ZERO EMISSION TRANSPORTATION ASSOCIATION

June 10, 2024

Office of Manufacturing and Energy Supply Chains
United States Department of Energy
1000 Independence Ave SW
Washington, DC 20024

RE: Request for Information on Clean Energy Supply Chain Analysis
Submitted electronically via MESCanalysis@hq.doe.gov.

The Zero Emission Transportation Association (ZETA) is an industry-backed coalition of member companies advocating for 100% electric vehicle (EV) sales. ZETA is committed to enacting policies that drive EV adoption, create hundreds of thousands of jobs, dramatically improve public health, and significantly reduce emissions. Our coalition spans the entire EV supply chain including vehicle manufacturers, charging infrastructure manufacturers and network operators, battery manufacturers and recyclers, electricity providers, and critical minerals producers, among others.

We thank the Department of Energy's (DOE) Office of Manufacturing and Energy Supply Chains (MESC) for the opportunity to respond to this Request for Information related to clean energy supply chain analysis.[1] ZETA supports MESC's goal of developing secure domestic supply chains in strategic sectors.[2]

Forward-thinking, strategic, and predictable federal investment and policymaking will be key to developing a robust domestic clean energy industrial base, and we appreciate the opportunity to provide an overview of EV supply chains to help inform MESC's analysis. ZETA has also encouraged its members to submit responses in their individual capacities, and we urge MESC to give those full consideration as well. The issues that ZETA has highlighted below are key to protecting American economic competitiveness and domestic industrial investment.

Thank you in advance for your consideration.

Sincerely,

Albert Gore
Executive Director
Zero Emission Transportation Association (ZETA)

[1] https://www.energy.gov/sites/default/files/2024-04/MESC_Request_For_Information_Supply_Chain.pdf
[2] https://www.energy.gov/mesc/about-us

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Supply Chain Risks

1.1 *Using the illustrative table provided as a guide, indicate where there exist supply chain risks for specific technologies and/or components along the 9 supply chain categories described above. Components and technologies should draw from Table 1 where applicable, but other components and technologies will also be accepted.*

ZETA is providing feedback on the lithium-ion battery (LIB), electric vehicle supply equipment (EVSE), and grid infrastructure supply chains. We have also encouraged our members to respond with further details in their individual capacities.

We recommend that MESC conduct future supply chain analysis on a finer scale. Investigation into individual raw material and sub-component inputs could effectively identify additional vulnerabilities in clean energy supply chains. For example, the high prices of individual minerals have driven the LIB market towards alternative battery chemistries; analyzing the projected demand for and price of each critical mineral is crucial to a comprehensive understanding of the entire EV battery supply chain.

The lack of geopolitical diversity in the processing, pre-assembly, and final assembly stages of the LIB supply chain is an economic and national security concern that impacts price stability and reliable supply. China controls more than half of the processing supply chain for nearly all EV battery minerals and produces over 90% of all final EV-ready batteries.

Significant vulnerabilities also exist in grid equipment supply chains, which will affect EVSE buildout and future EV demand. A critical element of an expanded EV charging network are strong, reliable supply chains able to meet the needs of an evolving electricity sector. In the last several years, lead time for grid component orders, particularly transformers, has increased. Distribution transformers—often required for the addition of new charging stations—convert high-voltage electricity from transmission lines to lower voltage for commercial and residential consumers. Owned and installed by utilities, such transformers are critically important for national security. As the demand for electricity increases in the coming decades, transformers are essential to weatherizing the electrical grid, expanding domestic manufacturing capacity, and are key to the successful deployment of EV charging infrastructure. We recommend that MESC work with stakeholders across government agencies, including relevant trade policymakers, to better measure and quantify trade flows of EVSE.

ZETA has provided summary tables detailing the relative risks faced along relevant segments of the EV supply chain and overall risk assessments and time horizons of each segment.

