EVs' Tough Road Ahead

By John Benson

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1. Introduction

As I started considering the IEEE Spectrum article referenced at the end of this paragraph as a source for a future article, I found a lot to like. First of all, it described in detail the changes we (our societies) must make to implement Electric Vehicles, but also explored the risk of over-simplifying the challenges in implementing those changes.[1]

Many parts of the referenced Spectrum article that I do strongly agree with is that the whole life-cycle of EVs, including electric generation fuels (for manufacturing and operation), EV-component manufacturing, recycling and supply-chains matters mightily. However, you can only go so far down each supply-chain before any greenhouse gas (GHG) emissions become trivial.

But as I excerpted content from this article, I also found it necessary to add some counterpoints, where we have made progress in moving towards EVs.

2. Sharp Curves and Possible Straightaways

EVs Have Finally Come of Age. The total cost of purchasing and driving one–the cost of ownership–has fallen nearly to parity with a typical gasoline-fueled car. Scientists and engineers have extended the range of EVs by cramming ever more energy into their batteries, and vehicle charging networks have expanded in many countries. In the United States, for example, there are more than 49,000 public charging stations, and it is now possible to drive an EV from New York to California using public charging networks.

With all this, consumers and policymakers alike are hopeful that society will soon greatly reduce its carbon emissions by replacing today's cars with electric vehicles. Indeed, adopting electric vehicles will go a long way in helping to improve environmental outcomes. But EVs come with important weaknesses, and so people shouldn't count on them alone to do the job, even for the transportation sector.

Why not? EVs lack tailpipe emissions, sure, but producing, operating, and disposing of these vehicles creates greenhouse gas emissions and other environmental burdens. Driving an EV pushes these problems upstream, to the factory where the vehicle is made and beyond, as well as to the power plant where the electricity is generated. The entire life cycle of the vehicle must be considered, from cradle to grave. When you do that, the promise of electric vehicles doesn't shine quite as brightly. Here we'll show you in greater detail why that is.

The life cycle to which we refer has two parts: The vehicle cycle begins with mining the raw materials, refining them, turning them into components, and assembling them. It ends years later with salvaging what can be saved and disposing of what remains. Then there is the fuel cycle–the activities associated with producing and using the fuel or electricity to power the vehicle through its working life.

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[1] Heather L. Maclean, et al, IEEE Spectrum, "The Electric Vehicle is not Enough," Nov, 2022, https://ieeexplore.ieee.org/document/9941035, Note that access is limited.

For EVs, much of the environmental burden centers on the production of batteries, the most energy- and resource-intensive component of the vehicle. Each stage in production matters–mining, refining, and producing the raw materials' manufacturing the components, and finally assembling them into cells and battery packs.

Where all this happens matters, too, because a battery factory uses a lot of electricity, and the source for that electricity varies from one region to the next. Manufacturing an EV battery using coal-based electricity results in more than three times the greenhouse-gas emissions of manufacturing a battery with electricity from renewable sources. And about 70 percent of lithium-ion batteries are produced in China, which derived 64 percent of its electricity from coal in 2020.

Author's comment: EV-Manufacturers and new EV-buyers hoping to take full advantage of the Inflation Reduction Act (IRA) tax credits, will need to make / buy EVs with batteries that comply with the following requirements:

EVs with battery components sourced from "foreign entities of concern," like China, where the vast majority of battery parts and minerals come from, will no longer qualify for the full tax credit. If the battery only contains minerals from these countries, then it will become ineligible for the credit starting December 31st, 2024.

Batteries must have at least 40 percent of materials sourced from North America or a U.S. trading partner by 2024 in order to be eligible for the tax break. By 2029, battery components would have to be 100 percent made in North America.

Most automotive manufacturers say they plan to use renewable energy in the future, but for now, most battery production relies on electric grids largely powered by fossil fuels. Our 2020 study, published in Nature Climate Change, found that manufacturing a typical EV sold in the United States in 2018 caused about 7 to 12 tonnes of carbon dioxide emissions, compared with about 5 to 6 tonnes for a gasoline-fueled vehicle.

You also must consider the electricity that charges the vehicle. In 2019, 63 percent of global electricity was produced from fossil-fuel sources, the exact nature of which varies substantially among regions. China, using largely coal-based electricity, had 6 million EVs in 2021, constituting the largest total stock of EVs in the world.

Author's comment: The one part of the prior paragraph that I need to clarify is that I agree that a large majority of private EV drivers purchase default grid power. However, then the situation gets more complex. Using my home state (California) as an example, as a whole our gird is using about 50% renewable or zero-carbon power (the latter is nuclear or large hydro). I purchase power from PG&E, but don't own an EV. The default supplier for most in PG&E's service territory is their local Community Choice Aggregator (CCA), and most of these have aggressively contracted for renewable power. However, this power goes over PG&E's grid from the generator to the CCA's service territory. As I said, this is complex, but California is scheduled to have 100% renewable and zero carbon electric power by 2045, so at least we are moving in the right direction.

