Testimony of
Mark P. Mills, Senior Fellow, Manhattan Institute
Before
U.S. House Committee on Agriculture
"*Implications of Electric Vehicle Investments for Agriculture and Rural America*"

January 12, 2022

Good afternoon. Thank you for the opportunity to testify. I'm a Senior Fellow at the Manhattan Institute where I focus on science, technology, and energy issues. I am also a Faculty Fellow at the McCormick School of Engineering at Northwestern University where my focus is on supply chain systems and future manufacturing technologies. And, for the record, I'm a strategic partner in a venture fund focused on software startups in energy.

Since the purpose of this hearing is to explore actions that might be directed at "*the needed infrastructure and possible impediments to electric vehicle (EV) adoption in rural America,"* permit me to highlight some of the infrastructure realities and some of the impediments emerging from the underlying engineering and physics of EVs, in particular for rural markets.

I should begin by pointing out the obvious. Without regard to government interventions or incentives, we will see a lot more EVs on roads in the future. Electric cars are now a viable consumer product. This transformation happened because of the combination of the unheralded advances in high-power semiconductors along with the far more heralded, forty-year-ago, invention of lithium battery chemistry. It bears noting that these twin technology revolutions emerged without government intervention or policies. The ultimate extent to which EVs can displace internal combustion engines, and how soon, will be determined, ultimately, by the limits of the technologies that now exist.

As the Committee knows, while in recent years we've seen rapid growth in consumer purchases of EVs, the total number of EVs in use today remains, overall, at about a 0.6% share of all light duty vehicles on America's roads. And, relevant to this hearing, the EV share of vehicles in rural America is at least ten times *lower* than that. At issue is whether that rural-urban asymmetry is amenable to policies that would incentivize greater rural EV penetration, and at what cost. Also relevant to this exploration is whether subsidizing greater EV use in rural America would make a significant difference in global carbon dioxide emissions. I'll focus on three key realities.

EVs still can't meet overall practical performance requirements, especially in rural areas.

It is well-known and obvious that rural residents drive more miles, on average about 40% more per person per year than urban drivers. And similarly well-known is the fact that pickup trucks make up about 40% of the share of new car purchases in rural areas, compared to a 20% share nationally. Manufacturers are rushing to offer all-electric pickups. Rural consumers will soon have that option.

The conventional wisdom has it that consumer reluctance to embrace EVs in general, and especially in rural areas, arises primarily from so-called "range anxiety," and cost. The former, it is commonly argued, can be solved with more charging stations. The latter we're told can be alleviated with subsidies while awaiting ostensibly inevitable declines in costs. The facts, however, suggest otherwise.

Most EVs available today, or announced, offer a range comparable to a conventional car's full gasoline tank, including for example the new Ford F150 Lightning pickup truck, as well as GM's emerging offering. Both the latter have 400-mile range batteries. The practical problem is the time it takes to refuel a battery. While that's an issue that can be ameliorated, solutions come at great cost both for the consumer and for the electrical infrastructure. And in the time frames proposed in aspirational policies, there's no visible path to refueling a battery even close to as fast as filling up a gasoline tank.

A standard gas station pump can fill a 26-gallon F150 fuel tank in about five minutes. Meanwhile, charging an EV with a standard Level 2 charger (which constitutes the majority of both public and home chargers today) takes about 10 hours. A so-called supercharger can drop that time to 40 minutes, which is still nearly ten times longer than filling up a gas tank. Set aside the inconvenience for most drivers, most of the time, of a 40-minute fill-up, using superchargers has critical infrastructure implications. In order for an EV filling station to provide the same functional utility consumers experience for their vehicles today, far more electric 'pumps' will be needed than gas pumps; maybe 10-fold more. And the capital cost of a supercharger is roughly double the cost of a gasoline pump. Thus, in rough terms, that constitutes a 20-fold higher infrastructure cost per consumer served to provide the same functional utility. That cost differential is anchored in basic electric equipment realities that are not subject to profound or rapid cost reductions.