Lithium-Ion Batteries

Raw Materials

Copper

Availability: Low-risk

- Total worldwide identified resources are more than 2 billion tons, with yearly production nearing 27 million tons in 2023.[3]

Extraction: Low-risk

- Nearly half of production in 2023 occurred in Chile, the Democratic Republic of the Congo (DRC) and Peru.[4]

Processing: Medium-risk

- China controls 40% of all copper processing capacity. Similar to lithium, China mines less than 10% of the global copper supply, yet has a clear downstream advantage when it comes to processing of the material.[5]

Supply-demand mismatch: high-risk

- Copper supply is projected to drop after 2030 while demand is expected to rise, creating a demand-supply gap. Copper projects are anticipated to meet 70% of global demand requirements by 2035.[6]

Cobalt

Availability: low-risk

- 2023 worldwide cobalt production was 230,000 tons, while global terrestrial resources are estimated at 25 million tons.[7]

Extraction: high-risk

- "The Democratic Republic of the Congo (DRC) produces 70% of cobalt today." Chinese companies own or have a stake in 15 of the 19 cobalt-producing mines in the DRC.[8]

Processing: high-risk, medium-term

- China refines three-quarters of the world's cobalt.[9]

Supply-demand outlook: low-risk

- Expected supply from announced projects is within the range of projected 2035 demand under announced policies.[10]

Graphite

Availability: low-risk

[3] USGS, 2024
[4] IEA, 2024
[5] ZETA, 2023
[6] IEA, 2024
[7] USGS, 2024
[8] Castillo et al, 2022
[9] IEA, 2024, p. 155
[10] Ibid, p. 99

- Global production in 2023 of natural graphite was 1.6 million tons, with 800 million tons of recoverable graphite resources worldwide.[11]

Extraction: high-risk, short-term
- China currently accounts for 80% of global natural graphite production.[12]

Processing: high risk, short-term
- China refines more than 90% of the world's graphite, producing 93% of battery-grade supply.[13]

Supply-demand outlook: low-risk
- Expected supply from announced projects is within the range of projected 2035 demand under announced policies.[14]

Lithium

Availability: Low-risk, long-term
- Global identified lithium reserves have increased by more than 50% since 2020,[15] as investment and interest in lithium has grown. Total measured and indicated lithium resources are greater than 100 million tons worldwide, while global production numbers hit 180 thousand tons in 2023.[16]

Extraction: Medium-risk, long-term
- Australia is the primary producer of hard rock lithium with 33% of projected 2030 production, with China (23%) and Chile (12%) also producing significant amounts. Argentina is also attracting significant capital investment and is expected to be a major player by 2030.[17]

Processing: Medium risk, short-term
- China holds less than 7% of the global lithium resources and produces less than 15% of global lithium raw material, yet it produces nearly 60% of the world's refined lithium.[18]

Supply-demand outlook: high-risk
- Lithium production is projected to triple by 2035, but will still only meet 50% of demand requirements due to exceedingly high growth in demand associated with clean energy technologies.[19]

Manganese

Availability

[11] USGS, 2024
[12] IEA, 2024, p. 172
[13] Ibid, p.168
[14] Ibid, p. 99
[15] USGS, "Lithium"
[16] USGS, 2024.
[17] IEA, 2024.
[18] IEA. 2021.
[19] IEA, 2024.

- The U.S. does not hold any manganese reserves; the majority are found in South Africa, Gabon, Australia, and Brazil, in that order.[20]

Extraction

- Australia has a well-developed manganese mining sector, providing 16% of the world's manganese in 2022.[21]

Processing

- China processes over 90% of global manganese supply.[22]

Supply-demand outlook: low-risk

- Manganese production is projected to expand in the coming years, while demand will also increase with the introduction of lithium-manganese-iron-phosphate (LMFP) batteries into mainstream production.[23]

Nickel

Availability: low-risk

- Global reserves are more than 130 million tons, with 3.6 million produced in 2023.[24]

Extraction: low-risk

- The U.S. currently imports a majority of the resource that is consumed, with 68% coming from allies in Canada, Norway, Australia, and Finland.[25]
- Indonesia produces 62% of nickel worldwide.[26]

