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S. HRG. 118–388

CHARGING AHEAD: THE FUTURE OF ELECTRIC VEHICLES

HEARING

BEFORE THE

COMMITTEE ON THE BUDGET UNITED STATES SENATE

ONE HUNDRED EIGHTEENTH CONGRESS

SECOND SESSION

July 31, 2024

Printed for the use of the Committee on the Budget

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CHARGING AHEAD: THE FUTURE OF ELECTRIC VEHICLES

WEDNESDAY, JULY 31, 2024

COMMITTEE ON THE BUDGET,
U.S. SENATE,
Washington, DC.

The hearing was convened, pursuant to notice, at 10:00 a.m., in the Dirksen Senate Office Building, Room SD–608, Hon. Sheldon Whitehouse, Chairman of the Committee, presiding.

Present: Senators Whitehouse, Stabenow, Merkley, Kaine, Van Hollen, Grassley, Graham, Johnson, Marshall, Braun, Kennedy, and R. Scott.

Also present: Democratic Staff: Dan Dudis, Majority Staff Director; Kara Allen, Senior Energy and Climate Advisor, Energy Lead.

Republican Staff: Chris Conlin, Deputy Staff Director; Krisann Pearce, General Counsel; Jordan Pakula, Professional Staff Member; Ryan Flynn, Budget Analyst.

Witnesses:

Dr. Jesse Jenkins, Assistant Professor and Macro–Scale Energy Systems Engineer, Department of Mechanical and Aerospace Engineering, and the Andlinger Center for Energy and Environment, Princeton University

Ms. Britta Gross, Director of Transportation, Electric Power Research Institute

Ms. Maureen Hinman, Co-Founder and Chairwoman, Silverado Policy Accelerator

Mr. Dave Schwietert, Chief Government Affairs and Policy Officer, Alliance for Automotive Innovation

Mr. Jeff Davis, Senior Fellow, Eno Center for Transportation

OPENING STATEMENT OF CHAIRMAN WHITEHOUSE [1]

Chairman WHITEHOUSE. Good morning. I am going to call this hearing of the Senate Budget Committee to order and welcome my distinguished Ranking Member, Senator Grassley.

We are going to begin with opening remarks and then Ranking Member Grassley, and then Senator Graham, at whose request this hearing is taking place. So let me start by thanking Senator Graham and his staff for their partnership on today's hearing, and thank Ranking Member Grassley for his blessing of this effort.

Today's bipartisan hearing looks at transitioning away from fossil fuels, in my view an economic, national security and climate im-

[1] Prepared statement of Chairman Whitehouse appears in the appendix on page 43.

perative, in a way that effectively seizes opportunities and addresses challenges.

The auto industry is a major economic engine as Senator Stabenow, who is here, will be the first to argue. In 2023, the global auto market was valued at $4 trillion, of which the United States (U.S.) accounted for a bit less than 17 percent.

Two U.S. automakers, Ford and General Motors (GM), are among the world's five largest automakers. Foreign companies operate assembly plants in the U.S. Senator Graham is attentive to the BMW plant that operates in his home state, and whenever we go to the Munich Security Conference, he is sure to check in with the BMW folks, to make sure they keep building in South Carolina.

Motor vehicles and parts were America's second largest export, and the auto market could increase to over $6 trillion by 2031. So we want to be a part of that action. To grow U.S. automakers' share of this growing pie, we need to understand and respond to this global market.

So here is where we are. Globally, 20 percent of vehicles sold in 2023 around the world were electric, 20 percent. In China, which is the world's largest auto market, 33 percent of cars were electric. In Europe, 20 percent of vehicles sold were electric, and other major markets are racing to Electric Vehicles (EV)s.

Between 2022 and 2023, electric car sales tripled in Brazil, and more than quadrupled in Thailand. And I put into the record an article from the New York Times, which I have just now misplaced, but that points out how the Thai auto market has been lost to Japanese manufacturing, which used to control it, because they are not producing the electric vehicles that the Thai market demands.

So you have got to have the vehicles people want to meet the market. Ah, here it is. Thank you. Without objection, I will add that to the record.[2]

The writing is on the wall for us. Around the world, the future of personal transportation is electric, completely independent of whatever the United States decides to do. And that is great. First, it means more freedom from a global commodity whose price is manipulated by international petro-dictators.

Over and over American consumers suffer as the geopolitical designs of petro-dictators cause oil prices to soar. Real energy independence comes from independence from fossil fuel cartels. Going electric benefits western democracies, as oil and gas revenues fund many of our worst foreign adversaries.

Look no further than the corrupt petro-tyrant Vladimir Putin. As we reduce our dependence on oil and gas, we diminish our foreign adversaries' ability to bully and corrupt. Senator Graham and I wrote in 2021 op-ed published in Time magazine, "If you wave a magic wand and transition the world away from fossil fuels, American would instantly be safer."

And without objection I ask that that be made a part of the record.[3]

As the driver and owner of two Chevy Bolts, I will also add they are just better cars. They are quieter, faster and more fun to drive.

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[2] Statement submitted by Chairman Whitehouse appears in the appendix on page 146.
[3] Statement submitted by Chairman Whitehouse appears in the appendix on page 140.

They do not have tailpipe emissions stinking up highways and neighborhoods. Repair and maintenance costs are nearly non–existence. No oil changes, one–tenth the number of parts to break or fail, no expensive, dangerous, smelly gasoline.

In emergencies, EV fleets can even provide backup power to families when the grid goes down, and smart EV chargers can help shave dangerous load peaks for electric utilities, if we make the needed small investments in the required infrastructure.

And of course yes, electric vehicles dramatically reduce carbon pollution in the transportation sector, currently the largest source of fossil fuel emissions in the U.S. The more we reduce carbon pollution, the better our chances of avoiding the dire systemic climate–related economic risks we have discussed in this Committee over the last 18 months.

It may be too late to save Florida's property insurance market, but there are plenty of other risks we would be wise to avoid and fools to stumble into. Electrifying the transportation sector presents a tremendous economic opportunity. Automakers get the message that people want EVs and they are responding.

Since 2017 they have, along with their battery partners, invested $125 billion in electrification. 20 states have or will have EV production or assembly of battery facilities. For some reason, Tesla is taking a hit but other makers are seeing surging sales year over year. Ford EV sales increased 86 percent from the first quarter of 2023 to the first quarter of 2024. Rivian sales jumped 59 percent over the same period.

So how do we position our auto industry and our nation for that economic opportunity and for global competitiveness? As our economy electrifies, it needs to be supported by a 21st, not a 20th century grid. The grid will need to handle increased demand, from electric vehicles, from heating and cooling, from manufacturing from hydrogen electrolyzing, and from energy–gobbling data centers.

To meet this demand with clean power requires new and upgraded transmission to deliver that power to consumers. That means smart reforms to our cumbersome and antiquated permitting process.

Domestic supply chain investments must accelerate. Look at China. 15 years ago, China saw the value of electric vehicles and batteries and began investing, and now it dominates critical mineral and battery manufacturing markets.

Let us learn the servitude lessons of from fossil fuel dependence, and from our lost manufacturing capacity. Let us swiftly counter this emerging geopolitical risk with smart investment, and take back our economic dominance in clean energy products.

We must also find a way to reconcile the surging EV market with the Highway Trust Fund, that provides 80 percent of federal highway spending with a majority of its revenue from federal gas taxes. The Bipartisan Infrastructure Law, which most recently replenished the fund, sunsets in just two years. The clock is ticking on highway infrastructure funding.

To my mind this is a morning in America moment. Freedom from dependence on petro-dictators; opportunity to reclaim from China

clean energy leadership; better, safer products for American consumers, with more money in their pockets.

Cleaner air to breathe along highways and neighborhood streets, and an important step forward on our pathway to climate safety. What is not to love if we do this right? Thank you again to Senator Graham for this hearing. I look forward to the conversation, and I turn now to Senator Grassley, followed by Senator Graham for opening statements.

OPENING STATEMENT OF SENATOR GRASSLEY [4]

Senator GRASSLEY. Thank you, Mr. Chairman. Welcome to our expert witnesses. Our last hearing was with Congressional Budget Office (CBO) Director Swagel. He was welcomed, a very welcoming event at this Committee, and unfortunately a rare opportunity for this Committee to focus on critical broken budget process.

It gives us a chance to talk to somebody that knows that that process needs to be fixed, and a primary responsibility of this Committee. In exchange for holding a CBO hearing at my request, I agreed to Senator Graham working with Chairman Whitehouse to put together today's hearing.

We will be discussing electric vehicles and barriers to the electrification of America's light duty fleet. The Biden-Harris administration's unattainable goal of 50 percent new EV sales by 2030 has been on full display over the last four years, from the imposing expensive Environmental Protection Agency (EPA) regulations to doling out about billions in EV subsidies for the rich.

The economic detriment to America's EV policy is quite evident. Now I do not want to give the wrong impression. EV technology is impressive for some, but Iowans know that there are far more challenges to EV adoption than many care to admit. EVs best serve wealthier people, who also live in or near suburban and urban areas. Perhaps the most prominent barrier to EV adoption is that EVs are uneconomical.

CBO's February baseline set the record straight, telling us that the so-called Inflation Reduction Act's EV handout would increase the deficit by hundreds of billions of dollars. I also could not help but notice that the price of EVs rose immediately after the IRA's passage, to absorb the bill's $7,500 new EV tax credit. These EV costs were then of course passed on to the consumer.

Of course, now many had to be discounted because they have not been able to sell them, and I have yet to hear a comprehensive plan to make EV owners pay into federal Highway Trust Fund. EV drivers are currently free riding on the backs of the middle class, and although some states have instituted an extra fee for so-called fuel efficient vehicles, making them even more expensive.

There are many holes in the rapid EV transition fantasy. They include a lack of critical minerals needed to produce EVs, lack of transmission infrastructure needed to support the increased electricity demands, and our current reliance upon nefarious countries in the EV supply chain. According to the University of Michigan, the world would need to mine 115 percent more copper from 2018

[4] Prepared statement of Senator Grassley appears in the appendix on page 45.

to 2050 than has been mined in all of human history up until 2018, just to do business as usual.

This copper mining does not even include the green transition, and the EV, they take three to five times as much copper as a standard vehicle. I hope we discuss where these critical minerals for the so-called EV transition will come from.

China dominates the global critical mineral supply chain, accounting for approximately 60 percent of the worldwide production, and 85 percent of processing capacity, and we struggle to permit federal projects here in America.

From wind turbines to transmission lines to pipelines to hard rock mines, left wing environmentalists are holding the permitting reform needed for the very EV expansion that they claim to support. The left claims climate crisis, but backs away from comprehensive reform when the environmental lobby comes calling.

They also claim to care about air quality and environmental justice, but ignore the unreported and under-reported particulate emissions from tires under the heavy weight of EVs. Legislators must do better, and I hope this hearing serves as a stepping stone for honest permitting of dialogue moving forward.

As we grapple with the environmental red tape, the Chinese are rapidly expanding coal power plants to fuel the EV manufacturing boom. I would like to welcome all today's witnesses invited here by Senator Whitehouse and Graham, and finally Mr. Chairman, I request unanimous consent to put this article called "Copper Can't Be Mined Fast Enough to Electrify Vehicles."

I thank you. Before you go on, I was thinking I mentioned a few inconsistencies in my opening remarks, but I think of others. And maybe it is being the adjective unrealistic or inconsistency may fit a couple of things.

But Iowa is the number one producer of ethanol. We have 43,000 jobs in Iowa, and if we had every vehicle in the United States be EVs, you could see what that could do to the particular jobs that we created 40 years ago, to produce a more environmentally friendly product then petroleum is.

We have the inconsistency of the rain forest being hacked away to mine nickel in Indonesia. We have the inconsistency of people in the Congress that talk about we gotta stop the use of child labor around the globe, and yet we have children mining cobalt in Congo. I mentioned transmission in my opening comment. The Chairman mentioned transmission. But this permitting process is halted by environmentalists not wanting to cut red tape here in Washington, D.C.

And then you have the silly posture of the Inflation Reduction Act, appropriating billions of dollars for charging stations, and I guess to date we have about eight. So I just think there is a lot about this whole process that has not been thought out very well. I am done now.

Chairman WHITEHOUSE. Well, I hope that the $125 billion in private capital that has been dedicated to this says otherwise. Senator Graham.

Senator GRASSLEY. That's mercantile economic policy of the federal government.

OPENING STATEMENT OF SENATOR GRAHAM

Senator GRAHAM. Well, thank you. Good morning. What have I learned? We have donuts at the Budget Committee, and I am going to take a wild guess. Senator Grassley did not buy them. But he is welcome to as many of them as he wants.

Senator Grassley, you laid out real challenges, and everything you said is real. So what I want to do is thank the Chairman for having this Committee hearing about electric vehicles, because I am in a very heavy car manufacturing state. And they are making electric cars and hybrid cars and all kind of cars.

And I am trying to figure out, sort of like where should we—what should we be doing and when should we do it as a nation. I met with the Chinese Ambassador yesterday. I had not talked to him in a very long time. I am going to go to China next year.

They decided 15 years ago to get in this business for some reason. It seems to be like they were pretty smart. A lot of people are buying electric cars. President Trump says let them buy electric cars, do away with the mandate. Yeah, it makes some sense to me.

The world seems to be making more electric cars and using electric cars, and what does that mean for us? Well, if you really want to compete in this space, Senator Grassley laid out some real challenges. Power. Let us say half the cars on the road at some point in time become electric.

The grid demand will go through the roof. How can you generate enough power to accommodate electric vehicles and where does it come from? Can you do it with all renewables, and how do you do it without natural gas? You can't. So to my friends in the environmental world, we need to be thinking about increased power production that can actually occur.

That means regulatory form and everything Senator Whitehouse just mentioned, but nuclear power. EVs as projected will take up all the power produced by the nuclear industry and certain renewables just by themselves. These data centers, you know, you are blessed to have them but you are cursed too, because they are just power consumers.

So it seems that the digital economy and electric vehicles is going increase demand for power in a way nobody has really thought through. And where does the new power come from? How you get it online and how do you get it delivered is something I think worthy of the Congress's consideration, not just this Committee.

So Chairman Whitehouse, thank you very much for having this. The demand seems to be real, apart from the mandate.

So what happens to the Highway Trust Fund? $5 billion in lost revenue if the numbers projected come true in the United States. So as Senator Grassley indicated, if you are driving an electric vehicle, we have got to find some way for you to pay in to maintaining the roads.

I do not know what the right answer is, but we had better come up with it pretty quick. You know, we aim and—shoot first and aim later is sort of what we are doing here. We are setting a goal to have 50 percent of all the cars in America become electric, but we have not really thought through how you improve the grid to get there.

Where does the revenue come from that will be lost, and China, to my colleagues, we are in competition with China in many areas. They dominate this market. Do we really want to replace dependence on Mideast oil and gas with China dominance of the supply chain in electric vehicles?

The processing facilities to make a battery really do not exist here. How do you create them, and as Senator Grassley indicated, where do the resources necessary to make a battery come from? If we could make a battery out of corn, that would be good. I do not think we can, but I am willing to have an open mind about that.

So the bottom line is this is coming whether we like it or not, and I think there is an upside to it, to be honest with you, and there is definitely a down side. So from a national point of view, it seems to me that we have set a goal and we have not put the infrastructure in place to meet that goal.

And from a Republican point of view, if you said there is no more mandate, I would be curious to see what kind of sales would occur without a mandate. It would not go to zero. Over the arc of time, there are going to be more electric vehicles not less and in the United States, and over the arc of time they are going to be a lot of Chinese electric cars all over the world.

I would like to compete in this space. Forget about the mandate for a moment. Consumers, particularly younger people, are into this and the world is into this. America needs to play in this space for a variety of reasons, whether it is clean air, whether it is just creating jobs for the new economy.

Whatever reason, we need to think long and hard about how we compete, the challenges we face and we are behind in a game that is being played by China very aggressively. When it comes to America's national security interest, I think we need to compete in the transportation space. So thank you for having the hearing. I do not know what the answers are to all these questions, but I do know that the march toward electric vehicles is inevitable.

Chairman WHITEHOUSE. Thank you, Senator Graham. We have five witnesses here today who have been agreed on, each a bipartisan selection. The first is Dr. Jesse Jenkins, Assistant Professor at Princeton University with a joint appointment in the Department of Mechanical and Aerospace Engineering, and the Andlinger Center for Energy and Environment.

Dr. Jenkins also leads Princeton's Zero Carbon Energy Systems Research and Optimization Laboratory, which conducts modeling to evaluate low carbon energy technologies, and generate insights to improve energy and climate planning.

Our second witness is Britta Gross, Director of Transportation at EPRI, formerly the Electric Power Research Institute. In her role, Ms. Gross is responsible for defining the market strategies needed to accelerate the electrification of the transportation system, with a focus on identifying the gaps that need to be addressed to achieve 2030 climate goals.

She was formerly the director of Advanced Vehicle Commercialization at General Motors, so I hope she was smiling when we talked about Bolts.

Third is Maureen Hinman, the co-founder and executive chair of Silverado Policy Accelerator. Prior to founding Silverado, Ms.

Hinman served as Director for Environment and Natural Resources at the Office of the United States Trade Representative.

She also served at the U.S. Department of Commerce as senior industry trade specialist responsible for international policy development and interagency advocacy for the U.S. Environmental Technology.

Silverado is helping this Committee in a number of areas, and I am grateful to Ms. Hinman for being here.

Our next witness is David Schwietert, the Chief Policy Officer at the Alliance for Automotive Innovation. Before joining the Alliance, David Schwietert was the interim president and Chief Executive Office (CEO) of the Alliance for Automobile Manufacturers.

Prior to joining the Auto Alliance in 2015, Mr. Schwietert worked in the U.S. Senate for over 15 years, holding various positions including staff director of the Committee on Commerce, Science and Transportation. Welcome back, Mr. Schwietert.

And last but not least, we have Jeff Davis, a senior fellow with the Eno Center for Transportation. Mr. Davis joined Eno in 2015 from his own transportation and public works research and consulting company. He started his career working in the House of Representatives, so also welcome back to you, Mr. Davis.

Thank you all for joining us today. Dr. Jenkins, please proceed. You have five minutes for an oral statement, and your testimony, like that of all the others, will be put into the record completely.

STATEMENT OF DR. JESSE JENKINS, ASSISTANT PROFESSOR AND MACRO-SCALE SYSTEMS ENGINEER, DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING, AND THE ANDLINGER CENTER FOR ENERGY AND ENVIRONMENT, PRINCETON UNIVERSITY[5]

Dr. JENKINS. Thank you, Chairman and Ranking Member and Senator Graham for organizing the hearing and the opportunity to testify. My name—thank you. I thank the Chairman and the Ranking Member and Senator Graham for the opportunity to testify and for organizing the hearing today.

I am Jesse Jenkins, a professor of Energy Systems Engineering at Princeton University. I also lead the Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) Project, which assesses the impacts of federal energy and climate policy. I have to note that all views expressed today are my own.

The United States is now in the early stages of a momentous transition in the automotive sector. Over 1.1 million battery electric vehicles were delivered to U.S. consumers in 2023, alongside over 183,000 plug-in hybrid electric vehicles. So by the end of 2023, almost one in ten light duty vehicles sold in the U.S. had a plug.

This transition to electric vehicles is a central pillar in the United States' efforts to both cut greenhouse gas emissions and reduce our vulnerabilities to shocks in global oil markets. Today, the United States is producing more oil than any country at any point in history. And yet the U.S. economy remains dangerously exposed to the volatility of global oil prices.

[5] Prepared statement of Dr. Jenkins appears in the appendix on page 48.

The decisions of a dictator to invade a neighbor or a disaster on the other side of the world can send the cost of filling the tank in Denver or Des Moines soaring, and every $10 per barrel increase in the price of oil is $210 million per day tax on American consumers and businesses.

So we simply cannot drill our way to energy security, but we can electrify. By severing our reliance on gasoline and diesel to fuel our cars and trucks, we can finally secure America's independence from global oil shocks.

Electrifying transportation is also critical to meet national climate objectives. Switching to EVs and cleaning up our grid is the critical 1–2 punch that will decarbonize transportation. President Biden established a goal to cut U.S. greenhouse gas emissions to half of our peak levels by 2030.

To reach this goal, electric vehicle sales should make up about half of all light duty vehicle sales by that date. That is up about fivefold from today's share. Yet over the last nine months, sales of plug-in vehicles in the United States have plateaued, driving a growing gap between current trends and our U.S. climate targets.

Electric vehicle sales growth actually accelerated through the third quarter of 2023, regularly exhibiting explosive year on year growth rates of roughly 40 to 60 percent. But beginning in the fourth quarter of 2023, growth in U.S. EV sales has stalled, a trend that has continued through the first half of this year.

At the current pace, sales of plug-in vehicles are up just nine percent this year. If we look beyond the top-line numbers, it is clear that the story so far is mostly about Tesla.

Over the first half of 2024, Tesla sales contracted by 13 percent, while sales of all other plug-in hybrid vehicles and electric vehicles are up a healthy 31 percent. That is right in line with the REPEAT Project's expectations for this year for the sector as a whole.

Taking a step back, consumer surveys find that about half of U.S. vehicle buyers are considering buying an EV within the next 12 months, indicating substantial consumer interest and potential for large market growth. Cost and charging-related concerns remain the most commonly cited barriers to consumer adoption, but both trends are improving, thanks to both market competition and private investment, as well as supported public policy.

Millions of new EVs do mean much more demand for electricity, raising the question is the U.S. grid prepared.

First, it is important note that given the dynamics of the fleet turnover, even if 100 percent of new vehicle sales were electrified tomorrow, it would still take about 15 years before the entire fleet of on-road vehicles were electrified, and it will take considerably longer than that given current trends.

So we have some time to prepare America's electricity infrastructure, markets and regulations for widespread adoption. But we best not waste that time. REPEAT Project's 2024 current policy scenario expects EVs to consumer the equivalent of about eight percent of current total U.S. electricity use by 2030, and 17 percent by 2035.

To put it another way, by 2035 EVs could consume nearly as much electricity as is produced today by the entire fleet of nuclear power plants, or all non-hydro renewables combined. So while a lot of attention has recently been paid to increasing demand from data

centers and Artificial Intelligence (AI), electric vehicles are actually likely to be a larger driver of electricity demand growth over the next decade than artificial intelligence.

EV chargers also represent large new instantaneous power demands that could put stress on grid infrastructure. Coming home and plugging an EV into a Level 2 charger is like flipping the switch on about a dozen or more window-mounted air conditioning units. Fortunately, it should be possible to avoid charging EVs during peak periods.

Assuming only a modest level of flexible charging, REPEAT Project scenarios expect EVs to contribute less than four percent of peak U.S. electricity demand in 2030, and seven percent by 2035. Broader use of managed charging programs could further reduce if not eliminate the contribution of electric vehicles to peak grid uses.

The technology for that is available today. All that is missing are the appropriate incentives. Thank you.

Chairman WHITEHOUSE. Thank you very much. Ms. Gross, please proceed.

STATEMENT OF BRITTA GROSS, DIRECTOR OF TRANSPORTATION, ELECTRIC POWER RESEARCH INSTITUTE [6]

Ms. GROSS. Mr. Chairman, Mr. Ranking Member and Members of the Committee, thank you for the opportunity to testify today. I am Britta Gross, the Director of Transportation at EPRI. EPRI's an independent, non-profit energy research and development institute founded in 1972.

The electrification of the transportation sector is challenging from a grid perspective. Given the size of the load, the shorter lead times and the fact that cars and trucks are mobile, which means this load can appear just about anywhere on the grid.

But a load of this size is not unprecedented. Between 1965 and 2005, the grid adapted to a load twice as large as transportation. Electrifying transportation is also an opportunity to diversify the load that is currently on the grid, which normally shows up as early morning or late afternoon load peaks.

Utilities have to design for these peak loads to ensure electricity is reliable. But if utilities can take advantage of this typically flexible transportation resource, for example to charge most vehicles at night, this can help minimize new grid investments and ensure a more affordable transition. Though the grid impacts of electric transportation will eventually be felt across the generation, transmission and distribution systems, the near-term impacts are being felt on local distribution systems, those wires that lead to our homes or offices, fleet depots and charging sites today.

When we look at the overall impact that 279 million vehicles will have on the grid, the light duty vehicles, the cars most of us drive everyday, they will consume the most energy. But that load will be distributed across the entire grid, and its impact on a local distribution circuit is generally minimal.

But heavily concentrated fleets such as airport, car rental fleets and trucking fleets, will bring larger loads to these local distribution systems. So in EPRI's work though we consider all loads from

[6] Prepared statement of Ms. Gross appears in the appendix on page 58.

light duty vehicles to heavy duty vehicles, we are especially focused on fleets and trucking loads.

A challenge that is unique to transportation is the timing mismatch between vehicle procurement and the time it takes to make grid upgrades. A fleet operator can order a dozen heavy duty electric semis to be delivered in about four to six months today.

Yet the time it takes to bring additional power to that site for charging can take anywhere from 18 months on average to multiple years if more significant grid upgrades are required.

A second challenge is the market complexity. There are over 3,000 utilities and tens of thousands of fleet operators who have seldom had to deal with electric utilities. This means a fleet operator or a charging property developer with hundreds of sites nationwide has to be able to identify the right utility to begin planning efforts, and then figure out how to apply for service when utilities all use different processes.

To address these pain points, these key industries have to work together with utilities in unprecedented ways to share their electrification plans earlier with utilities and with utility regulators, so that there is advance knowledge of where and when loads will show up on the distribution system.

Drawing on the expertise of the utility industry, fleet operators, charger providers and vehicle manufacturers, we launched the EVs2Scale Initiative, and identified two critical tools to address current challenges and enable industry to get to scale.

The first is an interactive online map that identifies where and when transportation loads are likely to appear on the grid at a local distribution feeder level. As fleet operators and charging providers share more of their electrification plans with us, confidence grows in where to prioritize these grid investments.

And this map also now shows how much power is currently available on a utility's feeders, to serve these loads. To our knowledge, this is the first time available hosting capacity maps have been aggregated in a single location and made public. This online mapping tool is available today.

The second tool is a standardized service application template for the utility industry that provides fleet operators and charging developers with a common application form to request service for a charging site anywhere in the U.S.

This will eliminate much of the time, complexity and cost involved in reaching out to one utility at a time, and providing the same information to different utilities. It is analogous to the college Common App process. This common app tool is in development and will be available by the end of this year.

Leading companies in transportation electrification including Amazon, Enterprise, Daimler Truck, Volvo Truck and many others are working with EPRI and the utility industry leaders to design these tools to ensure they will address the barriers to large-scale electrification of transportation.

Thank you again to the Committee for the opportunity to share insights on this important topic. I look forward to answering your questions.

Chairman WHITEHOUSE. Thanks so much, Ms. Gross. Dr. Jenkins. Dr. Hinman, sorry.

STATEMENT OF MAUREEN HINMAN, CO-FOUNDER AND CHAIRWOMAN, SILVERADO POLICY ACCELERATOR [7]

Ms. HINMAN. Chairman Whitehouse, Ranking Member Grassley, Senator Graham and distinguished Members of the Committee, it is my sincere pleasure to appear before you today.

My name is Maureen Hinman, and I am the chair and co-founder of Silverado Policy Accelerator, a non-profit bipartisan think and do tank, focusing on developing novel policy solutions to our most pressing economic, environmental and national security challenges, through a focus on rigorous research, cross-domain policy engagement and granular policy implementation.

Fittingly, the challenges before the global battery and electric vehicle supply chain represent a fulcrum of these risks, challenging our ability to transition American lives and livelihoods to clean economy, maintain critical manufacturing base, and to preserve energy independence.

Currently, the EV battery sector is following the well-tread pattern of the United States acting as chief global innovator on critical emerging technologies, but falling short on the downstream industrial development because our market economy, bound by the rule of law, cannot reasonably compete with the openly predatory, non-market industrial policies of the Chinese Communist Party.

To change this script, we need to broaden the collective understanding of the impact the CCP's policies have on global competition and American national security. While yielding price distortions that have created low costs for consumers in the short term, the CCP's industrial policies ultimately create an unsustainable risk matrix for the United States.

For example, battery cell production costs, which comprise about 30 to 40 percent of the total vehicle production cost sell at $114 per kilowatt hour in the United States, compared to just $82 per kilowatt hour in China.

This difference is owed to the fact that materials remain about 30 percent cheaper in China.

A cursory look at the EV battery supply chain reveals a troubling state of play. China has captured the balance of global supply chains for refined minerals products, battery components and final products including battery cells and electric vehicles.

For several of the mined products that are unavailable within China itself, Chinese firms own a major stake in mines globally. China controls 28 percent of lithium mines, 41 percent of cobalt mines and nearly 20 percent of copper mines. The Chinese Communist Party (CCP) achieves these results through an industrial policy playbook I call "The Successes."

First, China sets specific goals and targets for what it determines to be priority sector, including through sector-specific five year plans. Next, the CCP shelters its infant industries from markets and competition using tools such as tariff and non-tariff barriers, and limits on foreign investment.

Simultaneously, China subsidizes target industries directly across the value chain and through a variety of payment systems, both formal and informal, including environmental arbitrage, and

[7] Prepared statement of Ms. Hinman appears in the appendix on page 70.

operating firms in a way that a market economy, underpinned by the rule of law, could simply not sustain.

Concurrently, Chinese firms and often the government itself are encouraged to acquire or outright steal foreign technologies and then merge and innovate upon them without the costs associated with legal acquisition of intellectual property. Once Chinese technologies have a toehold in global markets, the CCP subverts competition through a variety of market strategies, including undermining market pricing by building overcapacity and production untethered to real demand, and then exporting the surplus onto global markets at below cost prices, throttling or limiting supply to undermine competitors, making strategic investments in adjacent industries and critical infrastructure in key markets, and engaging in economic coercion and intimidation.

Finally, once China has established a near-market monopoly, Chinese firms sell everywhere at a price of their choosing, weaponizing supply chains in their favor.

The CCP's approach dwarfs other nations' efforts, not just in strategy but critically in scope, scale and consistency across the entirety of the supply chain. Put simply, China unfairly and illegally subsidizes more programs for more critical nodes over a longer period, and with more dollars.

The CCP's stated goal is to establish a global monopoly power in all critical industries, and they are well on their way to achieving this end in the EV battery market. The International Energy Agency anticipates that China's battery manufacturing capacity will account for 77 percent of world demand by 2030. These cheap batteries are no deal.

Effectively countering these efforts will require that the United States and market economies deploy coordinated, agile policies at a scale sufficient to correct for the market distortions and to protect U.S. public and private investments in industrial and environmental security.

Silverado and I remain at your service, as you devise policies that can meet this generational challenge. Senators, I thank you for your time.

Chairman WHITEHOUSE. Thank you so much, Ms. Hinman. Next is Mr. Schwietert.

STATEMENT OF DAVE SCHWIETERT, CHIEF GOVERNMENTAL AFFAIRS AND POLICY OFFICER, ALLIANCE FOR AUTOMOTIVE INNOVATION[8]

Mr. SCHWIETERT. Chairman Whitehouse, Ranking Member Grassley, Senator Graham and Members of the Committee, my name is David Schwietert. I am the Chief Government Affairs and Policy Officer at the Alliance for Automotive Innovation, representing the automakers, battery suppliers and producing most of the vehicles sold in the U.S.

Thank you for the invitation to testify and to share our perspective this morning on the U.S. electric vehicle market and policies to help accelerate this transition.

[8] Prepared statement of Mr. Schweitert appears in the appendix on page 80.

Today, I want to provide the auto industry perspective on the shift towards electrification, and to give the Committee a status report about not only what is working but also where there is work to be done.

Let us start with this. Electrification is transforming personal mobility. It is rewriting global supply chains, rebuilding domestic industrial base and creating jobs, and underpinning of the American economy and of course our national security in fundamental ways.

Today, 113 electrified products, sedans, pickups, utility vehicles and van models are available for sale in the U.S. This includes battery electric, plug-in hybrid and fuel cell vehicles. There is also increasingly efficient internal combustion engine technologies, lots of choices in power train and vehicle type, something for sale that meets the needs of every customer.

Choice is a priority for automakers. Last year, 9-1/2 percent of all U.S. light duty sales were electric or zero emission, up from 2.4 percent in just 2020. Even with this major momentum, we are in a challenging period, as Senator Graham noted this morning.

Yes, the EV market is growing, but the growth is slowing. One reason, most EV early adopters have already adopted the technology. Spikes in EV demand or choppy growth are certainly not surprising. In our view, this massive transformation is a marathon, not a sprint.

Shifting to electric personal mobility requires nothing short of a complete transformation of the global automotive industrial base, and the companies I represent are self-funding this transition, and have committed over $125 billion to EV production and battery manufacturing across the country so far.

This is expected to create 100,000 jobs at major facilities in South Carolina, Georgia, Tennessee, Alabama, Michigan, Ohio, Kentucky, Kansas, Indiana and other states. My written testimony includes a map of these cutting edge facilities all over the Midwest and Southeast.

Senators, we are building these vehicles and localizing these supply chains here at home right now. But the truth is these massive capital transformations are huge bets, and they are funded using profits generated from gas-powered vehicles. Automakers know that a shift at this scale will not happen overnight. The transition takes time and patience, and it is important to the Committee and policymakers to understand these dynamics as well.

Collectively, we cannot get ahead of the customer, especially when we are expanding public charging infrastructure or expanding grade capacity. Finding the right balance between markets and regulations and policy is absolutely key to remaining globally competitive.

Let me take one observation about supply chains. This is partially a point about geopolitics, namely China that controls a vast amount of raw materials and processing capacity for EV batteries. By 2035, the U.S. is anticipated to have supply gaps in excess of 50 percent of needed cathode and anode materials, nickel, cobalt, manganese and graphite.

At the same time, America's allies and rivals are trying to secure the same mineral supplies to support their own electrification

goals. Domestic mining and processing facilities face long lead times for permitting and development, as well as other obstacles.

This is an area where I believe Congressional attention and action is needed, and I am actually pleased to know this morning the Senate Energy Committee is taking up bipartisan permitting reform legislation.

One last point on China and U.S. competitiveness. At the turn of the century, China was manufacturing around two million vehicles. Today, they manufacture 30 million vehicles and have capacity for nearly 50 million. Nearly one-third of that production last year was for EVs alone.

In other words, China is manufacturing EVs equivalent to the entire U.S. manufacturing output. Without question, the future offers consumers more vehicle choices than ever, but we have got some challenges in front of us.

The auto industry and policymakers need a shared and a realistic vision of success when it comes to automotive electrification. Regardless of political views and what state you live in, we need an approach in this country that balances emission reductions and consumer choice, and expands our industrial base and America's ability to compete around the world. Thank you and I look forward to your questions.

Chairman WHITEHOUSE. Thanks very much. Before I turn to Mr. Davis, an administrative moment to let everybody know that Senator Graham and I are yielding our positions to first Senator Stabenow and then Ranking Member Grassley. So the order at the conclusion of Mr. Davis' five minutes will be Stabenow, Grassley, Whitehouse, Graham, Merkley, Braun, at least for openers. Mr. Davis, please proceed.

STATEMENT OF JEFF DAVIS, SENIOR FELLOW, ENO CENTER FOR TRANSPORTATION[9]

Mr. DAVIS. Mr. Chairman, Mr. Ranking Member, Senators, my name is Jeff Davis. I'm a Senior Fellow at the Eno Center for Transportation. Eno is a 501(c)(3) non-profit, non-partisan think tank founded by traffic pioneer William Phelps Eno in 1921.

All federal gasoline and diesel fuel tax receipts, along with trucking industry excises, have been deposited in a Highway Trust Fund since 1956, to make it clear that those levies on highway users could only be spent on specific highway programs.

Congress has since opened up the Trust Fund to highway safety and mass transit spending as well. The Highway Trust Fund has been fundamentally insolvent since 2008. Electrification did not start this problem, but it stands to make the problem much worse in the coming years.

The state of insolvency is the result of three trends. First, the rate at which driving on U.S. roads increases every year has leveled off. From the 1950's to the end of the 1970's, total vehicle miles traveled (VMT) on American roads, grew at a pace double every 16 years. It slowed so much now that the Federal Highway Administration this month projected a future rate at which it would take VMT 140 years to double.

[9] Prepared statement of Mr. Davis appears in the appendix on page 95.

Second, taxing the number of gallons of gasoline and diesel fuel used on roads was originally a proxy for taxing VMT. In 1976, the average passenger car on the road burned 7.2 gallons of gasoline for every 100 miles driven. Today, the average passenger car on the road burns four gallons of gas every 100 miles.

For SUVs and pickups, fuel efficiency has increased from 9.3 gallon per 100 miles in 1976 to 5.6 gallons per 100 miles today. Third, Congress has been unable to either keep Trust Fund spending constrained to tax receipt levels, or else increase tax receipts.

Congress now enacted five consecutive multi-year funding bills, in which case new funding in the final year of each bill was at least 25 percent above new Trust Fund taxes and interest. These trends caused the Highway Trust Fund to run out of money in 2008, before the first plug-in EV, and Congress has since provided $272 billion in ad hoc bailouts from the General Fund.

Now electrification is having its effects. According to the Congressional Budget Office's June 2024 forecast, the number of gallons of gasoline tax from the Highway Trust Fund will fall from about 138 billion gallons in 2024 to 89 billion gallons in 2034.

Annual gasoline tax receipts are projected to drop more than five percent per year starting in 2030. If we combine this newly-projected drop in gas tax revenues with currently predicted Trust Fund spending, annual cash deficits in the $13 billion a year range today will jump to an astounding $51 billion deficit in 2034, a decade from now.

Because the Trust Fund used to be solvent on a user pay basis and for other historic reasons, Trust Fund spending is exempt from most of the restrictions and controls in federal spending written into the Budget Act and subsequent process statutes in this Committee's jurisdiction.

If one were to try to fix that projected $51 billion Trust Fund deficit in 2034 solely by increasing gasoline taxes, and let me emphasize absolutely no one is advocating this, the current 18.3 cent per gallon gasoline tax to the Trust Fund will need to be increased by about 58 cents per gallon, to a total tax of about 76 cents per gallon of gasoline.

There are alternatives to motor fuel taxes that could continue the user pay/user benefit paradigm that underlies federal trust funds, which I address in my written testimony, but none are nearly easy to administer as the gasoline tax.

Going from fuel to vehicle as the subject of taxation, means going from about 1,300 points of collection of gasoline taxes and diesel taxes, to 279 million points of collection, which is the number of registered private vehicles in the U.S. in 2022. Taxing vehicles will be over 200,000 times as much work for the Internal Revenue Service (IRS) as taxing motor fuel.

In short, if rapid decarbonization of highway transportation is to be federal policy goal, Congress should carefully consider whether and how to replace the fossil fuel-based highway user taxes that currently support highway and mass transportation with some other revenue source. Thank you, and I look forward to your questions.

Chairman WHITEHOUSE. Thanks very much, and I will now turn to the distinguished Senator from Michigan, who I think knows

and cares more about the auto industry than pretty much anybody around here, Senator Stabenow.

STATEMENT OF SENATOR STABENOW

Senator STABENOW. Well thank you so much, Mr. Chairman and Senator Graham, who I know cares passionately about manufacturing. We share that in common, and I could talk all day. I will not. I know I do not have all day to talk about this.

But let me first start by saying that no one is forcing Americans to buy electric vehicle, but I have one. Nobody forced me to get it. My price did not go up with the Tax Code. Unfortunately, the latest round of the Tax Code is so complicated and limiting that I do not—it is certainly not helping as much as it could help.

But I will say the biggest issue is charging stations, and I am about to test that again. I mentioned to the Chairman I have not driven my car from here to Michigan in about a year, and I am going to test it again to see how many charging stations we have, to be able to get me back to Michigan in a couple of days.

I do want it emphasized, and I said this before, you know in 1917, when Congress began heavily subsidizing oil production because of fines down in Texas, we did not have gas stations on every corner either. And in fact at the same time, Henry Ford and Thomas Edison were working to develop a battery operated car, but they had no subsidies.

So Congress picked a winner and they won for over 100 years, and now we are trying to expand this out. And I would say also, Senator Graham, I agree with you. We have a lot of issues, and I guess what I would say is I think we know more of what the answers are; we just need to do it, and then we need to find out where we need to, you know, know more about this.

But chargers not, you know, we know we need more charging stations. Electric grid capacity, absolutely. Both of those things are beginning to happen. We are investing in that through the Bipartisan Infrastructure bill. More usable consumer credit; more American access to rare earth materials.

We actually have new mining capacity, lithium capacity being developed in Nevada, which is very exciting because we are way behind. I would also say that our companies are looking at using different kinds of technology, that do not take all those rare earth materials.

Also recycling, which is becoming a job creator in Michigan for materials. So there is a lot of things. More battery production, which we know that we need in the United States, and of course we need to change the Highway Trust Fund, absolutely.

But I support American innovation. I will tell you in Michigan right now, we have a stretch of road being built, that actually has the charging technology in the road, Mr. Chairman. So that when you drive, you will automatically have your car charged.

So I support American innovation. Are we there? No. But we are certainly getting there, and I would also say this. Our biggest competitor, there is no question about it, is China. But right now our companies are competing against the country. That is what is happening. There is not a level playing field.

Specifically, China is coming for us. They want to corner the EV market, and their government has heavily subsidized this effort. And they have also been willing to steal our patents, I should tell you, coming from Michigan.

So what do we do? I mean we, I believe, have the smartest most talented auto workers and automakers in the world. We need to do our part to help them create a level playing field, and that is why I am so glad that we are doing this hearing, because we are talking about more than ten million good-paying jobs right now.

So Mr. Jenkins, in your testimony you mentioned the most important thing Congress can do now for the EV sector is to provide policy certainty and continuity. Could you talk a little bit more about that? I know our private sector, our automakers are saying just give me certainty about what is going on.

Dr. JENKINS. Thank you, Senator. By that I mean that the tax credits that were implemented in the Inflation Reduction Act (IRA) have just been finalized in terms of their guidance, and many of the programs authorized and funded by the Infrastructure law are authorized to spend down through 2026.

So these programs are just getting underway, and industry needs to know that they can count on a stable policy environment, to make the hundreds of billions of dollars of investment they have announced across the United States, to do that with confidence to drive innovation and to expand our supply chains.

So I think the most important thing that can be done now is to provide that confidence for the industry with bipartisan support for the maintenance of existing policies. Also note that on the consumer side, consumers are just getting familiar with how these tax credits work.

You know January this year, we started to offer at point of sale rebates. That is a new thing for people. So there is a lot for people to get familiar with. We just set the stage. Let us let our American companies and innovators play on that stage and do what they do best.

Senator STABENOW. Great, thank you. And Mr. Schwietert, would you just briefly comment on the same issue?

Mr. SCHWIETERT. Sure, Senator. Obviously policy certainty is absolutely essential. I mean you talked about not just the certainty as it relates to potential tax incentives, but in a competitive environment, we need to look beyond just five or ten years. We need to ensure that policies are in place to ensure that the U.S. is competitive, not just tomorrow but well beyond that.

So that certainty is important and Senator as you know, oftentimes the general public forgets about the long lead times in automobile manufacturing and production. The decisions made today in calendar year '24, model year '25, are effectively locked. Manufacturers are already looking out to model years '28.

So policies that change today have a material impact, but they do not fully get realized for years to come. So that is why that policy certainty is so important. We need to ensure incentives are here to build resilient supply chains, to support consumers as well as to attract the investment and the jobs that we are witnessing.

Senator STABENOW. Thank you. Thank you, Mr. Chairman.

Chairman WHITEHOUSE. Thank you very much Chairman Stabenow. Ranking Member Grassley.

Senator GRASSLEY. I am going to start with Dr. Jenkins. Your written testimony notes "President Biden established a target to cut U.S. greenhouse gas emissions to half of peak levels by 2030. To reach this goal, electric vehicles sales should be making up about 50 percent of the light duty vehicle market by that date, up about fivefold from today. Your testimony also recognized "a remarkable collapse in EV sales this year."

Given the evident lack of demand for EVs, is this Biden-Harris administration goal of five times today's EV sales attainable by 2030?

Dr. JENKINS. Great questions, Senator Grassley. At this stage, I should note that is a goal. It is non-binding, and we will see where consumers go with the products that are being offered on the market. I will note as I did in my oral testimony that most of the collapse in sales, all of it really is Tesla, who is the market leader responsible for about 45 percent of all plug-in vehicle sales.

So if they are stumbling to sell their vehicles, it is very difficult to see the overall market expand at a pace that is consistent with that goal. But the rest of the market is becoming increasingly diversified. We are seeing strong growth in a variety of companies offering more and more products that consumers want, at price points that they can afford, and we are seeing increased interest from consumers. As I mentioned, over half of consumers surveyed are interested in buying an EV within the next year. Not all of them will do so, but that indicates substantial opportunity to grow, and we are in the early stages of this transition.

Senator GRASSLEY. Dr. Schwietert, your written testimony states in bold "If U.S. policymakers do not support the development, commercialization and acceptance of electrified vehicles, our nation risks becoming more dependent on foreign sources for raw materials and critical minerals and the future defined by our competitors."

You also note that "China is manufacturing EVs on a scale equivalent to the entire manufacturing output of the auto industry in the United States." The left is holding up the environmental permitting reform necessary to mine for the domestic critical mineral which we need to compete with China, while urging a massive EV market share expansion. It just does not add up.

So my question. Should we mine for more critical minerals domestically, and what specific pieces of environmental legislation should we amend to improve our mining capacity? And let me suggest, before you answer that, that maybe a couple of months ago I read about the nickel mining in Indonesia at the same time that our own government was not allowing such mining in Minnesota.

Mr. SCHWIETERT. Well Senator, thank you for those questions. I would like to underscore that you know, again there is a record number of options and choices available to consumers today. As it relates to the supply chains, the best time to start was yesterday. The next best time on permitting was to start today.

So we cannot have permitting reform fast enough, as it relates to addressing not only what the U.S. may need for future supply chain resilience, but also working with our allies and partners,

knowing that obviously auto standards are set well into the future, and even if we started today with mining and extracting in the U.S., it might be 15 or more years before we may see the benefits of that extraction processing.

So again, I think that underscores the critical importance. If the U.S. is to remain competitive across all vehicle platforms, that the supply chain piece is fundamental.

Senator GRASSLEY. I think you expressed the inconsistency between environmental policies, and what the same environmentalists think we ought to do for EV vehicles.

Mr. Davis, as you know, the federal Highway Trust Fund has operated at a deficit. It is currently projected by the Congressional Budget Office to become insolvent in 2028, even though the existing taxes that fund the Trust Fund generally adhere to user pays principle for surface transportation.

The federal government has not followed the lead of at least 24 states that impose higher registration fees on EVs, to compensate for lost gas revenue. Do you agree that if we want to maintain the user fee pays principle that has traditionally guided these Trust Fund taxes, we should ensure EVs are also paying their fair share?

Mr. DAVIS. Thank you, Senator. If you want to maintain the user pay/user benefit principle, that all vehicles that use the road should pay something, the question of what would the proper way be to tax EVs depends on first of all, if the government is going to shift away from gasoline tax to another method in general. If so, you tax EVs like you tax the rest of them on mileage or whatever.

If not, the states that are doing EV registration fees, as long as they are around the ballpark average of what an internal combustion vehicle of the same size and actual weight would do on average mileage, is a sort of proxy.

It is not a great proxy because it does not differentiate between the car that drives 3,000 a year and the car that drives 30,000 a year. But right now, it is about $89 a year is the average in gasoline taxes paid for the passenger car, and it is about $110 in federal fuel taxes paid for a larger Sport Utility Vehicle (SUV) or pickup truck.

If annual registration for EVs were in that ballpark, you could honestly say that it was as close in approximation of a true user fee as it would easier for the IRS to administer, and would be consistent with the user pay/user benefit principle.

Chairman WHITEHOUSE. Thank you very much, Senator Grassley. Ms. Gross, you and Dr. Jenkins both talked about how EVs can contribute to our electric grid security through peak shaving, or even putting power back into the grid when it is needed.

In terms of peak shaving, you would need the capacity to tell charging EVs to stop charging through the peak period, and then automatically resume charging. So you would need a signal to the automobile from the utility, and willingness of the consumer to accept that.

To do that peak shaving function, what does Congress need to do to help? Are there standards that need to be built in? Is industry doing that on its own? Let me ask you to go first, and Dr. Jenkins if you had added thoughts, you can follow up. But Ms. Gross, you first, please.

Ms. GROSS. Sure, happy. Thank you Senator for the question. Happy to talk through this one. Yeah, the electric vehicles, it is unlike a load we have ever seen before on the grid. It is the smartest, biggest and most flexible load. So there is this huge opportunity to charge the vehicles at night. Many, not all, not all. Not if you are taking a long distance trip or you are trucking and you have to travel during the day.

But that opportunity to charge when the grid has spare capacity is a huge opportunity. It is going to keep our costs low on the grid too, that capital investment in ever increasing the peak that has to be served on the load—on the grid.

So this idea that V2G and V1G, either single direction, which is basically smart charging, charge when I want to.

Chairman WHITEHOUSE. V2G meaning vehicle to grid?

Ms. GROSS. Beg your pardon?

Chairman WHITEHOUSE. V2G meaning vehicle to grid?

Ms. GROSS. Vehicle to grid, perfect. Vehicle to grid is—and also vehicle to grid meaning—and also bidirectional. So that not only can I take power from the grid when there is plenty of surplus capacity, at night or maybe when a lot of sun is shining in some of the states, but I can also give back to the grid when there are times when the grid is struggling to keep up with maybe load on the grid.

And so V2G is certainly a promise that is out there. There is a lot of work getting done in that area, but smart charging is here today.

Chairman WHITEHOUSE. Let me ask you and Dr. Jenkins both to provide a written recommendation to Senator Graham and to myself, about what we might do working together to make sure that as EVs come online, they have the necessary capability so that the consumer can take advantage of that capability.

And also, if you are going to offer a utility that capability, that adds value to the utility. What benefit should the consumer get from the utility for offering up their vehicle as a resource, either by taking it willingly offline during peak periods, or by limiting charging to the night or however that works.

It is a bit of a complicated question, but I think there is room for real bipartisan activity here, and I would love to have a recommendation from both of you.

In my remaining two minutes, Ms. Hinman, first of all thank you for all your terrific work. You have described the economic and national security risks of Chinese, which you called "weaponized" supply chains. Is there also a climate risk associated with China's supply chains?

Ms. HINMAN. Yes. Thank you so much, Senator, absolutely. So China——

Chairman WHITEHOUSE. And is there a policy that would help fix that?

Ms. HINMAN. I think I—I think I know of at least one. China's rent-seeking also arrives in this form of sort of what we call environmental arbitrage or creating a pollution subsidy.

So essentially how it works, even though China has the technical capacity to enforce its own environmental rules, because it pro-

duces many of those technologies and in fact is the world's leading exporter of air pollution control technology.

There is widespread evidence that China, particularly among their state-owned enterprises, intentionally reduces its inspection rates, and then refuses to operate its air pollution control machinery. Now if you look at a coal fire power plant scrubber, if you leave that scrubber off, that reduces your energy cost of operation of air pollution control technologies by about 15 to 20 percent total.

So you are getting a 15 to 20 percent pollution subsidy on your total energy production for everything that you produce that comes off that coal fire power plant. I do not know a single manufacturing firm in the United States that would not love a 20 percent subsidy on their energy costs. This is deeply unfair. It is unfair in terms of competitive sense, but also in a climate and environmental sense, because that is Sulphur Oxides (SOx), Nitrogen Oxides (NOx), and of course carbon and other climate pollutants being pumped up into the air at a deeply unfair rate, that advances our decline in terms of climate stability.

One important way that we could counter this is that both the United States and friends could levy a border fee that corrects for this market imbalance and levels the playing field in terms of both climate and other pollution values.

The figures behind this are known, and I know there are several very good bills floating around the Hill right now, both on the quantification side, but also on the particulars on those measures and how we might work with partners.

Chairman WHITEHOUSE. And that makes the perfect segue to Senator Graham, who along with Senator Cassidy, has a bill to that effect, and I would note that Ambassador Lighthizer, who was President Trump's Trade Representative, is also a fan of that policy.

So with that, let me turn it over to Senator Graham and thank him again for helping put this hearing together.

Senator GRAHAM. And I will thank you and Senator Grassley for having it, because this is the first of many conversations I think we are going to have. Mr. Schwietert, did I say your name right?

Mr. SCHWIETERT. Schwietert.

Senator GRAHAM. Schwietert, I am sorry.

Mr. SCHWIETERT. It is a mouthful.

Senator GRAHAM. How about David? Okay. David. Are car companies making electric vehicles because they have to or they want to?

Mr. SCHWIETERT. Senator, I think there is no question, as you noted earlier, that electrification is the future. So for purposes——

Senator GRAHAM. Well, I mean is it the future based on consumer demand or government policy?

Mr. SCHWIETERT. I would say it is a mix. Obviously, I think regulations are positive.

Senator GRAHAM. Well, I agree. Mr. Jenkins, why does—does China make electric vehicles because of climate policy?

Dr. JENKINS. No. It is primarily a response to its strategic manufacturing policy and air pollution reduction goals. They basically strategically selected electric vehicles as an opportunity to leapfrog

internal combustion engine manufacturing, which is an area that the west, the United States has obviously dominated.

Senator GRAHAM. But it is not driven by climate. I mean——

Mr. SCHWIETERT. It's not primarily driven by climate.

Senator GRAHAM [continuing]. If you are really worried about the climate, you would not use a coal fire plant to power an electric vehicle plant, right?

Mr. SCHWIETERT. Well, with China's average grid mix, it actually does reduce greenhouse gas emissions relative to an internal combustion engine.

Senator GRAHAM. So are they making all these cars because they are worried about the environment?

Mr. SCHWIETERT. They are worried primarily about air pollution and their strategic role in manufacturing in the global market.

Senator GRAHAM. Okay, Ms. Hinman. Why do we make electric cars? Is it because of consumer demand or government policy?

Mr. SCHWIETERT. My sense is it is, per my colleague to my left, is because it is a combination of the two. But you know, we are a market economy, so the government does work——

Senator GRAHAM. Right. So some people want them, right? So David, if we did away with the mandate or the goal of having half the vehicle electrified, a government policy, by 2035 what percentage of the cars on the road do you think would be electric without a mandate?

Mr. SCHWIETERT. Senator, that is a very good question. Last year was 9.5 percent. So if we fast forward, it is hard to say. A lot of it depends on how reliant we are——

Senator GRAHAM. Well, let us just say we did away with the mandate. Trump says he wants to do away—we will end the electric car manufacturing in America.

Mr. SCHWIETERT. No. However, we might have unbalanced things as it relates to whether or not the U.S. is competitive as it relates to some of those supportive policies. Whether it is tax incentives or——

Senator GRAHAM. Right.

Mr. SCHWIETERT. Yes.

Senator GRAHAM. So Ms. Hinman? Is that right, Hinman?

Mr. SCHWIETERT. It is Hinman.

Senator GRAHAM. Okay, all right. Is the dominance of China irreversible in this supply chain?

Ms. HINMAN. I believe not, absolutely not. I believe the U.S. and its allies and friends, if we move quickly to create, agile, responsive and coordinated policies, could flip the script and reestablish market dynamics in the global economy.

Senator GRAHAM. Okay. I want to talk to you about that in more detail. So forget about what we do here, Mr. Jenkins. Does everybody agree China is going to continue to make a bunch of electric vehicles no matter what we do.

Dr. JENKINS. Correct.

Senator GRAHAM. Everybody agree with that?

Ms. HINMAN. Yes sir.

Senator GRAHAM. For whatever reason, they are going to make a bunch of them, and it seems to me that the supply chain to make a battery, if we do not change our policy, is going to be so domi-

nated by China we may just have lost this entire area of our economy. Is that fair to say, David?

Mr. SCHWIETERT. Yes. Senator I would note, and this is something that hopefully resonates with this Committee. If we did not have the regulations, obviously electrification is the future. If the U.S. is taking itself off the global stage for competition, for instance, on average we are exporting two million vehicles a year.

So if the U.S. is not competing on electrification and the rest of the world is, we have got a real risk.

Senator GRAHAM. Well, that is what BMW is trying to do and Volvo in South Carolina. Can you be for EVs and against mining? Mr. Jenkins.

Dr. JENKINS. Well, I think we would need to source the requisite materials for the entire supply chain, and I will note the environmental impact of that is substantially lower than mining billions of tons of coal or billions of tons equivalent of oil each year that light on fire.

Senator GRAHAM. So if you—okay. That is good. So if you are for EVs, you need to be for mining here at home. Does that make—does everybody agree with that? If you are for EVs, you need to have a robust grid. Do you agree with that, Ms. Gross?

Ms. GROSS. I agree with that.

Senator GRAHAM. Because the demand is real. Mr. Jenkins, are you opposed to natural gas as being part of the future of the grid?

Dr. JENKINS. Natural gas generation is going to remain a part of the grid for quite some time, particularly for capacity needs, so to meet peak demands. And so——

Senator GRAHAM. So without natural gas, it would be pretty unrealistic to meet the demand?

Dr. JENKINS. That said, we are going to see a reduction in the amount of natural gas consumed by those power plants as we scale up American renewable energy resources that can displace gas burnt, if not the capacity.

Senator GRAHAM. Yeah, but as a—is a baseload fuel, are renewables going to get us to where we need to go without natural gas and nuclear power?

Dr. JENKINS. Senator, we do not need a baseload fuel. We need as a combination of resources that can meet all of demands throughout the year. Renewables are great at supplying energy, but they are reliably unreliable. We know they are not going to be there all the time.

Senator GRAHAM. So natural gas is——

Dr. JENKINS. And so gas power plants are dispatchable, as well as nuclear power plants.

Senator GRAHAM. This is a rational discussion. I know I am 18 seconds over here.

Chairman WHITEHOUSE. That is okay.

Senator GRAHAM. What I want to do is just think it through. I am a car heavy state, and they are making EVs and I agree with that. I think the mandate has probably pushed us. I do not like it, but I think consumers are going to demand some electric vehicles. China is not going to change their policy.

It seems to be a part of the future economically, and if we do not watch it we are going to be out of the battery business. And I

would just like to have a rational approach to what I think is an irreversible trend, that there will be more electric cars over time not less.

And I think it would be a shame to not play in this space, for whatever reason drives you, no pun intended. I think America's got to make some real hard decisions quickly, and if we do it, we will dominate this market, no matter how big it is or how small it might be. I would like to dominate this market for a lot of reasons, or at least be competitive.

I met with the Chinese Ambassador yesterday, and I will close with this. I said we are going to have an honest discussion about the way you produce electric cars. Get ready for that discussion.

Chairman WHITEHOUSE. I think before I turn to Senator Merkley, there is a very significant bipartisan common cause towards cleaner energy, lower emissions and taking back Chinese dominance in this area, that they have achieved, to use Ms. Hinman's words unfairly, through mercantilistic interventions and cheating, essentially, in the marketplace.

So we need to have ways to respond to that, to make sure we are not dependent on their supply chains for national security, economic and climate safety reasons. And I think there is a big bipartisan opportunity.

So I am delighted that we are having this, and Senator Graham, I fully look forward to working with you to flesh out what those strong bipartisan policies look like that support our auto manufacturers and the workers who build these beautiful vehicles.

Senator MERKLEY, and then here is the—here is the roster. Senator Merkley, Senator Braun, Senator Kaine, Senator Johnson.

STATEMENT OF SENATOR MERKLEY

Senator MERKLEY. Thank you, Mr. Chairman, and certainly one of the reasons there is so much interest in my home state in electrics is because of what is happening right now. We have 121 fires burning in my state. Over one million acres have already burned this year. Two weeks ago, we had more acreage of flame than all the rest of the United States combined. Massive impact on all parts of our state, both with the fires and the smoke. We simply have to dramatically reduce the amount of methane and carbon dioxide we are putting into the atmosphere.

But I will tell you another reason it is so appealing, is because of the cost differential. Now Mr. Jenkins or Dr. Jenkins, you were talking about the peak load pricing challenge. My local utility offers a plan where if I am charging after 9:00 p.m., it is 7.4 cents per kilowatt hour. If I charge from 5:00 to 9:00 p.m., which is peak load in my area, it is 33 cents.

So we have a little note on our dryer, reminding us to turn it on after 9:00 p.m. But it really has an impact on simply turning on our charger at 9:00 p.m. at night, and at 220 volts our car is completely charged, even though it is depleted by the next morning.

Mr. Chairman, you were mentioning the question of whether we need a sophisticated system to tell the cars. This is a system that does not require anything sophisticated. It is just a pricing plan where people remember to turn on their electric chargers for their

chargers at night, and it shifts a huge part of our electric consumption in that fashion.

Now let us take that cost that we are paying of 7.4 cents, let us run it off to 8 cents. We get over 4 miles per kilowatt hour. Basic math, it is costing us 2 cents per mile to charge our—or to drive our car. Now we will take our gas and 40 miles per gallon at $4, that is ten cents.

So it is five times more expensive to drive a fuel powered car. Why do we never hear about this? If it was the reverse, and driving your electric car was five times more expensive than driving your fuel combustion car, you can bet every fossil fuel company in America would be publicizing that.

Why do we not hear that it is five times cheaper to drive an electric car? Dr. Jenkins, you want to comment on that?

Dr. JENKINS. Well, I do think you raise a great point, Senator Merkley. We are at the early stages of this transition, and I think we do need a lot more advertising and proactive efforts to educate the public from the industry itself, from automakers and dealerships, and potentially from public sources as well. It is a significant cost differential.

The up-front purchase prices are higher, and that is another reason why the tax credits established by the IRA are critical to bring down that up-front purchase price. If you build that into the cost of a lease, which many people are turning to purchase new EVs, that is basically a $7,500 additional down payment on the—on the vehicle, and that covers a large amount of the depreciation that you would normally pay for in your lease payments.

And that is really the cheapest vehicles on the market right now to lease in virtually every category are electric vehicles. So it is not just cheaper when you operate it, it could be cheaper on a monthly payment basis as well today.

Senator MERKLEY. Well, I have talked to a lot of folks who previously were intimidated by those high up-front prices, and they are buying used electrics. Now that we are this far into it, they are buying a used Tesla, or a used whatever, and because even though the amount of range declines modestly over time, you are still starting with enough range. You have a lot of range left.

I want to—so it is really becoming much more affordable to middle class families through both—both points that you are making, about leasing and about being able to buy a used vehicle.

I want to turn to this issue that Senator Stabenow raised about the charging stations. One of the things that has been interesting is how slowly we developed a national standard for the interface. We now have the North American charging standard, the NACS standard.

Rivian has adopted it. Ford is adopting it or has adopted it. Chevy is adopting it next year. So Mr. Chairman, your Chevy Bolt, your next Chevy Bolt will be able to use the NACS standard. And Nissan's adopting it.

So that is starting to become a solved problem. But one of the ways we could rapidly expand the ability of folks who have cars currently is to have electric charging stations—chargers at rest stops. However, national law, federal law prohibits that. Is that something we should change?

Dr. JENKINS. Yes.

Senator MERKLEY. Ms. Gross, would you like to comment on that?

Ms. GROSS. Well, we do not normally comment on policy at EPRI.

Senator MERKLEY. Well, if you do not want to comment, somebody else, anybody else want to comment?

Ms. GROSS. However, more charging stations are, you know, required. They are going to be necessary and they are going to be required for consumers. If consumers demand it, they are going to need it.

Senator MERKLEY. Yeah. Are all the charging stations that are going to be deployed under the Inflation Reduction Act going to have a NACS standard? Does anybody know the answer to that?

Dr. JENKINS. I do not believe that is required, but it is increasingly the case that all chargers are converging to the NACS standard going forward, and there are adaptors now coming to market that allow interoperability. There is already the reverse. You can plug your Tesla into a Combined Charging System (CSS) charge port with an adaptor.

I am still waiting for Ford to ship me my adaptor for the Mustang Mach E, but they are sending them for free to all owners of existing Ford vehicles. So this is going to become an increasingly solved problem, as you noted.

Senator MERKLEY. This is the Magic dock adaptor, right?

Dr. JENKINS. Or just any others. So yeah. So that I am—you can have your own adaptor you just carry with you in your trunk.

Senator MERKLEY. Okay. Listen, my time is up. But I just want to close with this, everyone. It is five times cheaper per mile to drive an electric, and if you buy a used electric, you do not have to worry about the up-front high cost because the depreciation has been paid by somebody else, and it is a sweet deal.

Chairman WHITEHOUSE. And Dr. Jenkins had to show off that he has a Mustang Mach E after I said I only had Chevy Bolts. Senator Braun.

STATEMENT OF SENATOR BRAUN

Senator BRAUN. Thank you, Mr. Chairman. The average cost of an electric vehicle is over $17,000 more than the average price of a gas-powered vehicle. So we are doing a lot that is force-feeding something in that is very expensive.

We have got other issues with it in the context of here, we are borrowing now a couple of trillion dollars a year, where it was just a trillion dollars six months ago, and everything we do new, it is 100 percent borrowed.

I think what I am wondering, and I would like to ask Dr. Jenkins, Ms. Gross and Ms. Hinman, given this context, do the three of you believe that consumers should have the right to choose the type of vehicle that best fits their own needs, economic circumstances? Or do you think we ought to be orchestrating this from here, when we have never even figured out how to spend less than we take in, and we are currently borrowing from these very same consumers and others around the world, to the tune of $2 trillion a year currently?

Dr. JENKINS. Senator, I would say that consumers do you have the option to choose the vehicles that best suit them. We have a wide variety of offerings on the market today and no requirement that anyone anywhere purchases an electric vehicle.

The prices are increasingly affordable as well, so this is a moving target. Cost of batteries, which are the largest component of an electric vehicle, have fallen by about 50 percent over the last three years. They are expected to continue to decline going forward.

And so that cost premium, you said it is $17,000. I looked right now in the compact SUVs category like, you know, a Mustang Mach E or Tesla Model Y, the gap is about $10,000 up front, and again, the cost of ownership is quite low. So the total cost of ownership is already about at parity.

Senator BRAUN. Do you know the current federal subsidy that goes into electric vehicles, what the amount is per vehicle?

Dr. JENKINS. It is up to $7,500 for the consumer purchases.

Senator BRAUN. Do you know what that is in total that we are currently doing?

Dr. JENKINS. I believe I just read it was about 125 billion or——

Senator BRAUN. And then would you agree that all of that is being borrowed to push that onto consumers?

Dr. JENKINS. Well, CBO's estimate was that the Inflation Reduction Act was more than paid for, so I am not sure I agree with that.

Senator BRAUN. I would say that is a fake pay for, but thank you for your opinion. Okay. We will go on to Ms. Gross and Ms. Hinman.

Ms. GROSS. Senator, thank you for that question. I will just add, without commenting too much on the policy, I will just add that consumers are choosing these vehicles. Senator Merkley talked about the energy wallet, the fact that you can feel it in your pocketbook when you do not have to go to the gas station, and the cost of electricity is so much less when you are charging an electric vehicle.

I will also say that truck drivers, data out there shows that truck drivers actually like driving electric vehicles, because you do not experience that fatigue that you have with the rumble and the roar of a combustion engine vehicle. So this issue of fatigue is also a safety issue.

So we are starting to see there is—there are reasons to want to drive an electric vehicle, based on data that is out there that are really extremely compelling for automakers and truck drivers out there, and manufacturers.

Senator BRAUN. Thank you. Ms. Hinman.

Ms. HINMAN. Yeah. Thank you so much, Senator. I think it is a little bit of an uncomfortable conversation to have about the fact that we have got a very large predatory market who is influencing prices up and down the value chain, in ways that U.S.—that Americans just cannot simply compete with.

And to me, this sense of sort of how much we are spending is really hard to sort of square against the massive amount of spend and predatory nature that occurs from the Chinese Communist Party. You know, in a perfect world this would be a pure, you know, a global market, right? And we would not feel the need to have to subsidize in the way that we do.

I do think there is scope for new tools, particularly trade policy tools and environmental policy tools at the border. But certainly, you know, I think some of these distortions we have to kind of appreciate its source, which is not coming from Americans, but it is coming from an adversary overseas.

Senator BRAUN. Thank you, and I have got one more question. But I would like to also tell you that it was about nine months ago, and I was holding up a letter from 4,000 dealers that said please do not send us any more EVs. I am for the cleanest, least expensive and like the idea that it is out there as a choice.

But 4,000 dealers said they are choking on them. It is even hurt their own enterprises to have to tie it up, because they are not moving at the speed at which the government would like to see it, even when they are offering $7,500 a pop.

I have got one more question, and I would like a yes or no answer on the part of all of you. I am for whatever is going to be the cleanest, least expensive fuel in the long run, and even how that impacts electric generation, transportation, the whole gamut.

There has been a very robust discussion in the Senate Climate Caucus on that, which I was part of that. We still have great conversations. But a lot of it says that so much of this is going to be due to technological breakthroughs in the future, and as much as we would like to see those results in the present, we either cannot afford it, just does not make sense to do it.

Now as it relates to electric vehicles, to all witnesses does the U.S. currently have the grid capacity to sustain a growing domestic vehicle fleet, that is being mandated on consumers by policies from the Biden administration? And respecting time, just give me a yes or a no. Dr. Jenkins.

Dr. JENKINS. We can expand the grid at a pace that is sufficient to accommodate all of those EVs, as we have in the past. This is not an unprecedented challenge. It is one that American utilities can easily meet.

Ms. GROSS. With planning and investment, the pace can be met and the grid can be ready.

Ms. HINMAN. Yes.

Mr. SCHWIETERT. We can meet—we can meet the demands today, and we need to plan for the future, absolutely.

Mr. DAVIS. Yes. If you start today and anticipate where the EV demand will be ten years from now, you can get there.

Senator BRAUN. Thank you so much.

Dr. JENKINS. Mr. Chairman, can I correct the record on one of the statements I just made. The total tax outlays this year, according to Treasury are $1 billion for the EV subsidies to date. So that is through the first half of this year. I think I misspoke by several orders of magnitude, so I apologize about that.

Chairman WHITEHOUSE. Thank you, Dr. Jenkins. Senator Kaine.

STATEMENT OF SENATOR KAINE

Senator KAINE. Thank you, Mr. Chair and I—I love walking in and seeing the title of the hearing "Bipartisan Senate Budget Committee Hearing." And I appreciate that this has been a hearing and a discussion with witnesses who are really trying to explore an op-

portunity that has a real upside, that is going to need some planning and investment.

In Virginia, there is 100,000 electric vehicles on the road in my Commonwealth of eight plus million people, and those who charge at their home pay about a dollar a gallon. That is what folks in Virginia are paying if they charge at their home.

We need to have some advances in charging. In Richmond where I live, a lot of people do not have driveways, apartments or multifamily communities. So more curbside, rest area. We need to make sure in the deployment of charging technologies we are not just look at passenger vehicles, but we are also looking at trucks.

Every Volvo Mack truck that you see on the road in North America is made in Dublin, Virginia, which is in Appalachia, about 3,000 workers there. In the last ten days, the Department of Energy (DOE) announced a $208 million investment through the Inflation Reduction Act, to match an equivalent investment by the company to expand electric vehicle production.

I would encourage, if anybody ever wants to do something fun, come with me to Dublin and drive an over-the-road Volvo Mack truck on their test track. It is about a three mile test track. You will get in that vehicle and it is so smooth you think you are going 35, and I looked down at the speedometer, I was going 65.

The point about fatigue was remarkable. A diesel truck just has this kind of low grade rattle that really takes a toll on over-the-road drivers if they are in that truck for multiple hours a day, whereas the electric vehicle is as smooth as can be.

And so it is going to be kind of a fatigue health improvement for those who are doing this job. It is hard to recruit enough over-the-road drivers now. I think this is a technology that might make it a little bit easier.

But in addition to the $208 million investment into the Volvo plant through the IRA, there has also been the announcement in the last year of an $100 million investment through DOE to a company called Microporous, a company that will manufacture separators for lithium ion batteries that are necessary for the EV supply chain, and that is likely to land in rural Southside Virginia near Danville.

Both Dublin, Virginia and Danville, Virginia are in economically hard-hit parts of the state. They are both in rural Virginia. Talk a little bit about how the growth of an EV supply chain could be a powerful economic development tool for rural America.

Dr. JENKINS. Thanks, Senator. Look, my father is from Youngstown, Ohio. I grew up in Oregon in the shadow of the timber industry and forest products industry that had decayed during my childhood.

I have been hearing, you know, politicians talking about bringing manufacturing jobs back to America literally my entire life, right, and we are finally doing it, right? We are seeing those investments now across, you know, EVs, clean energy, batteries, semiconductors, et cetera.