Then there are the incremental costs for the local electrical distribution infrastructure. In order to achieve a faster charge rate, superchargers operate at about a ten-fold higher power level. Supporting that kind of power, especially for multiple superchargers operating simultaneously, will require a radical and expensive upgrade to the existing rural power distribution infrastructure. Such upgrade costs are often ignored but are unavoidable and particularly impactful in rural areas where distribution infrastructure costs are far greater per household than in urban areas.

It is very unlikely that a significant share of either rural or urban households will spend the 20-fold higher costs to have a so-called Level 3 superchargers. The more common Level 2 chargers that take overnight to refill pose other practical challenges in rural areas where the frequency of grid outages is, on average, about 50% higher than for urban and suburban grids. In order to ensure the ability to travel during outages—which, if caused by weather or natural disasters, is even more important—rural homeowners using gasoline vehicles can spend a few hundred dollars on a storage tank that can hold enough gasoline to fill an F150's tank. But in the event of a grid outage with an F150 Lightning that's, say, only half charged, one would need to have an onsite a Generac or Tesla Powerwall with enough stored power to fill up the pickup's battery. A Powerwall with that much storage—half a 'tank'—costs over $30,000. The other alternative for that rural homeowner of course would be to keep a small tank of fuel on hand and a $5000 generator to charge the truck.

Finally, none of this says anything about the practical utility of a truck with a fuel system—the battery—that weighs one ton instead of 150 pounds. The latter is the weight of full gasoline tank for a conventional truck with the same range. Of course, for rural homeowners with two vehicles, it is possible many people would choose to own second vehicle with limited emergency fuel capability, and more limited cargo capacity, if there were no cost penalty because of subsidies.

Which brings us to the ubiquitous policy assumption that EV subsidies can decline and soon become unnecessary because of the expectation that batteries will soon become far cheaper. Whether costs decline at the rate assumed, or at all, is an issue anchored in supply chains.

Mass adoption of EVs will stress global supply chains and lead to higher, not lower, prices.

The energy transition, as it's conceived today will create an upstream demand for tens of gigatons of materials to be mined in order to fabricate car batteries. In addition, gigatons more will be needed for the grid storage batteries contemplated, and yet more to build solar and wind machines. Using batteries entails at least a 1,000% increase in the tonnage of materials extracted from the earth to deliver the same mile driven by a gasoline vehicle. Given the integration of the transition proposals, it is relevant that a similar increase in materials is associated with using solar and wind to replace hydrocarbons to make the same unit of electricity to charge the battery. The IEA has observed that the transition is a "shift from a fuel-intensive to a material-intensive energy system." This unavoidable, physical reality has profound implications for costs, not to mention the implications in environmental and geopolitical domains.

So far, the upstream, energy minerals supply chain has yet to be fully stressed with EVs still accounting for well below 5% of new vehicle purchases. The increase in demand for materials to build EVs at the rate proposed by governments around the world will be far greater than the rate at which the world's miners are planning, or likely able to expand supply.

The contemplated increase in solar/wind/battery construction is estimated to create a jump in demand for the various critical energy minerals from 400% to over 4,000%. In a nearly 300 page report issued last year by the IEA, that agency's analysts observed that an energy transition plan that is more ambitious than implied by the Paris Accord, but one that remains far short of eliminating hydrocarbons, would increase demand for minerals such as lithium, graphite, nickel and cobalt rare earths by 4,200%, 2,500%, 1,900% and 700%, respectively, by 2040.

The fact that an EV uses, for example, about 300 to 400% more copper than a conventional car has yet to impact global supply chain because EVs still account for such a small share of global auto production. Producing EVs at scale, along with plans for grid batteries as well as for wind and solar machines, will push the "clean energy" sector up to consuming over half of all global copper (from today's 20% level). For nickel and cobalt, to note two other relevant minerals, energy transition aspirations will push clean energy use of those two metals up from a negligible share today of global demand for all other purposes, to 60% and 70%, respectively, of all demand.