Processing: medium-risk

- China controls 21% of refining capacity, with Indonesia accounting for 41% worldwide.[27] Chinese companies also account for a significant portion of refining investment in Indonesia.[28]

Supply-demand outlook: medium-risk

- Current low prices threaten to chill investment, and potential supply gaps may appear as early as 2030.[29]

Rare Earth Elements

Availability: low-risk

- Global reserves are 110 million tons, while 350 thousand tons were produced in 2023.[30]

Extraction: high-risk

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[20] ZETA, 2023
[21] Ibid.
[22] IEA, 2024.
[23] Ibid.
[24] USGS, 2024.
[25] ZETA, 2023.
[26] IEA, 2024.
[27] Ibid.
[28] IEA, 2021, "The Role of Critical Minerals"
[29] Ibid.
[30] USGS, 2024.

- China is the top REE producer, and is projected to produce 54% of REEs globally by 2030.[31]

Processing: high-risk

- China processes 85% of REEs.[32]

Supply-demand outlook: low-risk

- Expected supply from existing and announced projects is within the range of projected 2035 REE requirements.[33]

Sub-Assembly

Cathode Active Materials:[34] high-risk

- Transition metal oxides, including lithium cobalt oxide, lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminum oxide (NCA), and lithium iron phosphate (LFP), are the leading cathode active materials for LIBs.
- Seven companies produce 55% of global cathode active materials.
- China controls 70% of production capacity for cathode active materials.

Anode Active Materials:[35] high-risk

- Graphite is the dominant anode material, and is thus produced almost exclusively by China.
- The top six AAM producers are all Chinese and account for two-thirds of global production capacity.
- China controls 85% of anode production capacity.

Separators:[36] medium-to-high-risk

- Production is concentrated, with five companies responsible for half of the global production capacity.
    - Two of the top three key players are Chinese companies.
- Data is not available on the exact market share of China.

Electrolytes:[37] high-risk

- One Chinese company produces 35% of global electrolyte salt.

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[31] IEA, 2024.
[32] ZETA, 2023.
[33] Ibid.
[34] IEA, 2022, "Global Supply Chains."
[35] Ibid.
[36] Ibid.
[37] Ibid.

- The top producers of electrolytes (which require both electrolyte salts and solvents) are all Chinese, though IEA was not able to estimate China's total market share.

Battery cells:[38] high-risk
- In 2021, the top three producers accounted for 65% of global production: CATL (China), Panasonic (Japan), and LG Energy Solutions (Korea).
- China controls 60% of the world's battery component manufacturing.

Batteries: high-risk[39]
- China controls over 75% of EV battery manufacturing.

Grid and Charging Equipment

Large Power and Distribution Transformers
Sub-assembly: high-risk[40]
- Availability of Grain-Oriented Electrical Steel (GOES) presents a bottleneck to many electricity producers.
    - Only produced by one manufacturer, with insufficient quality, domestically. This manufacturer has also announced plans to sell the company to an overseas buyer.
    - GOES production has decreased in response to increased demand for non-oriented electrical steel (NOES).

Construction: high-risk
- Workforce challenges
    - A DOE survey found that transformer component manufacturers have difficulties hiring employees with the necessary skill sets and qualifications such as welding, coil winding, and transformer testing. Few secondary institutions offer specializations in the necessary programs required for transformer production, creating an insufficient supply of workers.[41]

Capital Equipment: medium-risk[42]
- Lack of test beds increases lead times.
- Logistics and transportation challenges in delivery.

Energy Storage

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[38] Ibid.
[39] Ibid.
[40] DOE, 2022
[41] Ibid.
[42] Ibid.