So we are already seeing over $140 billion of announced investment in battery manufacturing and supply chain capacity across the country, and $57 billion in EV manufacturing. That is since the Infrastructure law passed. That could support over 240,000 jobs.

And we all know these are more than just the direct employment, right? These are anchor employers in these industries or in these communities. And over—the vast majority of those are located in rural and exurban communities or communities who are designated as energy communities by the Inflation Reduction Act.

So these are exactly the communities that are seeing a renewed economic future.

Senator KAINE. And say that last point—say that last piece again. The vast majority——

Dr. JENKINS. Yeah. So the vast majority are in rural and exurban areas, and the energy communities that have traditionally relied on fossil fuel extraction processing or transportation that were designated by the IRA.

Senator KAINE. This is a hearing about electric vehicles, but the same week that the announcement was made about DOE supporting the manufacturing of electric over-the-road vehicles in Dublin, there was also an IRA-driven announcement of $100 million to a facility that is opening up in Chesapeake, Virginia, which is in the Hampton Roads area, metropolitan area.

But it is going to manufacture in the United States for the first time the cables that connect to offshore wind and put the power into the grid. All of this has been manufactured overseas, because we did not have an offshore wind industry.

Now because of the IRA, we will be manufacturing those cables, and not just for use in U.S. offshore wind. Those cables, and the company is a Korean company that is investing in Virginia, will be manufactured in the United States and then sold to offshore wind development all over the United States. Just another example of an IRA success story.

Okay. Now here is a personal story that is embarrassing. I got stuck in my car for 27 hours in January of '22, driving from Richmond to D.C., and it was 18 degrees when the sun was up. It was colder overnight, and it was a freak snowstorm and the signs on the highway said proceed with caution.

They did not say "turn around and go home"; they said proceed with caution. I proceeded with caution and I was stuck for 27 hours. My senior Senator, Mark Warner, said I would have gotten Seal Team 6 to come out and get me. You sat there with a Dr. Pepper and an orange for 27 hours.

There was a lot of concern about what would happen to electric vehicles. I had—in a gas vehicle, I had to, you know, run the engine for ten minutes with the heat at full blast, turn it off until the car got too cold an hour later and do it again, to try to take my half tank of gas and make it work.

And there was a lot of questions about what would happen to electric vehicles that night. I have never introduced into the Senate Record an article from Kelley Blue Book, but I just—there is a first time for everything.

Kelley Blue Book did a study. They reached out to people who had been stuck in that snowstorm who were driving Teslas or other electric vehicles, and they found out that they actually performed better than gas vehicles, and that the way electric vehicle engines work, you can operate just a small portion of the engine that runs

the heater. You do not have to have the engine running for the whole car.

It does drain the, you know, the reserve, but very slowly. When finally the traffic started to move, it was blocked by the fact that so many vehicles had run out of gas, that even trying to move on the ice-driven roads, you were kind of like a Jenga game. You were kind of moving here, there and everywhere to kind of get around them.

But it turned out that the electric vehicles performed quite well in those adverse conditions. And so Mr. Chair, if I could, let me introduce this article from Kelley Blue Book "I–95 Traffic Nightmare: What if You Were Stuck in an Electric Car for 24 Hours" into the record.[10]

Chairman WHITEHOUSE. Without objection, it shall be entered into the record.

Senator KAINE. I yield back.

Chairman WHITEHOUSE. And we turn now to Senator Johnson, who will be followed by Senator Van Hollen.

STATEMENT OF SENATOR JOHNSON

Senator JOHNSON. So to prove my environmental bona fides here, I have a—my wife has a hybrid SUV, a pretty good-sized one, and we have actually had up over 30 miles per gallon. That is when she plugs it in. Every now and again she does, and so I think we are down to about 28 right now. So we watched that, okay.

Now I have always wondered, and it is interesting. Senator Kaine, you mentioned a dollar a gallon. Is that a—I do not know. I have never heard really what does it cost. Is that—is that about right, that it is an equivalent of about a dollar a gallon for gas to charge an EV versus what it costs on the—for a gallon of gas? Whoever has got the information.

Dr. JENKINS. Yeah. Senator, I think that is fair. Obviously it is going to base largely on the utility rates. But I think the working number is anywhere from, you know, two-thirds less costly compared to a gallon equivalent. So whether it is $1 or $1.50.

Senator JOHNSON. So I would say it is about a third of the cost. Again, that is pretty attractive, okay. You have got the smooth ride. You have got fast acceleration. There is a lot of benefits, okay, as well as—and in fact if you are just using a hybrid like my wife does driving around town, she never even has to use gas. So I am not opposed.

But my question is, if they have got so many market appeals, why do we need government subsidies? Take it up. I would say you do not. We should end them. Mr. Schwietert.

Mr. SCHWIETERT. Sure, Senator. Obviously, you are talking about affordability generally, excuse me. Obviously, when it comes to the record number of products, it is both the industrial policy as well as, you know, the marketplace dynamics.

Senator JOHNSON. Well I—we mess up when we—you know, government does not do very well. For example, we spent 7½ billion dollars to do charging stations. After more than two years, we have got seven of them, you know. Tesla was talking about we have

[10] Statement submitted by Senator Kaine appears in the appendix on page 153.

run—we have basically run the Highway Trust Fund into insolvency, and we have not really fixed that.

You know, why is—why is China producing all these electric vehicles? For its own home market? It is for central planning, industrial engineering in other countries; correct? Is there any major western country that does not subsidize EVs, because of climate alarmism? How many U.S. automakers are making money producing EVs?

Mr. SCHWIETERT. Senator, as I said in my remarks, we are in the early innings. This is a marathon, not a sprint. So yes, costs are going to have to come down.

Senator JOHNSON. Yeah. Well, how much are they losing on average?

Mr. SCHWIETERT. It depends on the manufacturer and their product cycle.

Senator JOHNSON. So why are they doing it?

Mr. SCHWIETERT. It ultimately——

Senator JOHNSON. Because they are getting government subsidies, right? The consumers are being subsidized and the automakers are also being subsidized, correct, and the mandate we are talking about are the things like cafe standards that coerce them to offer EVs, so they can produce vehicles that American consumers do want.

I mean I would never go to 100 percent EV. Happy to do the hybrid. Happy to be environmentally friendly. I want the comfort of having an internal combustion engine.

Mr. SCHWIETERT. Yeah. Senator, as it relates to the recent auto standards, we have been pretty clear with the Biden administration. Obviously, we need to ensure that there is alignment as it relates to where the market is, as well as encouraging——

Senator JOHNSON. Well, there will not—there will not be alignment with where the market is. Government is not that smart. I mean honestly, $7.5 billion. We have seven charging stations. We have run the Highway Trust Fund back 2008 insolvent. We have not fixed that problem, and we are going to have this command economy, and we are going to plan for a growth in the electrical grid?

By the way, we do not have the mining capacity. I would argue we really do not have the electrical capacity. Those climate alarmists are generally opposed to nuclear, which certainly would be part of the problem. China dominates the battery industry and our subsidies are providing a market for China's command economy. How does any of this make sense?

Dr. JENKINS. Senator, just with respect, our subsidies are targeted to U.S. manufacturing of batteries through 45X, and the consumer EV tax credits are specifically designed to excise China from the supply chain.

Senator JOHNSON. How many consumers have experienced the cost of replacing a battery in an EV?

Dr. JENKINS. It is an extremely rare occurrence.

Senator JOHNSON. What percent? What percent?

Dr. JENKINS. It is an extremely rare occurrence.

Senator JOHNSON. It is going to—they do not last forever, do they? How long do they last?

Dr. JENKINS. Neither does the—neither does an internal combustion engine car or transmission.

Senator JOHNSON. There are cars on the road from the '30s and '40s and '50s. How long is an EV battery going to last, and what is the cost to replace it?

Mr. SCHWIETERT. EV batteries account for anywhere from 30 to 40 percent of the up-front cost. Obviously, there is warranty and durability built into those batteries. But yes——

Senator JOHNSON. How long do they last?

Mr. SCHWIETERT. The battery itself can last quite some time, and then of course it can be repurposed and reused.

Senator JOHNSON. How long?

Dr. JENKINS. A couple of hundred thousand miles at least. We have had Teslas on the road with that many miles already.

Senator JOHNSON. And it is going to cost how much, 10, 20 thousand dollars to replace?

Mr. SCHWIETERT. Well, that is the cost today.

Senator JOHNSON. What about recycling of them? What about recycling of wind turbines? Now I am seeing these pictures of these massive dumps of these wind turbines just collapsing and—again, this—it does not make economic sense, because government is trying to essentially plan, and government is awful at it.

Ms. HINMAN. I just wanted to pipe in if I could, sir.

Senator JOHNSON. Sure.

Ms. HINMAN. On battery recycling. Batteries are eminently recyclable and are——

Senator JOHNSON. Not these. Not the lithium batteries. We do not have the capacity for doing it right now. We have not developed a way of doing it.

Dr. JENKINS. We're building that capacity.

Ms. HINMAN. We are building that capacity, and certainly the U.S. is a leader in the standards——

Senator JOHNSON. Kind of like what Senator Braun was talking about. Yeah, we have to rely on all these technological innovations we do not have yet. Let us face it, they have been trying to innovate batteries for decades and really have not been able to do it, have they?

Dr. JENKINS. I am not sure I would agree with that. The costs have fallen dramatically. The density has doubled in the last nine years or seven years. So battery innovation is dramatic and with support——

Senator JOHNSON. That is good. So let the marketplace dictate the speed of this innovation. Stop subsidizing this. That is my only point.

Again, I am not opposed to it, but I am opposed to government intervention in the marketplace. We just screw things up and as Senator Braun said, we cannot afford it. $35 trillion in debt. How are we going to afford all this stuff? Thank you, Mr. Chairman.

Chairman WHITEHOUSE. Senator Van Hollen.

STATEMENT OF SENATOR VAN HOLLEN

Senator VAN HOLLEN. Thank you, Mr. Chairman. Thank all of you for your testimony. I would just make a couple of points at the outset. When you have a huge, what economists call externality,

which is climate change, I know some of my colleagues do not really believe in that as a threat.

But that is exactly where you want government action, and I also heard Senator Graham at the outset talk about how China will potentially and is right now on a road, if we do not do something about it, to eat our lunch.

I mean the reality is countries around the world, consumers around the world are going to be purchasing electric vehicle, and either we are at the top of our game or we are going to left dramatically behind. So that is why I am pleased that Maryland is one of the states that has set very ambitious goals in terms of EVs.

Target for 300,000 by 2025, and we are one of 15 states that have committed to ramp up the electrification of medium and heavy duty trucks, so that all sales of those vehicles are zero emission by 2050. There has been lots of evidence of the health benefits of this.

The Rocky Mountain Institute estimates that among the 15 states that along with Maryland are participating in this effort, they will see fewer premature deaths, 477 fewer premature deaths, and over 6,000 fewer asthma incidents per year, and that is 3.5 billion a year.

And that is on top of the climate benefits. I think it is important to point out to my colleagues that heavy duty trucks and medium trucks account for only ten percent of vehicles on the road, they produce about a quarter of the overall greenhouse gas emissions. So one of the challenges that Volvo, which is a company in Hagerstown, Maryland is facing, and they developed the power train manufacturing, the power trains.

They have a facility there. One of the issues they have there is the issue of charging infrastructure for medium and heavy duty trucks. So Ms. Gross, could you briefly describe some of the challenges we are facing in this particular sector, and what we should be doing about it?

Ms. GROSS. Thank you Senator, for that question. Let me focus on the solutions first, and then I will go to maybe recap on some of the challenges. The most important thing that we can do in this sector for heavy duty-medium duty sector, is to get pilot programs out there.

It is amazing what fleet operators learn by just purchasing and putting into their fleet the first one or two trucks, understanding what the relationship has to be with the utility, understanding what charging is, how it works, what it means to discuss rates and off-peak times and on-peak times, and what the economic opportunities are to actually work with the utility on those rates.

So the fleet, this idea that we need to continue pilot programs is really important. It is not the ones that have already started, but every fleet in the country should start to understand what it would mean to actually have that experience behind you.

Once you have that experience, you make better decisions about right-sizing charging and right-sizing the grid requirements for it. We need to prioritize feeders. Where are these truck loads likely to show up? So you have got the eRoadMAP out there that describes and shows you visually where the loads are expected to come from.

We have got Volvo data, Daimler truck data, we have the telemetry. We know where diesel vehicles travel throughout the country. So being able to prioritize where they are today and where they are likely to be when they are electric is super-important for prioritizing these investments on the grid.

And then finally, one interesting thing is we are kind of going about this piecemeal today. This holds true for light duty vehicles as well. But on the medium and heavy duty trucking sector, where these loads can be very concentrated at a local distribution systems, we wait, you know.

The utility industry can really only invest once a customer shows up and says hey, I have got this load coming. Can you please, you know, upgrade the grid for me, I am coming with this charging load.

If we would step back and consider, you know, in its totality how much load is coming, when more fleets, 20 percent, 40 percent, 80 percent, we could do a better job up front, a more cost effective job of putting these solutions in place.

And so almost—I would encourage everyone to focus on sort of those big nuances about the trucking sector that are important, and this whole timing mismatch. I know that that is on top of mind for Volvo as well, the timing mismatch between the time it takes to upgrade power to a site, versus the time it takes to order a few semi trucks.

I said in my testimony earlier, I can order a fleet of semi-electric trucks and they can be delivered in four to six months, and the grid upgrades probably cannot be made in those same four to six months. So we have got to get ahold—we have got to get ahead of this.

Senator VAN HOLLEN. Right. So this is the issue. I mean Volvo is actually losing orders right now from people that want to, you know, purchase these electric medium and heavy duty trucks, but cannot because of this issue of charging stations.

So I hope we will, on a relatively urgent basis, move forward. I mean this is the sort of chicken and the egg problem we have seen in other parts of this sector. I may have some questions to submit for the record, but I see my time is up. Thank you, Mr. Chairman.

Chairman WHITEHOUSE. Senator Van Hollen, Senator Graham and I spoke earlier about trying to pull together some bipartisan technical recommendations for facilitating the transition in a whole variety of ways. Things like supporting peak-shaving and this would be another good example.

So I look forward to working with you on that, and thank you very much for your interest, and now we turn to Senator Kennedy.

STATEMENT OF SENATOR KENNEDY

Senator KENNEDY. Thank you, Mr. Chairman. Welcome to all our witnesses. I am sorry I was late. I was in another committee. How many of you drive an electric car, own an electric car?

(Show of hands.)

Okay. You gentleman do not?

Dr. JENKINS. If you mean electric by a battery electric, no. If you mean plug-in electric, yes.

Senator KENNEDY. Okay. Of the three folks who raised your hand, how many electric—do you own gasoline powered cars at all? No?

Mr. SCHWIETERT. No, Senator.

Senator KENNEDY. No, no. All electric. Okay. Let me ask you all this, and please give me brief answers, because I am only—there are five of you and there is only one of me, okay? If electric cars are so swell, how come we have to pay people to drive them?

Dr. JENKINS. The up-front costs of an electric vehicle are about $10,000 higher today than they are for an equivalent internal combustion engine vehicle today——

Senator KENNEDY. Well, they are more expensive. Anything else?

Dr. JENKINS [continuing]. But that cost is declining substantially. So this is a temporary intervention to help the auto industry strategically compete in global markets, and to transition as battery costs fall.

Senator KENNEDY. You did not hear my admonition, okay.

Dr. JENKINS. Sorry.

Senator KENNEDY. But how about if electric vehicles are so swell, how come we have to pay people to drive them?

Ms. GROSS. I think I will—sorry, Senator. I'll stay away from——

Senator KENNEDY. I am sorry. I cannot see the names.

Ms. GROSS. Oh I am—it is Gross, Ms. Gross here. I will—I'll defer to not comment on policy questions about incentives and so on.

Senator KENNEDY. Would you start over?

Ms. GROSS. I was just going to say I would like to defer on policy grounds not to talk about policy, incentives, and so on and defer over to my colleague, Ms. Hinman.

Senator KENNEDY. Why not? You do not believe in electric cars?

Ms. GROSS. Oh, totally support electric vehicles and drive three of them myself.

Senator KENNEDY. So if they are so swell, how come we are having to pay people to drive them?

Ms. GROSS. So just speaking personally then, not representing my company at this point——

Senator KENNEDY. Sure. Who is your company?

Ms. GROSS. EPRI, the Electric Power Research Institute, and I have to be careful about policy, stepping into—wading too deeply into policy as an independent leader here. But when I—when we think about again, I just want to ditto what Dr. Jenkins said. This is an effort to compete globally.

Senator KENNEDY. Yes ma'am. I know all that. But how—if they are so swell, how come we have to pay people to drive them?

Ms. GROSS. Well, maybe then the quick answer for me is I did not take advantage of incentives. But I also bought used vehicles on the market. I love it. They are wonderful to drive. That is all.

Senator KENNEDY. Okay.

Ms. HINMAN. Senator, similar for myself. We purchased——

Senator KENNEDY. What is your name?

Ms. HINMAN. Maureen Hinman.

Senator KENNEDY. Damn——

Ms. HINMAN. My hair is longer in my picture, sorry.

Senator KENNEDY. I am sorry. I do not even know who I am talking to. Go ahead, Ms. Hinman.

Ms. HINMAN. I did want to follow up with my colleague, Ms. Gross. I purchased my first EV, fully electric, in 2015.

Senator KENNEDY. Yes ma'am. But if they are so swell, how come we have to pay people to drive them?

Ms. HINMAN. Well, I purchased—I can only speak for myself, but we purchased our first vehicle in 2015 because it was easier to charge, cheaper to drive, it drives better, faster, smoother. There is no muck on the bottom of my garage. And frankly when I had my first child, some of the safety features were just better.

Senator KENNEDY. Oh, but here is what I am—I am sorry, you are not answering my question. How many vehicles—how many cars do we have in the United States?

Dr. JENKINS. 280——

Senator KENNEDY. This lady right here. In the middle. I am sorry. If I could see your name, I would not just point to you.

Ms. GROSS. If I could, I would like to defer to my colleague, who has a better——

Senator KENNEDY. Well, I want to hear your answer, okay?

Ms. GROSS. How many cars?

Senator KENNEDY. How many cars are there——

Ms. GROSS. 295 million.

Senator KENNEDY. Okay. And what percentage are electric vehicles?

Ms. GROSS. 1.6.

Senator KENNEDY. Okay. Hold up that chart. Here is where all the electric vehicles are. California loves them. The west coast loves them. Everybody else is kind of lukewarm, okay. I am trying to understand why. But let me move on to this.

Let me ask these two gentlemen. I think the reason is is because they are more expensive, and people do not—people, when they drive a car, like it to run, and when it runs out of electricity it stops, and they cannot find a place to charge.

So let me ask these two gentlemen, I do not want to be unfair. So it is clear we have got a long way to go. We have got 283 million cars in America, and we have got 3.3 million electric vehicles.

We have got a long way to go, and at least these three folks think that we need to take taxpayer money and give enough money to the American people, so they will walk away from gas cars and drive electric vehicles.

How much is that going to cost? I am going to ask them in a second, if I have time. But how much do you think it will cost for us to basically bribe every American to drive an electric car?

Mr. SCHWIETERT. Well Senator, excuse me. Dave Schwietert with the Alliance for Automotive Innovation. I would just underscore your original question with this. There is really two things at play as it relates that what is happening.

Senator KENNEDY. How much money do you think it will cost to bribe the American people enough to make them drive electric cars, to move those numbers?

Mr. SCHWIETERT. Electrification is increasing as it relates to cost. Only a fraction of currently eligible vehicles are eligible for the federal tax credit so——

Senator KENNEDY. How much do you think it will cost?

How much do you think it cost David?

Dr. JENKINS. Senator, I think I quoted earlier that——

Senator KENNEDY. I am not calling on you, sir. How much do you think it will cost?

Mr. SCHWIETERT. It ultimately depends on consumer adoption.

Senator KENNEDY. You do not know do you?

Mr. SCHWIETERT. We do not have an exact figure.

Senator KENNEDY. You think we ought to just keep throwing money at it until we hit the jackpot. How about you, Mr. Davis?

Mr. DAVIS. Eventually, if you put enough charger stations, that will stop the range anxiety, because the reason I did not buy one is because I may have to drive 450 miles to East Tennessee——

Senator KENNEDY. How much do you think it will cost the American taxpayer, for us to convince the American people, frankly just bribe the American people, to get rid of a gas car and drive an electric car? Have any of you—can any of you give me a figure?

Dr. JENKINS. Yeah Senator, the Treasury Department reports we have spent a billion dollars year-to-date. So for the first half of this year, so roughly $2 billion this year. As I noted——

Senator KENNEDY. Well, we are behind. How much do you think it will cost, Doctor? You are a doctor, right?

Dr. JENKINS. So $2 billion this year is what the estimate from the Treasury Department is.

Senator KENNEDY. Okay. How much do you think it will cost for us to let us say get 75 percent of these 200 million——

Dr. JENKINS. How much will it cost American consumers to remain——

Senator KENNEDY. How much? Do you know how much it will cost, Doc?

Dr. JENKINS. No one knows the future with certainty, Senator.

Senator KENNEDY. Right. You just think we ought to keep throwing money at it until we hit the jackpot.

Dr. JENKINS. I think we ought to set a stable policy framework that allows American consumers to become familiar with the environment, and American businesses to innovate and to compete within that stable framework. That is what I said in my testimony.

Senator KENNEDY. And how much will that cost?

Dr. JENKINS. It will cost less than the benefits delivered by the policy.

Senator KENNEDY. You do not care how much it costs, do you?

Dr. JENKINS. I care if the benefits exceed the costs. I do not care about the costs if they are investments in the public.

Senator KENNEDY. You do not care how much it costs, do you?

Dr. JENKINS. I care very much how much it costs. As long as the benefits exceed the costs, that is an investment worth making.

Senator KENNEDY. Well, okay.

Dr. JENKINS. How much does it cost to cede the industries of the future to China?

Senator KENNEDY. I get to ask the questions, Doc. You are at Princeton, right?

Dr. JENKINS. That is correct.

Senator KENNEDY. Yeah. How are Jewish students doing at Princeton? Are they feeling better?

Dr. JENKINS. That has nothing to do with the hearing today. I do not have any comment on that.

Senator KENNEDY. I did not think you want to—I did not think you would want to talk about that. Do any of you have any idea how much it would cost if say 75 percent off the American people are driving electric cars?

Mr. SCHWIETERT. Senator, if I could, your question is fair. One answer to it is the cost of inaction of the U.S. not competing is far greater than any incentive on the front end.

Senator KENNEDY. Okay. Quantify that for us? Oh man, I am way over. I am sorry, Sheldon. Quantify that for me, because here is my——

Chairman WHITEHOUSE. Why do you not wrap up with this, because I think everybody has had a chance to try to answer your question and you are still repeating it at this point.

Senator KENNEDY. Okay, I will. Here is my problem. Okay. We all want clean air, we all want bright water. We all want to eat and we all want to live indoors, okay. But there are tradeoffs in all of this. Despite what the Princeton professor thinks, we do not have unlimited money. This is not Princeton.

So we have to decide the cost and the benefits, and nobody seems to be able to quantify the costs. They just say "keep throwing money at it, throwing money at it, throwing money at it," and nobody can really quantify the benefits except if we do not do it, then we are all going to die.

And when I go back to my people and say your electricity costs have gone up 30 percent, but it is for a good cause. Why Kennedy? Because you are going to die if we don't do it. Why Kennedy? Because a professor at Princeton says so.

That does not work for most Americans. Can you answer that for me? You see my frustration. I love—I love driving an electric car. I think they are really cool. But the median household income in my state is $55,000. Our Princeton professor probably makes that in a week, okay. They do not care what they think at Princeton. Can you answer that for me, guys?

Ms. HINMAN. I can't answer how much it is going to cost, but I can tell you that just last year alone, China in the EV market subsidized it by $12.4 billion, and that is their annual spend. It is more than—even with our—in our best year, it is more two-thirds what the United States spends.

Senator KENNEDY. And China is doing great. But let me ask you a question. How much will it cost China to become carbon neutral by 2050?

Ms. HINMAN. I am very concerned—they will not. But I am more concerned about the risk to the U.S. economy of losing the auto manufacturing industry.

Senator KENNEDY. How much would it—how much would it cost them? Do you know? See, nobody talks about the cost. I will tell you how much it will cost them. It will cost them a trillion dollars a year starting today to be carbon neutral by 2050. Do you know how much it will cost Russia? $250 billion a year, three times what their defense budget.

Now if you believe that Vladimir Putin is going to spend $250 billion for—for climate change, then you never owned your own

home. So we are going to spend all this money, which y'all cannot quantify. We just keep spending. They do not spend the money. They are at an advantage and you know how much world temperatures are lowered? None. Zero, zilch, nada.

And I cannot believe our Chairman has not cut me off, but I am done.

Chairman WHITEHOUSE. Now is your moment.

Senator KENNEDY. I am done.

Chairman WHITEHOUSE. Thank you, Senator Kennedy, for your enthusiastic participation in this hearing.

Senator KENNEDY. I just wish we had time to talk about all this. I think this is fascinating.

Chairman WHITEHOUSE. We will wrap up with a couple of clarifications. First of all, the word "mandate" has come up repeatedly during this hearing, and I just want to make sure everybody understands. There is no mandate.

What there is is a tax incentive, and for those of us who believe in traditional economic policy, what the tax incentive is there to do is to offset the negative externality of all of the pollution that comes out of an internal combustion engine that society at large pays for, but is not baked into the price of the vehicle. And you can go all the way to Milton Friedman to get the economic theory that supports that.

Second, EVs have been more expensive than internal combustion engine, largely because of a market decision by the electronic vehicle innovators come in at the high end of the market. Because Tesla, for instance, could compete with Maserati and Lamborghini on performance.

And so of course they came in at the high end of the market, particularly when you are starting with small initial manufacturing runs. But as the market has grown, costs are now coming down to where it is maybe a thousand, two thousand dollars' difference between the average EV cost and the average internal combustion engine cost, just around $50,000 in each case.

There are available electronic vehicles that are less expensive than the average internal combustion engine now. So depending on what you want to choose, if you want to go and compete with Maseratis, you can go to the high end. But they are also cheaper than average internal combustion electric vehicle options.

And the last thing I will point out is that while tire emissions are obviously real and tire emissions are greater from an electric vehicle than internal combustion vehicle because the electric vehicle is (a), heavier because of the battery, and (b), higher performance because it is higher performance. So you have more tire wear and that creates some additional measure of tire wear-related pollution.

To complain about that in the context of tailpipe pollution and tailpipe emissions, calls to mind the old biblical verse about the moat in your own eye or moat in your brother's eye compared to the beam in your own eye. The beam here is tailpipe emissions, which pollute enormously and create massive climate risk.

I agree that tire emissions need to be dealt with, but if you put them to scale and compare their hazard for humankind and for local health, it is moat versus beam.

So with that, let me say that questions for the record are due by noon tomorrow, with signed, hard copies delivered to the Committee Clerk in Dirksen 624. In particular, Ms. Gross and Dr. Jenkins, if you could even perhaps coordinate recommendations for us in that peak shaving space.

However you want to do it is fine, but I would love to get those in, and we ask that our witnesses respond to those questions within seven days of receipt. So that would be within a week, if you guys could do that. With no further business before the Committee, the vote on the floor has already begun, and our hearing is adjourned. Thank you.

[Whereupon, at 12:06 p.m., Wednesday, July 31, 2024, the hearing was adjourned.]

Opening Statement of Chairman Whitehouse
Senate Budget Committee Hearing: "Charging Ahead: The Future of Electric Vehicles."
July 31, 2024

I want to start by thanking Senator Graham and his staff for their partnership on today's hearing, and Ranking Member Grassley for blessing this effort. Today's bipartisan hearing looks at transitioning away from fossil fuels — an economic, national security and climate imperative — in a way that effectively seizes opportunities and addresses challenges.

The auto industry is a major economic engine. In 2023, the global auto market was valued at $4 trillion, of which the U.S. accounted for a bit less than 17 percent. Two U.S. automakers, Ford and GM, were among the world's five largest automakers. Foreign companies operate assembly plants in the U.S. Motor vehicles and parts were America's second largest export. The auto market could increase to over $6 trillion by 2031. To grow U.S. autoworkers' share of this growing pie, we need to understand and respond to this global market.

Globally, 20 percent of vehicles sold in 2023 were electric. In China, the world's largest auto market, 33 percent of cars were electric; in Europe, 20 percent of vehicles sold were electric. Other major markets are racing to EVs. Between 2022 and 2023, electric car sales tripled in Brazil, and more than quadrupled in Thailand.

The writing is on the wall: around the world, the future of personal transportation is electric, independent of whatever the United States decides to do. And that's great. First, it means freedom from a global commodity whose price is manipulated by petro-dictators. Over and over, American consumers suffer, as the geopolitical designs of petro-dictators cause oil prices to soar. Real energy independence comes from independence from fossil fuel cartels.

Going electric benefits Western democracies, as oil and gas revenues fund many of our foreign adversaries. Look no further than the corrupt petro-tyrant Vladimir Putin. As we reduce our dependence on oil and gas, we diminish our foreign adversaries' abilities to bully and corrupt. Senator Graham and I wrote in a 2021 op-ed published in *Time* magazine, "If you could wave a magic wand, and transition the world away from fossil fuels, Americans would instantly be safer."

As the driver and owner of two Chevy Bolts, I'll also add — they're just better cars. They're quieter, faster and more fun to drive. They don't have tailpipe emissions stinking up highways and neighborhoods. Repair and maintenance costs are nearly nonexistent. No oil changes, one tenth the number of parts to break or fail. No expensive, dangerous, smelly gasoline.

In emergencies, EV fleets can provide backup power to families when grids are down; and smart chargers can help shave dangerous load peaks for utilities, if we make the needed small investments in the required infrastructure.

And of course, yes, electric vehicles dramatically reduce carbon pollution in the transportation sector, currently the largest source of fossil fuel emissions in the U.S. The more we reduce carbon pollution, the better our chances of avoiding the dire, systemic climate-related economic

risks we've discussed in this committee over the last 18 months. It may be too late to save Florida's property insurance market, but there are plenty of other risks we'd be wise to avoid and fools to stumble into.

Electrifying the transportation sector presents a tremendous economic opportunity. Automakers are getting the message that people want EVs, and they are responding. Since 2017, they have, along with their battery partners, invested $125 billion in electrification. 20 states have or will have EV production or assembly of battery facilities.

For some reason, Tesla is taking a hit, but other makers are seeing surging sales year-over-year. Ford EV sales increased 86 percent from Q1 2023 to Q1 2024; Rivian sales jumped 59 percent over the same period.

So, how do we position our auto industry and our nation for that economic opportunity and global competitiveness?

As our economy electrifies, it needs to be supported by a 21st (not a 20th) century grid. The grid will need to handle increased demand from electric vehicles, heating and cooling, manufacturing, hydrogen electrolyzing, and energy-gobbling data centers. To meet this demand with clean power requires new and upgraded transmission to deliver that power to consumers. That means smart reforms to our cumbersome and antiquated permitting process.

Domestic supply chain investments must accelerate.

Look at China. 15 years ago, China saw the value of electric vehicles and batteries, began investing, and now it dominates critical mineral and battery manufacturing markets. Let's learn the servitude lessons from our fossil fuel dependence, and our lost manufacturing capacity. Let's swiftly counter this emerging geopolitical risk with smart investment, and take back our economic dominance in clean energy products.

We must also find a way to reconcile the surging EV market with a Highway Trust Fund that provides 80% of federal highway spending with a majority of its revenue from federal gas taxes. The Bipartisan Infrastructure Law, which most recently replenished the Fund, sunsets in just two years. The clock is ticking on highway infrastructure funding.

To my mind, this is a "morning in America" moment: freedom from dependence on petro-dictators; opportunity to reclaim from China clean energy leadership; better, safer products for American consumers, with more money in their pockets; cleaner air to breathe along highways and neighborhood streets; *and* an important step on our pathway to climate safety. What's not to love, if we do this right?

Thank you again to Senator Graham for this hearing, and I look forward to the conversation.

UNITED STATES SENATE
BUDGET COMMITTEE
RANKING MEMBER CHUCK GRASSLEY

Opening Statement by Senator Chuck Grassley of Iowa
Ranking Member, Senate Budget Committee
Hearing titled, "'Charging Ahead' The Future of Electric Vehicles"
Wednesday, July 31, 2024

Thank you, Mr. Chairman.

Welcome to our expert witnesses.

Our last hearing was with Congressional Budget Office (CBO) Director Swagel.

The hearing was a very welcome event at this committee. Unfortunately, [it was] a rare opportunity for this committee to focus on the critical, broken budget process.

It gives us a chance to talk to somebody who knows the process needs to be fixed and a primary responsibility of this committee.

In exchange for holding a CBO hearing at my request, I agreed to Senator Graham working with Chairman Whitehouse to put together today's hearing.

We'll be discussing electric vehicles (EVs) and barriers to the electrification of America's light-duty fleet.

The Biden-Harris administration's unattainable goal of 50 percent new EV sales by 2030 has been on full display over the last four years.

From imposing expensive EPA regulations, to doling out billions in EV subsidies for the rich, the economic detriment of America's EV policy is quite evident.

Now, I don't want to give the wrong impression. EV technology is impressive and works well for some.

But Iowans know that there are far more challenges to EV adoption than many care to admit.

EVs best serve wealthier people who also live in, or near, suburban and urban areas.

Perhaps the most prominent barrier to EV adoption is that EVs are uneconomical.

CBO's February baseline set the record straight, telling us that the so-called *Inflation Reduction Act* (*IRA*)'s EV handout would increase the deficit by hundreds of billions of dollars.

I also couldn't help but notice that the price of EVs rose immediately after the IRA's passage to absorb the bill's $7500 new EV tax credit.

These EV costs were then, of course, passed on to the consumer.

Now, many [EVs] have had to be discounted because they haven't been able to sell them.

And I've yet to hear a comprehensive plan to make EV owners pay into the Federal Highway Trust Fund.

EV drivers are currently free-riding on the backs of the middle class, although some states have instituted an extra fee for so-called 'fuel-efficient' vehicles, making them even more expensive.

There are many holes in the rapid EV transition fantasy.

They include a lack of critical minerals needed to produce EVs, lack of transmission infrastructure needed to support their increased electricity demands and our current reliance on nefarious countries in the EV supply chain.

According to the University of Michigan, the world will need to mine 115 percent more copper from 2018 to 2050 than has been mined in all of human history up until 2018, just to do business as usual.

This copper mining doesn't even include the 'green transition.'

And, the EVs, they take three-to-five times as much copper as a standard vehicle.

I hope we discuss where these critical minerals for the so-called 'EV transition' will come from.

China dominates global critical mineral supply chains, accounting for approximately 60 percent of worldwide production and 85 percent of processing capacity.

And, we struggle to permit federal projects here in America.

From wind turbines, to transmission lines, to pipelines, to hard rock mines, left-wing environmentalists are holding up the permitting reform needed for the very EV expansion they claim [to value].

The left claims climate crisis but backs away from comprehensive reform when the environmental lobby comes calling.

They also claim to care about air quality and 'environmental justice' but ignore the unreported and underreported particulate emissions from tires under the heavy weight of EVs.

Legislators must do better, and I hope this hearing serves as a steppingstone for honest permitting of dialogue moving forward.

As we grapple with environmental red tape, the Chinese are rapidly expanding coal power plants to fuel an EV manufacturing boom.

I'd like to welcome all today's witnesses invited here by Senators Whitehouse and Graham.

And finally, Mr. Chairman, I request unanimous consent to put [into the record] this article called, "Copper can't be mined fast enough to electrify [the U.S.]."

Before you go on, I mentioned a few inconsistences in my opening remarks, but I can think of others, and maybe it's the adjective 'unrealistic' or 'inconsistency' that may fit a couple things.

Iowa's the number one producer of ethanol. We have 443,000 jobs in Iowa, and if we had every vehicle in the United States be EVs, you can see what that could do to those particular jobs that we created 40 years ago to produce a more environmentally-friendly product than petroleum.

We have the inconsistency of the rainforest being hacked away to mine nickel in Indonesia, we have the inconsistency of people in Congress who talk about, 'We need to stop the use of child labor around the globe,' and yet we have children mining cobalt in the Congo.

I mentioned transmission in my opening comment, the chairman mentioned transmission.

But this permitting process is halted by environmentalists not wanting to cut red tape here in Washington, D.C.

And then you have the silly posture of the *Inflation Reduction Act* appropriating billions of dollars for charging stations. I guess, to date, we have about eight.

So, I think there's a lot about this whole process that hasn't been thought out very well.

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Testimony of Dr. Jesse D. Jenkins

Assistant Professor

Princeton University

Budget Committee

United States Senate

The U.S. Electric Vehicle Transition:
Recent Trends and Current Outlook

July 31, 2024

1. Introduction

I would like to thank Chairman Whitehouse, Ranking Member Grassley, and the members of the Committee for the opportunity to testify before this committee.

My name is Jesse Jenkins. I am an expert on energy systems engineering and climate policy and an assistant professor at Princeton University with a joint appointment in the Department of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and Environment. I am also an affiliated faculty at the Center for Policy Research in Energy and Environment at Princeton's School of Public and International Affairs and at the High Meadows Environment Institute.

I lead the Princeton ZERO Lab (Zero-carbon Energy systems Research and Optimization Laboratory), which focuses on improving and applying optimization-based energy systems models to evaluate and optimize low-carbon energy technologies, guide investment and research in innovative energy technologies, and generate insights to improve energy and climate policy and planning decisions.

I received a PhD in Engineering Systems and S.M. in Technology and Policy from the Massachusetts Institute of Technology and a B.S. in Computer and Information Science from the University of Oregon. I have served previously as a postdoctoral Environmental Fellow at the Harvard Kennedy School and the Harvard University Center for the Environment, a researcher at the MIT Energy Initiative, a research fellow at Argonne National Laboratory, the Director of Energy and Climate Policy at the Breakthrough Institute, and a Policy and Research Associate at Renewable Northwest.

I have published 37 peer reviewed journal articles as well as multiple working papers, technical reports, and policy briefs. I am one of the principle investigators of the Princeton *Net-Zero America* study, served as a member of the National Academies of Science Engineering and Medicine (NASEM) Committee on *Accelerating Decarbonization of the U.S. Energy System*, and currently lead the REPEAT Project, which provides regular, timely, and independent environmental and economic evaluation of federal energy and climate policies as they're proposed and enacted.

Since 2012, I have also provided decision support, analytics, and policy advisory services to various non-profit and for-profit clients working to accelerate the deployment of clean energy. I am currently a technical and scientific advisor to Energy Impact Partners and MUUS Climate Partners, which are both venture capital firms investing in early-stage climate technology companies. **Please note that I also serve on the advisory boards of Eavor Technologies Inc., Rondo Energy, and Dig Energy, and I have a significant financial interest in each company.** A full list of past consulting clients can be found on my LinkedIn profile. Finally, I serve as co-host of the podcast *Shift Key* on the shift away from fossil fuels, published by Heatmap News.

All views expressed in this testimony are my own, and I am not speaking as an official representative of Princeton University or any of my co-authors or consulting clients.

###

2. A rapidly evolving sector

The United States is now in the early stages of a momentous transition in the automotive sector. Over the last decade, improvements in lithium-ion battery technology and electric motors have made long-range, highly-capable and increasingly-affordable electric vehicles a reality (Figures 1 and 2).

It is important to recall how rapidly the electric vehicle sector is evolving. The first true mass-market electric vehicle, the Tesla Model 3 sedan, was launched just seven years ago. Over that time, the cost of lithium-ion battery packs has been cut in half, while the energy stored per kilogram has nearly doubled.[1] Tesla's Model Y crossover was only released in 2020. Just four years later, Tesla delivered 1.2 million Model Ys, making it the world's best-selling vehicle last year.[2] Not the world's best-selling *electric* vehicle (though it also held that title), but *the best-selling vehicle in the world, period.*

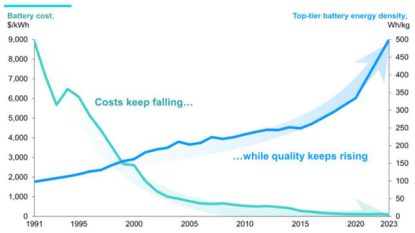

Figure 1. Battery Cost and Energy Density Since 1990
Source: RMI, https://rmi.org/the-rise-of-batteries-in-six-charts-and-not-too-many-numbers/

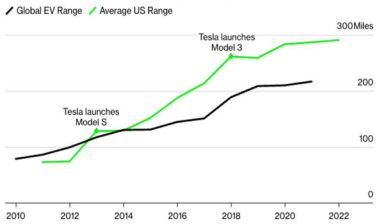

Figure 2. Average EV Range Approaches 300 Miles in U.S.
Source: Bloomberg, https://www.bloomberg.com/news/articles/2023-03-09/average-range-for-us-electric-cars-reached-a-record-291-miles

Today, Tesla is no longer (virtually) alone in the market. There are now more than 40 fully electric car or truck models to choose from in the U.S. (and many more plug-in hybrid electric models) produced by virtually every major automaker.[3] Over 1.1 million battery electric vehicles (BEVs) were delivered to U.S. consumers in 2023, alongside over 183,000 plug-in hybrid electric vehicles (PHEVs).[4] By the end of 2023, almost one in ten light duty vehicles sold in the U.S. had a plug (including both BEVs and PHEVs; Figure3).[5]

Worldwide, nearly one in five new cars and trucks were electric in 2023, with almost 14 million EVs sold, while in China, the world's largest automotive market, plug-in vehicles took 38% of the market last year.[6]

###

[1] RMI, "The Rise of Batteries in Six Charts and Not Too Many Numbers," https://rmi.org/the-rise-of-batteries-in-six-charts-and-not-too-many-numbers/
[2] Will Rimell, "Tesla Model Y becomes first EV to top global sales charts," Autocar.co.uk, January 25, 2024, https://www.autocar.co.uk/car-news/new-cars/tesla-model-y-becomes-first-ev-top-global-sales-charts
[3] CNET, "Every EV Available in 2024, Ranked by Range," https://www.cnet.com/home/electric-vehicles/every-ev-available-ranked-by-range/
[4] Statistics are for light duty cars and trucks (medium and heavy vehicle sales are not included in this figure). Argonne National Laboratory, "LDV Total Sales of PEV and HEV by Month (updated through June 2024)," https://www.anl.gov/sites/www/files/2024-07/Total%20Sales%20for%20Website_June%202024.pdf
[5] Ibid.
[6] International Energy Agency, "Global EV Outlook 2024: Trends in electric cars," https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-cars

3. Why electrification is important

The transition to electric vehicles is a central pillar in the United States' efforts to both cut greenhouse gas emissions *and* reduce our vulnerability to shocks in global oil markets.

Today, the United States is producing more oil than any country in the history of the world (including at any point during the previous administration).[7] And yet, the U.S. economy remains dangerously exposed to the volatility of global oil prices. The decisions of a dictator to invade a neighbor or a disaster on the other side of the world can send the cost of filling the tank in Denver or Des Moines soaring almost overnight and tip the whole U.S. economy towards recession. Every $10 per barrel increase in the price of oil is a $210 million per day tax on American households and businesses,[8] and soaring energy costs are a primary driver of inflation. We simply cannot drill our way to energy security. But we can electrify. By severing our reliance on gasoline and diesel to fuel our cars and trucks, we can finally secure America's independence from global oil shocks.

Electrifying transportation is also critical to meeting national climate objectives. Switching to electric vehicles and cleaning up our grid is the critical 'one-two punch' that will decarbonize transportation. President Biden established a target to cut U.S. greenhouse gas emissions to half of peak levels by 2030. To reach this goal, electric vehicle sales should make up about 50% of the light duty vehicle market by that date, up about five-fold from today.[9]

Yet over the past nine months, sales of plug-in vehicles in the United States have plateaued, driving a growing gap between current trends and U.S. climate targets. Let's dive into the numbers…

###

4. Recent trends in the U.S. EV market

Electric vehicle sales growth accelerated through the 3rd quarter of 2023, regularly exhibiting year-on-year growth rates of roughly 40-60%. Beginning in the 4th quarter of 2023, however, growth in EV sales stalled, a trend that has continued through the first half of this year (see Figure 3).

At the current pace, sales of fully electric vehicles are basically flat in 2024 (up only 2% year to date) while sales of plug-in vehicles (including PHEVs) are up 9% year-on-year (see Figure 4). That is a remarkable collapse from 2023, which saw EV sales grow by more than 50% for the year (notwithstanding the slowdown in the fourth quarter).[10]

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[7] Energy Information Administration, "U.S. Field Production of Crude Oil," https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus2&f=m
[8] The U.S. consumes about 21 million barrels of petroleum products per day. Energy Information Administration, "U.S. Weekly Product Supplied" https://www.eia.gov/dnav/pet/pet_cons_wpsup_k_w.htm
[9] REPEAT Project, Net-Zero Pathway scenario. See https://repeatproject.org/results?comparison=benchmark&state=national&categories=transportation&subcategories=equipment-sales-light-duty-autos,equipment-sales-light-duty-trucks&page=1&limit=25
[10] Argonne National Laboratory, "LDV Total Sales of PEV and HEV by Month (updated through June 2024)," https://www.anl.gov/sites/www/files/2024-07/Total%20Sales%20for%20Website_June%202024.pdf

New technologies typically follow an S-shaped adoption curve, with an early phase of exponential growth that eventually gives way to a linear phase after early adopters are exhausted (see Figure 6). Experts thus expected a slow-down in 2024 sales growth. But this collapse is atypically fast: Bloomberg NEF projected 20% annual growth in EV sales in 2024 while our most recent REPEAT Project scenarios expected 30-40% growth, rates that are now nearly impossible to reach this year (Figure 4).

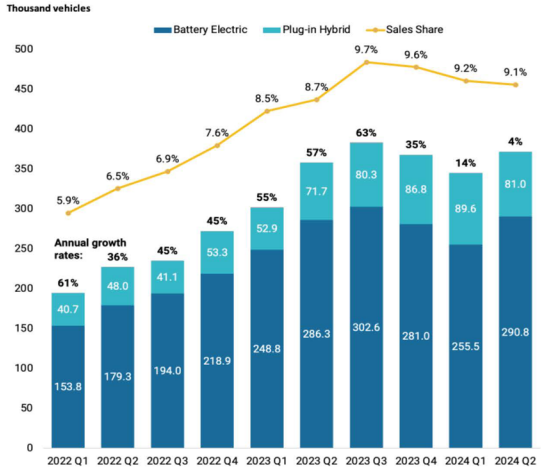

Figure 3. Quarterly U.S. Battery Electric and Plug-in Hybrid Electric Vehicle Sales
Data source: Argonne National Laboratory, "Light Duty Electric Drive Vehicles Monthly Sales Updates - Historical Data." https://www.anl.gov/esia/reference/light-duty-electric-drive-vehicles-monthly-sales-updates-historical-data (accessed July 27, 2024)

Looking behind the headlines, it is clear that the story is mostly about Tesla. The EV market leader has stumbled: over the first half of 2024, Tesla sales *contracted* by 13% year-on–year, while sales of all other plug-in vehicles are -actually up a healthy 31% (see Figure 4).

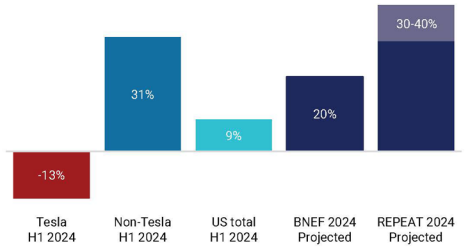

Figure 4. Comparison of Actual vs Projected Year-on-Year Growth Rates for 2024 U.S. Battery Electric and Plug-in Hybrid Electric Vehicle Sales
Data source: Historical data for overall market from ANL (full citation see Figure 3 above) and for Tesla from Marklines, https://www.marklines.com/en/statistics/flash_sales/automotive-sales-in-usa-by-month. Projected growth rates from Bloomberg NEF Global EV Outlook 2024 *and REPEAT Project 2024 annual update (forthcoming).*

Tesla currently has an aging and comparatively limited product line-up. The company depends on the Model 3 and Y to drive volume sales, with these two models historically accounting for about 95% of Tesla's deliveries in recent quarters.[11] While the Model 3 went through a modest update earlier this year, the Model Y has not been substantially redesigned since its release in 2020. Instead of refreshing their top-selling models or producing a cheaper compact EV, Tesla devoted most of its product development efforts over the past several years to the Cybertruck, which launched at the end of 2023. While the distinctive vehicle has quickly become the top-selling electric truck in the market,[12] the Cybertruck currently retails for over $100,000 and is selling at an annualized pace of less than 50,000 units (as of May 2024). Meanwhile, Tesla has used substantial price reductions (beginning in 2023) to sustain sales of the Model 3 and Y (see Figure 5), which have nevertheless been stagnant over this period.

As Tesla still represents over half of the total U.S. market for fully electric vehicles and 41% of the market for plug-in vehicles, it is difficult for the U.S. market overall to rapidly expand when Tesla is flat or declining.

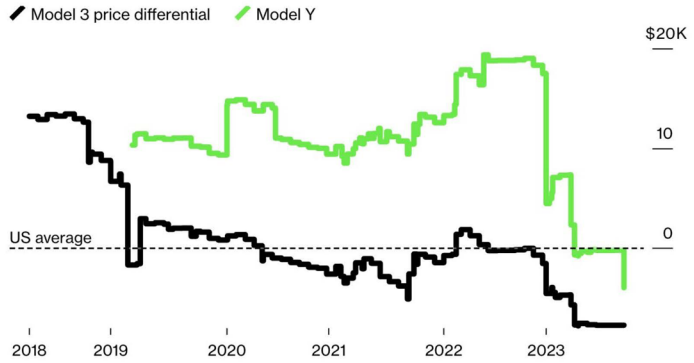

Figure 5. Tesla Prices Now Compete with the Average New Car
Starting prices fall below the U.S. benchmark transaction price
Source: Bloomberg, https://www.bloomberg.com/news/articles/2023-10-05/where-is-tesla-s-ev-competition

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[11] @TroyTeslike, "Tesla Production & Delivery History, created by @TroyTeslike, last updated on 18 July 2024," https://docs.google.com/spreadsheets/d/1wiNeeKfpT73YIhpgdaqyCe1wyMue5wX0STSpcy-C6IY/edit?gid=327884293#gid=327884293
[12] Owen Bellwood, "The Tesla Cybertruck has dethroned Ford's F-150 Lightning as the best-selling electric truck," Quartz, July 17, 2024 https://qz.com/tesla-cybertruck-ford-f150-lightning-electric-trucks-1851596485

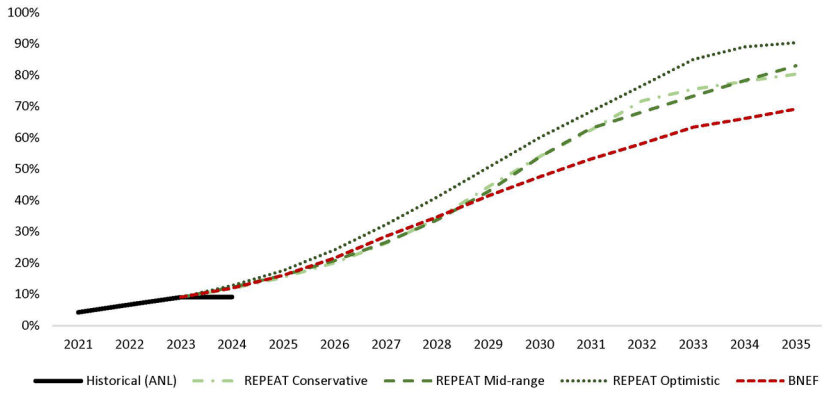


Figure 6. Historical vs Projected Battery Electric and Plug-in Hybrid Electric Vehicle Sales Shares
Share of light duty vehicle sales
Source: Historical data for overall market from ANL (full citation see Figure 3 above). Projected growth rates from Bloomberg NEF Global EV Outlook 2024 *and REPEAT Project 2024 annual update (forthcoming).*

5. Addressing barriers to EV adoption and the outlook ahead

Taking a step back, consumer surveys find that about half of U.S. vehicle buyers are considering buying an EV within the next 12 months, indicating substantial consumer interest and potential for market growth.[13]

Cost and charging-related concerns remain the most commonly cited barriers to consumer adoption.[14] Both trends are improving, thanks to both market competition and investment and supportive policy.

Today, outside the luxury vehicle segment (which is already at price parity), EVs in the mass-market compact SUV and mid-size car segments are still roughly $10,000 more expensive to purchase than comparable internal combustion vehicles (before any applicable tax credits or state incentives).[15]

Looking forward, battery prices continue to decline and competition is driving automakers to focus relentlessly on lowering the cost of manufacturing.[16] New more affordable EV models in the small crossover segment are also coming to market, like the new 2024 Hyundai Kona EV (which starts at ~$32k), the 2024 Chevy Equinox EV (starting MSRP ~$35k) and 2025 Volvo EX30 (starting at ~$36k).

[13] Cox Automotive, "2024 Cox Automotive Path to EV Adoption Study – Summary," May 2024 https://www.coxautoinc.com/wp-content/uploads/2024/05/2024-Path-to-EV-Adoption-Study-Summary.pdf
[14] Ibid.
[15] The Toyota RAV4 and Honda CRV retail for ~$30,000-$41,000, while the electric Mustang Mach-E, Hyundai Ioniq 5 and Tesla Model Y are priced at roughly ~$42,000-$62,000 (though the entry level EV trims generally come with more premium features than the entry trims of comparable ICE vehicles). Similarly, a Toyota Camry or Honda Accord retails for ~$28,000-40,000 while a Tesla Model 3 or Hyundai Ioniq 6 is priced at ~$39,000-$56,000. See Edmunds, "Big Gap Remains in Average Price of Electric vs. Gas Car," https://www.edmunds.com/car-buying/average-price-electric-car-vs-gas-car.html
[16] See e.g. Abhirup Roy and Nora Eckert, "Ford asks suppliers to cut costs in push to turn EV business profitable, memo says," Reuters, May 16, 2024, https://www.reuters.com/business/autos-transportation/ford-asks-suppliers-cut-costs-push-turn-ev-business-profitable-memo-says-2024-05-16/

Public charger networks are also expanding, helping address anxiety about charger access and electric vehicle range. The U.S. added about 700 new public fast-charging stations in the 2nd Quarter of 2024, an increase of 9% in three months, bringing the total to nearly 9,000 sites. The number of public fast-charging stations in the U.S. could outnumber gas stations by 2032 or sooner, according to Bloomberg.[17] The industry's convergence on the North American Charger Standard (NACS) will also ensure that EV owners have access to the broadest possible network of public fast-chargers. Companies will invest a collective $6.1 billion on North American charging infrastructure this year, nearly double their 2023 investment[18]—and federal funds are helping pave the way.

The most important thing Congress can do now for the EV sector is to provide policy certainty and continuity. By providing continuity and avoiding abrupt changes in policy conditions, Congress can create the right conditions for America's dynamic automotive sector to invest, compete, and meet consumers' needs.

###

6. Is the U.S. grid ready for EVs?

All those EVs and chargers mean more demand for electricity, raising the question: is the U.S. grid prepared to handle millions of new EVs?

To address this question, we need to take it in two parts and consider contributions of EVs to *total* electricity consumption and *peak* electricity demand.

First, it is important to note that even as EV *sales shares* increase, the *stock* of EVs on American roads lags behind sales. Only a portion of the overall U.S. automotive fleet turns over each year, with about 15-17 million vehicles sold each year and a total fleet of just over 280 million vehicles.[19] So while nearly 10% of *new* vehicles sold in recent months were plug-in vehicles, only about 1% of the on-road fleet of light duty vehicles are electric today. Even if 100% of *new* vehicles sold were electric tomorrow, it would take about 15 years before the entire fleet of U.S. vehicles is electrified—and it will take considerably longer than that given current trends. We thus have some time to prepare America's electricity infrastructure, markets, and regulation for widespread EV adoption—but we best not waste it.

REPEAT Project's 2024 Current Policies scenario — which most closely matches (yet still exceeds) current EV market trends — expects EVs to consume about 322 terawatt-hours (TWh) of electricity by 2030 and 723 TWh by 2035, equivalent to about 8% and 17% of total U.S. electricity use today (Figure 7).[20] Putting it another way, by 2035, electric vehicles could consume nearly as much electricity as is produced today by the nation's entire fleet of nuclear power plants or all non-hydro renewables combined.

[17] At the *current* pace, public fast-charging sites will outnumber gas stations in eight years, but the pace of charger deployment is expected to accelerate.
[18] Kyle Stock, "US Public EV Chargers Set to Surpass Gas Stations in Eight Years," Bloomberg, July 18, 2024, https://www.bloomberg.com/news/articles/2024-07-18/when-will-the-us-have-more-public-ev-chargers-than-gas-stations
[19] Statista, "Number of motor vehicles registered in the United States from 1990 to 2022," https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990/
[20] REPEAT Project 2024 annual update (forthcoming), "Current Policies – Conservative" scenario.

While a lot of attention has recently been paid to increasing demand from data centers and AI, electric vehicles are actually likely to be a larger driver of electricity demand growth over the coming decade.

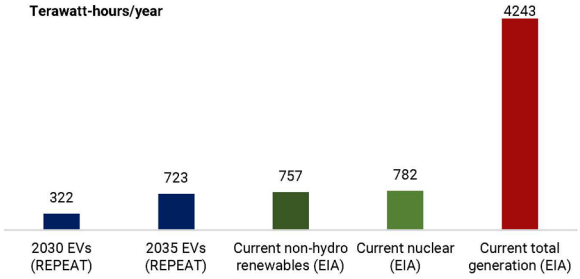


Figure 7. Projected Electricity Demand From Battery Electric and Plug-In Hybrid Electric Vehicles vs Current U.S. Electricity Generation

Source: EV demand projections from REPEAT Project 2024 annual update (forthcoming), "Current Policies – Conservative" scenario. Actual U.S. electricity generation from EIA Electric Power Monthly, for last 12 months ending in May 2024, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_1_01

To ensure that EVs deliver the greatest emissions reductions, the U.S. needs to add substantial new clean electricity generating capacity. Sustaining existing federal policies to support renewable electricity deployment and retain (and uprate) nuclear power plants are thus paramount, as are efforts to reform permitting and accelerate the construction of U.S. high voltage transmission networks.

It is important to note though that even when consuming today's average U.S. electricity mix, EVs produce about 80% less greenhouse gas emissions than a comparable gasoline vehicle and about 60% less than a comparable hybrid[21] — and the mix of *new* generation added to the U.S. grid will be *much cleaner* than today's supply. According to the Energy Information Administration (EIA), 99% of new capacity expected to come online in the U.S. over the next 12 months will be zero emissions generation or battery storage.[22]

Beyond contributions to overall electricity use, EV chargers also represent large new instantaneous power demands that could contribute to stress on local and national grid infrastructure. Coming home and plugging an EV into a typical Level 2 EV charger is like flipping the switch on a dozen or more window mounted air conditioners — or enough to roughly double or more the peak demand of a typical U.S. household. Poorly timed charging *could* therefore put considerable strain on local grid equipment, particularly at the distribution level.

Fortunately, it should be possible to avoid charging EVs during periods of peak grid stress. An EV with ~300 miles range has enough charge for a whole week's worth of average household driving, giving EV owners considerable flexibility to decide not just what time of day but *what day of the week* to charge their vehicles. Assuming only a modest level of flexible charging, REPEAT Project scenarios thus expect EVs to contribute 4% of peak U.S.

[21] Argonne National Laboratory, "Emissions from Electric Vehicles," https://afdc.energy.gov/vehicles/electric-emissions
[22] Energy Information Administration, Electric Power Monthly Table 6.1 https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_6_01

electricity demand in 2030 and 7% in 2035 (vs ~8% and 13% of total annual electricity consumption, respectively). Electric vehicles contribute ~41 gigawatts (GW) to a peak demand of 922 GW in 2030 and ~66 GW to a peak demand of 975 GW in 2035 in this scenario.[23] For comparison, the U.S. has ~506 GW of natural gas generating capacity today and is expected to add nearly 17 GW of new battery storage capacity to the grid in the next 12 months alone.[24] Broader use of managed charging could further reduce (and nearly eliminate) the contribution of electric vehicles to peak grid use.

It is thus critical to provide incentives for EV owners to participate in managed charging programs or "smart charging" programs that smooth out the aggregate demand EV chargers put on the grid at any one time. By charging during periods when distribution networks have ample spare capacity and electricity prices are lower, EV owners should also enjoy significantly lower costs to fuel their vehicles.

The technology is available today to coordinate EV charging and avoid stressing our grid infrastructure; all that is missing are appropriate regulatory reforms to retail rate design, demand response aggregation, and distribution utility remuneration. While these reforms are the domain of state utility regulators, Congress could consider measures to incentivize states to undertake these reforms, expand knowledge on best practices across the country, and establish appropriate technical standards for smart charging.

END

[23] REPEAT Project 2024 annual update (forthcoming), "Current Policies – Conservative" scenario.
[24] Energy Information Administration, Electric Power Monthly Table 6.1 https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_6_01

Written Testimony

Hearing of the Senate Budget Committee

United States Senate

Britta Gross

Director of Transportation

EPRI

"Charging Ahead: The Future of Electric Vehicles"

31 July 2024

Mr.Whitehouse, Mr. Ranking Member, and members of the committee, thank you for the opportunity to testify today. I am Britta Gross, the Director of Transportation at EPRI.

Background

EPRI is an independent, non-profit, global energy research, development, and deployment (RD&D) institute organized under section 501(c)(3) of the Internal Revenue Code. EPRI's experts collaborate with more than 450 companies in 45 countries, driving innovation to support clean, safe, reliable, affordable, and equitable access to electricity for the public across the globe.

EPRI brings together electric utility companies, scientists, and engineers, along with experts from academia, industry, and other centers of research to:

- Collaborate in solving challenges in electricity generation, delivery and use;
- Provide technical, scientific, and economic analyses to drive long-range research and development planning;
- Support multi-disciplinary, objective research in emerging technologies; and
- Help accelerate the commercial deployment of advanced electricity technologies for the benefit of the public.

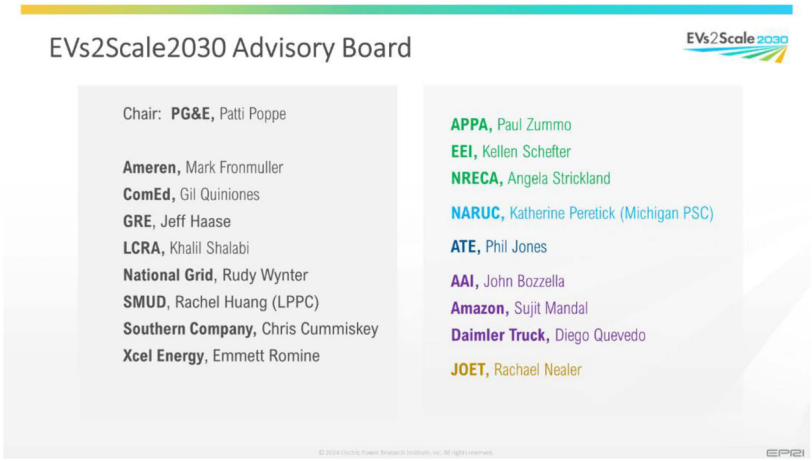
For over 34 years, **EPRI's Electric Transportation Program** has been working with utilities, vehicle manufacturers, and other key stakeholders worldwide to research, demonstrate, and assist in readying the grid for the deployment of electric vehicles and electric vehicle charging. With 5.2M+ EVs on the road in the U.S., the market transformation is underway, and while ~$5B in EV infrastructure has been installed or proposed by utilities in recent years, understanding this marketplace requires ongoing multi-faceted expertise and the ability to support a rapidly changing landscape while keeping rates low, the grid reliable

and resilient, and supporting individual and fleet customers. EPRI's Electric Transportation program gathers insights through collaboration with cross-industry stakeholders, national labs, and many others, and its research provides data, reports, tools, and easy-to-understand guides to help utilities and other public and private stakeholders expedite actions to achieve EV-related goals—whether they've recently engaged or are long-time market participants.

EVs2Scale2030 is a special three-year initiative led by EPRI that is focused on leveraging industry scale to galvanize and align critical market stakeholders as electric vehicles (EVs) are deployed at scale to achieve 2030 goals. The project aims to:

- Ensure utilities (and utility oversight bodies) are in lockstep with vehicle manufacturers, fleet operators, charging providers and consumers to build confidence in achieving 2030 goals.
- Help streamline the systems and processes needed to support the pace of activity and investment required to meet large-scale electrification by 2030.
- Develop needed tools and technologies required to enable and sustain EVs at scale and capture the grid benefits of this large and flexible load.

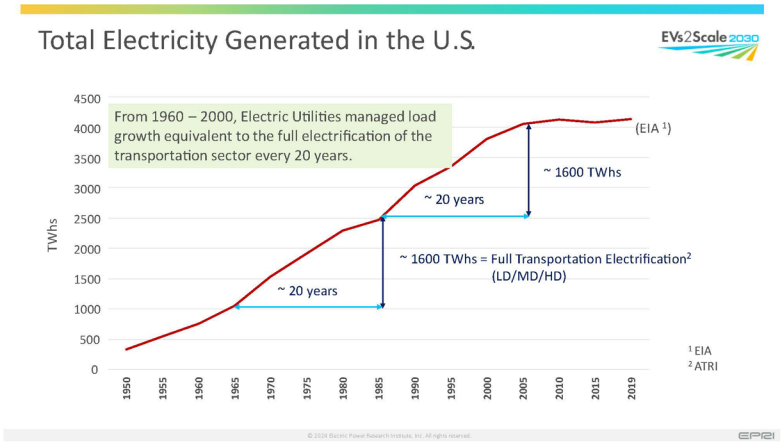
Industry collaboration is critical to the success of this initiative and the Advisory Board of EVs2Scale is illustrative of the cross-industry interest and collaboration in this project:



Current Landscape of Transportation Electrification and Grid Readiness

The electrification of the transportation sector is challenging from a grid perspective, given both the size of this load, the shorter lead-times, and the fact that cars, buses, and trucks are mobile, which means this load can appear just about anywhere on the grid.

The 5.2 million EVs on the road today have added roughly 18TWh (terawatt-hours) of energy demand – largely unnoticed. Fully electrifying the on-road transportation sector will require an estimated 1600 TWhs of energy (ATRI [2]). The following figure shows the utility industry has successfully adapted to load growth of this size at least twice before – once from 1965-1985 and again from 1985-2005. That is, in these 20-year periods, the grid has served new load that is approximately equal in size to fully electrifying the transportation sector – where the full transition of transportation is likely to take place over a period of time much longer than 20 years. The key is early planning and engagement with the utility industry, as well as industry collaboration across the vehicle manufacturers, fleet operators, and charging property developers. If the appropriate investments are enabled, the grid can support this transition.



1. Electricity Net Generation: Electric Power Sector - Microsoft Word - MER_S7 (eia.gov) [eia.gov]
2. ATRI report: ATRI-Charging-Infrastructure-Challenges-for-the-U.S.-Electric-Vehicle-Fleet-12-2022.pdf (page 16-17)

Transportation electrification is **also an opportunity** to **diversify** the load currently on the grid, which normally shows up as early morning or late afternoon load peaks. Utilities have to design for these "peak loads" to ensure electricity is reliable. If transportation loads simply add to these peak times, this could drive grid costs higher. But if utilities can take advantage of this typically flexible transportation resource, for example to charge most vehicles at night, this can help minimize new grid investments and support a more affordable transition.

Though the grid impacts of electric transportation will eventually be felt across the generation, transmission and distribution systems – the nearterm impacts, including to early fleet electric vehicle adoption, are being felt on **local distribution systems** – the wires that lead to our homes, offices, fleet depots, and charging sites.

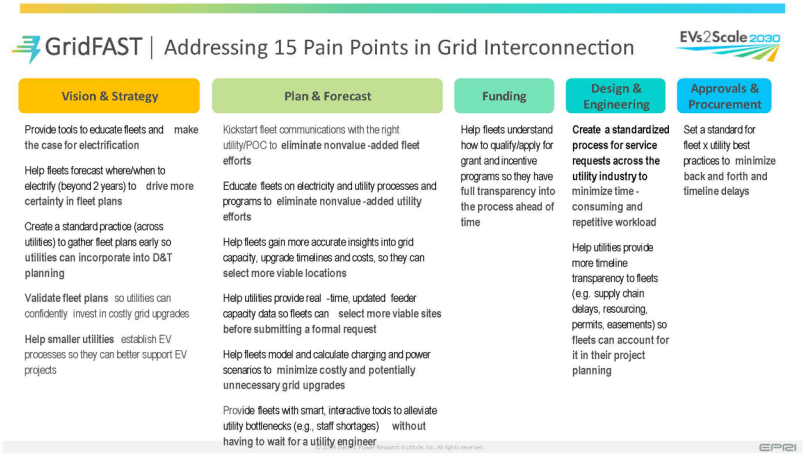
When we look at the overall grid impact of 279 million privately-owned vehicles (295 million vehicles overall) on the road today (97% of which are cars and light-duty trucks), the light-duty vehicle sector will consume by far the most energy. However, that load will be distributed across the entire grid, and its impact on a local distribution circuit is generally minimal. But heavily-concentrated fleets (such as airport car rental fleets) and trucking fleets, in particular, will bring larger loads to these local distribution systems. So in EPRI's work, though we consider all loads from light-duty to heavy-duty vehicles, we're especially focused on the impacts of fleets and trucking loads. It's worth noting, that Daimler Truck North America, Navistar, and Volvo Group North America already manufacture and sell electric medium-duty and heavy-duty trucks in the market today and are seeing these trucks deployed into fleets with local and regional short-haul routes for the movement of goods in areas such as grocery distribution and drayage operations.

Unlike building electrification, a challenge unique to transportation is the **timing mismatch** between shorter vehicle procurement times and longer grid interconnection timelines – i.e. the time it takes to make any necessary grid upgrades to bring additional power to a site. A fleet operator today can order a dozen heavy-duty electric semis and these will be delivered in four to six months, yet the time it takes to bring additional power to that site to serve vehicle charging can take anywhere from 18 months on average to multiple years if more significant grid upgrades are required. Truck manufacturers, including Daimler Truck, Navistar, and Volvo Group, flagged this issue in a recent utility proceeding in California and emphasize that sales of medium- and heavy-duty electric vehicles are dependent on the readiness of the grid to supply power to the charging sites – and that confidence in grid readiness for vehicle charging is critical for customers and has a direct impact on electric truck sales.

This "grid interconnection" time is a key focus area for EPRI, as all stakeholders are impacted by this challenge and this longer lead time for grid upgrades means the utility sector already needs to begin planning today for the transportation loads expected over the next five to ten years.

A second challenge is the **market complexity** – there are over 3,000 utilities (including investor-owned utilities, public/municipal utilities, and rural cooperatives) and tens of thousands of fleet operators who have seldom had to deal with electric utilities. This means a fleet operator or a charging property developer with hundreds of sites nationwide has to be able to identify the right utility to begin planning efforts and then figure out how to apply for service when utilities all use different processes, application forms, differing questions, and different levels of detail required in their applications.

Last year, EPRI studied the issues related to the grid interconnection process and identified 15 pain points at this intersection between transportation electrification customers and utilities. The following slide summarizes the findings of EPRI's research and has informed the design of a tool, GridFAST, that is currently in development and is part of our EVs2Scale2030 initiative.



To address these transportation-specific challenges and pain points, key industries **have to work together with utilities** in unprecedented ways to share their electrification plans earlier with utilities – and utility regulators – so that there is **advance knowledge** of where and when loads will show up on the distribution system. Fleet operators and charging providers are increasingly recognizing that outreach to utilities needs to be among the first steps to install vehicle chargers.This improved leadtime is critical for investment planning and accelerating grid interconnections for customers, while utilities also balance the need to ensure they continue to provide reliable electrical service to the broader public across all loads.

