Written Testimony of JB Straubel

CEO Redwood Materials

Before the U.S. Senate Committee on Energy and Natural Resources

The scope and scale of critical mineral demand and recycling of critical minerals

April 7, 2022

Chairman Manchin, Ranking Member Barrasso, and members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to testify at today's hearing.

My name is JB Straubel and I am Founder and Chief Executive Officer of Redwood Materials. Prior to joining Redwood Materials, I co-founded Tesla and was Chief Technical Officer at the company for 15 years. At Tesla I led battery cell design, supply chain and designed and scaled the first Gigafactory through the production ramp of the Model 3. It was during this time that I had a front row seat to the challenges that the industry will face as both the vehicle and energy markets electrify. It became clear from that vantage point that the supply chain around batteries could gate the speed of our clean energy transition.

I started Redwood Materials to develop a fully closed-loop, domestic supply chain for lithium-ion battery materials. To close the loop and create a secure domestic supply chain, Redwood is: (a) collecting and recycling end-of-life lithium-ion batteries from consumer devices, electric vehicles, and energy storage systems, (b) refining the materials sustainably, and (c) re-manufacturing them into battery materials – specifically, cathode active materials and battery copper foils – that can go directly to U.S. battery manufacturers, including our current partners Panasonic and Ford. Increasing our nation's production of these resources will serve as a key enabler to decrease the cost and environmental footprint of batteries and scale-up U.S. battery manufacturing. The US has seen a significant increase in domestic battery cell production, however, in order to increase production of electric vehicles in the U.S. and decrease our foreign reliance on the supply chain that builds them, we must ensure that we focus on producing critical materials and battery components in the U.S., in addition to securing critical minerals, through both terrestrial mining and lithium-ion battery recycling.

This Committee has shown tremendous foresight under your leadership Chairman Manchin, and that of your predecessor, Senator Murkowski, in recognizing the urgent risk posed to our nation's security and energy independence due to shortages of critical minerals. We saw evidence of this leadership last week, when President Biden announced that he would be enacting the Defense Production Act to address this issue. I want to personally thank you, Chairman Manchin, and Senators Murkowski, Risch and Cassidy for your letter to the President highlighting this issue. Equally important are the downstream components that these minerals build. Today, the two most critical and expensive components of lithium-ion batteries, the cathode and the anode, are produced via a convoluted supply chain based almost entirely in Asia. Our current supply chain today would require that metals and minerals, whether newly mined or recycled, travel outside the United States, in most cases to Asia, where this component manufacturing expertise and infrastructure exists. This is because there is a gap today in the U.S. between critical mineral extraction and domestic battery cell manufacturing.

Redwood is working to address this gap by offering large-scale domestic sources of these battery materials, anode and cathode components, produced from as many recycled batteries as available and augmented with sustainably mined materials. If we were to limit our production to what is available today for recycling, we would not be able to create nearly enough critical battery materials. Quickly ramping a domestic battery materials supply chain and using the highest possible percent of local recycled and raw materials is the best way we can meet the U.S.'s electrification and clean energy goals.

The Electrification Opportunity

The world is transitioning to electric vehicles-as a response to mitigating climate change, decreasing regional pollution, and capitalizing off continually improving electric vehicle (EV) performance and costs. EVs accounted for 5% of total new car sales in 2020 and are projected to account for 20% of total new car sales in 2025, 50% in 2030, and nearly all new cars in 2040.[1][2]

American automobile manufacturers including Ford, General Motors, Stellantis, and others have each made declarations to go all-in on electrifying their fleet over the next decade and Tesla and Rivian plan to exponentially ramp their domestic EV production.

As such, the demand for lithium-ion batteries in the United States is projected to skyrocket over the coming decade, presenting a critical opportunity for the U.S. economy. Globally, demand for lithium-ion batteries is projected to grow by more than 500% to meet rapid electrification of transportation and the increased need to store intermittent renewable energy. Additionally, exponential growth in the consumer and industrial electronics industry, which use lithium-ion batteries will add to battery demand.

Building out domestic lithium-ion battery manufacturing capabilities can position the United States as an international leader in the global automotive manufacturing space, which accounts for approximately 3% of our nation's GDP[3], and help secure our energy independence through increased penetration of renewable energy.

