A DP WORLD REPORT WITH CANARY CREATIVE

Navigating the Opportunities and Challenges of an Electric Vehicle–Centric Manufacturing Supply Chain

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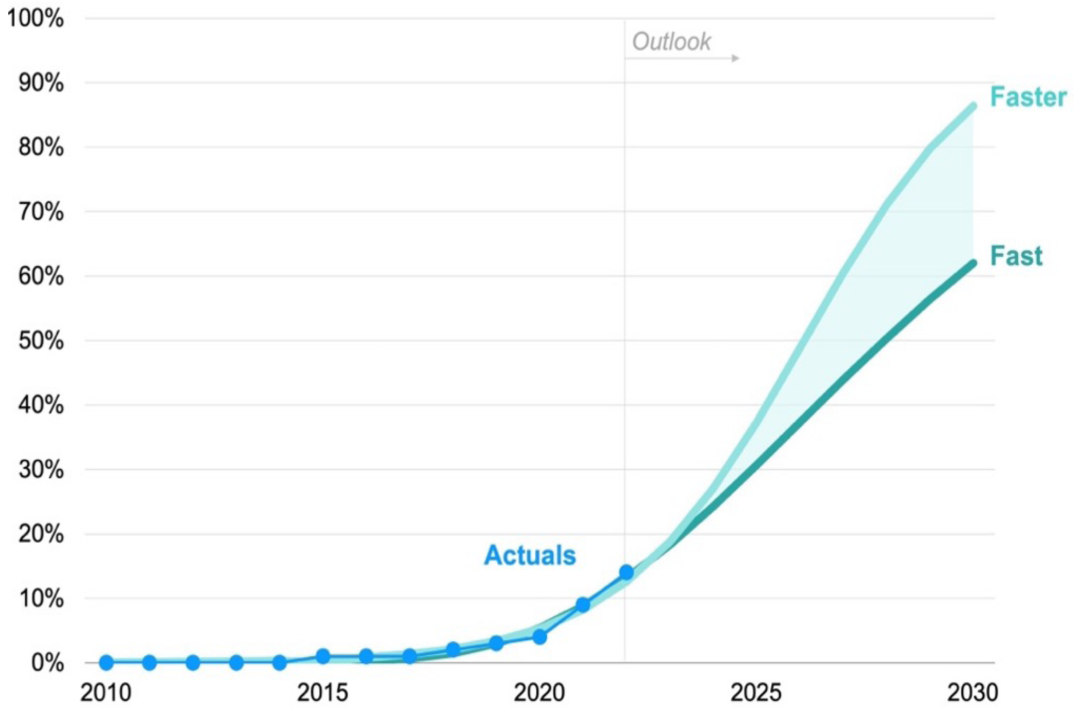
INTRODUCTION

Electric vehicle sales have been on a dramatic upswing over the past few years. In the U.S., the first three quarters of 2023 saw **record sales** for EVs, according to Kelley Blue Book, and the country is on track to exceed 1 million annual EV sales for the first time ever.

A recent **report** by think tank RMI forecasts a rapid acceleration of EV adoption both in the U.S. and around the globe. While it took six years for EVs to move from 1 percent to 10 percent of new vehicle sales, RMI predicts that the next six years will see that share increase to 80 percent of the total global new-vehicle market.



Source: IEA (past data); RMI forecasts

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Because of this rising demand, a reshaping of the global and U.S. manufacturing supply chain is underway. As of mid-November 2023, 77 projects totaling $80 billion in investment had been publicly announced since the passage of the Inflation Reduction Act, according to a tracking project at **Wellesley College**. Project announcements ranged from the mining of minerals and elements, including nickel, graphite, and lithium, to the production of battery cells, battery packs, and finished EVs.

This paper will unpack some of the most consequential shifts that are occurring for U.S. manufacturers across the emerging EV supply chain, including:

- The battery supply chain
- From the factory floor to the customer door
- The role of parts and services with low-maintenance EVs
- The circular-economy potential of EVs

BATTERY-FIRST CONSIDERATIONS

Understanding the supply-chain changes driven by the mass production of EVs begins by grasping the component differences between EVs and their internal combustion engine (ICE) counterparts.

