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U.S. Challenges in EV Battery Production

BY AMANDA MAYORAL

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Executive Summary

The U.S. is lagging behind China and the European Union in production of lithium-ion batteries for electric vehicles. Forecasts show the U.S. will fall further behind China by 2025 and remain dependent on imports for more than half of its EV battery needs.

This working paper evaluates the U.S.'s ability to produce EV batteries. The analysis is split into three components: how well the U.S. manufactures EV's, how well the U.S. can produce critical minerals, and lastly the paper outlines policies to stimulate U.S. efforts in these critical areas. Overall, while some U.S. companies have made large strides in EV production, a more concerted effort by the U.S. government and private companies is needed to meet the growing demand for EV's, and maintain the U.S. position as a leader in EV production with a large domestic industry. Other countries have already adopted such strategies and are relatively more prepared.

Key Points

- The U.S. is lagging in the production of lithium-ion batteries, the most important single component of an electric vehicle (EV). China is the world leader, with 12 times the battery production of the U.S. last year.
- According to CPA analysis, by 2025 both China and Europe will continue to be ahead of the U.S. in production of EV batteries. Of the world's three major advanced economic regions, the U.S. is in third place, and likely to remain there. China will continue to hold its leadership position, and likely account for 56% of global battery production in 2025.
- The U.S. government must develop a strategy to stimulate investment in battery production with the aim of the U.S. achieving the capacity to produce the majority of our battery needs within five to ten years. Without such a strategy, the U.S. risks losing control over its EV automotive industry.
- Several U.S. companies have ambitious production plans in batteries. However, these focus primarily on assembly of batteries, and ignore the more complex and technologically important challenge of designing and producing battery components.
- The relatively poor position of the U.S. industry is due to fragmented U.S. supply chains, under-investment in advanced battery technology and a lack of U.S. government industrial policies to promote R&D and manufacturing in the industry.
- The U.S. has limited access to the critical minerals used in battery components. It needs to gain access through a combination of new mining investments in the U.S. and partnerships with friendly nations that have mineral deposits we lack.
- Tesla's model of vertical integration has delivered technological innovation and a market-leading position in EVs in the U.S. and overseas markets. It could serve as a model for other, larger automakers.

1. The Issue: The U.S. is not well-positioned to be a major player in the future EV battery market

U.S. battery independence is critical for the future U.S. economy. The growing demand for electrification in transportation cannot presently be met by U.S. suppliers. While the U.S. is investing to build a sizeable capacity to assemble batteries for electric vehicles (EVs), the U.S. is relatively weak in the more technologically sophisticated process of building battery components. It is also weak in mining of some key materials that go into battery manufacturing. Myopic decisions on the part of U.S. firms and policy makers have left the U.S. behind its European and Asian counterparts. China is relatively new to the global battery industry but investments by the Chinese government in the past decade have made China the producer of most global supply.

With the global shift away from fossil fuels, the demand for electric or hybrid vehicles using electric batteries is growing rapidly. By some estimates, the demand for electric and hybrid vehicles will surpass that of standard motors by 2030 (UltimaMedia & ABB, 2021).

For the U.S., CPA estimates that U.S. production will increase to around 320 Gigawatt hours (GWh) in 2025, up from 44 GWh in 2020. A back of the envelope calculation shows that the level of battery output is barely enough to cover rising demand. For instance, if electric vehicle sales reach 6.9 million units by 2025, and assuming that each EV battery contains power of 100 kilowatt hours (kWh), then the U.S. would need at least 690 GWh to meet its EV needs (Holman, 2020). Under this scenario, the demand for EV batteries is more than double the anticipated domestic supply.

In terms of material inputs, the U.S. is highly dependent on mineral imports. Easing mining restrictions would help. However, the U.S. does not have enough reserves to fully meet its own demand. The U.S. should invest in technologies that use its relatively abundant resources but also seek strategic trade relationships that support U.S. leadership in batteries and vehicles.

The U.S. produces less than European and Asian countries, despite its large and growing demand

As the world shifts from internal combustion engines to EVs, the U.S. risks losing its share in the U.S. and global EV market to foreign imports, especially from China. While American companies such as Ford and GM have produced a few electric models, the batteries used so far are far less efficient, provide consumers with fewer miles per gigawatt, and ultimately use more energy.

