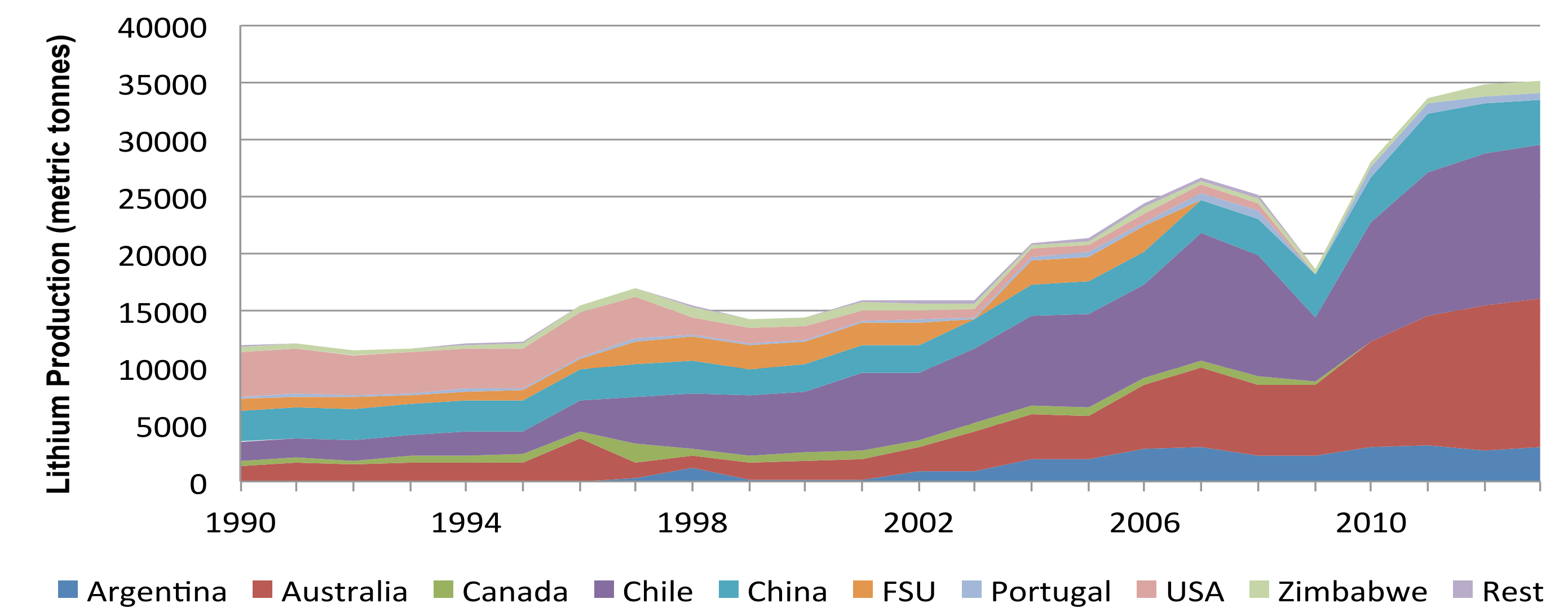


## Storage Requirements for the LDV Sector

The movement towards longer range vehicles is likely to result in non-linear increases in demand for traction battery storage and materials. Global lithium reserves are likely ample to create billions of kWh of Li batteries, but current production levels will have to increase dramatically to meet projected demand. Current Li-battery production levels is 30-35 GWh per year, which is likely enough to provide storage for ~1 million mixed type passenger PEVs.