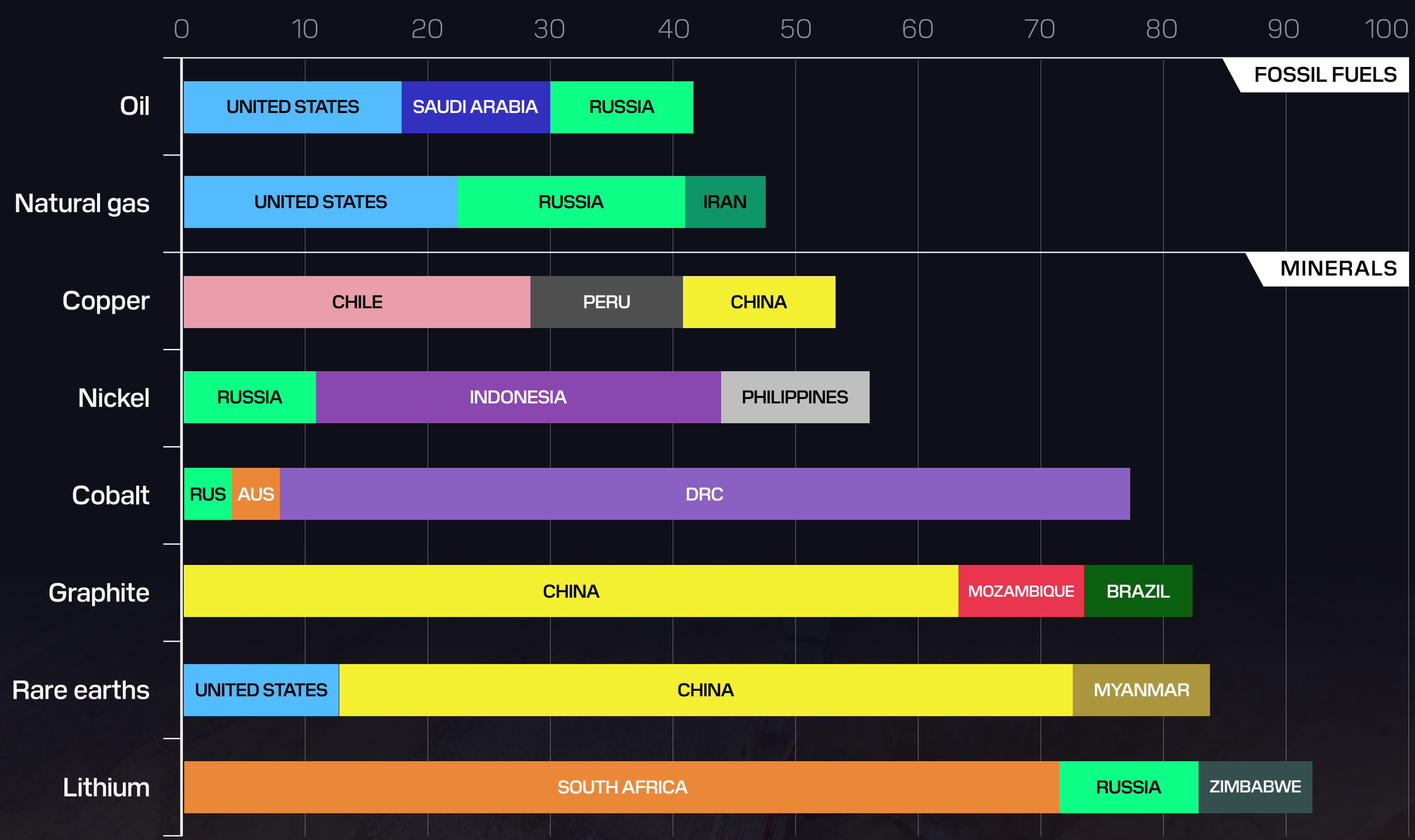
The critical difference: ICE vehicle drivetrains have about 200 moving parts — including the engine, transmission, clutch, driveshaft, and axles — compared to **just 20** in an EV.

EV supply chains are mainly configured around batteries, the **costliest component** in the vehicle. Although the price of lithium-ion battery packs rose for the first time in 2022, Bloomberg New Energy Finance **forecasts** that prices will drop from an average of $151 per kilowatt-hour to under $100 per kilowatt-hour by 2026. Falling battery prices are particularly important in the U.S. market, where the average battery size is about **40 percent larger** than the rest of the world due to the popularity of roomier electric SUVs.