Relevant to the transportation sector alone is a recent analysis from Wood Mackenzie of the mineral demands to fabricate automotive batteries to meet the goal to have EVs account for two-thirds of all new car purchases by 2030. Such a goal would create a demand for lithium, nickel and copper, requiring dozens of new mines to be opened, before 2030, each the size of the world's biggest in each category today. Such a possibility is fantastical considering, as the IEA reported, that the global *average* is 16 years to open a new mine. That average timeline is far longer in the U.S., and often infinite.

As demand for EV battery minerals rises—and that increase occurs contemporaneously with rising demand for minerals for grid batteries, and for solar and wind machines—it will inevitably lead to price increases in those commodity markets, not the decreases that are assumed in nearly all forecasts. Few analysts seemed to have incorporated that fact in the assumptions about the future cost of the necessary minerals for a far producing a far greater quantity of batteries.

The commodity materials alone comprise 60 to 70% of the cost to produce a battery. This is a testament to the incredible progress on reducing costs in the engineering and manufacturing of battery cells and systems. But it also means that modest rises in commodity prices can now wipe out future gains in reducing the far smaller share of costs associated with the electronics and labor. The IEA has noted as much in its report, concluding that future mineral price escalations could "eat up the anticipated" reductions in manufacturing costs expected from the "learning effects" in further scaling up of battery production.

It is notable that 2021 saw a rise in commodity material costs, and that lead directly to a dramatic slow-down in the decadal trend of declining battery costs. Lithium battery costs declined by only 6%last year. And the current forecast is for batteries to *rise* in cost in 2022, again because of the ongoing increases in materials commodities prices. The overall price index for the suite of EV battery metals is up some 200% over the past two years. And that trend comes with EVs still at only about 5% of new car sales. The future price direction for batteries is now determined mainly by the mining and commodities markets and not by the manufacturing.

Commodity inflation has begun to escalate the cost to build solar and wind machines as well, also slowing or reversing long-run cost declines. Solar module prices were *up* nearly 50% last year over 2020. Progress in manufacturing efficacy has reduced those costs so much that commodity inputs now make up about 70% of the cost of solar modules.

Producers do respond to higher prices by adding more supply, in every business. But for infrastructure-scale supplies of minerals and metals it takes at least a decade, under ideal circumstances, from discovery and decision to see production emerge from new mines. And even then, expansion typically begins a while after producers come to believe that prices will stay escalated long enough to recover multi-billion-dollar investments.

Finally, it bears noting that most of the primary minerals and the chemical processing of those minerals takes place overseas. The issue of foreign dependencies on energy materials used to be something that Congress worried about because of both practical supply chain exposures and geopolitical challenges. The U.S. is today dependent on imports for 100% of some 17 critical minerals and, for 28 others, net imports account for more than half of existing domestic demand. Insufficient attention has been afforded the impact of accelerating adoption of EVs and the resultant realignments of energy-material supply chains. Shifting the United States from hydrocarbon energy self-sufficiency to energy-mineral dependency entails some obvious consequences, and almost certainly some wildcards that are not obvious today.

As it stands today, Chinese firms dominate the production and processing of many critical rare earth elements, and nearly all the growth in mining is expected offshore, increasingly in fragile, biodiverse wilderness areas. More mining can be done in an environmentally responsible way, but so far there's little evidence of support for a massive expansion of new mines in America. The path the United States is proposing with EVs is the practical, economic, and geopolitical equivalent of building conventional cars in America but importing nearly 100% of all gasoline.

This brings me to my final point regarding the offshoring of energy materials. Mining and processing minerals is an energy-intensive activity that is dominated by the use of fuel-burning machinery. Since the primary, if not sole motivation for incentivizing the purchase of EVs is to reduce carbon dioxide emissions, there has been insufficient attention afforded the issue of the offshore and out-of-sight emissions from accessing, processing, and transporting all the associated materials to fabricate the batteries themselves.

EVs will reduce oil use only slightly, and have an even smaller impact on carbon dioxide emissions

The question of how much carbon dioxide—as opposed to how much oil—is eliminated by using an EV is not one solely about counting the emissions resulting from producing the electricity to charge the battery. Instead, it's dominated by what know about the "embodied" emissions arising from the labyrinthine supply chains to obtain and process all the materials needed to fabricate batteries.