As a nation, this tremendous growth represents an opportunity as an increasing number of batteries reach end of life each year, for a sizeable recycling resource. Additionally, to meet the demand growth curve for batteries, there will need to be exponential increases not just in the critical minerals but, additionally, in the production of battery materials (anode and cathode components) vs. the global existing capacity today. Central to these opportunities is establishing U.S. leadership across an end-to-end lithium-ion battery supply chain.

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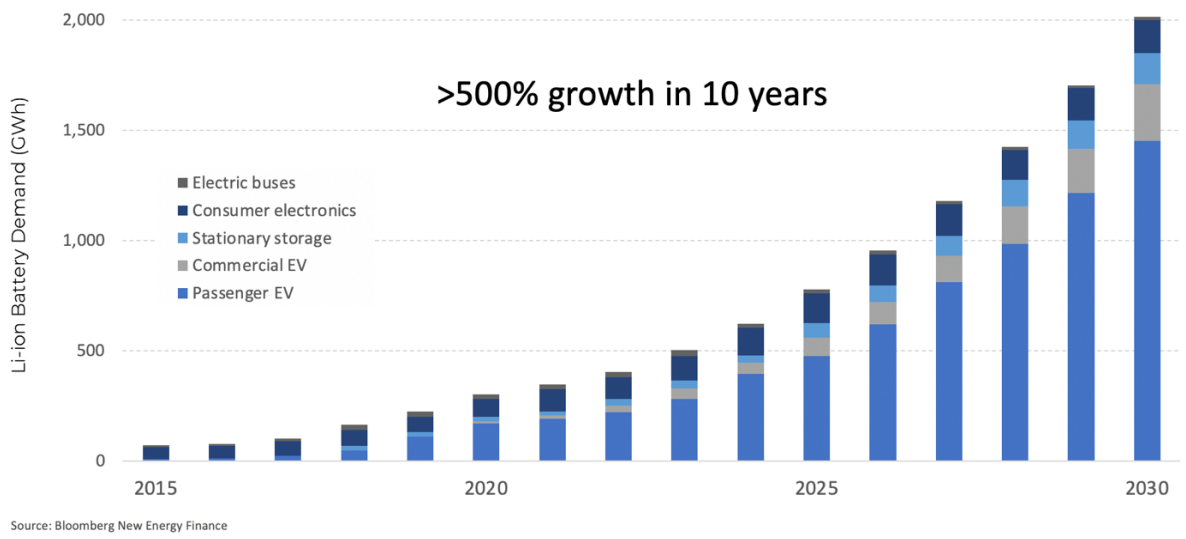
[1] *See* Rowlatt, J. (2021, June 1). *Why electric cars will take over sooner than you think*. Retrieved from BBC: https://www.bbc.com/news/business-57253947

[2] *See* UBS. (2021, March 3). *The electric vehicle revolution is shifting into overdrive*. Retrieved from UBS: https://www.ubs.com/global/en/investment-bank/in-focus/2021/electric-vehicle-revolution.html

[3] *See* Forbes. (2021, October 4). *Every Automaker's EV Plans Through 2035 And Beyond*. Retrieved from Forbes: https://www.forbes.com/wheels/news/automaker-ev-plans/

Lithium-ion battery demand (GWh)