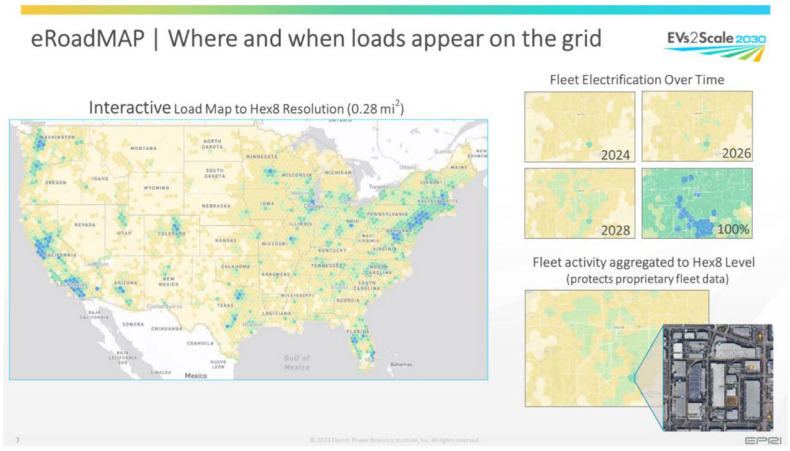
Solutions EPRI is Developing

Drawing on the expertise of the utility industry, fleet operators, charging providers, and vehicle manufacturers, EPRI launched the EVs2Scale2030 initiative and identified two critical tools to address current challenges and enable industry to get to scale.

The first tool is an interactive online map available to the public called eRoadMAP™ that is based on an unprecedented data-gathering approach to drive confidence into grid investment decision-making. This mapping tool identifies where and when transportation loads (from light-duty to heavy-duty vehicles) are likely to appear on the grid at a local distribution "feeder" level. More than eight expert organizations in data analytics and more than 10 different data sources (from OEM telematics to purchased vehicle behavioral and registration data to actual national fleet electrification plans) have been integrated in a complex undertaking to identify the likely location of future transportation charging loads – emphasizing that the actual electrification plans from participants are as certain as anyone can be about where and when loads will appear. eRoadMAP will continue to provide confidence as more fleet operators and charging providers share their electrification plans – informing utilities and utility regulators where to prioritize prudent grid investments.

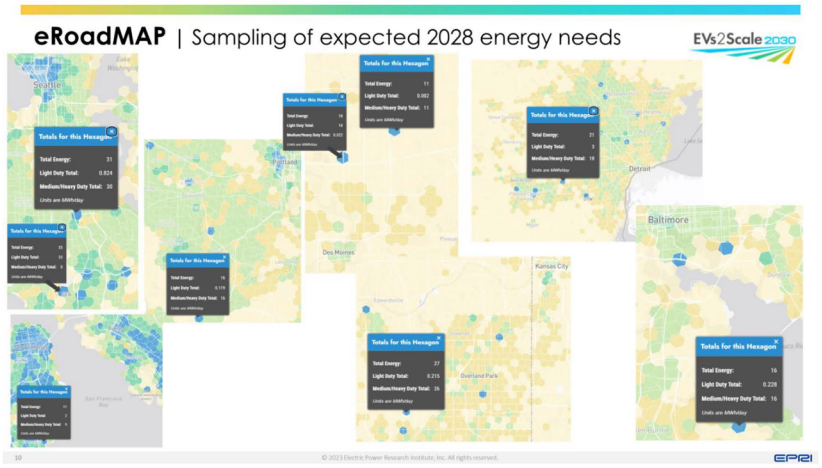


The following figure provides an overview of some of the data and features available in eRoadMAP. Note the simple use of color in visualizing priority hot spots, the importance of the timeline, and the ability to zoom into any area in the U.S. to see the forecasted feeder-level loads and what may be driving these loads in the satellite view. The map provides data at a "Hex8" level of resolution, where each hexagon covers an area of 0.28 mi^2. This is an important feature of eRoadMAP. Fleet operators are competitors, as are vehicle manufacturers and charging providers. EPRI and these industry stakeholders are sensitive to sharing data that one of their competitors can use to its advantage and committed to compliance with applicable law. We are able to preserve the confidential nature of the load data by aggregating the data at the Hex8 level, thereby obscuring the specific details from other fleet operators and charging providers, yet provide a resolution that is important to the utility industry and regulators, as planning and investment decisions are made at this roughly feeder level. This was a critical decision early in the planning for this tool and illustrates the trust needed between the various stakeholders. (eRoadMAP is found at https://eroadmap.epri.com/)



The following slide shows a sample from eRoadMAP of forecasted energy needs for a number of cities and surrounding areas (from Seattle to DesMoines to Baltimore) in 2028 at the most granular Hex8 level ($0.28mi^2$), illustrating the communicating power of this visualization tool. The examples shown here include hexes with airports, large charging hubs with already-heavy light-duty vehicle traffic, and sites with large logistics fleets planning to electrify.

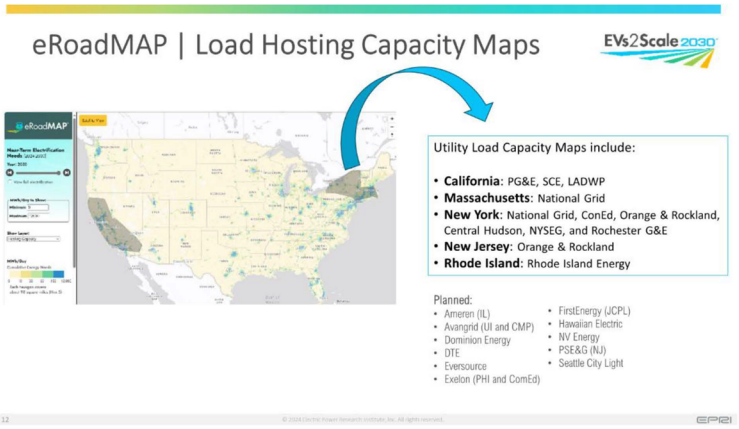
Note that all results currently display load in terms of energy (MWh), which tends to be more useful at the bulk level, for example to estimate the amount of generation required. We are in the process of converting energy to power (MW), which is a more useful measure for utility planning at the distribution level as power determines the size of equipment needed (wires, transformers, …) and ultimately the cost of serving this new load. This effort is expected to be completed in September 2024.



As described earlier, Amazon, Enterprise, Daimler Truck, Navistar, Tesla, Volvo Group, and many other stakeholders are providing vehicle telemetry and their fleet electrification plans to eRoadMAP so that this load information can be aggregated and shared responsibly with the utility industry, policymakers, utility regulators, and other interested stakeholders. The aim is to encourage fleet operators and charging property developers to move from months-ahead planning to years-ahead planning to enable utilities to plan for the grid upgrades and investment approvals much earlier than currently possible and with data that informs near-term, mid-term, and long-term planning horizons.

In addition to load forecasting, eRoadMAP is also integrating all available load hosting capacity maps from utilities across the U.S. that show the amount of power currently available on distribution feeders. **To our knowledge, this is the first time load hosting capacity maps have been aggregated in a single location and made publicly available**. Fleet operators and charging property developers can use this feature to help prioritize which sites to electrify first. For example, a fleet operator with 400 distribution centers across the U.S. can view the available grid capacity for all its sites to determine where the grid has available capacity today and where grid interconnections are likely to be faster to implement.

Establishing load hosting capacity maps is a relatively new utility concept – certainly relative to sharing this information publicly. Therefore, we expect it to take some time to establish a fully national capability. To date, EPRI has integrated 10 utility hosting capacity maps into eRoadMAP that cover some of the largest utility service territories across California and the Northeast, including Pacific Gas and Electric, Southern California Edison, National Grid, and ConEd. This effort continues, as we identify additional maps available from utilities – and work with the industry more broadly to communicate the usefulness of this information in accelerating electrification efforts.



To illustrate how the load forecasting and the hosting capacity maps work together to inform planning, three examples are shown here for Rochester, NY (a 2026 case), Providence, RI (a 2030 case), and Compton, CA (a 2027 case). These are relatively typical examples for illustrative purposes. If we, however, examine the forecasted loads across every Hex8 in the U.S. and identify the number of hexagons with estimated transportation loads greater than 60MWh (~2.5-15MW) -- an arguably challenging new load on most feeders -- we find that in 2026 only 3% of hexagons exceed this level and only 7% in 2030. This highlights that concentrated local grid impacts are not ubiquitous, but that where these higher loads are expected, it is important to begin grid planning as soon as possible.


EVs2Scale 2030
Rochester, NY
Load Forecast in 2026
Totals for this Hexagon
Total Energy: 13
Light Duty Total: 0.101
Medium/Heavy Duty Total: 13
Units are MWh/day
The forecasted energy need in this hexagon is 13 MWh in 2026 (~1-3 MW, depending on the load shape – i.e. whether this charging would be spread out evenly over a 24-hour period or concentrated into a few hours each day)
Line Capacity
Load Capacity (MW): 1.913
Data Source: NY State Gas & Electric, Rochester Gas & Electric
Line Capacity
Load Capacity (MW): 5.153
Data Source: NY State Gas & Electric, Rochester Gas & Electric
Rochester
Brighton
Greater Rochester International Airport
Clinton-Crossings
If 1-3MW are required by 2026 and today there are several feeders in this hexagon with 1.913-5.153MW available capacity, then it depends which feeder will be used to serve the load in 2026. Regardless, planning for this near-term load should start now.
Currently available grid capacity
• 1.913MW – 5.153MW on the "black" feeders
• < 1MW on the "gray" feeders
Large companies operating in this hexagon:
• Amazon Delivery Station
• GM Components Holdings
• US Postal Service
12
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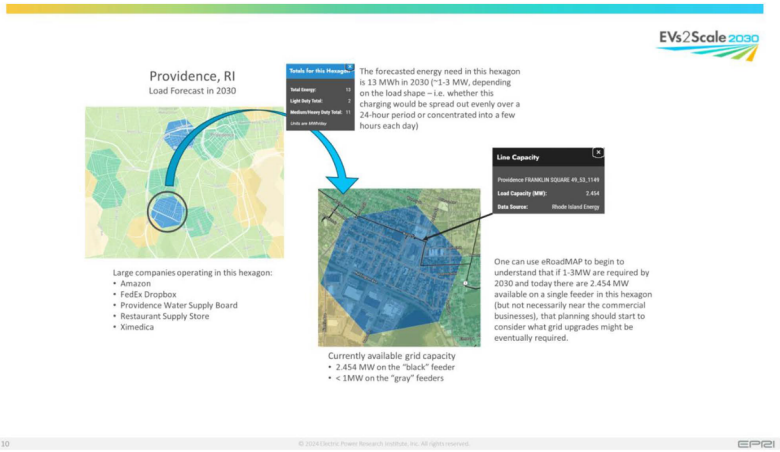
EPRI


EVs2Scale 2030
Providence, RI
Load Forecast in 2030
Totals for this Hexagon
The forecasted energy need in this hexagon is 13 MWh in 2030 (~1-3 MW, depending on the load shape – i.e. whether this charging would be spread out evenly over a 24-hour period or concentrated into a few hours each day)
Line Capacity
Providence FRANKLIN SQUARE 49_53_1149
Load Capacity (MW): 2.454
Data Source: Rhode Island Energy
One can use eRoadMAP to begin to understand that if 1-3MW are required by 2030 and today there are 2.454 MW available on a single feeder in this hexagon (but not necessarily near the commercial businesses), that planning should start to consider what grid upgrades might be eventually required.
Large companies operating in this hexagon:
• Amazon
• FedEx Dropbox
• Providence Water Supply Board
• Restaurant Supply Store
• Ximedica
Currently available grid capacity
• 2.454 MW on the "black" feeder
• < 1MW on the "gray" feeders
10
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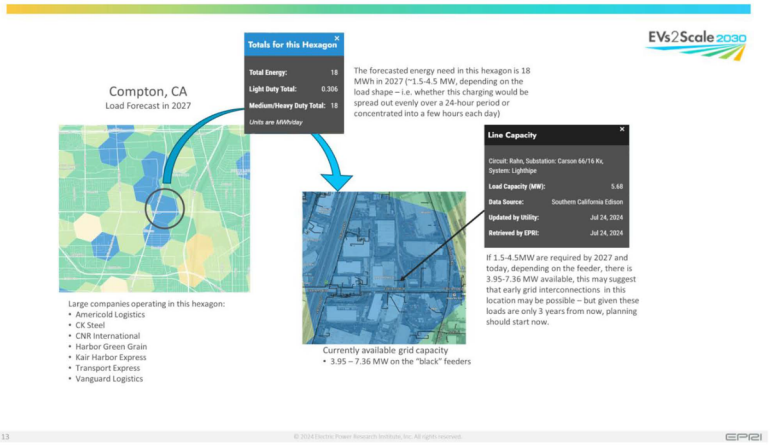
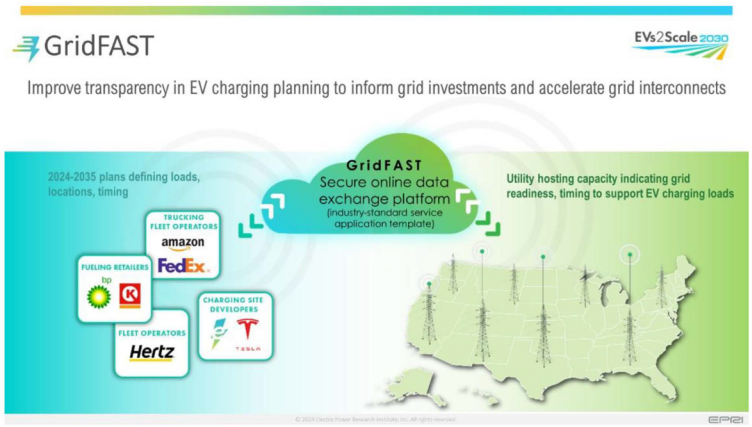


The second tool, currently in development at EPRI, is GridFAST, an online data-exchange platform that will act as a portal that all customers with transportation projects can use to automate the process of identifying and connecting with utilities to begin early project planning. The tool will identify which of the 3,000 utilities serve any community across the country, identify a point of contact at the utility, and allow utilities the ability to provide materials about their EV programs that are especially relevant to larger commercial customers.



A critical feature of GridFAST that has the support of several major utility CEOs will be a standardized "service application" template for the utility industry that will provide fleet operators and charging property developers with a common application form to request service for a charging site anywhere in the U.S. This will address one of the most-often cited pain points in the grid interconnection process and eliminate much of the time, complexity, and cost involved in reaching out to one utility at a time and providing the same information to the utilities over and over again. Much like the "College Common App" that allows college applicants to apply to multiple colleges at the same time without having to upload their resumes and provide identical transcripts each time, EPRI will include this EV Common App in its GridFAST platform. It is in development with a multi-industry steering group to include considerations of a wide range of stakeholders. In addition to the common service application questions, utilities will also be able to customize additional questions to meet their specific needs. GridFAST is planned to be available by the end of this year.

Summary

In summary, the electrification of the transportation sector is a challenging undertaking, but the utility industry has a proven record of adapting to loads of this size before. The key is early planning and engagement with the utility industry, as well as industry collaboration across the vehicle manufacturers, fleet operators, and charging property developers. More information can be found at: https://msites.epri.com/evs2scale2030 and epri.eroadmap.com

Thank you again to the Committee for the opportunity to share insights and comments on this important topic and I look forward to answering your questions.

EV BATTERY SUPPLY CHAINS AND ANTI-COMPETITIVE INDUSTRIAL POLICY



UNITED STATES SENATE COMMITTEE ON THE BUDGET HEARING
JULY 31, 2024

MS. MAUREEN HINMAN
SILVERADO POLICY ACCELERATOR

OPENING STATEMENT

Chairman Whitehouse, Ranking Member Grassley, and distinguished Members of the Committee, it is my sincere pleasure to appear before you today.

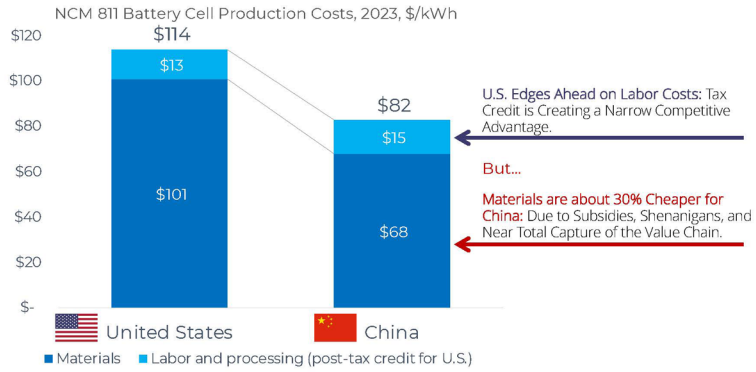
My name is Maureen Hinman, and I am the Chair and Co-founder of Silverado Policy Accelerator, a non-profit, bipartisan think and do tank focusing on developing novel policy solutions to our most pressing economic, environmental, and national security challenges through a focus on rigorous research, cross-domain policy engagement, and granular policy implementation.

Fittingly, the challenges before the global battery and electric vehicle supply chain represent a fulcrum of these risks, challenging our ability to transition American lives and livelihoods to a clean economy, maintain a critical manufacturing base, and preserve energy independence.

Currently, the EV battery sector is following a well tread pattern of the United States acting as chief global innovator on critical emerging technologies but falling short on the downstream industrial development because our market economy, bound by the rule-of-law, cannot reasonably compete with the openly predatory, non-market industrial policies of the Chinese Communist Party (CCP).

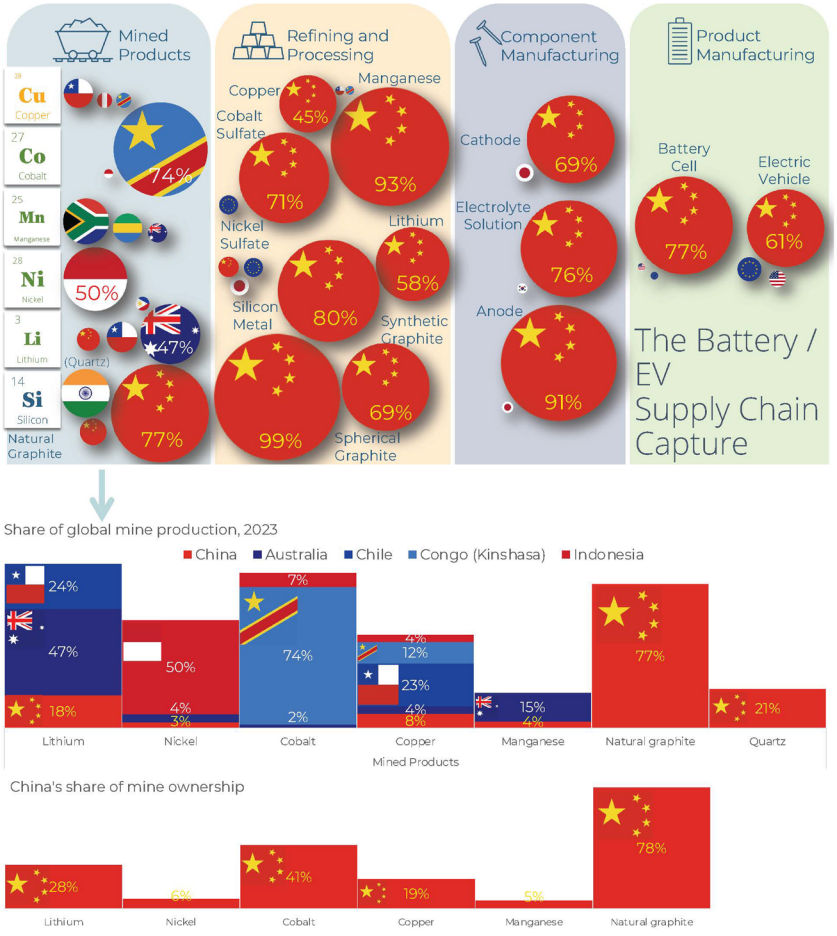
To change this script, we need to broaden the collective understanding of the impact the CCP's policies have on global competition and American national security. While yielding price distortions that have created low costs for consumers in the short-term, the CCP's industrial policies ultimately create an unsustainable risk matrix for the United States. For example, battery cell production costs, which comprise about 30-40 percent of the total vehicle production cost, sit at $114 per kWh in the United States compared to just $82 per kWh in China. This difference is owed to the fact that materials remain about 30 percent cheaper in China.

FIGURE 1. NCM 811 BATTERY CELL PRODUCTION COSTS



A cursory look at the EV battery supply chain reveals a troubling state of play: China has captured the balance of global supply chains for refined mineral products, battery components, and final products including battery cells and electric vehicles. For several of the mined products that are unavailable within China itself, Chinese firms own a major stake in mines globally. China controls 28 percent of lithium mines, 41 percent of cobalt mines, and nearly 20 percent of copper mines.

FIGURE 2. GLOBAL EV BATTERY SUPPLY CHAIN CAPTURE AND CRITICAL MINE OWNERSHIP AND INVESTMENT

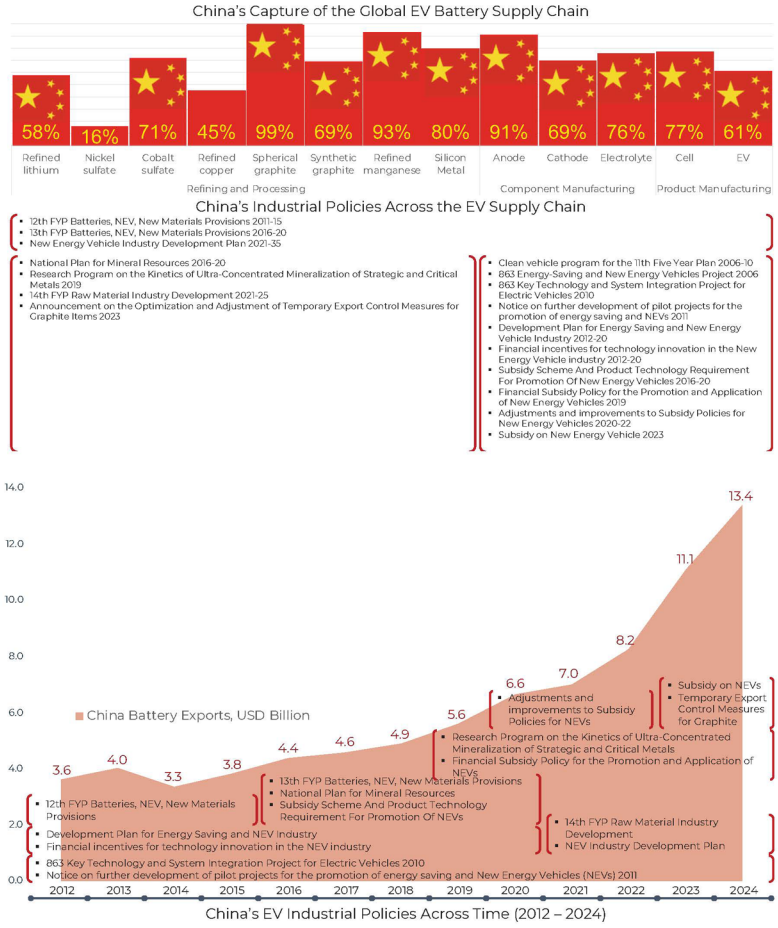


The CCP achieves these results through an industrial policy playbook I call the six S's:

1. First, China **sets** specific goals and targets for what it determines to be priority sectors including through sector specific 5 Year Plans and policies like Made in China 2025.
2. Next the CCP, **shelters** its infant industries from markets and competition using tools such as tariff and non-tariff trade barriers and limits on foreign investment.
3. Simultaneously, China **subsidizes** target industries directly, across the value chain through a variety of payment systems both formal and informal that firms operating in a market economy, underpinned by the rule of law, could simply not sustain.
4. Concurrently, Chinese firms and often the government itself are encouraged to acquire or outright **steal** foreign technologies and then merge and innovate upon them without the costs associated with legal acquisition of intellectual property.
5. Once Chinese technologies have a toehold in global markets, the CCP **subverts** competition through a variety of non-market strategies including undermining market pricing by building overcapacity and production untethered to real demand and then exporting the surplus on the global market at below cost prices, throttling or limiting supply to undermine competitors, making strategic investments in adjacent industries and critical infrastructure in key markets, and engaging in economic coercion and intimidation.
6. Finally, once China has established a near market monopoly Chinese firms **sell** everywhere at a price of their choosing, weaponizing supply chains in their favor.

The CCP's approach dwarfs' other nations efforts not just in strategy, but critically in scope, scale, and consistency across the entirety of the supply chain. Put simply, China unfairly and illegally subsidizes more programs, for more critical nodes, over a longer period, and with more dollars. The CCP's stated goal is to establish global monopoly power in all critical industries and they are well on their way to achieving this end in the EV battery market. The International Energy Agency anticipates that China's battery manufacturing capacity will account for 77 percent of world demand by 2030.

FIGURE 3. EV AND EV BATTERY INDUSTRIAL POLICIES ACROSS THE SUPPLY CHAIN, OVERTIME, AND ANNUAL SUBSIDIES



These cheap batteries are no deal.

Effectively countering these efforts will require that the United States and market economies deploy coordinated, agile policies at a scale sufficient to correct for market distortions and to protect U.S. public and private investments in industrial and environmental security. Silverado and I remain at your service as you devise policies that can meet this generational challenge.

Senators, thank you for your time.

APPENDIX: SUPPLEMENTAL INFORMATION

FIGURE 1. U.S. AND CHINESE BATTERY PACK PRICES AND PRODUCTION MARGINS

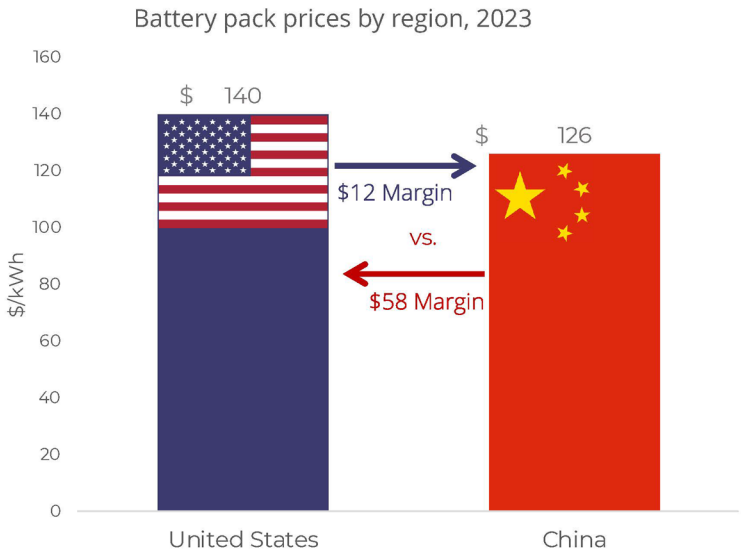
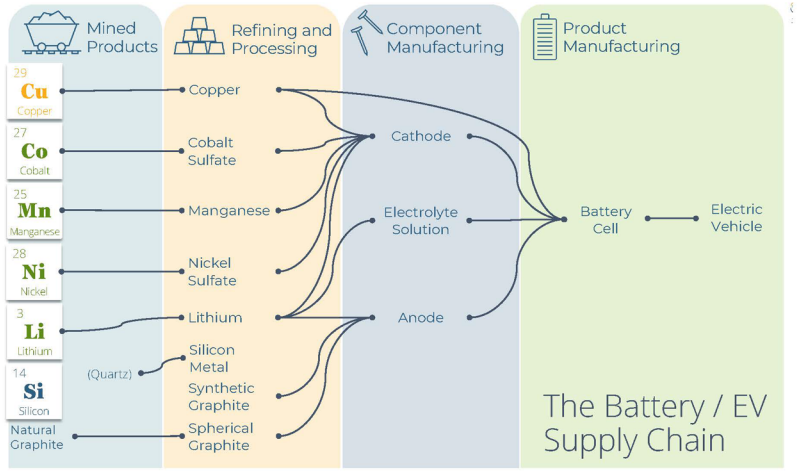


FIGURE 2. SIMPLIFIED EV BATTERY SUPPLY CHAIN



EV battery supply chains begin with mined products, including critical minerals such as copper, cobalt, nickel, and of course manganese. Mined products are refined and processed into industrial grade sulfates and metals that are used in the manufacture of the three critical components of cathodes, anodes, and electrolyte solution that comprise the finished battery cell.

FIGURE 3. COMPARATIVE MARKET ACCESS: U.S. AND CHINA

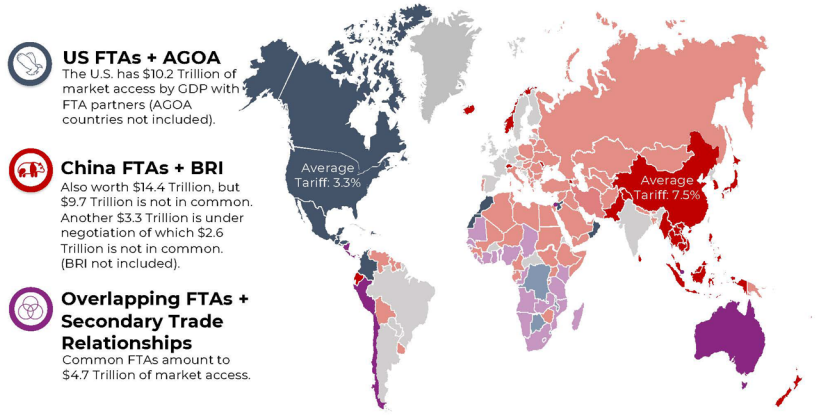
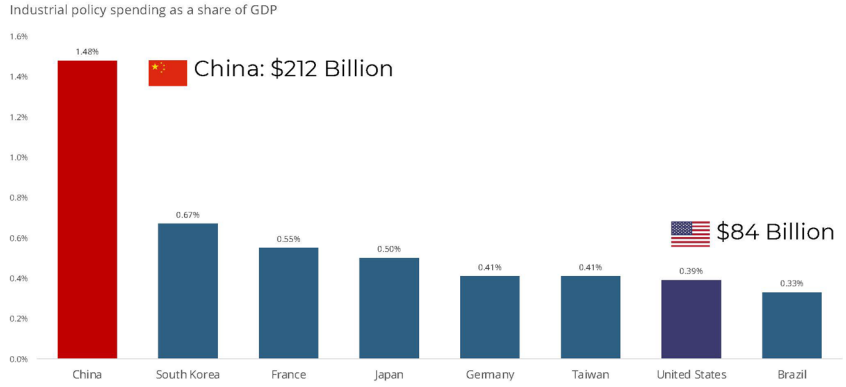


FIGURE 4. COMPARATIVE GROSS INDUSTRIAL POLICY SPENDING



NOTES AND SOURCES

Critical Mineral Supply Chains*: The data, except quartz, are production or production capacity for the latest available year (2021, 2022, or 2023). Quartz data are share of global exports. USGS; Global Trade Tracker; OECD; Visual Capitalist; Benchmark Mineral Intelligence; BloombergNEF; OECD.

CCP Industrial Policies Span the Battery / EV Supply Chain: USGS; OECD; Visual Capitalist; Benchmark Mineral Intelligence; BloombergNEF; OECD National Plan for Mineral Resources; 2016-2020. "Unlocking the true value of the EV battery through price" Simon Kucher, 2023.

Battery Critical Mine Ownership & Investment: Quartz data are the share of global exports. Copper mine ownership data are 2023, all other mine ownership data are 2022. The ownership share for all minerals except copper is from New York Times data and "is based on estimated production volumes multiplied by ownership equity stake." The methodology for calculating the copper mine ownership was not published in the data source. Other approaches to calculating ownership can result in significantly different ownership shares. For example, Benchmark Mineral Intelligence estimated that 60 percent of lithium mine output in 2023 was "associated with a Chinese company." USGS; Global Trade Tracker; Benchmark Mineral Intelligence; Open Mineral, "Who Controls Copper? Geotechnical Shifts in Copper Mine Ownership,,: May 16, 2024, https://openmineral.com/2024/05/16/who-controls-copper-geotechnical-shifts-in-copper-mine-ownership/; Chang, Agnes and Keith Bradsher, "Can the World Make an Electric Car Battery Without China?" *The New York Times*, May 16, 2023, https://www.nytimes.com/interactive/2023/05/16/business/china-ev-battery.html.

Comparing 1 Year of Year of Battery Subsidies: Tariff rates are for electric passenger vehicles. Tariff rates as of May 2, 2024. Subsidy estimates are preliminary estimates for the latest available year, which is 2022 for China and 2023 for the United States. The China data includes direct government subsidies, low interest loans, and tax refunds. U.S. data are primarily the Inflation Reduction Act (IRA) and federal R&D expenditures. State and local incentives for the United States are not included. The estimates are based on publicly available data sources and financial data from Bloomberg L.P.

Active CCP Battery/EV Industrial Policies Overtime: IEA, Silverado Policy Accelerator, Global Trade Tracker.

Emergent Competitive Differences: Battery Cell Production Costs: CRU Group, "What Could It Cost for Europe and North America to Localise the Battery Supply Chain?" April 11, 2024. Note: Values are derived from a chart and, therefore, are approximate.

Emergent Competitive Differences: Battery Pack Prices: BloombergNEF, Lithium-Ion Battery Pack Prices Hit Record Low of $139/kWh, November 26, 2023, https://about.bnef.com/blog/lithium-ion-battery-pack-prices-hit-record-low-of-139-kwh/.

Battery Manufacturing Capacity to 2030, GWH: IEA, "Lithium-ion Battery Manufacturing Capacity, 2022-2030," May 22, 2023, https://www.iea.org/data-and-statistics/charts/lithium-ion-battery-manufacturing-capacity-2022-2030; IEA, *Batteries and Secure Energy Transitions*, April 2024, https://www.iea.org/reports/batteries-and-secure-energy-transitions/executive-summary.

Industrial Policy Spending as Share of GDP – Macro, 2019: DiPippo, Gerard, Ilaria Mazzocco, and Scott Kennedy, *Red Ink*, Center for Strategic and International Studies, May 2022, https://csis-website-prod.s3.amazonaws.com/s3fs-

public/publication/220523_DiPippo_Red_Ink.pdf?VersionId=LH8ILLKWz4o.bjrwNS7csuX_C04FyEre.

Access Match Up: Average tariff rates are from 2022. GDP data are 2023. IMF, "GDP, Current Prices," https://www.imf.org/external/datamapper/NGDPD@WEO/OEMDC/ADVEC/WEOWORLD; WTO Stats, https://stats.wto.org.

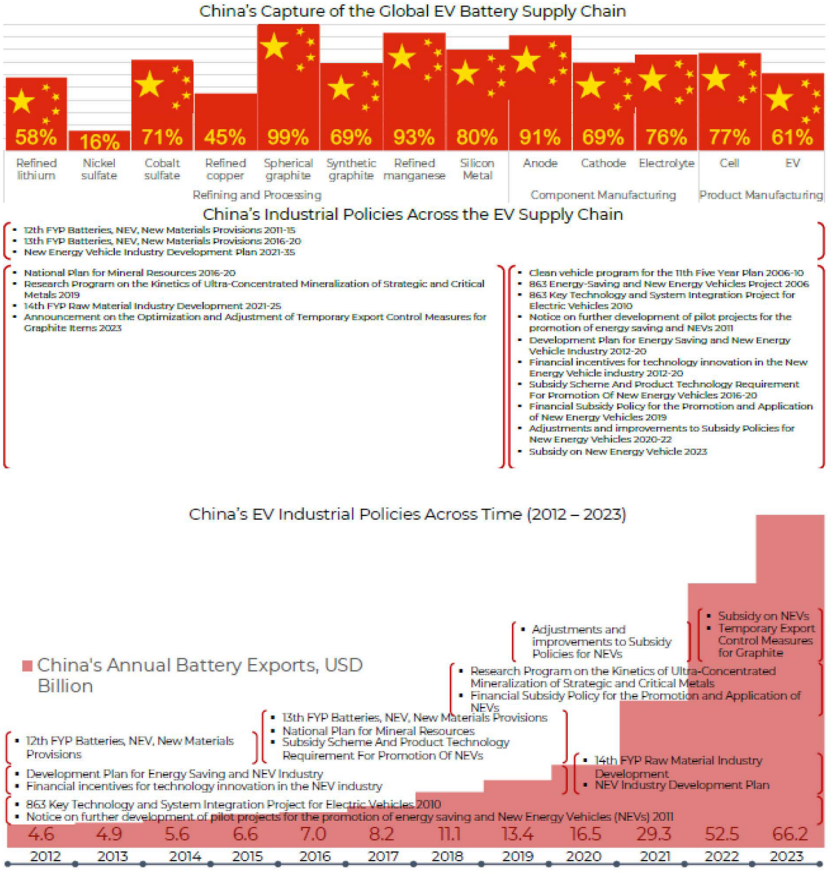
SILVERADO
POLICY ACCELERATOR

August 8, 2024

Errata to the original Testimony of Ms. Maureen Hinman
Co-founder and Chairman

Please find below an updated Figure 3. "China's EV Industrial Policies Across Time," as an errata to the original testimony submitted by Ms. Hinman on July 30, 2024.

FIGURE 3. EV AND EV BATTERY INDUSTRIAL POLICIES ACROSS THE SUPPLY CHAIN, OVERTIME, AND ANNUAL SUBSIDIES



STATEMENT

OF THE

ALLIANCE FOR AUTOMOTIVE INNOVATION

BEFORE THE:

COMMITTEE ON THE BUDGET

U.S. SENATE

HEARING TITLE:

"Charging Ahead: The Future of Electric Vehicles"

July 31, 2024

PRESENTED BY:

David Schwietert

Chief Government Affairs and Policy Officer

ALLIANCE FOR AUTOMOTIVE INNOVATION

Chairman Whitehouse, Ranking Member Grassley, Senator Graham and distinguished members of the Committee: on behalf of the Alliance for Automotive Innovation (Auto Innovators) and our members, thank you for the opportunity to appear today to share my perspective on expanded electrification in the auto industry and what this means for the future of automotive innovation and manufacturing across the United States. This is a pivotal period for the automotive sector and policy decisions made over the coming years will have lasting implications for decades to come.

Auto Innovators was formed in 2020 to serve as the singular, authoritative, and respected voice of the automotive industry in the United States. Our members represent the full automotive industry, from the manufacturers producing most vehicles sold in the U.S. to autonomous vehicle innovators to equipment suppliers, battery producers, and semiconductor makers. As the nation's largest manufacturing sector, the automotive industry is responsible for nearly 10 million U.S. jobs and contributes $1 trillion to the U.S. economy each year – representing nearly 5 percent of the country's gross domestic product.[1]

Leadership in automotive technology and manufacturing has underpinned a century of U.S. economic growth and innovation. The leadership of the auto industry in the United States and our global competitiveness is not a forgone conclusion. The ability of the auto industry to maintain its position in our economy rests on our country's leadership in, and acceptance and integration of, the innovative technologies - including electrification, automation, and connectivity - that will define the future of mobility for the American public.

It is no longer a question of whether these technologies will prosper. Rather, it's a question of where and at what pace. Nations around the world are moving aggressively to lead the development and deployment of these emerging automotive technologies. These same nations have clearly recognized that, as we have witnessed with respect to other sectors, those that lead

[1] https://www.autosinnovate.org/EconomicImpactReport

the development and deployment of these technologies will also guide the development of international standards, control supply chains, and drive international markets.

I do not state this lightly – the future of this highly competitive, capital-intensive industry hangs in the balance. The next decade will define which nations shape the future of automotive innovation and manufacturing. If U.S. policymakers do not support the development, commercialization, and acceptance of electrified vehicles, our nation risks becoming more dependent on foreign sources for raw materials and critical minerals in a future defined by our competitors.

If you think this sounds hyperbolic, look no further than the current realities of the global shift toward electrification and electric vehicle battery supply chain. For well over a decade, China made strategic investments in EV technologies and supply chains, placing that nation – and its manufacturing sector – in a position of strength as the global shift to expanded electrification gains momentum. Supply chains do not emerge overnight and while our members are fully committed to an expanded electrified future, we also cannot snap our fingers and magically overcome nearly two decades of investment and innovation by a foreign competitor. It is fairly simple – China moved first and now they are in a position of strength as other nations play catch-up in the transition to electrified vehicles.

It is important to put this in perspective. Two decades ago, the U.S. was the leading manufacturer of automobiles in the world. Today, we remain one of the global leaders, manufacturing approximately 10 million vehicles in the U.S., and more than 16 million across North America.

But our position in the global market has been dramatically outpaced by China. At the turn of the century, China was manufacturing around 2 million vehicles. Today, they manufacture 30 million vehicles and have capacity for nearly 50 million. Nearly one-third of that production was for new energy – or electrified – vehicles. Put differently, China is manufacturing EVs on a scale equivalent to the entire manufacturing output of the auto industry in the U.S.

Despite those sobering statistics, the auto industry in the U.S. remains at the forefront of innovation and manufacturing capacity that is critical to our national and economic security.

Since 2009, the auto industry has invested $322 billion to strengthen or expand automotive manufacturing in the U.S. Keep in mind, every direct job in vehicle manufacturing creates another 10.5 American jobs. These are not just auto jobs – these are jobs throughout communities and the economy necessary to support our manufacturing sector and provide $650 billion in payroll compensation as well as more than $220 billion in federal and state revenue annually. As a result, every $1 added to the economy by vehicle manufacturing creates an additional $3.45 in economic value.[2]

Today, the auto industry supports 10 million jobs, coast-to-coast. This is what is at stake as we look toward the future of the industry. If we do not invest in the technologies of the future, this critical manufacturing base and the jobs it supports are at risk.

Auto manufacturers and suppliers are committed to keeping the U.S. at the forefront of automotive innovation and manufacturing – and are investing in that future. In recent years, the auto industry has announced over $125 billion in EV investments, from battery factories to assembly plants.[3] Investments that will create more than 100,000 jobs and increase U.S. battery plant capacity by 649%.[4]

The success of these investments, however, depends on a host of factors outside the auto industry's control. Consumers must have confidence in the technology. This, in turn, depends on access to charging infrastructure, as well as overcoming concerns around range anxiety and the realities of longer fueling times. There are realities to the up-front costs of EVs, especially as we seek to transition the supply base to support this new technology – a transition that relies on mining, processing and other components that do not exist in the U.S. at a scale necessary to

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[2] https://www.autosinnovate.org/EconomicImpactReport

[3] This does not include needed investments in subcomponent capacity as reflected in Alliance for Automotive Innovation, *The Future is Electric: Let's Drive Together* (Feb 2024), available at https://www.autosinnovate.org/posts/communications/the-future-is-electric-infographic.pdf.

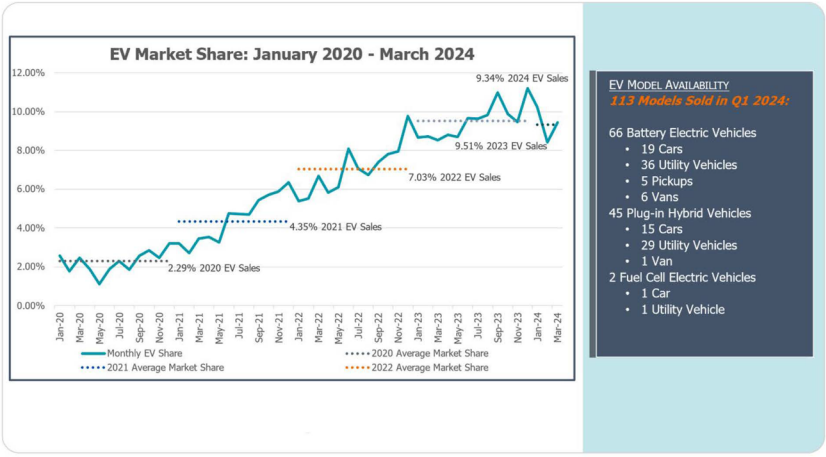
[4] Id.

meet existing, let alone future, demand. We call these supportive policies or "necessary conditions".

Current Vehicle Market in the U.S.

Let's start by looking at the U.S. vehicle market and then how that relates to the EV transition. Last year, the industry produced 10. million vehicles in the U.S., or 16.1 million in North America. Each year, manufacturers in the U.S. export 2 million vehicles, contributing to the incredible $140 billion in motor vehicles and parts exports – the second largest U.S. export.

In terms of sales, last year 15.4 million new vehicles were sold across the country. Of those vehicles, 80% were light duty trucks – crossovers, SUVs, pickups, and vans – continuing the trend of U.S. consumers preference for larger vehicles. We also see consumers holding on to vehicles for longer, with the average age of vehicles on the road at over 12 years.



EV sales have been increasing in recent years and of the 15.4 million vehicles sold in the U.S. last year, roughly 10 percent of these vehicles – or 1.4 million – were electrified products (battery electric, plug-in hybrid, or fuel cell). Today there are 113 electrified models available in

the U.S.[5] Over the past eight years, internal combustion engine (ICE) market share has steadily declined from more than 97 percent in 2016 to 78.6 percent in 2024 for an overall loss of 18.6 percentage points (pp). The ICE market share loss was replaced by increases in share of hybrids, BEVs, and PHEVs. Hybrids made up most of the alternative vehicle gains (+10.1 pp) followed by BEVs (+6.6 pp) and PHEVs (+1.9 pp) over the last eight years. Despite this trend, we must keep in mind that EVs remain just north of 1% of the 286 million vehicles registered in the U.S.

The market has changed substantially from where we were just a few years ago but, without question, the pace of consumer acceptance and willingness to purchase EVs has slowed in recent months. In response, you have seen a number of manufacturers reevaluating their product mix to respond to consumer expectations.

So what is driving this shift in consumer acceptance in electrified vehicles? In my opinion, there are a number of factors at play from higher interest rates to reaching the peak of "early adopters." As a result, the EV market will be choppy for some time as customers get comfortable with the technology, charging becomes installed and noticeable, and prices come down. Further, it must be stressed that most of these companies are self-funders, meaning they must raise and allocate massive capital to invest in cutting edge technologies through the sale of profitable ICE vehicles That process takes some time and recognition that companies can't get too far ahead of the customer.

Strategies that facilitate consumer awareness and wider-scale adoption are critical to sustaining a robust supply base and providing a smooth transition to advanced clean technologies. Rather than viewing this through the lens of "cost parity" to achieve meaningful consumer acceptance, we need to examine supportive policies that take it a step further, toward "convenience parity" — what is necessary to reach a point where a consumer can go shopping for a new vehicle and look at the EV and internal combustion engine (ICE) options with few questions about the

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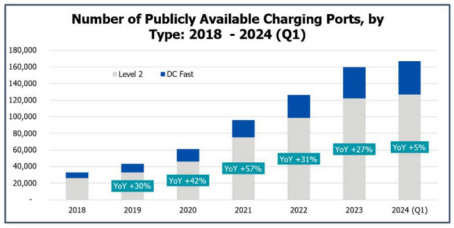
[5] Alliance for Automotive Innovation, *New American Auto Industry*, available at https://bit.ly/3Ss17tA (see also Attachment 1)

relative costs, ease, or convenience of ownership between the two. Let's take a look at some of the chief impediments to consumer acceptance of EVs – charging infrastructure and cost.

Charging Infrastructure

Access to convenient and reliable electric charging and hydrogen fueling infrastructure along with concerns surrounding "range anxiety" are among the most substantial impediments to widespread EV adoption. The Department of Energy estimates that 80 percent of vehicle charging occurs at home or work.[6] Most homes and businesses, however, lack the electric infrastructure to support vehicle charging, creating additional expense or inconvenience for those seeking to adopt the technology. Unfortunately, the ratio of publicly available EV charging infrastructure is widening and going in the wrong direction despite continued private and public sector investments to ensure reliable public EV charging across the country. Further, geographic disparities in charging infrastructure are pervasive. At the end of 2023, nearly 30 percent of all public charging infrastructure was located in California. Of the more than 3,100 counties in the U.S., 53 percent had five or fewer chargers installed; 31 percent had zero. The top 25 counties with the highest number of chargers accounted for one-third of all U.S. EV charging infrastructure.[7]

Level 2: 54,332 Locations, 126,630 EVSE Ports
DC Fast: 9,619 Locations, 40,583 EVSE Ports
Hydrogen Refueling: 56 Stations (55 are in California)
U.S. Total: *62,760 Locations, 167,213 EVSE Ports*
Some station locations have both Level 2 and DC Fast installed.

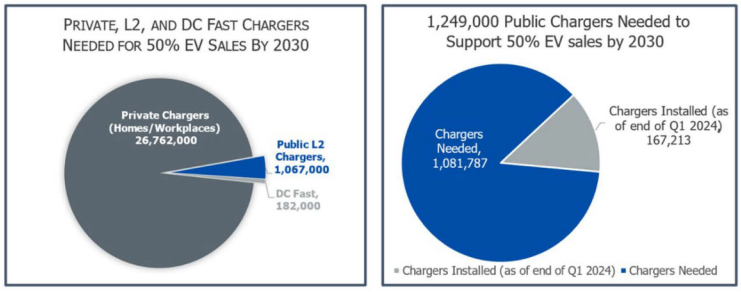


[6] U.S. Department of Energy. "Batteries, Charging, and Electric Vehicles." Accessed November 24, 2020. https://www.energy.gov/eere/electricvehicles/charging-home

[7] Auto Innovators, *Get Connected: Electric Vehicle Quarterly Report 2023 (Q4)* available at, https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%202023%20Q4.pdf

There are 4.7 million EVs on the road and a total of 167,213 publicly available charging outlets in the U.S. – a ratio of 28 EVs for every public port. Nationwide, in the first quarter of 2024 the number of publicly available EV chargers increased 5 percent from the previous quarter – while total EVs on the road increased 8 percent. Only 7,247 new public chargers were added while 344,533 new EVs were registered – a ratio of 48 new EVs for every new public port.

Number of Chargers needed to support 33 M EVs in 2030



More than 1 million additional public chargers (940,370 L2 and 141,417 DC Fast) will need to be installed to satisfy the necessary infrastructure estimate to accommodate 33 million EVs by 2030. This means that between the end of Q1 2024 and December 31, 2030, 438 chargers need to be installed every day, for the next 6.75 years. Or 3 chargers every 10 minutes through the end of 2030.[8]

Auto Innovators recently highlighted the importance of collaboration across government and multiple sectors to ensure a more seamless pathway to vehicle grid integration (VGI) – a simplified term to describe the converge of automotive and electric power sectors. This

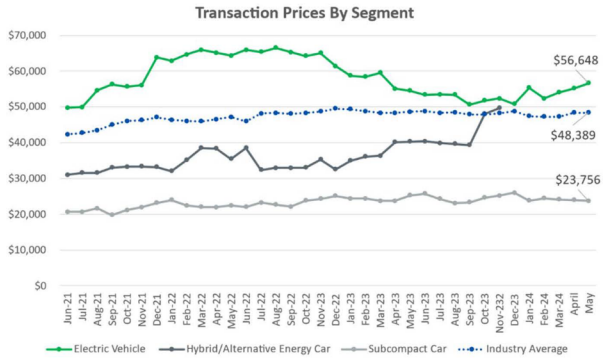
[8] Auto Innovators, *Get Connected: Electric Vehicle Quarterly Report 2024 (Q1),* available at, https://www.autosinnovate.org/posts/papers-reports/get-connected-q1-2024

partnership and coordination with the utility sector is critical to ensure the level of power needed to service both light and medium-heavy duty vehicles is commensurate with state and federal regulatory requirements (see Get Connected and Vehicle Grid Integration: The Convergence of the Automotive and Electric Power Industries for more information on charging infrastructure and modernizing the electric grid).

One additional note on the access to infrastructure, we need to work together with state and local governments to carefully consider what is necessary to equip homes and businesses (especially new construction) with the infrastructure to support cleaner transportation both now and in the future. Multiunit dwellings (MUDs) like apartment or condominium buildings pose a particular challenge to ubiquitous home charging capabilities. A large number of MUDs can be found in underserved communities where construction and accessibility to charging infrastructure should be prioritized and supported in order to ensure entire communities have the opportunity to participate in the EV transformation.

Costs

The auto industry has made significant progress in driving down electric vehicles costs — specifically battery technology, which is the largest cost-driver for EVs – typically around 30-40% of the vehicle cost.



Growing global demand for EVs coupled with constraints in a transitioning global supply chain continue to add cost pressures for new vehicle costs. As a result, these vehicles up-front generally remain more expensive than their ICE counterparts. For example:

- In May, according to estimates by Kelley Blue Book, the average transaction price (ATP) for a new vehicle in the U.S. was $48,389.
- The average price paid for an electric vehicle in May was $56,648.
- In May, the average incentive package offered by OEMs/Dealers – excluding any federal or state incentives - for an electric vehicle was 12.4% of the ATP, up from April and 5.7 percentage points higher than the industry average.

One of the greatest opportunities to continue to lower costs and bolster economic security is the establishment of robust and resilient supply chains for electrified vehicles. My fellow witness, Ms. Hinman, has provided more detail and context around the current supply chain realities relative to our largest global competitor. So what does this mean for the auto industry in the U.S., especially as we face increasing pressure to eliminate components and minerals from China?

It is fairly simple on paper - as U.S. EV manufacturing grows, we need complementary support for the entire supply chain, including mining, processing and associated permitting reform, to reduce dependence on foreign sources. We also need to work collaboratively with neighbors, allies, and partners across the globe to establish robust and resilient supply chains, even if they extend beyond our borders. Failure to do so will stress limited global capacity and – as witnessed with the semiconductor shortage – result in constrained supply and higher prices for consumers. Worse, if we do nothing to bolster key supply chains, it will leave us dependent on and exposed to foreign competitors and their ability to manipulate the market for materials, components, or finished products through market dominance.

I cannot stress enough the importance of accelerating our efforts to secure the upstream supply chain – specifically around mining and processing. While the U.S. has vast resources, our nation lacks sufficient geologic deposits of several critical minerals and the mining and processing capacity to support the growing demand and regulatory requirements for electric vehicles. Simply put, new mines and processing facilities face long lead times for permitting and

development, raising questions about how quickly domestic capacity can be developed. As we have noted previously - "While it only takes two to four years to bring battery cell and active component manufacturing online, mining and refining can take 10-15 years of development and an additional ten years until nameplate capacity is reached. The lag time between permitting, opening, mining, and refining available critical minerals domestically and processing the material into components and building the cells is significant, leaving the U.S. dependent on foreign sources of minerals for at least a decade."[9] (See Get Connected (2023-Q3) for more information on critical minerals and mines.)

If we do not develop a holistic national strategy for these emerging and future supply chains, from mineral extraction to battery end-of-life, we will cement future dependence on foreign competitors for the minerals and components critical to the future of the industry.

This is not simply a question, therefore, of global or economic competitiveness. It is about defining the future of this technology - and associated infrastructure - in a manner that emphasizes safety, responsibility, and opportunity for more citizens to benefit from this transformative shift in personal mobility.

We are approaching a pivotal moment in the evolution of our industry and have an opportunity to work collaboratively to chart a course that sustains U.S. leadership and innovation in personal mobility solutions for decades to come. It is not just about the future of the auto industry - it is about the nation's global competitiveness and economic security.

The industry is committed to this future, but we cannot do it alone – nor do we want to. It will take all of us to realize the benefits of expanded electrification and what it means to the future of our industry and U.S. competitiveness. Consumers must trust the technology. Companies must

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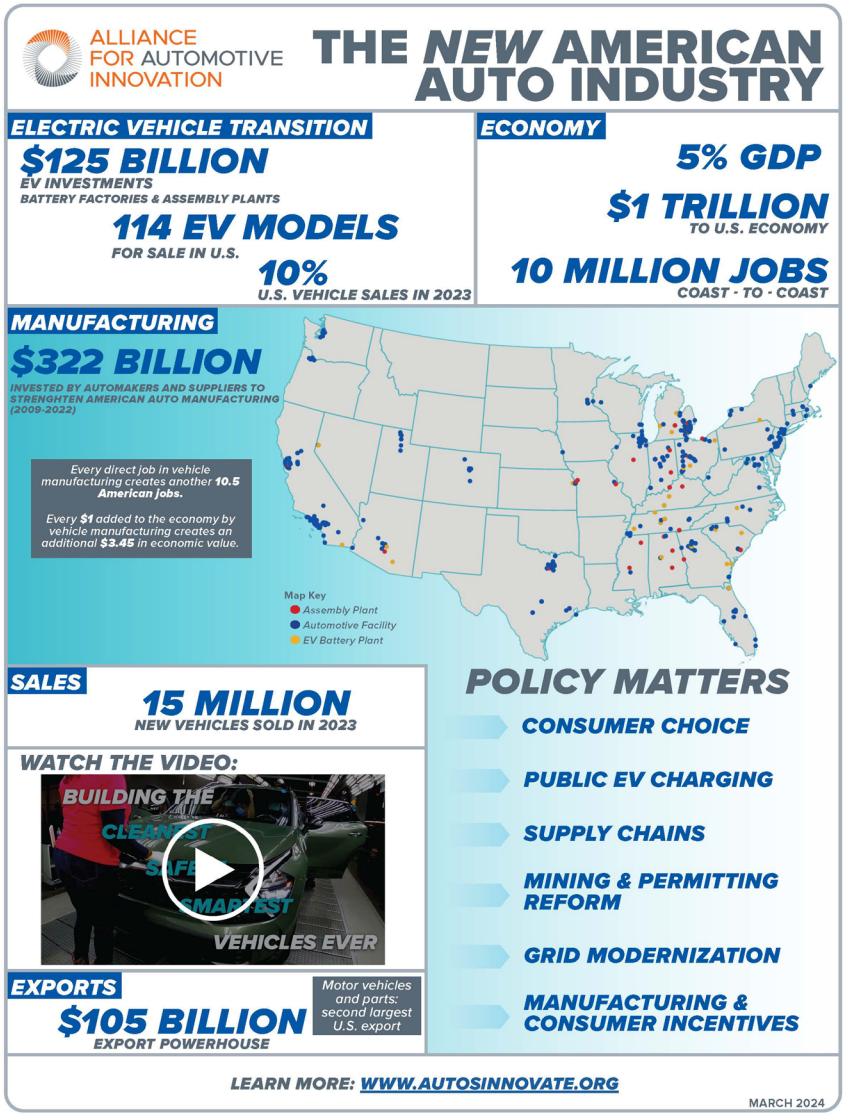
[9] Auto Innovators, *Get Connected: Electric Vehicle Quarterly Report 2023 (Q4)* available at, https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%202023%20Q4.pdf

earn that trust. And policymakers – at all levels – must implement the policies that facilitate those shared objectives, while recognizing market realities and consumer choice.

The global shift to expanded electrification is no longer a concept. The technology is here and scaling around the world. The question we must all ask ourselves is whether the U.S. will continue to be a leader in defining the future of personal mobility or allow it to be defined by others?

This is not about the next 5-10 years, specific technologies or policy objectives – it is about the future of automotive innovation and manufacturing in the U.S. for decades to come.
We look forward to continuing to work with you and your colleagues in Congress, as well as the Administration and other stakeholders, to shape the future of cleaner, safer, and smarter personal mobility.

ATTACHMENT 1


ALLIANCE FOR AUTOMOTIVE INNOVATION
THE NEW AMERICAN AUTO INDUSTRY
ELECTRIC VEHICLE TRANSITION
$125 BILLION
EV INVESTMENTS
BATTERY FACTORIES & ASSEMBLY PLANTS
114 EV MODELS
FOR SALE IN U.S.
10%
U.S. VEHICLE SALES IN 2023
ECONOMY
5% GDP
$1 TRILLION
TO U.S. ECONOMY
10 MILLION JOBS
COAST - TO - COAST
MANUFACTURING
$322 BILLION
INVESTED BY AUTOMAKERS AND SUPPLIERS TO STRENGHTEN AMERICAN AUTO MANUFACTURING (2009-2022)
Every direct job in vehicle manufacturing creates another 10.5 American jobs.
Every $1 added to the economy by vehicle manufacturing creates an additional $3.45 in economic value.
Map Key
Assembly Plant
Automotive Facility
EV Battery Plant
SALES
15 MILLION
NEW VEHICLES SOLD IN 2023
WATCH THE VIDEO:
BUILDING THE
VEHICLES EVER
EXPORTS
$105 BILLION
EXPORT POWERHOUSE
Motor vehicles and parts: second largest U.S. export
POLICY MATTERS
CONSUMER CHOICE
PUBLIC EV CHARGING
SUPPLY CHAINS
MINING & PERMITTING REFORM
GRID MODERNIZATION
MANUFACTURING & CONSUMER INCENTIVES
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MARCH 2024

50-STATE AUTOMOTIVE DATA

State	Auto Jobs*		Automotive Economic Impact*			2023 Powertrain Sales**					
	Total	%Sate Total	% State GDP	Vehicle & Parts As % of All Trade	New Vehicles Sold 2023**	ICE	Hybrid	PHEV	BEV	FCEV	ZEV Total
AK	12,455	2.9%	1.8%	0%	24,662	88.2%	8.2%	0.8%	2.8%	0.0%	3.6%
AL	134,774	5.1%	5.8%	31.4%	192,270	88.9%	8.5%	0.6%	2.0%	0.0%	2.6%
AR	53,514	3.3%	3.1%	3%	110,264	90.3%	7.4%	0.5%	1.7%	0.0%	2.3%
AZ	171,152	4.3%	3.7%	3%	352,667	81.1%	9.5%	1.2%	8.2%	0.0%	9.4%
CA	772,112	3.3%	2.6%	9%	1,721,223	60.4%	13.8%	3.5%	22.1%	0.2%	25.7%
CO	120,735	3.1%	2.6%	1%	268,324	74.7%	10.1%	4.2%	10.9%	0.0%	15.1%
CT	65,911	3.0%	2.5%	1%	144,927	77.4%	12.4%	3.4%	6.7%	0.0%	10.2%
DC	1,454	0.2%	0.1%	1%	16,847	64.9%	15.4%	4.0%	15.6%	0.0%	19.6%
DE	18,777	3.2%	3.4%	1%	47,195	80.0%	11.2%	2.2%	6.6%	0.0%	8.8%
FL	489,663	3.9%	3.5%	6%	1,308,738	82.9%	9.7%	0.9%	6.5%	0.0%	7.4%
GA	257,586	4.1%	3.9%	10.7%	450,362	83.8%	8.8%	0.8%	6.5%	0.0%	7.4%
HI	22,812	2.7%	3.0%	9.5%	71,138	82.0%	7.0%	1.3%	9.8%	0.0%	11.0%
IA	64,913	3.2%	2.5%	6%	120,983	88.2%	8.7%	0.9%	2.3%	0.0%	3.2%
ID	40,129	3.7%	3.4%	1%	68,219	84.3%	11.0%	1.4%	3.4%	0.0%	4.7%
IL	256,778	3.4%	3.0%	3%	518,575	81.7%	10.5%	1.3%	6.5%	0.0%	7.8%
IN	200,348	5.2%	6.1%	10.2%	239,187	85.7%	10.2%	1.0%	3.2%	0.0%	4.1%
KS	63,619	3.4%	3.8%	2%	93,869	86.2%	9.1%	1.0%	3.8%	0.0%	4.8%
KY	141,589	5.7%	7.2%	9%	138,947	87.5%	9.2%	0.8%	2.6%	0.0%	3.3%
LA	79,759	3.1%	2.5%	1%	192,187	90.9%	7.1%	0.5%	1.4%	0.0%	2.0%
MA	109,477	2.3%	1.6%	1%	307,590	75.2%	12.8%	4.0%	8.1%	0.0%	12.0%
MD	104,727	2.9%	2.5%	24.2%	272,204	76.2%	12.1%	2.9%	8.8%	0.0%	11.7%
ME	32,096	3.9%	4.0%	1%	64,201	84.1%	9.8%	2.8%	3.2%	0.0%	6.0%
MI	392,193	7.2%	9.3%	50.8%	479,866	88.7%	7.3%	1.0%	3.0%	0.0%	4.0%
MN	107,188	2.9%	2.4%	3%	228,949	84.0%	9.6%	1.4%	5.0%	0.0%	6.4%
MO	168,454	4.6%	5.3%	10.6%	284,658	86.3%	7.7%	2.4%	3.5%	0.0%	5.9%
MS	67,782	4.3%	5.1%	6%	101,935	90.9%	7.5%	0.5%	1.0%	0.0%	1.5%
MT	27,360	4.0%	3.1%	1%	58,276	86.6%	10.0%	1.2%	2.2%	0.0%	3.4%
NC	221,071	3.6%	2.8%	3%	422,990	82.1%	10.8%	1.1%	5.9%	0.0%	7.0%
ND	17,781	1.4%	2.6%	3%	37,914	92.5%	6.2%	0.5%	0.8%	0.0%	1.3%
NE	44,878	3.4%	2.5%	4%	81,465	88.1%	8.2%	1.2%	2.5%	0.0%	3.7%
NH	34,094	3.9%	3.5%	1%	87,297	85.0%	10.0%	1.7%	3.2%	0.0%	4.9%
NJ	146,997	2.8%	2.2%	5%	492,075	75.7%	10.7%	2.7%	10.9%	0.0%	13.6%
NM	32,833	3.0%	2.6%	2%	76,764	85.3%	9.8%	1.2%	3.7%	0.0%	4.9%
NV	57,203	3.2%	3.1%	1%	133,103	76.5%	10.2%	1.7%	11.6%	0.0%	13.2%
NY	239,384	2.0%	1.3%	1%	839,538	80.0%	11.0%	3.5%	5.6%	0.0%	9.1%
OH	305,340	4.5%	4.4%	13.3%	509,566	86.4%	9.4%	1.1%	3.1%	0.0%	4.2%
OK	80,160	3.6%	3.0%	2%	488,934	90.9%	4.4%	3.0%	1.7%	0.0%	4.7%
OR	80,763	3.2%	2.7%	8%	151,929	70.8%	13.7%	3.7%	11.8%	0.0%	15.4%
PA	235,623	3.2%	2.4%	4%	541,989	82.6%	11.0%	2.1%	4.2%	0.0%	6.3%
RI	17,422	2.8%	2.2%	30.6%	47,468	81.9%	10.4%	3.4%	4.4%	0.0%	7.8%
SC	131,581	4.7%	5.2%	24.8%	211,948	86.4%	9.7%	0.8%	3.1%	0.0%	3.9%
SD	21,801	3.6%	3.1%	3%	37,684	90.9%	7.0%	0.9%	1.3%	0.0%	2.1%
TN	214,130	5.2%	6.4%	14.1%	266,032	86.5%	8.6%	0.6%	4.2%	0.0%	4.9%
TX	685,089	3.9%	3.9%	8%	1,462,554	85.8%	8.0%	0.7%	5.5%	0.0%	6.2%
UT	75,385	3.5%	3.1%	4%	146,441	80.5%	10.8%	1.6%	7.1%	0.0%	8.7%
VA	160,474	3.1%	2.4%	5%	334,908	78.3%	11.9%	1.4%	8.3%	0.0%	9.7%
VT	14,986	3.6%	3.2%	1%	39,210	79.1%	10.6%	3.6%	6.7%	0.0%	10.3%
WA	113,800	2.6%	1.9%	5%	276,907	65.8%	15.4%	3.0%	15.8%	0.0%	18.8%
WI	127,419	3.5%	3.0%	3%	220,530	86.0%	9.7%	0.9%	3.3%	0.0%	4.3%
WV	27,186	3.2%	2.8%	12.3%	72,184	89.7%	8.5%	0.6%	1.1%	0.0%	1.8%
WY	11,627	3.0%	2.3%	0%	22,615	89.6%	8.3%	0.8%	1.3%	0.0%	2.1%
U.S.	**9,668,915**	**4.94%**	**4.9%**	**9%**	**14,880,308**	**80.4%**	**10.1%**	**1.9%**	**7.6%**	**0.0%**	**9.5%**

*Multi-industry contribution analysis of the economic impact of automotive manufacturing, selling, repairing, renting, and additional manitenance model using IMPLAN economic analysis data software, 2021 data year;
** Figures compiled by Alliance for Autotmoive Innovation with new registration retail and fleet data provided by S&P Global Mobility covering January 1, 2023 - December 31, 2023

Eno Center for Transportation

Written statement of Jeff Davis, Senior Fellow, Eno Center for Transportation

Before the Senate Committee on the Budget, July 31, 2024

"Charging Ahead: The Future of Electric Vehicles"

Mr. Chairman, Mr. Ranking Member, Senators, my name is Jeff Davis and I am a Senior Fellow at the Eno Center for Transportation. Eno is a nonpartisan think tank founded by traffic pioneer William Phelps Eno in 1921 to carry on his work increasing the safety and flow rate of vehicular traffic. We are a 501(c)(3) nonprofit organization that now studies all modes of transportation up and down the federalist chain of government.

The federal government began taxing motor fuels in 1932, to balance the federal budget, after the Depression collapsed incomes (and thus income tax receipts) but somehow people kept driving. By 1932, net income reported on tax returns had dropped 55 percent from its pre-Depression peak, but the number of gallons of gasoline used on roads had only dropped 9 percent.[1] The gas tax was a very broad-based and non-volatile revenue stream.

Gasoline and diesel fuel receipts were transferred to a new Highway Trust Fund created by Congress on July 1, 1956 to reassure the House members who had defeated the 1955 Interstate highway bill that the increased taxes levied by the revised 1956 legislation would be held separately from general revenues and would only be spent on specific highway programs. After Congress killed the 1972 highway bill, the Trust Fund was opened to mass transit spending as well, at local option, in 1973 and on a permanent basis by the establishment of a Mass Transit Account in 1982.

The Highway Trust Fund has been fundamentally insolvent since 2008. Electrification did not start this problem, but it stands to make the problem much worse in the coming years.

From the Trust Fund's inception on July 1, 1956, through the end of last month, the Trust Fund had received $1.4 trillion in excise taxes on highway users, principally from almost $900 billion in gasoline and gasohol taxes and $300 billion in diesel fuel taxes. Over the same 67-year period, the Trust Fund has paid out $1.6 trillion in outlays.[2]

That "revenue gap" of $0.2 trillion has been filled primarily with *ad hoc* transfers from the General Fund of the Treasury, to the tune of $272 billion since the Trust Fund first became insolvent in 2008. The Infrastructure Investment and Jobs Act of provided the last $118 billion tranche of General Fund transfers, of which $113 billion remained unspent as of one month ago. The Trust Fund is expected to need replenishing again in the middle of 2028.

Table 1

Special Transfers to the Highway Trust Fund by Acts of Congress

Special General Fund Transfers to the Highway Trust Fund, 2008 to Present

(Billions of Dollars -Showing the Effects of Joint Committee Sequestration in FY 2014)

			Highway Account			Mass Transit Account			HTF
Public Law	Enacted	Effective	Enacted	Sequest.	Net Total	Enacted	Sequest.	Net Total	Net Total
PL 110-318	9/15/08	9/15/08	8.017		8.017	0.000		0.000	8.017
PL 111-46	8/7/09	8/7/09	7.000		7.000	0.000		0.000	7.000
PL 111-147	3/18/10	3/8/10	14.700		14.700	4.800		4.800	19.500
PL 112-141	7/6/12	10/1/12	6.200		6.200	0.000		0.000	6.200
PL 112-141	7/6/12	10/1/13	10.400	-0.749	9.651	2.200	-0.158	2.042	11.693
PL 113-159	8/8/14	8/8/14	7.765		7.765	2.000		2.000	9.765
P.L. 114-41	7/31/15	7/31/15	6.068		6.068	2.000		2.000	8.068
P.L. 114-94	12/4/15	12/4/15	51.900		51.900	18.100		18.100	70.000
P.L. 116-159	10/1/20	10/1/20	10.400		10.400	3.200		3.200	13.600
P.L. 117-58	11/15/21	11/15/21	90.000		90.000	28.000		28.000	118.000
Total, GF to HTF			**212.450**	**-0.749**	**211.701**	**60.300**	**-0.158**	**60.142**	**271.843**

Leaking Underground Storage Tank Trust Fund Transfers to the Highway Trust Fund

(Billions of Dollars -Showing the Effects of Joint Committee Sequestration in FY17 and FY18)

			Highway Account			Mass Transit Account			HTF
Public Law	Enacted	Effective	Enacted	Sequest.	Net Total	Enacted	Sequest.	Net Total	Net Total
PL 112-141	7/6/12	7/6/12	2.400		2.400	0.000		0.000	2.400
PL 113-159	8/8/14	8/8/14	1.000		1.000	0.000		0.000	1.000
P.L. 114-94	12/4/15	12/4/15	0.100		0.100	0.000		0.000	0.100
P.L. 114-94	12/4/15	10/1/16	0.100	-0.007	0.093	0.000		0.000	0.093
P.L. 114-94	12/4/15	10/1/17	0.100	-0.007	0.093	0.000		0.000	0.093
Total, LUST to HTF			**3.700**	**-0.014**	**3.687**	**0.000**		**0.000**	**3.687**

Total GF & LUST Transfers to HTF			**216.150**	**-0.762**	**215.388**	**60.300**	**-0.158**	**60.142**	**275.529**

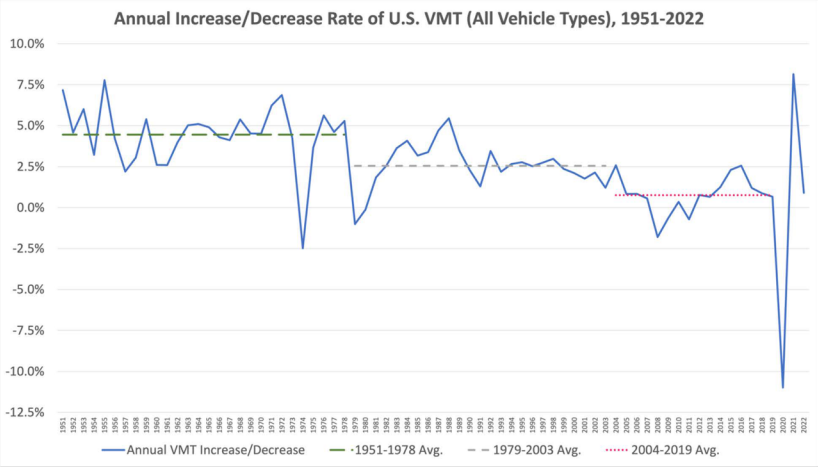
The insolvency problem predates modern, mass-marketed electric vehicles, and the trendlines were negative even before hybrids appeared on the market in 2000, but the latest U.S. policies towards rapid electrification of the U.S. vehicle fleet will have the side effect of making the Trust Fund's imbalance much worse in the coming decade.