Also note that "40% of ZEVs (zero emission vehicles) sold in the U.S. are sold in California…" and "18.8% of all new cars sold in California are ZEVs…"[2]

[2] Press Release from Governor Gavin Newsom, "California ZEV Sales Near 19% of All New Car Sales in 2022," Jan 20, 2023, https://www.gov.ca.gov/2023/01/20/california-zev-sales-near-19-of-all-new-car-sales-in-2022/

But coal use varies, even within China. The southwest province of Yunnan derives about 70 percent of its electricity from hydropower, slightly more than the percentage in Washington State, while Shandong, a coastal province in the east, derives about 90 percent of its electricity from coal, similar to West Virginia…

The U.S. falls somewhere in the middle, deriving about 60 percent of its electricity from fossil fuels, primarily natural gas, which produces less carbon than coal does. In our model, using electricity from the 2019 U.S. grid to charge a typical 2018 EV would produce between 80 and 120 grams of carbon dioxide per kilometer traveled, compared with about 240 to 320 g/km for a gasoline vehicle. Credit the EV's advantage to its greater efficiency in the conversion of chemical energy to motion–77 percent, compared with 12 to 30 percent for a gasoline car–along with the potential to generate electricity using low-carbon sources. That's why operating EVs typically releases less carbon than operating gasoline vehicles of similar size, even in coal-heavy grids like Shandong or West Virginia.

But when you factor in the greenhouse gas emissions associated with vehicle manufacture, the calculus changes. As an illustration, an EV operated in Shandong or West Virginia causes about 6 percent more greenhouse gas emissions over its lifetime than does a conventional gasoline vehicle of the same size. An EV operated in Yunnan causes about 60 percent less.

Author's comment: Any vehicle manufacturer can purchase renewable power for their operations. However, since they produce most of the EVs in the U.S., I decided to focus on Tesla.[3] Go through the link at the end of this paragraph for their complete story, but their main argument seems to be that the PV panels they produce (in their solar energy business) more than offset the amount of power that they use to operate their automotive assembly plants and that are used to charge their EVs.[4]

Can EVs be good enough–and can manufacturers roll them out fast enough–to meet the goals set in 2021 by the 26th United Nations Climate Change Conference (COP26)? The 197 signatory nations agreed to hold the increase in the average global temperature to no more than 2 °C above preindustrial levels and to pursue efforts to limit the increase to 1.5 °C.

Our analysis shows that to bring the United States into line with even the more modest 2°C goal would require electrifying about 90 percent of the U.S. passenger-vehicle fleet by 2050–some 350 million vehicles.

Author's comment: Again, using California as an example: "The California Air Resources Board today approved the trailblazing Advanced Clean Cars II rule that sets California on a path to rapidly growing the zero-emission car, pickup truck and SUV market and deliver cleaner air and massive reductions in climate-warming pollution.[5]

[3] Tesla accounted for 64% of the EVs sold in the U.S. through third quarter 2022. See https://electrek.co/2022/10/18/us-electric-vehicle-sales-by-maker-and-ev-model-through-q3-2022/ for more information.

[4] Tesla, Impact, Environment, https://www.tesla.com/impact/environment

[5] California Air Resources Board (CARB), California moves to accelerate to 100% new zero-emission vehicle sales by 2035, Aug 25, 2022, https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035

“The rule establishes a year-by-year roadmap so that by 2035 100% of new cars and light trucks sold in California will be zero-emission vehicles, including plug-in hybrid electric vehicles.”

Also note the following: “Other states are indeed following California's example. New York, Washington, Massachusetts, Oregon and Vermont are expected to adopt a similar 2035 mandate. Minnesota and Virginia may also follow suit.”[6]

To arrive at this number, we first had to decide on an appropriate carbon budget for the U.S. fleet. Increases in global average temperature are largely proportional to cumulative global emissions of carbon dioxide and other green-house gases. Climate scientists use this fact to set a limit on the total amount of carbon dioxide that can be emitted before the world surpasses the 2°C goal: This amount constitutes the global carbon budget.

We then used results from a model of the global economy to allocate a portion of this global budget specifically to the U.S. passenger-vehicle fleet over the period between 2015 and 2050. This portion came out to around 45 billion tonnes of carbon dioxide, roughly equivalent to a single year of global greenhouse-gas emissions.

This is a generous allowance, but that's reasonable because transportation is harder to decarbonize than many other sectors. Even so, working within that budget would require a 30 percent reduction in the projected cumulative emissions from 2015 to 2050 and a 70 percent reduction in annual emissions in 2050, compared with the business-as-usual emissions expected in a world without EVs.

