The Missing Link to Secure Battery Minerals: Intermediate Processing

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Key Messages for Policymakers

- China controls 53–72% of critical mineral refining and precursor production. Even though upstream mining is geographically diverse, this massive concentration creates a midstream bottleneck, which could become a single point of failure for the entire global lithium-ion battery supply chain.
- Federal policy should target this choke point by incentivizing "dual-feedstock" facilities—regional plants capable of refining both imported virgin ores and domestically recycled materials into battery-ready cathode precursors.
- Federal policy should view recycling as a major source of domestically produced battery materials. This approach is essential to ensure security, strengthen industry, and reduce emissions.
- Decentralizing battery preprocessing by shifting black-mass production to regional collection hubs is a third element of an effective battery supply chain policy. It can reduce transportation costs by up to 42 percent while ensuring compliance with hazardous-material shipping regulations and improving infrastructure responsiveness.

Policy Context

Critical minerals are essential for advanced technologies across the defense, healthcare, energy, and automotive sectors. The United States depends on imports for most of these minerals. Although federal policy has encouraged investment in mining of these minerals and the assembly of products that use them, intermediate processing remains overwhelmingly concentrated in China. Midstream concentration of six critical metals—lithium, cobalt, nickel, manganese, copper, and aluminum—threatens U.S. supply chain security far more than mineral scarcity. Neither the One Big Beautiful Bill Act, the Inflation Reduction Act, nor escalating tariffs on imports from China adequately addresses this problem.

Research Findings

Five peer-reviewed studies provide an integrated evidence base for battery minerals supply chain policy development. First, a global mapping of mine-to-processor flows for 2024 reveals stark concentration [1]. Cobalt's Herfindahl-Hirschman Index (HHI) is well above the threshold for "highly concentrated." The Democratic Republic of the Congo supplies over 75 percent of mined cobalt output and China, 72 percent of refined material. For lithium, the refining bottleneck is also severe, with all major miners route processing their output in China. Copper and aluminum are far more diversified, but even these metals converge on East Asian smelting hubs.

Second, a global lithium supply chain optimization model reveals a striking asymmetry with respect to recycling [3]. Under pure cost minimization—the default logic of private capital—the model builds zero recycling facilities through the end of the century. But when the model takes emissions into account, 243 recycling facilities are built by 2050. Models that value security, resilience, or reduced import dependence would produce a similar shift in this direction. If lithium recycling is to gain traction, policy must provide the signal.

Third, optimization modeling of the U.S. lithium reverse logistics network reveals that regional preprocessing hubs substantially outperform centralized facilities [2]. The regional approach reduces total network costs by 42 percent between 2021 and 2040 and eliminates $59.6 billion in hazardous-material transportation costs. Finally, a review of climate and trade policy finds no existing analytical frameworks that integrate climate, economic, innovation, and geopolitical concentration risks into energy systems models, leaving policymakers without tools to evaluate trade-offs between cheaper imports and supply chain resilience [4].

Research Design

These studies use complementary methods applied to authoritative data. The supply chain mapping harmonizes 2024 company disclosures, Bloomberg Terminal equity screening, and US Geological Survey country totals using explicit attribution rules for joint ventures and operator- vs.-owner splits. These data are converted to HHIs to measure concentration. The

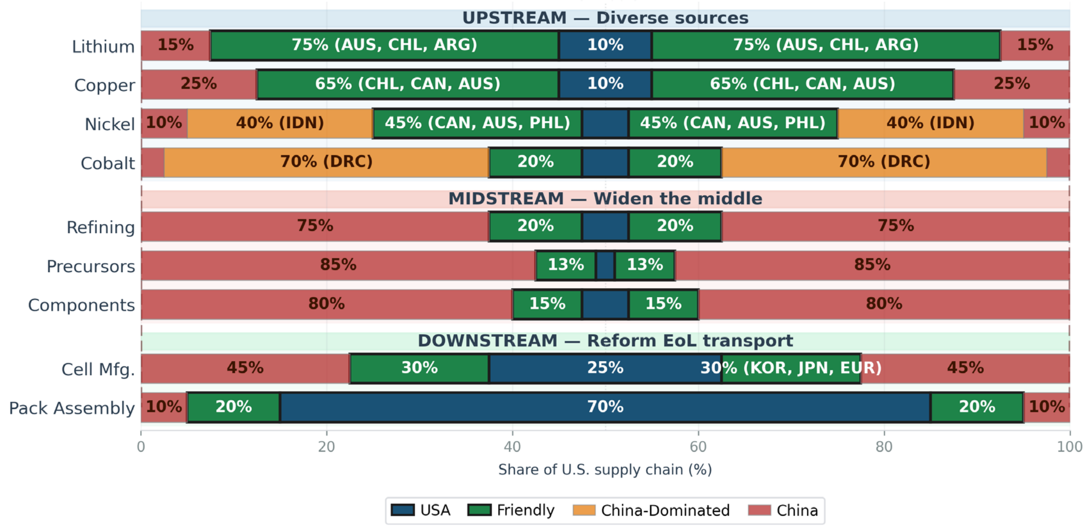

Figure 1. Lithium Supply Chain Diagram (Figure 1, Jones, 2024, [3]) illustrating the different stages in the lithium-ion battery supply chain and shows the corresponding optimization model variables.

reverse logistics models employs mixed-integer linear programming (MILP), parameterized with NREL lithium battery supply chain data, investor disclosures, and EPA emission factors. The global optimization framework uses S-curve demand projections calibrated to IEA, BloombergNEF, and USGS data, with costs benchmarked against announced investments. Physical lab experiments validated the technical feasibility of small-scale black-mass production, grounding the optimization assumptions in demonstrated processes [5].

Policy Implications

These results point to four actionable shifts in policy. First, **target the midstream gap**. Incentives should shift from mining and final pack assembly, which are less vulnerable, to intermediate processing where US vulnerability to China is acute. Second, **design dual-feedstock processing facilities**. New facilities should be able to process both imported or domestically mined virgin ore and recycled materials. Such plants provide a hedge against import disruption and accommodate expansion of domestic mining and recycling. Third, **reform end-of-life transport regulations**. Federal agencies should create a “circular resource” classification for end-of-life technologies destined for domestic recycling. The shift would reduce hazardous-material shipping costs and enable lower-cost decentralized processing facilities to be built. Fourth, **build integrated climate-and-trade analytical capacity**. Current energy models cannot evaluate how tariffs, carbon border adjustments, and friend-shoring strategies interact. Policymakers need frameworks that jointly model cost, emissions, and geopolitical concentration risk—otherwise, policies designed to solve one problem (e.g., CBAM for carbon leakage) may worsen another (e.g., raising costs on allies).

Caveats: The optimization models are deterministic and assume a single global planner; real-world fragmentation will introduce inefficiencies. HHI calculations focus on top producers and may understate true concentration. Facility sizes were fixed for tractability; the optimal regional scale remains an open question. These findings provide a conservative baseline: actual vulnerabilities are likely worse.

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