To begin with, taxing motor fuels on a fixed cent-per-gallon basis has always been a proxy for taxing the act of driving a vehicle itself. And the rate at which Americans drive, day-to-day, has stabilized after decades of rapid growth.

From the 1950s to the end of the 1970s, the number of miles driven on American roads grew on a pace to double every 16 years. Driving behavior changed following the second major worldwide oil shock of the decade, and beginning in 1979, driving only increased on a pace to double every 30 years.

But then, around 2004, habits changed again, and from then to 2019 (the pre-COVID year), total Vehicle-Miles Traveled (VMT) was basically stagnant, only increasing at a rate to double every 90 years.

Figure 1



Data sources: FHWA Table VM-201 in Highway Statistics Summary to 1995, and the December 2023 Traffic Volume Trends.

The new (June 2024) forecast from the Federal Highway Administration is for the VMT growth rate to keep slowing. For light-duty vehicles (the ones that use most gasoline), VMT is projected to grow at an 0.5% per year rate over the next two decades and slow after that. At that rate, VMT would take over 140 years to double again.

Table 2

Federal Highway Administration June 2024 Projected Compound Annual Growth Rates in Vehicle Miles Traveled (VMT)

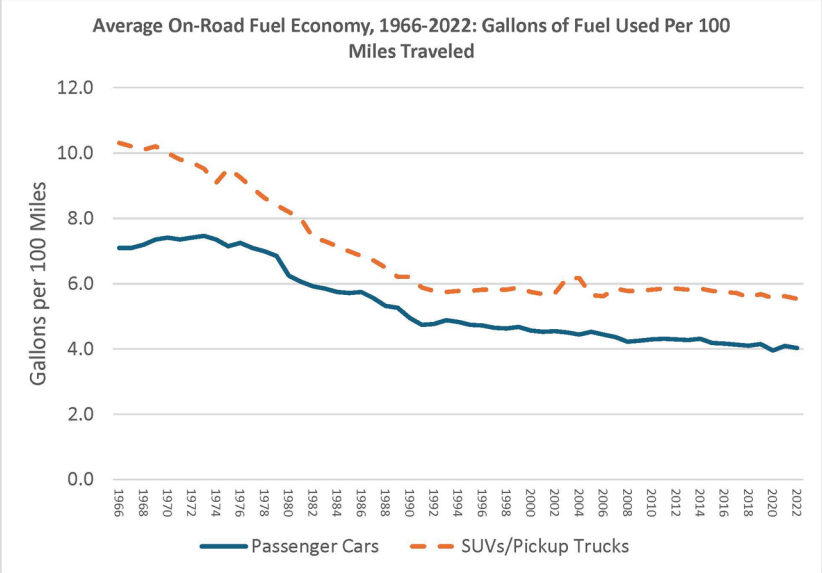
Vehicle Class	Pessimistic Economic Growth Outlook* 2019-2040 (21 Year)	Pessimistic Economic Growth Outlook* 2019-2050 (31 Year)	Baseline Economic Growth Outlook* 2019-2040 (21 Year)	Baseline Economic Growth Outlook* 2019-2050 (31 Year)	Optimistic Economic Growth Outlook* 2019-2040 (21 Year)	Optimistic Economic Growth Outlook* 2019-2050 (31 Year)
Light-Duty Vehicles	0.4%	0.3%	0.5%	0.4%	0.7%	0.6%
Single-Unit Trucks	1.5%	1.4%	2.1%	1.9%	2.9%	2.6%
Combination Trucks	1.1%	1.0%	1.3%	1.1%	1.5%	1.3%
Total	0.5%	0.4%	0.6%	0.5%	0.9%	0.8%

Because taxing gallons of gasoline consumed was a proxy for taxing miles driven, the number of gallons sold and taxed per year grew with VMT, and that was faster than inflation in the 1950s and 1960s, preventing the need for tax rate increases.

But after those oil shocks, the number of gallons of gasoline used on roads became a less and less perfect proxy for miles driven. Federal energy independence policy in the 1970s mandated more fuel-efficient cars, and these standards were raised again in the late 2000s as part of federal energy and environmental policy. To make the trend lines point the same direction, we can invert the ratio and look at gallons per mile instead of miles per gallon – in this instance, the average number of gallons of gasoline used for every 100 miles driven.

In 1976, the average passenger car on the road burned 7.2 gallons of gasoline for every 100 miles driven. Today, the average passenger car on the road only burns 4.0 gallons of gas every 100 miles. For SUVs and pickups, fuel efficiency has increased from 9.3 gallons per hundred miles in 1976 to 5.6 gallons per hundred miles today.

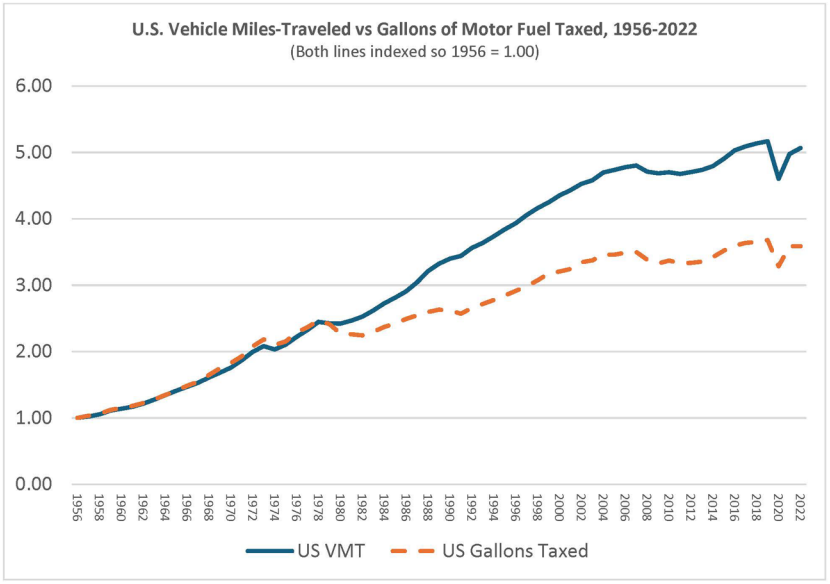
Figure 2



Data source: U.S. Energy Information Administration, Monthly Energy Review (June 2024), Table 1.8, Motor Vehicle Mileage, Fuel Consumption, and Fuel Economy

Putting the VMT trendline and the gallons taxed trendlines together and indexing them to the same starting point shows how the gas tax has become a worse and worse proxy for miles driven since the early 1980s.

Figure 3

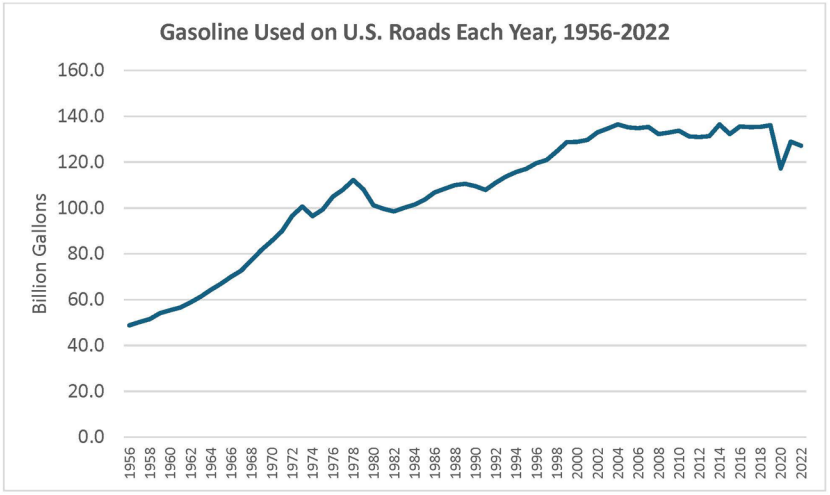


Data sources: For VMT: FHWA Table VM-201 in Highway Statistics Summary to 1995 and the December 2023 Traffic Volume Trends. For gallons: FHWA Table MF-202 in Highway Statistics 2022.

It became a feature of federal energy and environmental policy to reduce the number of gallons of fossil fuel used on roadways. But it was still federal transportation policy to fund highways and transit based on the number of gallons of fossil fuel used on roadways. In effect, the separate federal policies have been at war with each other since the 1970s, and although it took a while, the Highway Trust Fund eventually paid the price.

The following chart shows the number of taxable gallons of motor gasoline used on highways each year from 1956 to 2022.

Figure 4



Data source: FHWA, Highway Statistics 2022, Table MF-226.

Gasoline use on roads plateaued in 2004 at around 136 billion gallons per year and has floated around that level ever since. (Increases in diesel fuel use and in trucking industry tax receipts have provided some Trust Fund revenue growth since then to compensate.)

With the number of gallons of gasoline used each year essentially flat, Congress could have increased the cent-per-gallon tax rate for the Highway Trust Fund (set at 18.3 cents per gallon since the 1990s). Or they could have increased other Trust Fund tax rates. Or they could have reduced Trust Fund expenditures to ensure insolvency. Instead, they did none of these things. Congress has now enacted five consecutive multi-year funding bills in which new funding in the final year of the bill was at least 25 percent above new Trust Fund tax receipts and interest.

Table 3

Relation of New HTF Contract Authority to HTF Receipts and Interest, by Reauthorization Act

(Billion Dollars)

Last/Peak Year of	New HTF Contract Authority	New HTF Tax Receipts & Interest	New CA As Percent of New Receipts/Int
ISTEA (FY 1997)	$24.5	$25.3	97%
TEA21 (FY 2002)	$41.2	$32.6	126%
SAFETEA-LU (FY 2009)	$52.2	$35.0	149%
MAP-21 (FY 2014)	$50.8	$39.1	130%
FAST (FY 2020)	$58.7	$42.7	137%
IIJA (FY 2026)	$80.0	$44.4	180%

As a result of these trends, for several years, annual tax receipts from the 18.3 cent-per-gallon Highway Trust Fund excise tax on gasoline were predicted to slowly wither away over time, usually by about a half-percent per year (after some wild COVID-related fluctuations). The projected rate of decline increased after the April 2022 final CAFE standard increase, but the CBO forecast from February of this year, and the subsequent June baseline, have changed the picture drastically.

Table 4

Recent Congressional Budget Office Projections for Highway Trust Fund Gasoline/Gasohol Net Tax Receipts

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Billion $$ per year at 18.3 cpg															
Jan 2020 Outlook	25.81	25.61	25.31	25.02	24.72	24.39	24.11	23.89	23.69	23.53	23.38				
Sept 2020 Update	23.60	24.59	25.11	24.89	24.68	24.45	24.28	24.15	24.03	23.93	23.83				
Feb 2021 Outlook		23.24	25.25	25.17	24.98	24.77	24.59	24.43	24.27	24.13	24.01	23.87			
July 2021 Baseline		23.81	25.27	25.56	25.43	25.22	25.01	24.83	24.65	24.49	24.35	24.22			
May 2022 Baseline			25.39	25.34	25.25	24.97	24.53	24.10	23.69	23.32	22.97	22.65	22.34		
Feb 2023 Outlook				25.01	24.81	24.55	24.13	23.72	23.36	23.01	22.70	22.41	22.12	21.83	
May 2023 Baseline				25.01	24.81	24.55	24.13	23.72	23.36	23.01	22.70	22.41	22.12	21.83	
Feb 2024 Outlook					25.09	24.67	24.11	23.44	22.62	21.75	20.86	19.92	19.07	18.33	17.67
June 2024 Baseline					25.26	24.90	24.50	23.99	23.23	22.25	21.03	19.56	18.25	17.15	16.21
Increase/decrease from prior year															
Jan 2020 Outlook		-0.8%	-1.2%	-1.1%	-1.2%	-1.4%	-1.1%	-0.9%	-0.8%	-0.7%	-0.6%				
Sept 2020 Update		+4.2%	+2.1%	-0.9%	-0.8%	-0.9%	-0.7%	-0.5%	-0.5%	-0.4%	-0.4%				
Feb 2021 Outlook			+8.7%	-0.3%	-0.7%	-0.8%	-0.7%	-0.6%	-0.7%	-0.6%	-0.5%	-0.6%			
July 2021 Baseline			+6.1%	+1.1%	-0.5%	-0.8%	-0.8%	-0.7%	-0.7%	-0.6%	-0.6%	-0.5%			
May 2022 Baseline				-0.2%	-0.4%	-1.1%	-1.7%	-1.8%	-1.7%	-1.6%	-1.5%	-1.4%	-1.4%		
Feb 2023 Outlook					-0.8%	-1.0%	-1.7%	-1.7%	-1.5%	-1.5%	-1.4%	-1.3%	-1.3%	-1.3%	
May 2023 Baseline					-0.8%	-1.0%	-1.7%	-1.7%	-1.5%	-1.5%	-1.4%	-1.3%	-1.3%	-1.3%	
Feb 2024 Outlook						-1.7%	-2.3%	-2.8%	-3.5%	-3.8%	-4.1%	-4.5%	-4.3%	-3.9%	-3.6%
June 2024 Baseline						-1.4%	-1.6%	-2.1%	-3.1%	-4.2%	-5.5%	-7.0%	-6.7%	-6.0%	-5.5%

These last two forecasts incorporate real-world sales increases in electric vehicles, and some of the EV sales targets in recent regulations from the EPA. The new EPA rules are specifically designed to reduce fossil fuel consumption and accelerate EV adoption. The February 2024 forecast incorporated the EPA's April 2023 and the new June 2024 forecast incorporates the EPA's March 2024 final rule.

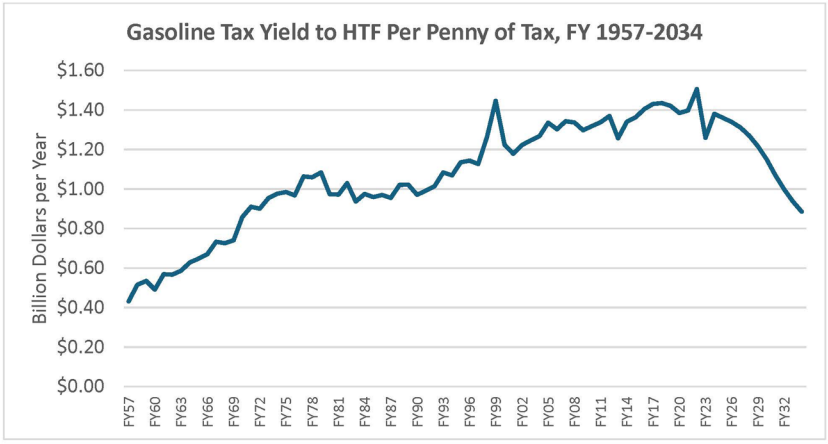
According to the June 2024 forecast, the number of gallons of gasoline taxed for the Highway Trust Fund will drop by one-third over the next decade, falling from around 138 billion gallons in 2024 to 89 billion gallons in 2034.

Because this is a cent-per-gallon tax, fewer gallons scales proportionally into fewer dollars. In the most recent forecast, annual gasoline tax receipts are projected to drop more than 5 percent per year starting in 2030. In 2033, the new prediction for gasoline tax receipts is almost $5 billion per year lower than the projection from one year ago.

Increased fuel efficiency results in decreased tax yield (the amount of money raised per unit of tax, in this case each cent per gallon. After several decades of stability at around $1.3 billion of net yield to the Trust Fund per penny of gasoline tax, and brief COVID instability, CBO's new projections call for the gas tax yield to plummet to $886 million per penny of tax by 2034.

Figure 5

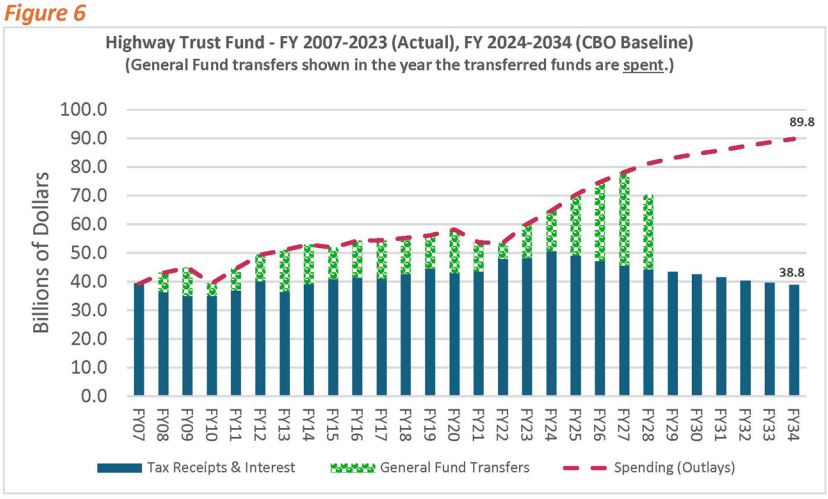
Testimony of Jeff Davis
Eno Center for Transportation



Data sources: For 1957-2023: FHWA Highway Statistics 2022, Table FE-210. For 2024-2034: Congressional Budget Office, Revenue Projections by Category, June 2024, "Excise Taxes" tab.

If we combine this sudden drop in gas tax revenues with currently projected Trust Fund spending, annual cash deficits in the $13 billion per year range today will jump to an astounding $51 billion per year deficit a decade from now.

Figure 6



Data source: For 1957-2023: Congressional Budget Office, "Baseline Projections June 2024, Highway Trust Fund Accounts".

This insolvency is subject to this committee's jurisdiction. Section 401 of the Congressional Budget Act purported to prevent trust funds from creating new contract authority unless that spending was at least 90 percent supported by user excise tax receipts at all times. This year, only 70 percent of Trust Fund outlays are expected to be supported by user tax receipts. CBO projects that to drop to 50 percent by 2030, and that the Trust Fund will only be 43 percent self-sufficient on user tax receipts in 2034.

While I am on the subject of SBC jurisdiction, I should point out that a series of loopholes in budget process law effectively exempts Highway Trust Fund spending from budget enforcement. Through some historical accidents, 99 percent of Highway Trust Fund spending is "split-scored," with budget authority scored as mandatory and outlays scored as discretionary. This means that:

1. HTF spending is exempt from spending caps, such as those in the Budget Control Act or the new ones in the Fiscal Responsibility Act, because those caps only measure discretionary budget authority, and HTF budget authority is mandatory.
2. HTF spending is exempt from statutory and Senate pay-as-you-go budget rules, because PAYGO only measures mandatory outlays, and HTF outlays are discretionary.
3. HTF spending thus cannot be reduced by budget sequestration, since sequestration is just a tool to enforce cap overages and PAYGO violations.
4. HTF spending is difficult to target via budget reconciliation, because reconciliation is almost exclusively used to change mandatory outlays, not discretionary outlays.

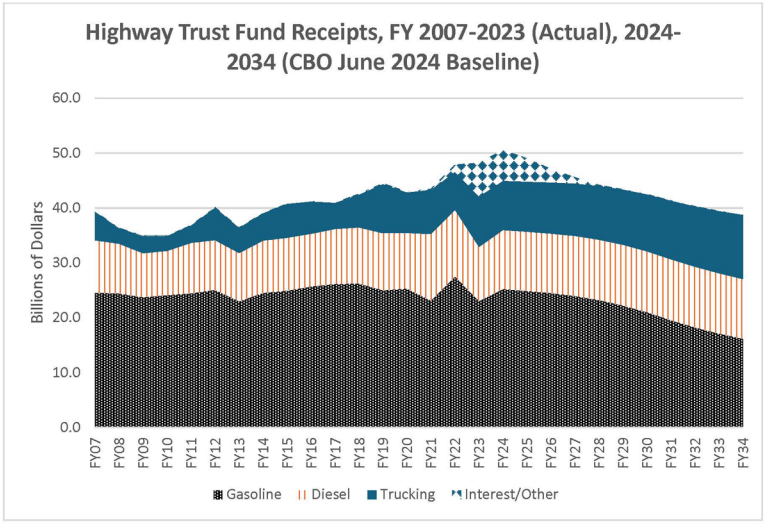
The highway program has such a broad base of political support that paring it back is never easy, regardless of the procedural situation. But on the rare occasions when Congress is in the mood for broad deficit reduction deals, the Trust Fund is never even part of the discussion.

With federal policy accelerating the trend away from fossil fuel use by motor vehicles, it is long past the time when Congress should decide whether or not to stick with the user-pay, user-benefit principle as the primary means of funding surface transportation. Reaffirming user-pay will mean some combination of significant spending cuts from highway and transit programs or significant tax increases on transportation system users. Formally jettisoning user-pay would mean getting rid of the Trust Fund concept and funding these programs some other way.

If Congress were to try to fix that projected $51 billion Trust Fund deficit in 2034 solely by increasing gasoline taxes – which, let me emphasize, **absolutely no one is advocating** – the current 18.3 cent per gallon gasoline tax would need to be increased by around 58 cents per gallon, to a total tax of about 76 cents per gallon of gasoline. (This assumes complete inelasticity of demand, which gasoline shows at nickel-and-dime price variations but not at this level.)

Projections for the Trust Fund would be even worse were it not for stable demand for diesel fuel and increased revenues from the other taxes on the trucking sector, which have a robust growth forecast.

Figure 7



Data sources: For 2007-2023: FHWA Highway Statistics 2022, Table FE-210. For 2024-2034: Congressional Budget Office, Revenue Projections by Category, June 2024, "Excise Taxes" tab.

A large part of that is an increase in receipts from the 12 percent federal sales tax on new single-unit trucks and tractor-trailer combinations. Alone amongst Trust Fund excise taxes, this one is effectively indexed for inflation by begin pegged to current prices. In fiscal 2007, the 12% truck/trailer tax brought in 40 percent of the dollars that the diesel fuel tax did. Today it brings in around two-thirds as much as the diesel tax, and CBO projects that because of increasing truck prices and relatively flat-lined diesel use, the truck-trailer tax will bring in 85% as much money as the diesel tax in 2034.

But trucking companies argue that retaining this tax is inconsistent with federal electrification goals, because it will make new electric trucks – already considerably more expensive than new diesel trucks – even more expensive and thus slow their adoption. If the 12 percent truck tax were to be repealed, the Trust Fund's revenue hole would be $9 billion per year deeper in 2034, according to CBO.

There are alternatives to motor fuel taxes that could maintain the user-pay, user-benefit paradigm that underlies federal trust funds, but none are as easy to administer as the gas tax.

Federal motor fuel taxes are levied at the "rack," the point at which fuel is loaded from a refinery or tank farm onto a tanker truck for delivery to service stations. There are only around 1,300 such points of collection, and many fewer taxpaying entities, paying taxes of around $35 billion per year. Going from the fuel to the vehicle as the point of taxation means going from 1,300 points of collection to 279 million points of collection (the number of privately owned

motor vehicles registered in the U.S. in 2022). Put another way, taxing vehicles would be over 200,000 times as much work for the IRS as taxing motor fuel.

Four states have now adopted voluntary road user charge (RUC) payment schemes in lieu of motor fuel taxes, and several more states are conducting pilot programs. Additionally, the IIJA provided USDOT with $50 million and a mandate to conduct a national pilot program for such a fee, but the Administration is over 2 years behind in taking the first steps to implement such a pilot program, making it doubtful the pilot will yield results in time for IIJA reauthorization.

Other alternatives for raising revenue from road users either measure actual use inefficiently (annual registration fees) or create situations where the federal government is creating contradictory financial incentives.

For any mileage-based tax, there is also a replacement level issue. At present (in 2022), the federal gasoline taxes paid by motorists in the U.S. averaged from around $80 per vehicle for cars and small crossovers to just over $110 per year for large SUVs, pickups, and vans. Using fuel consumption averages for these types of vehicles, this works out to about three-quarters of a cent per mile for cars and smaller crossovers, and about one cent per mile for larger vehicles.

Table 5

2022 VMT and Fuel Consumption Averages for Light-Duty, Gasoline-Powered Vehicles

	Wheelbase Under 121 in.	Wheelbase Over 121 in.	Average Light-Duty
Vehicle-Miles	10,847	11,412	10,917
Gallons of Fuel	437	617	480
Avg. MPG	24.8	18.1	22.8
HTF Fuel Taxes	$79.97	$112.91	$87.84
Cent-per-Mile Eqv.	0.74	0.99	0.80

Data source: FHWA Highway Statistics 2022, Table VM-1.

With the high fixed administrative costs that would come from monitoring the mileage of every vehicle in the U.S. (electronically or manually), would it really be worth it just to collect an average of $88 in taxes per vehicle?

An average of $88 per vehicle per year doesn't sound like a lot compared to the general tax burden. But it adds up. There were 1.4 million plug-in electric vehicles sold last in the U.S. in 2023, and at an average of $88 per year, that's an additional $1.2 billion per year that motorists will no longer be paying into the Highway Trust Fund to support highway and mass transit programs.

Some states are experimenting with special registration fees on electric vehicles to recapture their lost motor fuel tax revenues. Flat fees are not particularly good proxies for actual road use because they are mileage-indifferent – the fee on a car that is only driven 3,000 miles per year is the same as a car that is driven 30,000 miles per year. But as long as an annual EV fee approximates the average amount that an internal combustion vehicle of the same size and

weight would pay in annual fuel taxes, such fees could be considered a fair balance between ease of administration and the user-pay principle.

The amount of revenue needed to actually fill the Trust Fund's projected revenue gap would require a tax rate much higher than this (if Congress were to try and solve the problem with revenues alone). But judging by the state experience with pilot programs, public acceptance of a new road user charge system seems dependent on convincing the public they are paying the same amount under each system, just with a different form of collection. Coupling a new, and more intrusive, collection system along with a significant tax rate increase would be politically problematic.

In conclusion, the revenue damage done to the Highway Trust Fund should be at least a part of the debate when Congress is discussing advancing electric vehicles. It is long past time for Congress to either strengthen, or else abandon, the user-pay model for surface transportation, since electrification is accelerating the demise of fossil fuel taxes, and the underlying goal of zero-emission transportation by 2050 would inherently eliminate fossil fuel taxation as a revenue stream.

Thank you very much, and I would be happy to answer any questions.

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[1] Income: U.S. Census Bureau, *Statistical Abstract of the United States: 1935*, Table 177. Gallons: U.S. Public Roads Administration, *Highway Statistics Summary to 1945*, Table G-221.

[2] U.S. Federal Highway Administration, *Highway Statistics 2022*, Table FE-210; U.S. Treasury Department, *Treasury Bulletin – March 2024*, Table TF-6, and Funds Management Program Monthly Financial Reporting for the Highway Trust Fund, October 2023 through June 2024.

Questions for the Record
from Senator Sheldon Whitehouse
for Dr. Jesse Jenkins
"Charging Ahead: The Future of Electric Vehicles"
July 31, 2024
Senate Budget Committee

Question #1:
With telematics and bidirectional charging, electric vehicles (EVs) can contribute to electric grid security through services like peak load shaving and discharging stored electricity to the grid. What is industry doing to enable these services? What can Congress do to help? What benefits should consumers receive from the local utility for EV grid services, like demand response or energy discharge?



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To the Honorable Senator Sheldon Whitehouse:

I am writing in response to your written Question for the Record related to the July 31st Budget Committee hearing "Charging Ahead: The Future of Electric Vehicles." You inquired specifically about the potential for flexible charging and discharging (or "vehicle to grid") capabilities to provide services to electricity systems and contribute to grid security.

Current Status:

As I stated in my testimony, EVs represent large instantaneous demands on the grid, but through flexible and managed charging—and potentially even discharging back to the grid—impacts on coincident system-wide peak demands and requirements for grid upgrades from EVs can be dramatically reduced, if not entirely eliminated.

The potential economic benefits of flexible EV charging and discharging—what the industry refers to as "vehicle-grid integration" or VGI—are enormous. A recent study by the Public Advocates Office of California found that that managed EV charging can help avoid $35 billion or more in distribution investments.[1] National Grid ESO, the electricity system operator of the UK, predicts that winter peak demand from EVs in the UK could be reduced by 30 gigawatts (GW) by 2040 through mass adoption of smart charging and discharging.[2] That's equal to about half of the UK's peak electricity demand today. A modeling study performed by my Princeton ZERO Lab exploring pathways to reach 100% carbon-free electricity in New Jersey similarly found that if 90% of EVs participate in managed charging by 2050 (along with 25% of hot water heaters and 30% of building HVAC systems), the peak demand in the state could be reduced by 17% or 6.4 GW—that's 6-7 large nuclear power stations worth of capacity—and save New Jersey electricity consumers $500 million annually just at the bulk power system level (e.g. generation, storage and transmission); avoided distribution network costs were uncalculated in the study by likely of a similar magnitude.[3]

There are many ways that the flexible charging and discharging of EVs can benefit the electric grid's reliability and resiliency, as well as aid with decarbonization and reducing the cost of electric bills for all U.S. consumers. Alongside EV owners, non-EV owners also benefit from flexible charging/discharging, which places downward pressure on electricity rates leading to lower prices, increases grid stability, and delivers environmental benefits through reduced transportation and power sector emissions. Flexible EV charging can also support integration of variable renewable energy resources onto the grid by enabling demand flexibility and supporting grid operators to consume abundant wind and solar energy—and in the case of bidirectional charging, dispatch that clean energy back onto the grid during peak periods.

Methods to encourage flexible EV charging vary from simple behavioral programs (text messages and other communications asking people to not charge at certain times) to time-of-use rates, which provide financial incentives to charge during lower cost time periods with a regular fixed schedule (e.g. peak and off-peak periods), to more sophisticated managed charging programs that use algorithms to optimize charging down to the distribution system and even service transformer level. Today, most major utilities have at least one program encouraging customers to shift EV load to create system benefits, though participation has been modest to date.

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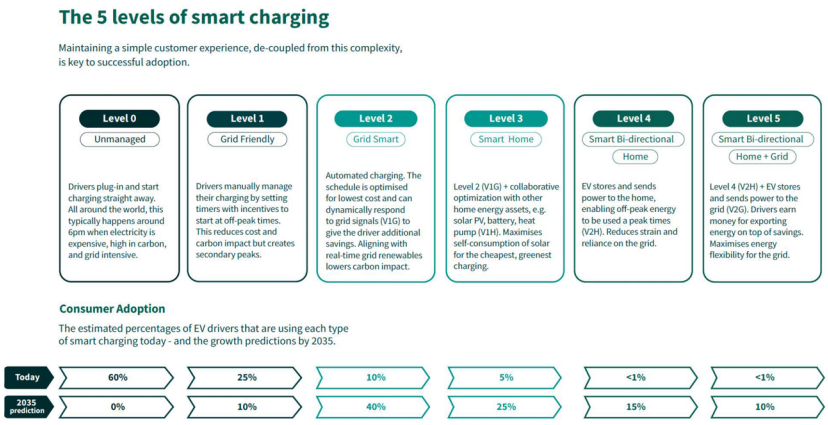
[1] The Public Advocates Office, California Public Utilities Commission, "Distribution Grid Electrification Model: Study and Report," August 2023, https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/230824-public-advocates-distribution-grid-electrification-model-study-and-report.pdf

[2] ev.energy, "Unlocking industry barriers to providing V2X energy flexibility," June 2023, https://www.ev.energy/business/v2x-white-paper

[3] Xu, Q., Patankar, N., Zhang, C., & Jenkins, J. D., "New Jersey's Pathway to a 100% Carbon-Free Electricity Supply: Policy and Technology Choices Through 2050" March 2022, Princeton ZERO Lab: https://doi.org/10.5281/zenodo.6386823



Source: ev.energy, "Unlocking industry barriers to providing V2X energy flexibility," June 2023.

Technologies, programs, and businesses in this sector are rapidly evolving. Nearly all chargers are now capable of scheduling or programming to reflect time-of-use rates or off-peak time periods, and most are Internet-enabled and technically capable of participating in networked or managed charging programs. However, to enroll in managed charging or off-peak rebate programs, electric distribution utilities typically only interface with approved models using specific software protocols that are robust enough to provide credible metering, integrate with the utility's distribution system management software, and/or receive dynamic controls. Some third party "smart charging" aggregators of EVs are also emerging, which recruit EV owners to group together multiple EVs and bid their combined flexibility into wholesale electricity markets (or in some cases to distribution utilities for local peak shaving or 'non-wires alternative' programs). This market segment is nascent, though it is currently much more advanced in Europe than in the United States.

Bidirectional charging programs, which use an EV to send power to a home/building, the grid, or to power something else, are still at an early stage. To date, there are some demonstration projects focused on bidirectional charging using EVs to power a home or building (and thus relieving the electric system of needing to provide that power/capacity) or even using EVs to send electricity back to the grid (effectively acting as a small power plant for a limited time). Some pilot programs also involve use of commercial or fleet vehicles (such as this pilot using a school bus fleet in Cajon Valley Union School District in southern California). However, regularly discharging to the grid or to supply a portion of household or business demand is not yet common practice. That said, it is becoming increasingly common for light duty EV models to offer so-called "vehicle to load" capabilities which allow the vehicle to directly supply AC power to one or more loads or act as backup generators, increasing household resilience to power outages (which does not require coordination with the distribution grid).

Several industries are involved in enabling these services: software platform companies that support managing and optimizing charging (such as WeaveGrid and ev.energy), EV manufacturers, charger OEMs, and electric utility companies.

What Congress can do:

The federal government's policies during the Biden Administration have been focused on increasing EV adoption and the deployment of charging stations (through the IRA, IIJA/NEVI). These are critical efforts, but they should ideally be paired with policies that incentivize the proper integration and management of EVs on our grid. Without the additional support for VGI there is a greater risk of EVs negatively impacting the grid (e.g., increased costs to customers for infrastructure upgrades, increased strain on the distribution system, increased peak demand, etc.), rather than being utilized as beneficial assets.

Under the Federal Power Act, states have authority to regulate electricity distribution and retail rates. As rate design and distribution network integration are the primary touch-point between EV customers and the grid, that means much of the work related to VGI must be done by state public utility commissions and other regulators at the state level.

However, the Federal government can have a greater role in advancing VGI. What follows are several concepts (in no particular order) that you and your colleagues may wish to explore further:

1. Data accessibility and standards: Lack of access to the customer's charging data, from both EV telematics and charger hardware, presents an industry-wide issue that is blocking the rollout of valuable VGI services. The customer owns their charging data. They should be empowered to access it, and use it to enroll and fully benefit the grid through VGI services. A lot of work has been done with utilities to ensure customers have access and control over their energy usage information (e.g., Green Button Connect). A similar effort with auto OEMs and charging station manufacturers to develop open access to those assets for smart charging aggregators and provide some standardization for the data formatting would ensure that customers are not blocked from participating in managed charging programs. Ensuring that vehicles communicate seamlessly with chargers and help determine expected range can also facilitate a more intuitive and reliable customer experience—e.g. customers can specify how much range they desire by the end of the charging period, and software can then automate charging to minimize customer costs and grid impacts. There is also a role here for the government to set clear expectations with industry (both auto OEMs and electric utilities) that the customer owns their data and they should not be blocked from using it to participate freely in demand flexibility programs, including VGI services. Standards setting bodies such as NIST could also assist in such efforts.

2. Incentives for vehicle grid integration: Congress could consider modifying the EV tax credits and 30C charging station tax credits to provide larger credits for vehicles and charging stations that are capable of grid-integrated VGI services and bidirectional charging. This would properly reflect the additional value of VGI and bidirectional charging. Additional eligibility requirements could also be developed for EV and charging station incentives that could require any make/model to adhere to open access data requirements that prevent OEMs from blocking access to customer's charging/telematics data and participation in flexible charging programs.

3. Modernizing incentives for distribution utilities: Electric distribution utilities are the first point of contact for EV owners and the grid. They manage interconnection of new chargers, establish utility rates, upgrade and maintain the grid, and may establish managed charging or demand flexibility programs. However, most utilities in the United States are regulated under a 'cost of service' or 'rate of return' framework in which utilities primarily earn profits by expanding investment in capital assets, including grid equipment (transformers, substations, wires, poles etc.). Under this model of remuneration, utilities may be actively discouraged from implementing smart charging and VGI programs that can *significantly reduce* capital expenditures, as this may directly reduce utility profits. Utilities need appropriate financial incentives that level the playing field between capital investment in grid upgrades and operational strategies to reduce peaks and avoid unnecessary investments.[4]

In general, state public utility commissions (PUCs) currently evaluate and remunerate demand-side management programs (including energy efficiency programs, demand response, and managed EV charging) by analyzing the

[4] See MIT *Utility of the Future*, Chapter 5: "The Future of the Regulated Network Utility Business Model," 2016 https://energy.mit.edu/research/utility-future-study/

costs avoided through these programs. However, the methodologies and inputs for these "avoided cost calculations" may need to be revised to properly reflect the current state of the electric system and the cost of building new generation. With increased demand growth, higher capacity market prices, new EPA power plant regulations, and increasingly ambitious decarbonization policies in many jurisdictions, the potential range and magnitude of avoided costs is rapidly evolving. Ensuring that these values are properly reflected in avoided costs for EV programs is necessary to providing the financial incentives for companies to invest in these resources and scale VGI services. While specific avoided cost methodologies are subject to review and approval by state PUCs, Congress could explore ways to provide direction and financial incentives for state regulators that update their methodologies to better reflect the true value of these resources.

Congress could go even further and provide resources to help state regulators complete more substantial overhauls and updates of distribution utility remuneration. Numerous state commissions have recognized the limitations of 20th century regulatory models and embarked on various "grid modernization" or "utility of the future" type reforms. However, state commissions often lack substantial staff resources to both maintain critical regulatory responsibilities and simultaneously execute major reforms. Congress could fund the DOE or another office to develop model regulations, compile best practices from around the world, provide technical expertise, and even rotate staff through state agencies to support comprehensive modernization and reforms of distribution utility regulation. This would be a bold measure that would facilitate much broader benefits than enabling flexible EV charging alone, including unlocking the full potential of distributed energy resources and demand flexibility.

4. The value of bidirectional charging: The Department of Energy and National Laboratories could spearhead a modeling effort to better determine the value of bidirectional charging resources in the U.S. This could culminate in some recommendations for utilities regarding the interconnection process for bidirectional charging technologies and for the design of pricing mechanisms to compensate customers for exporting energy onto the grid from EVs. This could also support updates to avoided cost methodologies (as recommended above).

5. Fund and disseminate best practices: Congress could direct (and resource) federal agencies (including DOE, DOT, the Joint Office of Energy and Transportation and NIST) to share and disseminate best practices and provide continued support for RD&D in emerging applications, including grant opportunities. For example, flexible EV charging companies I've spoken to have appreciated the federal government's work promoting thought leadership and sharing best practices, like the DOE's "Vehicle to Everything" MOU, the Loan Program Office's "Pathways to Commercial Liftoff: Virtual Power Plants" report, DOE's Grid Resilience and Innovation Partnerships (GRIP) grant program, and efforts by the Joint Office, like the Communities Taking Charge Accelerator.

6. Leading by example: The Federal government could also lead by example by adding requirements for the procurement of bidirectional-capable EVs for federal vehicle fleets and chargers installed at federal properties.

I hope these suggestions are useful for the Committee as it continues to explore strategies to accelerate EV adoption, support competitiveness of US manufacturing, and address potential challenges posed by vehicle electrification.

Sincerely,



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Charles E. Grassley
United States Senator

Question for the Record
from Senator Charles E. Grassley
for Dr. Jesse Jenkins
"Charging Ahead: The Future of Electric Vehicles"
July 31, 2024
Senate Budget Committee

During the hearing, you noted your belief that the Inflation Reduction Act (IRA) was "more than paid for." Since the IRA was enacted, Goldman Sachs has estimated that the actual cost to the federal government of the energy incentives contained in the IRA could be as much as $1.2 trillion, rather than the original $391 billion estimate from CBO and JCT. In the February baseline, CBO increased projections for the cumulative deficit from 2024-2033 by $428 billion solely due to re-estimations of amounts claimed for clean vehicle and energy-related tax credits. In the report for this baseline, CBO states that "[t]he budgetary effects of energy-related tax provisions remain highly uncertain," suggesting the cost of the IRA energy provisions could be even more expensive than now projected.[1]

I'd like to give you the opportunity to the correct your previous statement. Do you still believe the IRA was fully paid for?

[1] Congressional Budget Office, *The Budget and Economic Outlook: 2024 to 2034*, (February 7, 2024), https://www.cbo.gov/publication/59710.



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To the Honorable Senator Charles E. Grassley:

I am writing in response to your written Question for the Record related to the July 31st Budget Committee hearing "Charging Ahead: The Future of Electric Vehicles."

With regards to the ultimate budgetary impact of the Inflation Reduction Act (IRA), as you know, future outcomes are always uncertain on both the tax credit expenditures and revenue side. For the latest projections, I refer you to the Congressional Budget Office (CBO) February 2024 Budgetary and Economic Outlook.[1]

It is true that CBO estimates of the budgetary impact of Inflation Reduction Act energy related tax credits has increased since passage. At the time it became law, CBO and the Joint Committee on Taxation (JCT) estimated energy related direct spending and tax credits under the IRA would total about $391 billion through FY 2031 and would be more than fully offset by other parts of the law, reducing deficits by $238 billion over a decade.[2]

Since passage, higher inflation (which raises the capital cost basis for investment tax credits) and higher demand for tax credits (reflecting larger investment in the U.S. clean energy economy) has led to upward revisions in CBO's estimate for the budgetary impact of these credits. CBO's latest baseline increased the estimated cost of energy-related tax provisions in the IRA by $355 billion.[3] This increase is mostly due to greater expected investment in battery manufacturing and wind and solar energy, and increased uptake of clean vehicles, including the impacts of recently finalized EPA tailpipe emissions regulations for light and heavy-duty vehicles.[4] The latest CBO estimate of the budgetary impact of the IRA's clean energy provisions is thus approximately $750 billion over ten years.

However, CBO revenue estimates are just as uncertain as estimated outlays. Indeed, in February 2024, the Internal Revenue Service published a report concluding that modernization and tax enforcement efforts funded by the approximately $80 billion appropriated to the IRS by the IRA will raise $561 billion over the period FY 2024 to FY 2034[5]—which compares to CBO's original estimate of approximately $180 billion in additional revenue from FY 2022 to FY 2031. As such, revenues from IRS modernization and enforcement funded by the IRA are now expected to be approximately $380 billion higher than originally estimated, a figure that exceeds CBO's upward revisions in the estimated cost of IRA energy-related tax credits. Revenue and savings from other offsets in the IRA are also uncertain and may have been revised since passage.

Of course, CBO budgetary estimates also disregard any dynamic effects of policy on the overall economy and associated tax receipts, making the final budgetary impact even more uncertain. Thanks largely to the Inflation Reduction Act, the past 12 months saw $284 billion in new investment in the manufacture and deployment of clean energy, clean vehicles, building electrification and carbon management technology in the United States, a 71% increase from the year prior to passage of the Act.[6] Over the past two years since passage of the law, the United

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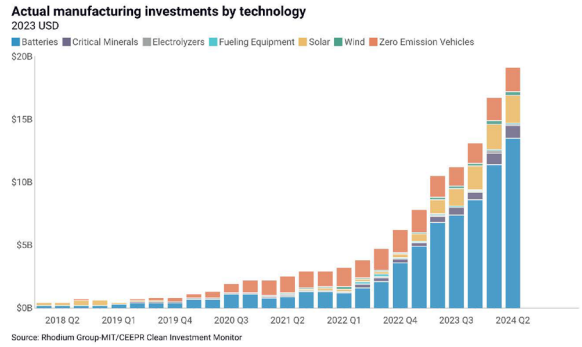
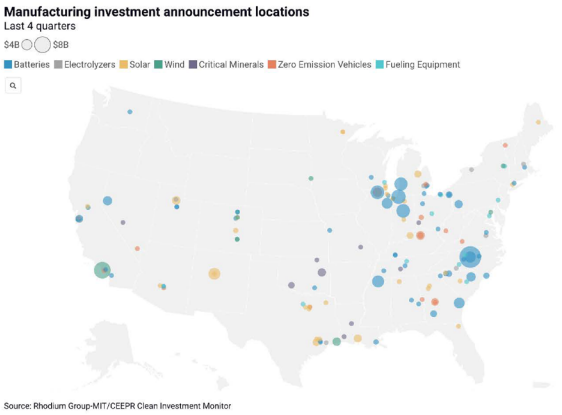
[1] Congressional Budget Office, "The Budget and Economic Outlook: 2024 to 2034," February 2024, https://www.cbo.gov/system/files/2024-02/59710-Outlook-2024.pdf
[2] Congressional Budget Office, "Estimated Budgetary Effects of Public Law 117-169, to Provide for Reconciliation Pursuant to Title II of S. Con. Res. 14," September 7, 2022, https://www.cbo.gov/publication/58455; See also Committee for a Responsible Federal Budget, "CBO Scores IRA with $238 Billion of Deficit Reduction," September 7, 2022 https://www.crfb.org/blogs/cbo-scores-ira-238-billion-deficit-reduction
[3] Committee for a Responsible Federal Budget, "IRA Energy Provisions Cost Could Double With New Emissions Rule," February 13, 2024, https://www.crfb.org/blogs/ira-energy-provisions-cost-could-double-new-emissions-rule
[4] This reflects an increase of $206 billion for provisions other than EVs and $159 billion due to increased adoption of clean vehicles, including use of the EV tax credit and reduced collection of gasoline excise taxes. See CRFB citation above.
[5] Internal Revenue Service, "Return on Investment: Re-Examining Revenue Estimates for IRS Funding," February 2024, https://www.irs.gov/pub/irs-pdf/p5901.pdf
[6] Clean Investment Monitor, "Tallying the Two-Year Impact of the Inflation Reduction Act," August 7, 2024, https://www.cleaninvestmentmonitor.org/reports/tallying-the-two-year-impact-of-the-inflation-reduction-act

States has seen $133 billion in new investments in clean energy and vehicle technology manufacturing, a 52% increase over the previous two years, with over 80% of this total going to the manufacture of batteries, zero-emissions vehicles (including EVs), and critical minerals production and processing.[7] An additional $250 billion in planned investments in U.S. clean vehicle and clean energy manufacturing has been announced (but not yet finalized), with over three-quarters of this planned investment going to districts represented by Republicans.[8]





Sincerely,

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[7] Ibid.
[8] Clean Economy Tracker, https://cleaneconomytracker.org/ Accessed August 7, 2024.

Questions for the Record
from Senator Sheldon Whitehouse
for Ms. Britta Gross
"Charging Ahead: The Future of Electric Vehicles"
July 31, 2024
Senate Budget Committee

Question #1:
With telematics and bidirectional charging, electric vehicles (EVs) can contribute to electric grid security through services like peak load shaving and discharging stored electricity to the grid. What is industry doing to enable these services? What can Congress do to help? What benefits should consumers receive from the local utility for EV grid services, like demand response or energy discharge?

Over the last 20+ years, there have been considerable advancements in technology that enable electric vehicles (EV) to be used as grid resources. In the early stages of vehicle electrification, much of this work was intended to increase the overall value of the electric vehicle – buying down the total cost of ownership of transportation electrification (TE) for EV owners and drivers. The result has been products, demonstrations, and pilots establishing the technical feasibility of various uses of electric vehicles to potentially support the reliability of the grid, enable affordability of electric transportation, and potentially enhance resiliency of the grid and/or community.

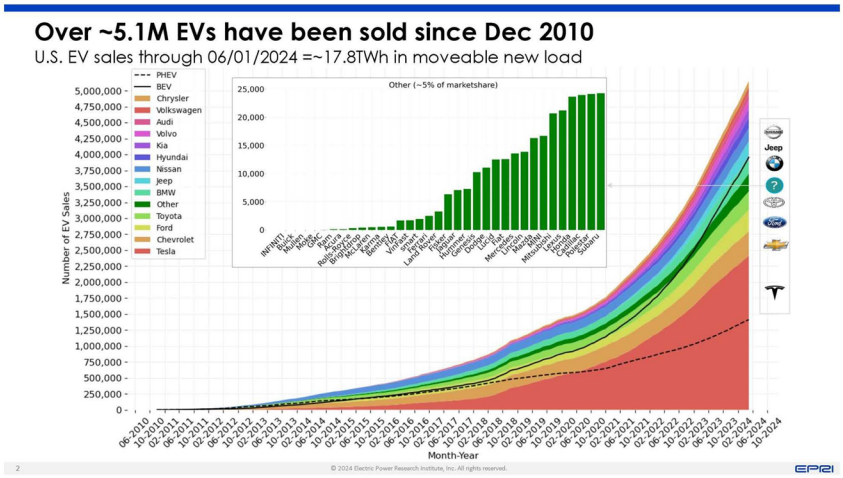

Figure 1: Electric Vehicle Sales in the United States since December 2010 (through June 1, 2024). Source: EPRI

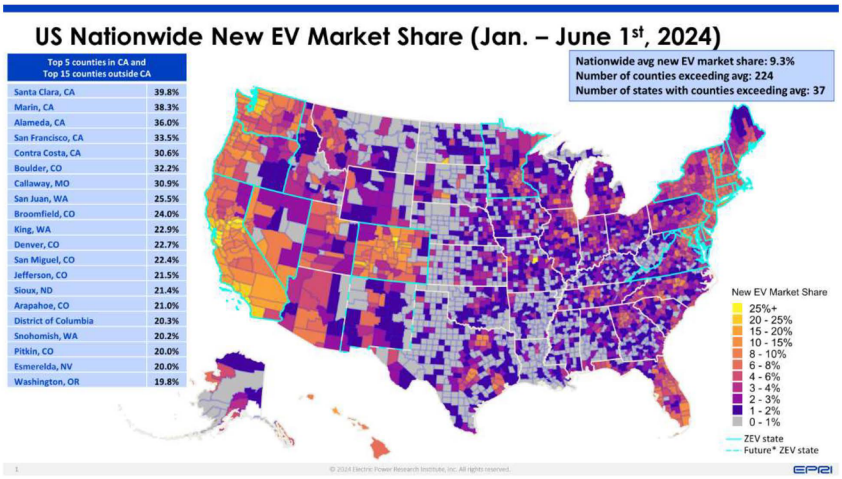

Figure 2: EV Market Share by County in the US (January- June 1st, 2024). Source: EPRI

Figure 1 and Figure 2 show exponential, albeit non-uniform increases in US TE over the last 14 years. The growth in EVs is not just by number of electric vehicles, but also electric vehicle types and classes available. EPRI's *2023 Consumer Guide to Electric Vehicles* (public link) identifies a growth from 20 electric vehicle types in 2014, to over 140 electric vehicle types in 2024. As of 2023, electric vehicle manufacturer suggested retail prices (MSRP)s ranged from over $27,000 for compact hatchback battery electric vehicles (BEV) to ultra-limited plug-in hybrid electric cars costing well above $200,000. [1] This variety indicates the differences in customer willingness to pay for vehicles as well as increased variety of vehicle options.

On average, the US Department of Transportation estimates that Amercians spend over $12,000 on transportation costs per year. That include items such as car payments, insurance, and fuel.[2] Of this, ~25% of costs are on fuel – over $3,000 per year. This equates to over 50% of the costs the average American spends on energy per year. While customer willingness to pay for EVs may differ, there is one common denominator: maintaining reliable access to energy and ensuring affordable electricity rates is critical to short, medium, and long term goals for decarbonizing the transportation sector.

EPRI's research has been wholistically focused on energy affordability and minimizing the cost to prepare the electric grid for transportation electrification. This includes a concentrated effort to ensure the energy industry neither overbuilds (causing energy costs to increase) nor underbuilds (causing impacts to energy reliability) the electric grid and the infrastructure to support it. In other words, utilities carefully build to serve peak load. Transportation electrification represents a relatively large, inherently smart, and potentially flexible resource that could be leveraged by the grid to put downward rate pressure on electricity costs – minimizing a potential energy burden sometimes associated with

[1] *EPRI Consumer Guide to Electric Vehicles*. EPRI, Palo Alto, CA: 2023. 3002026815.
[2] *Consumer Expenditure Survey.* US Bureau of Labor and Statistics: 2022.

electrifying transportation[3]. Data collected from EVs can also provide insights into energy-impacting decisions – helping support planning, operating, and managing the electric grid. These capabilities are often summarized as vehicle grid integration (VGI), vehicle-to-grid (V2G), managed or smart charging, etc., each used to describe the application of electric vehicle technology as a grid resource. There has been more than 20 years of technology innovation and demonstration of VGI capabilities using various vehicles and electric utilities across the country.

While there have been technology advancements in VGI, and there are smart charging programs being approved recently by states such as Colorado, the scaled deployment of electric vehicle programs to support affordability of vehicle electrification have been limited. EPRI research in 2023 estimates that only 15 percent of electric vehicles across the country participate in some form of utility VGI program these are predominantly time-of-use programs intended to incentivize or reward charging EVs at times and places that provide net benefits to the grid and customers.[4] Lack of program offerings is potentially due to these following challenges:

1. **Electric utilities are at various levels of electric vehicle adoption and grid modernization:** Figure 2 shows the variance in electric vehicle adoption over the different counties and US states. In addition, each of the 3,200+ US electric utilities has developed an infrastructure of technology providers and support services to maintain its current and future business practices. This includes different levels of advanced metering infrastructure deployments, meter data management systems, and/or distribution management systems – different components that need to be integrated with VGI product providers to successfully deploy solutions to EV owners and drivers. In addition, states and local jurisdictions are also governed by different data management and privacy requirements. This variability limits EV OEMs and other technology and service providers in providing scalable solutions that integrate and interface with each utility in a standardized/uniform way – potentially resulting in increased costs and complexities of VGI products and solutions.
    - One possible action to consider is to encourage and fund activities that standardize integration between utility systems and electric vehicle charging infrastructure (e.g. OEM telematics, etc.) through developing requirements around needed data parameters, communication protocols, and regulatory reporting requirements that could streamline the interface between electric utilities and EV OEMs, as well as product providers.
2. **Accuracy and availability of electric vehicle telematics varies from one electric vehicle OEM and electric vehicle service provider:** While vehicle telematics data can potentially be made available by EV OEMs, its availability is heterogeneous from one EV OEM to another. This includes data resolution and data parameters reported as well as overall availability and cost of data reporting. In addition, there is little known about the accuracy of the data as it pertains to providing energy-related information required to ensure that vehicles can provide the grid service needed at the place and time it is needed. Information that helps attribute, calculate, and understand the persistence of electric vehicles as a grid resource is needed by many utilities and regulatory bodies to understand infrastructure needs and costs which is important – especially in areas of the United States where advanced metering infrastructure is not widely

[3] *The Future of Vehicle Grid Integration: Harnessing the Flexibility of EV Charging.* U.S. Department of Energy: 2024.
[4] *Overview of Managed Charging in the United States.* EPRI, Palo Alto, CA: 2023. 3002026770.

deployed. So, while vehicle telematics can be a potential solution for this, little is known of its availability, accuracy, and the long-term infrastructure required to provide this type of information.

3. **Current pilots and programs are still nascent – with limited information on persistence, scalability, and operational costs of these VGI solutions:** Grid planning, especially electric distribution system planning, requires assurance that technologies can be called upon if/when needed as an inability to call upon these resources can lead to an unreliable grid, including power outages. Current VGI activities are relatively nascent. For example, there is limited information on the lifetime and reliability requirements of the infrastructure needed to integrate the grid side needs with EV capabilities as well as how long EV owners and drivers may participate in these programs.
4. **Electric grid needs vary not only by time, but also by location – even within the same utility:** Maintaining the affordability and reliability of electricity, generally starts with a discussion on peak energy management. Electric utilities have to design infrastructure to generate, transmit, and distribute electricity for consistent, reliable power for 8,760 hours each year. This has historically resulted in designing electrical infrastructure, especially distribution level infrastructure, to support a community in the projected time of the year when it will use the most electricity. This becomes more challenging as energy resources are more distributed and as new energy generation and utilization vary. Variations are caused by factors such as level of electric vehicle adoption and amount of distributed energy resources (DER) deployed at a specific location of the grid. Therefore, balancing supply and demand is challenging, even within an electric utility as peak energy demand may vary from one location to another at a distribution system level. And that peak energy demand may be different from the generation peak, which varies across utilities, locations, times, and seasons. This variablity makes developing rates and programs to support both time and location variability challenging. And while there is work that is currently ongoing to evaluate the feasibility of local real-time pricing, there are limited results to assess its effectiveness.
5. **Regulatory reporting requirements vary from one area to another:** Public Utility Commissions and other regulatory bodies currently have different reporting requirements for utilities and VGI technology providers to validate impact of their VGI-related solutions and programs. In addition, many of these utility offerings are still in demonstration or pilot phases – where long-term viability is still unknown. This makes it challenging for EV OEMs and the industry to build products and the infrastructure needed to support the seamless integration across those products as requirements vary by region, and the predictability of a longer term/scalable market is limited.

EPRI's research has shown one way of maintaining energy affordability, grid reliability, and potentially community resiliency using EVs is to focus on VGI approaches that are scalable from one utility to another and from one regulatory jurisdiction to another. This could enable EV OEMs and technology providers to develop products and solutions that are not contingent upon a favorable energy market and/or other location-specific conditions to provide positive benefits to the public. In turn, having reliable technologies and information supports the availability of these EV technologies and VGI products as a resource to help ensure a more reliable grid and prevent power outages from occurring – and potentially supporting communities during power outages. This can potentially be done through developing infrastructure that focuses on using vehicle technologies as grid resources with standardized

and transparent methods to collect and evaluate impacts to energy affordability.[5] This could support stakeholders and decision makers to enable grid planning and energy programs in a manner that supports innovation. But this requires stronger coordination amongst critical stakeholders such as electric utilities and EV OEMs. Steps that may enable this infrastructure could be:

1. **Prioritize electric grid needs that maintain affordability and reliability of the electric grid.** These activities include work to understand the applicability of electric vehicles into existing tools that electric utilities use to manage peak usage such as demand response programs (used since the mid-1970s by utilities on industrial customers) and time-of-use (TOU) programs (used by some utilities since the 1980s to shift electricity usage away from peak energy consumption.) Programs – that help support emerging tools to provide regional/local peak shaving capabilities or support integrating renewable energy resources such as solar and/or wind resources – are needed at scale. This is seen today by states and utilities with high concentration of renewable energy or electric vehicle adoption.
2. **Identify critical vehicle functions that enable critical grid functions.** While existing charge management (e.g. charge, stop charging, etc.) can be enabled by EVs and charging stations (EVSEs), it is unclear what these critical vehicle functions are that enable specific prioritized electric grid needs. In addition, infrastructure – including back-office software systems at the OEMs and at the utilities – to support the translation of vehicle functions into energy resources, while also ensuring reliable transportation for vehicle drivers is needed. This infrastructure must also provide a greater level of confidence to electric utilities if EVs are also to serve as resources that meet electric grid needs.
3. **Standardize information that validates vehicle functions which enable grid functions.** Validating that vehicles successfully perform critical grid functions over time is essential as many operational aspects of a vehicle can change. Software can continuously be updated – potentially impacting the way vehicles are controlled. Customer driving needs may change. EV owners and operators may change. These factors present challenges to resiliency of electric vehicles as a grid resource – especially in emergency situations to prevent power outages. Standardizing information reported by the EV energy industry – including utilities and EV OEMs can potentially help support confidence that vehicles can provide these grid functions – and help build infrastructure and workforces to support them.

An electric vehicle has the potential to function as a mobile battery, with the capability to charge in times when there is excess electricity, including low carbon generation. In addition, it also has the ability to discharge electricity to a building and/or grid. This can be an additionally powerful tool to further help prevent a power outage or support communities during power outages, and could provide the public additional benefits. These benefits should be assessed to determine whether they can be scaled in a manner that supports value streams enabled by bi-directional power flow, while maintaining the reliability of the electric grid and the safety of utility workers operating it.

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[5] *Vehicle-to-Grid: A Strategic Update on V2G Technology*, Standards, and Pilots, EPRI, Palo Alto, CA: 2023. 3002026825. *Can AC Vehicle-to-Grid Enable Zero Cost Home Charging as a Service Programs?* EPRI, Palo Alto, CA: 2024. 3002029675. *Demand Flexibility for Grid Reliability and Resilience: Planning Tool Integration of Demand Flexibility – Phase II* EPRI, Palo Alto, CA: 2023. 3002029675.

Three main considerations to assess the viability of V2G, or bi-directional power flow, could be:

1. **Communications and control requirements**: Two-way power flow is more complicated, has higher cost, and has higher potential for communication problems. Bi-directional power flow requires lower latency, higher bandwidth, and more active/continuous management of power and information flow, whereas one-direction power flow functions (called V1G), can utilize higher latency and passive control systems, or time-of-use rate structures that can be programmed remotely or on-site.
2. **Electrical Equipment:** Bi-directional charging capability requires more and higher cost of off-vehicle electrical systems. These off-vehicle electrical systems include switches, protection devices, controls, and measurement devices. In addition, changes to customer electrical panels will usually be required to segment and route power flow as desired. In contrast, V1G can be accommodated via vehicle-based telematics which require no additional electrical equipment, or via intelligent EVSE that are in common use today.
3. **Safety:** Two-way power flow is potentially more dangerous than one-way power flow. Specifically, bi-directional charging creates additional personal risk to electrical workers and the public, and additional risk for property damage. Mitigating these risks creates interconnection requirements that increase the cost compared to V1G solutions.

On the other hand, bi-directional charging capabilities can provide increased revenue generation opportunities. Some energy markets found within Independent System Operators (ISO) like California ISO are currently set up to do so, and some valuation studies[67] show its potential cost-effectiveness in specific locations. For example, California's Emergency Load Reduction Program (ELRP) incentivizes DER, including EVs for injecting power back to the grid.[8] However, there is additional work needed to weigh potential operational costs associated with developing an infrastructure to support these revenue-generating opportunities, evaluating alternative methods (e.g. V1G) to maintain affordability and reliability of the energy infrastructure to support transportation electrification, and assessing the long-term viability of these revenue generation opportunities at scale.

Electric vehicles are a relatively large, inherently smart, and potentially flexible resource that can be a powerful tool used by the electric grid to help maintain the affordability and reliability of the electric grid. And while technology feasibility has been proven through demonstration and pilots, adoption of these VGI solutions and the deployment and customer adoption of these VGI solutions and products are still nascent. Uniformity of requests from the electric utility industry can help EV OEMs and other technology service providers develop and embed VGI products within their existing product offerings. Transparency and consistency of information reported by EVs can help electric utilities and regulators gain confidence that EVs and VGI solutions can be relied upon if/when needed. An emphasis on solutions that focus on maintaining affordability and enhancing community resiliency can potentially help EVs, OEMs, and other critical TE stakeholders and market players prioritize solutions that are not contingent upon certain favorable energy market conditions to scale.

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[6] *Distribution System Constrained Vehicle-to-Grid Services for Improved Grid Stability and Reliability*, California Energy Commission, Sacramento, CA 2019. CEC-500-2019-027.
[7] *Open Standards-Based Vehicle-to-Grid: Value Assessment.* EPRI, Palo Alto, CA: 2019. 3002014771.
[8] *Emergency Load Reduction Program*. California Public Utilities Commission. Accessed August 7, 2024. (link)

SILVERADO
POLICY ACCELERATOR

August 8, 2024 - Maureen Hinmann Responses to Senate Budget Committee QFRs

SENATOR WHITEHOUSE

QUESTION 1:

You identified that China engages in a form of "environmental arbitrage" that gives their manufacturers an unfair competitive advantage in the market at the expense of the environment and climate safety. How do the U.S. and its allies compare to China in terms of the carbon intensity of our manufacturing?

The U.S. and its allies generally have significantly lower carbon intensities in manufacturing than China. China's vastly higher emissions intensity of production occurs across a range of products. For example:

- China's production of metals is significantly more carbon intensive than U.S. production.[1] The carbon intensity of steel production in China is more than double the carbon intensity of steel production in the United States and significantly higher than the intensity of production in the European Union.[2]
- An OECD analysis found that the carbon intensity of the production of chemicals and chemical products in China was more than twice the carbon intensity of production in the United States and Canada and more than three times the carbon intensity of production in the European Union.[3]
    - Looking at five specific chemicals and plastics, the Climate Leadership Council found that China's production ranged from 1.2 to 2.9 times more carbon intensive than U.S. production.[4]
- An analysis by Skarn and Associates found that the carbon intensity of nickel production in China is almost 10 times the intensity of production in the United States, about 13 times the intensity of nickel production in Canada, and about 6 times the intensity of nickel production in Australia.[5]
- According to an analysis by the National Renewable Energy Lab, the emissions intensity of U.S. solar photovoltaic module (panel) production in China in 2018 was 1.3 to 2.5 times more

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[1] OECD, Intensity of CO2 Emissions in Total Gross Exports, Carbon Dioxide Emissions Embodied in International Trade (2021 ed.), https://stats.oecd.org/Index.aspx?DataSetCode=IO_GHG_2021.

[2] CRU International, "Opportunities for US-EU Steel Trade Agreement," Executive summary, Prepared for Climate Leadership Council, December 22, 2022, https://clcouncil.org/media/2024/04/Opportunities_for_US-EU_steel_trade_agreement.pdf; CRU International, "Emissions Analysis Executive Summary," Prepared for the Steel Manufacturers Association, June 14, 2022, https://steelnet.org/steelmaking-emissions-report-2022/.

[3] OECD, Intensity of CO2 Emissions in Total Gross Exports, Carbon Dioxide Emissions Embodied in International Trade (2021 ed.), https://stats.oecd.org/Index.aspx?DataSetCode=IO_GHG_2021.

[4] Rorke, Catrina, *The U.S. Carbon Advantage in Chemicals Manufacturing*, September 2022, https://clcouncil.org/media/2024/04/chemicals_advantage.pdf.

[5] Skarn Associates, "Introducing Skarn Associates," https://mining.ca/wp-content/uploads/dlm_uploads/2021/12/Introducing-Skarn-October-2021.pdf

carbon intensive than production in the United States and 1.8 times more carbon intensive than production in the European Union.[6]

QUESTION 2:
Could you expand on how a border fee, levied by the U.S. and its allies, that corrects for this pollution subsidy, could help counter China's industrial policy and lower global greenhouse gas emissions? What might the economic and geopolitical benefits be for the U.S. and our allies?

Applying a fee at the border that corrects for the performance differences between clean U.S. production and China's intentionally poorer performance is an important environmental and geopolitical counterbalance. China has the technical capacity to implement cleaner manufacturing, as evidenced by being the world's leading exporter of many environmental control technologies, but nevertheless avoids utilizing these technologies domestically, thereby providing its firms with a production cost advantage over foreign competitors. For example, the parasitic load, that is the energy cost of operating environmental controls, for a typical air pollution scrubber in a coal fire power plant range from 15-20%. As a point of reference, for coal power plants in the United States, parasitic losses, including those to operate air pollution control equipment and other environmental infrastructure such as water treatment systems, account for around 30% of the difference between gross and net power generation[7]. Evidence that China intentionally reduces inspection rates and enforcement stringency for the operation of air pollution control equipment in coal fire power plants to avoid the additional energy costs associated with operation, particularly among State Owned Enterprises (SOEs)[8] is widespread. Despite China's status as a major global exporter of air pollution control equipment, it gains market advantage by avoiding the additional energy costs of operating air scrubbers and other environmental equipment in its own market creating insurmountable competitive differences in production costs.

Imposing a fee based on carbon content can level the production cost advantage created by the pollution subsidy yielded from a failure to implement environmental controls in production despite a technical capacity to do so. Specifically, a fee at the border that equates with the dollar cost of performance differences would help close the "carbon loophole" by ensuring imported goods face similar GHG and other pollution control and mitigation costs as domestically produced goods thereby leveling the playing field between the environmental performance of the goods we produce domestically and those we consume from abroad through imports.

Such a mechanism would not only incentivize a race to the top on the GHG performance in global industries but would also bolster supply chain diversification and reduce single points of failure in global supply chains by drawing into the global market producers that can compete on the price of their goods once the underlying environmental performance of traded products is realized by the market through a border pollution fee. A fee for dirty production methods would therefore lead to a major economic and geopolitical benefit by shifting the competitive advantage of production to the U.S. and its allies. Imposing a fee at the border on dirtier

[6] The U.S. data includes both cadmium telluride production and crystalline silicon production, while the data for the European Union and China are crystalline silicon. Both technologies are included for the United States since cadmium telluride accounts for a significant share of U.S. production. Wikoff et al., Joule 6, 1710–1725, July 20, 2022, 1718, https://doi.org/10.1016/j.joule.2022.06.006.

[7] Electricity Data Browser, U.S. Energy Information Administration, 2022.

[8] Karplus VJ, Wu M. Dynamic responses of SO_2 pollution to China's environmental inspections. Proc Natl Acad Sci U S A. 2023 Apr 25;120(17):e2214262120. doi: 10.1073/pnas.2214262120. Epub 2023 Apr 17. PMID: 37068224; PMCID: PMC10151602.

products would make it economically viable for domestic companies to invest in cleaner production methods and instigate demand for green technological innovation, bolstering the U.S. economy and creating durable market incentives to manufacture in America or buy from friends and allies. This would position the U.S. as a leader in not only environmentally sound manufacturing, but manufacturing in general.

Furthermore, a carbon pollution fee that envisions enabling least developed and lower-middle income countries to forego border pollution fees in exchange for the purchase and installation of qualified U.S. environmental technologies would not only facilitate concrete technology transfer and climate action in those countries but would promote U.S. exports. Such a program would produce geopolitical benefits for the United States by giving developing countries a viable alternative to acquiescing to China's economic coercion.

SENATOR VAN HOLLEN

QUESTION 1:

Ms. Hinman, thank you for your testimony highlighting the ways in which China has come to dominate the critical minerals supply chain. This is an issue I am quite concerned about, given the importance of these minerals to successful decarbonization. That's why I joined a bipartisan letter to the Biden Administration last year, urging improved coordination within the federal government and with external partners to improve the domestic supply chain for critical minerals. I see the development of a robust recycling supply chain for critical minerals in the United States as an important part of the solution too since this could help us to reduce our dependence on the raw materials controlled by our adversaries.

Ms. Hinman, can you talk about the role that recycling and the circular economy could play in securing the domestic critical mineral supply chain?

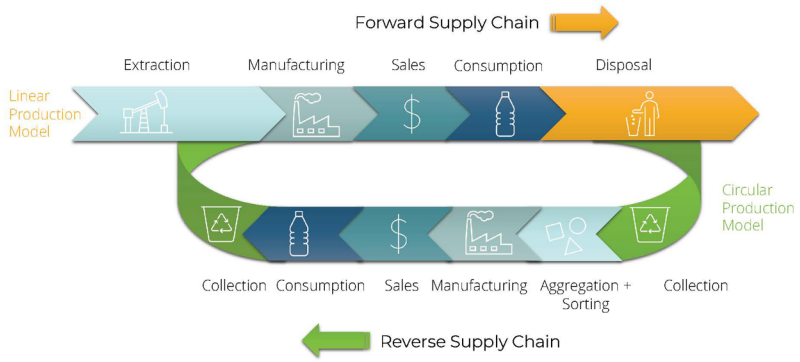
Put simply, before we mine the ground, we need to fully mine society. The U.S. consumes vast amounts of mineral resources in everyday products, especially consumer electronics and the EV industry via batteries. Finding and implementing an effective circular economy approach that allows the U.S. to de-manufacture and retain these valuable inputs rather than treating them as consumer waste would create an alternative to importing the same minerals from countries abroad, many of which have questionable commitment to environmental and labor standards.