Next, we turned to our model of the U.S fleet of light vehicles. Our model simulates for each year from 2015 to 2050 how many new vehicles are manufactured and sold, how many are scrapped, and the associated greenhouse-gas emissions. We also keep track of how many vehicles are on the road, when they were made, and how far they are likely to drive. We used this information to estimate annual greenhouse-gas emissions from the fuel cycle, which depend partly on the average vehicle size and partly on how much vehicle efficiency improves over time.

Finally, we compared the carbon budget with our model of total cumulative emissions (that is, both vehicle-cycle and fuel-cycle emissions). We then systematically increased the share of EVs among new vehicle sales until the cumulative fleet emissions fell within the budget. The result: EVs had to make up the vast majority of vehicles on the road by 2050, which means they must make up the vast majority of vehicle sales a decade or more earlier.

That would require a dramatic increase in EV sales: In the United States in 2021, just over 1 million vehicles–less than 1 percent of those on the road–were fully electric. And only 3 percent of the new vehicles sold were fully electric. Considering the long lifetime of a vehicle, about 12 years in the United States, we would need to ramp up sales of EVs dramatically starting now to meet the 2°C target. In our model, over 10 percent of all new vehicles sold by 2020 would have had to be electric, rising above half by 2030, and essentially all by 2035. Studies conducted in other countries, such as China and Singapore, have arrived at similar results.

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[6] Rob Lenihan, The Street, “Year End: California's Electric Vehicle Law Takes Nation into New Territory,” Dec 24, 2022, https://www.thestreet.com/electric-vehicles/year-end-californias-electric-vehicle-law-takes-nation-into-new-territory

Author's comment: in 2022, in the range of 5.3% to 6.4% of all vehicles sold in the U.S. were fully electric per the site linked below. As I pointed out earlier, California is approaching 19%.

https://joinyaa.com/guides/electric-vehicle-market-share-and-sales/

The good news is that 2035 is the year suggested at the COP26 for all new car and vans in leading markets to be zero-emissions vehicles, and many manufacturers and governments have committed to it. The bad news is that some major automotive markets, such as China and the United States, have not yet made that pledge, and the United States has already missed the 10 percent sales share for 2020 that our study recommended. Of course, meeting the more ambitious 1.5 °C climate target would require even larger-scale deployment of EVs and therefore earlier deadlines for meeting these targets.

Author's comment: I assume the first sentence above should read …*all new car and vans* **sold** *in leading markets…*

It's a tall order, and a costly one, to make and sell so many EVs so soon. Even if that were possible, there would also have to be an enormous increase in charging infrastructure and in material supply chains. And that much more vehicle charging would then put great pressure on our electricity grids.

Charging matters because one of the commonly cited obstacles to EV adoption is range anxiety. Shorter-range EVs, like the Nissan Leaf, have a manufacturer's reported range of just 240 km (about 150 miles), although a 360-km (223 miles) model is also available. Longer-range EVs, like the Tesla Model 3 Long Range, have a manufacturer's reported range of 600 km (372 miles). The shorter driving ranges of most EVs are no problem for daily commutes, but range anxiety is real for longer trips, especially in cold weather, which can cut driving ranges substantially due to the energy demand of heating the cabin and the lower capacity of cold batteries.

Most EV owners recharge their cars at home or at work, meaning that chargers need to be available in garages, driveways, on-street parking, apartment building parking areas, and commercial parking lots. A couple of hours at home is sufficient to recharge from a typical daily commute, while overnight charging is needed for longer trips. In contrast, public charging stations that use fast charging can add several hundred kilometers of range in 15 to 30 minutes. This is an impressive feat, but it still takes longer than refilling a gas tank.

Author's comment: Newer EV designs with 800 volt electric systems, like the Hyundai Ioniq 5 and Kia EV6 (specifically) can charge from 10% to 80% battery capacity in 18 minutes using the new 800 volt fast-charging systems.[7]

However, "…most level 3 chargers run on 400-volt systems and can deliver from 50 to 150 kW; 800-volt chargers can deliver up to 350 kW but are still not very common. Ionity,

[7] Fred Lambert, Electrek, "Watch Hyundai Ioniq 5 charge to 80% in 18 minutes with impressive charge rate," April 26, 2021, https://electrek.co/2021/04/26/hyundai-ioniq-5-charge-to-80-percent-18-minutes-charge-rate-video/

Tritium, and Electrify America are the biggest players, with most offering at least one 350-kW charger alongside multiple 150-kW chargers in convenient locations."[8]

Thus the near future will bring us charging stops that are compatible with a gasoline fill-up plus potty and/or snack break. Now, back to the Reference 1 Spectrum Article.