Global production of batteries reached 747 GWh in 2020. Global demand for electric vehicles is expected to drive up this figure to 2,492 GWh by 2025 (FCAB, 2021). Table 1 shows the current and predicted level of battery production capacity for select countries between 2021 and 2025. Significant investment by the Chinese government over the past decade enabled China to lead the world in battery production with a 79% share in 2021. U.S. capacity should increase from 44 GWh in 2021 to 320 GWh in 2025, reflecting a 627% increase. But even with this rapid rate of growth, the U.S. would end up with 19% of global capacity, behind the EU with 22%, and China with 56%.

Table 1: Battery Production in Gigawatt Hours (GWh) by Country, 2021 -2025

	GWh 2021	GWh 2025	% Change	% Global 2021	% Global 2025
China	558	944	69%	79%	56%
EU Region	68	368	441%	10%	22%
U.S.	44	320*	627%	6%	19%
South Korea	18	18	0%	3%	1%
Japan	17	17	0%	2%	1%
Australia	1	7	600%	0%	0%
Thailand	1	2	100%	0%	0%
TOTAL	706	1676	137%	100%	100%

Source: S&P Global Market Intelligence, 2021, Company reports, *CPA estimates.

Europe will likely have greater battery production capacity than the U.S. in 2025. This is driven largely by local content requirements by European governments which are forcing auto companies to source batteries within Europe. Since the U.S. produced 26% of the world's cars in 2021 (OICA), a forecast of battery production of just 19% of the world's total in 2025 highlights the huge risk that U.S. share of global auto production will fall as we move to EVs.

The U.S. is facing dramatic growth in the demand for EV's. Yet despite this opportunity, battery production in the U.S. will be less than half what it needs to be, if it achieves the aggressive targets the industry has set for itself. By our estimates, the U.S. will also fall further behind production levels in China and the EU region. In this article, we look at the U.S. position in battery development, production and material sourcing.

Weak Start in Lithium-Ion Battery Production

Tesla has been a technological and production leader in lithium-ion batteries. In contrast, the rest of the U.S. auto industry depends heavily on foreign owned battery technology. The U.S. lithium-ion battery industry is primarily engaged in the downstream part of the battery production process, final assembly of batteries. Batteries are costly to ship, pushing Asian battery firms to ship battery cells and do final assembly in the U.S. While this sounds good for American workers, it contributes relatively little value in the overall battery manufacturing process. Competitive advantage in producing batteries would include the technical design, intellectual property and process expertise in battery component manufacturing as well as the assembly. The U.S. needs to lead and innovate throughout the battery design and manufacturing process to create real wealth and give U.S.-produced batteries and EVs an enduring competitive advantage and strategic autonomy.

Another reason foreign auto manufacturers have increased their production in the U.S. is the revised rules of origin under the U.S.-Mexico-Canada trade Agreement (USMCA). The USMCA rules replace the NAFTA rules while raising the requirements for tariff-free entry of EVs into the U.S. market. Specifically, the share of core parts of a vehicle that must be produced within the three USMCA members increases from 60% to up to 75% (U.S. Congressional Research Service, 2021). Considering that batteries tend to comprise about 40% of the total costs of an EV, all auto manufacturers are now incentivized to manufacture batteries in the U.S., Mexico, or Canada (Rogers, 2022).

The largest battery producers in the U.S. market include BYD Co. Ltd (Chinese), Panasonic (Japanese), Contemporary Amperex Technology Co. (Chinese), LG Chem Ltd (Korean), Samsung SDI (Korean), and Tesla (U.S.) (Mordor Intelligence, 2022). Many global auto manufacturers are partnering with Asian battery specialists for their EV batteries.

Battery producers are competing to produce batteries with the longest battery range, maximizing the miles traveled per kilowatt for an EV. They also compete to produce batteries with the lowest cost per GWh. Tesla is leading the industry, recently announcing vehicles that can reach up to 600 miles on a single charge (Weise, 2022). Tesla has also said that its new battery factory in Texas will have an annual capacity of 100 GWh.

The major automakers' supply-chain for production is largely based on third-party sourcing, especially partnerships with battery producers, most of them Asian-owned. South Korea's LG Chem is building several new plants including one in partnership with General Motors in Lordstown Ohio. LG has three more battery factories planned with General Motors, one recently announced in Michigan with an investment of \$1.7 billion (Achtenberg, 2022).