Closing the loop on lithium and other critical minerals, such as nickel and cobalt, would reduce our reliance on sourcing these minerals from U.S. adversaries. Employing circular economic principles through recycling these important materials would also give our industrial base, including the EV industry, more control over who and where they source their materials. Additionally, we wouldn't have to rely predominantly on one country for materials necessary to achieve national climate and energy goals. Finally, developing reverse supply chains would necessarily create local jobs for the critical nodes along the reverse supply chain that feeds the circular economy including de-manufacturing, sorting, and processing, therefore improving the U.S. economic and job prospects of the emergent clean economy.

Examining the current ecosystem for recycling in the United States shows the benefits of recycling to create more secure and resilient supply chains. The United States, for example, has significantly reduced its reliance on imported palladium—a mineral widely used in air pollution control—through robust recycling of automobile catalytic converters. Through such recycling the United States reduces—though does not eliminate—its need to import palladium from Russia, the largest global mine producer. In the aluminum industry, the recycling of aluminum scrap makes a major contribution to the supply of aluminum in the United States, though even more could be done to increase aluminum recovery to further reduce our reliance on imports

and meet future supply needs.[9] The benefits of recycling are also demonstrated through the U.S. steel industry's use of recycled scrap in electric arc furnaces (EAFs), a significant contributor to the U.S. carbon advantage in steel manufacturing.[10]

Figure 1. The Reverse Supply Chain



Implementing a robust circular economy and boosting the recycling of critical minerals requires the formation of reverse supply chains that can compete on price and quality with materials produced in the forward supply chain (see figure 1). An effective reverse supply chain for battery materials has the potential to extend the lithium loop indefinitely and ease import demand for minerals such as nickel and cobalt. Currently, there are several key barriers to the formation of competitive reverse supply chains in the United States.

1. **Stocks in Society are Unknown.** The volume, quality, and estimated timeframe for end-of-life recovery of products currently in use is unknown and therefore recyclers and potential investors and developers of recycling businesses can neither anticipate market potential nor bank-on unknown market opportunity. Congress could remedy this market information failure by directing the Federal Government to produce a stocks in society report similar in scope to the U.S. Geological Survey's annual Mineral Commodities Summary report.
2. **The Quality and Useability of Recycled Materials is Often Ambiguous.** In the absence of quality standards and component markings that enable recyclers to identify and market recycled components at the level of quality and technical specification required by Original Equipment Manufacturers (OEMs), OEMs have little choice but to default to utilizing mined materials whose technical composition and quality is readily available. Collaboration between the OEMs and recyclers on the development of technical standards and markings for components could improve the potential for closed-loop utilization of recycled products.
3. **Diffusion of Recycling Feedstock and Logistics of Recycling Hinders Certainty in and Competitiveness of Reverse Supply Chains.** As illustrated by figure 2., reverse supply chains must collect products from a diffuse consumer base, aggregate products, de-

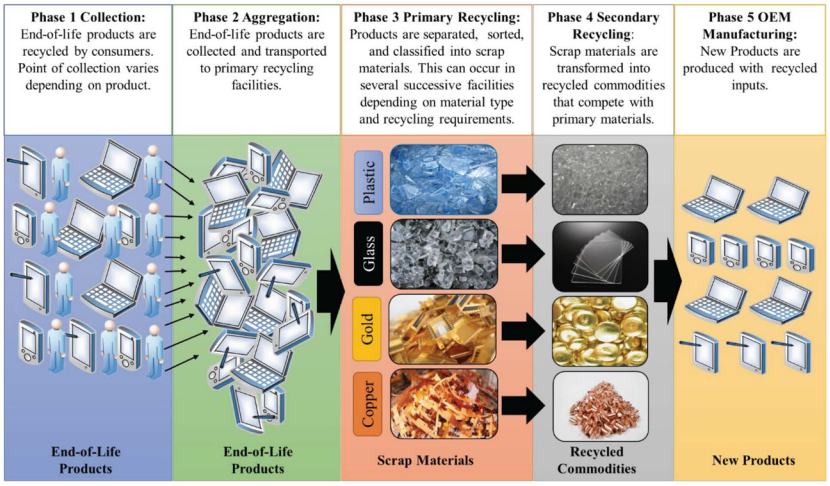
[9] USGS, Mineral Commodity Summaries, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-platinum-group.pdf and https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-aluminum.pdf; David, Andrew, Critical Minerals in AGOA: Platinum-Group Metals, Silverado Policy Accelerator, July 2024, https://silverado.org/reports-and-publications/critical-minerals-in-agoa-platinum-group-metals/.

[10] Recycling Today. "Scrap Viewed Favorably In Emissions Study." Brian Taylor, September 12, 2023.

manufacture them, and sort and process constituents into useable commodities, before they are sold to OEMs. These additional steps raise production costs that create challenges for individual processed materials that must compete on price with centrally located and processed mined products. Smoothing the logistical costs of reverse supply chains will require improved market information and innovation in collection, sorting, and processing efficiency.

4. **Recyclable Technologies Are Not Designed for De-manufacturing.** To be truly recyclable, products, particularly complex technologies, must be designed to be de-manufactured at end-of-life and critically, information on how to de-manufacture said products must be transferred to qualified recyclers with the technical know-how and legal liability to safely de-manufacture products and handle hazardous materials entrained therein.
5. **Recycling Products and Intermediaries are Treated Like Trash in International Trade.** The minute amounts of certain critical materials entrained in end-of-life products often requires that products need to cross international borders multiple times to aggregate sufficient material amounts to provide for economies and scale in recycling. Unfortunately, the bodies and even customs language that govern international trade in recyclable products and recycling intermediaries such as scrap metals equate these valuable products with waste, therefore triggering insurmountable barriers to cross-border transactions. Fixing this challenge will require divorcing waste and scrap in the customs nomenclature and creating international customs standards for the identification and validation of recycling products and intermediaries so they might have the same freedom of movement across borders as their primary mined and processed counterparts.

Figure 2. Recycling Phases in the Reverse Supply Chain



Effective end-of-life usage through recycling and circular economic principles is important for securing domestic critical mineral supply chains. Doing so would ensure that critical minerals not only remain at home, but also that they are utilized to their fullest lifecycle potential throughout the U.S. economy.

QUESTION 2:
Given that China is on track to establish global monopoly power in critical mineral industries -as you point out in your testimony, Ms. Hinman -- it seems to me that the United States should do more to coordinate with friendly nations on this issue and collectively regain market power.

Ms. Hinman, can you expand on the importance of close collaboration with our allies as we work to secure our critical mineral supply chain?

We cannot and should not go it alone. We need to leverage the collective market power of other market economies and act in unison with our trading partners, who are also feeling the impact of China's imports and non-market policies. Some useful moves the U.S. could pursue with partners include common external trade remedies, carbon pollution fees, and enforcement on products made in whole or in part with stolen intellectual property.

We also need more and better market access. China, through its FTAs, enjoys $9.7 trillion in access to markets with which the United States does not have an FTA. Therefore, we need more deals, not just for the markets, but also for the binding and sanctionable standards on labor and the environment unique to U.S. FTAs. It should be noted that the U.S. lacks a strong trade agreement model that gives developing countries, many of them rich in the minerals we need for the clean transition, a path upward through a meaningful role in the global clean economy.

A prime example of the importance of collaboration with our partners is the lithium-ion battery supply chain. Lithium is an essential component in the production of lithium-ion batteries which are a critical input to EVs, portable electronic devices, and energy grid storage. U.S. FTA partners (Australia, Chile, and Canada) accounted for more than 70 percent of non-U.S. global lithium mine production in 2023.[11] While the United States has the opportunity to collaborate more closely with these allies, these countries currently have lithium supply chains that are closely connected with China. In 2023, 99 percent of Australia's lithium exports were to China, and 61 percent of Chile's lithium exports were to China[12]

Therefore, there is a need for the U.S. to pursue trade strategies with our allies, friends, and developing partners that explicitly focus on the critical mineral supply chain. Laudable Administration efforts to address this gap include the 2023 U.S.-Japan Critical Minerals Agreement and the Minerals Security Partnership (MSP), where the U.S. has taken the initiative to boost cooperation among its allies on critical minerals. But there are limits to these types of collaborative agreements and programs: they do not explicitly provide for greater market access of critical and processed materials, they lack binding and reciprocal commitments, cover a limited scope of materials, and have no appropriated mechanism for their administration. Congress could remedy this and enhance U.S. mineral supply chain security through the provision of narrowly scoped trade promotion authority to seek binding and reciprocal minerals agreements with relevant partners. Ideally this type of authority would entail:

1. Reciprocal market access on raw and processed minerals of broad scope that includes recycling products and intermediaries in addition to mined and primary processed goods.
2. Coherence on standards for safe, humane, and environmentally sound mining, processing, and recycling.

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[11] The global total excludes the United States since the USGS did not publish data on U.S. production for confidentiality reasons. USGS, *Mineral Commodity Summaries*, https://www.usgs.gov/centers/national-minerals-information-center/lithium-statistics-and-information.

[12] Three percent of Chile's exports went to the United States in 2023. The data for Australia are for lithium concentrates (which is the primary product exported by Australia), lithium carbonates, and lithium oxide and hydroxide. The data for Chile exclude lithium concentrates, as lithium production in Chile is from brine rather than from ore. Global Trade Tracker database.

3. A template that addresses the status of developing countries by creating a credible and binding pathway to socially and environmentally high-standard mining, processing, and recycling practices in exchange for U.S. market access.
4. High standard commitments on labor and environment and an economically viable off-ramp from purchasing products from markets with cut-rate labor and environmental practices.
5. Common procurement and offtake rules and performance standards to counterbalance non-market actors through collective market power.

Responses for the Record
from Mr. David Schwietert
Chairman Whitehouse and Senator Van Hollen
"Charging Ahead: The Future of Electric Vehicles"
July 31, 2024
Senate Budget Committee

Senator Whitehouse:

Question: Does the U.S. have an electric vehicle mandate that requires consumers to purchase electric vehicles or prohibits the sale of internal combustion engine vehicles?

Answer: U.S. EPA sets greenhouse gas regulations with annually declining (more stringent) targets for individual vehicles based on their "footprint" (i.e., the area between the tire ground contact points). Compliance is based on the average emissions of the individual vehicles in a manufacturer's fleet relative to the average targets of those same vehicles, both on a sales-weighted basis. Therefore, manufacturers may build some vehicles with emissions higher (i.e. worse) than their targets as long as they build a commensurate number of vehicles with emissions lower (i.e. better) than their targets. Future targets are set at a level where only plug-in and fuel cell vehicles are likely to be better than target, so most manufacturers will likely have an increasing proportion of plug-in (or fuel cell) vehicles to balance the emissions of their ICE vehicles. Manufacturers that focus efforts on production of lower-emitting ICE vehicles (for example, hybrid electric vehicles) will not need as many plug-in vehicles as manufacturers that do not hybridize their ICE vehicles to the same extent. EPA's primary (central) analysis for its recent final rule (covering Model Years 2027-2032) projects its MY2032 standards will result in 56% battery electric plus 13% plug-in hybrid electric new vehicle sales. See 89 Fed. Reg. 27842, 27856 (Apr. 18, 2024)

The National Highway Traffic Safety Administration sets corporate average fuel economy (CAFE) regulations that generally overlap the EPA GHG regulations. (The combustion of liquid fuel has a direct relationship to GHG emissions based on the amount of carbon in the fuel.) The NHTSA regulations are similar to the GHG regulations in their approach of individual vehicle targets and fuel economy levels averaged to determine compliance. Other statutory requirements differ, creating challenges for planning a single compliant fleet. These include backstop domestic passenger car standards, which have resulted in over $1 billion in civil penalties for automakers between 2011 and 2020 despite the automakers' compliance with EPA greenhouse standards. See "Civil Penalties Report" at https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-public-information-center. Another key difference is the statutory limitations on credit transfers that become increasingly constraining as fuel economy standards are increased. CAFE regulations were recently finalized for Model Years 2027-2031.

California and states that have adopted California's regulation via Section 177 of the Clean Air Act have a direct ZEV mandate that requires 100% of new vehicle sales to be battery electric, fuel cell electric, or (up to 20% maximum) plug-in hybrid electric vehicles by 2035. Some "Section 177" states have only adopted the California Mandate through 2032, which requires 82% EV sales (including up to 16% plug-in hybrids). Note, the U.S. EPA is reviewing California's waiver request to

allow it to establish more stringent regulations under its Advanced Clean Car Rule II rule for MY26-2035.

Senator Van Hollen:

Question: This Spring, my home state of Maryland became the first state to pass vehicle-to-grid legislation that requires utilities to develop interconnection processes for bidirectional chargers. This legislation also creates a pathway for customers with storage capacity-which an EV battery can provide -to sell electricity back to the grid. A pilot is underway right now in Maryland to demonstrate what can happen when bidirectional charging technology and enabling policy come together to advance decarbonization. We face electricity reliability concerns in our region, but this "EV virtual power plant" model can help stabilize the grid. Customers in the pilot program charge their Ford F-150 Lightnings overnight at their homes when electricity prices are low, and then sell electricity back to the grid during peak demand. Customers are expected to receive around $800 each in payments for energy they sell back to the grid over the four-month pilot. Furthermore, these customers no longer need to buy generators -they can rely on their EV s for electricity if the power goes out. One customer noted that his F-150 could power his home for around 5 days.

[Question]: Mr. Schwietert, what needs to be done to fully commercialize this technology?

Answer: An increasing number of EV models arriving on the market will be capable of bidirectional charging. These EVs can discharge a portion of their battery directly to the grid (V2G), a house (V2H), or equipment (V2L), providing many types of services to the grid, the public, and drivers. However, fully commercializing bidirectional charging technology requires pricing, managed charging programs, and policies that support a sound business case for automakers to invest in developing it and installing it on vehicles. Technical standards are also needed to ensure the safety of the consumers and utility personnel.

To fully commercialize V2G, a number of factors are needed, most outside the control of the automaker. Below are a few of those factors:

- Utilities, Regional Transmission Operators, and regulators should adopt programs and policies that compensate EV drivers for exporting power to the grid.
- Utilities and their regulators should coordinate with other agencies to align incentives for drivers that provide other charging-enabled services to the public.
- Utilities and their regulators should adopt streamlined interconnection rules consistent with and informed by learnings from other jurisdictions.

The auto industry is supportive of bidirectional charging, including V2G, but it is more than just the automakers that need to be involved. We applaud Maryland for passing their vehicle-to-grid legislation requiring utilities to develop an interconnection process for bidirectional chargers, and our Association has even advocated for similar pilots or processes in other states. Having the utilities engaged is a critical piece to bring this technology to market. A vehicle capable of bidirectional charging will do nothing to support the grid if utilities do not have systems in place for vehicles to interconnect. While bidirectional capable EVs offer a wide range of opportunities, it is

important to remember that a vehicle's primary purpose is transportation. An EV driver must have confidence that they will have enough "fuel" to get where they need to in an emergency situation.

The Alliance for Automotive Innovation recently published a white paper on vehicle-grid integration, *The Convergence of the Automotive and Electric Power Industries,* which includes V2G policy recommendations (pages 14-16). We'd welcome the opportunity to answer follow-up questions.

Questions for the Record
from Senator Roger Marshall
for Mr. Jeff Davis
Charging Ahead: The Future of Electric Vehicles
Wednesday, July 31, 2024
Senate Budget Committee

Question #1:

CBO predicts that the Highway Trust Fund will become insolvent by 2028 – with revenues continuing to decrease in large part due to improved vehicle fuel efficiency, new drivetrains and considerably more EV's on the market. But for all their fuel efficiency praise, EVs are significantly heavier, which creates more wear and tear on the roads while not contributing a single dollar into the HTF. How do we get EV owners to pay their fair share to use our roadway network? What do you think that looks like? And can we afford to allow this market to grow without capturing any HTF revenue benefits?

Response of Jeff Davis, Senior Fellow, Eno Center for Transportation
to Question for the Record from Sen. Roger Marshall (KS)
Re: Senate Budget Committee hearing on electric vehicles, July 31, 2024

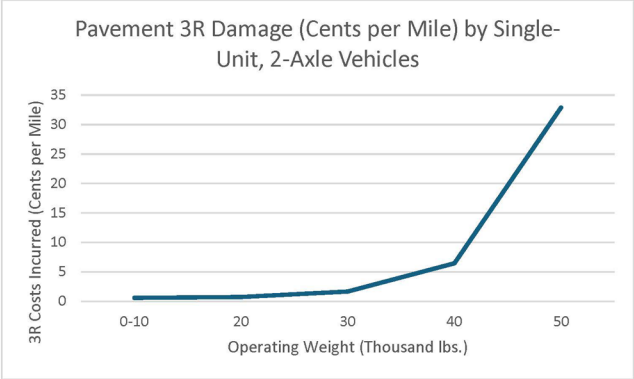
"...EVs are significantly heavier, which creates more wear and tear on the roads while not contributing a single dollar into the HTF."

The strain put upon pavements and bridges by wheeled vehicles is a product of the weight of the vehicle and the number of points at which that weight meets the road (axles), called axle-weight.

It is impossible for a vehicle with lower axle-weight to put more wear-and-tear on the same road, per mile, than a vehicle of higher axle-weight. But the evidence suggests that the difference between damage done by weight classes is smaller at the lighter end of the spectrum and much more pronounced with heavier trucks.

The last Highway Cost Allocation Study performed by the Federal Highway Administration was completed in 1997 (https://rosap.ntl.bts.gov/view/dot/13475) . Table V-9 of that study indicated that the responsibility for pavement resurfacing, restoration, and rehabilitation (3R) costs was borne at a rate of 0.063 cents per mile for passenger automobiles and 0.075 cents per mile for pickup trucks and vans, a difference of 19 percent between the average car and the average two-axle truck or van.

But this is far, far lower than the costs incurred by very heavy trucks, the damage from which rises almost asymptotically once a certain weight threshold is crossed:



Data Source: Federal Highway Administration, *1997 Federal Highway Administration Cost Allocation Study: Final Report,* Table V-10.

If the average pickup truck or van only puts 19 percent more wear-and-tear on pavement than the average passenger car (at year 1997 average weights), and assuming that the average pickup truck was almost twice the weight of the average passenger car then, then the wear-

and-tear costs incurred by an EV that weighs one-third more than the comparable ICE vehicle can't be more than 19 percent higher and are probably less than half that.

In short, their additional weight could be a legitimate justification for charging EVs slightly more than comparable ICE cars pay in Highway Trust Fund (HTF) fuel taxes, perhaps five to ten percent more, but not much more than that.

Since the last formal highway cost allocation study was in 1997, section 11530 of the Infrastructure Investment and Jobs Act of 2021 (Public Law 117-58) requires the Department of Transportation to conduct a new study to estimate direct costs incurred by different classes of vehicle. That section also requires the study to "compare the costs occasioned by various highway user classes with the user fee revenue contributed to the Highway Trust Fund by those highway user classes."

Because electric vehicles under 33,000 pounds (and thus not subject to the heavy truck tax) currently don't pay any revenue into the Highway Trust Fund, the study should give an update on the direct costs incurred by electric vehicles so that Congress, if it chooses, could levy user taxes on electric vehicles in proportion to their direct costs incurred on roads and bridges.

"How can we get EV owners to pay their fair share to use our roadway network?"

If the user-pay, user-benefit paradigm for road finance is to be retained, EV operators should pay something into the Highway Trust Fund for their use of federally subsidized roads. As long as fossil fuel taxes continue to be the only method of taxing light-duty vehicles for the Trust Fund, a separate revenue mechanism would have to be established to bring EV revenue into the HTF.

Raising user revenues from EVs has one fundamental problem: as long as the federal government is in the business of encouraging EV purchase by providing financial incentives towards the purchase and use of EVs, raising federal revenue from the purchase and/or use of EVs raises the specter of the government working at cross-purposes with itself.

Conceptually, there is a huge difference between a federal user tax on a good or service (going to a trust fund that only pays for programs that benefit that taxpayer) and a federal tax or tax credit on that good or service from general revenues. But they are the same economically, and explaining the difference to voters can be difficult politically.

That said: the simplest method to administer would be a federal sales tax on EVs. (There was a federal sales tax on all automobiles in effect from 1917 to 1971, at rates varying from 3 to 10 percent of manufacturer's sales price.) If the tax rate were *ad valorem* (a percentage of the price), like most sales taxes, this would pose two problems: (a) the price of a vehicle bears no relation to the number of miles it will be driven, making it a particularly bad proxy for road use, and (b) the incongruity of levying a special federal sales tax on a product that is also receiving a special federal tax credit is striking. A flat federal sales tax charging a specific amount for the sale of an EV, based on average lifetime mileage of that class of vehicle, would avoid problem (a) but would still face all of problem (b).

Several state governments have levied special EV road use fees as part of their annual vehicle registration process. If fairly allocated, such fees are easier on EV owners than a sales tax would be, because owners would be spreading out the total fee over multiple years of use instead of

paying it all at the time of purchase. However, since the federal government currently has no system for non-commercial vehicle registration, the administrative costs would be high, and the IRS would probably have to piggyback on top of the state vehicle registration process to some degree, with unknown results.

The ability of an EV to use the roads is limited by the size of its battery. Federal EV registration fees could vary based on vehicle weight and/or the kilowatt-hours of the battery. Or, for ease of tax administration, the federal government could levy a manufacturer's excise tax on EV batteries based on its kilowatt-hours.

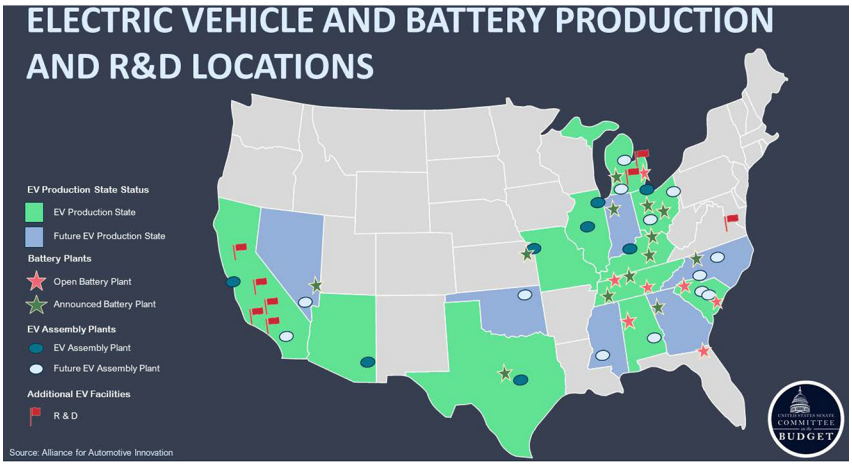
If Congress eventually chooses to move from fossil fuel taxes to some other kind of user-based revenue source for supporting the Trust Fund, such as a federal mileage fee, internal combustion vehicles and EVs could be treated completely equally for Trust Fund revenue purposes.

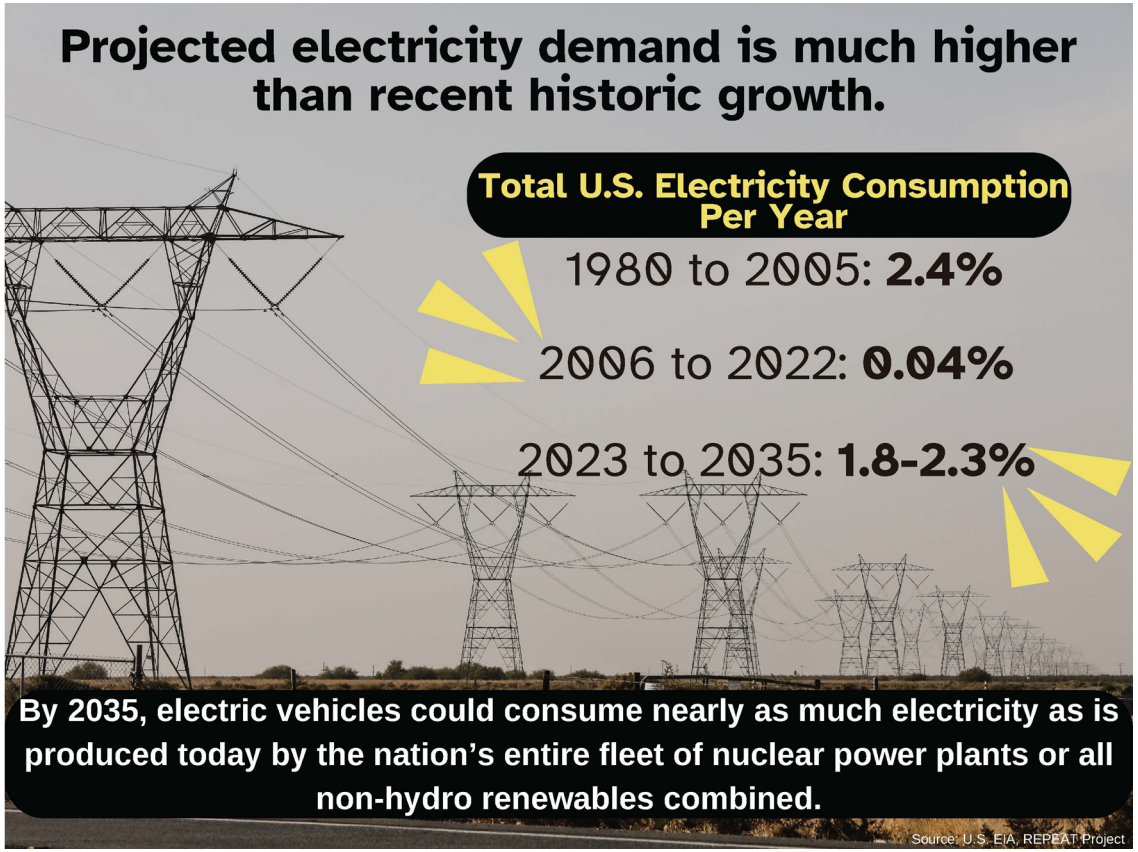
"...can we afford to allow this market to grow without capturing any HTF revenue benefits?"

Not for long, no. The most recent Congressional Budget Office projections indicate that , starting in 2030, the number of gallons of gasoline taxed for the Highway Trust Fund will drop by one-third over the next decade, falling from around 138 billion gallons in 2024 to 89 billion gallons in 2034. The annual rate of decrease will be as high as 7 percent, year-over-year, and could accelerate after 2034.

USDOT and three other federal agencies confirmed in their May 2024 "U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation" that the goal is for 50 percent of new vehicle sales being zero-emission by 2030 and the entire economy being GHG-emission-neutral by 2050.

As long as we are sticking with the user-pay, user-benefit paradigm for road finance, the fastest-growing road vehicle class, which could be the majority of new vehicles sold a decade hence, should have to pay <u>something</u> into the Highway Trust Fund that supports the majority of U.S. road upkeep.


ELECTRIC VEHICLE AND BATTERY PRODUCTION AND R&D LOCATIONS
EV Production State Status
EV Production State
Future EV Production State
Battery Plants
Open Battery Plant
Announced Battery Plant
EV Assembly Plants
EV Assembly Plant
Future EV Assembly Plant
Additional EV Facilities
R & D
Source: Alliance for Automotive Innovation
COMMITTEE
BUDGET


Projected electricity demand is much higher than recent historic growth.
Total U.S. Electricity Consumption Per Year
1980 to 2005: 2.4%
2006 to 2022: 0.04%
2023 to 2035: 1.8-2.3%
By 2035, electric vehicles could consume nearly as much electricity as is produced today by the nation's entire fleet of nuclear power plants or all non-hydro renewables combined.
Source: U.S. EIA, REPEAT Project


$5 billion:
Annual lost revenue to the Highway Trust Fund due to electric vehicles by 2034

ELECTRIC VEHICLE BATTERIES

U.S. production capacity for EV batteries is growing but still lagging behind China.



In 2023, the U.S. mined:
5,000 metric tons of **lithium**
500 metric tons of **cobalt**
17,000 metric tons of **nickel**
1.1 million metric tons of **copper**

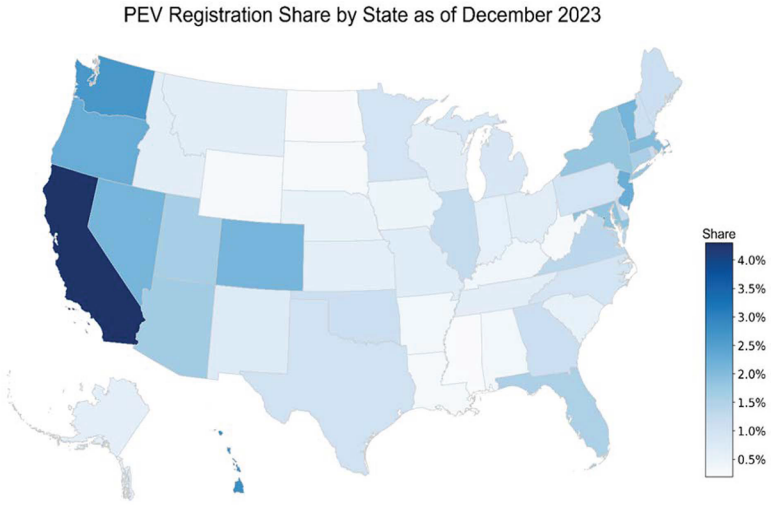
Manganese or **graphite** are not mined domestically, requiring the U.S. to heavily rely on imports. **More than 40% of graphite imports come from China.**



In 2023, China mined:
33,000 metric tons of **lithium**
1.7 million metric tons of **copper**

In 2023 China processed:
175,000 metric tons of **cobalt**
110,000 metric tons of **nickel**
740,000 metric tons of **manganese**
1.23 million metric tons of **graphite**

Source: Silverado Policy Accelerator


PEV Registration Share by State as of December 2023
Share
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%

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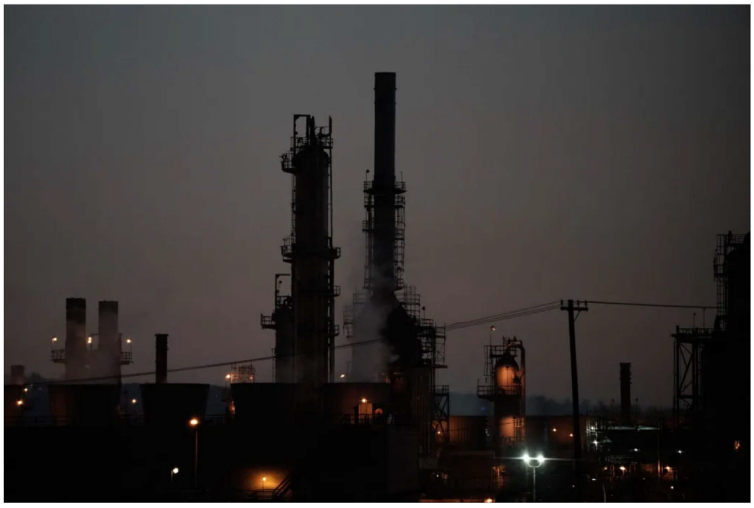

Distillation towers stand at dusk at the Marathon Petroleum Corp. Los Angeles Refinery in Wilmington, California, U.S., on Tuesday, April 21, 2020. American crude surged above $13 a barrel after President Donald Trump ordered the navy to destroy any Iranian gun boats that harass American ships at sea. Bing Guan/Bloomberg via Getty Images

BY LINDSEY GRAHAM AND SHELDON WHITEHOUSE JUNE 17, 2021 10:09 AM EDT

IDEAS *Sheldon Whitehouse, a Democrat, represents Rhode Island in the U.S. Senate. Lindsey Graham, a Republican, represents South Carolina in the U.S. Senate.*

We are a conservative Republican and a progressive Democrat who disagree on a great many things. We write today, however, to highlight an area of strong agreement: a global transition to renewable energy would greatly assist in our nation's fight against the world's most corrupt and illicit regimes. If you could wave a magic wand, and transition the world away from fossil fuels, Americans would instantly be safer.

Oil and gas development has often been associated with autocracy and corruption. Governments in countries such as Russia and Iran have used oil and gas to threaten neighbors and fund terrorism. Corruption, autocracy, and terrorism are a persistent threat to nations that stand on the rule of law, and America has long been the exemplar of the rule-of-law nation. A world in which oil and gas money has less power is a world that will likely have less corruption, autocracy, and terror. That world will be a safer world for America.

Let's be more specific. Iran is the most dangerous enemy we have in the Middle East. Iran is the largest state sponsor of global terrorism today, and a serial human rights abuser at home. It is the implacable enemy of our ally and friend, Israel. It is developing nuclear weapons, which would create a nightmare arms race in the already unstable Middle East. And Iran keeps itself afloat on tens of billions of dollars of export revenues from its oil and gas industry. It has vast oil and gas reserves, with one field estimated to have a trillion dollars in production capacity. Deprive Iran of that revenue, and it becomes a less dangerous nation. Without the potential for future fossil fuel revenue, Iran would have a strong incentive to engage in the world economy in ways that would force it to stand down from its worst behavior, and, hopefully, even join the community of nations. The Middle East becomes a safer place.

Look at Russia. Russia is the most dangerous enemy we have in Europe, and poses a threat to our interests around the world. Russia is the primary sponsor of autocracy, corruption, and discord in Europe. Russia's agents commit murders in London; Russia's army occupies Eastern Ukraine, Crimea, and parts of the Republic of Georgia. Vladimir Putin's petro-politics leverages Russian gas supplies to put constant hostile pressure on its Western neighbors. Russia

gas supplies to put constant hostile pressure on its Western neighbors. Russia was memorably described by our departed friend Senator John McCain as "a gas station run by a mafia ... masquerading as a country." Take away the gas in the gas station, and the gangsters have nothing to run their gang. Without that source of money and power, Russia's ability to bully and corrupt its neighbors diminishes, its gangster oligarchs have less to steal, and its economy shrinks from the size of Italy's to the size of Switzerland's. All of Europe becomes a safer place.

Look at Saudi Arabia. Nominally our strategic partner, Saudi Arabia has a history of funding madrassas that spawned and nurtured anti-Western hatred and recruited terrorist fighters. The Saudi government was responsible for the disgusting murder of Jamal Khashoggi, a U.S. permanent resident who was dismembered at a Saudi consulate in Turkey. His remains have still not been recovered. Only recently have Saudis allowed women to get behind the wheel of a car in their country. Sunni extremism would dramatically diminish if its Saudi oil financing expired.

Our point today is not about climate change. That has its own set of national security concerns. This is about who our friends are and who our foes are; and what the stabilizing and destabilizing forces in our world are. This is about where our foes, and the forces they employ like terror and corruption, get their resources. All too often, it's from extractive industries like oil and gas. Some see this as a "resource curse" in which countries with wealth to extract fail to develop healthy models of governance. One need not agree on the reasons to observe the fact, and we cannot leave the damage unaddressed.

The fact is simple: a world without fossil fuel resources funding foreign adversaries would be a safer world for America.

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The New York Times https://www.nytimes.com/2024/07/30/business/japan-thailand-cars.html

Japan Built Thailand's Car Industry. Now China Is Gunning for It.

After dominating sales in Thailand for decades, Mazda, Nissan and other Japanese companies are losing their grip on a market long viewed as a regional hub.

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By Daisuke Wakabayashi, River Akira Davis and Claire Fu
Daisuke Wakabayashi and Claire Fu reported from Bangkok, and River Akira Davis from Tokyo.

July 30, 2024

Get it sent to your inbox.

Japanese companies established Thailand's auto industry virtually from scratch, dating back to the years after World War II. By the late 1970s, Japanese brands commanded around 90 percent of car sales in Thailand. They invested in building Thai supply chains, and their cars were also widely perceived by customers as reliable.

In the 1990s, American and South Korean automakers targeted the Thai market but barely made a dent in Japan's share.

Now Japanese automakers' stronghold is finally being loosened by Chinese manufacturers that offer something they don't: electric vehicles at affordable prices. The influx of Chinese brands like BYD, Great Wall Motor and SAIC Motor in the past two years is ringing alarms in Japan.

In December, Srettha Thavisin, Thailand's prime minister, traveled to Japan with a message for Japanese companies: Move quickly, invest in electric vehicles or lose out to China.

"You are not alone in the world," Mr. Thavisin warned Japan's automakers in an interview with Japanese media.

Japanese companies' unwillingness to fully embrace electric vehicles, which are popular in Thailand, has held them back in the Thai market. Mazda, Mitsubishi, Nissan, Suzuki and Isuzu have taken the heaviest blows, in part because of their limited lineups of plug-in hybrid or fully electric models. Last year, new car sales in Thailand for those companies collectively dropped 25 percent while overall sales fell 9 percent, according to data compiled by MarkLines, an automotive information provider.



Factory employees inspecting the chassis of a GAC Aion electric vehicle in Rayong, Thailand. GAC Aion is the E.V. arm of the Chinese state-owned Guangzhou Automobile Group. Lauren DeCicca for The New York Times

This month, Honda announced it would cease vehicle production at one of its two factories in Thailand next year. And Suzuki said in June that it would close its only vehicle-manufacturing plant in the country.

Japanese manufacturers, which account for about 75 percent of vehicle sales in Thailand, are taking steps to stem the erosion of their position. During Mr. Thavisin's trip to Japan, Toyota, Honda, Isuzu and Mitsubishi said they would invest $4.3 billion over five years to convert their Thai factories to make electric vehicles. Late last year, Honda began producing electric vehicles in Thailand.

Nissan established Thailand's first Japanese auto assembly plant in Bangkok in 1962, a time when Thais bought only a few thousand vehicles a year. Toyota followed shortly

after, starting vehicle production in Thailand in 1964.

From early on, the Japanese companies viewed Thailand as a regional export hub for Southeast Asia. They spent decades investing to develop Thai supply chains and sales networks, predominantly for pickup trucks that are exported and sold domestically. Japan's strategy paid off in the 1980s and 1990s in particular, when Japanese automakers cashed in on booming demand in Southeast Asia while the United States and Germany were largely focused on Eastern Europe.

Southeast Asia, including Thailand, stands as the largest market for Mitsubishi and other smaller Japanese automakers. In the fiscal year that ended in March, Mitsubishi's sales in the region fell 9 percent from the previous year.

Mitsubishi and other Japanese automakers are pinning hopes on developing new hybrid and electric models to regain lost ground. In February, Mitsubishi introduced a hybrid version of its Xpander multipurpose vehicle in Thailand, and the company said orders had surpassed expectations.

But the Chinese electric vehicle companies are formidable competition.

GAC Aion, the E.V. arm of the state-owned Guangzhou Automobile Group, has quickly established a manufacturing and sales business in Thailand and is trying to break into another Japanese stronghold: taxis. Toyota accounts for a vast majority of taxis on the road in Thailand.



Huang Yongjie, chairman of Gold Integrate, is helping bring Chinese-made GAC Aion electric taxis into Thailand. Lauren DeCicca for The New York Times

Through a Thai partner, Gold Integrate, Aion has released a fully electric sedan dedicated solely for the country's ride-hailing and taxi market.

Over the past year, the Aion-Gold Integrate partnership has sold several thousand of a taxi-only model to commercial customers in Thailand for about $25,000 with a nine-year warranty.

Huang Yongjie, chairman of Gold Integrate, which also invested in 15 showrooms for Aion, said Toyota had responded to Aion's entry into the Thai market by cutting the price of its main taxi model by nearly $3,000. It was notable, Mr. Huang said, because "Toyota never cuts prices."

Daisuke Wakabayashi is an Asia business correspondent for The Times based in Seoul, covering economic, corporate and geopolitical stories from the region. More about Daisuke Wakabayashi

River Akira Davis covers Japan, including its economy and businesses, and is based in Tokyo. More about River Akira Davis

Claire Fu covers China with a focus on business and social issues in the country. She is based in Seoul. More about Claire Fu

Copper can't be mined fast enough to electrify the US

May 15, 2024Morgan Sherburne



Pima County Arizona copper mine. Image credit: Joyce Cory, CC BY 2.0, via Wikimedia Commons

Copper cannot be mined quickly enough to keep up with current U.S. policy guidelines to transition the country's electricity and vehicle infrastructure to renewable energy, according to a University of Michigan study.

Study: Copper mining and vehicle electrification

The Inflation Reduction Act, signed into law in 2022, calls for 100% of cars manufactured to be electric vehicles by 2035. But an electric vehicle requires three to five times as much copper as an internal combustion engine vehicle —not to mention the copper required for upgrades to the electric grid.

"A normal Honda Accord needs about 40 pounds of copper. The same battery electric Honda Accord needs almost 200 pounds of copper. Onshore wind turbines require about 10 tons of copper, and in offshore wind turbines, that amount can more than double," said Adam Simon, U-M professor of earth and environmental studies. "We show in the paper that the

amount of copper needed is essentially impossible for mining companies to produce."



The study examined 120 years of global data from copper mining companies, and calculated how much copper the U.S. electricity infrastructure and fleet of cars would need to upgrade to renewable energy. It found that renewable energy's copper needs would outstrip what copper mines can produce at the current rate. The study, led by Simon and Cornell University researcher Lawrence Cathles, was published by the International Energy Forum and discussed in a webinar, "Copper mining and vehicle electrification."

The shortfall is in part because of the permitting process for mining companies. The average time between discovering a new copper mineral deposit and getting a permit to build a mine is about 20 years, according to Simon.

Copper is mined by more than 100 companies operating mines on six continents. The researchers drew data for global copper production back to the year 1900, which told them the global amount of copper mining companies had produced over 120 years. They then modeled how much copper mining companies are likely to produce for the rest of the century.

The researchers found that between 2018 and 2050, the world will need to mine 115% more copper than has been mined in all of human history up until 2018 just to meet "business as usual." This would meet our current copper needs and support the developing world without considering the green energy transition.

To meet the copper needs of electrifying the global vehicle fleet, as many as six new large copper mines must be brought online annually over the next several decades. About 40% of the production from new mines will be required for electric vehicle-related grid upgrades.

"I'm a huge fan of the Inflation Reduction Act. I think it's fantastic. I've got solar panels, batteries and an electric vehicle," Simon said. "I'm fully on board with the energy transition. However, it needs to be done in a way that's achievable."

Instead of fully electrifying the U.S. fleet of vehicles, the researchers suggest focusing on manufacturing hybrid vehicles.

"We are hoping the study gets picked up by policymakers who should consider copper as the limiting factor for the energy transition, and to think about how copper is allocated," Simon said. "We know, for example, that a Toyota Prius actually has a slightly better impact on climate than a Tesla. Instead of producing 20 million electric vehicles in the United States and globally, 100 million battery electric vehicles each year, would it be more feasible to focus on building 20 million hybrid vehicles?"

The researchers also point out that copper will be needed for developing countries to build infrastructure, such as building an electric grid for the approximately 1 billion people who don't yet have access to electricity; to provide clean water drinking facilities for the approximately 2 billion people who don't have access to clean water; and wastewater treatment for the 4 billion people who don't have access to sanitation facilities.

"Renewable energy technologies, clean water, wastewater, electricity—it cannot exist without copper. So we then end up with tension between how much copper we need to build infrastructure in less developed countries versus how much copper we need for the energy transition," Simon said.

"We think our study highlights that significant progress can be made to reduce emissions in the United States. However, the current—almost singular—emphasis on downstream manufacture of renewable energy technologies cannot be met by upstream mine production of copper and other metals without a complete mindset change about mining among environmental groups and policymakers."

I-95 Traffic Nightmare: What If You Were Stuck in an Electric Car for 24 Hours? - Kelley Blue Book

Sean Tucker



A rapid early January storm created a unique traffic nightmare for hundreds of drivers in Virginia. Interstate 95, the East Coast's primary north-south highway corridor, came to a complete standstill just south of Washington, D.C. Hundreds of drivers sat trapped in their cars for as long as 24 hours, waiting for tow trucks to clear away a series of accidents.

The incident triggered media reports nationwide. It also launched a debate. Did the standstill prove that America isn't ready for electric vehicles (EVs)? Many assumed that EVs would run out of stored electricity long before gasoline-powered cars would run out of gas.

That could, the theory went, create medical risks for their drivers and passengers in the extreme cold. Even if drivers made it through the night safely, they'd need a tow, possibly very far, to the nearest charging station when the crisis ended.

A Washington Post columnist went so far as to write that the event "provides a reality check on the push by government and business to electrify cars and trucks."

No one, it seemed, followed up with the EV drivers who got stuck in the crisis.

"Especially Grateful" to Be Stuck in an EV

"I am especially grateful that I was driving my EV when I got stuck on I-95," writes Dan Kanninen.

Kanninen isn't neutral on the subject. He told his story to the Zero Emission Transportation Association (ZETA) website, a coalition of companies working to advocate for pro-EV policies.

"While fellow drivers burned gasoline running their engines to stay warm, my EV intelligently directed power solely to temperature regulation," he wrote. He "did not have to inefficiently burn fuel to power my entire engine" to keep himself and his passengers warm in the standstill.

Kanninen sat trapped for over 14 hours, he writes. But his Tesla Model 3 Standard Range "nevertheless made it to the charger with a 50-mile range surplus" when traffic moved again.

Tesla Driver Made it Home

A second Tesla driver trapped in the storm triggered that Washington Post column. Columnist Charles Lane wrote that a tweet sent under the handle My World Through a Windshield inspired his piece. The name belongs to a Canadian long-haul truck driver who sat stuck in the I-95 mess. The tweet expressed worry about a nearby Tesla driver, who knocked on the truck's door and asked to borrow a blanket.

My World Through a Windshield later followed up with the Tesla driver. The man's electric vehicle charge reportedly lasted through the night. His battery stood at 18% when traffic cleared.

A Home Test Shows 75% Charge After 12 Hours of Idling

A clever writer at Inside Hook last week decided to conduct an experiment to explore the question of how well an EV would perform stuck in the cold for hours. Alex Lauer borrowed a Ford Mustang Mach-E for his test. He drove the car for a few miles, then got "stuck on the highway" in his driveway in 13-degree-Fahrenheit cold.

A Ford spokesperson suggested he rely on the heated steering wheel and seats for warmth. But Lauer wanted to "keep the cabin warm enough that even backseat passengers would be comfortable." So, he alternated "using only the footwell heating as well as the full-on blast from the footwell and dashboard vents, toggling between 70 and 75 degrees."

After 12 hours of idling, Lauer writes that the Mach-E retained 75% of its charge and 132 miles of range.

Norwegian YouTuber Bjorn Nyland performed a similar experiment with a Tesla Model 3 Performance model, running its heater for 72 hours in a Norwegian winter before the battery depleted.

RELATED STORIES: 5 Fastest-Charging Electric Cars

What It All Means



As America's automakers shift to mainly building electric cars, drivers will develop a new understanding of how these cars function. The assumptions we've all learned from years of driving gasoline-powered vehicles can keep us from understanding how electric vehicles work.

At first glance, it seems perfectly reasonable to think EVs stuck in traffic are running out of electricity the same way idling gasoline-powered cars are running out of gas. But they're not.

Running the heater in an internal combustion engine car requires running the entire engine. Each gasoline engine burns fuel at a different rate while idling, but there is no way to set an engine to use only as much fuel as necessary to run the heater.

An electric vehicle, it turns out, can do that. "Idling" in an EV means draining the battery extremely slowly, as only the heater uses electricity. An EV can stay warm with its motors off. That does gradually rob a car of range. But it does so so slowly that EVs stuck in Virginia's traffic nightmare seem to have made it through the 24-hour traffic jam with enough juice to get their drivers comfortably to a charging station.

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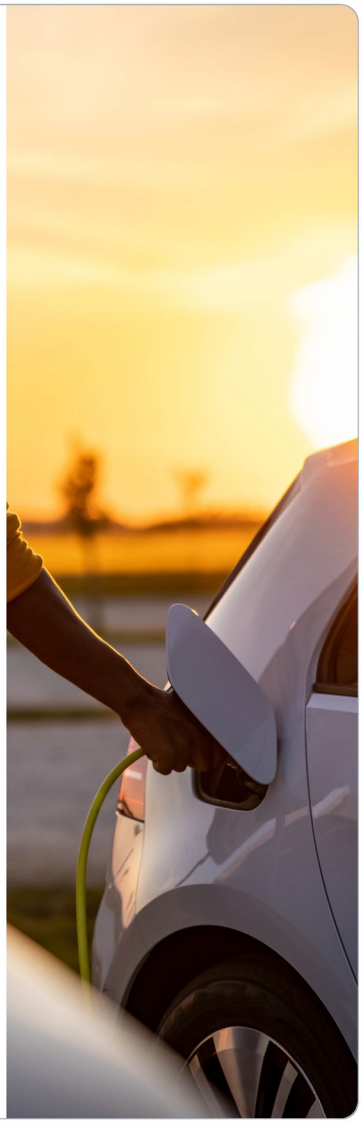
ALLIANCE
FOR AUTOMOTIVE
INNOVATION
VEHICLE GRID INTEGRATION
THE CONVERGENCE OF THE AUTOMOTIVE AND ELECTRIC POWER INDUSTRIES
JULY 2024

SUMMARY

The automotive and electric power industries are converging. Born in the late 1800s, the industry traveled separate paths and grew to vast scale by the end of the 20th century. Utilities bought cars and trucks to support their operations, and the auto industry purchased electricity to light offices and power factories. Today, automakers and their customers increasingly see electric utilities as the enabler of reliable and affordable mobility. In the 21st century, transportation electrification will be a significant driver of electric utilities' load growth.

The Alliance for Automotive Innovation (Auto Innovators) is committed to making electrified transportation a success for all EV drivers and for all utility customers. For EV drivers, success means no compromise mobility, enabled by convenient, reliable, and affordable charging that is coupled with opportunities to save on charging costs through EV-enabled grid services. For utility customers, success means that utilities serve EV charging load in a cost-effective manner that delivers economic and environmental benefits to all utility customers, supports utilities' efforts to modernize their systems, and takes advantage of technological advancements in the latest generation of EVs to enhance grid reliability and resilience.

To reach this future, our industries must successfully navigate the intersection of EVs and the grid. This White Paper focus on both economic and technological aspects of vehicle-grid integration (VGI). It highlights recent research and regulatory actions, identifies lessons learned and best practices from demonstrations and pilots, and recommends policies to achieve this win-win outcome. The intended audience is utilities, their regulators and governing boards, policymakers, and the broader community of transportation electrification stakeholders.



Rates and managed charging are the keys to capturing the benefits of EVs

EV rates and driver-centered managed charging programs are the keys to realizing the potential economic and environmental benefits of EV charging.

Well-designed residential tariffs and programs deliver cost-based incentives to use the grid efficiently, share savings with participating EV drivers, and do not compromise their mobility.

Getting Commercial and Industrial (C&I) rates right is also essential to attract investment to electrify fleets and build out the public high-power charging network needed for future light-, medium-, and heavy-duty fleets.



RECOMMENDATIONS

- *Utilities and regulators should adopt optional Commercial and Industrial EV rates that ensure commercial viability of fleet electrification and DCFC stations in the early stages of operation and in lightly trafficked areas, while fully recovering costs and preserving incentives for innovation.*
- *Utilities should make Time of Use (TOU) rates universally available to all EV drivers, and structure programs to ensure that suitable enabling technologies, such as smart charging, are available to all participants.*
- *Utilities should make both Whole-house and EV-only time varying rates available to their customers.*
- *Utilities should develop dynamic EV charging rates and include EVs in Demand Response (DR) Programs. These opportunities should be available to all EV drivers on an opt-in basis.*
- *EV Tariff and DR program rules should permit revenue stacking for multiple types of grid services that are mutually exclusive.*
- *Early-acting utilities should promptly scale up successful pilots to full-scale programs and pro-actively market them to maximize participation.*
- *Utilities in more nascent stages should build on the experience of early actors and draw on lessons learned to avoid repetitive pilots and to accelerate availability of mass market programs open to all EV drivers.*
- *Utilities should partner with OEMs to develop and implement marketing, education, and outreach to EV drivers about opportunities to provide valuable grid services and lower their electricity bills by participating in EV rates and DR programs.*

Technology and Standards

Innovation is rapidly transforming the ways EVs interact with the grid. Telematics capabilities in vehicles enable remote charge management as well as delivery of vehicle data that could be used for billing purposes. New standards and policies can help accelerate the use of telematics for these purposes.

EVs with bidirectional charging capabilities (V2X), such as the Ford F-150 Lightning and the Chevrolet Silverado RST pickup trucks, can power a home during an outage, or provide clean, quiet electricity at a campground or job site.

Fully commercializing bidirectional charging requires pricing, managed charging programs, and policies that support a sound business case for automakers to invest in it and install it on vehicles. Technical standards also ensure the safety of consumers and utility personnel, protect customers' privacy, and support cybersecurity efforts.







RECOMMENDATIONS

- *EV rates and DR programs should include options for EV drivers to participate by leveraging vehicle telematics to manage EV charging energy use. Utilities and regulators should draw upon the experiences of utilities across the country that have piloted telematics-based charge management for a variety of rates and programs.*
- *Utilities should move expeditiously to validate the accuracy of telematics data for calculating billing determinants, and demonstrations and pilots should be designed to support robust analysis that can be extrapolated to other utilities' service territories.*
- *Utilities and regulators involved in developing mobile submetering standards should coordinate to avoid duplicated effort and hasten development of a single approach that can be adopted nationwide.*
- *Utilities, Regional Transmission Operators, and regulators should adopt programs and policies that compensate EV drivers for exporting power to the grid.*
- *Utilities and their regulators should coordinate with other agencies to align incentives for drivers that provide other services to the public.*
- *Utilities and their regulators should adopt streamlined interconnection rules with and informed by learnings from other jurisdictions.*
- *Utilities and their regulators should build off successful V2X pilots and demonstrations and incorporate the efforts of the DOE's Vehicle to Everything Initiative to ensure that their efforts advance the electricity and auto industries' understanding of and ability to benefit from bidirectional charging.*
- *Utilities and their regulators should disseminate best practices, findings on benefits and value streams, and lessons learned about how to overcome barriers to V2X deployment.*

ALLIANCE FOR AUTOMOTIVE INNOVATION

INTRODUCTION

The automotive and electric power industries are converging. Born in the late 1800s, the industries traveled separate paths and grew to vast scale by the end of the 20th century. Utilities bought cars and trucks to support their operations, and the auto industry purchased electricity to light offices and power factories. Today, automakers and their customers increasingly see electric utilities as an enabler of reliable and affordable mobility. In the 21st century, transportation electrification will be a significant contributor to electric utilities' load growth. However, with proper planning and coordination, transportation electrification can be an asset to the grid.

The future of mobility is electric. Since 2017, automakers and their battery partners have committed to invest over $125 billion in the U.S. to electrify vehicles.[1] There are currently 113 electric vehicle (EV) models for sale at U.S. dealerships,[2] and that number is expected to exceed 150 in the next couple of years.[3] EV options exist in every class of light-duty vehicle, including pickup trucks, SUVs, and minivans. Electrified medium- and heavy-duty trucks, buses and off-road vehicles are also available, with more models coming soon.[4]

Figure 1: EV Market Share[5]

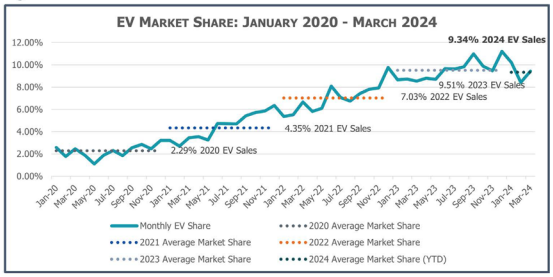
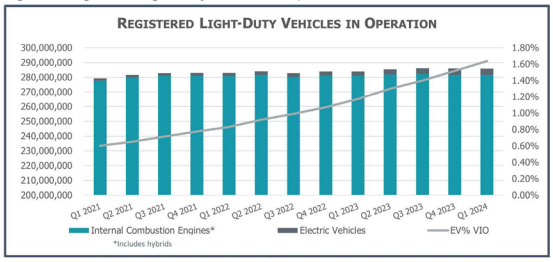


Figure 2: Registered Light-Duty Vehicles in Operation[6]



[1] https://www.autosinnovate.org/posts/communications/the-future-is-electric-infographic.pdf
[2] https://www.autosinnovate.org/posts/papers-reports/get-connected-q4-2023
[3] (2022) EVs, PHEVomes hitting U.S. dealerships through 2026 | Automotive News. Available at: https://www.autonewsh.com/future-product/evs-phevs-hitting-us-dealerships-through-2026 (Accessed: 10 June 2024).
[4] https://californiahvip.org/vehiclecatalog/
[5] https://www.autosinnovate.org/posts/papers-reports/get-connected-qt-2024. Note: EV market share includes hydrogen fuel cell electric vehicles, which do not depend on electricity from the grid
[6] https://www.autosinnovate.org/posts/papers-reports/get-connected-qt-2024. Note: EV market share includes hydrogen fuel cell electric vehicles, which do not depend on electricity from the grid.

ALLIANCE FOR AUTOMOTIVE INNOVATION

INTRODUCTION

Recent advancements in battery technology have enabled the latest EVs to offer 200-300 miles of range, some upwards of 400 miles. Some new EVs have bidirectional charging capabilities, which means that they can also discharge electricity to the grid, power a home during an outage, or provide clean and quiet electricity at a campground or job site.

The latest generation of EVs are also smart and connected. The systems of sensors, microprocessors, and communications capabilities commonly available on today's vehicles can enable an inexpensive means to manage charging. Once standards and policies are in place, the ability to send and receive data through a vehicle's telematics system could also provide a low-cost way to separately meter EV charging load.

These capabilities enable EV drivers to provide a variety of grid services that can improve reliability and resiliency, support integration of renewable energy, and lower the average cost of service—putting downward pressure on rates for all utility customers. The emissions reductions and consumer savings, including the total cost of ownership, are even greater when utilities successfully implement rates and programs that harness the flexibility of EV charging load at home or work.[7]

The Alliance for Automotive Innovation (Auto Innovators)[8] is committed to making electrified transportation a success for *all* EV drivers and for *all* utility customers. For EV drivers, success means *no compromise mobility*, enabled by convenient, reliable, and affordable charging that is coupled with opportunities to save on charging costs through EV-enabled grid services. For utility customers, success means that utilities serve EV charging load in a cost-effective manner that delivers economic and environmental benefits to all utility customers, supports utilities' efforts to modernize their systems, and takes advantage of technological advancements in the latest generation of EVs to enhance grid reliability and resilience.

To reach this future, our industries must successfully navigate the intersection of EVs and the grid. This white paper focuses on both economic and technological aspects of vehicle-grid integration (VGI). It highlights recent research and regulatory actions, identifies lessons learned and best practices from demonstrations and pilots, and recommends policies to achieve a variety of benefits. The intended audience is utilities, their regulators[9] and governing boards, policymakers, and the broader community of transportation electrification stakeholders.

The paper begins by discussing Commercial and Industrial (C&I) tariffs, considering how alternatives to conventional rate designs can support growth of the nascent DC Fast Charging (DCFC) industry and encourage fleet electrification, while recovering the cost of serving these loads. Next, it examines residential rates and managed charging programs, and outlines approaches that can reduce drivers' cost to charge their EVs and put downward pressure on the utilities' overall cost of service by providing incentives to charge when energy is less costly, or the local distribution grid is uncongested. It then considers ways to advance two technologies that offer tremendous potential to capture more savings and deliver additional grid services—vehicle telematics and bidirectional charging.

[7] The U.S. Department of Energy indicates that 80% of EV charging is done at home due to the convenience and low cost of residential charging (https://www.nrel.gov/docs/fy21osti/78540.pdf)
[8] From the manufacturers producing most vehicles sold in the U.S. to autonomous vehicle innovators to equipment suppliers, battery producers and semiconductor makers – Alliance for Automotive Innovation represents the full auto industry, a sector supporting 10 million American jobs and five percent of the economy. Active in Washington, D.C. and all 50 states, the association is committed to a cleaner, safer and smarter personal transportation future. www.autosinnovate.org.
[9] Throughout this paper we will use "Regulators" as shorthand for the many different types of bodies that oversee the nation's electricity suppliers.

ALLIANCE FOR AUTOMOTIVE INNOVATION

TARIFF DESIGN

Utility rate design can significantly impact the business case for fleet electrification and deployment of charging infrastructure, especially high-powered charging. In their first few years of operation, DCFC stations in high traffic areas may have "spikey" loads, with short bursts of high demand interspersed with idle intervals. While load is likely to level out as station utilization grows over time, this pattern may persist at less-traveled locations. Loads for fleets in the early stages of electrification may display similar patterns. In both cases, the demand charges commonly included in traditional C&I tariffs can account for a much larger portion of the customer's bill than energy charges, averaging out to a very high cost per kWh.[10] For fleet operators, this translates into an unfavorable Total Cost of Ownership (TCO) for EVs compared to conventional vehicles. For electric vehicle service providers (EVSPs), this means choosing between passing these costs on to their customers through high per-kWh prices for charging sessions, which creates uneconomical conditions at low traffic stations, or simply not operating in high-cost/low-traffic areas. These outcomes discourage EV adoption and can cause "charging deserts."

Several utilities have already developed alternative C&I tariff designs to tackle this problem.[11] In many other states, regulators and utilities are addressing this issue in response to the Infrastructure Investment and Jobs Act's requirement for them to consider tariff reforms that promote electrification.[12]

Table 1 provides several examples, including temporary demand charge holidays, preserving only the non-coincident demand charge, offsetting the demand charge with declining short-term subsidies, and replacing the demand charge with a kW-based subscription fee that gradually ratchets up as charging load grows at a site. Auto Innovators does not favor any one of these options over the others, but instead encourages utilities and regulators to look to these examples as potential templates for alternative C&I EV rates.

» RECOMMENDATION: *Utilities and regulators should adopt optional Commercial and Industrial (C&I) EV rates that ensure commercial viability of fleet electrification and DCFC stations in the early stages of operations and in lightly trafficked areas, while fully recovering costs and preserving incentives for innovation.*

Table 1: Examples of Alternatives to Conventional Commercial & Industrial Rates

Rate Design	Description	Utility	State
Fully Volumetric	Distribution charges recovered on a kWh basis, no demand charge	DTE	MI
Coincident Demand Charge	Based upon coincident, instead of more common, non-coincident demand	Versant	ME
Demand Charge Discount	Demand charge rebate 50% first two years, 25% next two years	PSE&G	NJ
Demand Charge Limiter	10 year declining demand charge limiter credit	Ameren	IL
Demand Charge Holiday	Demand charges waived for a specified period	SCE	CA
EV TOU + Subscription Rate	Demand charge holiday + monthly subscription charge	SDG&E	CA
EV TOU + Declining Block Rate	DCFCX - Declining block tiered structure with TOU	Tuscon Electric Power	AZ
EV TOU + Demand Charge Reduction	EV Rate "Business Electric Vehicle Charging Service"	Evergy Kansas	KS
EV TOU + Demand Charge Reduction + CPP	Demand charge reduction and critical peak pricing	Xcel CO	CO
Real Time Rate	Real time day ahead rate (available to all commercial customers)	Georgia Power	GA

Automated Load Management (ALM), the practice of balancing vehicle energy needs with site energy control and grid needs, can help improve the transportation electrification business case for fleets. In certain cases, ALM can reduce the capital costs associated with charging infrastructure installations and utility upgrades as well as the ongoing operational costs associated with charging the vehicles. As fleets' operating hours and flexibility vary widely, participating in ALM should be strictly voluntary.

[10] Fitzgerald, Garrett, and Chris Nelder. DCFC Rate Design Study. Rocky Mountain Institute, 2019 (Rev. Feb. 2020). Available at: http://www.rmi.org/insight/DCFC-rate-designstudy
[11] Fitzgerald, op. cit. and Ryan, N., et. al., Best Practices for Sustainable Commercial EV Rates and PURPA 111(d) Implementation, National Association of Regulatory Utility Commissioners Regulatory Training Initiative, Dec. 2022. Available at https://pubs.naruc.org/pub/55C47758-1866-DAAC-99FB-FFA9E6574C2B
[12] Infrastructure Investment and Jobs Act of 2021, Public Law 117-58, Section 40431, https://www.congress.gov/117/plaws/publ58/PLAW-117publ58.pdf.

ALLIANCE FOR AUTOMOTIVE INNOVATION

RESIDENTIAL EV RATES AND MANAGED CHARGING

Most EV drivers only need to charge their car for a few hours per day; if they can, they usually charge at home.[13] To maximize the economic and environmental benefits of electrifying personal transportation, utilities must focus on availability, awareness, and accessibility of EV rates and managed charging programs. Utilities should make available a variety of optional EV rates and programs. Effective marketing, education and outreach are crucial to ensure that EV drivers are aware of these opportunities and appreciate the potential bill savings. EV drivers also need inexpensive, hassle-free ways to access the cost savings afforded by these rates and programs.

A variety of EV rates and managed charging programs should be available to all drivers

All EV drivers should have the opportunity to leverage their charging flexibility to provide grid services and receive compensation. Flexibility can be monetized via targeted EV rates or Demand Response (DR) programs. Participation can be enabled with a variety of technologies, and control can be implemented by the customer directly or remotely by the utility, automaker, or a third-party aggregator.

Table 2: Examples of Residential EV Rates and Managed Charging Programs

State	Tariff/ Program Type	Example	Metering Method(s)
WHOLE HOUSE RATES			
MI	2-3 period TOU -- Whole House	DTE Time of Day Plan (D1.2) https://www.dtenergy.com/rates/residential/service-request/pe-ui/pes-res-rate-plans.html	Existing Meter
MI	Critical Peak Pricing w/ TOU	DTE Dynamic Peak Pricing Plan (D1.8) https://www.dtenergy.com/rates/residential/service-request/pe-ui/pes-res-rate-plans.html	Existing Meter
EV ONLY RATES (WITH SUBTRACTIVE BILLING)			
MI	2-3 period TOU -- EV Only	DTE EV Rate (D1.9) - requires separate utility meter https://www.dtenergy.com/rates/residential/service-request/pe-ui/pes-res-rate-plans.html	2nd Utility Meter
MD	2-3 period TOU -- EV Only	BG&E EVSmart (Uses networked L2 or telematics) https://www.bge.com/SmartEnergyRenovation/Technology/Pages/EVTOURate.aspx	Networked L2 Charger or Vehicle Telematics
CA	Dynamic Time Varying Rate	SCE Dynamic Rate Pilot https://www.sce.ca.com/Dynamic-rate-pilot/	Exisitng Meter
CA	Dynamic Time Varying Rate with Location Adder	SDG&E Power Your Drive https://www.sdge.com/residential/electric-vehicles/power-your-drive/power-your-drive-ev	2nd Utility Meter
MA	Demand Response: Off-Peak Charging Rebate custmer receives a payment for NOT charging during peak hours	National Grid Charge Smart MA https://www.nationalgridus.com/Charge-Smart-MA	Networked L2 Charger or Vehicle Telematics
NC	Subscription Rate: Unlimited charging up to a cap for a flat monthly fee with DR events	Duke EV Complete Home Charging Plan Pilot Program https://www.fleet.com/grid/duke	Vehicle Telematics

Time-of-use (TOU) rates are a foundational option. They are easy to understand, allow drivers to save money by shifting when they charge their EVs, and deliver a threshold level of benefits to the grid. Pilots have shown that EV drivers respond to TOU rates, especially when they have access to enabling technology.[14,15]

Technology can enable either "passive" or "active" charge management. With passive management, the customer adjusts the timing of charging in response to a price signal, perhaps using a timer built into the vehicle or charger. With active management, a third-party (i.e., utility, automaker, or aggregator) determines when charging occurs, usually subject to constraints and parameters set by the driver. Smart phone apps provided by automakers, utilities, and third parties increasingly offer drivers active charge management, making it easy for them to maximize bill savings without risking the possibility of an incomplete charge. Active charge management also helps minimize the risk of "timer peaks," which can occur when a population of EVs simultaneously start charging at the beginning of the off-peak or super off-peak period.

» RECOMMENDATION: *Utilities should make optional TOU rates universally available to all EV drivers and structure programs to ensure that suitable enabling technologies, such as timers and smartphone apps, are available to all participants.*

[13] Blair, Brittany, G. Fitzgerald and C. Dougherty, *The State of Managed Charging in 2021*, Smart Electric Power Alliance, Nov. 2021, p. 8
[14] Smart Electric Power Alliance, *Residential Electric Vehicle Rates that Work*, Nov. 2019.
[15] Cook, Jonathan, C. Churchwell and S. George, *Final Evaluation of San Diego Gas & Electric's Plug-in Electric Vehicle Pricing and Technology Study*, Nexant, Inc., Feb. 20, 2014.

ALLIANCE FOR AUTOMOTIVE INNOVATION

RESIDENTIAL EV RATES AND MANAGED CHARGING

Whether the rate or program applies only to an EV's charging load or to the entire load at the driver's home is a critical distinction. Separating out an EV's energy use on a driver's utility bill spotlights the savings that come from shifting charging. Since the public's perception of EVs and charging behavior are still in the formative stages, highlighting these benefits will be crucial in the near term. Available evidence suggests that TOU rates that apply only to the vehicle (EV-only) are more effective in shifting load than whole-house TOU rates.[16] As discussed below, the main barrier to widespread enrollment in EV-only rates is the cost and inconvenience of separately metering EV charging load for billing purposes.

» RECOMMENDATION: *Utilities should make both whole-house and EV-only TOU rates available to their customers.*

Over time, utilities can introduce more complex options that yield additional grid benefits and offer higher compensation for participating EV drivers. More sophisticated time varying rates and DR programs create value by shifting charging in response to day-to-day (and even hour-to-hour) fluctuations in electricity market and grid conditions.[17] These rates and programs are usually implemented via remote "active" charging. Utilities have piloted a variety of optional rates including day ahead, locational Real Time Pricing, Peak Time Rebates, and event-based DR programs.[18,19] Drivers participating in DR programs usually have the ability to opt-out of events. These rates and programs are not for everyone: they should be open to all EV drivers, but participation should be voluntary, and drivers should be allowed to opt-out of events.

» RECOMMENDATION: *Utilities should develop dynamic EV charging rates and include EVs in Demand Response (DR) programs. These opportunities should be available to all EV drivers on an opt-in basis.*

Some EV drivers may be able to provide multiple types of grid services that are mutually exclusive. Allowing these drivers to "stack" revenues can enhance the value proposition of EV ownership and augment savings in the utility's cost of service. For example, a driver taking service on an EV-only TOU rate could provide additional value and further lower their monthly electricity bill by also participating in a DR program that rewards them for not charging during periods when the local distribution grid is most stressed.[20] However, EV drivers may not be able to deliver and receive compensation for these services if overly restrictive tariff or program rules prohibit dual participation.

» RECOMMENDATION: *EV tariff and DR program rules should permit revenue stacking for multiple types of grid services that are mutually exclusive.*

[16] Compliance Filing of Southern California Edison Company (U 338-E), San Diego Gas & Electric Company (U 902 E), And Pacific Gas and Electric Company (U 93 E) Pursuant to Ordering Paragraph 2 of Decision 16-06-011, filed with the California Public Utilities Commission Docket No. R18-12-006, April 1, 2022.
[17] For examples see Energy + Environmental Economics, *Rate Designs Harnessing Vehicle Grid Integration Technology: Novel Rate Designs for Aggregator Enabled Smart Charging*, May 2021.
[18] Blair (2021), op. cit.
[19] Opinion Dynamics, *PG&E Electric Vehicle Automated Demand Response Study Report*, CALMAC Study ID PGE0469.01, Feb. 2022.
[20] This example assumes that peak load on the local distribution grid does not coincide with the systemwide peak, which would presumably be the basis for setting TOU periods.

ALLIANCE FOR AUTOMOTIVE INNOVATION

RESIDENTIAL EV RATES AND MANAGED CHARGING

Finally, promptly transitioning successful pilots to mass market programs is crucial to achieving cost-effective VGI as EV adoption accelerates. In one survey, most EV drivers reported that they are willing to participate in EV rates and/or managed charging programs.[21] Yet, only about 25% of residential customers had access to time varying EV rates as of 2019, and about a third of the available rates were still pilot programs. Most residential managed charging programs are classified as pilots, with enrollment capped at a few hundred or thousand EV drivers.[22] New York is an important exception: in 2020, the New York Public Service Commission (PSC) ordered the state's utilities to scale up successful pilots and recently issued an order approving their proposed mass market programs.[23] Outside of New York, the majority of EV drivers have little or no opportunity to receive compensation for shifting charging to low-cost hours and ratepayers lose out on the associated cost savings. The opportunity to shape consumers' expectations and behavior around charging is also lost at this early stage of EV adoption.