Another barrier to the adoption of EVs is the price, which is largely a function of the cost of the batteries, which make the purchase price 25 to 70 percent higher than that of an equivalent conventional vehicle. Governments have offered subsidies or tax rebates to make EVs more appealing, but such measures, while easy enough to implement in the early days of a new technology, would become prohibitively expensive as EV sales mount.

Author's comment: The Ioniq 5 mentioned above was Motor-Trend's SUV of the Year, and has a base price of around $45K without any federal or state rebates.

Although EV battery costs have fallen dramatically over the past decade, the International Energy Agency is projecting a sudden reversal of that trend in 2022 due to increases in prices of critical metals and a surge in demand for EVs. While projections of future prices vary, highly cited long-term projections from BloombergNEF suggest the cost of new EVs will reach price parity with conventional vehicles by 2026, even without government subsidies. In the meantime, EV buyers' sticker shock could be alleviated by the knowledge that fuel and maintenance costs are far lower for EVs and that total ownership costs are about the same.

Author's comment: As I'm writing this Tesla just reduced the price of their most popular models 6% to almost 20%.[9]

But what drivers gain, governments might lose. The International Energy Agency estimates that by 2030 the deployment of EVs could cut global receipts from fossil-fuel taxes by around US $55 billion. Those tax revenues are necessary for the maintenance of roads. To make up for their loss, governments will need some other source of revenue, such as vehicle registration fees.

The growth in the number of EVs introduces various other challenges, too, not the least of which are the greater demands placed on material supply chains for EV batteries and electricity grids. Batteries require raw materials such as lithium, copper, nickel, cobalt, manganese, and graphite. Some of these materials are highly concentrated in a few countries.

For example, the Democratic Republic of Congo (DRC) holds about 50 percent of the world's cobalt reserves. Just two countries–Chile and Australia–account for over two-thirds of global lithium reserves, and South Africa, Brazil, Ukraine, and Australia have almost all the manganese reserves. This concentration is problematic because it can lead to volatile markets and supply disruptions.

The COVID pandemic has shown just what supply-chain disruptions can do to other products dependent on scarce materials, notably semiconductors, the shortage of which has forced several automotive manufacturers to stop producing vehicles. It is unclear

[8] Kevin Jennings, Green Cars, "New 800-Volt Fast Charging Systems," Feb 2022, https://www.greencars.com/news/new-800-volt-fast-charging-systems

[9] Maria Merano, Teslarati, "Tesla reduces Model 3 and Model Y prices in the United States," Jan 12, 2023, https://www.teslarati.com/tesla-model-3-model-y-price-cut-united-states-update/

whether suppliers will be able to meet the future demand for some critical raw materials for electric batteries. Market forces may lead to innovations that will increase the supplies of these materials or reduce the need for them. But for now, the implications for the future are not at all obvious…

Author's comment: There are many alternatives for battery supply chains. For instance the least expensive battery commonly used for EVs is the LFP, and its chemistry mainly uses lithium, iron and phosphate, all of which have huge supplies. LFP chemistry does not use any cobalt. LFP batteries have long lives, but a lower energy density than other chemistries. Other battery manufacturers have found ways to reduce the cobalt in their high-energy designs. For instance, NCMA (Nickel Cobalt Manganese Aluminum, a.k.a., GM's Ultium Battery), reduces cobalt by 70% verses other high energy-density batteries.

All said, EVs present both a challenge and an opportunity. The challenge could be hard to manage if EVs are deployed too rapidly–but rapid deployment is exactly what is needed to meet climate targets. These hurdles can be overcome, but they cannot be ignored: In the end, the climate crisis will require us to electrify road transport. But this step alone cannot solve our environmental woes. We need to pursue other strategies.

We should try as much as possible, for example, to avoid motorized travel by cutting the frequency and length of car trips through better urban planning. Promoting mixed-use neighborhoods–areas that put work and residence in proximity–would allow more bicycling and walking…

We should also shift from using cars, which often have just one person inside, to less energy-intensive modes of travel, such as public transit. Ridership on buses and trains can be increased by improving connectivity, frequency, and reliability. Regional rail could supplant much intercity driving. At high occupancy, buses and trains can typically keep their emissions to below 50 grams of carbon dioxide per person per kilometer, even when powered by fossil fuels. In electrified modes, these emissions can drop to a fifth as much…

Implementing these complementary strategies could ease the transition to EVs considerably. We shouldn't forget that addressing the climate crisis requires more than just technology fixes. It also demands individual and collective action. EVs will be a huge help, but we shouldn't expect them to do the job alone.

Final author's comment: I will only add one brief comment: moving to low-carbon transportation will require a major societal shift. For instance, I have frequently used mass transit in the past, and written about it often, but increased use of mass transit will require better security and policing. This can be implemented though a combination of technology and security personnel, but this <u>must</u> be prioritized.