Ford Motor Company has engaged in a 50/50 venture with SK Innovation. This partnership is investing \$11.4 billion to build a major EV manufacturing corridor in Tennessee and Kentucky. Ford and SK Innovation plan to produce an additional 129 GWh and an estimated 11,000 new jobs could be created by these facilities by 2025 (Kane, 2021).

Germany's Mercedes-Benz has announced ambitious plans to move to a 100% EV model lineup in the U.S. by 2030. To support this, Mercedes has made several investments to build up its capacity in Alabama, primarily in Tuscaloosa. The newest edition by Mercedes is an EV plant in Bibb County Alabama. In total, Mercedes has invested over \$7 billion to build its supply chain in Alabama. The Mercedes operation in Alabama is so large that current plans project the plant will export roughly 2/3 of its production (Thornton, 2022)

Toyota became the top selling auto manufacturer in the U.S, surpassing GM, the first time GM lost the top slot since 1931. Toyota's ambitions for the EV market are equally ambitious, as they recently announced a goal to raise EVs to 70% of their U.S. sales by 2030. To reach this goal, Toyota plans to invest \$3.4 billion in its U.S. operations over the next 10 years. (Toyota, 2021 (a)). Toyota has since then announced plans to open a new battery factory in North Carolina, costing \$1.3 billion and creating 1,750 jobs (Toyota, 2021 (b)).

2. Battery Technology

Today's lithium-ion batteries include four major inputs or components: cathodes, anodes, separators, and electrolytes. Table 2 shows the relative cost of battery components and the materials used to produce them. Cathodes are the most expensive component for manufacturing batteries.

Table 2 also shows that today the U.S. has small production capabilities for battery components. The cost of a battery is dominated by the cathode, where the U.S. produces no significant quantities. This is a critical issue, because the ability to produce these components drives the value created in battery production, the power to drive the future technological path of the product, and the flexibility to increase production in response to changes in demand.

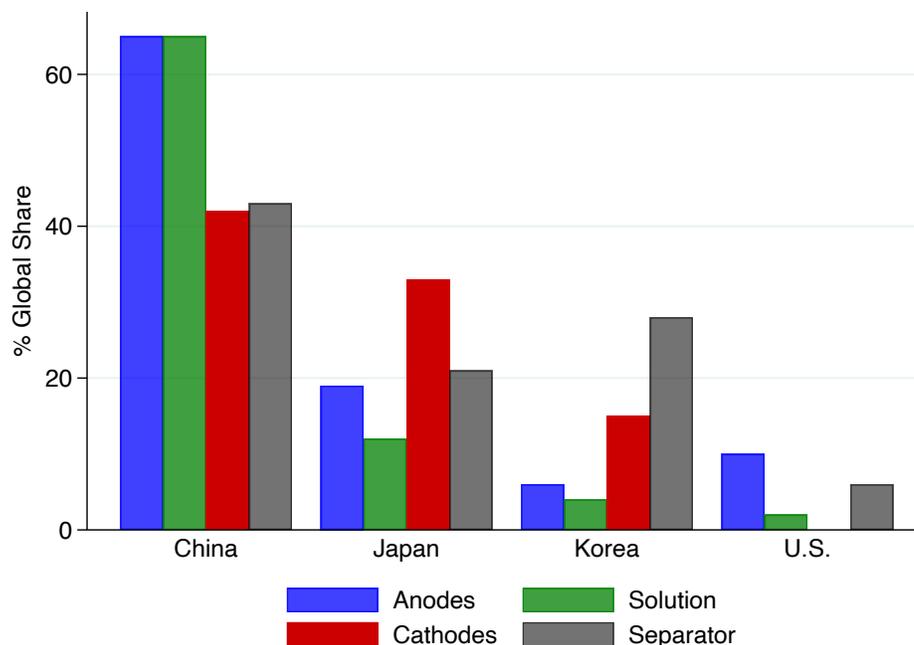
Table 2: Battery Manufacturing Components and U.S. Capacity Share

Battery Component	Share of Battery Cost	Elements Used	U.S. Mfg Capacity Share
Cathode	51%	Lithium, Nickel, Cobalt Manganese, and others	0%
Anode	12%	Graphite and Lithium	10%
Separators	7%	Copper and Aluminum	6%
Electrolyte Solution	4%	Lithium, Fluorine and Phosphorus	2%

Sources: Cost: (Bhutada, 2022), Materials: (The White House, 2021), Capacity: Federal Consortium for Advanced Batteries, June 2021

Figure 1 shows the global share for battery component production by country. The U.S. is far behind the levels produced by China, Japan, and Korea. Figure 1 shows that China dominates the industry for every key component.