- RECOMMENDATION: *Early-acting utilities should promptly scale up successful pilots to full-scale programs and proactively market them to maximize participation.*
- RECOMMENDATION: *Utilities in more nascent stages should build on the experience of early actors and draw on lessons learned to avoid repetitive pilots and to accelerate availability of mass market programs open to all EV drivers.*

Effective marketing programs are needed to make drivers aware of opportunities

EV drivers must be aware of opportunities to save money though EV rates and DR programs to benefit from them. Even in states with the highest EV adoption, awareness is currently low. For example, a survey of Northern California EV owners found that only 24% of EV drivers and just 30% of drivers with networked Level 2 chargers were aware of DR programs or of their benefits.[24] A survey of utilities found that availability of a marketing budget, free enrollment (e.g. no 2nd meter), and having multiple utility and non-utility marketing channels can boost enrollment.[25] As trusted mobility providers, automakers can help market VGI rates and programs to their customers.[26]

- RECOMMENDATION: *Utilities should partner with automakers to develop and implement marketing, education, and outreach to EV drivers about opportunities to provide valuable grid services and lower their electricity bills by participating in EV rates and DR programs.*

EV drivers also need low-cost, hassle-free ways to access EV-only rates and DR programs

To participate in an EV-only tariff or DR program, drivers must be able to separate their charging load from their overall electricity use. A recent survey of Investor-Owned Utility's (IOU) EV rates found that about half of the residential EV tariffs identified required some form of dedicated metering for the vehicle.[27] Until very recently, the only authorized way to isolate EV charging load was by installing and, in some cases, purchasing a second revenue grade meter dedicated to the vehicle. This is both expensive and inconvenient, deterring drivers from opting in to EV only rates.[28] In 2022, the California Public Utility Commission approved a submetering protocol that permits data from qualifying networked Level 2 chargers to be used for billing purposes.[29] Although an improvement on the status quo, this approach still requires drivers to install a costly charger that many find unnecessary to meet their needs. The following section outlines steps to overcome this barrier.

[21] SEPA (2019), pp. 18-20 and 22-23; Opinion Dynamics (2022) pp. 25 ff.
[22] Opinion Dynamics (2022), pp. 69-74.
[23] State of New York Public Service Commission, Order Approving Managed Charging Programs with Modifications," Case 18-E-0138, July 14, 2022.
[24] Opinion Dynamics, pp 54-56.
[25] SEPA (2019) p.26-28.
[26] SEPA (2023), *Managed Charging Programs: Maximizing Customer Satisfaction and Grid Benefits.*
[27] P. Cappers, et. al., April 2023, *A Snapshot of Rate Designs Among U.S. Investor-Owned Utilities*, available at https://eta-publications.lbl.gov/sites/default/files/ev_rate_snapshot_report-final-20230424.pdf.
[28] SEPA (2019), pp. 16 and 28-29.
[29] See "Decision Adopting Plug-In Electric Vehicle Submetering Protocol and Electric Vehicle Supply Equipment Communication Protocols" (D.22-08-024), available at: https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-decision-makes-california-first-state-in-the-nation-to-allow-submetering-of-electric-vehicles.

ALLIANCE FOR AUTOMOTIVE INNOVATION

VEHICLE TELEMATICS

Innovation is rapidly transforming the ways EVs interact with the grid. Telematics capabilities in vehicles enable remote charge management as well as delivery of vehicle data that could be used for billing purposes. New standards and policies can help accelerate the use of telematics for these purposes.

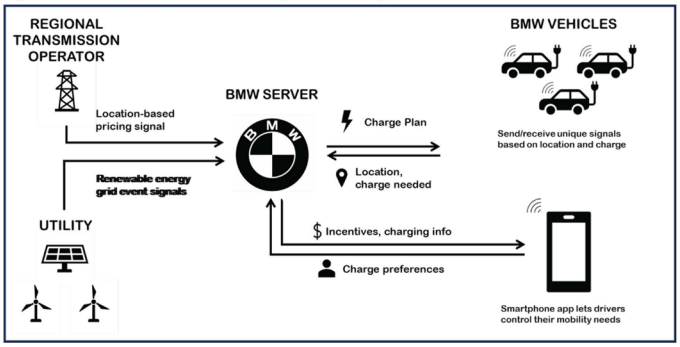
Using telematics data enhances the value proposition of managed charging

The term telematics refers to the integrated use of two technologies—telecommunications and informatics (or computing). Today, most new light-duty vehicles are equipped with a host of sensors and microprocessors, Wi-Fi, and - in some cases - GPS capability. Like stationary chargers, telematics-based systems can monitor the rate of charge (kW) and total energy dispensed (kWh) in a charging session. For over 25 years, automakers have used telematics systems to offer optional features such as navigation, remote diagnostics, and roadside assistance. Examples include GM's OnStar®, Ford's SYNC®, and BMW's ConnectedDrive® systems.

Telematics systems are already ubiquitous in commercial fleets, which combine them with enterprise fleet management systems to optimize operations, monitor vehicles' health and ensure timely maintenance. As they electrify their fleets, operators are also using telematics data to manage charging to lower their electricity bills and provide grid services, optimize use and deployment of charging infrastructure, and defer the need for on-site electrical and grid upgrades.

Telematics-based managed charging programs integrate vehicle and utility data to optimize the timing of charging, thereby enhancing the value of an EV as a grid resource. Utility rate tariffs and program guidelines inform charging schedules set via a smart phone app that does not require a Wi-Fi network connection. By factoring the state of charge into the optimization algorithm, telematics-based managed charging systems can determine how long it will take to replenish the battery and therefore how much latitude there is to modulate charging to shift load and provide grid services. Figure 3 shows how these data are used to develop a charge plan in BMW's ChargeForward Program (discussed further below).

Figure 3: Information Flows in BMW's ChargeForward Program[30]



[30] Source: https://www.bmwchargeforward.com/assets/BMW-ChargeForward-Report-667376fa.pdf

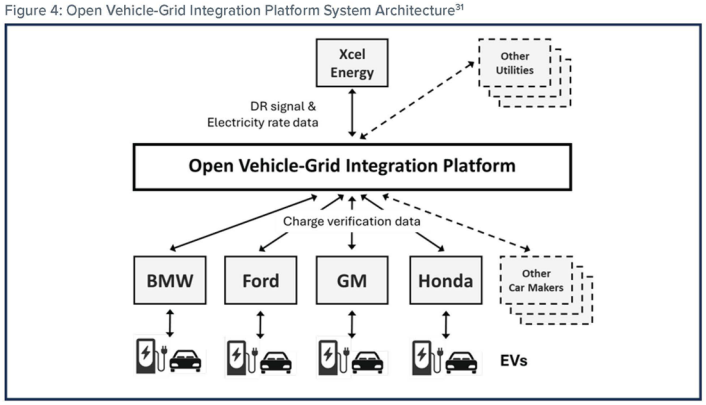
ALLIANCE FOR AUTOMOTIVE INNOVATION

VEHICLE TELEMATICS

Managed charging aggregators are essential partners

Automakers are exploring go-to-market approaches with utilities to efficiently utilize vehicle telematics for VGI pilots and programs. To facilitate vehicle-to-utility communications, aggregators must be employed to bridge the gap of communication between utilities and vehicles from different automakers. These software platforms solve the "many-to-many" problem, making it possible for multiple automakers' vehicles to exchange data with an individual utility, for a single automaker's vehicle to communicate with multiple utilities, or both. One approach to aggregation is the Open Vehicle-Grid Integration Platform (OVGIP). Developed by a consortium of automakers, OVGIP supports management and monitoring of vehicle charging using telematics data (Figure 4). In addition to OVGIP, companies like WeaveGrid and EnergyHub also support the management and monitoring of vehicle charging, and have partnered with automakers like Toyota, Hyundai and KIA.

Figure 4: Open Vehicle-Grid Integration Platform System Architecture[31]



Aggregators,[32] whether third-parties or operated by the automakers themselves, should be included in program development, especially with respect to compensation design. Aggregators should be seen as strong allies, given their ability to enable customer enrollment. This is especially true for bidirectional vehicle programs because business models for bidirectional charging are still in the early stages of development. As discussed in the next section, it is imperative to include strong earning opportunities for aggregators to develop enabling solutions and an attractive value proposition for customers to encourage their enrollment. Today, many customers are unable to participate in programs, such as the Pacific Gas and Electric (PG&E) V2X Pilot, without an aggregator.[33] In the future, programs without proper consideration for the aggregators' roles will likely be passed over in favor of those that are well-designed.

[31] Source: https://sumitomoelectric.com/press/2021/12/prs111
[32] An aggregator can be a company that works with utilities on the behalf of a group of automakers.
[33] https://www.pge.com/en/clean-energy/electric-vehicles/getting-started-with-electric-vehicles/vehicle-to-everything-v2x-pilot-programs.html#tabs-b0ada91e14-item-0334db-

ALLIANCE FOR AUTOMOTIVE INNOVATION

VEHICLE TELEMATICS

VGI pilots are demonstrating the value of telematics-based managed charging

Utilities across the country have conducted pilots of various managed charging programs that use telematics data and systems. Xcel Energy, Duke Energy, and several other utilities are piloting programs that employ the OVGIP. In California, BMW and PG&E's ChargeForward pilot demonstrated the use of telematics to schedule vehicle charging sessions to support grid reliability and prioritize charging with renewable energy.[34] Drivers specify their charging preferences (e.g., least cost, lowest emissions) and planned departure time in a smartphone app, and the system schedules charging. In select territories across the U.S., Toyota has partnered with WeaveGrid and EnergyHub to enable real-time data and grid services for utilities by utilizing relevant software platforms for actionable load management.[35,36]

In some of these pilots and programs, telematics data flowing from the EV to the utility through automaker servers, and/or the OVGIP platform, are also used to meter the EVs' electricity use, eliminating the need for a costly second utility meter. Several utilities, including National Grid,[37] ConEd,[38] and DTE,[39] are already using telematics-based systems to implement incentive programs to encourage drivers to charge outside of peak hours and verify eligibility for incentive payments. The next step is to develop the rules, standards, and policies to use more granular telematics data to measure billing determinants.

- RECOMMENDATION: *EV rates and DR programs should include options for EV drivers to participate by leveraging vehicle telematics to manage EV charging energy use. Utilities and regulators should draw upon the experiences of utilities across the country that have piloted telematics-based charge management to implement a variety of rates and programs.*
- RECOMMENDATION: *Utilities should move expeditiously to validate the accuracy of telematics data for calculating billing determinants, and demonstrations and pilots should be designed to support robust analysis that can be extrapolated to other utilities' service territories.*
- RECOMMENDATION: *Utilities and regulators involved in developing mobile submetering standards should coordinate development of mobile submetering standards to avoid duplicative efforts and hasten development of a single approach that can be adopted nationwide.*

[34] Lipman, Timothy, Alissa Harrington, and Adam Langton, Total Charge Management of Electric Vehicles, California Energy Commission, Dec. 2021. Available at: https://www.energy.ca.gov/sites/default/files/2021-12/CEC-500-2021-055.pdf
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[36] Press release of EnergyHub and Toyota released on March 6, 2024, available at: https://www.energyhub.com/blog/energyhub-and-toyota-collaborate-to-support-the-electrical-grid-and-improve-ev-ownership-experience/
[37] https://www.nationalgridus.com/News/National-Grid-Launches-Off-Peak-Electric-Vehicle-Charging-Program-for-Massachusetts-Customers/
[38] https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-residential-customers/electric-vehicle-rewards
[39] DTE Press Release, "BMW joins Ford, GM in DTE Energy's Smart Charge Program, integrating electric vehicle charging with their net zero carbon emissions goals," May 9, 2022. Available at: https://ir.dteenergy.com/news/press-release-details/2022/BMW-joins-Ford-GM-in-DTE-Energys-Smart-Charge-Program-integrating-electric-vehicle-charging-with-their-net-zero-carbon-emissions-goals/default.aspx

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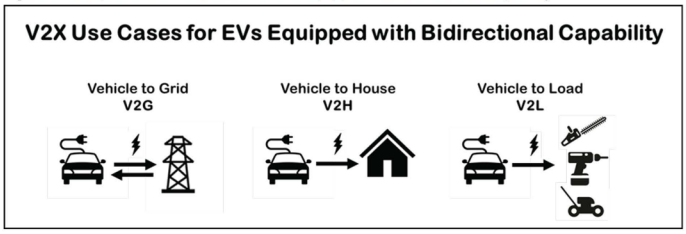
BIDIRECTIONAL CHARGING TECHNOLOGY

Many of the new EV models arriving on the market will be capable of bidirectional charging, commonly referred to as vehicle-to-everything (V2X). Examples of bidirectionally-equipped EVs that are available today include the Ford F-150 Lightning and the Chevrolet Silverado RST pickup trucks. These EVs can discharge their battery directly to the grid (V2G), a house (V2H) or equipment (V2L), providing many types of services to the grid, the public and drivers (See Figure 5). The range, scale, and value of the services bidirectionally-capable EVs can deliver will grow as battery storage capacity continues to increase. Fully commercializing bidirectional charging technology requires pricing, managed charging programs, and policies that support a sound business case for automakers to invest in developing it and installing it on vehicles. Technical standards are also needed to ensure the safety of consumers and utility personnel.

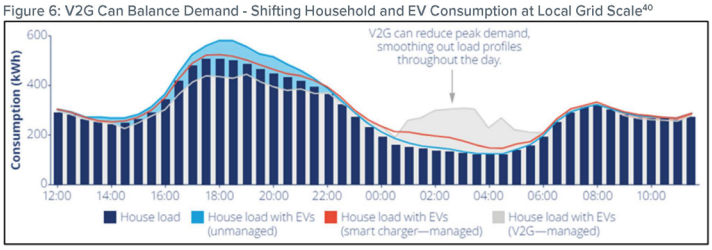
Figure 5: Examples of V2X Use Cases for EVs Equipped with Bidirectional Capability



Bidirectional EVs can provide a range of services to drivers, the public and the grid

Bidirectional EVs effectively function as mobile batteries that can provide many of the same services as a stationary battery, including frequency regulation, spinning reserves, and load shifting. Their ability to charge and discharge multiple times while plugged in significantly augments their value relative to standard EVs (See Figure 6). They can also travel to sites where electricity is most needed. In an electrical outage or other emergency, a bidirectional EV could power a home, an emergency shelter, a hospital, or another critical facility for several hours, reducing the need for alternative power sources, such as expensive diesel generators. Similarly, they can provide clean, quiet power at campgrounds, parks, and job sites.

Figure 6: V2G Can Balance Demand - Shifting Household and EV Consumption at Local Grid Scale[40]



[40] Reproduced from Cutler, Harry, Ted Davidovich, Erika H. Meyers, A Regulatory Roadmap for Vehicle-Grid Integration, Smart Electric Power Alliance, Dec. 2020. Available at: https://sepa-power.org/knowledge

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BIDIRECTIONAL CHARGING TECHNOLOGY

Across the country, V2X pilots and demonstrations are proving out the benefits of V2X technology.[41] Many focus on school buses, which offer a unique use case because they have big batteries and are typically idle during the summer and daytime hours when demand peaks in many utilities' service territories.[42] Fleets of light-duty vehicles with regular routes and predictable schedules can also function in similar fashion. In a pilot project at the Los Angeles Air Force Base, a fleet of 29 electric vans, trucks, and cars delivered frequency regulation services to the California Independent Systems Operator's wholesale electricity market.[43] New York ridesharing operator Revel is currently collaborating with Consolidated Edison and aggregator Fermata to assess the tradeoffs between earning revenue from ridesharing operations versus parking fleet vehicles to earn revenue by providing grid services during peak hours. Revel expects to earn approximately $10,000 a year from three bidirectionally-equipped Nissan Leaf vehicles enrolled in the utility's Value of Distributed Energy Resources (VDER) tariff.[44] In Florida, Duke Energy is exploring the viability of using the batteries in Ford's F-150 Lightning pickup truck for a variety of residential use cases, including how the vehicle interacts with rooftop photovoltaic solar and customer home batteries, how the truck's battery performs in powering homes during an outage, how the electric pickup trucks will be used to feed the grid during peak times of use, and how these uses might impact the trucks' batteries over a longer period of time.[45]

» RECOMMENDATION: *Utilities and their regulators should disseminate best practices, findings on benefits and value streams, and lessons learned about how to overcome barriers to V2X deployment.*

Appropriate incentives are needed to capture the value of V2X technology

Adding V2G capability to an EV is costly. Automakers need to see sufficient consumer demand before making the option widely available. Drivers and fleet operators, in turn, need ways to monetize bidirectional services to justify the added expense. Offering cost-based incentives will enhance V2X's value proposition, promoting adoption of bidirectionally-equipped EVs. For example, in 2022, California regulators approved PG&E's first-in-the nation V2G export rate for commercial EV fleets and chargers. The three-year pilot will offer upfront incentives to defray equipment costs and employ day-ahead hourly pricing to encourage discharging during times of peak demand and for backup power during outages.[46]

Successful commercialization of V2X technology requires action at both the state and federal level. Utilities and their regulators are well positioned to make significant contributions toward this end.[47]

» RECOMMENDATION: *Utilities, Regional Transmission Operators (RTOs), and regulators should adopt programs and policies that compensate EV drivers for exporting power to the grid.*

» RECOMMENDATION: *Utilities and their regulators should coordinate with other agencies to align incentives for drivers that provide other charging-enabled services to the public.*

[41] B. Blair, et. al., *The State of Bidirectional Charging in 2023*, Smart Electric Power Alliance (SEPA), Sept. 2023. Retrieved from https://sepapower.org/resource/the-state-of-bidirectional-charging-in-2023/.
[42] SAFE, Op.cit. pp. 17-18
[43] D. Black, et.al, *Final Project Report: Los Angeles Air Force Base Vehicle-to-Grid Demonstration*, California Energy Commission Alternative and Renewable Fuel and Vehicle Technology Program, 2018. Available at: https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2018-025.pdf
[44] B. Blair, et al, Sept. 2023, *Case Study: Revel Rideshare Commercial Fleet V2G & Demand Response*, Smart Electric Power Alliance (SEPA). Retrieved from: https://sepapower.org/resource/the-state-of-bidirectional-charging-in-2023/.
[45] https://news.duke-energy.com/releases/electrifying-the-future-duke-energy-to-explore-how-ford-f-150-lightning-all-electric-trucks-can-serve-as-a-grid-resource-in-florida
[46] https://www.utilitydive.com/news/pge-launches-dynamic-export-rate-for-commercial-electric-vehicle-fleets/635622/
[47] The discussion and recommendations in this section draw upon *Advancing Vehicle to Grid Technology Adoption*, SAFE and the Electrification Coalition, June 2022. Retrieved at https://2uj256fs8px404p3p2l7nvkd-wpengine.netdna-ssl.com/wp-content/uploads/2022/06/Advancing-Vehicle-to-Grid-Technology-Adoption.pdf

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BIDIRECTIONAL CHARGING TECHNOLOGY

Technical standards for V2X should be developed and adopted nationwide

Safety is a paramount consideration whenever a distributed energy resource injects energy into the grid or powers a building or piece of equipment. Interconnection processes and associated technical standards are needed to protect utility personnel, customers, and the public. Fortunately, it is not necessary to start from square one since V2X systems can usually fit within existing interconnection processes. For example, islanded systems (V2H, V2L) can fit into processes for back-up generators, and V2G systems can fit into processes for exporting stationary energy storage systems.[48]

V2X demonstrations have provided a venue to develop the necessary interconnection rules and underlying technical standards. Under the auspices of the California Public Utilities Commission, automotive and utility engineers are working together to streamline interconnection processes, identify the need for new standards, and develop them. As both on- and off-board equipment are required to implement V2X use cases, a combination of standards from multiple bodies is required. These include the Society of Automotive Engineers (SAE), Institute of Electrical and Electronics Engineers (IEEE), and International Standards Organization (ISO). Other states should build on this initiative's successes to expand opportunities for V2X.

The U.S. Department of Energy (DOE) has also created a national forum, the Vehicle to Everything Initiative, to coordinate research and development on V2G technologies and disseminate findings. This effort between utilities, automakers, regulators, labor, technology companies, and national laboratories provides a platform for collaboration, innovation, and workforce development.[49] It will also serve as a resource for utilities and regulators as they develop pilots, tariffs, interconnection rules, and policies to capture the benefits of V2G technology.

- RECOMMENDATION: *Utilities and their regulators should adopt streamlined interconnection rules consistent with and informed by learnings from other jurisdictions.*
- RECOMMENDATION: *Utilities and their regulators should build off successful V2X pilots and demonstrations and incorporate the efforts of DOE's Vehicle to Everything Initiative to ensure that their efforts advance the electric utility and auto industries' understanding of and ability to benefit from bidirectional charging.*

[48] For additional recommendations see Vehicle Grid Integration Council, *V2X Bidirectional Charging Systems: Best Practices for Service Connection or Interconnection*, August 2022. Available at: https://static1.squarespace.com/static/5dcde7af8ed96b403d8aeb70/t/62fd4c3cfc19490ee68d71eb/1660767294489/VGIC-Special-Initiative-2022.pdf.
[49] https://www.energy.gov/technologytransitions/articles/department-energy-announces-first-its-kind-collaboration-accelerate

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CONCLUSION

The auto industry is supportive of expanding vehicle electrification. Automakers are producing the electric cars and trucks of the future today. They need the utility industry's full support to ensure that EV drivers can count on no-compromise mobility. The auto industry is committed to partnering with regulators, governing boards, utilities, retailers, Regional Transmission Organizations, and stakeholders to craft workable, cost-effective, win-win solutions that drive EV adoption and benefit all utility customers.



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How Innovative Is China in the Electric Vehicle and Battery Industries?

STEPHEN EZELL I JULY 2024

China is at the global forefront of the electric vehicle (EV) and EV battery industries. Its firms produce nearly two-thirds of the world's EVs and more than three-quarters of EV batteries. They also have produced notable innovations in EV products, processes, and customer experiences.

KEY TAKEAWAYS

- Chinese automakers produce 21 percent of the world's passenger vehicles—a figure analysts estimate will reach 33 percent by 2030—and as of 2022 they produced 62 percent of the world's EVs and 77 percent of EV batteries.
- From 2020 to 2023, China's global EV exports increased by 851 percent, with the largest share of those exports (nearly 40 percent) going to Europe.
- Collectively, Chinese EV and EV battery enterprises have at least equaled—and in some cases surpassed—their Western peers in innovation capacity and product quality.
- Chinese EV companies are 30 percent faster in developing and releasing new car models than are so-called "legacy" American, European, and Japanese carmakers.
- Chinese institutions today account for 65.4 percent of the high-impact research publications in electric batteries, substantially outpacing U.S. institutions' 11.9 percent.
- Chinese entities' global share of patents in the field of electric propulsion increased from 2.4 percent in 2010 to 26.9 percent in 2020.
- China's EV and battery manufacturers have benefitted from a range of innovation mercantilist policies, including over $230 billion in subsidies from 2009 to 2023, plus local content requirements, intellectual property (IP) theft, and forced tech transfers.
- America's long-term response to China's dominance in EVs should include investing in R&D to accelerate technological innovation, stimulating consumer adoption of EVs (e.g., by deploying charging infrastructure), and defensive trade measures.

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INTRODUCTION

In 1985, Chinese enterprises manufactured a grand total of 5,200 passenger vehicles.[1] In 2024, they will manufacture a total of 26.8 million—21 percent of global production—a share automotive analysts expect will reach one-third by 2030.[2] The now more than 200 EV manufacturers operating in China will produce an estimated 10 million EV units in 2024, up from 8.9 million vehicles in 2023. In 2022, China accounted for 62 percent of global EV production (though this figure also counts Western manufacturers operating in China, such as Tesla) and 59 percent of global EV sales.[3] Similarly, China's battery manufacturing capacity in 2022 stood at 0.9 terawatt hours, roughly 77 percent of the global share.[4] China's two largest EV battery producers—CATL and FDB—alone account for over one-half of global EV battery production and in total, Chinese manufacturers produce 75 percent of the world's lithium-ion batteries.

As *The Wall Street Journal's* Greg Ip wrote, China's global lead in EVs stems from "a unique combination of industrial policy, protectionism, and homegrown competitive dynamism."[5] Indeed, there's no doubt China's EV industry has benefited greatly from aggressive industrial policy, spearheaded in particular by China's lavish expenditure of over $230 billion in subsidies to the sector from 2009 to 2023, principally in the form of buyers' rebates and sales tax exemptions.[6] China's EV and EV battery companies have also benefitted from other "innovation mercantilist" policies including local content requirements, forced technology transfer, and state-blessed IP theft. Yet, they have also benefitted from less injurious (to foreign competitors) forms of government support, including world-leading levels of public research and development (R&D) investment in EVs, proactive government procurement policies, aggressive deployment of electric charging infrastructure, and consumer incentives to purchase EVs (such as free vehicle licenses or exemptions from roadway restrictions).

The Chinese government—at both the federal and provincial levels—has made EV competitiveness a national priority. It's important to note that China's drive toward EVs stems from a recognition made in the mid-2000s that Chinese enterprises were unlikely to become globally competitive in the dominant technological paradigm of internal combustion engines (ICE) at the time (despite aggressive technology transfer requirements) and so China's leaders identified EVs as a breakthrough, or "leapfrog," technology that could at once enable China to develop a globally competitive domestic industry while breaking the country's dependence on foreign automotive technologies—and, crucially, the imports of ICE automobiles (and their oil) that this entailed. As one industry observer explained, "The primary motivation for China to push for EVs was energy security. Second was industrial competitiveness, and a far distant third was sustainability."[7] Today, China's push toward leadership in EVs—just as for artificial intelligence (AI), aerospace, biotechnology, nuclear power, semiconductors, high-speed rail, or any another advanced technology—should be construed as an effort to accumulate and extend its national power.

But while China's EV industry has certainly benefitted from intense government support, Chinese EV and EV battery enterprises have become increasingly innovative in their own right across a number of dimensions of product innovation, process innovation, business model innovation, and even customer experience innovation. In EV batteries, Chinese enterprises have made important breakthroughs in battery chemistry, with some Chinese EV battery start-ups now working to develop EV batteries they assert will have a 2,000 kilometer (km) (1,300 miles) range. With the

battery accounting for as much as 40 percent of the value of an EV, the country's dominance in EV battery production gives its EV manufacturers an important first-mover advantage.

Moreover, Chinese enterprises are leading in other aspects of vehicle technology, from innovative vehicle suspension systems to the incorporation of a range of novel digital features; from autonomous driving, interactive voice control to multiple touch screens that enable everything from watching movies to singing karaoke. Chinese firms are also aggressively innovating vehicle production processes, from robotic automation to digital production systems (i.e., digitalized manufacturing execution systems) to innovative aluminum diecasting processes. Chinese EV manufacturers are also accelerating the pace of product innovation. One assessment finds that Chinese EV companies are 30 percent faster in developing and releasing a new car model than "legacy" American, European, and Japanese carmakers are. In short, the quality and innovativeness of EVs from leading Chinese manufacturers such as BYD, Li Auto, Xiaomi, and others increasingly rival or exceed offerings from Tesla or BMW.

Chinese EV enterprises are backed by an increasingly capable support ecosystem, including everything from the quality of the R&D conducted at Chinese universities and research institutions to a deep local supplier base. In particular, the number and quality of Chinese scientific publications pertaining to EVs and EV batteries has increased markedly in recent years. For instance, the Australian Strategic Policy Institute (ASPI) found that Chinese institutions account for 65.4 percent of the high-impact publications for electric batteries, substantially outpacing the United States' 11.9 percent. And, as ASPI wrote, "The Chinese Academy of Sciences is a stand-out performer in the *Critical Technology Tracker* datasets. It leads in six of the eight energy and environment technologies [and is] no. 1 globally for electric batteries."[8] Meanwhile, Chinese entities' global share of patents in the field of electric propulsion increased 11-fold from 2.4 percent in 2010 to 26.9 percent in 2020.

The quality and innovativeness of EVs from leading Chinese manufacturers such as BYD, Li Auto, Xiaomi, and others increasingly rival or exceed offerings from Tesla or BMW.

China's EV makers have undeniably become critical global players in the sector, and certainly a long-term threat to once-dominant Organization for Economic Cooperation and Development (OECD) nation auto manufacturers. In response to this threat (in no small part a result of China's industrial subsidies), the United States has introduced tariffs of 100 percent on Chinese EVs and the European Union has established tariffs of up to 38 percent. While that's a stopgap to prevent what the Alliance for Automotive Manufacturing referred to as a potential "extinction-level event" (should Chinese EV companies come to significantly penetrate the U.S. vehicle market), market limitations alone will not be fully effective.[9] Rather, the leading OECD nations will need to double down on genuine technological innovation. Here, policymakers should support the sector with robust R&D funding, R&D programs such as a "BatteryShot" initiative that could help produce EV batteries with longer range and better price performance, and supportive policies to stimulate consumer adoption, such as the deployment of a nationwide EV charging infrastructure. Moreover, policymakers must recognize that green technologies such as EVs will only become attractive to American buyers once they reach price/performance parity (P3) with existing technologies, meaning that for a given level of performance, a green technology has reached price parity with an existing dirty technology without subsidies or taxes on the latter.

BACKGROUND AND METHODOLOGY

The common narrative is that China is a copier and the United States is an innovator. That narrative often supports a lackadaisical attitude toward U.S. technology and industrial policy. After all, America leads in innovation, so there is nothing to worry about. First, this assumption is misguided because innovators can lose leadership to copiers with lower cost structures, as has been the case in many U.S. industries, including consumer electronics, semiconductors, solar panels, telecom equipment, and machine tools.[10] Second, it's not clear that China is a sluggish copier and always destined to be a follower.

To assess how innovative Chinese enterprises and industries are, the Smith Richardson Foundation provided support to the Information Technology and Innovation Foundation (ITIF) to research the question. As part of this research, ITIF is focusing on particular sectors, including EVs and their batteries.

To be sure, it is difficult to assess the innovation capabilities of any country's industries, but it is especially difficult for Chinese industries. In part, this is because, under President Xi Jinping, China discloses much less information to the world than it used to, especially about its industrial and technological capabilities. Notwithstanding this, ITIF relied on three methods to assess Chinese innovation in EVs and EV batteries. First, we conducted in-depth case study evaluations of two Chinese EV companies randomly selected from EV companies listed on the "2023 EU Industrial R&D Investment Scoreboard." Second, we conducted interviews and held a focus group roundtable with global experts (to whom we offered anonymous participation) on the Chinese EV industry. And third, we assessed global data on EV innovation, including scientific articles and patents.

IMPORTANCE OF EVS AND EV BATTERIES AND THE U.S. ROLE

Concerns over climate change have prompted governments to start focusing on finding alternative sources of energy. As such, EVs, and the battery technologies associated with them, have gained an increasing importance in recent years. In an effort to reduce greenhouse gas (GHG) emissions, governments have adopted various strategies to spur investment in and adoption of EVs. For instance, between the 2021 Infrastructure Investment and Jobs Act and the subsequent Inflation Reduction Act, the U.S. Congress has allocated over $245 billion in public expenditures toward supporting EV development and adoption.[11]

Despite their increasing popularity, EVs have existed longer than most appreciate. U.S. inventor William Morrison invented the first operational EV in 1890.[12] More current interest arguably started in the 1970s, when the rise in oil prices and attendant gas shortages sparked an interest in alternative energy sources. This motivated Congress to pass the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976.[13]

Lithium iron phosphate (LFP) battery technology originated in the United States (particularly important breakthroughs were made at the University of Texas in 1996), but, as one observer argued, "U.S. companies abandoned it for lack of a near-term payback."[14] Instead, the technology was initially commercialized in Japan in the 1990s and was long dominated by Japanese and South Korean manufacturers.[15] However, LFP battery technology has been refined and improved over the past two decades by several Chinese companies, notably CATL, FDB, and BYD.

Tesla has become an important American innovator of EV and EV battery technology, while others such as Rivian and Lucid Technology have stepped into the game, along with traditional manufacturers such as Ford and General Motors (GM). GM, which in 2010 introduced the Volt EV as a response to Toyota's Prius, promised in 2021 to produce only EVs by 2035, although GM CEO Mary Barra backtracked on this in January 2024 by saying GM's product introductions henceforth "will be guided by customer demand," and that it would reintroduce a gasoline-electric car with a plug.[16] From 2018 to 2023, 4.1 million EVs were manufactured in the United States, making America the world's third-largest EV manufacturer (after China and Germany) and giving the United States a 16 percent global share (among the top-six EV-producing nations) of EV production over that timeframe.[17] While the United States has fallen off the global lead in EV battery production, several innovative start-ups including QuantumScape, Factorial Energy, and Solid Power are now trying to develop a next generation of so-called "all-solid-state batteries" (ASSBs) that would reestablish an American foothold in the field (while foreign firms such as Korea's LG and SK have recently expanded their EV battery manufacturing operations in the United States).

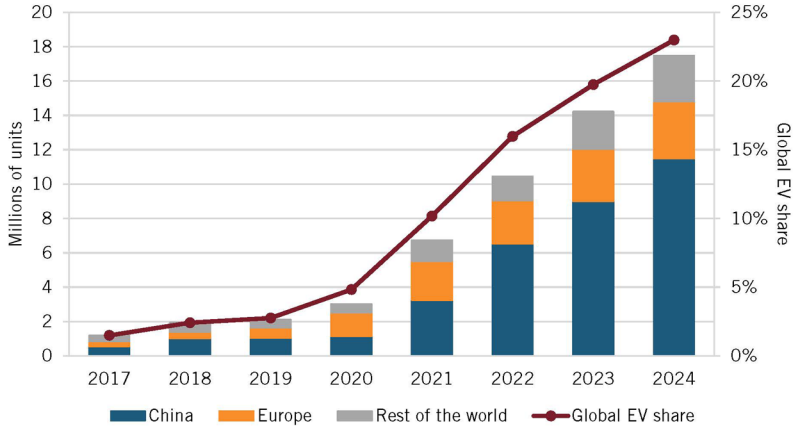
Lastly, it's imperative to note that a healthy automotive sector is critical to the U.S. economy. The sector has historically contributed from 3 to 3.5 percent of overall U.S. gross domestic product (GDP).[18] The industry supports a total of 9.7 million American jobs, or about 5 percent of private sector employment. Each job for an auto manufacturer in the United States creates nearly 10.5 other positions in industries across the economy.[19] In 2022, U.S. entities invested $48.4 billion on automotive R&D, which represented about 39 percent of global automotive R&D spending.[20] The industry represents the core of U.S. metal working and related production capabilities, which also entail very important dual-use applications (such as the key role GM played in building tanks, vehicles, and even aircraft during World War II). In short, the U.S. automotive industry is simply too big to fail if the United States is to have a robust manufacturing sector and vibrant advanced-technology economy.

CHINA'S ELECTRIC VEHICLE INDUSTRY

There exist several types of new energy vehicles (NEVs), with the most significant being fully battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid-electric vehicles (HEVs).[21] By year-end 2024, analysts expect that BEVs and PHEVs will account for 21.8 percent of all new vehicles sold globally, an increase of 2 percentage points from the 19.2 percent they accounted for in 2023.[22] (See figure 1.)

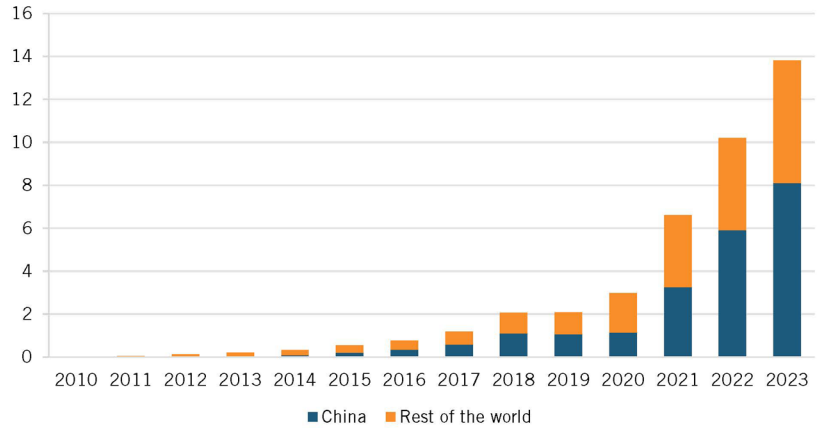
China has become the dominant market for both EV production and EV sales. Analysts expect that 11.5 million new EVs will be sold in China in 2024 (compared with 3.3 million in Europe and 2.7 million across the rest of the world), which they expect will account for 44 percent of new vehicles sold in the country this year. (See figure 1.) In 2023, sales of EVs in China increased by 37 percent from the year prior. In December 2023, China accounted for 69 percent of the world's EV sales for that month, while for 2023, China accounted for 60 percent of global EV sales.[23] By 2030, analysts expect EVs to account for over 70 percent of annual vehicle sales in China.[24]

Figure 1: EV sales by country and EVs as a share of all car sales[25]



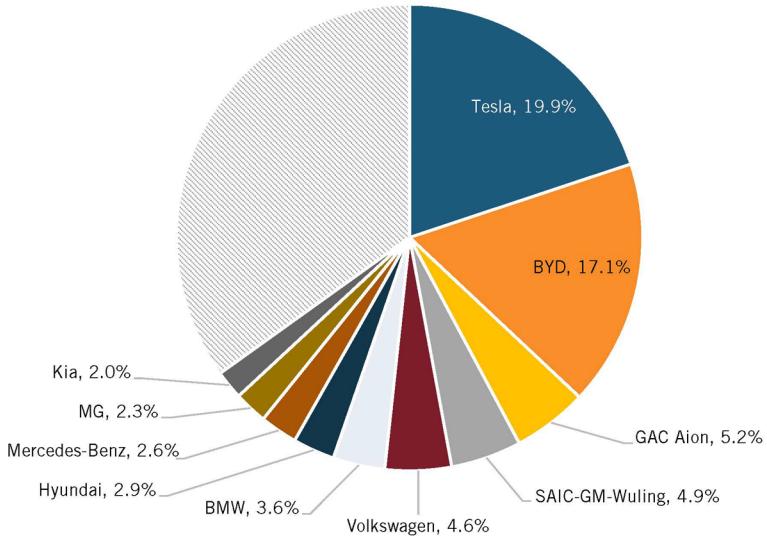
Overall, Chinese enterprises have come to be the leading players in the global EV industry. As of 2022, Chinese manufacturers accounted for 62 percent of all EVs produced in the world, a tremendous increase from the 0.1 percent of global EV sales Chinese enterprises accounted for in 2012.[26] (See figure 2.) In 2023, China's total NEV production reached 8.91 million units, up 34.2 percent over the previous year, and analysts expect China's total NEV production will exceed 10 million units in 2024.[27] For 2023, China produced 6.11 million BEVs (accounting for 68.6 percent of its NEV production) and an additional 2.8 million PHEVs.[28]

Figure 2: Global EV sales in millions of units[29]



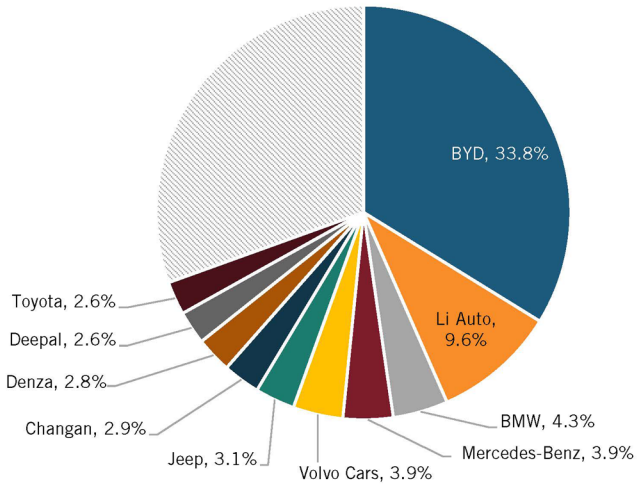
According to market research firm TrendForce, as of year-end 2023, Tesla commanded 19.9 percent of the global BEV market, followed by the Chinese firms BYD with 17 percent, GAC Aion with 5.2 percent, SAIC-GM-Wuling with 4.9 percent, and Volkswagen with 4.6 percent.[30] (See figure 3.) (All other manufacturers outside the top 10 accounted for 34.9 percent of sales.) However, based on Q1 and Q2 2024 production (and remainder of year forecasts), analysts expect that BYD will surpass Tesla as the top producer of BEVs by year-end 2024.[31]

Figure 3: Global market shares of top 10 BEV manufacturers, year-end 2023[32]



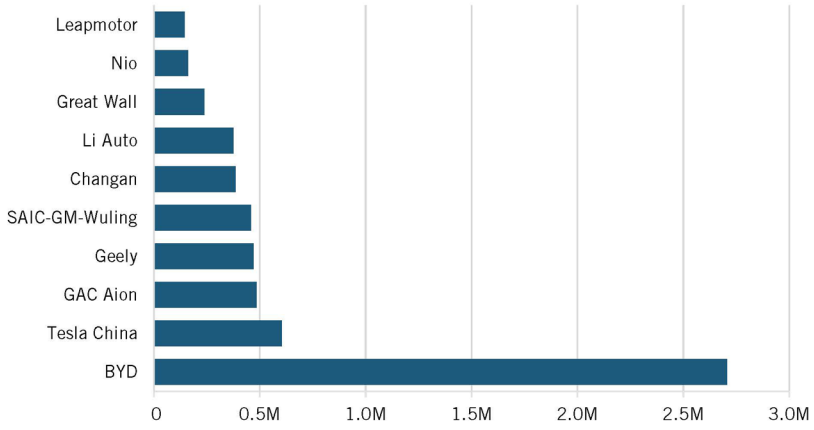
Considering PHEVs only, BYD dominates the global industry, with a 33.8 percent market share, followed at the top by Chinese firm Li Auto with 9.6 percent, BMW with 4.3 percent, and Mercedes-Benz and Volvo with 3.9 percent each. (See figure 4.) Li Auto's share of the global PHEV market grew 182 percent from 2022 to 2023.

Figure 4: Global market shares of top 10 PHEV manufacturers, year-end 2023[33]



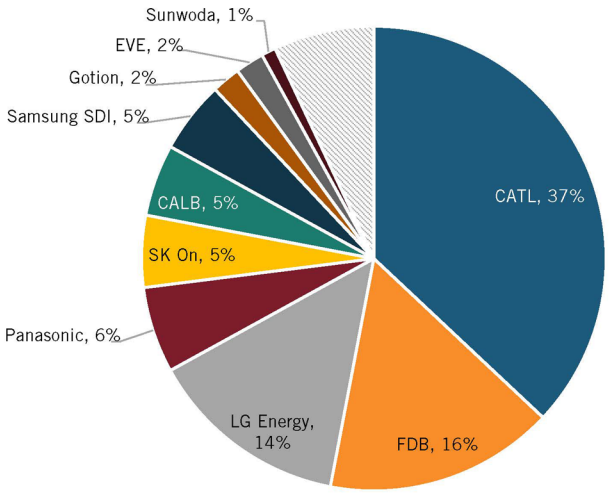
In terms of the Chinese NEV retail sales market specifically, BYD sold 2.76 million vehicles in 2023, followed by Tesla China with 603,664 vehicles sold and GAC Aion with 483,632. (See figure 5.) Overall, BYD accounted for 35 percent of Chinese NEV sales in 2023 and was the only manufacturer with a market share of more than 10 percent.[34]

Figure 5: Top 10 manufacturers' NEV retail sales in China, 2023[35]



Likewise, Chinese enterprises dominate in the global share of EV battery manufacturing. CATL accounts for 37 percent of the global EV battery market followed by FDB with 16 percent, giving China's top two competitors alone over half the global market. (See figure 6.) The twain are followed by LG Energy and Panasonic, with 14 percent and 6 percent of the market, respectively.[36] In total, Chinese EV battery manufacturers hold about 75 percent of the global market.[37] Morgan Stanley analysts predict that, by 2030, CATL alone will account for 35 percent of batteries sold in the European market.[38]

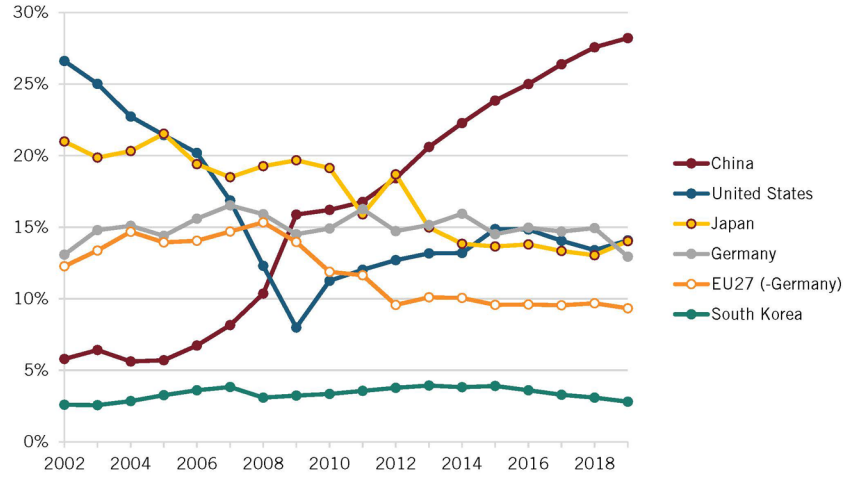
Figure 6: Leading EV battery manufacturers' global market shares, 2023[39]



As of 2022, China accounted for 62 percent of all EVs sold in the world, a tremendous increase from the 0.1 percent of global EV sales Chinese enterprises accounted for in 2012.

The U.S. National Science Foundation (NSF) provides data on countries' shares of total value added in the motor vehicle, trailer, and semi-trailer industries (unfortunately, it does not break out EVs separately) and it finds that China's share of value added in the automotive industry increased nearly fivefold from 6 percent in 2002 to roughly 28 percent by 2019. By contrast, the United States' global share fell significantly over the 2000s and has never meaningfully recovered since the end of the 2008 recession, while the European Union's share declined about one-third from its 2008 peak (31.2 percent) to 2019 (22.3 percent). (See figure 7.)

Figure 7: Global shares of value added in the motor vehicles, trailers, and semi-trailers industry[40]



China has become the leading global exporter of vehicles (including cars, sport utility vehicles (SUVs), pickups, and vans) with its nearly six million (5.6 million) vehicle exports in 2023 far surpassing those of Germany and Japan.[41] Chinese BEV exports rose 70 percent in 2023, reaching $34.1 billion in value.[42] Chinese producers accounted for approximately 35 percent of global EV exports as of year-end 2022.[43] From 2000 to 2023, Chinese EV exports increased over 850 percent.[44] Forty percent of Chinese BEV exports are destined for European markets, explaining how China's share of the European EV market grew from just 0.5 percent in 2019 to 9.3 percent in 2023, with that share expected to reach 25 percent by year-end 2024.[45]

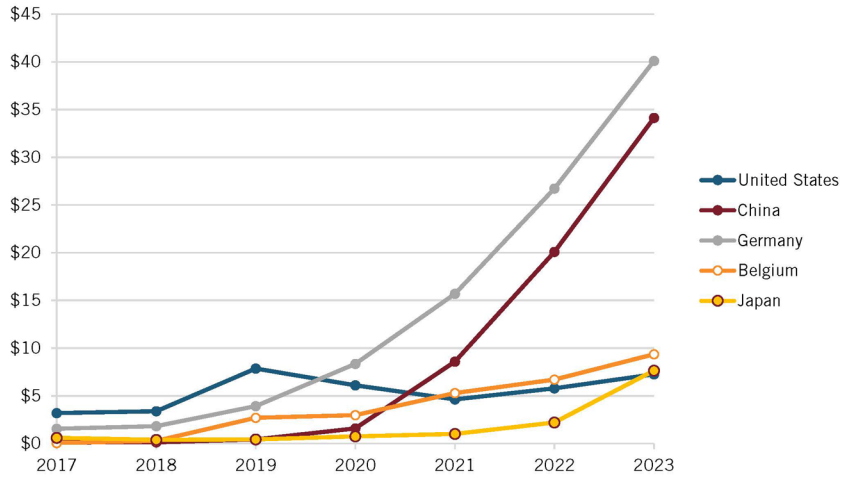
Analysts predict that Chinese carmakers will capture one-third of the global auto vehicle market by the end of this decade.

Perhaps surprisingly, it is a lack of specialized ships that has been the biggest obstacle holding China back from exporting even more vehicles. As Michael Dunne, a former president of GM Indonesia, explained, "They (China) are building cars a lot faster than they are building ships."[46] As *The Economist* wrote, the biggest "constraint on their (Chinese EV) export today is the scarcity of vessels for shipping them."[47] For this reason, the Jinling shipyard (near Nanjing) is "busy around the clock, there are night shifts every day."[48] Chinese carmaker BYD itself has commissioned construction of a fleet of eight car carriers to underpin its global EV expansion; its BYD Explorer 1 can ship 7,000 vehicles at a time.[49] BYD exported 242,765 NEVs in 2023, which translates to a year-on-year growth of 334 percent.[50] In total, Chinese automakers (and shipping company agents) are responsible "for almost all of the orders now pending worldwide for 170 car-carrying vessels."[51]

It should be noted, however, that Western auto manufacturers operating in China still account for a significant share of EV exports from China. For instance, in 2022, Tesla alone accounted for 40 percent of China's total EV exports.[52]

By value of EV exports, according to United Nations (UN) Comtrade data, Germany retains a slight edge over China. (See figure 8.) As of 2022, Germany remained the leading exporter of EVs, by value, with a 28.5 percent share, but China placed second at 18.6 percent.[53] This of course is likely explained by Germany's greater levels of production of luxury vehicles (although Chinese EV makers such as Xiaomi and Li Auto are rapidly closing that gap).

Figure 8: Exports, by value, of top five EV-exporting nations ($ billions)[54]



HOW INNOVATIVE ARE CHINA'S EV AND EV BATTERIES INDUSTRIES?

Chinese enterprises have become highly competitive and innovative players in the global EV and battery industries. As one report observes, many contend that "China is the epicenter of EV innovation."[55] Indeed, as commentators at an ITIF roundtable of experts on China's EV industry observed, "Chinese enterprises are very innovative, especially in EVs" and "China is doing really remarkable, innovative work in the vehicle electrification space."[56]

It's a long cry from the year 2011, when Tesla CEO Elon Musk, being interviewed by *Bloomberg* and asked about rival BYD's prospects, commented, "Have you seen their car? ... I don't believe they offer a superior product."[57] As Musk continued in the interview, "I think their focus should be on making sure they don't die in China."[58] Asked the same question during a June 2024 analyst call, Musk sang a different tune, responding, "Our observation is, generally, that the Chinese car companies are the most competitive car companies in the world."[59]

Enterprises can pursue a multitude of different types of innovation, including with regard to product innovation, process innovation, business model innovation, and even customer-experience-driven innovation.[60] The following section analyzes how innovative Chinese EV and battery makers are along these different innovation trajectories.

Product Innovation

This section examines Chinese enterprises' innovations with regard to both the batteries powering the EVs and product innovations across the rest of the vehicle.

EV Battery Innovation

Batteries account for approximately 40 percent of the value of an EV—and thus essentially constitute the essence of what an EV represents.[61] While a wide variety of EV batteries exist, the two most prominent types have historically been LFP or nickel and cobalt-based batteries, which can come in nickel cobalt aluminum (NCA) or nickel manganese cobalt (NMC) varieties. Nickel/cobalt batteries have tended to be more popular in American- and European-produced EVs. Tesla, for instance, uses NCA batteries, in part because they have high energy density, meaning the batteries are smaller and lighter than others that can store the same amount of energy.[62] In contrast, LFP batteries represent an older battery chemistry, which tends to cost less, have a longer life cycle, and be safer when it comes to the possibility of catching fire. LFP batteries historically were more popular in markets such as China, where city drivers drove shorter, more frequent trips (than long hauls across U.S. highways) and so drivers favored the lower cost and longer life cycle of the battery (more recharging opportunities) while drivers in the U.S. and Europe tended to prefer larger vehicles with longer range.

Batteries account for approximately 40 percent of the value of an EV—and thus essentially constitute the essence of what an EV represents.

However, as Zeyi Yang wrote in *MIT Technology Review*, "Just a few years ago, LFP batteries were considered an obsolete technology that would never rival NMC batteries in energy density."[63] Indeed, from 2016 to 2018, LFP batteries accounted for just 10 percent of the global EV battery market.[64] But today, LFP batteries account for about 40 percent of the global market for EVs, and as Yang wrote, "It was Chinese companies, particularly CATL, that changed this consensus through advanced research."[65]

As Max Reid, a senior research analyst for EVs and batteries at research firm Wood Mackenzie, explained, "That's purely down to the innovation within Chinese cell makers. And that has brought Chinese EV battery [companies] to the front line, the tier one companies."[66] By February 2023, Ford announced it would invest $3.5 billion to build an LFP plant, licensing "battery cell knowledge and services provided by CATL."[67] In March 2023, news broke that GM was in discussions with CATL "about establishing a North American battery production facility that would duplicate the licensing agreement Ford arranged with CATL."[68] That America's largest auto manufacturers are seeking to license Chinese EV battery technology would certainly seem to validate the innovativeness of that company's products. The same applies to German carmakers: BMW has produced and exported its iX3 battery EV through a China-based joint venture with Brilliance since 2020.[69]

In April 2024, CATL announced that it had developed its fast-charging "Shenxing Plus" LFP battery, which is capable of a driving range of more than 1,000 km (621 miles) off a single charge.[70] CATL asserts that the battery can achieve a range of 400 km off just a 10-minute charge.[71] A notable innovation in CATL's "Shenxing" battery is its elimination of dead space within the battery, allowing it to nearly double its energy density. In June 2023, another Chinese EV battery maker, Shenzhen-based Gotion High-Tech. Co. (whose largest publicly listed shareholder is Volkswagen), announced it had designed a lithium-iron-manganese phosphate (LFMP) battery also capable of a 1,000 km range off a single charge. The company asserts its LFMP costs 5 percent less than conventional LFP batteries in terms of dollars per kilowatt hour (kWh), and 20 to 25 percent less than nickel-cobalt units.[72] The company, now China's fourth-largest EV battery maker, envisions large-scale delivery of the battery to EV assemblers in early 2025.[73]

EV battery technology continues to evolve, and the next generation of EV batteries is expected to be ASSBs. Unlike lithium-ion batteries, which use liquid electrolytes between their electrodes, solid-state batteries employ a solid electrolyte, which can provide a higher energy density, enabling lighter and more efficient EVs with longer driving ranges.[74] As market research firm TrendForce wrote, "ASSB has emerged as the high ground in the competition for next-generation battery technology" and "in the future competition for ASSB, companies from Japan, South Korea, Europe and the US have the opportunity to surpass China and reshape the competitive landscape of [the] future EV battery industry."[75] BMW intends to launch its first prototype vehicle based on U.S.-based Solid Power's ASSB technology by 2025, while, "Japanese companies like Toyota and Nissan have stated their intention to achieve mass production of ASSB around 2028."[76]

But China's EV battery makers may already be beating competitors to the punch—or will at the very least be well in the mix. In December 2023, Chinese EV maker Nio unveiled its ET7 sedan with a semi-solid state, 150 kWh battery made by Chinese battery company WeLion, which can travel 650 miles on a single charge and which the company's CEO, William Li, asserted currently represents the "battery pack with the highest energy density in mass production in the world."[77] In April 2024, Chinese automaker GAC group (also an LFP battery maker) asserted it had developed an ASSB capable of 620 miles per charge that would be production ready at scale for its Hyper vehicles by 2026.[78] The Chinese government has provided 6 billion yuan (nearly $830 million) to Chinese companies including CATL and BYD to research and develop the next generation of solid-state batteries in China.[79]

Perhaps most intriguing is a new entrant, Tailan New Energy, a Chongqing-based start-up formed in 2018 that in April 2024 had developed the first automotive-grade, all solid-state lithium-metal prototype that has a single-cell capacity of 120 amperes (Ah) and a real-world energy density of 720 watt hours per kilogram (wh/kg).[80] If the technology can be mass produced, the battery could in theory support a range of 2,000 km (over almost 1,300 miles) on a single charge.[81] According to Tailan, the company "has achieved several technological breakthroughs in all-solid-state lithium batteries."[82] Those breakthroughs pertain specifically "to ultra-thin and dense composite oxide solid electrolytes, high-capacity advanced positive and negative electrode materials, and an integrated molding process that culminates into a 120 Ah solid-state lithium metal cell."[83] While the company asserts its batteries are vehicle grade, it has yet to announce specific plans for passenger vehicle integration. Regardless, companies such as CATL, GAC,

Tailan, WeLion, and others certainly seem likely to keep Chinese firms at the forefront of global EV battery innovation in the years ahead.

It should be noted that, broadly, one reason China's EV battery makers (and thus EV car makers) have been able to innovate so rapidly and cost-effectively in this space pertains largely to the country's dominance over the middle and lower segments of the EV battery supply chain. For instance, regarding raw materials, China mines over two-thirds of the world's graphite and 18 percent of its lithium.[84] Overall, China extracts 60 percent of all rare earths mined annually in the world, and Chinese companies own almost half the world's cobalt mines and one-quarter of lithium ones.

Chinese dominance is even stronger in raw materials processing and refining, where China in 2023 refined 95 percent of the world's manganese, 70 percent of cobalt and graphite, 67 percent of lithium, and over 60 percent of nickel.[85] Translating these raw materials into EV components, China accounts for nearly 90 percent of cathode active material capacity globally and more than 97 percent for anodes, according to the International Energy Agency (IEA).[86] China also accounts for 78 percent of separator and 82 percent of electrolyte processing.[87] Moreover, IEA research expects China's dominance to only grow further in coming years, with a new report asserting that "over 90% of battery-grade graphite and 77% of refined rare earths will originate from China by 2030."[88] Chinese dominance of these supply chains gives its battery makers access to key chemical inputs at lower price points and affords them a first-mover advantage in experimenting with new combinations of materials (not to mention the potential capacity to block competitors' ability to access these inputs). As Alicia García-Herrero, chief economist for Asia Pacific at Natixis, explained, China's control of critical chemical materials represents "the ultimate control of the sector, which China has clearly pursued for years well before others even figured that this was something important."[89]

EV Innovation

As Andrew Bergbaum, global co-leader of the automotive and industrial practice at AlixPartners commented, "The revolution taking place in the global auto industry is driven by the incredible and once unthinkable maturation of Chinese automakers that do a number of things differently."[90] An important point here is that, as *The New York Times'* Keith Bradsher noted, "Beyond the battery itself, China also dominates electric motor production, and in designing high-efficiency systems that tie together batteries and motors."[91]

Moreover, as with Tesla, Chinese EV makers have intensely focused on innovating beyond the battery itself, particularly in incorporating digital features into the vehicle, such as autonomous driving, driver-assistance features, navigational aids, virtual reality, and even "multiple high-res dashboard screens pimped with generative AI and streaming video."[92] As Paul Gong, UBS head of China auto research, explained, "New EVs are more like computers with batteries on wheels. Chinese carmakers are now ahead of almost everyone else along the entire EV supply chain."[93] As the hardware has become simpler, the focus for what makes an appealing product has shifted decisively to software and new features.[94] Ade Thomas, who founded World EV Day, coined the phrase "digital bling" cars to describe the tech-laden EVs now being manufactured in China.[95]

Indeed, as *The Wall Street Journal's* Ip wrote, "Chinese EVs feature at least two, often three, display screens, one suitable for watching movies from the back seat, multiple lidars (laser-based sensors) for driver assistance, and even a microphone for karaoke."[96] Elsewhere, at Auto China

2024, Chinese automaker JiYue (a joint venture between Geely and Baidu) showcased a "stylish saloon that can be entirely controlled by voice commands and a touch screen." Nio offers $350 augmented reality glasses for each seat in its cars, and has introduced a smartphone that interacts with the car's self-driving system.[97] Chinese EV makers are also working to develop interactive control systems that can perform functions such as analyzing drivers' health data and stress levels to provide driving suggestions and allowing drivers and passengers to control car systems by voice and gestures.[98]

However, it's not just that modern vehicles represent "digital bling," for in reality, the digital components of modern vehicles—everything from electric steering and power brakes to navigational systems and autonomous driving—are increasingly powered by digital technology. In fact, the contribution of electronics and digital technologies to a vehicle's cost has increased from just 18 percent in 2000 to over 40 percent today and an estimated 45 percent by 2030.[99]

In May 2024, XPeng Motors said it intends to introduce its AI-powered in-car operating system (the XOS 5.1.0), with the aim of delivering full autonomous driving (Level 4) in China by 2025.[100] The Society of Automotive Engineers (SAE) has defined six levels of driving automation ranging from 0 (fully manual) to 5 (fully autonomous).)[101] In 2023, Mercedes-Benz became the first automaker to offer an SAE Level 3 conditionally automated driving vehicle with its DrivePilot technology.[102] JiYue's Point-to-Point Autopilot (PPA) offers Level 2 autonomous driving, in which computers take over multiple functions from the driver—and are intelligent enough to weave speed and steering systems together using multiple data sources.[103]

In April 2024, Xiaomi, historically a maker of smartphones and home appliances such as vacuums and rice cookers, which only entered the auto industry in 2021, became China's eighth-largest EV manufacturer after selling more than 7,000 units of its first model, the Xiaomi SU7.[104] As *The Wall Street Journal* wrote, Xiaomi "has pulled off what Apple, its longtime rival, couldn't: Make an electric car and bring it to market. And it did it in three years."[105] The company has invested over one billion dollars in becoming an EV manufacturer.[106]

Auto industry analysts view Xiaomi's SU7 as a serious competitor to Tesla's Model 3, priced about $4,000 cheaper, with an EV battery that has a distance about 200 miles greater and roughly comparable Level 2 autonomy features. For instance, Xiaomi's Pilot autonomous driving system intelligently adjusts driving paths for seamless navigation and offers object perception with a grid that detects objects from 5 cm to 250 meters away.[107]

Xiaomi's rapid pace of innovation owes both to fast-follower techniques and genuine and novel innovation efforts. As Sha Hua and Yoko Kubota elaborated in *The Wall Street Journal*:

> To save on time and costs, the company adopted practices from Tesla and other automakers, mined its own product-development know-how and plugged into China's fast-moving car supply chain. Years of honing laptops, blenders and petcams helped it develop features tailored to a fickle consumer base, including a detachable panel of physical buttons that magnetically clips on below the 16.1-inch center screen for those who don't like to control their volume or seat via touch screen.[108]

It was Tesla that pioneered the "gigacasting" process for manufacturing vehicle chassis, a metal die-casting process characterized by forcing molten metal under high pressure into a mold cavity.

By combining hundreds of manufacturing steps into one, thus saving on components, weight, cost, and time, the technique helped Tesla reduce production costs for the underbody of its Model Y by some 40 percent.[109] As Hua and Kubota wrote, Xiaomi adopted Tesla's gigacasting process, but "Xiaomi also had to innovate."[110] Specifically:

> The liquid aluminum that gets injected into the die-casting machine has to be a certain variety that can withstand an extraordinary amount of pressure. Xiaomi had to come up with its own material, building an artificial-intelligence program that used a method known as deep learning to simulate how different materials would behave when placed inside the die-cast machine.[111]

Other Chinese EV makers are aggressively adopting die-casting practices. Nio and XPeng supplier Guangdong Hongtu Technology (GHT) have already produced a 6,800-ton die-casting machine. Now GHT has announced it will start developing a 12,000-ton casting machine in partnership with Tesla supplier LK Technology.[112] It's worth noting that one of the world-leading pioneers of the die-casting process was Brescia, Italy-based Idra srl. A leading manufacturing of aluminum and magnesium die-casting machines, over the last 68 years it has designed, produced, customized, and serviced more than 13,000 machines around the world.[113] However, in 2008, Hong Kong-based LK Technology purchased Idra, another example of Europe allowing the crown jewels of its manufacturing sector, such as the German industrial robot manufacturer, Kuka, to fall into Chinese hands.

Overall, research firm Bernstein estimates that Chinese EVs can cost half as much to make as European ones, even while they can boast of better tech.[114] And while certainly the Chinese government's efforts to drive the industry have been a key factor in its growth, considerable innovation is now being driven among the automotive firms themselves. As one analyst noted, "The competition is so fierce that it pushes every automaker to develop new technologies."[115]

Chinese carmakers are innovating many other vehicle features aside from electrification and digital features. For instance, in 2023, Yangwang (BYD's luxury electric sub-brand) introduced its DiSus-X suspension technology, which enables its quad-motor EV, the U9, to drive on only three wheels and hop up and rotate in the air on all four wheels.[116]

Another affirmation that Chinese EV makers are indeed innovative comes from Western companies' investments in the firms. For instance, in July 2023, Volkswagen paid $700 million for a 4.99 percent stake in XPeng.[117] In April 2024, the companies agreed to "expand their platform and software partnership" including "[j]oint development of the China Electrical Architecture, [and] a zonal Electrical/Electronic architecture, to make China-specific electric vehicle models fit for the next leap in innovation."[118] Elsewhere, in May 2024, South Korea's Hyundai Motor and Kia unveiled plans to work with Chinese Internet giant Baidu on mapping and AI technologies for auto-driving and vehicle software systems in China, while Nissan announced a partnership with Baidu on AI, and Toyota entered an agreement with Tencent to collaborate on AI models, cloud services, and big data.[119] And in October 2023, Stellantis cut a deal with China's Leapmotor with the latter sharing EV technology and Stellantis launching a European venture to sell and make Leapmotor's products outside China.[120]

To be sure, there are numerous market-based reasons driving these tie-ups: Tech talent tends to be more available and less expensive in China (certainly than it is in Europe) and foreign players

get an opportunity to be closer to local markets, local tastes, and technologies being locally developed. However, another key factor is that the Chinese government is effectively requiring such tie-ups if a foreign company is to be permitted access to information such as mapping data to support vehicle autonomy and navigational aids. For instance, for years, Beijing withheld approvals for data transfers Tesla needed for development of autonomous vehicles for the Chinese market, a factor multiple analysts have noted gave Chinese players crucial time to catch up to Tesla in vehicle autonomy.[121] In fact, only in April 2024 did Tesla receive approval to sell autonomous driving services in China, though Beijing stipulates that they must be based on mapping and navigation functions provided by Chinese technology giant Baidu.[122]

Other Vehicle Innovations

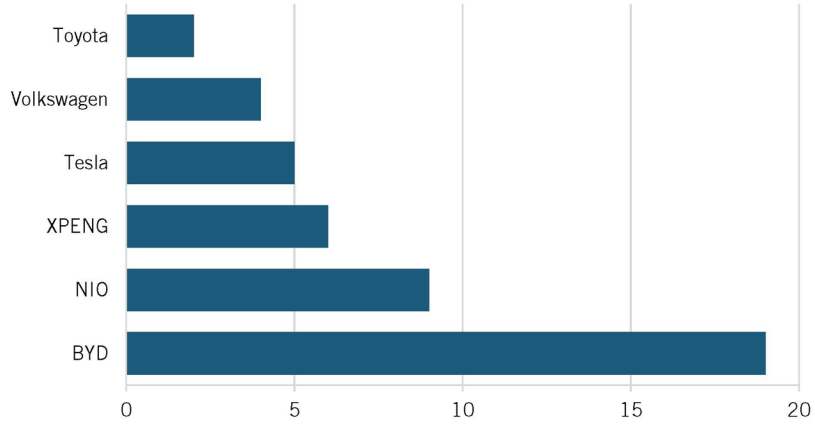
China's carmakers aren't innovating only EVs. For instance, in June 2022, a team of researchers from 42 companies and three universities unveiled the Tianjin solar car, which its developers touted as "the country's first smart vehicle to be powered solely by the sun."[123] Developed in just five months, the car uses 87 square feet of solar panels, which deliver 7.6 kWh of power per day. Elsewhere, Chinese start-up AutoFlight has developed a proof-of-concept electrical-vertical-takeoff-and-landing air taxi.[124] The vehicle has 10 lift rotors on wing booms for vertical flight and three pusher propellors for cruise flight. The company plans to initially develop an uncrewed cargo version and later an interior cabin accommodating one pilot and four passengers.

Process Innovation

Process innovation refers to the process of development and implementation of new or improved processes, methods, or systems within an organization to enhance efficiency, effectiveness, and value creation.[125] Product and process innovation are often inherently interlinked—biologic drugs, which are derived from and manufactured within living cells, represent a good example of fundamentally intertwined process and product innovation—but they do represent separate steps in the innovation process.

Chinese EV makers do seem distinctively strong at process innovation, and particularly at accelerating speed to market with their products. As Selina Cheng and Yoko Kubota of *The Wall Street Journal* wrote, "Many Chinese EV makers operate more like startups than legacy automakers."[126] As they noted, "Chinese automakers are around 30% quicker in development than legacy manufacturers, largely because they have upended global practices built around decades of making complex combustion-engine cars."[127] In fact, Chinese EV makers offer models for sale for an average of 1.3 years before they are updated or refreshed, compared with 4.2 years for foreign brands.[128] For instance, Nio takes less than 36 months from the start of a project to delivery to customers, compared with roughly four years for many traditional carmakers. For this reason, Chinese EV manufacturers were able to introduce substantially more new and updated EV releases from 2017 to 2023 than did their foreign counterparts. Over that time frame, BYD introduced 19 new vehicles, Nio 9, and XPeng 6, compared with Tesla's 5, Volkswagen's 4, and Toyota's 2. (See figure 9.) Chinese EV makers' rapid pace of innovation recalls then-Nokia CEO Stephen Elop's "Burning Platform" memo, in which he famously observed that "Chinese mobile phone makers are bringing out new versions faster than it takes Nokia to polish off a power point presentation."[129] Chinese EV companies will put at least 71 new models on the market in 2024.[130]

Figure 9: New and updated EV releases in China, 2017–2023[131]



Several factors explain Chinese EV makers' rapid pace of process innovation, with digital automation of design practices being a key factor. And, in fact, the use of digital tools and other process innovations has facilitated the pathway for new entrants into the industry. As one article explains, "Chinese EV companies heavily use simulation software to create virtual prototypes and run tests in more iterations and in faster time. Virtual parts and mock-ups can be worked on between teams and 3D printed prototypes allow engineers to go through loops of trial and error much quicker."[132] As an industry analyst commented at ITIF's roundtable, "For China's EV manufacturers, it's more digital modeling and simulation in the design phase and fewer crash-test dummies."[133] JiYue asserts it can complete its vehicle product designs in six months.

In 2023, Chinese enterprises deployed more industrial robots than did firms across the rest of the world combined.

Another example of innovative use of digital production systems comes from XPeng, which in 2023 introduced "a new platform architecture for making vehicles" with its Smart Electric Platform Architecture (SEPA) 2.0. It provides a modular, interchangeable vehicle platform that can support a range of vehicle types, such as XPeng's upcoming G6 coupe SUV. XPeng asserts that SEPA 2.0 will help it shorten the R&D cycle for its future models by 20 percent and cut costs on adaptations for advanced driver assistance systems and smart infotainment systems by 70 percent and 85 percent, respectively.[134]

Chinese EV manufacturers are also devout adopters of a process pioneered by Tesla: leveraging software to update vehicle features. For instance, Nio releases cars with latent technology such as a spare chip that allows it to frequently add new features through software updates.[135] Managing the vehicles' features more dynamically through software enables another process innovation. As Cheng and Kubota explained, "China's carmakers are increasingly standardizing

their models to cut time. Beyond traditional mechanical platforms, they standardize everything from important software to the digital vehicle operating systems that executives liken to the nerve center of smartcars."[136] The technique recalls how John Deere can manufacture a single tractor but control the horsepower of its engines through the use of software.

Another factor contributing to Chinese EV makers' rapid time to market is the depth of the supplier ecosystem within China. As one observer commented, "If customer feedback suggests a display screen in a Chinese EV should be a couple inches bigger, for instance, they can just go down the road to their supplier and have that change made in a couple months. The same process would have to go into a design cycle and might take three or even four years at a Western vehicle manufacturer."[137] But it's not just that, as Chinese EV manufacturers "are willing to substitute traditional suppliers for smaller, faster ones."[138] Certainly the depth of the auto parts supplier ecosystem in China creates agglomeration effects and a time-to-market advantage for China's EV makers.