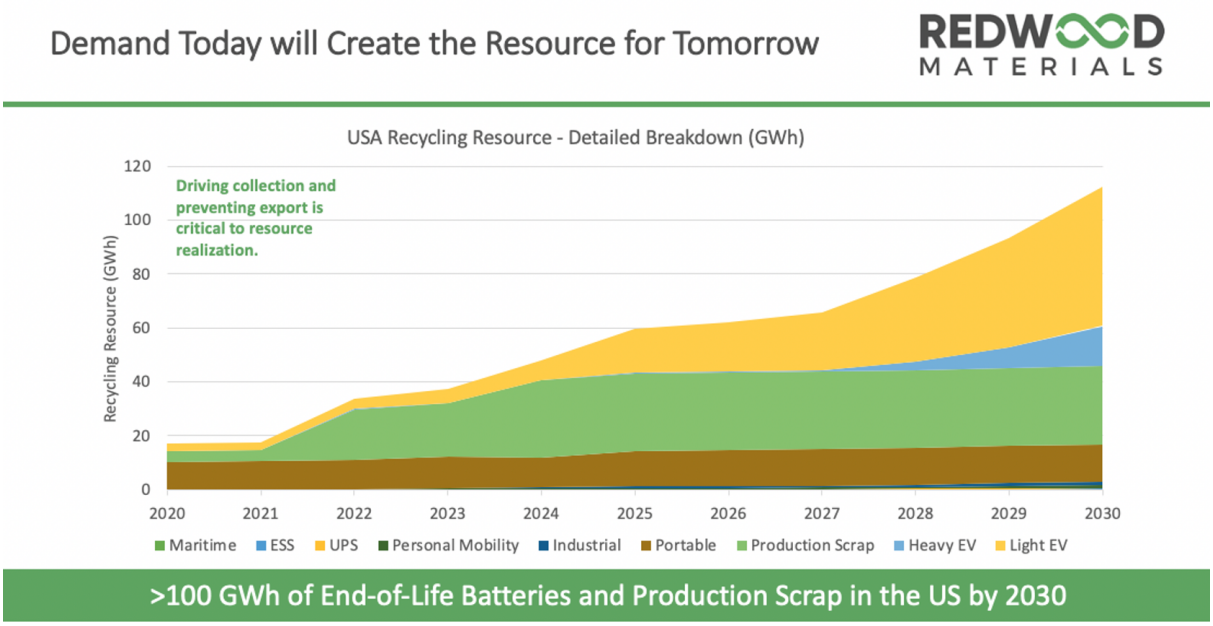


Critical Minerals to Build Critical Materials

Redwood Materials is developing a fully closed-loop, domestic supply chain for lithium-ion battery materials that begins with collecting and recycling end-of-life lithium-ion batteries from consumer devices, electric vehicles, and energy storage systems, then refining the materials we recover, and finally re-manufacture them into battery materials that can go directly to U.S. battery manufacturers.

Today, Redwood is already receiving approximately 6 GWh end-of-life lithium-ion batteries annually, which equates to about 60,000-80,000 electric vehicles or 20,000 metric tons of material every year for recycling. The vast majority of lithium-ion batteries collected and recycled in North America today come through our doors. This material is a combination of production scrap directly from battery cell manufacturers, like Panasonic at the Tesla Gigafactory, and from end-of-life lithium-ion batteries, in the form of both consumer devices (phones, laptops, and electric vehicle packs) and end-of-life batteries available for recycling will skyrocket in coming years as both consumer devices continue to increase and as the first wave of electric vehicles begin to retire from our roads.

Redwood recovers, on average, 95% of the elements from batteries, like nickel, cobalt, lithium and copper, and uses those critical minerals to remanufacture anode and cathode components, domestically, that we can supply back to US battery cell manufacturers without the need for these critical minerals to leave the U.S.