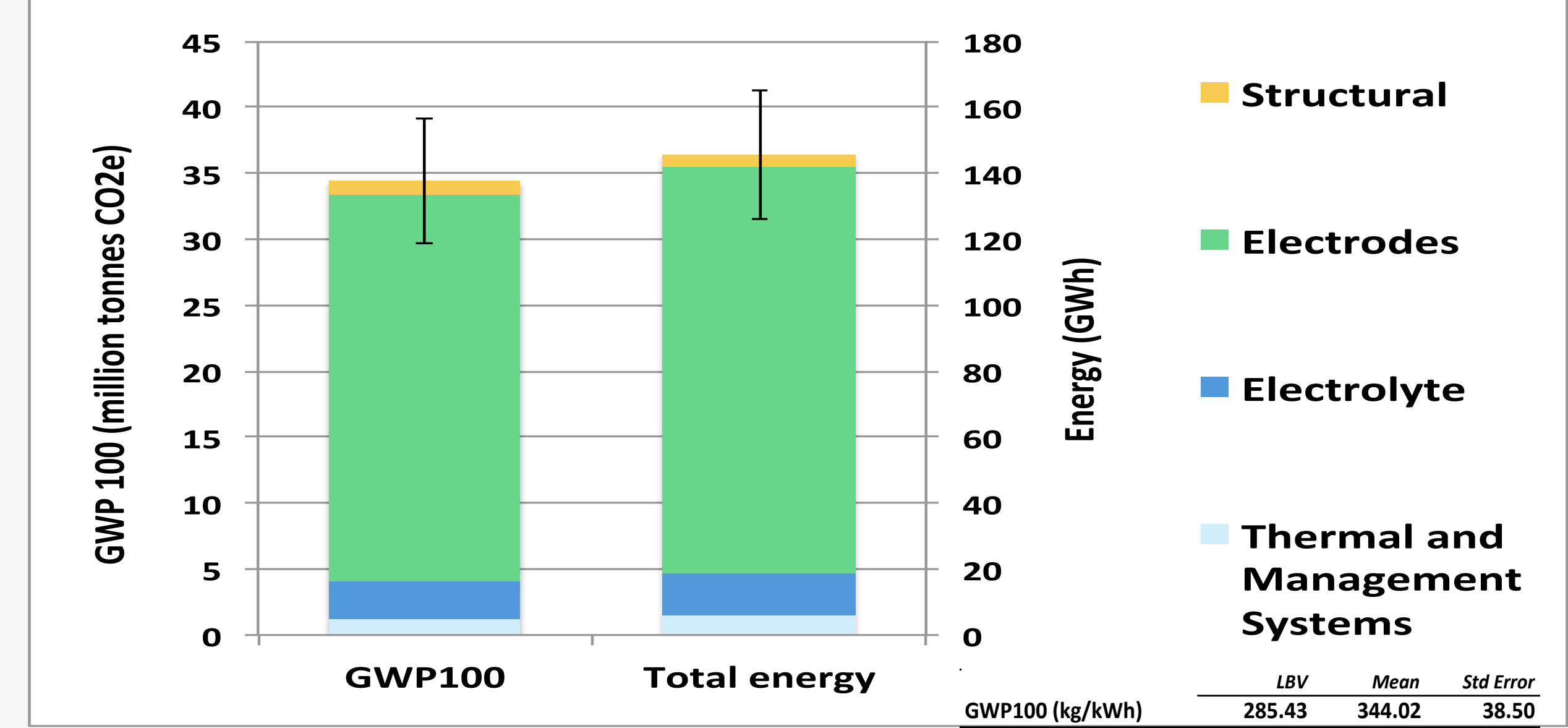
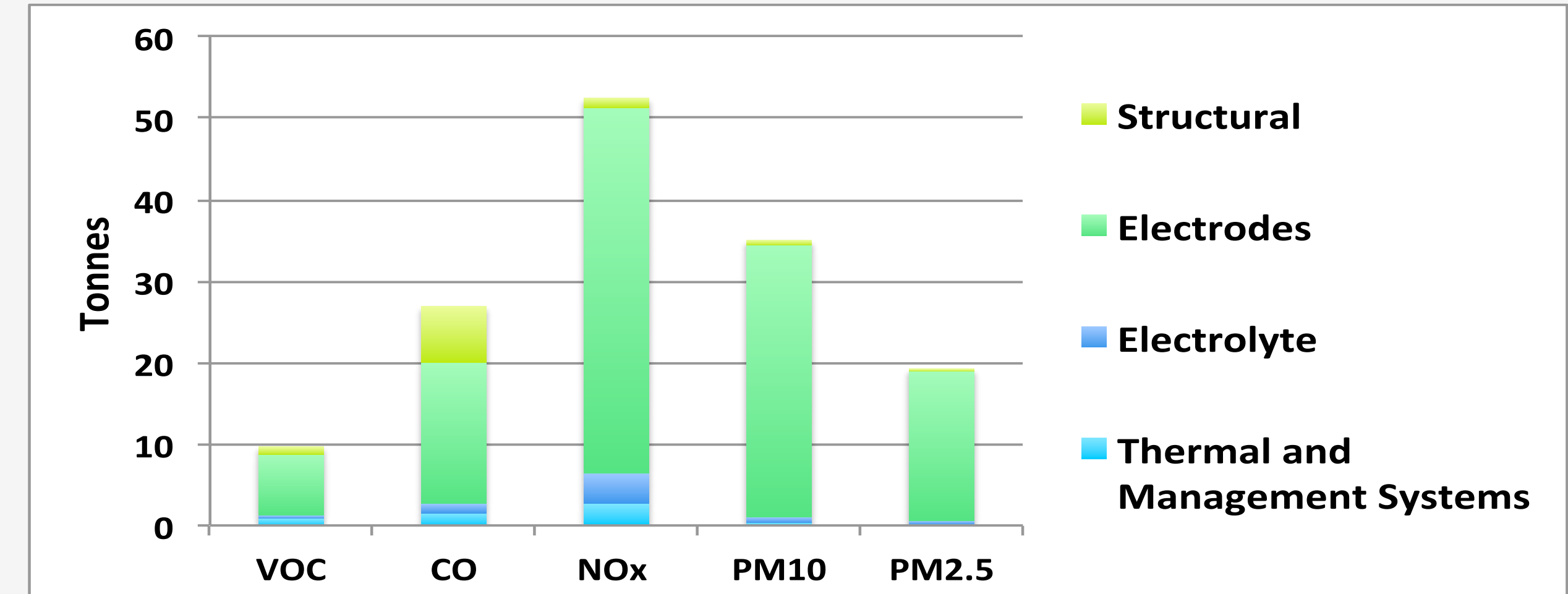
## Global Lithium Production