When considering all the factors in mining the necessary minerals to fabricate a battery, fabricating a *single* one-ton EV battery for a pickup truck can entail digging up and moving a total of about 500 tons of earth. After that, an aggregate total of roughly 100 tons of ore are transported and processed to separate out the targeted minerals. That's where all the hidden, upstream energy and emissions come from.

As a benchmark, the technical literature shows that the embodied energy associated with all that industrial activity ranges from 2 to 6 *barrels* of oil (in energy-equivalent terms) needed to fabricate a battery that can store the energy-equivalent of one *gallon* of gasoline.

Embodied emissions can be difficult to accurately quantify. And unlike the petroleum fuel cycle, nowhere are there more complexities and uncertainties than with EVs. For example, one review of fifty academic studies found estimates for embodied emissions to fabricate a *single* EV battery ranged from a low of about eight tons to as high as 20 tons of CO2. And that's for a battery that is half the size of what is used in an electric pickup truck. The high end of that ranges is nearly as much CO2 as is produced by the lifetime of fuel burned by an efficient conventional car. Again, that's before the EV is delivered to a customer and driven its first mile and does not include emissions associated with producing the electricity to charge the battery.

The uncertainties come from inherent—and likely unresolvable—variabilities in both the quantity and type of energy used in the battery fuel cycle with factors that depend on geography and process choices, many of which are proprietary. Thus, any calculation or claim about emissions saved by using an EV is necessarily an *estimate* based on myriad *assumptions.*

The embodied energy is also impacted by a mine's location, something that is in theory knowable today but is a guessing-game regarding the future. Remote mining sites typically involve more trucking and depend on more off-grid electricity, the latter commonly supplied by diesel generators. As it stands today, the mineral sector alone accounts for nearly 40% of global industrial energy use. And over one-half of the world's batteries or the key battery chemicals are produced in Asia with its coal-dominated electric grids. Despite hopes for more factories in Europe and North America, every forecast sees Asia utterly dominating that supply chain for a long time, a part of the supply chain where coal produces over half of the electricity used.

Some forecasts of emissions savings from EVs explicitly assume that the future battery supply chain will be located in the country where the EVs operate. One widely cited analysis assumed aluminum demand for U.S. EVs would be met by domestic smelters and powered mainly from hydro dams. While that may be theoretically possible, it doesn't reflect reality. The U.S., for example, produces just 6% of global aluminum. If one assumes instead the industrial processes are located in Asia, the calculated lifecycle emissions are 150% higher.

For EV carbon accounting, the problem is that there are no reporting mechanisms or standards equivalent to the transparency with which petroleum is obtained, refined, and used. Researchers are aware of this issue, even if concerns don't show up in popularized claims. One often finds cautionary statements such as a "greater understanding of the energy required to manufacture Li-ion battery cells is crucial for properly assessing the environmental implications of a rapidly increasing use of Li-ion batteries." Or in another paper: "Unfortunately, industry data for the rest of the battery materials remain meager to nonexistent, forcing LCA [lifecycle analysis] researchers to resort to engineering calculations or approximations to fill the data gaps."

As the IEA report also observes, the direction of global mining is toward a higher "emissions intensity," because the energy-use-per-pound of mining is rising because of long-standing declines in ore grades. If mineral demands accelerate, miners will necessarily chase ever lower grade ores, and increasingly in more remote locations. The IEA sees, for example, a 300% to 600% *increase* in emissions to produce each pound of lithium and nickel respectively.

Those realities mean that as the world's mineral supply chain expands to support the production of tens of millions more EVs, the future embodied emissions could easily mean there are nearly trivial decreases—and even an increase—in overall transportation carbon dioxide emissions.

For the record, a world going from today's 10 million to having 500 million EVs on the roads would eliminate only about 15% of world oil use. And, bringing the realities back to rural America: if half of all rural homeowners could be induced to replace their second vehicle with an electric pickup truck, that would reduce U.S. oil consumption by barely 3%, and world oil consumption by about 0.5%. And it would have even less impact, perhaps none, on global carbon dioxide emissions.

<>