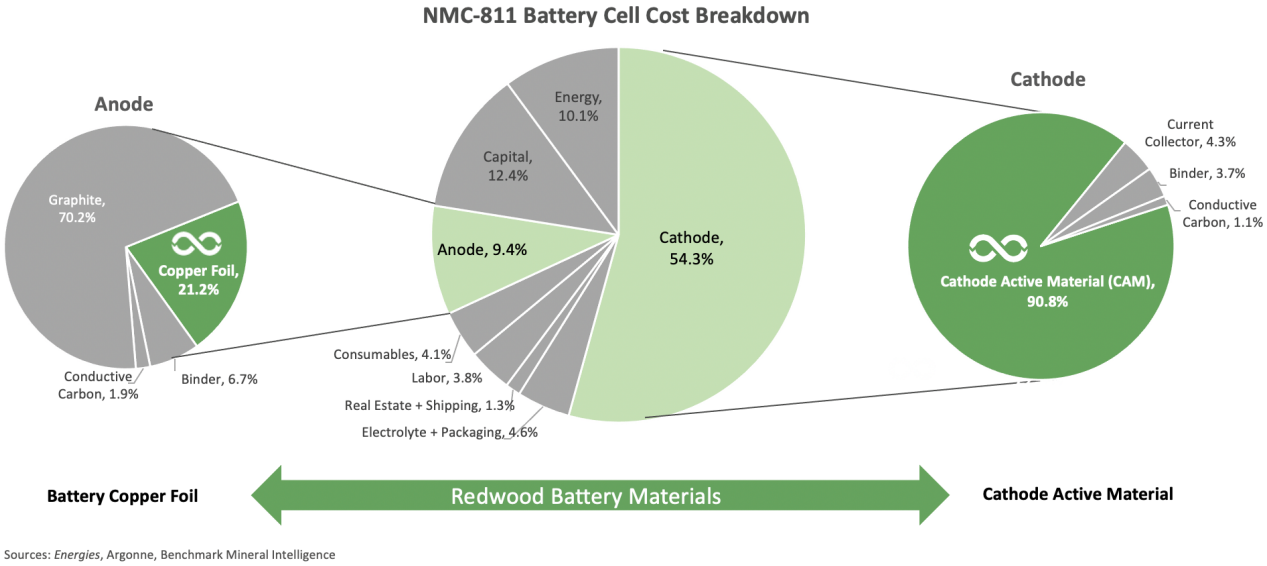
While today the United States accounts for about 10% of global battery cell production, the critical components that build those battery cells are manufactured overseas. The existing supply chains to source these materials from foreign producers are complex, disparate, and extended across multiple continents, with center of gravity in Asia. As a result, existing supply chains are imbued with risk, prone to interruption, slow to incorporate feedback and learnings, and expensive, as each separate transaction adds cost. Battery metals, including nickel, lithium, cobalt and copper, often travel greater than 50,000 nautical miles before reaching a battery cell factory in the United States.

To secure our supply chain and feed our domestic battery factories we need to first increase our sources of critical minerals, through both terrestrial mining and recycling, and then ensure those metals can be remanufactured into components in the US without traveling overseas. If we do not accomplish this goal, we risk supply chain issues similar to what we're experiencing today across the semiconductor industry. Accomplishing this goal would decrease our overreliance on foreign markets, cement the United States as a leader in global lithium-ion battery manufacturing and allow today's battery demand to create the domestic resource for tomorrow.

Cathode active material and copper foil make up nearly 65% of the cost of a battery because of the critical minerals they require. Today, the US does not manufacture these components domestically however Redwood is focused on scaling production of these components this year. Integrated lithium-ion battery recycling and manufacturing of cathode active materials and battery copper foils in the U.S. is critical not only to reduce the costs of lithium-ion batteries but to secure our nations' environmental, sustainability, and geostrategic goals, as well.

Accomplishing this will transform the lithium-ion battery supply chain by offering, for the first time, large-scale sources of domestic cathode active materials and battery copper foils to U.S.-based battery manufacturing partners. Increasing our nation's production of these components will serve as a key enabler to decrease the products' environmental footprint and scale-up U.S. manufacturing of lithium-ion batteries. In turn, this will increase domestic production of electric vehicles and decrease our foreign reliance. Creating a comprehensive component supply chain for EV

manufacturing in the United States will fuel both technology development and the local monetization for domestically developed technologies.