- For Li-ion battery energy storage systems (BESS), which makes up the majority of battery storage systems, identical considerations apply to EV batteries.
- Additionally, use of end-of-life EV batteries in battery storage systems may dampen the impact of supply chain risks on BESS deployment and cost.[43]

EV Chargers
Sub-assembly: medium-risk

- China was the primary source of imports for electrical converters that are used to produce EV chargers, though its share has decreased from 63 percent in 2017 to 35 percent in 2021.[44]
- Trade and production data for EV chargers are not readily available and are often aggregated with other electrical products, making it difficult to gain significant insight into EVSE supply chain dynamics.[45]

Current and Future Risks

1.2 *For technologies and/or with identified supply chain risks, indicate whether these risks:*

- *currently exist and affect the respondent, or*
- *are anticipated to arise in the next 5-10 years*

All risks identified exist currently and affect the domestic electric vehicles sector, with the exception of mismatches in demand and supply for copper and lithium, which are anticipated within the next five to ten years.

Qualitative Description of Risks

1.3 *For technologies and/or with identified supply chain risks, provide a qualitative description of the extent to which the supply chain risk is the result of:*

- *demand and supply mismatches - symptoms of demand supply mismatch can include: long lead times for specific components, high demand for specific end products leading to shortages, high profit margin industries capturing supply of specific components that are critical for multiple clean energy technologies, or others.*
- *Fragile supply chains – symptoms of fragile supply chains can include: challenges with vendor lock-in, sole-source suppliers, particular components that are sourced exclusively abroad, workforce development and skill shortages, price manipulation by foreign entities, market monopolies or monopsonies, price instability affecting long-term facility planning, or others.*

[43] IEA, 2024, "Batteries."
[44] Adhanom et al, 2022.
[45] Ibid.

EV Battery Raw Materials

Most EV battery supply chain risks identified are attributed to fragility; namely, China's control of extraction and processing capacity, and a lack of domestic and Free Trade Agreement countries[46] capacity. Multiple nodes of the critical minerals supply chain are sourced exclusively from abroad, with most processed critical minerals produced worldwide coming from China. This creates myriad risks; in addition to vulnerabilities related to disruptions to trade and shipping activity, price volatility created by powerful market actors through deliberate industrial and trade policy can create long-term price instability that suppresses capital investment. An IEA analysis shows that if Chinese markets were cut off on both demand and supply fronts, supply for every major critical mineral except copper would fall significantly short of global demand.[47]

The Chinese Communist Party (CCP) has effectively wielded export controls in the past for minerals used in semiconductor manufacturing, including graphite, creating price volatility and demonstrating its ability to disrupt strategically important U.S. manufacturing sectors.[48] Prices in lithium, cobalt, graphite, and nickel markets have seen significant fluctuations since 2021.[49] In lithium[50], cobalt[51], and nickel[52] markets, observed overcapacity among Chinese refiners and mid-stream producers was a major cause of this uncertainty. Low prices tend to chill investment in future extraction,[53] while high prices, especially combined with short-term uncertainty or fluctuations, can affect downstream manufacturers' decisions to sign offtake agreements or expand production capacity. Fluctuating prices and long-term market uncertainty stunt market growth and restrain EV deployment.

Another source of unpredictability for U.S. producers occurs in the domestic pre-extraction process. The current critical material permitting landscape in the United States creates a perverse incentive to remain reliant on foreign supply chains, which leaves the U.S. vulnerable to geopolitical forces outside of our control. While the U.S. attracted almost 20% of the world's total mining investment in previous decades, duplicative, inefficient, and costly permitting timeframes have created a lack of confidence in the U.S. as a viable mining jurisdiction. The numerous complications, delays, and unpredictability built into today's permitting system create uncertainties and risks for investors. These factors place the U.S. at a competitive disadvantage to foreign governments and push mining activities to parts of the world with minimal requirements for environmental, ethical, and labor protections and mitigation activities. By disincentivizing investment domestically, permitting practices push capital abroad and reinforce existing fragile supply chains.

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[46] USTR, 2024.
[47] Ibid, p. 102,
[48] CSIS, 2024.
[49] IEA 2023.
[50] Oxford Energy, 2024.
[51] Shi, 2024.
[52] Duan, 2024.
[53] IEA, 2024.