## A Gigawatt of Production

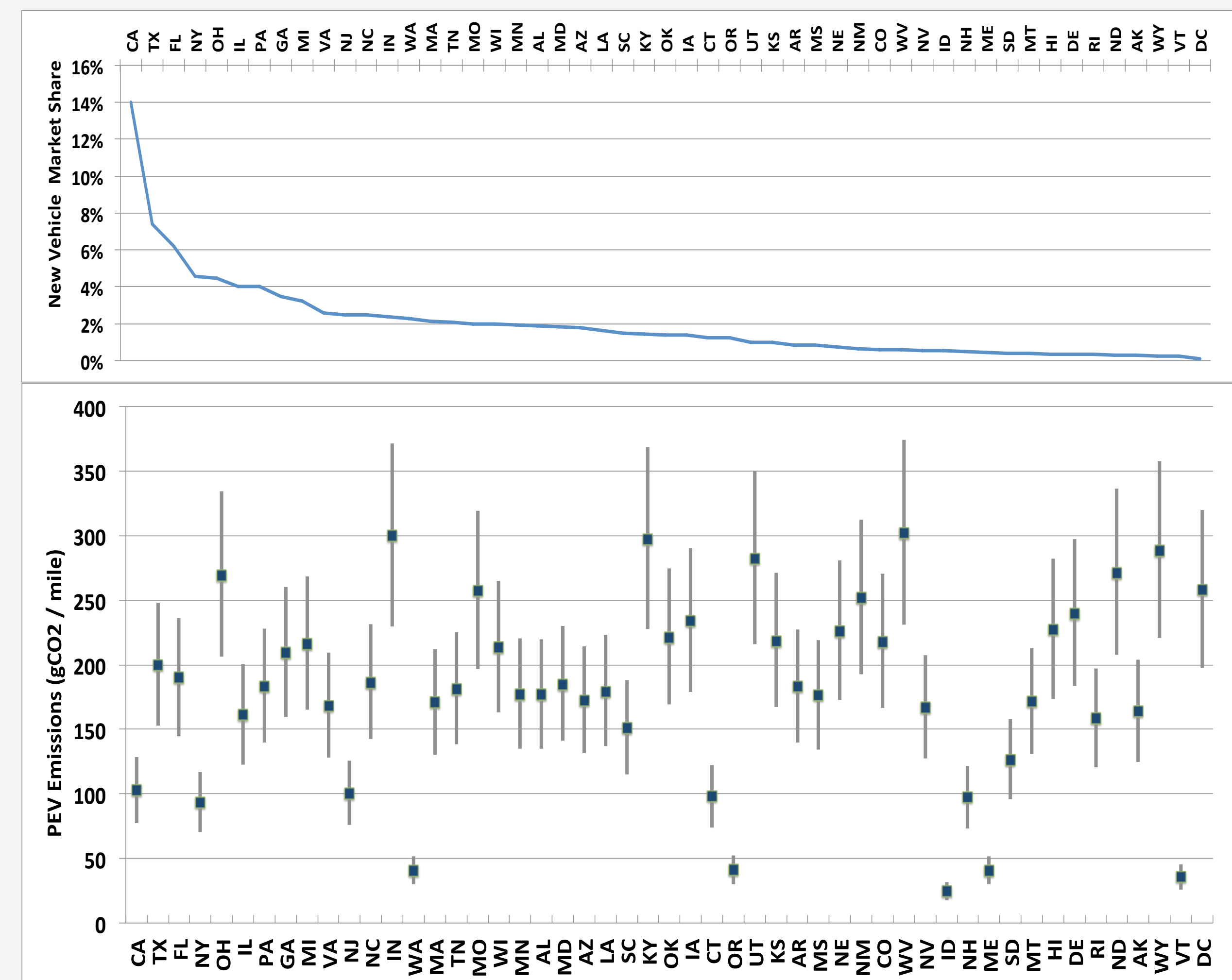
The cradle to gate production impacts of Li-ion batteries are driven by cell manufacture, including electrodes (cathode active material and negative collector foil), and cell assembly.

### ~1 GWh of Lithium Traction Batteries



## Vehicle Use-phase Emissions

PEV emissions performance can have significant regional variability because of differences in electricity generation portfolios. Several states have insufficient low-carbon generation to produce significant emissions reductions from electrification, but they also compose very little of the PEV market. California represents ~15% of the new vehicle market, ~50% of new PEV sales, and grid charged PEVs produce ~30-35% of the emissions of a comparable ICE vehicle.



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