Cathode Active Materials

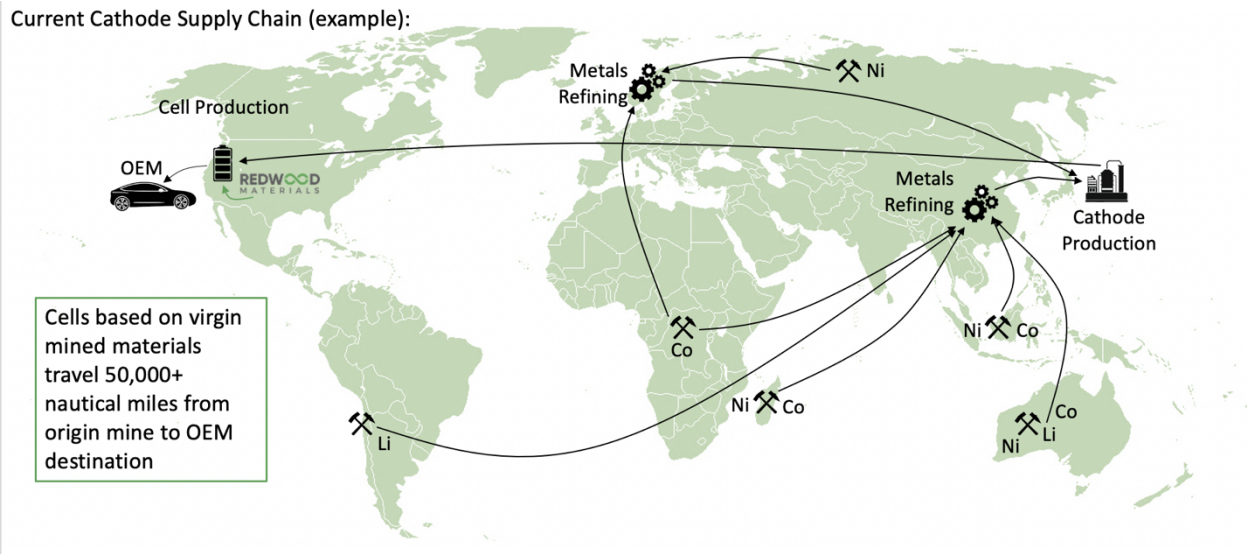
Cathode active material demand growth is following battery demand growth and is expected to increase by 600% over the decade in the United States, from roughly 50,000 MT in 2020 to nearly 450,000 MT by 2030.

Cathode active materials have a long and complex supply chain. The supply chain typically involves mining and refining metal ores on multiple continents, manufacturing cathode precursors, and the final production of cathode active materials. Batteries based on virgin mined materials typically travel over 50,000 nautical miles before reaching battery cell factories in the United States.

Today, finished cathode active material is imported into the U.S. from Asia for local integration into batteries. To keep pace with EV plans domestically, the U.S. would need to import greater than 2,000,000 MT of cathode active material through 2030 with a lost economic value of greater than 85 billion USD.[4]

Further, cathode active materials, which represent more than half the cost of a battery cell, typically contain greater than 30% nickel, 7% cobalt, and 7% lithium. These minerals come from mining today in diverse, and sometimes complex, places. However, there is a tremendous opportunity to recover and recycle these elements, as they are infinitely reusable. This recovered, recycled content, combined with sustainably mined materials and domestic manufacturing of cathode represents an opportunity to significantly decrease the costs of lithium-ion batteries.

[4] Redwood Materials conducted its own internal analysis.



Battery Anode Copper Foil

Lithium-ion battery manufacturing capacity, and the resulting demand for battery anode copper foil, is projected to skyrocket worldwide over the coming decade. The United States is projected to see a 600% increase in battery copper foil demand from 2020 to 2030.[5]

Both the production and mining of copper foil is currently dominated by other countries. Copper raw materials are predominantly mined in Chile, Peru, and China, while production occurs in China, Japan, and South Korea. Together, Chile and Peru control a larger share of this critical market than OPEC+ does of oil. China imports copper concentrate from both Chile and Peru, refining nearly 40% of the global supply.[6]

Finished foils are imported into the U.S. for local integration into batteries. To keep pace with the announced EV plans domestically, the U.S. would need to import greater than 800,000 MT of copper foil through 2030 with a lost economic value of greater than 13 billion USD.[7] To establish secure and robust battery supply chains and manufacturing capabilities capable of meeting our nation's rapidly growing demand, it is imperative that copper foil production within the United States expands.

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[5] *See* Melin, H. E. (2021). Batteries Placed on the Market: Latest Update: 1 August, 2021. London, UK: Circular Energy Storage. Redwood Materials also conducted its own internal analysis.

[6] *See* Els, F., *Copper mining is Opec on crack, so why is the price falling?*, Mining, (July 13, 2021), https://www.mining.com/copper-mining-is-opec-on-crack-why-is-the-price-falling/.

[7] Redwood Materials conducted its own internal analysis.