Demand and supply mismatches are significant for copper and lithium. Copper supply is projected to drop after 2030 while demand is expected to rise, creating a demand-supply gap. Copper projects are anticipated to meet 70% of global demand requirements by 2035. Lithium production is projected to triple by 2035, but will still only meet 50% of demand requirements due to exceedingly high growth in demand associated with clean energy technologies. Given the long lead times observed for the development of mining operations in the United States and worldwide, production may take some years to fully catch up to demand. Such delays will result in impending growth for the electric vehicle market, but also other clean energy supply chains.

Limitations in current battery recycling methods present a further hurdle for developing a reliable and sustainable lithium supply. Traditional methods of hydro- and pyrometallurgy, in reducing batteries to their elemental forms, destroy lithium in the process due to its volatility. Additionally, anode recycling has seen underinvestment due to the relatively low value of graphite. Technological underdevelopment and underinvestment thus further contribute to supply issues with respect to raw materials.

EV Battery Sub-Assembly

Similarly to critical minerals, China controls significant portions of the sub-assembly process, from cathode- and anode-active materials to final battery assembly, causing significant fragility in mid-stream EV supply chains. This is the result of decades of conscious industrial policy, and provides China's industries with a significant edge over competitors in terms of technological sophistication, production capacity, and industrial knowledge. One way in which this dominance is maintained is the significantly lower cost of production equipment in China relative to the United States, Japan, and Korea. Current policies and announcements are expected to shift the center of gravity of battery production, resulting in about a quarter of battery production occurring in Europe or the United States by 2030.[54] China will still likely be a major player for years to come particularly in the area of anode-active materials, given its dominance in graphite production and refining.[55]

Grid and Charging Equipment

Ensuring reliable and abundant energy and charging infrastructure is crucial to enabling reliable use of existing EVs and creating the charging capacity needed to attract further demand. The EVSE and grid infrastructure supply chain contains fewer high-risk choke points compared to critical minerals and battery supply chains. Still, it faces its own unique sets of challenges, including workforce issues and a lack of relevant data that may obscure shortages or vulnerabilities.

[54] IEA, 2022, "Global Supply Chains"
[55] Ibid.

Transformers

Transformers, while not exclusively used for EV charging, are an essential component used to connect Electric Vehicle Charging Equipment (EVSE) to the grid. Distribution transformers are currently estimated to facilitate the distribution of over 90 percent of the nation's electricity, much of which is for large renewable energy additions and commercial and residential end-use. While other uses of certain transformers mainly include large projects with long lead times, EVSE demands much more electric power than its size or production time would indicate. Thus, long lead times for transformers have a larger impact on EVSE buildout than on other projects. Transformer supply chain risks are the result of a combination of demand and supply mismatches for key inputs, as well as fragility related to manufacturing components and workforce.

Shortages of transformers initially began during the supply chain crunches of the COVID-19 pandemic, with lead times increasing from 50 weeks in 2021 to 120 weeks in 2024.[56] High costs and shortages of inputs have also been a major contributor, including volatile prices of copper and aluminum.[57] Grain-oriented electrical steel (GOES), a key input with its own complex manufacturing process, is largely imported from Asia—only one domestic manufacturer exists and is unable to meet the specifications required for high-performance transformers.[58] Additionally, since GOES often shares manufacturing facilities with other electrical steel used in EVs, shifts in production to accommodate increased EV manufacturing have created shortages in an already vulnerable supply chain.[59]

Domestic manufacturers of transformers utilized just 40% of their overall capacity in 2020, due to a combination of workforce challenges and a lack of testing capacity.[60] Manufacturers have difficulties hiring employees with the necessary skill sets and qualifications, and few post-secondary institutions offer specializations relevant to transformer manufacturing. The COVID-19 pandemic and the remote location of factories have also created difficulties in attracting and retaining workers, making it difficult to ramp up production in response to shortages.[61] Furthermore, the lack of test beds, which are used to perform quality checks on finished transformers, have also created significant bottlenecks in production.[62] Without necessary workforce and capital investments, lead times for domestic transformers are likely to remain high as transportation electrification continues, increasing the cost of EVSE buildout and encouraging foreign sourcing of transformers.