Figure 1: Battery Manufacturing Capacity, Global Share by Country and Component



The battery market is at an early stage. It is very possible that lithium-ion battery technology will be replaced by a different technology. In China, Tesla is manufacturing lithium-iron-phosphate (LFP) batteries, which are safer and potentially less costly than traditional lithium-ion because they eliminate the need for expensive minerals nickel and cobalt. GM and a startup called QuantumScape are developing lithium metal batteries, which could deliver more charge per pound of weight. Other startups and research groups are experimenting with other technologies. With billions of dollars of investment capital going into the high-stakes EV battery market, it is fairly likely that battery technology will look very different in ten years' time. In one sense, this favors the U.S., because the U.S. has a tradition of investing in long-shot technologies. China rarely develops disruptive technologies. However, even if a U.S. firm develops a breakthrough battery technology, there is no guarantee the production will take place in the U.S.

In summary, U.S. carmakers are gaining publicity for opening billion-dollar battery plants in the U.S. However, most of these plants are limited to battery assembly with little investment in building the components that drive the value and the future technological direction of the batteries. Tesla stands out as the exception: a true innovator that drives its own technological innovation. But Tesla is still a small player in a 60 million vehicles a year global auto industry. The U.S. is a long way from securing its historic share in battery production, let alone a position as a global leader.

Tesla: Leading the U.S. Industry

Elon Musk's implementation of a vertically-integrated model for an electric vehicle producer has enabled Tesla to dominate the production and technology of EV's. This fact is apparent with Tesla the only U.S. auto manufacturer to show sustained growth in recent years.

Tesla provides an example of how the U.S. can beat the Chinese in the ongoing US-China trade and technology war. Leading the industry in advanced battery technology and producing vertically within the domestic market has allowed Tesla to streamline production and gain a substantial technological advantage.

The traditional U.S. automakers have moved away from integration and towards purchasing parts and components, a growing share of them imported, from separate companies. In contrast, Tesla's U.S. production model is highly vertical and U.S.-centric, producing nearly all major components in house.

With a vertical supply chain in each of the three major markets (North America, Asia/China and Europe), Tesla can reduce supply chain risks, increase production efficiency, and reduce transportation costs. CEO Elon Musk indicated his plan to continue this business model and have a Tesla manufacturing plant on each continent (Musk, 2020). Attracted by the strong demand for EV's in China, Tesla has become the only major U.S. company to have a fully owned factory in China, in Shanghai. In spite of China's core industrial policy practice of forcing foreign companies to operate through joint ventures in China, the Chinese Communist Party allowed Tesla to own 100% of its Shanghai plant. Tesla's strategic advantage is its unique technology edge.

While an industry leader, Tesla cannot alone meet all future U.S. demand, which is expected to exceed 300 GWh by 2025. To address a broader market, Tesla is focused on improving the cost and performance of its batteries. It has said it plans to sell an electric vehicle for \$25,000.

A newer startup, Lucid Motors, is copying the Tesla model. Headquartered in California and founded by former Tesla executives, Lucid is targeting the six-figure luxury EV market. It manufactures its own batteries and motors and is aiming to sell 12,000 vehicles this year.

The Tesla emphasis on vertical integration harks back to the roots of the U.S. auto industry. In his most successful years, Henry Ford acquired coal mines to make steel for his cars, a glassworks, and acres of forest for the wood needed in the Model T. Ford wanted absolute control over his entire production process. Later, General Motors seized leadership from Ford in part because of its technological breakthroughs in electric starter motors (1915) and the automatic transmission (1940).