These dynamics — fewer components in EVs compared to ICE vehicles and the higher prevalence of large batteries in the U.S. market — have important supply-chain implications. The typical EV requires **six times** more mineral inputs than an ICE vehicle, according to the IEA. The ability to manufacture large numbers of the big EV batteries that American drivers demand depends on reliable access to **critical minerals** and materials such as lithium, cobalt, manganese, nickel, and graphite.

CURRENT PRODUCTION OF MANY ENERGY TRANSITION MINERALS IS MORE GEOGRAPHICALLY CONCENTRATED THAN THAT OF OIL OR NATURAL GAS

Share of top three producing countries in total production for selected minerals and fossil fuels, 2019



Source: IEA (2020b); USGS (2021).

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There are also supply-chain uncertainties around obtaining the critical materials used in the cathodes and anodes that go into battery cells that are then assembled into the modules and battery packs inserted into **finished EVs**. Various automakers, including **Ford**, **Stellantis**, and **BMW**, have forged joint ventures and partnerships with battery-makers to supply batteries for their EVs in an effort to alleviate some of those uncertainties.

Those partnerships, however, don't fully assure sustainable access to the critical minerals that go into lithium-ion batteries because their extraction and processing are concentrated in relatively **few countries**, primarily China. Elevated tension in U.S.-China relations introduces geopolitical risks that could threaten reliable supplies of critical minerals. Removing as much of that risk as possible — while also driving economic and employment benefits domestically — was a significant driver for the EV incentives included in the IRA.

The centrality of batteries introduces other nuances to EV supply chains. EV batteries are extremely heavy, **averaging about 1,000 pounds**, with some of the longest-range batteries tipping the scales at around 2,000 pounds. The heavy weight of batteries, especially those for electric SUVs, has also led EV manufacturers to **prioritize proximity** between where battery packs are produced and EV assembly lines.

FACTORY FLOOR TO CUSTOMER DOOR

The EV transition raises other questions for established car manufacturers that are modifying existing factories to produce EVs.

In the late summer of 2023, the U.S. Department of Energy **announced** loans and grants totaling around $15.5 billion, focused primarily on retrofitting existing ICE vehicle factories to produce EVs and to expand domestic battery manufacturing.

Heavy batteries require the factories dedicated to manufacturing finished EVs to incorporate **expensive equipment** able to move battery modules and packs around the plant and to have a conveyor system able to handle the heavy weight of a completed EV. When plants are producing a variety of EVs, a traditional assembly line is replaced by an automated factory vehicle that transports car bodies to individual workstations set up to produce a specific vehicle model.

Other factory and supplier changes reflect the different components that go into EVs compared to ICE vehicles. For example, EVs have power electronics like DC-DC and DC-AC converters and controllers that aren't used in ICE vehicles. As a result, plants need to have quality-control systems in place to evaluate electronics and the capability to coil, seal, and integrate wires into EVs. EVs also accentuate the need for precision sequencing because the chassis assembly and electrical systems are both more complex and more interconnected than in ICE vehicles.

Makers of ICE vehicle components require casting and machining equipment and expertise to produce the rods, cylinders, and camshafts that go into

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gas-powered cars and trucks. EVs, by contrast, need components for much simpler electric motors, such as rotor hubs, magnets, and bearings, all of which can be produced with less complex machining equipment.

Unlike ICE vehicle factories, EV plants don't need the infrastructure and equipment to incorporate exhaust and fuel systems. And because most EVs are single-speed, the components and systems required to install multi-gear transmission systems in ICE vehicles are also unnecessary.

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From the point of view of focusing purely on logistics, the fact that EVs require significantly fewer components is driving the transition from sequenced just-in-time manufacturing to bulk-metered, just-in-time deliveries; this means moving from providing individual components as needed to delivering larger batches of components.

Battery weight and safety concerns also impact EV supply-chain logistics. Battery packs must be stored in warehouses outfitted with temperature and humidity controls and fire-suppression systems to protect against fire danger. Those climate-controlled warehouses will increase investment and operating costs. Companies assembling battery packs can also reduce fire risk through just-in-time delivery of battery modules, which is already standard with ICE vehicle parts.