Energy storage

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[56] Wood Mackenzie, 2024.
[57] Moore, 2023.
[58] DOE, 2022.
[59] Ibid.
[60] Ibid.
[61] Ibid.
[62] Ibid.

Lithium-ion batteries are often utilized as battery energy storage systems (BESS), accounting for 85 GW of capacity and 80% of new battery storage in 2023 globally.[63] The applications of BESS vary but are useful for capturing energy from renewable and or non-renewable sources and storing it in rechargeable batteries for future use. For example, battery storage systems can be used by solar-based off-grid applications, including those that power off-grid EV charging. Battery storage systems are less dependent on size and weight requirements than EVs, and can also utilize second-life batteries, such as those formerly used in EVs.[64] This increased input flexibility somewhat insulates lithium-based storage solutions from volatile critical minerals markets, but does present risks in the long-term, especially if lithium chemistries continue to be the dominant technology deployed.

EV Chargers

Due to the nascent market EVSE supply chains are understudied compared to other segments of the EV supply chain. They lack their own classification under the U.S. Harmonized Tariff System (HTS) and are included with a variety of other electrical converters. They are similarly aggregated with other products in the manufacturer's production reports.[65] China was the top source of imported electrical converters, including EV chargers, in 2021 at 35%, but this was a decline from 65% in 2017. ZETA recommends that MESC engage with stakeholders to identify and explore potential bottlenecks and risks.

Quantitative Risk Assessments

For technologies and/or with identified supply chain risk, provide a quantitative assessment of relative degree of supply chain risk on a 1-4 scale, where 1 is lowest risk and 4 is highest risk. Use the following scale to quantify the information or data provided for a given component in a present or future state in the following way:

- *1: Demand does not exceed supply and there are no identified vulnerabilities in the supply chain*
- *2: Demand exceeds supply or there are some vulnerabilities in the supply chain*
- *3: Demand exceeds supply and there are some vulnerabilities in the supply chain*
- *4: Demand far exceeds supply and there are multiple vulnerabilities in supply chain*

ZETA has included quantitative assessment of the relative degree of supply chain risks in summary tables, which can be found below:

[63] IEA, 2024, "Batteries"
[64] Ibid, p. 21.
[65] Adhanom et al, 2022.

Segment	Raw Materials			Manufacturing and Assembly			Labor Availability			Overall Risk Assessment (Timing and Level of Concern)		
Critical Materials	Availability	Extraction	Processing	Capital Equipment	Sub-Assembly	Final Assembly	Construction	Operations	Installation	Today	5-10 Years	Score
LIBs	Low Risk	High Risk	High Risk	N/A	High risk	High risk	N/A	N/A	N/A	Yes	Yes	4
EVSE	Low Risk	Low Risk	N/A	N/A	Medium risk	Medium risk	N/A	N/A	N/A	Yes	No	2
Transformers	N/A	N/A	N/A	Low risk	Medium risk	Low risk	Medium risk	Medium risk	Medium risk	Yes	No	3

	Raw Materials			Overall Risk Assessment (Timing and Level of Concern)		
Critical Materials	Availability	Extraction	Processing	Today	5-10 Years	Score
Cobalt	Low Risk	High Risk	High Risk	Yes	No	4
Copper	Low Risk	High Risk	High Risk	Yes	Yes	3
Graphite	Medium Risk	High Risk	High Risk	Yes	No	4
Lithium	Low Risk	Medium Risk	High Risk	Yes	Yes	3
Manganese	Low Risk	High Risk	High Risk	Yes	No	3
Nickel	Low Risk	High Risk	High Risk	Yes	No	3
REEs	Medium Risk	High Risk	High Risk	Yes	No	3

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