EV production in the U.S. is constrained by the limited availability of battery raw materials, even for Tesla. To help meet EV demand in the U.S., Tesla is working with mining companies Rio Tinto and Talon Metals to open the Tamarack Mine in Minnesota (Brigham, 2022). The opening of a new nickel mine is helpful but will not be enough to meet the U.S. demand. Last year, Elon Musk indicated his plans to largely switch battery materials towards LFP batteries which replace expensive minerals like nickel with cheap, common iron. The core LFP technology is owned by a consortium of Canadian and French research institutes. So far, no U.S. company has announced plans to use this technology in mass-market batteries in the U.S. Private company Lithion has licensed the technology, but its plans remain confidential.

3. Lack of U.S. Supply of Critical Minerals

Elements used to produce lithium-ion batteries include nickel, lithium, manganese and cobalt. These elements are not easily accessible to US producers due to both limited physical resources and highly restrictive mining policies. As a result, the U.S. is highly dependent on imports.

Mining and refining of these metals are concentrated in a few countries. The U.S. has a small share of world reserves, only 4% of lithium, less than 1% of cobalt and nickel (The White House, 2021 & FCAB, 2021).

To understand the magnitude of these shortages, consider an estimate by the White House on the resources necessary to build an all-electric federal fleet by 2035 (Edelstein, 2021). For this estimate, consider that there are roughly 645,000 vehicles operated by the federal government (Kaplan, 2021). The estimates below only factor the needs of producing cathodes, which is one part of the battery cell. Table 3 shows that, except for lithium, the volume of metric tons (tonnes) needed to produce all key elements far exceeds U.S. reserves.

Table 3: Demand and Supply of EV Elements to Produce Cathodes for Federal Fleet (tonnes)

Cathode Element*	Amount Needed to Meet EV Demand	Global Reserves	U.S. Reserves
Nickel	1,272,650	89,000,000	110,000
Lithium	188,700	17,000,000	630,000
Cobalt	159,800	7,000,000	55,000
Manganese	148,300	810,000,000	-

Source: (The White House, 2021)

*Reported in Tonnes

The largest producers of lithium globally have been Australia (60%), China (9%), and South American countries such as Chile (19%) and Argentina (7%) (The White House, 2021 & UN Comtrade, 2022).

For the U.S., mining restrictions and red tape are an added challenge. The U.S. only has one lithium producing mine in Clayton Valley, Nevada. While this mine produces over 5 tonnes per year, the U.S. still imports the majority of lithium it uses. The situation could improve. Last year a potentially large lithium mine was discovered in Maine. However, to protect Maine's natural resources, the state has put in place strict mining regulations that could clash with a large mine. Currently, there are no active mining operations in Maine (Cough, 2021).

Manganese is another important element in batteries. However, many countries including the U.S. do not allow for the intensive mining of manganese, due to environmental concerns. The world's largest exporter of manganese is China (UN Comtrade, 2022).

Lithium-ion batteries will likely consume more than 90% of the world's nickel supply by 2030 (The White House, 2021). The conflict in Ukraine has caused a surge in global nickel prices as Russia and China are among the world's largest miners/refiners. The U.S. only has one operating nickel mine in Michigan called the Eagle Mine, and it will close by 2025. Tesla has partnerships with mining companies to address the problem with investment in new mines.

4. Policy Recommendations:

Critical Minerals

Heavy regulations that limit production of critical minerals is a major impediment to U.S. production of batteries. The U.S. should ease mining restrictions to enable more mines to be built, while at the same time maintaining reasonable environmental standards to prevent contamination of U.S. land, air, and water. Alternative methods of extraction are necessary as well, American companies like The Metals Company have developed cleaner extraction methods by harvesting critical minerals from the ocean. But even if this is done, the U.S. will need to import materials from abroad for years to come. The U.S. should offer preferable terms for businesses in allied and reliable countries to gain reliable access to critical minerals. This might include South American countries such as Chile and Argentina, as well as Australia.

At the tail end of the battery supply chain is the critical process of advanced battery recycling. Recycling and reusing battery materials can help alleviate the critical mineral constraints facing the U.S. The challenge of advanced battery recycling is the potential for toxic fumes and exposure to landfill waste that accompanies the extraction of critical minerals. There are a few U.S. companies that have developed sustainable recycling programs with minimal waste, such as American Manganese. The U.S. government should promote policies to help invest in these clean recycling processes and innovations in American firms.

Policy Recommendations: Battery Manufacturing

China has made long-term investments in the battery industry in anticipation of growing demand. Industrial policies adopted by China include subsidies for more than 50% of the cost of batteries for Chinese firms. Another important industrial policy was the limitation of foreign competition in the Chinese market. The Chinese government has banned all foreign suppliers by issuing a list of companies allowed to sell to its domestic market (U.S. Chamber of Commerce, 2017).