Beyond fire safety, batteries also introduce the complication of more expansive space needs. They usually are not stored in racking, so they take up more floor space. This results in the need for warehouses with more extensive square footage and does not fully utilize the typical ceiling heights in Class A warehouses that are often used for ICE vehicles.

The process of shipping completed EVs to dealer lots or individual consumers is also evolving to address battery-fire concerns. In some cases, batteries and EVs are shipped **separately**, which necessitates expanding the capacity and utilization of ports. Safety can also be improved by ensuring that EVs with batteries included are charged between **20 percent and 50 percent of capacity**. This is enough to reduce fire risks while still providing enough power to move vehicles on and off cargo ships.

The maritime classification organization American Bureau of Shipping also outlines **best practices** for transporting EVs on cargo ships, including stowing EVs in a designated area, charging with only ship-owned cables and connectors using sockets specified for EV charging, implementing video monitoring and crew patrols to detect any fire hazards, and training crew to effectively respond to the unique dangers of EV fires, including the possible release of toxic gas.

Vehicles transporting EVs, including both ships and trucks, must consider the weight of batteries and adhere closely to weight limits; in some instances, this may demand changes to current packing and loading procedures. Furthermore, many EVs will never reach a dealership, thanks to the availability of EVs that can be delivered directly to drivers. Direct-order EVs are driving a need for specialized packaging and transportation, including protecting sensitive electronics, ensuring vehicles are adequately charged when they arrive at an owner's home, and developing comprehensive user guides and materials to help drivers get oriented to EV ownership. Especially for EVs with lower production volumes than many traditional ICE vehicles, shipping cars in containers may be an attractive option.

BEYOND THE FACTORY FLOOR

For many drivers, one of the appeals of EVs is that fewer moving parts translate into lower maintenance costs.

For many drivers, one of the appeals of EVs is that fewer moving parts translate into lower maintenance costs. But that doesn't mean parts and maintenance — and the logistics and supply chains that support them — will disappear entirely. For example, the heavier weight of EV batteries increases tire wear by **about 20 percent**, which means EV drivers have to replace tires more frequently.

EV batteries also need to be replaced, albeit infrequently. Battery pack **warranties** extend at least eight years, or 100,000 miles (**California** and other states mandate even longer warranties). While many battery packs can last as long as **20 years and 200,000 miles**, typical performance degradation means drivers could eventually have to foot the bill for a replacement battery, which can cost from **$5,000 to more than $20,000**.

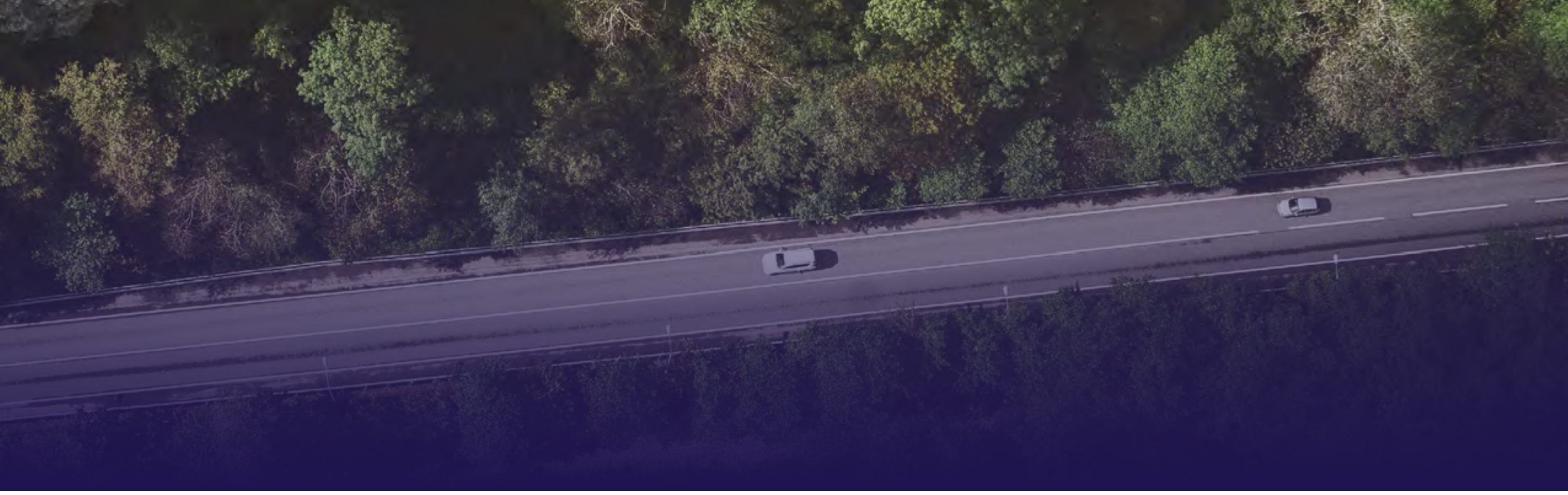
While significant investments will be needed to equip repair shops to service EVs, one **report** by the Auto Care Association and MEMA Aftermarket Suppliers estimated the potential of nearly 20 percent annual growth in EV maintenance and repairs.