Lastly, it's important to note that Chinese EV makers are using automation processes to the maximum extent possible. As one expert told ITIF, "China's firms are strong on the hardware side of robots, especially for automotive."[139] As ITIF has noted, in 2023, Chinese enterprises deployed more industrial robots than did firms across the rest of the world combined. Indeed, Chinese firms are now using industrial robots at 12 times the U.S. rate when controlling for wages.[140] As *The New York Times'* Bradsher explained, "[Nio] has invested so extensively in robots that one of its factories employs just 30 technicians to make 300,000 electric car motors a year."[141]

Market- and Customer-Experience-Driven Innovation

Chinese EV industry analysts have also spotlighted the industry's use of several additional innovation strategies worth mentioning. Writing in *Harvard Business Review,* Chengyi Lin noted that Chinese EV makers initially cut their teeth on EV battery technology as early as 15 years ago by experimenting with EV battery technologies in adjacent industries, before transitioning to the consumer vehicle market. As she explained, BYD and Geely "kickstarted their EV development by focusing on adjacent industries—namely, electric buses and motor cycles.... What they learned by tackling these challenges ultimately contributed to their EV manufacturing strategy."[142] As she continued:

> For instance, buses are heavier and carry more passengers than commercial sedans. Additionally, most buses are operational about 18 hours each day. They therefore have greater battery and power storage requirements. And more powerful batteries take longer to charge. By targeting an adjacent industry, BYD began pushing the boundaries of battery technology as early as 2009. BYD featured electric buses as its entry product into North American markets [and they] are now also prevalent in South American markets.[143]

A later section of this report, which examines China's government policies supporting the EV sector, explores the critical role the Chinese government played in driving the rollout of the EV charging infrastructure that built Chinese consumer confidence in the EV market. But Lin notes that Chinese EV makers have also worked closely with different customer bases to drive adoption. They recognized that taxi operators would essentially need to deploy two fleets of cars daily, a morning and evening rush shift, so they "designed jointly" a schedule that enables the morning

fleet to be charged after 8:00 p.m. and the evening shift to be charged overnight. Co-designing the schedule helped overcome initial resistance to EVs from taxi drivers because it "not only addresses the battery constraints of EVs but also helps to flatten the consumption curve of a city's power grid."[144] It's a nice example of the systemic coordination needed to manage the transition to vehicle electrification.

The vignette also amplifies the point that Chinese EV makers tend to be much more attuned to customer desires in the Chinese marketplace. As one observer of Germany's auto industry commented, "From the German carmaker's perspective [the approach to the Chinese market was] let's bring them either a second-tier vehicle that isn't top of class, or let's sell them a high-end vehicle that's been designed with the European market in mind, like a vehicle with a lot of horsepower. Chinese NEV companies have been much better at tapping into local markets and desires."[145] For instance, Xiaomi was "intimately familiar with [Chinese] customers' lifestyle preferences" and "could rely on its in-house expertise of household products and gadgets" as it started to develop EVs.[146] Elsewhere, Nio introduced an innovative subscription service for replaceable batteries.[147] Another observer commented that Chinese EV brands have benefited greatly from the "China chic" or "guochao" phenomenon, a consumer preference for domestic products and services.[148]

Lastly, from a "brand innovation" perspective, it's worth noting that China's companies have been shrewdly acquiring European vehicle brands as a back door to sell China-produced EVs under European brand names (in Europe and in third-party markets). For instance, the Chinese state-owned enterprise (SOE) Shanghai Automotive Industry Corporation (SAIC) acquired Britain's fabled MG brand in 2007 and is now exporting inexpensive cars from China under the MG name not just to Britain but also to Australia.[149]

INNOVATION INPUTS TO CHINA'S EV SECTOR

This section examines indicators assessing China's EV competitiveness at the industry level, considering such factors as R&D intensity, scientific publications, and patenting levels.

R&D Intensity

In terms of automotive companies' levels of R&D investments (as reported in the "2023 EU Industrial R&D Investment Scoreboard"), China places 8 of the top 15 in the study. U.S.-headquartered Fisker and Lordstown ranked first and second, although these are largely pre-revenue start-ups, which significantly skews their R&D intensity. Nio and XPeng were the leading Chinese companies, with an R&D intensity of about 21.3 percent of its revenue. That is ahead of well-known automotive manufacturers including Ferrari and Aston Martin. (BYD was not listed in the 2023 EU report, though ITIF research finds its R&D intensity to be roughly 6.7 percent.)

Table 1: Leading automotive R&D investors in the 2023 EU Industrial R&D Investment Scoreboard[150]

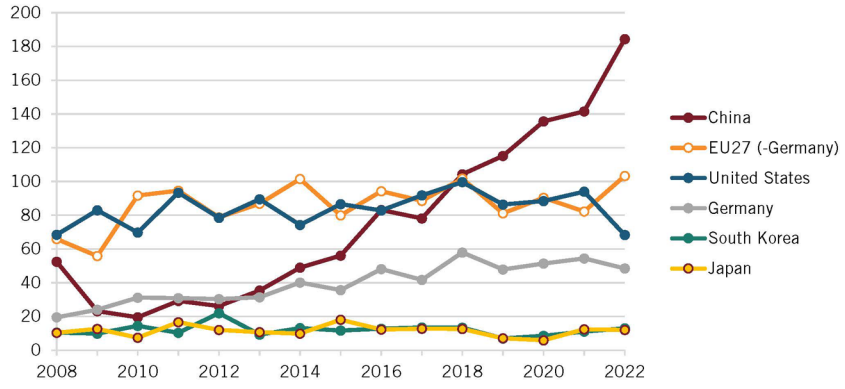
Company	Headquarters	R&D Investment (Millions)	R&D Intensity
Fisker	United States	€397.4	123949.0%
Lordstown	United States	€101.1	55575.0%
Nikola	United States	€256.7	538.7%

Company	Headquarters	R&D Investment (Millions)	R&D Intensity
Lucid	United States	€770.2	135.0%
Rivian Automotive	United States	€1,733.6	111.5%
Nio	China	€1,409.6	21.3%
XPeng	China	€699.9	19.4%
Ferrari	Italy	€934.2	18.3%
Aston Martin	UK	€278.5	17.8%
Zhejiang Century Huatong	China	€233.7	15.6%
Li Auto	China	€897.3	14.8%
Zhejiang Leapmotor	China	€180.0	10.8%
Seres	China	€413.2	9.6%
Great Wall Motor	China	€1,634.7	9.4%
Dongfeng Motor	China	€978.0	7.9%

Scientific Publications

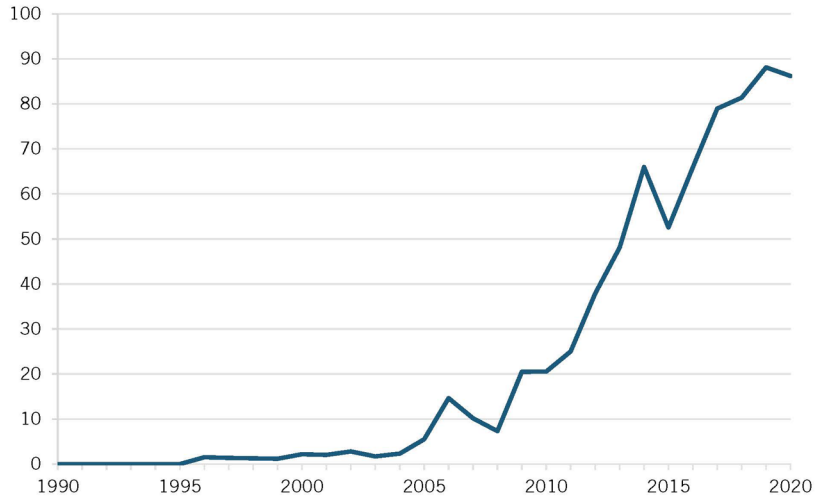
In 2021, Chinese institutions surpassed European ones in producing the most top-10 percent-cited publications in automotive engineering. In 2012, Chinese institutions only published about 26 such papers in automotive engineering; by 2022, that number had increased sevenfold, as Chinese institutions published about 184 top-cited papers. (See figure 10.)

Figure 10: Number of automotive engineering publications in top 10 percent of most-cited publications[151]



The number of Chinese scientific publications regarding EV research (relative to trillions of GDP) began to significantly accelerate around 2011, increasing from 25 papers then to 86 by 2020. (See figure 11.)

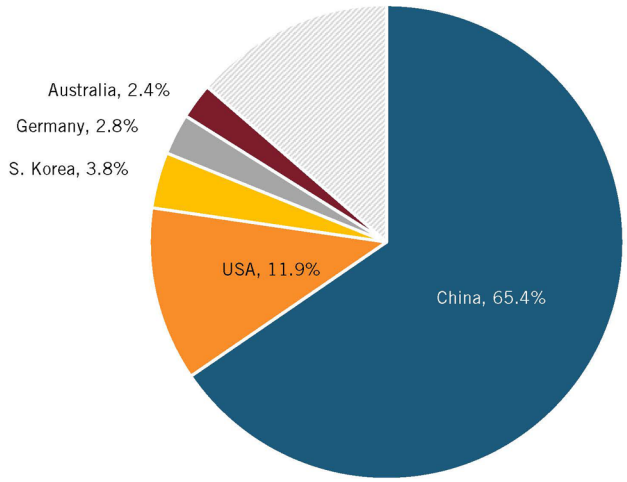
Figure 11: Number of EV scientific publications in China (per trillion $ GDP)[152]



The Australian Strategic Policy Institute does not track publications on automobiles or EVs in its Technology Tracker, per se. However, it does track publications for electric batteries, which serve as the critical input for EVs. In 2023, Chinese institutions held a 20 percent share of all scientific publications in the EV battery field. And as ASPI noted, "The Chinese Academy of Sciences is a stand-out performer in the *Critical Technology Tracker* datasets. It leads in six of the eight energy and environment technologies [and is] no. 1 globally for electric batteries."[153]

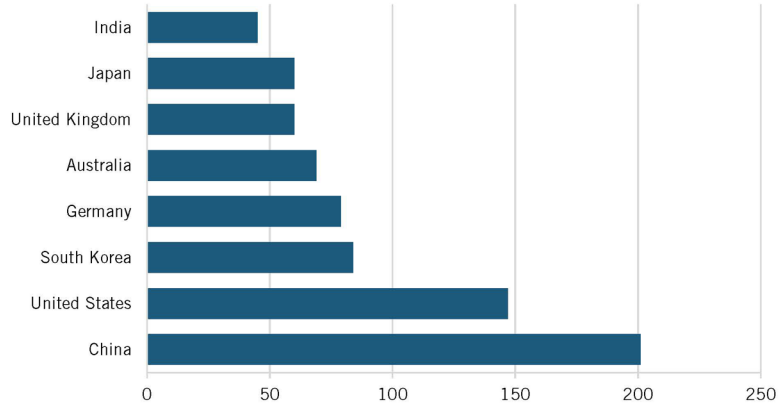
ASPI finds that Chinese institutions account for 65.4 percent of the high-impact publications for electric batteries, substantially outpacing the United States' 11.9 percent, South Korea's 3.8 percent, Germany's 2.8 percent, and Australia's 2.4 percent. (See figure 12.) And as ASPI wrote, "For electric batteries, China has a 5.5 times lead over the US in its share of high-impact research, and eight of the top 10 institutions are based in China."[154]

Figure 12: Top five countries for high-impact publications about electric batteries in the ASPI Critical Technology Tracker dataset[155]



Similarly, the H-index represents a quantitative metric that estimates the impact of a scientist's or scholar's research contributions; effectively, it signals the extent to which other scholars are referencing the original scholar's work. China's score on the H-index for scientific publications in electric barriers is the highest in the world, one-quarter greater than the United States'. (See figure 13.) In sum, China is a leader not only in the quantity of publications, but also in "high-quality" publications.

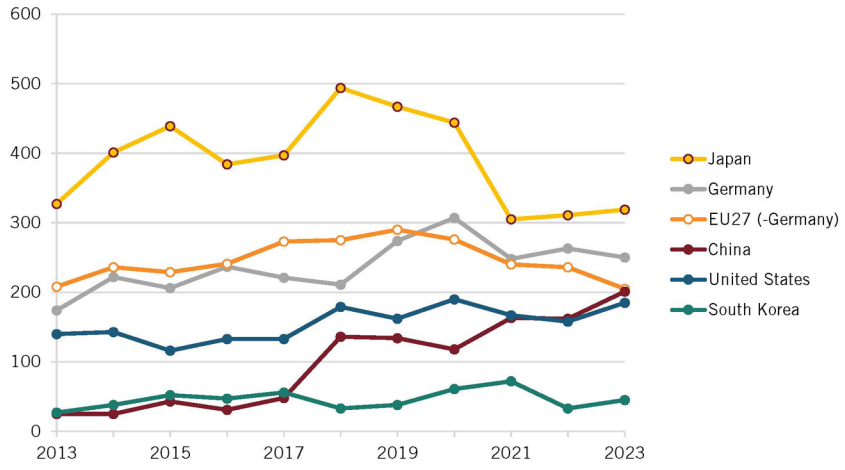
Figure 13: H-Index for scientific publications in electric batteries, 2023[156]



Patents

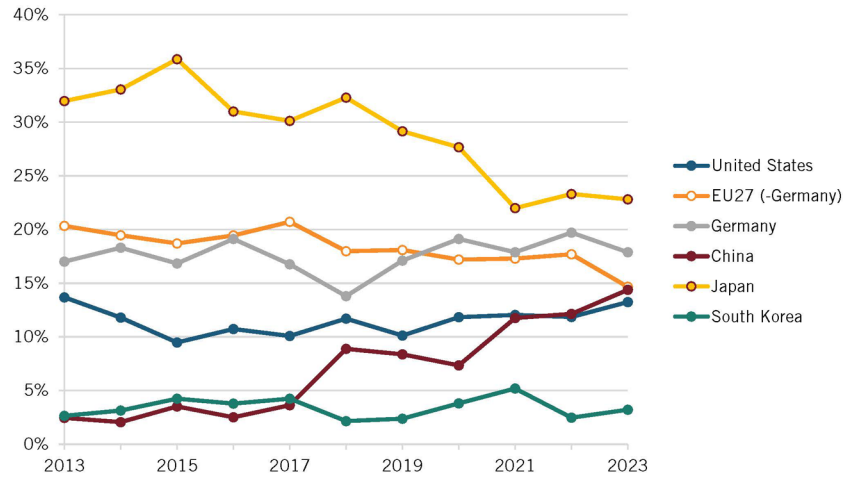
China's number of Patent Cooperation Treaty (PCT) patent publications in motor vehicle technologies increased from 25 in 2013 to 201 in 2023. (See figure 14.) That represents about a 700 percent increase over that period (albeit from a low base). By contrast, the United States and EU only increased these patents by about 32 percent and 19 percent, respectively.

Figure 14: Number of PCT patent publications in motor vehicles (B62D)[157]



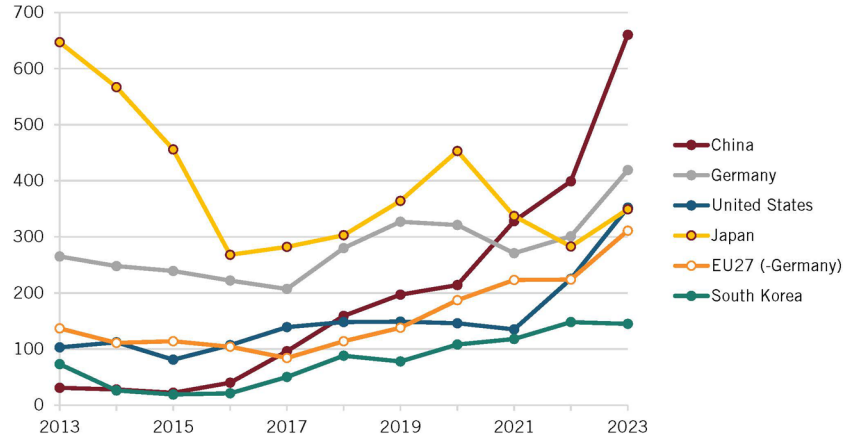
When considering global shares of PCT patent publications, China's global share increased 11.9 percentage points between 2013 and 2023. (See figure 15). By contrast, the global shares of patent publications for the EU and Japan declined by about 4.8 percentage points and 9.2 percentage points, respectively.

Figure 15: Global shares of PCT patent publications in motor vehicles (B62D)[158]



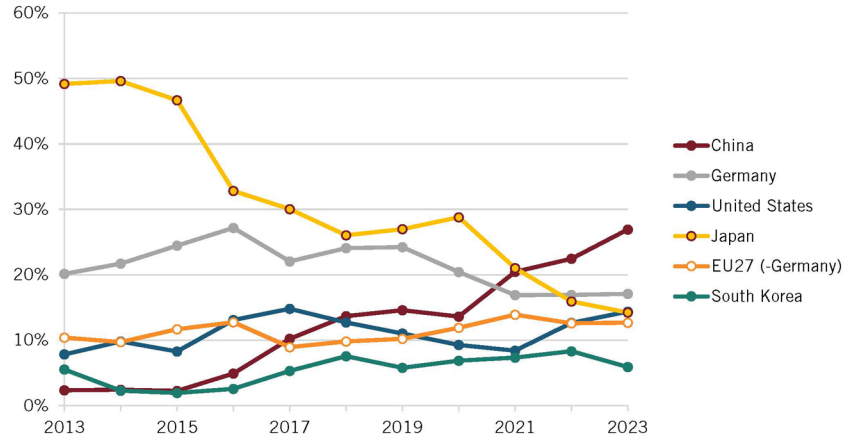
A related technology area is electric propulsion technology, which goes into the design of parts for EVs. In this area, China went from only 31 patent publications in 2013 to 660 patent publications in 2023. That's an astonishing increase of over 2,000 percent. (See figure 16.) By comparison, the United States increased its number of patent publications in this field by about 242 percent over that timeframe. Japan produced about 46 percent fewer patent publications in this area in 2023 than in 2013.

Figure 16: Number of PCT patent publications in electric propulsion technology (B60L)[159]



When considering global shares of PCT patent publications in this field, China's share increased from 2.4 percent in 2010 to 26.9 percent in 2020. (See figure 17.) That represents a 24.5 percentage point increase over that period. The United States also experienced an increase in its global share by about 6.5 percentage points. By contrast, the global share in this field for Japan declined by about 34.9 percentage points.

Figure 17: Global shares of PCT patent publications in electric propulsion technology (B60L)[160]



COMPANY CASE STUDIES

This section provides case study analyses of two Chinese EV companies: BYD and Li Auto. They were intentionally selected as representative from Chinese EV companies included on the "2023 EU Industrial R&D Investment Scoreboard" report.

BYD

BYD, the pinyin initials of the company's Chinese name, Biyadi, was founded in 1995 in Shenzhen, China. The company's name has now been "back-formed" into the Western-friendly slogan "Build Your Dream."[161] BYD entered the automotive sector through the acquisition of Qinchuan Automobile in 2003. BYD's initial focus was manufacturing batteries for ICE vehicles, although the company manufactured its first PHEV in 2008. In 2023, BYD became the world's largest manufacturer of EVs. It is also a significant manufacturer of EV batteries. Overall, BYD's product range covers the entire industrial chain of NEVs, including passenger vehicles, commercial vehicles, batteries, and automotive electronics.

In FY 2023, BYD's revenues reached 602 billion yuan ($82 billion), with EVs accounting for approximately 70 percent as the company accounted for 37 percent of EVs produced in China (a share analysts expect to reach 50 percent by 2026).[162] In 2022, BYD manufactured 4 of the top 10 EVs sold worldwide.[163] Overall, BYD is the world's largest producer of rechargeable batteries, including NiMH batteries, lithium-ion batteries, and NCM batteries.[164] In 2023, BYD manufactured 117 gigawatt hours (GWh) worth of EV battery production, compared with CATL's 243.3.[165] In 2020, BYD launched its then-revolutionary long-range Blade LFP battery, which is far less prone to spontaneous combustion than other EV batteries.[166] In April 2024, BYD introduced its second-generation blade battery pack, which the company asserted "will be lighter, smaller and more efficient than BYD's first-generation LFP batteries" with "as much as 190 kWh density enabling up to 1000 km range."[167] Beyond the Blade Battery, BYD's other core technologies include the (cell-to-body) CTB-integrated battery technology and the e^4 drive system.

BYD has received much recognition for its innovation and leadership in the industry. In fact, from 2020 to 2023, BYD received over 191 international awards in regions outside China, highlighting its global recognition and leadership within its sector. These accolades include the Zayed Future Energy Prize, the Japan EV of the Year, the UN Energy Special Award, nominations among the top three for the World Car of the Year and World Urban Car at the Geneva Motor Show, and Automotive Innovation Awards in Germany.

As of year-end 2023, BYD's R&D team comprised 69,700 personnel (significantly outnumbering Tesla's estimated 10,000 to 13,000 employees). The number of BYD R&D personnel increased 66 percent from 2021 to 2022, with BYD's R&D team representing 12.2 percent of the company's workforce. At year-end 2023, the team included 36,018 individuals with bachelor's degrees, 7,827 with master's degrees, and 590 with doctorates.[168] By July 2024, BYD reported employing 102,000 R&D personnel. In 2023, BYD hired some 30,000 university graduates (under- and post-graduate) with research personnel accounting for 80 percent of the total intake.[169] In 2023, BYD allocated 39.92 billion yuan ($5.5 billion) to R&D, which gave the company an R&D intensity of approximately 6.7 percent.

By year-end 2023, BYD held 29,201 patents globally, with 18,968 active. Annually, since 2016, BYD has consistently filed between 2,000 and 3,000 new patents. Within this portfolio, 23,346 patents were filed in mainland China, while 1,300 were registered in the European region, and 1,009 in the United States. Notably, of the U.S. filings, 893 patents originated from BYD's automobile business, with close to 570 receiving formal approval.[170]

BYD is a "privately-owned" company, although, of course, under Article 19 of China's *Company Law*, all SOEs or private Chinese companies have a Chinese Communist Party (CCP) cell that management must listen to, if not necessarily obey.[171] Article 19 in essence codifies CCP influence over corporate governance and business decisions in China.[172] From 2017 to 2022, BYD received government subsidies amounting to approximately $4.175 billion for NEV purchases and $0.92 billion in direct subsidies, reflecting significant government support for the NEV industry.

Li Auto

Founded in 2015 and headquartered in Beijing, Li Auto is an NEV company specializing in the design, development, manufacturing, and sale of EVs, particularly PHEVs. The company's current products include Li MEGA, a high-voltage BEV; Li L9, a six-seat flagship family SUV; Li L8, a six-seat family SUV; and Li L7, a five-seat flagship family SUV. In 2023, Li Auto sold 376,030 vehicles, an increase of over 180 percent from the year prior; this placed Li Auto as China's seventh-largest EV maker, with a 4.9 percent market share.[173] For the 12 months ending March 31, 2024, Li Auto earned $10.2 billion in revenues, a 182 percent increase year over year.

Li Auto has been developing technologies such as EREV4 Powertrain (combining battery power with range extension), BEV technologies, and autonomous driving. The company's intelligent system technology for EVs in the context of digital transformation made it the winner of the 2023 IDC China Future Enterprise Awards Excellence Award. Li Auto was also the first Chinese automaker to receive the world's highest MSCI ESG global "AAA" rating, which acknowledges its development and use of clean technology for environmental sustainability. Li Auto introduced its advanced integrated drive module (iDM220) to the company's EVs in 2023.

Li Auto took different development and innovation strategies compared with its domestic and global peers. Li Auto is backed by some of China's largest tech giants, such as Meituan and ByteDance. Having been in the Internet sector for two decades before starting the company, Li, the founder, took a different route from other Chinese EV start-ups by focusing on plug-in hybrids rather than pure EVs. Unlike BYD's more mass-market models, Li Auto's offerings are more niche, such as SUVs or larger multi-purpose vehicles targeting wealthier Chinese consumers with bigger families. The company has only recently entered the full BEV space with its Li MEGA.

In terms of its R&D and patent activity, Li Auto's R&D investments reached 1.3 billion yuan ($193 million), 742 million yuan ($103 million), and 61 million yuan ($8.5 million) in 2022, 2021, and 2020, respectively.[174] In 2022, Li Auto's R&D investment increased 87 percent over the prior year, although its R&D intensity for the year only reached about 3 percent (about half that of BYD's). Li Auto employed 4,318 R&D personnel at year-end 2022, accounting for 22.3 percent of its employees. The company states that it had 2,028 granted patents and 5,887 pending patent applications in China as of the end of 2022. Most of Li Auto's patents have been filed and granted in China.[175]

CHINA'S GOVERNMENT POLICIES SUPPORTING THE EV SECTOR

While Chinese EV enterprises have become increasingly innovative in their own right, there's little doubt that China's current leadership in EVs and EV batteries stems from a conscientious strategy and set of industrial policies designed to make it so. Indeed, as Gregor Sebastain, an analyst with the Rhodium Group, explained, "Without government-led industrial policy, the EV sector wouldn't be nearly what it is today in China."[176]

Or, as Erica Downs, an expert in Chinese energy markets at Columbia University's Center on Global Energy Policy explained, "The government in China went all in on EVs."[177]

The Chinese government began investing in EV-related technologies as early as 2001, when EV technology was introduced as a priority science research project in China's 10th Five-Year Plan.[178] However, observers credit much of China's EV vision to Wan Gang (a Chinese citizen employed as a Germany-based fuel-cell engineer at Volkswagen-Audi early in his career) who became China's minister of science and technology in 2007. Gang convinced Chinese leaders that China was unlikely to catch up to global leaders in ICE technologies but could potentially develop NEVs as a leapfrog technology.[179] One of China's earliest EV policy promulgations, from 2009, pledged 10 billion yuan ($1.375 billion) to support the industry over the ensuing three years and extended one-off purchase subsidies for NEVs to public sector companies in 13 cities.[180]

The support of China's government (at both the federal and provincial levels) has been instrumental at every stage in advancing China's EV industry.

While initially China wished to expand domestic vehicle production as a source of economic and employment growth, as former Chrysler executive (and current China auto industry analyst) Bill Russo explained, "The primary motivation for China to push for EVs was energy security," notably to reduce China's need for imports of oil (and autos). "Second was industrial competitiveness, and a far distant third was sustainability."[181] That said, Chinese leaders today bill sustainability—notably meeting the country's 2060 carbon-neutral climate goal—as a key rationale for EV deployment, and one study finds that EVs could help reduce China's GHG emissions from the transportation sector by up to 6.2 percent by 2030 with a 20 percent EV penetration rate (of the total Chinese vehicle fleet).[182]

Indeed, the support of China's government (at both the federal and provincial levels) has been instrumental at every stage in advancing China's EV industry, from setting strategic direction to financing R&D to providing the industry with tens of billions of dollars of subsidies to deploying charging infrastructure to incentivizing EV adoption through a range of policies from government procurement to consumer tax credits to readily providing licenses for electric (but not gas-powered) vehicles.

Subsidies

While all these factors have moved China's EV market forward, subsidies have far and away been the most substantial. Scott Kennedy and colleagues at the Center for Strategic and International Studies (CSIS) estimated that, from 2009 to 2023 alone, China channeled $230.9 billion in subsidies and other support to its domestic EV sector.[183] (Note: $25 billion of this amount was

R&D investment, which ITIF would generally not characterize as a market-distorting subsidy, so long as a country makes enterprises from all nations eligible for R&D tax credits or the ability to win R&D grants.) CSIS found that Chinese EV subsidies have only increased in recent years, with an estimated $120.9 billion in subsidies over just the previous three years ($30.1 billion in 2021, $45.8 billion in 2022, and $45.3 billion in 2023), compared with a total of $49 billion in subsidies the three years prior, and $60.7 billion in subsidies from 2009 to 2017 (then at a $6.74 billion annual rate).[184] In 2023, the Chinese government extended $809 million in subsidies to EV battery maker CATL (more than double the $401 million it provided in 2022) and $208.9 million to EVE Energy (China's fourth-largest EV battery producer).[185] From 2018 to 2023, the Chinese government extended a total of $1.8 billion in subsidies to CATL alone.

CSIS's estimates calculate five forms of subsidy support for China's EV sector: nationally approved buyer rebates, exemption from the 10 percent sales tax, government funding for infrastructure (primarily charging infrastructure), R&D programs for EV makers, and government procurement of EVs.[186] CSIS found that from 2009 to 2017, buyer's rebates accounted for 62 percent of the Chinese government's support for the sector, but with the Chinese government reducing the buyer's rebate in 2022 and eliminating it as of 2023, the largest form of support (87.4 percent of the total, or $39.6 billion) in 2023 came from sales tax exemptions.[187]

From 2009 to 2023 alone, China channeled $230.9 billion in subsidies and other support to its domestic EV sector.

A key reason why Chinese subsidies to the EV sector (just like any other advanced-technology sector) are so pernicious is that they enable Chinese companies to both sustain themselves in industries where they wouldn't be able to subsist if they had to earn market-based rates of return and, similarly, sell products below cost and sustain losses while still being able to build economies of scale. As *The New York Times'* Bradsher explained, China automaker Nio lost $835 million from April through June 2023, equivalent to a loss of $35,000 for each car it sold.[188] (A separate study finds that China BYD's profitability per vehicle in Q3 2023 was just $1,460, compared with $5,330 for Tesla, noting that BYD was underpricing its vehicles to build market scale.)[189] Moreover, if this aggressive strategy of selling vehicles below costs fails, China steps in to rescue the automaker. As Bradsher observed, "When Nio nearly ran out of cash in 2020, a local government immediately injected $1 billion for a 24 percent stake, and a state-controlled bank led a group of other lenders to pump in another $1.6 billion."[190]

Thus, an important point is that it's both the Chinese government and provincial governments that are providing financing and subsidies for Chinese EV players. As the U.S.-China Economic and Security Review Commission explained, "Local governments, rather than central ministries, [have] played the leading role in deploying consumer subsidies for EV purchases."[191] This matters because it means Chinese provincial governments have played a key role in propping up uncompetitive firms and contributing to overcapacity (and also inefficiency) in the sector. Local governments in China have given auto manufacturers nearly free land, loans at near-zero interest, and other subsidies.[192] (A World Bank report found that, in 2022, China's automotive sector as a whole received loans with interest rates of roughly 2 percent, half the weighted average for all commercial and industrial loans.)[193] As CSIS's Ilaria Mazzocco elaborated, "Local governments denied subsidies for EVs made in other provinces, and public officials supported local firms by

procuring solely from manufacturers located in the same city. This created a highly fragmented market with hundreds of EV manufacturers, many of which failed to bring a car into production."[194] The essential point is that subsidies at all levels of Chinese government have contributed considerably to industrial overcapacity in EVs and explain why there are over 200 EV car manufacturers currently operating in China.[195]

JVs and Technology Transfer Requirements

As *The Economist* wrote, Chinese EV subsidies "come on top of the ransacking of technology from joint ventures with Western carmakers and South Korean battery-makers."[196] Indeed, China has long employed a practice called "trading technology for market," conditioning foreign companies' access to Chinese markets on the transfer of technology and IP (and/or opening research or production facilities in China). In fact, China introduced its inaugural "Law on Joint Venture Using Chinese and Foreign Investment" in July 1979, and it yielded some important deals, including Volkswagen in 1994 signing a 25-year contract to build vehicles and engines in Shanghai.[197] However, over time, China's approach to attracting foreign direct investment, and thus technology transfer, evolved from attraction to compulsion, especially as its growing market gave it an increasing ability to dictate detailed terms. For instance, as ITIF wrote in its 2011 book *Innovation Economics: The Race for Global Advantage*, "Ford Motor Company has opened several automobile plants in China, but as a condition of access had to do so as part of a joint venture with a Chinese auto firm. Moreover, the Chinese government required Ford to open an R&D laboratory employing at least 150 Chinese engineers."[198]

However, as several analysts noted, "While certainly boosting production, the intention to also transfer critical internal combustion engine (ICE) capability to Chinese partners largely failed."[199] Indeed, it was this recognition that, despite tech transfer requirements and industrial upgrading efforts, Chinese firms simply weren't going to catch up in ICE vehicles that precipitated China's embrace of EVs as a potential alternative leapfrog technology. Nevertheless, Chinese tech transfer requirements forced Western automakers to divulge key clean energy technologies, especially in the early years.

For instance, as *The New York Times* wrote in 2011, "The Chinese government is refusing to let the Volt qualify for subsidies totaling up to $19,300 a car unless G.M. agrees to transfer the engineering secrets for one of the Volt's three main technologies to a joint venture in China with a Chinese automaker."[200] That said, as one observer noted, if anything, the reality in the EV industry today is the concept of "reverse joint ventures," where Chinese firms are sharing EV technology with Western companies (in exchange for market access or financing).[201]

IP Theft

Nevertheless, whatever EV IP or technologies Chinese entities can't acquire by enticing foreign enterprises to barter away, China seeks to acquire through state-sanctioned IP theft. As Nicholas Eftimiades, author of the book *Chinese Intelligence Operations* and who has extensively documented Chinese industrial espionage activities over his four-decade career, wrote, "Out of 724 cases of Chinese espionage, we find about 500 are directed toward main technologies, [including] aerospace technologies, IT technologies, clean energy technologies, and automotive, electric vehicle technology."[202]

In fact, in 2020, Federal Bureau of Investigation director Christopher Wray warned explicitly that "China is placing a priority on stealing electric car technology," as the Chinese government is "fighting a generational fight to surpass our country in economic and technological leadership."[203] As Wray elaborated, "We see Chinese companies stealing American intellectual property to avoid the hard slog of innovation, and then using it to compete against the very American companies they victimized—in effect, cheating twice over."[204] In February 2020, William Evania, director of the National Counterintelligence and Security Center, singled out two fields where China is putting a priority on technology theft: EVs and aircraft.[205]

Whatever IP or technologies can't acquire by enticing foreign enterprises to trade away, China seeks to acquire through state-sanctioned IP theft.

Indeed, U.S. EV companies are feeling the brunt of coordinated Chinese efforts to pilfer their technology. In September 2023, Tesla sued Chinese chip designer and auto parts maker Bingling for infringing its IP and stealing its trade secrets, both related to the integrated circuits (i.e., semiconductors) Tesla uses in its vehicles.[206] In June 2024, Klaus Pflugbell (a Canadian and German national living in China) pleaded guilty to conspiring to sell trade secrets (about EV batteries) that belonged to a leading U.S.-based EV company to Chinese entities.[207]

Favoring Domestic Enterprises

The Chinese government has long worked to favor domestic over foreign suppliers in automotive supply chains. For instance, China's "Made in China 2025" strategy (released in 2015) stipulates that more than 70 percent of the one million-plus EVs and plug-in hybrids (then sold annually) in China should be from homegrown brands by 2020. The target set for 2025 was 80 percent of the market (or a then-estimated three million vehicles).[208]

More recently, in March 2024, the Chinese government reportedly asked EV makers from BYD to Geely Automobile Holdings Ltd. to sharply increase their purchases from local auto chipmakers, part of a campaign to reduce reliance on Western imports and boost China's domestic semiconductor industry.[209] China's Ministry of Industry and Information Technology (MITI) has directly instructed Chinese automakers to avoid foreign semiconductors if at all possible.[210] The Ministry had previously "set an informal target for automakers to source a fifth [of] their chips locally by 2025."[211]

Other Policies

While most of the aforementioned Chinese policies to support the EV and EV batteries sectors have been innovation mercantilist in nature, certainly some policies have been legitimately or smartly designed to promote innovation in EVs and batteries or adoption of these technologies. For instance, China directed an estimated $25 billion toward R&D activities in its EV industry from 2009 to 2023.[212] As ITIF has written, countries electing to compete in advanced-technology industries through constructive policies such as investments in R&D or education can produce genuine innovations that benefit humankind.[213]

Certainly, Chinese policymakers have put their thumb on the scale for electric as opposed to ICE vehicle adoption among consumers. For instance, Shanghai authorities have long offered EV owners license plates at no cost.[214] In many Chinese cities, EVs are not restricted by traffic

control measures (policies to limit the number of cars on the road during a prescribed period), are allowed to use bus lanes, and are offered free parking.[215]

China has also established the world's largest public charging infrastructure network, with its public charger stock reaching 1 million—51 percent of the global total—and a total rated power exceeding 56 gigawatts as of 2022.[216] Several Chinese cities have established widely distributed public charging networks in their urban cores, in which virtually 100 percent of EV drivers can find a public charger within 20 minutes of driving time.[217] However, observers note that China has a considerable way to go with EV charging coverage in rural (and even suburban) areas and that "highways are a particular weak spot of China's public charging infrastructure network" with a highway public charger density one-sixth that of Norway.[218]

Active government procurement of EVs has also played an important role in creating a market for (and driving adoption of) EVs in China. In 2014, China required that the central government, as well as some cities and public organizations, have at least 30 percent of their vehicle fleet consist of EVs by 2016, a goal which increased to 50 percent in 2016.[219] One study finds that public sector entities across China's provinces had already procured over 550,000 EVs by the end of 2020.[220] CSIS estimates that China directed $18 billion in government procurement to EVs from 2009 to 2023.[221]

Chinese regulators also appear more predisposed to permit innovative automotive technologies to reach roadways more quickly. For instance, as Bradsher wrote, "In the United States, Tesla's so-called Autopilot feature has been the subject of a series of government safety investigations. But in China, regulators and the general public have tended to see the technology as safer than relying on human drivers."[222]

Analysis of Chinese Policies Supporting the EV Sector

Should China's success with EVs be viewed as beneficial to the global economic system and to global concerns such as mitigating global warming? *The Economist* wrote, "Now China's carmakers are enjoying an astonishing rise. That stokes fears of another ruinous shock. In fact, the successes of Chinese cars should be celebrated, not feared."[223] That would be true if competitive Chinese EVs were genuinely and solely the result of compelling innovations and efficient production processes, but as this report has shown, that's not truly the case. While Chinese EV makers have shown some degree of domestic innovation, the sector has benefitted tremendously from state-sponsored IP theft, massive industrial subsidization, and innovation mercantilist practices that distort the economics of the industry and severely disadvantage foreign automakers—and the employees who work at them. For instance, the auto industry supports 4.3 million U.S. jobs; these are as much at risk as the hundreds of thousands of jobs making solar panels or telecommunications networking equipment Americans have lost due to Chinese economic predation. *The Economist* is dead wrong to suggest that this is a cause of celebration; rather, it's one more salvo against the rules-based global trade order that *The Economist* otherwise professes to hold so dear.

It's also worth noting that the United States would likely be doing just fine in batteries (and EVs) had not a government artificially inflated supply, and demand, far ahead of vehicles' technological capabilities well beyond what consumers were ready to accept. But an authoritarian state such as China can massively distort markets and reap the benefits.

WHAT SHOULD AMERICA DO?

U.S. sales of EVs surpassed the one-million-unit mark in 2023 (an increase of 52 percent over the prior year), as the EV market share in the United States reached 7.5 percent.[224] There are now over 4.5 million EVs on America's roads. In contrast, more than half of EVs currently on the world's roads are found in China.

U.S. policy has already done much to stimulate EV production and adoption. As noted, between the 2021 Infrastructure Investment and Jobs Act and the subsequent Inflation Reduction Act, the U.S. Congress has allocated over $245 billion in public expenditures toward EVs.[225] As of July 2024, Americans who purchase new EVs may be eligible for a tax credit of up to $7,500, and buyers of used electric cars may qualify for up to a $4,000 credit.[226] In June 2024, the U.S. Department of the Treasury and Internal Revenue Service announced that American consumers had saved more than $1 billion in upfront costs on their purchase of more than 150,000 clean vehicles since January 1, 2024.[227] Since January 2023, the prices of EV vehicles sold in the United States have decreased by 20 percent, and the number of publicly available charging points has grown by 70 percent.[228] There are continued efforts to push out more charging points through both public and private investment, and U.S.-based production of fast chargers has increased.[229]

On January 18, 2024, the Department of Energy (DOE) announced over $130 million in funding for research, development, and technology integration projects for zero-emission vehicles and mobility, with the funds also to be used to launch an advanced battery R&D consortium. That funding built on an additional $32 million DOE for the same program earlier in the month.[230]

On July 11, 2024, the Biden administration announced $1.7 billion in grants to GM, Stellantis, and other carmakers to help restart or expand EV manufacturing and assembly in eight U.S. states. The grants will cover many parts of the automotive supply chain, including parts for electric motorcycles and schools buses, hybrid powertrains, commercial truck batteries, and electric SUVs.[231]

In May 2024, the Biden administration quadrupled U.S. tariffs on Chinese EVs entering the country, from 25 percent to 100 percent (that aside from an additional 2.5 percent duty that applies to all automobiles imported into the United States).[232] For its part, on June 12, 2024, the EU announced it would introduce, starting on July 1, 2024, tariffs that ranged from 17.4 percent to 38.1 percent on Chinese vehicle imports, on top of the EU's standard 10 percent car duty.[233]

The Inflation Reduction Act contains provisions whose intent is to impede imports of batteries and critical materials from companies from "foreign entities of concern" over the ensuing two years.[234] In particular, starting in 2025, buyers of vehicles using Chinese suppliers will become ineligible for the $7,500 clean energy vehicle tax credit.

For all this, as ITIF has written, clean energy technologies won't generally become competitive with existing ones until they reach P3 with them. So, for example, P3 for EVs will be achieved when the life cycle costs of EVs are the same as equivalent ICE vehicles, and have approximately the same performance in terms of reliability, refueling, range, acceleration, cargo capacity, etc.[235] Policymakers must also recognize that price signals, regulations, and subsidies alone will be insufficient to drive clean energy transformation. Instead, innovation- and technology-

advancing policies, such as investments in research and the development and commercialization of next-generation alternatives, are the best solution.[236]

In 2012, ITIF called for policymakers to organize a "BatteryShot Initiative" that would coordinate government battery research, development, and demonstration (RD&D) with the goal of producing a battery with a total system cost of less than $250/kWh and a range of at least 300 miles per charge.[237] While the targets will have changed in the 12 years since, the U.S. lag in the EV batteries space vis-à-vis China suggests **the next administration should launch such a "BatteryShot Initiative" with the goal of producing a battery with a total system cost of less than $200/kWh and a range of at least 1,000 miles per charge.** Such a BatteryShot effort could be part of the previously mentioned battery R&D consortium DOE said in January 2024 it would establish.

Created in 2014, the **Manufacturing USA network aims to secure the United States' leadership in advanced manufacturing product and process technologies, and therefore an additional institute should be stood up for EVs and EV batteries.** Manufacturing USA currently houses innovation institutes across five key sectors—electronics, materials, energy and the environment, digital and automation technologies, and biomanufacturing—and its commitment to clean energy manufacturing and manufacturing supply chains could be furthered by the addition of an EV institute, which could fall under the purview of the DOE-sponsored institutes.[238]

American drivers won't adopt EVs if they lack confidence in the existence of a comprehensive, reliable, and dependable national EV charging infrastructure. While some progress has been made in this area, much more needs to be done. For this reason, **U.S. government entities at all levels (federal, state, and local) should increase their coordination to create an easier-to-navigate environment for planning, funding, permitting, and infrastructure investments for EV charging stations.**[239] In particular, governments should implement interoperability and open access requirements for technical equipment while ensuring that they don't constrain the deployment of charging stations and pick "winners and losers."[240]

It was difficult to watch the 2024 European Championship and Copa America soccer tournaments without noticing that Chinese brands have become the events' dominant marketing partners. The Euros alone featured the Chinese brands Alibaba (AliExpress and Alipay+), BYD, Hisense, and Vivo. It should be galling—if not an exigent warning of a looming European industrial crisis—that Volkswagen refrained from becoming the leading 2024 Euro corporate partner (the tournament was played on German soil) due to "cost discipline" reasons, thus opening the door for BYD to become the lead automotive partner. This point aside, American (and European and Asian) policymakers **should pass legislation that precludes companies from countries of concern, such as China, from marketing their products in cases where 1) that country does not allow similar products from U.S. firms to be sold (and or marketed) in Chinese markets (i.e., lack of reciprocity), or 2) if products from such companies are benefitting from stolen technology or IP.**

For example, as a requirement of joining the World Trade Organization (WTO) in 2001, China committed to opening its financial markets to Western competitors. China slow-walked this commitment for years, and in 2012, the WTO ruled that China illegally protected UnionPay by not allowing foreign competition. Despite China losing the case, phase one of the resolution did not go into effect until 2020, inhibiting almost a decade's worth of competition and profit for

American companies such as Visa and Mastercard.[241] China still blocks various U.S. cloud and digital services products from its markets today.[242] Where this is the case, the United States and Europe should preclude equivalent Chinese firms from marketing their products in our markets.

This report has documented the extensive set of innovation mercantilist policies—including rampant IP theft and massive industrial subsidization—that has abetted China's rise in the EV and EV battery space. Section 337 of the 1930 Tariff Act allows the U.S. International Trade Commission (USITC) to bar imports when domestic industries suffer harm due to unfair competition.[243] **The next administration should designate a special task force to identify and document any Chinese or third-party countries' EV or EV battery companies that have benefited from innovation mercantilist practices and work with** the **United States Trade Representative and USITC to prevent such products from entering the U.S. market.** Historically, U.S. trade law, through trade tools such as Section 337, has conducted investigations to ascertain if specific products (such as aluminum foil of less than 8 microns of thickness) from specific companies have violated U.S. trade rules (such as dumping or IP theft).[244] This represents a very narrowly tailored instrument that makes it easy for foreign infringers to hop between infringing products and often evade effective prosecution. **U.S. policymakers should reform U.S. trade law such that, only for companies from nations identified as specific countries of concern, if a company is found guilty of selling more than three products in U.S. markets benefitting from pilfered IP (in any 10-year period), they are added to the U.S. entity list and wholesale blocked from selling its products in the U.S. market.**

To circumvent U.S. tariffs, many Chinese companies are eyeing Mexico as an attractive back door to start manufacturing their products and export them to the United States, taking advantage of the United States-Mexico-Canada's (USMCA) rules-of-origin provisions.[245] Indeed, there is strong evidence that Trump administration tariffs on China did decrease U.S. imports from China but increased imports from countries such as Mexico, and that's in part because more Chinese companies are establishing operations in Mexico.[246] Addressing this challenge will certainly be a key element in the upcoming 2026 review of the USMCA, but for the purposes of this report, **U.S. policy should make clear that EVs and EVs batteries manufactured by Chinese enterprises that have benefitted from IP theft or massive industrial subsidization will be subject to the aforementioned 100 percent tariff level no matter from which nation the Chinese company attempts to export.**

As noted, China dominates supply chains for the mining and refining of minerals and rare earths, giving its EV battery makers a cost and first-mover advantage. **The United States must lead an alliance of like-minded nations to build alternative EV battery input supply chains outside of Chinese control.** On June 22, 2023, India agreed to join the Minerals Security Partnership (MSP), a collaboration of 13 countries and the European Union designed to catalyze public and private investment in responsible critical minerals supply chains globally.[247] The MSP coordinates member nations to address four major critical minerals challenges: 1) diversifying and stabilizing global supply chains; 2) investment in those supply chains; 3) promoting high environmental, social, and governance standards in the mining, processing, and recycling sectors; and 4) increasing recycling of critical minerals.[248] Efforts here should be redoubled and more allies brought into the partnership.

Sourcing of clean energy and raw materials, as well as recycling of batteries, helps to lower production costs and should be encouraged. **The next administration should invest resources into**

clean recycling of batteries, which could meet as much as 18 percent of the cobalt demand and 17 percent of nickel demand by 2035.[249]

CONCLUSION

From manufacturing just 5,200 passenger vehicles in 1985 to manufacturing 26.8 billion this year, China has become a major player in the global automotive industry. Collectively, Chinese EV and EV battery enterprises have at least equaled—and in some cases surpassed—their Western peers in innovation capacity and product quality. While certainly the highest-end Western firms such as BMW and Tesla remain at the forefront, Chinese firms such as BYD, Xiaomi, and Li Auto are competing effectively at the luxury EV level, while in the mid-market, BYD, JiYue, Nio, and others are excelling at delivering attractive, cost-competitive EVs. China's leadership in EVs certainly began as a result of intentional industrial policy and guidance, especially through market-making activities such as intensive industrial subsidization. However, from that base, Chinese EV players have become increasingly capable, innovative, and competitive in their own right. Much is to be done if the United States is to recapture leadership in this critically important technological field.

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Any errors or omissions are the author's responsibility alone.

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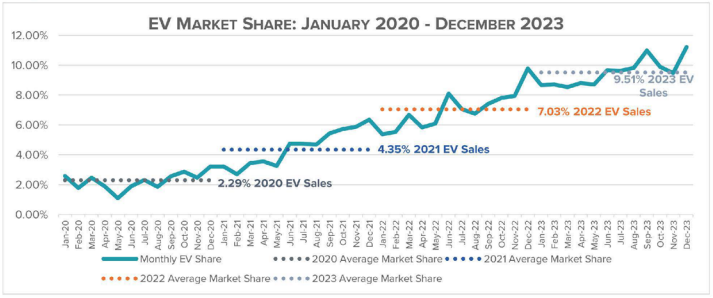
ELECTRIC VEHICLE SALES OVERVIEW (2023)

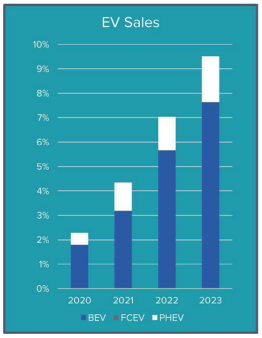
In the fourth quarter of 2023, automakers sold about 377,000 electric vehicles (EVs, including battery, plug-in hybrid, and fuel cell electric vehicles) in the United States, representing 10.2 percent of overall light-duty vehicle sales. This represents a 0.1 percentage point (pp) market share increase over the third quarter of 2023 and a decrease of about 500 vehicle sales.

Year-over-year (YoY), market share increased 1.7 pp from the fourth quarter of 2022. Over 94,000 more EV units were sold than the same period in 2022, a 34 percent increase. More than 1.4 million EVs were sold in 2023, 9.5 percent of all light vehicle sales and an increased market share of 2.5 pp over 2022. The total volume of all light-duty sales in 2023 was up 12 percent from 2022, while the volume for EVs increased 51 percent (an increase of nearly 481,000 vehicles). For comparison, internal combustion engine (ICE) vehicle market share decreased by 5.5 pp during 2023 compared to 2022. [1]





Historic Data on EV Sales



[1] Hybrid vehicles comprised the remainder of the gains in vehicle share.

ELECTRIC VEHICLE SALES BY SEGMENT

EV Model Availability

114 Vehicle Models Sold in Q4 2023:

67 Battery Electric Vehicles
- 23 Cars
- 35 Utility Vehicles
- 5 Pickups
- 4 Vans

45 Plug-in Hybrid Vehicles
- 15 Cars
- 29 Utility Vehicles
- 1 Van

2 Fuel Cell Electric Vehicles
- 1 Car
- 1 Utility Vehicle

See more information about ***EV CHOICE HERE***

For a list of EVs that qualify for the federal government's new clean vehicle tax credit of up to $7,500 ***CLICK HERE***.

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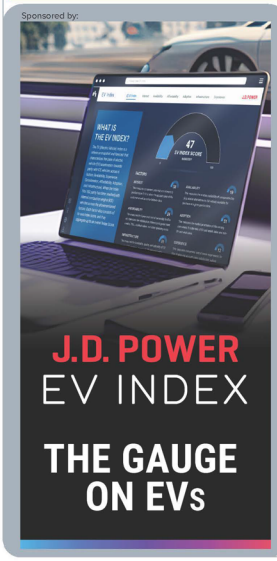
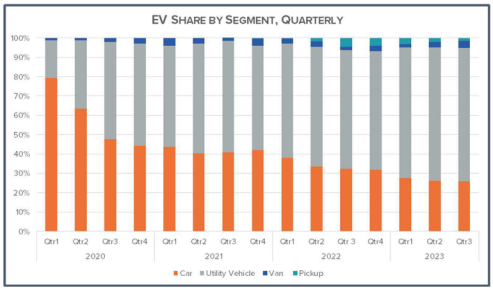
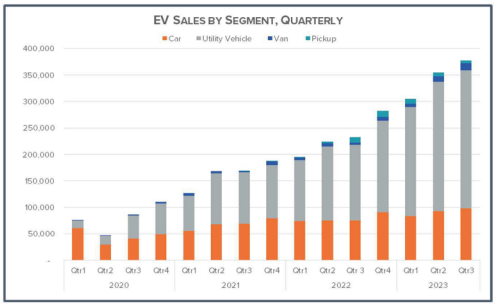


While passenger cars once dominated the EV market, manufacturers continue to introduce new models to satisfy a variety of consumer needs. Utility vehicle (UV) offerings continue to grow, and while electric pickup trucks are a relatively new entry to the market (making their commercial debut in September 2021), there are 5 models available now, with more expected soon. As a result, non-car segments are continuing to make gains, and in the fourth quarter of 2023, light truck (UVs, minivans, and pickups) sales comprised 78 percent of the EV market – a 10 pp increase over the fourth quarter of 2022.

Quarterly sales of BEV and PHEV UVs have grown from about 19 percent of EVs at the start of 2020 to 72 percent in the fourth quarter of 2023. Nearly 100,000 more UVs were sold in the fourth quarter of 2023 than the fourth quarter of 2022.

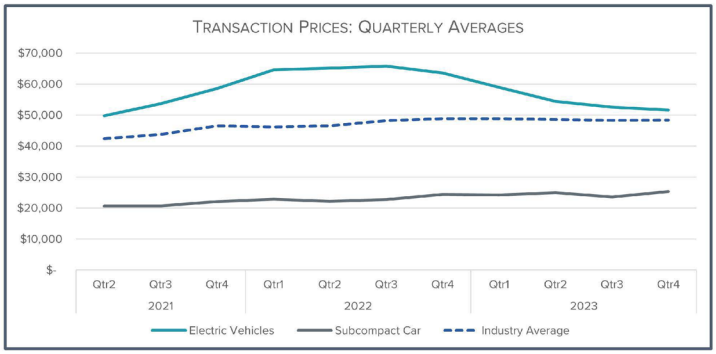




Source: Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobilitycovering January 1, 2020 – December 31, 2023

ELECTRIC VEHICLE TRANSACTION PRICES

The cost of the average EV in the fourth quarter of 2023 was about $51,600 while the average cost of all new light-duty vehicles in that time period was about $48,300. Year-over-year, EV prices declined more than $12,000 from the fourth quarter of 2022 while the average cost of all new light duty vehicles was mostly unchanged.[2] While increased competition in the EV market has led to some price decreases, slowing sales paired with increased inventory and incentives are also playing a part in lower transaction prices. As noted by Kelley Blue Book, "while the higher inventory levels and increased competition continue to drive down the price premium of EVs, it's important to acknowledge that EVs remain priced above mainstream non-luxury vehicles by nearly 19%.[3]"



[2] Average transaction prices from Kelley Blue Book, monthly press releases
[3] Kelley Blue Book, Press Release, "New-Vehicle Average Transaction Prices Retreat for Second Straight Month, According to Latest Kelley Blue Book Estimates," 3/11/2024

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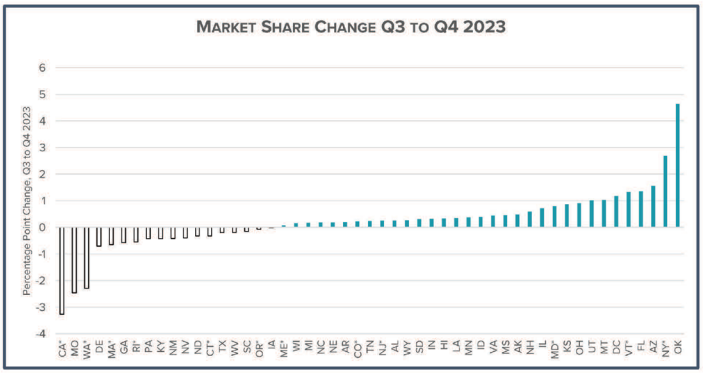
ELECTRIC VEHICLE SALES BY STATE

For the Fourth Quarter of 2023

California continued to lead the nation in EV sales, with BEVs, PHEVs and FCEVs making up 25 percent of new light-duty vehicle registrations in the fourth quarter of 2023. There are currently twelve additional states[4] and the District of Columbia with new vehicle EV registrations above 10 percent. However, more than one-third of states saw a decrease in market share from the third quarter of 2023. Eighteen states lost market share from the third quarter, including California (-3.3 pp), Missouri (-2.5 pp), and Washington (-2.3 pp).

For the fourth quarter of 2023 vs the fourth quarter of 2022, the market share of new EVs registered increased in all but three states[5]. Twelve states and the District of Columbia witnessed an increased market share of EVs by 2 pp or more. Making the largest increases were Colorado (6.9 pp), Oklahoma[6] (5.6 pp), District of Columbia (5.5 pp), New York (5.4 pp), New Jersey (3.7 pp), Maryland (3.6 pp), and Vermont (3.3 pp).

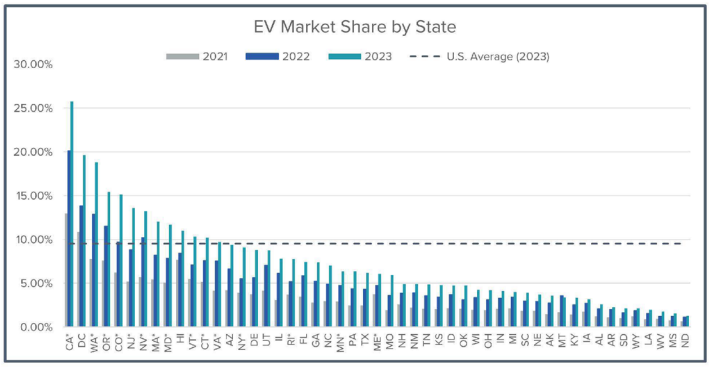


For the Full Year 2023

For the full year 2023, EV sales represented 9.5 percent of the market – a 2.5 pp increase over 2022. Nearly 26 percent of sales in California were EVs over this period, but Washington realized the greatest increase in market share, year-over-year with a 5.9 pp increase. Following Washington, the states with the largest market share gains were District of Columbia (5.8 pp), California (5.6 pp), Colorado (5.5 pp), and New Jersey (4.8 pp). Nineteen states and DC increased their year-over-year EV market share by 2 pp or more. Seventeen states increased by less than 1 pp. One state, Montana, decreased.

[4] States with more than a 10 percent market share of EVs: California, District of Columbia, Washington, Colorado, Oregon, New Jersey, Maryland, Nevada, Massachusetts, Vermont, New York, Hawaii, Connecticut, and Arizona
[5] The three states are: Michigan, North Dakota, and Missouri
[6] Oklahoma is an outlier state due to fluctuating fleet vehicle registrations.
[7] *Denotes states that have adopted California's ZEV program; Oklahoma is an outlier state due to fluctuating fleet vehicle registrations.

Eleven states and the District of Columbia had an EV market share above 10 percent while four states had an EV market share under 2 percent; California was the only state above 20 percent.[8]



2023 (Full Year) EV Market Share by State

1	CA*	25.71%	11	VT*	10.32%	21	GA	7.39%	31	KS	4.79%	41	MT	3.40%
2	DC	19.63%	12	CT*	10.19%	22	NC	7.03%	32	ID	4.75%	42	KY	3.34%
3	WA*	18.79%	13	VA*	9.73%	23	MN*	6.37%	33	OK	4.74%	43	IA	3.16%
4	OR*	15.42%	14	AZ	9.39%	24	PA	6.34%	34	WI	4.26%	44	AL	2.57%
5	CO*	15.14%	15	NY*	9.06%	25	TX	6.20%	35	OH	4.23%	45	AR	2.26%
6	NJ*	13.59%	16	DE	8.78%	26	ME*	6.05%	36	IN	4.13%	46	SD	2.12%
7	NV*	13.23%	17	UT	8.73%	27	MO	5.95%	37	MI	4.00%	47	WY	2.11%
8	MA*	12.04%	18	IL	7.80%	28	NH	4.91%	38	SC	3.88%	48	LA	1.98%
9	MD*	11.70%	19	RI*	7.75%	29	NM	4.89%	39	NE	3.72%	49	WV	1.77%
10	HI	11.01%	20	FL	7.43%	30	TN	4.88%	40	AK	3.58%	50	MS	1.53%
												51	ND	1.28%

[9]

[8] Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering January 1, 2021 – September 30, 2023
[9] *Denotes states that have adopted California's ZEV program

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21 INTEREST
100 AFFORDABILITY
43 AVAILABILITY
41 INFRASTRUCTURE
20 ADOPTION
85 EXPERIENCE

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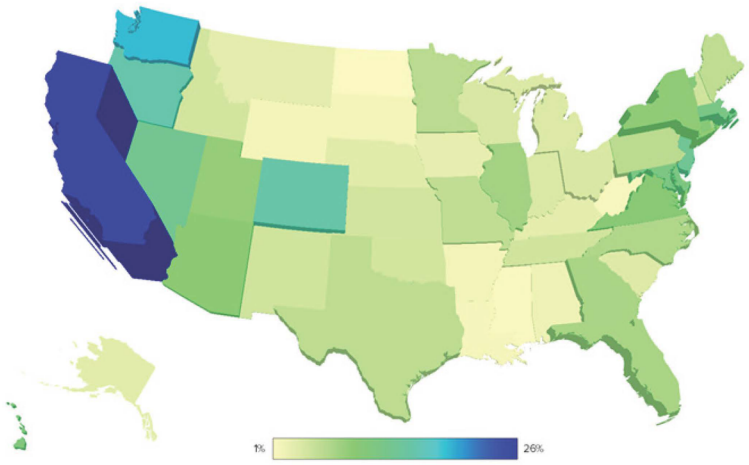
STATE EV MARKET SHARE (2023) AND INSTALLED CHARGING PORTS

(HEIGHT REPRESENTS NUMBER OF INSTALLED CHARGING PORTS AND COLOR REPRESENTS 2023 STATE EV MARKET SHARE)



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New Light-Duty Vehicle Registrations by Powertrain, Fourth Quarter 2023

Fourth Quarter 2023, New Light-Duty Vehicle Registrations By Powertrain					Change In Market Share (2023 Q4 vs 2022 Q4), New Light-Duty Vehicle Registrations Powertrain			
State	Advanced Powertrain Market Share				Advanced Powertrain Market Share (Percentage Point Change)			
	PHEV	BEV	FCEV	EV Total	PHEV	BEV	FCEV	EV Total
AK	0.57%	3.18%	0.00%	**3.75%**	-0.06	0.36	0.00	**0.30**
AL	0.89%	1.98%	0.00%	**2.87%**	0.28	0.15	0.00	**0.43**
AR	0.59%	1.88%	0.00%	**2.47%**	0.05	0.53	0.00	**0.59**
AZ	1.42%	8.98%	0.00%	**10.40%**	0.12	2.60	0.00	**2.72**
CA*	3.51%	21.31%	0.05%	**24.87%**	0.35	0.91	-0.12	**1.14**
CO*	4.50%	13.66%	0.00%	**18.16%**	1.83	5.10	0.00	**6.93**
CT*	3.75%	7.11%	0.00%	**10.86%**	1.23	0.79	0.00	**2.02**
DC	4.25%	16.22%	0.00%	**20.47%**	0.64	4.84	0.00	**5.49**
DE	2.35%	6.63%	0.00%	**8.98%**	0.84	1.24	0.00	**2.08**
FL	1.00%	7.76%	0.00%	**8.76%**	0.02	2.15	0.00	**2.18**
GA	1.26%	6.24%	0.00%	**7.50%**	0.37	0.85	0.00	**1.22**
HI	1.92%	9.65%	0.00%	**11.57%**	0.30	1.35	0.00	**1.65**
IA	0.90%	2.50%	0.00%	**3.40%**	-0.09	0.41	0.00	**0.32**
ID	1.66%	3.90%	0.00%	**5.56%**	0.23	1.27	0.00	**1.50**
IL	1.68%	6.87%	0.00%	**8.55%**	0.25	0.87	0.00	**1.13**
IN	1.30%	3.55%	0.00%	**4.85%**	0.35	0.56	0.00	**0.91**
KS	1.46%	4.29%	0.00%	**5.75%**	0.31	1.17	0.00	**1.48**
KY	0.74%	2.71%	0.00%	**3.45%**	-0.02	0.57	0.00	**0.55**
LA	0.82%	1.43%	0.00%	**2.25%**	0.28	0.20	0.00	**0.48**
MA*	3.86%	8.72%	0.00%	**12.58%**	0.92	1.41	0.00	**2.33**
MD*	3.65%	9.91%	0.00%	**13.56%**	1.44	2.21	0.00	**3.64**
ME*	3.21%	3.57%	0.00%	**6.78%**	0.86	0.37	0.00	**1.22**
MI	0.91%	3.25%	0.00%	**4.16%**	-0.42	0.41	0.00	**-0.01**
MN*	1.80%	5.38%	0.00%	**7.18%**	0.28	0.67	0.00	**0.94**
MO	1.21%	3.88%	0.00%	**5.10%**	-0.51	-0.06	0.00	**-0.57**
MS	0.79%	1.24%	0.00%	**2.03%**	0.41	0.38	0.00	**0.79**
MT	1.53%	2.71%	0.00%	**4.24%**	0.67	-0.43	0.00	**0.24**
NC	1.22%	6.01%	0.00%	**7.23%**	-0.05	1.25	0.00	**1.20**
ND	0.38%	0.81%	0.00%	**1.18%**	-0.21	0.00	0.00	**-0.21**
NE	1.46%	2.86%	0.00%	**4.32%**	0.18	0.77	0.00	**0.95**
NH	2.03%	3.49%	0.00%	**5.52%**	0.59	0.53	0.00	**1.12**
NJ*	2.87%	11.71%	0.00%	**14.59%**	1.09	2.56	0.00	**3.66**
NM	1.08%	4.01%	0.00%	**5.10%**	-0.10	0.76	0.00	**0.67**
NV*	1.79%	11.65%	0.00%	**13.43%**	0.32	0.43	0.00	**0.75**
NY*	3.69%	8.17%	0.00%	**11.86%**	1.80	3.59	0.00	**5.39**
OH	1.72%	3.35%	0.00%	**5.07%**	0.69	0.94	0.00	**1.63**
OK	7.39%	2.60%	0.00%	**9.99%**	6.34	-0.76	0.00	**5.59**
OR*	4.02%	12.22%	0.00%	**16.24%**	0.52	0.91	0.00	**1.43**
PA	2.31%	4.37%	0.00%	**6.68%**	0.94	0.16	0.00	**1.10**
RI*	3.76%	5.03%	0.00%	**8.79%**	1.67	1.07	0.00	**2.74**
SC	1.05%	3.01%	0.00%	**4.06%**	0.26	0.59	0.00	**0.85**
SD	0.99%	1.49%	0.00%	**2.48%**	0.17	0.27	0.00	**0.44**
TN	0.68%	4.51%	0.00%	**5.19%**	-0.12	1.65	0.00	**1.52**
TX	0.92%	5.47%	0.00%	**6.39%**	0.14	1.26	0.00	**1.40**
UT	1.97%	8.00%	0.00%	**9.97%**	0.45	1.32	0.00	**1.77**
VA*	1.57%	8.34%	0.00%	**9.91%**	-0.25	0.41	0.00	**0.16**
VT*	4.13%	8.21%	0.00%	**12.34%**	1.09	2.22	0.00	**3.32**
WA*	3.13%	16.24%	0.00%	**19.37%**	0.98	-0.09	0.00	**0.90**
WI	0.94%	3.83%	0.00%	**4.77%**	-0.15	0.71	0.00	**0.56**
WV	0.65%	1.22%	0.00%	**1.87%**	0.17	0.19	0.00	**0.36**
WY	0.91%	1.58%	0.00%	**2.49%**	-0.09	0.25	0.00	**0.16**
U.S.	**2.19%**	**8.03%**	**0.01%**	**10.23%**	**0.62**	**1.10**	**-0.02**	**1.71**

*Denotes states that have adopted California's ZEV program
Source: Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering October 1 – December 31, 2022, and October 1 – December 31, 2023

New Light-Duty Vehicle Registrations by Powertrain, Full Year 2023

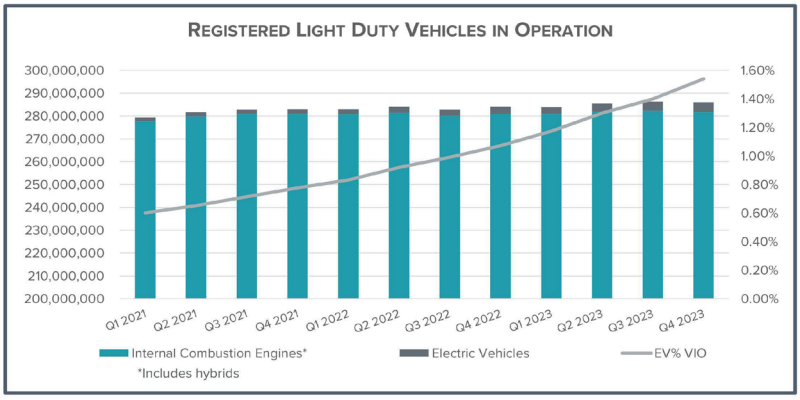
	2023 New Light-Duty Vehicle Registrations By Powertrain (Full Year)				Change In Market Share (2023 vs 2022 Full Year), New Light-Duty Vehicle Registrations Powertrain			
State	Advanced Powertrain Market Share				Advanced Powertrain Market Share (Percentage Point Change)			
	PHEV	BEV	FCEV	EV Total	PHEV	BEV	FCEV	EV Total
AK	0.78%	2.79%	0.00%	**3.58%**	0.17	0.67	0.00	**0.84**
AL	0.61%	1.96%	0.00%	**2.57%**	-0.11	-0.39	0.00	**0.50**
AR	0.53%	1.73%	0.00%	**2.26%**	-0.04	-0.20	0.00	**0.25**
AZ	1.24%	8.15%	0.00%	**9.39%**	-0.18	-2.59	0.00	**2.77**
CA*	3.46%	22.09%	0.17%	**25.71%**	-0.67	-4.91	0.00	**5.59**
CO*	4.22%	10.91%	0.00%	**15.14%**	-2.05	-3.40	0.00	**5.46**
CT*	3.44%	6.74%	0.00%	**10.19%**	-1.07	-1.52	0.00	**2.59**
DC	4.05%	15.58%	0.00%	**19.63%**	-0.61	-5.21	0.00	**5.82**
DE	2.16%	6.62%	0.00%	**8.78%**	-0.78	-2.38	0.00	**3.16**
FL	0.93%	6.50%	0.00%	**7.43%**	0.02	-1.63	0.00	**1.61**
GA	0.84%	6.54%	0.00%	**7.39%**	-0.04	-2.12	0.00	**2.16**
HI	1.26%	9.75%	0.00%	**11.01%**	0.50	-3.10	0.00	**2.59**
IA	0.88%	2.28%	0.00%	**3.16%**	-0.01	-0.45	0.00	**0.46**
ID	1.39%	3.36%	0.00%	**4.75%**	-0.39	-0.68	0.00	**1.07**
IL	1.28%	6.52%	0.00%	**7.80%**	-0.06	-1.58	0.00	**1.64**
IN	0.95%	3.18%	0.00%	**4.13%**	-0.09	-0.73	0.00	**0.83**
KS	1.03%	3.76%	0.00%	**4.79%**	-0.14	-1.22	0.00	**1.35**
KY	0.76%	2.58%	0.00%	**3.34%**	-0.06	-0.74	0.00	**0.80**
LA	0.54%	1.43%	0.00%	**1.98%**	-0.10	-0.33	0.00	**0.44**
MA*	3.96%	8.08%	0.00%	**12.04%**	-1.36	-2.48	0.00	**3.84**
MD*	2.94%	8.76%	0.00%	**11.70%**	-1.08	-2.75	0.00	**3.84**
ME*	2.81%	3.24%	0.00%	**6.05%**	-0.67	-0.71	0.00	**1.38**
MI	0.97%	3.03%	0.00%	**4.00%**	0.23	-0.84	0.00	**0.61**
MN*	1.41%	4.96%	0.00%	**6.37%**	-0.29	-1.33	0.00	**1.62**
MO	2.43%	3.52%	0.00%	**5.95%**	-1.31	-1.01	0.00	**2.32**
MS	0.48%	1.05%	0.00%	**1.53%**	-0.12	-0.18	0.00	**0.31**
MT	1.17%	2.22%	0.00%	**3.40%**	-0.35	0.51	0.00	**-0.16**
NC	1.08%	5.94%	0.00%	**7.03%**	-0.08	-2.08	0.00	**2.16**
ND	0.53%	0.76%	0.00%	**1.28%**	-0.17	0.02	0.00	**0.15**
NE	1.17%	2.55%	0.00%	**3.72%**	-0.16	-0.64	0.00	**0.80**
NH	1.73%	3.19%	0.00%	**4.91%**	-0.46	-0.62	0.00	**1.08**
NJ*	2.73%	10.85%	0.00%	**13.59%**	-1.10	-3.66	0.00	**4.76**
NM	1.16%	3.73%	0.00%	**4.89%**	-0.23	-0.75	0.00	**0.98**
NV*	1.68%	11.56%	0.00%	**13.23%**	-0.30	-2.72	0.00	**3.02**
NY*	3.49%	5.57%	0.00%	**9.06%**	-1.71	-1.81	0.00	**3.52**
OH	1.11%	3.11%	0.00%	**4.23%**	-0.27	-0.86	0.00	**1.13**
OK	3.04%	1.70%	0.00%	**4.74%**	-1.96	0.34	0.00	**1.62**
OR*	3.66%	11.75%	0.00%	**15.42%**	-0.64	-3.29	0.00	**3.93**
PA	2.14%	4.20%	0.00%	**6.34%**	-0.99	-0.99	0.00	**1.98**
RI*	3.36%	4.40%	0.00%	**7.75%**	-1.44	-1.14	0.00	**2.58**
SC	0.83%	3.05%	0.00%	**3.88%**	-0.04	-0.90	0.00	**0.94**
SD	0.87%	1.25%	0.00%	**2.12%**	-0.28	-0.20	0.00	**0.49**
TN	0.65%	4.23%	0.00%	**4.88%**	0.11	-1.45	0.00	**1.34**
TX	0.72%	5.48%	0.00%	**6.20%**	-0.07	-1.82	0.00	**1.89**
UT	1.63%	7.10%	0.00%	**8.73%**	-0.37	-1.31	0.00	**1.68**
VA*	1.38%	8.34%	0.00%	**9.73%**	0.17	-2.36	0.00	**2.19**
VT*	3.62%	6.70%	0.00%	**10.32%**	-0.97	-2.26	0.00	**3.23**
WA*	3.01%	15.77%	0.00%	**18.79%**	-1.26	-4.63	0.00	**5.88**
WI	0.92%	3.34%	0.00%	**4.26%**	-0.05	-0.84	0.00	**0.89**
WV	0.63%	1.14%	0.00%	**1.77%**	-0.24	-0.31	0.00	**0.55**
WY	0.84%	1.28%	0.00%	**2.11%**	-0.26	0.01	0.00	**0.25**
U.S.	**1.87%**	**7.62%**	**0.02%**	**9.51%**	**-0.51**	**-1.98**	**0.00**	**2.49**

*Denotes states that have adopted California's ZEV program

Source: Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering January 1 – December 31, 2022, and January – December 31, 2023

REGISTRATIONS AND INFRASTRUCTURE

Share of Registered EVs In U.S. Light-Duty Fleet Continues to Increase Incrementally. As sales of EVs increase, so does the total number of EVs operating on U.S. roads. There are now more than 4.3 million EVs in operation in the United States (1.5 percent of all light vehicles in operation). EVs represented more than 1 percent of total vehicles in operation (VIO) for the first time at the end of 2022. The EV VIO of 1.5 percent is an increase of 0.4 pp since the fourth quarter of 2022 and more than double the EV VIO from the first quarter in 2021 (0.60 percent).[10]



U.S. Public Charging Infrastructure: Overview

While the U.S. Department of Energy notes that roughly 80 percent of all EV charging occurs at home, reliable and convenient access to workplace and public charging and refueling stations help to support customers that purchase EVs or are considering purchasing an EV. Workplace and public charging infrastructure not only eases perceived "range anxiety" concerns but also increases consumer awareness of the technology. In addition, achieving EV market share envisioned by the Biden Administration will require moving beyond customers that have access to charging via privately-owned single-family dwellings. The bipartisan Infrastructure Investment and Jobs Act (IIJA) that was signed into law in November 2021, includes $5 billion in funding for states to establish a nationwide EV charging network along highway corridors and $2.5 billion in competitive grants to deploy publicly available EV charging and other alternative fuel stations through 2026. Here is a snapshot of publicly available EV charging and refueling infrastructure available across the United States at the end of the fourth quarter of 2023[11]:

[10] Registered vehicles in operation compiled by Alliance for Automotive Innovation with data provided by S&P Global Mobility as of December 31, 2023
[11] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of December 31, 2023
Note: prior editions of this report excluded proprietary chargers, however Tesla opened their previously proprietary chargers in November 2022 and their "North American Charging Standard" will be widely adopted by automakers.