In addition to enabling technology leadership across the battery supply chain and driving down costs, U.S.-based copper foil manufacturing presents an opportunity for utilizing the greater than 800,000 metric tons of scrap copper that the U.S. exports to Asia every year.

A Domestic Manufacturing Base

Redwood Materials plans to build U.S.-based production facilities for cathode active materials and battery copper foils. By producing critical battery materials domestically at scale, Redwood will help decouple U.S.-based battery production from a shock-prone international supply chain, enabling the growth of reliable, large-scale U.S.-based cell production. In addition, the proximity will enable faster cycles of learning between battery makers and Redwood Materials, resulting in faster and more meaningful technology and cost improvements.

In production facilities based in the United States, Redwood Materials will manufacture around 100 GWh of battery copper foil and cathode active materials by 2025, enough to domestically produce more than one million electric vehicles a year. By 2030, Redwood intends to increase production of both materials to 500 GWh, enough material to supply over 5 million electric vehicles.

By producing battery materials domestically through processes that convert end-of-life batteries into new components, nearly infinitely, Redwood Materials will help drive electrification of the U.S. economy and put our nation on the path towards net-zero emissions through domestic, sustainable manufacturing.

The construction of a domestic supply chain will help capture greater than 100 billion USD of economic value through 2030 that will otherwise be lost if we leave battery materials manufacturing to others abroad.

Panasonic, who is co-located at the Nevada Gigafactory with Tesla, will be among the first U.S. cell manufacturers to source Redwood's copper foil. Our partnership with Panasonic began in 2019 and since, we've been recycling all Panasonic's manufacturing scrap from the Tesla Gigafactory. The same material which we have been collecting and recycling will now be remanufactured into anode copper foil and returned to Panasonic at the Gigafactory. This will mark the first time batteries and production scrap will be recycled, remanufactured and then returned to the same U.S. battery cell factory in a fully closed loop.

A Policy Opportunity

The transition to electric transportation and clean energy is coming. As a nation we must ask ourselves if we want to create the infrastructure and jobs to support that shift here in the United States or allow other nations to develop the manufacturing capacity overseas. Building out domestic lithium-ion battery manufacturing capabilities can position the United States as a competitive international player in the global manufacturing space and help secure our nation's energy independence through increased penetration of renewables, supported by batteries.

The Defense Production Act is a critical step in addressing our upstream critical minerals supply but equally important is ensuring we address the downstream components that these minerals and metals are used to manufacture today. This means we need to implement additional policies immediately to support the efforts of the DPA by helping component manufacturers drastically scale their production in America so that our minerals do not need to leave the country once they're secured.

Reinstituting the 48C tax credit to support clean energy manufacturing would help companies invest in the United States and create thousands of high-quality jobs. This policy would complement the Battery Manufacturing Grant Program created in the bipartisan infrastructure bill, which unleashes an unprecedented federal investment in battery materials processing and manufacturing facilities.

Additionally, as a country, we should support the collection of lithium-ion batteries for recycling and decrease the export of old battery-powered products. We have an incredible opportunity in end-of-life lithium-ion batteries, which already represent some of the largest reserves of lithium and cobalt on earth, to collect and recycle these materials in the U.S., decreasing our need to mine new material.

Whether terrestrially mined material or recycled content, we should create opportunities to onshore cathode and anode manufacturing here in the United States for the first time, limiting the export of critical minerals or recycled intermediates.

Redwood is committed to localizing an end-to-end supply chain in the U.S. and plans to spend several billion dollars over the next few years to do so but we need others committed to onshoring this process as well. In the coming years, companies will need to decide whether to invest billions of dollars to establish manufacturing and technology hubs in the United States or abroad.

Creating a circular supply chain for electric vehicles and clean energy products in the U.S. is a win-win, allowing the country to counteract an important environmental risk, while creating economic security, tens of thousands of jobs, bolstering our supply chain, decreasing our risk and reliance on foreign component manufacturing, and ensuring that the billions of dollars that will be invested in the battery industry happens here in the U.S.

I thank the Committee for holding this important hearing and look forward to the discussion.

JB Straubel
Redwood Materials