Import controls may be necessary. It may be sensible to phase them in, so carmakers can import batteries in the interim, while they build battery manufacturing facilities. Incentives like rising import controls can provide long-term guidelines that encourage the private sector to begin investing today in battery production, with a required goal of supplying a large majority of U.S. needs in 5-10 years. Import controls could take the form of tariffs, quotas, or local content requirements. It is notable that China has used all three tools. Europe has primarily used local content requirements and already exceeds U.S. production.

Biden Administration: Highlighting the Right Issues But Must Move More Aggressively

According to the Biden White House, the lack of longer-term investments particularly in sustainable technologies such as the battery industry reflects a larger systemic failure of incentives among several industries (The White House, 2021). The incentives for investment in the battery industry only extends over a short period of time. U.S. corporate and financial investors will often avoid longer-term investments beyond 5 years. But other countries such as China have planned and implemented long-term investments over more than two decades, and they are paying off. There is a role for the government to incentivize the private sector to make longer-term investments where the market cannot.

The White House argues that insufficient U.S. manufacturing capacity is the number one driver of supply chain vulnerability and a key challenge to producing advanced batteries on a large-scale. The Biden Administration has focused on becoming carbon neutral by 2035. In line with this, the Biden Administration released a 100-day review of the U.S. supply chain which outlined a few key critical industries, at the top of the list was advanced battery technology and production:

“Maintaining America’s innovative and manufacturing edge in the automotive sector and other key industrial sectors will require the United States to undertake a concerted effort to shore-up sustainable critical material supply and processing capacity, expand domestic battery production, and support EV and storage adoption”

(The White House, 2021, pg. 9)

The White House also argued that industrial policies by China are a major driver of supply chain vulnerability. Chinese practices go far beyond the acceptable limits of trade practices, including heavily subsidized state-owned enterprises, and strict controls on imports and foreign ownership.

The U.S. government is ramping up its investment in the battery industry. For instance, the U.S. Department of Energy recently announced it will provide \$200 million in funding to help stimulate research and production for electric vehicles and batteries (U.S. DOE, 2021). Further, the Biden administration plans to invest \$2.91 billion to strengthen the U.S. advanced battery supply chain. Funding from the Bipartisan Infrastructure Law will be used to build facilities to both recycle and manufacture batteries (U.S. DOE, 2022).

These efforts are steps in the right direction, but more is needed. In particular, the U.S. government should outline a strategy to stimulate investment in battery production with the aim of achieving the capacity to produce the majority of our battery needs within five to ten years. To assist in this process, the U.S. government should make investments in battery manufacturing, through tax credits or another mechanism, to catapult the U.S. into a leadership position in this industry. The incentives should apply to both battery assembly and component manufacturing.

Conclusion

The U.S. is far behind China in lithium-ion battery production and the gap is widening. The U.S. needs to take aggressive action as soon as possible to stimulate mining of critical battery materials and production of batteries including the components as well as assembly. A large share of the U.S. economy is dedicated to the automotive industry, including some of the best-paid manufacturing jobs. The U.S. has a critical interest in ensuring we maintain a large, leadership position in this vital industry.

The Biden administration has begun to make significant efforts to build the advanced battery industry, but little has been done on the trade side to allow U.S. firms the space to fully develop. The U.S. government allows foreign firms to flood the battery and EV market before U.S. firms like GM or Ford have fully developed their own technologies and processes. These practices are often prohibited in other countries, especially China.

In the absence of our own expertise, the U.S. automakers are relying on joint ventures with mostly foreign companies to manufacture batteries. While this strategy will provide some U.S. manufacturing jobs, it will continue to shift production capacity, supply, innovation, and overall reliance towards foreign technology owners rather than domestic firms. Indeed, the pattern of U.S. industry over the past few decades has been to offshore and divest in the U.S. manufacturing process. This has left U.S. firms and consumers vulnerable to foreign supply chain issues and reduced real wealth and capacity in the U.S. The emerging EV battery industry offers an opportunity for real economic growth for U.S. companies and workers. Domestic manufacturing with a strong domestic supply chain should be the focus of U.S. government policies.

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