Some light refurbishment and repair of EVs could even be handled by logistics companies, which would be similar to work some companies already do for consumer-electronics customers. However, an even more robust EV supply-chain rethink may be required to address critical mineral risks.

The EV transition will likely take a circular-economy approach that assures that reusable minerals are repurposed for a second life in new EV batteries (or stationary storage systems). The **IRA** encourages this approach by allowing battery materials recycled in the U.S. to qualify for domestic-content incentives, regardless of their origin.

Besides bolstering reliable access to critical battery minerals, a **circular economy** for EV batteries also reduces the geopolitical risks of relying on minerals and battery cells imported from other nations. The smooth functioning of a circular economy can be enhanced by supply chains that can seamlessly supply minerals and products needed to manufacture new battery packs and then work in reverse to disassemble, recycle, and redistribute usable materials and parts.

A circular economy can only succeed, however, if a system of reverse logistics to collect, transport, store, and recycle end-of-life EV components emerges. The current approach is for auto OEMs to purchase battery packs from manufacturers. Currently, OEMs are not investing in handling end-of-life batteries. Instead, new companies are springing up to tackle this opportunity. At the end of their first life, if the batteries and other components have sufficient useful life and value remaining, they can be repurposed for a second life. But if a battery does not have enough capacity to be repurposed, it will then be reprocessed to recover the basic materials and minerals. Any reverse logistics system will need to be able to efficiently collect batteries from a wide geographic area and have the ability to break battery packs into their original components — including selling anode and cathode materials back to battery manufacturers for reuse.



A NEW ROAD AHEAD

Few parts of the auto ecosystem will remain untouched by EVs. The change can already be seen in many ways:

- The centrality of heavy battery packs made using critical minerals that are not yet produced at scale in North America is driving automaker partnerships with battery suppliers.
- Higher battery weights and fire risks are leading battery suppliers to locate near where EVs are assembled, and there's a growing emphasis on logistics partners equipping warehouses with temperature and humidity controls and other safety measures.
- The comparatively few moving parts of EVs are propelling a shift from sequenced inbound just-in-time manufacturing processes to bulk-metered, just-in-time component deliveries.
- EVs delivered to dealers and end customers must follow stringent safety precautions. Ocean transport, for example, can be made safer by training crew members about the unique risks of EV battery fires and installing fire-detection equipment.
- Incentives from the IRA and a growing industry awareness that access to critical minerals is fundamental to reaching scale are accelerating investments in a circular economy for batteries.

Many of these significant supply-chain changes will require retooling existing auto manufacturing plants and forging new partnerships with suppliers. But the EV ecosystem isn't limited to the supply chain for EVs alone. It also includes supply chains to build the necessary charging network to reliably deliver electrons into millions of new EVs. This includes reaching the federal government's **target of building out a network of 500,000** public EV chargers.

It also includes the supply chain for upgrading America's grid to manage and deliver the power needed to power the EVs, which could add more than **130 billion kilowatt-hours** of demand by 2050.

Establishing the supply chains to address the needs of EVs adequately and efficiently is ultimately about solving the supply-chain needs for the entire energy transition. This can only be accomplished through unprecedented collaboration and innovation. And the time to start building those relationships and partnerships is now.

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