Level 2: 52,344 Locations, 121,920 EVSE Ports
DC Fast: 8,892 Locations, 37,922 EVSE Ports
Hydrogen Refueling: 54 Stations (53 are in California)
U.S. Total: *60,065 [12] Locations, 159,842 EVSE Ports*

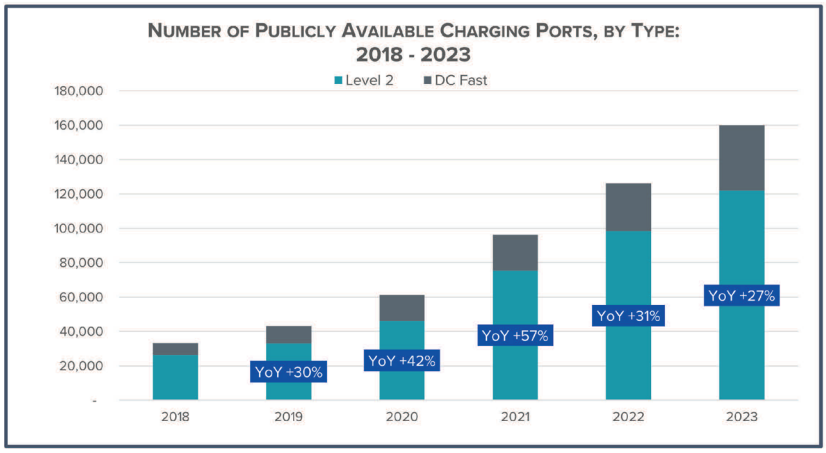
See Recommended Attributes for EV Charging Stations

Level 2 Chargers and DC Fast Chargers. Both Level 2 and DC Fast charging play important roles in electrifying the light-duty vehicle fleet. However, the key difference between Level 2 and DC Fast chargers is how quickly each will charge an EV's battery. Level 2 equipment is common for home, workplace, and public charging with longer dwell times. Level 2 chargers can fully charge a BEV from empty in 4-10 hours and a PHEV from empty in 1-2 hours. DC Fast charging equipment enables rapid charging of BEVs in 20 minutes to 1 hour along heavy-traffic corridors, in city centers, at transportation hubs, and fleet depots. Wider installation of both Level 2 chargers, DC Fast chargers, and hydrogen fueling will be necessary to support wider-scale adoption of EVs. The number of public Level 2 charging increased 24 percent at the end of 2023 over 2022. DC Fast chargers increased 37 percent. Total charging ports increased 27 percent in 2023. (For context, EV sales increased 51 percent from 2022 to 2023.)[13]

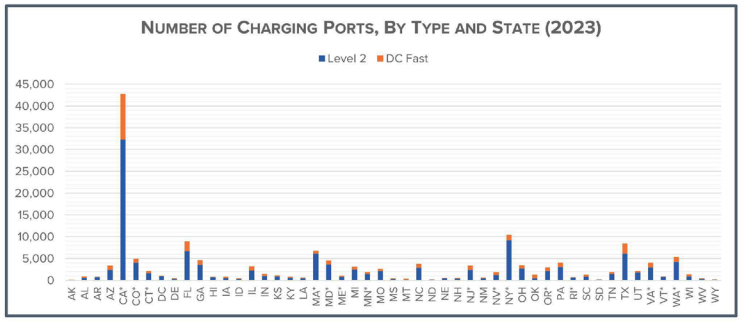
Through March 12, 2024, Nearly Two-Thirds of Installed DC Fast Charging Ports Were Tesla (North American Charging Standard)[14]:

DC Fast Chargers Installed		
Type	**Ports**	**%Total**
Tesla	24,644	63%
CCS Combo	14,379	37%
Total	39,023	100%

After Tesla opened their previously proprietary chargers (in November 2022), at least 18 EV manufacturers have announced that they will move to Tesla's North America Charging Standard.



[11] Some station locations have both Level 2 and DC Fast installed.
[12] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of 12/31/2023
[13] Charging information from U.S. Department of Energy Alternative Fuels Data Center, 3/12/2024; does not include J1772 or CHAdeMO connectors



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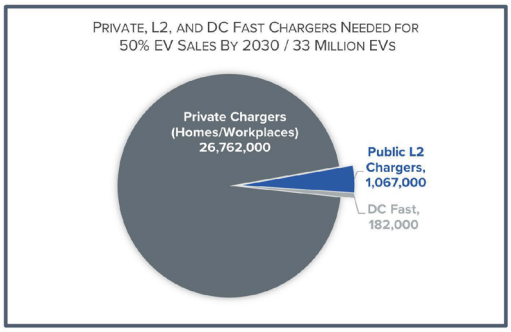
Infrastructure Investment Necessary

An assessment by the U.S. National Renewable Energy Laboratory (NREL) released in June 2023 estimated that a network of 28 million charging ports would be necessary to support 50 percent EV sales by 2030 (and 33 million EVs on the road).[16] NREL estimates that 96 percent of those charging ports would be privately accessible L1 and L2 chargers located at single-family homes, multifamily properties, and workplaces. The remaining 4 percent (1,249,000 ports) would be split between public L2 and high-speed DC Fast charging ports, with L2 making up 85 percent of those public chargers.



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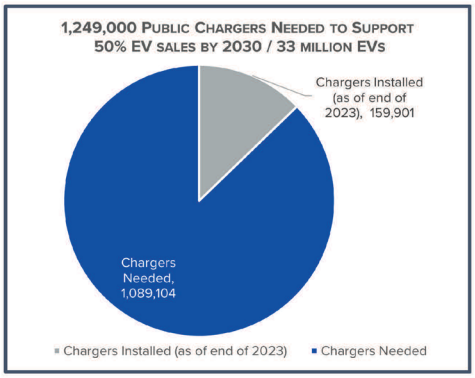
At the end of 2023, there were about 160,000 public charging ports across the country and 4.3 million EVs on the road. Total installed public charging ports are about 13 percent of the needed estimate to support EV penetration by 2030.

More than 1 million additional public chargers (945,000 L2 and 144,000 DC Fast) will need to be installed to satisfy the necessary infrastructure estimate. This means that between the end of 2023 and December 31, 2030, 437 chargers need to be installed every day, for the next 7 years. Or 3 chargers every 10 minutes through the end of 2030.

[15] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of 12/31/2023; *Denotes states that have adopted California's ZEV program.
[16] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[17] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023



Between the end of 2023 and December 31, 2030, 437 chargers need to be installed every day, for the next 7 years. Or 3 chargers every 10 minutes through the end of 2030

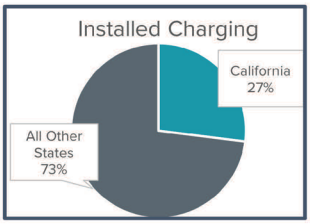
The Cost of This Substantial Infrastructure Necessity Will Largely Fall on Consumers and Commercial Real Estate Owners as They Install Home and Workplace Charging. According to NREL a national capital investment of $53–$127 billion in charging infrastructure is needed by 2030 (including as much as $72 billion for private residential charging) to support 33 million EVs.[18] The large range of potential costs is a result of variable and evolving equipment and installation costs across charging networks, locations, and site designs[19]. Notably, the estimates exclude the cost of grid upgrades and distributed energy resources. The estimated cumulative capital investment includes[20]:

- $22–$72 billion for privately accessible Level 1 and Level 2 charging ports
- $27–$44 billion for publicly accessible fast charging ports
- $5–$11 billion for publicly accessible Level 2 charging ports

Infrastructure Disparities by Geography

Geographic disparities in charging infrastructure are pervasive. At the end of 2023, nearly 27 percent of all public charging infrastructure was in California, which had 35 percent of all registered EVs.

Alliance for Automotive Innovation participates in EV policy development at the federal and state level via the Joint Office of Energy and Transportation's Electric Vehicle Working Group, through its lithium-ion battery recycling policy framework, recommendations for attributes of EV charging stations, and implementation of the Inflation Reduction Act's EV tax credits[21].



[18] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[19] Various state and federal incentives are available to consumers or businesses that install EV charging infrastructure, including from power utilities.
[20] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[21] Alliance for Automotive Innovation, Blog, What We Know (and Don't Know) About the New EV Tax Credit Rules, 12/20/2022; Alliance for Automotive Innovation, Blog, Foreign Entity of Concern: Finally... Some Clarity, 12/1/2023

Vehicles in Operation and Charging by State

Public Charging Outlets And Registerd EVs (as of 1/1/2024)

	EV Level 2	EV DC Fast	H2** Fueling	Total	Percent EVs of Total VIO***	Share of Registered EVs****	EVs Per Charger	EVs Per 10K Residents
AK	83	30	-	113	0.57%	0.08%	29	44.49
AL	569	353	-	922	0.31%	0.37%	17	32.91
AR	668	121	-	789	0.30%	0.19%	11	27.80
AZ	2,357	1,005	-	3,362	1.59%	2.51%	32	151.99
CA*	32,308	10,461	53	42,822	4.85%	34.85%	35	382.45
CO*	4,017	944	-	4,961	2.03%	2.56%	22	195.38
CT*	1,666	414	-	2,080	1.45%	1.03%	21	124.86
DC	979	55	-	1,034	3.21%	0.25%	11	156.07
DE	290	197	-	487	1.22%	0.26%	23	115.49
FL	6,737	2,177	-	8,914	1.45%	6.34%	31	129.14
GA	3,495	1,104	-	4,599	1.05%	2.29%	22	94.55
HI	702	44	1	747	2.64%	0.69%	40	211.31
IA	496	313	-	809	0.43%	0.32%	17	43.51
ID	289	137	-	426	0.62%	0.28%	29	70.41
IL	2,254	968	-	3,222	1.16%	2.66%	36	90.56
IN	931	516	-	1,447	0.56%	0.79%	24	51.39
KS	880	221	-	1,101	0.53%	0.36%	14	53.16
KY	579	215	-	794	0.37%	0.35%	19	33.61
LA	415	219	-	634	0.29%	0.25%	17	23.65
MA*	6,099	682	-	6,781	1.91%	2.42%	16	152.37
MD*	3,575	956	-	4,531	1.80%	2.12%	20	152.28
ME*	786	221	-	1,007	1.03%	0.32%	14	103.35
MI	2,436	697	-	3,133	0.76%	1.50%	21	64.95
MN*	1,420	452	-	1,872	0.90%	1.08%	25	83.67
MO	2,135	437	-	2,572	0.61%	0.81%	14	57.48
MS	279	115	-	394	0.17%	0.11%	13	16.66
MT	174	170	-	344	0.39%	0.15%	19	59.98
NC	2,832	982	-	3,814	0.90%	1.99%	23	83.10
ND	117	88	-	205	0.19%	0.03%	7	19.79
NE	385	154	-	539	0.45%	0.22%	18	49.65
NH	359	176	-	535	1.08%	0.33%	27	106.73
NJ*	2,378	999	-	3,377	2.08%	3.52%	45	171.33
NM	400	230	-	630	0.69%	0.32%	22	65.89
NV*	1,226	620	-	1,846	2.18%	1.26%	30	180.75
NY*	9,140	1,321	-	10,461	1.67%	4.44%	18	98.55
OH	2,706	751	-	3,457	0.63%	1.54%	19	57.18
OK	438	838	-	1,276	1.00%	1.06%	36	116.35
OR*	2,095	806	-	2,901	2.21%	1.97%	29	203.64
PA	3,088	997	-	4,085	0.90%	2.28%	24	77.25
RI*	591	91	-	682	1.18%	0.23%	15	96.03
SC	813	458	-	1,271	0.49%	0.60%	21	51.43
SD	122	102	-	224	0.27%	0.06%	12	30.43
TN	1,451	478	-	1,929	0.60%	0.95%	21	60.69
TX	6,130	2,282	-	8,412	1.02%	5.75%	30	86.99
UT	1,777	352	-	2,129	1.57%	1.09%	22	150.22
VA*	2,926	1,100	-	4,026	1.28%	2.26%	24	114.96
VT*	784	112	-	896	2.14%	0.27%	13	189.06
WA*	4,239	1,099	-	5,338	2.49%	4.01%	33	230.79
WI	911	419	-	1,330	0.61%	0.76%	25	56.88
WV	261	137	-	398	0.26%	0.09%	10	22.72
WY	132	106	-	238	0.27%	0.04%	7	30.88
U.S.	**121,920**	**37,922**	**54**	**159,896**	**1.52%**	**100.00%**	**27**	**132.70**

*Denotes states that have adopted California's ZEV program; **Hydrogen count denotes stations
*** VIO is vehicles in operation; **** State share of U.S. Total
Source: Figures compiled by Alliance for Automotive Innovation with registered vehicle data provided by S&P Global Mobility as of September 30, 2023; Charging information from U.S. Department of Energy Alternative Fuels Data Center, as of 9/30/2023

REGISTRATIONS

EV registrations as a share of all registered light-duty vehicles are 1.5 percent (as of December 31, 2023). There are about 286 million registered light-duty vehicles in the U.S.

At the end of 2023, California accounted for 35 percent of all registered light-duty EVs in the U.S.

States with highest portion of total EVs registered:

1. CA* (1,512,858, 4.85%)
2. DC (10,963, 3.21%)
3. HI (30,016, 2.64%)
4. WA* (173,911, 2.49%)
5. OR* (85,341, 2.21%)
6. NV* (54,847, 2.18%)
7. VT* (11,841, 2.14%)
8. NJ* (152,627, 2.08%)
9. CO* (111,282, 2.03%)
10. MA* (105,169, 1.91%)
11. MD* (92,017, 1.80%)

States with worst ratio of registered EVs per public charger:

1. NJ*
2. HI
3. OK
4. IL
5. CA*
6. WA*
7. AZ
8. FL
9. NV*
10. TX

Read more about automakers plans for an ***ELECTRIC FUTURE HERE***

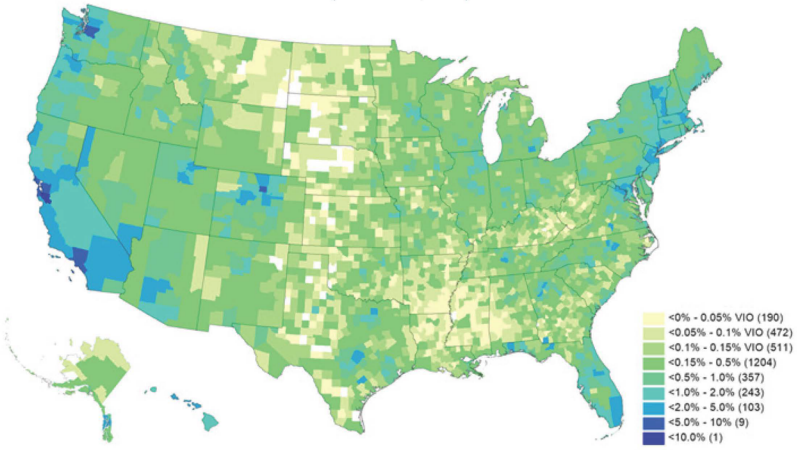
SPOTLIGHT ON:
GEOGRAPHIC DISTRIBUTION OF EVs AND INFRASTRUCTURE

Electric Vehicle Registrations by County

There are 3,152 counties and independent districts in the United States with more than 286 million vehicles in operation (VIO) – 4.3 million of which are electric. While it stands to reason that more populous states and counties would be home to more vehicles, the uptake of EVs does not follow the same pattern. For instance, California is home to nearly 11 percent of U.S. vehicles, but accounts for 35 percent of all electric vehicle registrations. By contrast, Texas, the state with the second highest number of registered vehicles represents 8.6 percent of total U.S. VIO but only 5.8 percent of electric vehicles in the country.

Half of all registered EVs are located within just 39 counties (1.2 percent of counties), while 53 counties have zero registered EVs. Only 356 counties (11 percent) have an EV VIO rate greater than 1 percent.

ELECTRIC VEHICLE REGISTRATIONS AS A PERCENT OF TOTAL VEHICLES IN OPERATION
(BY COUNTY, 2023)



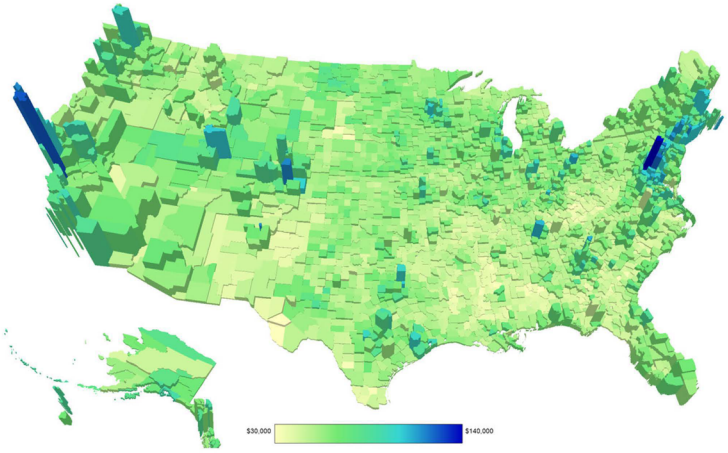
COUNTIES WITH THE HIGHEST RATE OF EV VEHICLES IN OPERATION

Rank	County	State	% County EV VIO	Rank	County	State	% County EV VIO
1	SANTA CLARA	CA	10.32%	6	ORANGE	CA	7.00%
2	SAN MATEO	CA	9.94%	7	CONTRA COSTA	CA	6.46%
3	MARIN	CA	9.69%	8	LOS ANGELES	CA	5.35%
4	SAN FRANCISCO	CA	9.23%	9	KING	WA	5.15%
5	ALAMEDA	CA	8.20%	10	BOULDER	CO	5.01%

Registrations of EVs tend to be highest in wealthier counties. The counties with the highest EV registration rates (top 10 percent | 314 counties), are also some of the wealthiest – more than half (54 percent) are in the top ten percent for median household income. The average median household income for the top ten percent of EV VIO counties is $77,770. Conversely, for the counties with the lowest percent of EVs of county VIO, the average median income is $45,435. The national median household income is $74,580

ELECTRIC VEHICLE REGISTRATIONS AS A PERCENT OF TOTAL VIO AND MEDIAN HOUSEHOLD INCOME

(Height represents percent of EV VIO and color represents median household Income)



Geographic Distribution of Charging Infrastructure

At the end of 2023, there were about 160,000 public charging ports across the country and 4.3 million EVs on the road, a ratio of 27 EVs per charger. While progress has been made installing public charging across the country, disparities persist. At the end of 2022, 39 percent of all U.S. counties had zero chargers installed – at the end of 2023, that number was 31 percent (983 counties with NO public charging).

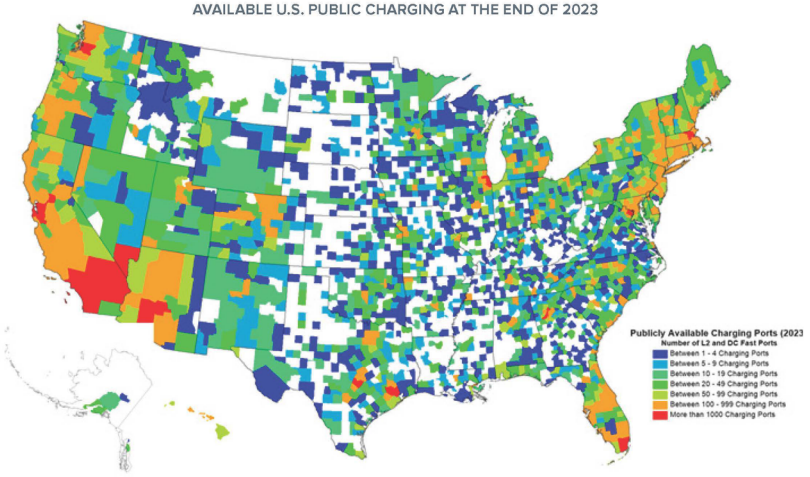
Counties with five or fewer charging ports account for more than half of all counties (53 percent). That number is an improvement from 2022's 63 percent.

The top 25 counties[22] with the most public charging ports installed accounted for one-third of all available U.S. charging.

At the end of 2023, more than half of the counties (52 percent) had NO DC Fast charging installed; nearly one quarter (24 percent) of the counties had access to only 1 port. California is home to 28 percent of all DC Fast ports.

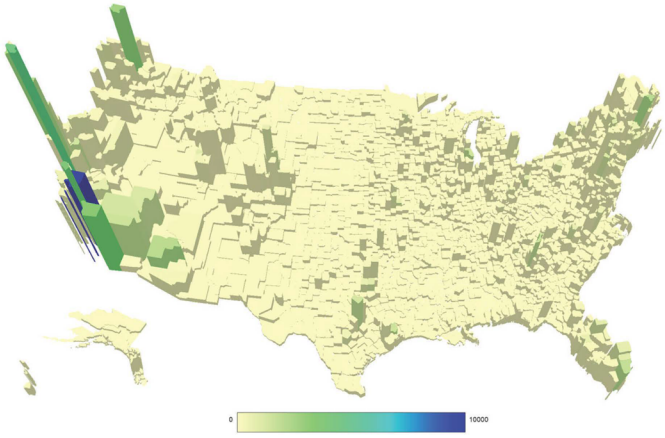
[22] See Appendix A for list of counties.

AVAILABLE U.S. PUBLIC CHARGING AT THE END OF 2023



ELECTRIC VEHICLES AS A PERCENT OF TOTAL VIO AND AVAILABLE CHARGING

(Height represents percent of EV VIO and color represents public charging)



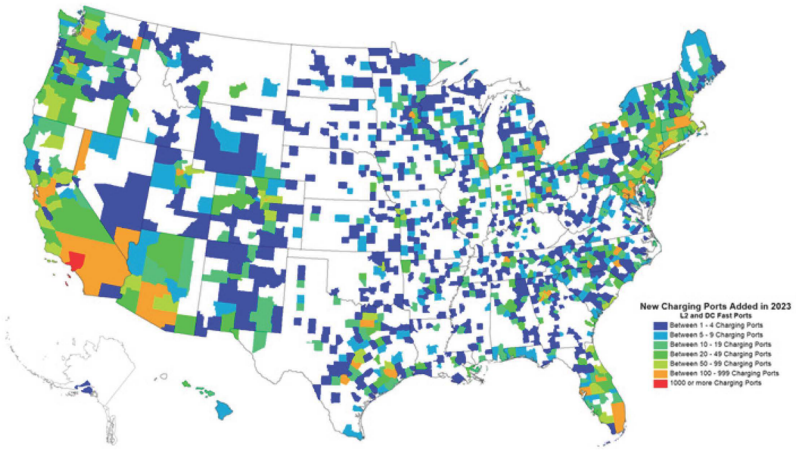
New Infrastructure Not Distributed Equally

In 2023, 22,591 Level 2 and 10,432 DC Fast chargers were added around the country for a total of 33,023 new chargers. With 1.4 million new EVs added to the roads in 2023, that amounts to a ratio of 43 new EVs for every new public port – worse than the current ratio of 27 EVs per charger.

Progress is being made (ninety counties installed their first chargers in 2023), however charging installations are still highly concentrated:

- 12 percent of counties added no new charging.
- 40 percent of counties added fewer than ten new charging ports.
- One-third of all new charging ports were installed in just 32 counties[23].
- 20 percent of all new charging ports were installed in California.
- 21 percent of all new DC Fast charging ports were installed in California.

NEW U.S. PUBLIC CHARGING IN 2023



[23] See Appendix B for a list of counties.

APPENDICES

Appendix A

The top 25 counties with the most public charging ports installed:

1. Los Angeles, CA
2. Santa Clara, CA
3. Orange, CA
4. San Diego, CA
5. King, WA
6. San Mateo, CA
7. Maricopa, AZ
8. Middelsex, MA
9. Alameda, CA
10. Miami-Dade, FL
11. Riverside, CA
12. Harris, TX
13. Fulton, GA
14. Cook, IL
15. Sacramento, CA
16. San Bernardino, CA
17. Travis, TX
18. Suffolk, MA
19. Clark, NV
20. New York, NY
21. Fairfax, VA
22. Contra Costa, CA
23. District of Columbia, DC
24. San Francisco, CA
25. Albany, NY

Appendix B

One-third of all new charging ports were installed in just 32 counties:

1. Los Angeles, CA
2. San Diego, CA
3. Orange, CA
4. King, WA
5. Harris, TX
6. Maricopa, AZ
7. Santa Clara, CA
8. Middlesex, MA
9. Clark, NV
10. Almadea, CA
11. Orange, FL
12. San Bernardino, CA
13. Fairfax, VA
14. Miami-Dade, FL
15. San Mateo, CA
16. Mecklenburg, NC
17. Suffolk, MA
18. San Francisco, CA
19. Allegheny, PA
20. New Haven, CT
21. Cook, IL
22. Arlington, VA
23. Riverside, CA
24. Wake, NC
25. Travis, TX
26. Fulton, GA
27. Hillsborough, FL
28. Tarrant, TX
29. Multnomah, OR
30. Oakland, MI
31. District of Columbia, DC
32. Norfolk, MA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ELECTRIC VEHICLE QUARTERLY REPORT
FIRST QUARTER, 2024

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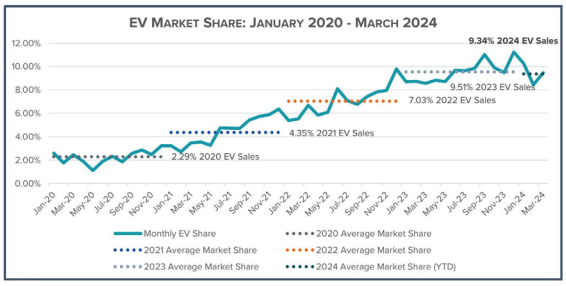
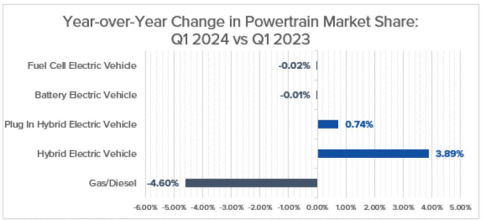
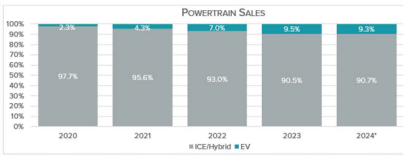
ELECTRIC VEHICLE SALES OVERVIEW (Q1 2024)

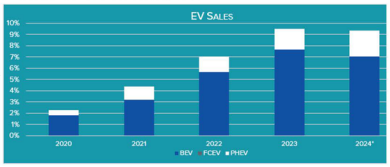
In the first quarter of 2024, automakers sold about 344,000 electric vehicles (EVs), including battery, plug-in hybrid, and fuel cell electric vehicles) in the United States, representing 9.3 percent of overall light-duty vehicle sales. This represents a 0.9 percentage point (pp) market share decrease over the fourth quarter of 2023 and a decrease of about 33,000 vehicle sales.



Year-over-year (YoY), market share increased 0.7 pp from the first quarter of 2023. The total volume of all light-duty sales in Q1 2024 was up 4.2 percent from Q1 2023, while the volume for EVs increased 13 percent (an increase of nearly 39,000 vehicles.) For comparison, internal combustion engine (ICE) vehicle market share decreased by 4.6 pp during Q1 2024 compared to the same period last year. Nearly all of ICE market share was displaced by gains of traditional hybrids and plug-in hybrid vehicles, offset slightly by market share losses from BEVs and FCEVs.



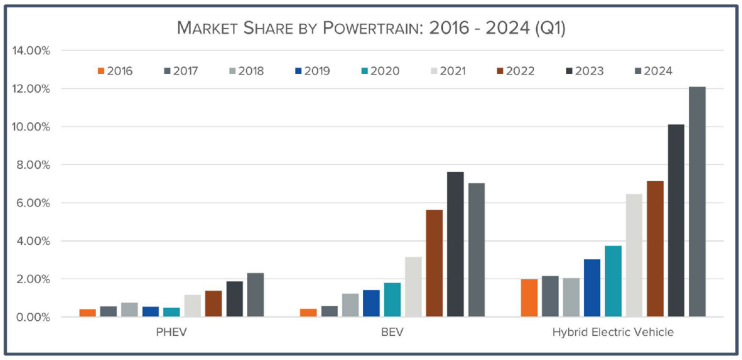


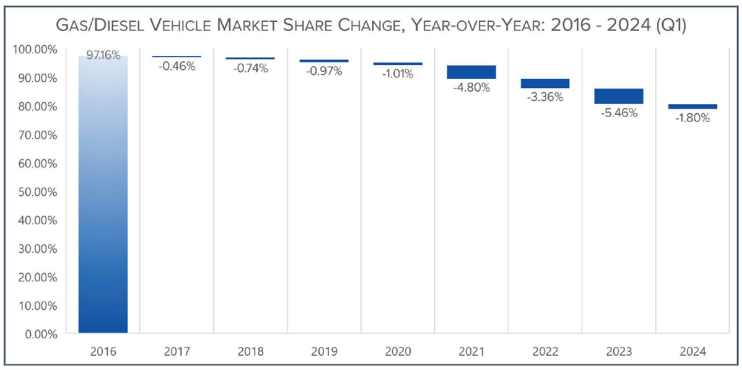


*Through Q1 2024

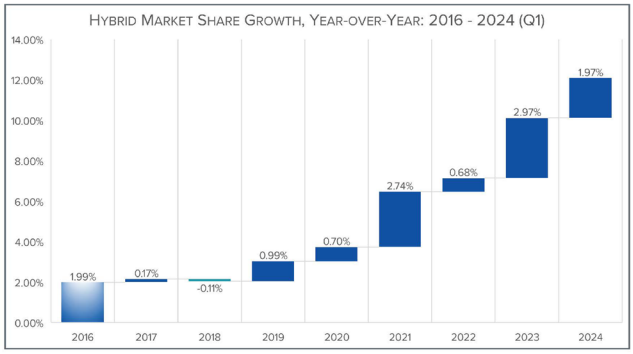
EVOLVING MARKET SHARE OF POWERTRAINS: 2016 - 2024

From 2016 through the first quarter of 2024, traditional internal combustion engine (ICE) market share has steadily declined. In 2016, ICE vehicles comprised more than 97 percent of all vehicle sales. In the first quarter of 2024, that share dropped to 78.6 percent for an overall loss of 18.6 pp. The ICE market share loss was replaced by increases in share of hybrids, BEVs, and PHEVs. Hybrids made up most of the alternative vehicle gains (+10.1 pp) followed by BEVs (+6.6 pp) and PHEVs (+1.9 pp) over the last eight years

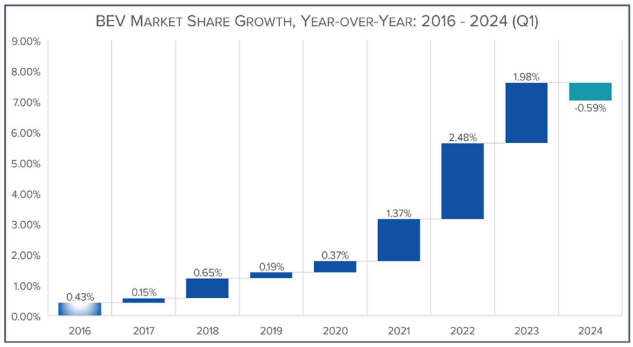




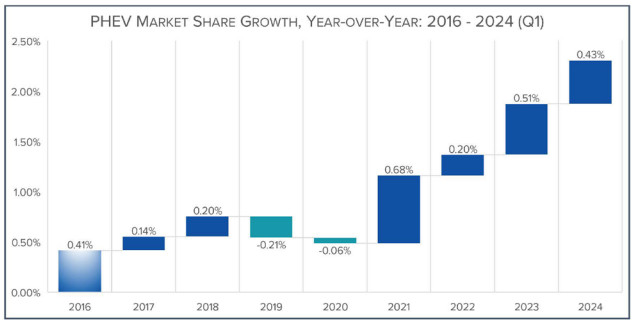
Hybrid market share grew from 2 percent in 2016 to 12.1 percent in Q1 2024 (+10.1 pp):



BEV market share grew from .43 percent in 2016 to 7.0 percent in Q1 2024 (+6.6 pp):



PHEV market share grew from .41 percent in 2016 to 2.3 percent in Q1 2024 (+1.89 pp):



See Additional Historic Data on EV Sales

ELECTRIC VEHICLE SALES BY SEGMENT

EV Model Availability

113 Vehicle Models Sold in Q1 2024:

66 Battery Electric Vehicles
- 19 Cars
- 36 Utility Vehicles
- 5 Pickups
- 6 Vans

45 Plug-in Hybrid Vehicles
- 15 Cars
- 29 Utility Vehicles
- 1 Van

2 Fuel Cell Electric Vehicles
- 1 Car
- 1 Utility Vehicle

See more information about ***EV CHOICE HERE***

For a list of EVs that qualify for the federal government's new clean vehicle tax credit of up to $7,500 ***CLICK HERE***.

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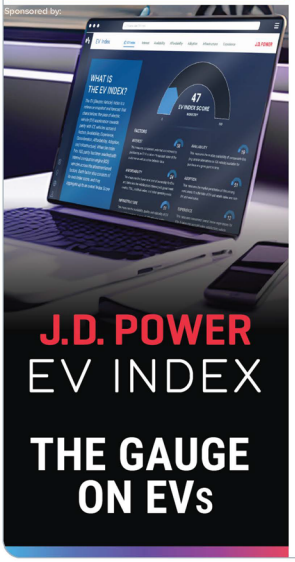
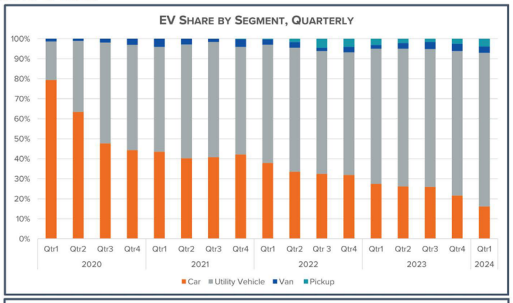
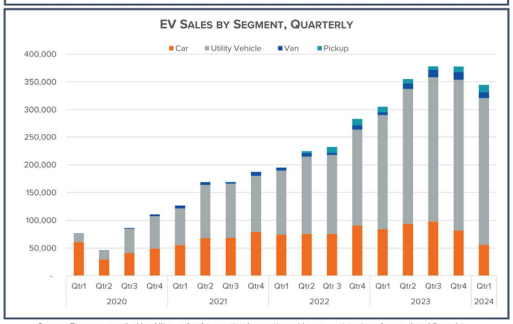


While passenger cars once dominated the EV market, manufacturers continue to introduce new models to satisfy a variety of consumer needs. Utility vehicle (UV) offerings continue to grow, and while electric pickup trucks are a relatively new entry to the market (making their commercial debut in September 2021), there are 5 models available now, with more expected soon. As a result, non-car segments are continuing to make gains, and in the first quarter of 2024, light truck (UVs, minivans, and pickups) sales comprised 84 percent of the EV market – an 11 pp increase over the first quarter of 2023.

Quarterly sales of BEV and PHEV UVs have grown from about 19 percent of EVs at the start of 2020 to 77 percent in the first quarter of 2024. Nearly 59,000 more electric UVs were sold in the first quarter of 2024 than the first quarter of 2023.

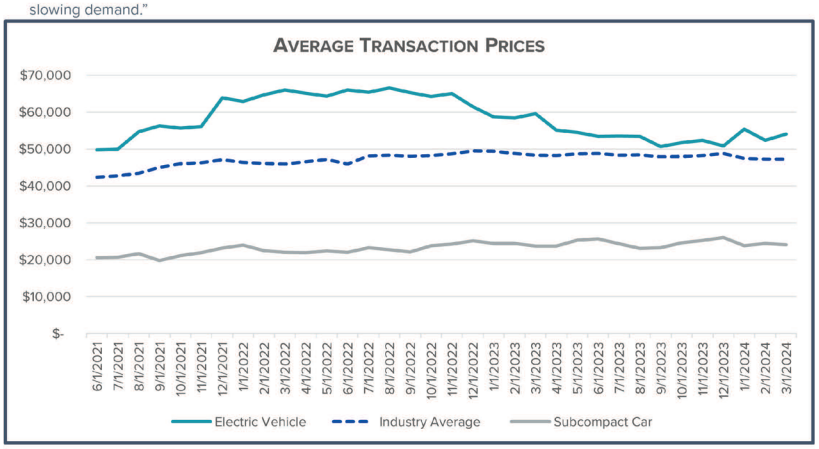




Source: Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobilitycovering January 1, 2020 – March 31, 2024

ELECTRIC VEHICLE TRANSACTION PRICES

"The average transaction price for a new EV in Q1 was $55,167, a 9.0 percent decrease compared to Q1 2023 and down 3.8 percent quarter over quarter." [1] While increased competition in the EV market has led to some price decreases, slowing sales paired with increased inventory and incentives are also playing a part in lower transaction prices. As noted by Cox Automotive, "Lower prices have supported EV sales volume in the U.S., particularly for key Tesla models... Tesla's average transaction price was $52,315 in Q1, down roughly 13.5 percent year over year. However, lower prices did not generate higher volume. Many automakers have followed Tesla's lead and slashed prices. Incentive spending on EVs has increased notably in the past year, another sign of slowing demand."



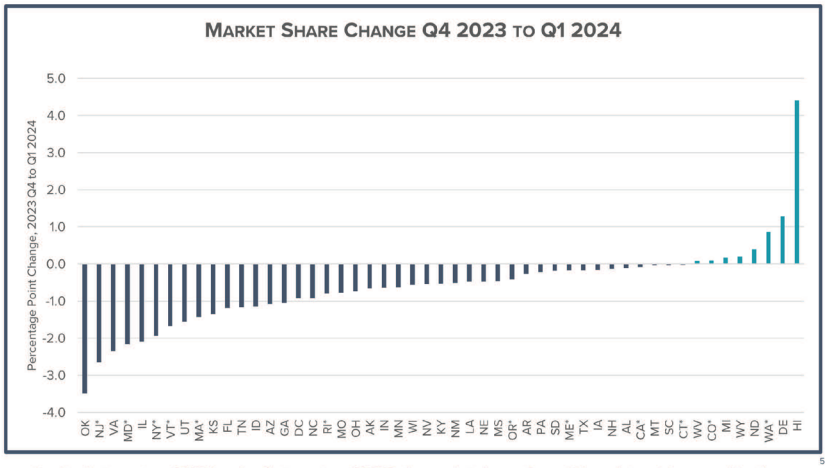
(Source: Compiled from Kelley Blue Book Press Releases, 6/2021 – 3/2024)

[1] Cox Automotive, Press Release, "EV Sales Growth Slows," 4/11/2024



ELECTRIC VEHICLE SALES BY STATE

California continued to lead the nation in EV sales, with BEVs, PHEVs and FCEVs making up 25 percent of new light-duty vehicle registrations in the first quarter of 2024. There are currently eleven additional states [2] and the District of Columbia with new vehicle EV registrations above 10 percent. However, only eight states [3] saw an increase in market share from the fourth quarter of 2023. Forty-two states and DC lost market share from the fourth quarter. Decreasing the most were Oklahoma [4] (-3.3 pp), New Jersey (-2.7 pp), Virginia (-2.3 pp), Maryland (-2.2 pp) and Illinois (-2.1 pp).

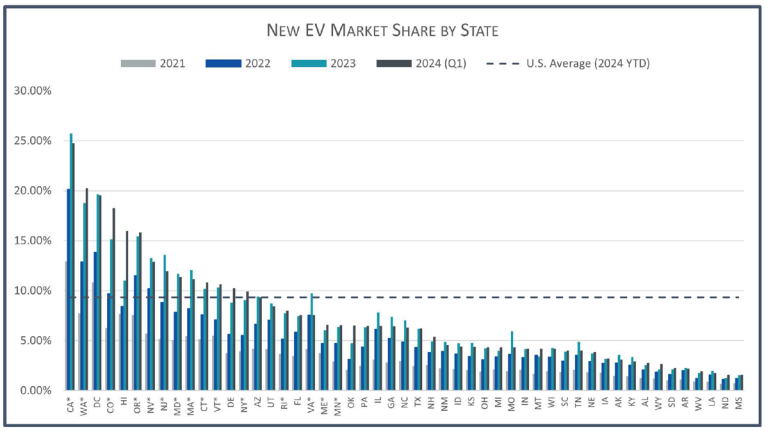


[5]

For the first quarter of 2024 vs the first quarter of 2023, the market share of new EVs registered increased in all but thirteen states [6]. Seven states witnessed an increased market share of EVs by 2 pp or more. Making the largest increases were Colorado [7] (6.0 pp), Oklahoma [8] (4.8 pp), Hawaii (4.1 pp), Washington (3.3pp), and New York (3.1 pp).

In the first quarter of 2024, twelve states and the District of Columbia had an EV market share above 10 percent while four states had an EV market share under 2 percent; California and Washington [9] were the only states above 20 percent. [10]

[2] States with more than a 10 percent market share of EVs: California, Washington, District of Columbia, Colorado, Hawaii, Oregon, Nevada, New Jersey, Maryland, Massachusetts, Connecticut, Vermont, and Delaware
[3] The eight states are: West Virginia, Colorado, Michigan, Wyoming, North Dakota, Washington, Delaware, and Hawaii
[4] Oklahoma is an outlier state due to fluctuating fleet vehicle registrations.
[5] *Denotes states that have adopted California's ZEV program; Oklahoma is an outlier state due to fluctuating fleet vehicle registrations.
[6] The thirteen states are: Virginia, Nevada, Tennessee, Alaska, Illinois, North Carolina, District of Columbia, Utah, Georgia, Louisiana, Kentucky, Oregon, New Mexico, Missouri
[7] Colorado taxpayers are eligible for a state tax credit of $5,000 for the purchase or lease of a new EV on or after July 1, 2023 with a manufacturer's suggested retail price (MSRP) up to $80,000. Lease agreements must have an initial term of at least two years. Beginning January 1, 2024, Coloradans purchasing an EV with an MSRP up to $35,000 will be eligible for an additional $2,500 tax credit.
[8] Oklahoma is an outlier state due to fluctuating fleet vehicle registrations.
[9] This is the first time Washington has been above 20 percent
[10] Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering January 1, 2021 – March 31, 2024



2024 New EV Market Share by State (Through Q1)[11]

1	CA*	24.78%	**11**	CT*	10.84%	**21**	MN*	6.55%	**31**	KS	4.39%	**41**	IA	3.23%
2	WA*	20.24%	**12**	VT*	10.66%	**22**	OK	6.50%	**32**	OH	4.33%	**42**	AK	3.09%
3	DC	19.54%	**13**	DE	10.26%	**23**	PA	6.47%	**33**	MI	4.33%	**43**	KY	2.92%
4	CO*	18.25%	**14**	NY*	9.92%	**24**	IL	6.46%	**34**	MO	4.32%	**44**	AL	2.76%
5	HI	15.98%	**15**	AZ	9.33%	**25**	GA	6.45%	**35**	IN	4.20%	**45**	WY	2.69%
6	OR*	15.83%	**16**	UT	8.41%	**26**	NC	6.30%	**36**	MT	4.20%	**46**	SD	2.29%
7	NV*	12.89%	**17**	RI*	8.00%	**27**	TX	6.22%	**37**	WI	4.20%	**47**	AR	2.20%
8	NJ*	11.93%	**18**	FL	7.57%	**28**	NH	5.39%	**38**	SC	4.02%	**48**	WV	1.96%
9	MD*	11.40%	**19**	VA*	7.56%	**29**	NM	4.59%	**39**	TN	4.02%	**49**	LA	1.77%
10	MA*	11.15%	**20**	ME*	6.60%	**30**	ID	4.41%	**40**	NE	3.85%	**50**	ND	1.58%
												51	MS	1.56%

*Denotes states that have adopted California's ZEV program



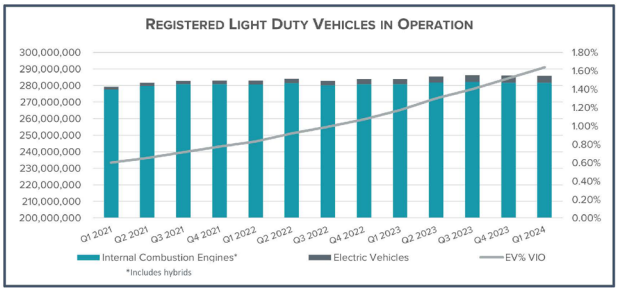
First Quarter 2024, New Light-Duty Vehicle Registrations By Powertrain					Change In Market Share (2024 Q1 vs 2023 Q1), New Light-Duty Vehicle Registrations Powertrain			
State	Advanced Powertrain Market Share				Advanced Powertrain Market Share (Percentage Point Change)			
	PHEV	BEV	FCEV	EV Total	PHEV	BEV	FCEV	EV Total
AK	0.58%	2.51%	0.00%	3.09%	-0.35	-0.53	0.00	-0.88
AL	0.61%	2.15%	0.00%	2.76%	0.13	0.21	0.00	0.34
AR	0.44%	1.76%	0.00%	2.20%	-0.07	0.12	0.00	0.04
AZ	1.78%	7.55%	0.00%	9.33%	0.71	-0.02	0.00	0.69
CA*	3.78%	20.95%	0.05%	24.78%	0.31	0.69	-0.13	0.86
CO*	6.94%	11.32%	0.00%	18.25%	3.39	2.59	0.00	5.98
CT*	4.11%	6.73%	0.00%	10.84%	1.39	0.17	0.00	1.56
DC	4.37%	15.16%	0.00%	19.54%	0.09	-0.69	0.00	-0.61
DE	2.37%	7.90%	0.00%	10.26%	0.60	2.19	0.00	2.79
FL	1.00%	6.58%	0.00%	7.57%	0.08	0.92	0.00	1.00
GA	0.99%	5.46%	0.00%	6.45%	0.27	-0.66	0.00	-0.40
HI	6.54%	9.44%	0.00%	15.98%	5.53	-1.44	0.00	4.09
IA	1.01%	2.22%	0.00%	3.23%	0.21	0.08	0.00	0.29
ID	1.55%	2.86%	0.00%	4.41%	0.37	-0.09	0.00	0.28
IL	1.41%	5.05%	0.00%	6.46%	0.29	-1.13	0.00	-0.84
IN	1.14%	3.07%	0.00%	4.20%	0.29	0.11	0.00	0.40
KS	1.24%	3.15%	0.00%	4.39%	0.48	-0.08	0.00	0.40
KY	0.65%	2.26%	0.00%	2.92%	-0.06	-0.20	0.00	-0.26
LA	0.65%	1.12%	0.00%	1.77%	0.19	-0.55	0.00	-0.36
MA*	4.24%	6.91%	0.00%	11.15%	1.19	-0.31	0.00	0.88
MD*	3.03%	8.37%	0.00%	11.40%	0.92	0.57	0.00	1.48
ME*	3.52%	3.08%	0.00%	6.60%	1.24	-0.14	0.00	1.11
MI	1.04%	3.29%	0.00%	4.33%	-0.06	0.51	0.00	0.45
MN*	1.66%	4.88%	0.00%	6.55%	0.42	0.37	0.00	0.78
MO	0.88%	3.45%	0.00%	4.32%	-0.18	0.09	0.00	-0.09
MS	0.44%	1.12%	0.00%	1.56%	0.15	0.10	0.00	0.25
MT	1.37%	2.84%	0.00%	4.20%	0.33	0.51	0.00	0.84
NC	1.06%	5.24%	0.00%	6.30%	-0.01	-0.61	0.00	-0.62
ND	0.59%	0.99%	0.00%	1.58%	-0.09	0.27	0.00	0.18
NE	1.34%	2.52%	0.00%	3.85%	0.32	0.35	0.00	0.67
NH	2.47%	2.92%	0.00%	5.39%	0.95	-0.24	0.00	0.70
NJ*	3.01%	8.93%	0.00%	11.93%	0.98	-0.77	0.00	0.21
NM	1.04%	3.55%	0.00%	4.59%	-0.12	-0.02	0.00	-0.13
NV*	1.72%	11.18%	0.00%	12.89%	0.12	-2.15	0.00	-2.03
NY*	5.25%	4.66%	0.00%	9.92%	2.52	0.59	0.00	3.11
OH	1.26%	3.07%	0.00%	4.33%	0.38	0.33	0.00	0.71
OK	5.56%	0.94%	0.00%	6.50%	5.03	-0.24	0.00	4.78
OR*	4.97%	10.86%	0.00%	15.83%	1.60	-1.78	0.00	-0.17
PA	2.81%	3.66%	0.00%	6.47%	1.36	-0.02	0.00	1.33
RI*	3.90%	4.09%	0.00%	8.00%	1.58	0.31	0.00	1.89
SC	0.96%	3.06%	0.00%	4.02%	0.15	0.25	0.00	0.41
SD	0.77%	1.52%	0.00%	2.29%	-0.08	0.19	0.00	0.11
TN	0.58%	3.44%	0.00%	4.02%	-0.10	-1.80	0.00	-1.90
TX	0.97%	5.25%	0.00%	6.22%	0.27	-0.12	0.00	0.16
UT	1.61%	6.80%	0.00%	8.41%	0.16	-0.76	0.00	-0.60
VA*	1.39%	6.17%	0.00%	7.56%	0.17	-2.30	0.00	-2.13
VT*	4.21%	6.45%	0.00%	10.66%	1.43	0.87	0.00	2.29
WA*	3.71%	16.52%	0.00%	20.24%	0.83	2.47	0.00	3.30
WI	0.83%	3.37%	0.00%	4.20%	-0.04	0.55	0.00	0.51
WV	0.62%	1.33%	0.00%	1.96%	0.08	0.30	0.00	0.38
WY	0.96%	1.73%	0.00%	2.69%	0.18	0.73	0.00	0.91
U.S.	2.30%	7.03%	0.01%	9.34%	0.74	-0.02	-0.02	0.70

*Denotes states that have adopted California's ZEV program
Source: Figures compiled by Alliance for Automotive Innovation with new registrations for retail and fleet data provided by S&P Global Mobility covering January 1 – March 31, 2023, and January 1 – March 31, 2024



REGISTRATIONS AND INFRASTRUCTURE

Share of Registered EVs In U.S. Light-Duty Fleet Continues to Increase Incrementally. As sales of EVs increase, so does the total number of EVs operating on U.S. roads. There are now nearly 4.7 million EVs in operation in the United States (1.64 percent of all light vehicles in operation). EVs represented more than 1 percent of total vehicles in operation (VIO) for the first time at the end of 2022. The electric vehicles in operation (E-VIO) of 1.6 percent is an increase of 0.5 pp since the first quarter of 2023 and more than two and a half times the E-VIO from the first quarter in 2021 (0.60 percent). [12]



U.S. Public Charging Infrastructure: Overview

While the U.S. Department of Energy notes that roughly 80 percent of all EV charging occurs at home, reliable and convenient access to workplace and public charging and refueling stations help to support customers that purchase EVs or are considering purchasing an EV. Workplace and public charging infrastructure not only eases perceived "range anxiety" concerns but also increases consumer awareness of the technology. In addition, achieving EV market share envisioned by state and/or federal regulators will require moving beyond customers that have access to charging via privately-owned single-family dwellings.

How is NEVI Funding Going?

"There are eight stations in six states with 33 public charging ports in operation supported by NEVI funding. A total of 36 states have released at least their first round of solicitations. Of these states, 23 have issued conditional awards or put agreements in place for more than 550 charging station locations that will each have at least four fast charging ports. Five states—Maine, Pennsylvania, Colorado, Ohio, and Kentucky—have released their second round of conditional awards."

– Joint Office of Energy and Transportation, Q2 Update

The bipartisan Infrastructure Investment and Jobs Act (IIJA) signed into law in November 2021 includes $5 billion in funding for states to establish a nationwide EV charging network (NEVI) along highway corridors and $2.5 billion in competitive grants to deploy publicly available EV charging and other alternative fuel stations through 2026. NEVI funding provides funding to states to strategically deploy charging infrastructure and to establish an interconnected network of publicly available charging.

Here is a snapshot of publicly available EV charging and refueling infrastructure available across the United States at the end of the first quarter of 2024 [13] :

[12] Registered vehicles in operation compiled by Alliance for Automotive Innovation with data provided by S&P Global Mobility as of March 31, 2024
[13] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of March 31, 2024

Level 2: 54,332 Locations, 126,630 EVSE Ports
DC Fast: 9,619 Locations, 40,583 EVSE Ports
Hydrogen Refueling: 56 Stations (55 are in California)
U.S. Total: *62,760 [14] Locations, 167,213 EVSE Ports*

See Recommended Attributes for EV Charging Stations

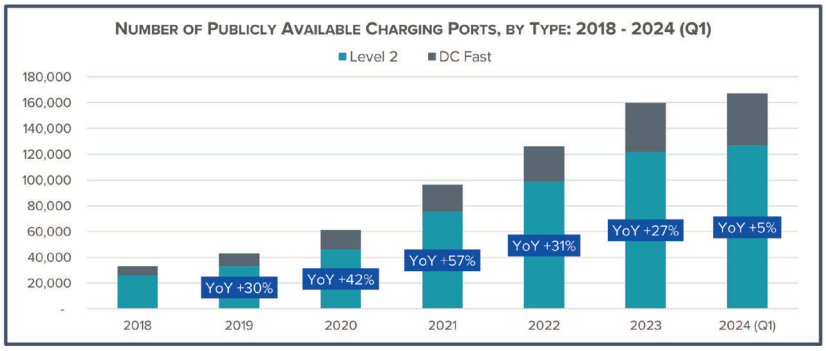
Level 2 Chargers and DC Fast Chargers. Both Level 2 and DC Fast charging play important roles in electrifying the light-duty vehicle fleet. However, the key difference between Level 2 and DC Fast chargers is how quickly each will charge an EV's battery. Level 2 equipment is common for home, workplace, and public charging with longer dwell times. Level 2 chargers can fully charge a BEV from empty in 4-10 hours and a PHEV from empty in 1-2 hours. DC Fast charging equipment enables rapid charging of BEVs in 20 minutes to 1 hour along heavy-traffic corridors, in city centers, at transportation hubs, and fleet depots. Wider installation of both Level 2 chargers, DC Fast chargers, and hydrogen fueling will be necessary to support wider-scale adoption of EVs. The number of public Level 2 charging increased 4 percent at the end of the first quarter of 2024 over the end of the fourth quarter of 2023. DC Fast chargers increased 7 percent. Total charging ports increased 5 percent from the end of 2023. [15] (For context, E-VIO increased 8 percent from the end of 2023 to the end of the first quarter of 2024.)

Through May 29, 2024, more than 60 percent of installed DC Fast charging ports were Tesla (North American Charging Standard) [16]:

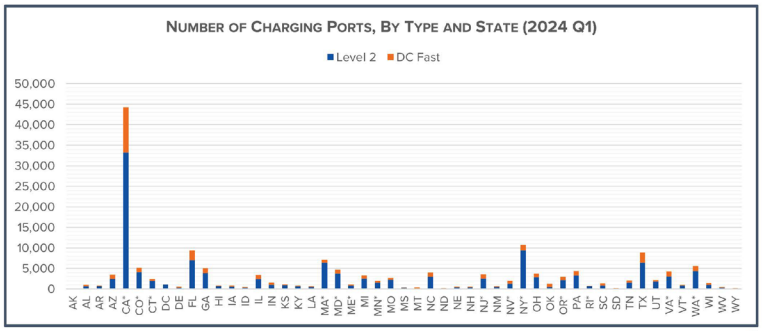
DC Fast Chargers Installed

Type	Ports	%Total
Tesla (NACS)	25,830	61%
CCS Combo	16,187	39%
Total	42,017	100%

After Tesla opened their previously proprietary chargers (in November 2022), at least 18 EV manufacturers have announced that they will move to Tesla's North America Charging Standard.



[14] Some station locations have both Level 2 and DC Fast installed.
[15] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of 3/31/2024
[16] Charging information from U.S. Department of Energy Alternative Fuels Data Center, 5/29/2024; does not include J1772 or CHAdeMO connectors



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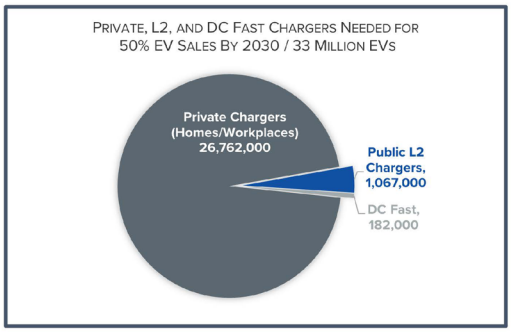
Infrastructure Investment Necessary

An assessment by the U.S. National Renewable Energy Laboratory (NREL) released in June 2023 estimated that a network of 28 million charging ports would be necessary to support 50 percent EV sales by 2030 (and 33 million EVs on the road). [18] NREL estimates that 96 percent of those charging ports would be privately accessible L1 and L2 chargers located at single-family homes, multifamily properties, and workplaces. The remaining 4 percent (1,249,000 ports) would be split between public L2 and high-speed DC Fast charging ports, with L2 making up 85 percent of those public chargers.



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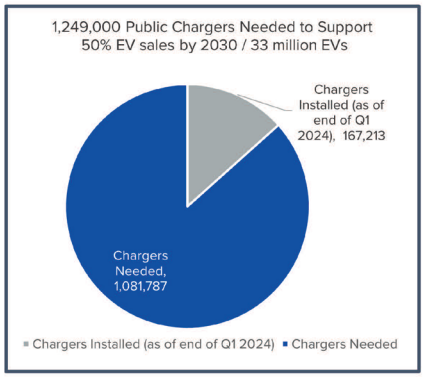
At the end of Q1 2024, there were about 167,000 public charging ports across the country and 4.7 million EVs on the road. Total installed public charging ports are about 13 percent of the needed estimate to support EV penetration by 2030.

More than 1 million additional public chargers (940,370 L2 and 141,417 DC Fast) will need to be installed to satisfy the necessary infrastructure estimate by 2030. This means that between the end of Q1 2024 and December 31, 2030, 438 chargers need to be installed every day, for the next 6.75 years. Or 3 chargers every 10 minutes through the end of 2030.

[17] Charging information from U.S. Department of Energy Alternative Fuels Data Center, stations in operation as of 12/31/2023; *Denotes states that have adopted California's ZEV program.
[18] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[19] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023



Between the end of 2023 and December 31, 2030, 438 chargers need to be installed every day, for the next 7 years. Or 3 chargers every 10 minutes through the end of 2030

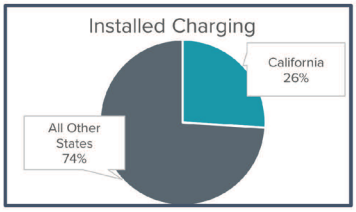
The Cost of This Substantial Infrastructure Necessity Will Largely Fall on Consumers and Commercial Real Estate Owners as They Install Home and Workplace Charging. According to NREL a national capital investment of $53–$127 billion in charging infrastructure is needed by 2030 (including as much as $72 billion for private residential charging) to support 33 million EVs.[20] The large range of potential costs is a result of variable and evolving equipment and installation costs across charging networks, locations, and site designs[21]. Notably, the estimates exclude the cost of grid upgrades and distributed energy resources. The estimated cumulative capital investment includes[22]:

- $22–$72 billion for privately accessible Level 1 and Level 2 charging ports
- $27–$44 billion for publicly accessible fast charging ports
- $5–$11 billion for publicly accessible Level 2 charging ports

Infrastructure Disparities by Geography

Geographic disparities in charging infrastructure are pervasive. At the end of Q1 2024, more than a quarter of all public charging infrastructure was in California, which had 34 percent of all registered EVs.

Alliance for Automotive Innovation participates in EV policy development at the federal and state level via the Joint Office of Energy and Transportation's Electric Vehicle Working Group, through its lithium-ion battery recycling policy framework, recommendations for attributes of EV charging stations, and implementation of the Inflation Reduction Act's EV tax credits[23].



[20] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[21] Various state and federal incentives are available to consumers or businesses that install EV charging infrastructure, including from power utilities.
[22] National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure," June 2023
[23] Alliance for Automotive Innovation, Blog, What We Know (and Don't Know) About the New EV Tax Credit Rules, 12/20/2022; Alliance for Automotive Innovation, Blog, Foreign Entity of Concern: Finally... Some Clarity, 12/1/2023

Vehicles in Operation and Charging by State

Public Charging Outlets And Registerd EVs (as of 3/31/2024)

	EV Level 2	EV DC Fast	H2** Fueling	Total	Percent EVs of Total VIO***	Share of Registered EVs****	EVs Per Charger	EVs Per 10K Residents
AK	85	34	-	119	0.61%	0.07%	29	47.35
AL	581	382	-	963	0.34%	0.38%	18	36.04
AR	679	137	-	816	0.33%	0.19%	11	29.99
AZ	2,441	1,040	-	3,481	1.71%	2.52%	34	164.69
CA*	33,197	10,990	55	44,242	5.16%	34.33%	36	406.77
CO*	4,093	1,013	-	5,106	2.25%	2.62%	24	215.96
CT*	1,922	449	-	2,371	1.56%	1.03%	20	135.01
DC	1,044	61	-	1,105	3.42%	0.25%	11	165.95
DE	311	214	-	525	1.34%	0.26%	23	126.31
FL	6,996	2,369	-	9,365	1.56%	6.39%	32	140.62
GA	3,839	1,187	-	5,026	1.13%	2.28%	21	101.72
HI	705	82	1	788	2.85%	0.69%	41	228.47
IA	515	328	-	843	0.45%	0.31%	17	46.07
ID	300	152	-	452	0.67%	0.28%	29	75.56
IL	2,350	1,036	-	3,386	1.28%	2.74%	38	100.63
IN	983	557	-	1,540	0.60%	0.79%	24	55.49
KS	906	227	-	1,133	0.57%	0.36%	15	57.48
KY	578	228	-	806	0.38%	0.32%	19	33.95
LA	433	235	-	668	0.32%	0.25%	18	25.55
MA*	6,367	761	-	7,128	2.05%	2.41%	16	163.82
MD*	3,726	964	-	4,690	1.95%	2.13%	21	164.87
ME*	815	240	-	1,055	1.11%	0.32%	14	111.05
MI	2,524	735	-	3,259	0.82%	1.49%	21	69.75
MN*	1,455	472	-	1,927	0.98%	1.09%	26	90.84
MO	2,196	488	-	2,684	0.66%	0.81%	14	61.85
MS	283	119	-	402	0.18%	0.12%	14	18.29
MT	186	193	-	379	0.42%	0.15%	18	65.28
NC	2,947	1,071	-	4,018	0.97%	2.01%	23	90.79
ND	117	88	-	205	0.20%	0.03%	8	21.54
NE	400	160	-	560	0.50%	0.22%	19	54.45
NH	373	179	-	552	1.16%	0.33%	28	113.97
NJ*	2,521	1,069	-	3,590	2.24%	3.53%	46	185.84
NM	444	250	-	694	0.73%	0.32%	21	70.55
NV*	1,253	739	-	1,992	2.37%	1.27%	30	196.90
NY*	9,325	1,404	-	10,729	1.84%	4.51%	20	108.20
OH	2,837	844	-	3,681	0.69%	1.56%	20	62.62
OK	459	834	-	1,293	1.20%	1.18%	43	140.25
OR*	2,182	816	-	2,998	2.38%	1.96%	31	218.90
PA	3,274	1,080	-	4,354	0.98%	2.30%	25	84.23
RI*	689	92	-	781	1.27%	0.23%	14	104.11
SC	857	494	-	1,351	0.52%	0.60%	21	55.60
SD	124	111	-	235	0.29%	0.06%	12	32.53
TN	1,507	539	-	2,046	0.64%	0.94%	22	65.40
TX	6,354	2,564	-	8,918	1.11%	5.82%	31	94.96
UT	1,814	377	-	2,191	1.68%	1.09%	23	161.82
VA*	3,059	1,143	-	4,202	1.37%	2.25%	25	123.57
VT*	805	132	-	937	2.35%	0.28%	14	207.28
WA*	4,402	1,198	-	5,600	2.70%	4.01%	34	249.50
WI	957	441	-	1,398	0.66%	0.76%	25	61.29
WV	288	150	-	438	0.28%	0.09%	10	24.31
WY	132	115	-	247	0.29%	0.04%	8	32.99
U.S.	**126,630**	**40,583**	**56**	**167,269**	**1.64%**	**100.00%**	**28**	**143.25**

*Denotes states that have adopted California's ZEV program; **Hydrogen count denotes stations
*** VIO is vehicles in operation; **** State share of U.S. Total
Source: Figures compiled by Alliance for Automotive Innovation with registered vehicle data provided by S&P Global Mobility as of March 31, 2024; Charging information from U.S. Department of Energy Alternative Fuels Data Center, as of 3/31/2024

REGISTRATIONS

EV registrations as a share of all registered light-duty vehicles are 1.6 percent (as of March 31, 2024). There are about 286 million registered light-duty vehicles in the U.S.

At the end of Q1 2024, California accounted for 34 percent of all registered light-duty EVs in the U.S.

States with highest portion of total EVs registered:

1. CA* (1,609,058, 5.16%)
2. DC (11,657, 3.42%)
3. HI (32,454, 2.85%)
4. WA* (188,016, 2.70%)
5. OR* (91,734, 2.38%)
6. NV* (59,747, 2.37%)
7. VT* (12,982, 2.35%)
8. CO* (123,003, 2.25%)
9. NJ* (165,552, 2.24%)
10. MA* (113,070, 2.05%)

States with worst ratio of registered EVs per public charger:

1. NJ*
2. OK
3. HI
4. IL
5. CA*
6. AZ
7. WA*
8. FL
9. OR*
10. TX

Read more about automaker plans for an ***ELECTRIC FUTURE HERE***

SPOTLIGHT ON:
ELECTRIC VEHICLE TAX CREDITS AND MODEL AVAILABILITY

EV tax credits, first established in 2010, were instituted to incentivize consumers by offsetting the cost premium on qualified EVs. Initially, the Federal 30D tax credit provided up to $7,500 (based on minimum battery capacity) for consumers purchasing a new EV. After a manufacturer sold 200,000 EVs, the credit would begin to phase out and that manufacturer's vehicles would no longer qualify for a consumer to claim the credit.

The Inflation Reduction Act of 2022 (IRA) instituted new vehicle and consumer requirements to qualify for the tax credit. Immediately following the law's enactment, a new North America assembly requirement kicked in. Before the law's enactment, roughly 92 percent of EVs for sale in the United States qualified for the credit. Enactment of the IRA (August 2022) lowered that number to 35 percent (or 25 out of 72 models sold in the U.S.)

On January 1, 2023, more provisions of the IRA took effect, further limiting availability of the credit. Those provisions included limits on manufacturer's suggested retail price (MSRP) and consumer's adjusted gross income (AGI). At this time, the 200,000-vehicle cap on manufacturers was also lifted. Upon being applicable at the start of 2023, the new requirements further lowered the number of qualified vehicle models to 21 out of 86 (24 percent). That said, a technical adjustment to vehicle classifications in February 2023 added five more vehicles back to the eligibility list that had previously been ineligible for the credit.

In April 2023, new critical mineral and battery component rules were instituted, splitting the $7,500 EV tax credit in two and based eligibility on EVs meeting certain requirements related to the origin and valuation of the battery's critical minerals and components:

1. To be eligible for half of the incentive ($3,750), 50 percent (increasing to 100 percent by 2029) of the value of the battery components must be manufactured or assembled in North America.
2. To be eligible for the other half of the incentive ($3,750), 40 percent of the value of critical minerals (increasing to 80 percent by 2027) in the EV battery must be extracted or processed in the U.S. – or in a country with a U.S. free trade agreement – or recycled in North America.

These provisions removed more previously eligible models from the qualifying tax credit list. As a result, only 17 out of 91 models (19 percent) were eligible for half or all of the federal tax credit.

After December 31, 2023, a vehicle did not qualify for any of the credit if any "components" contained in its battery are "manufactured or assembled by a foreign entity of concern." [24] Additionally, beginning in 2024, the critical mineral component requirement increased to 50 percent, while the battery component requirement increased to 60 percent.

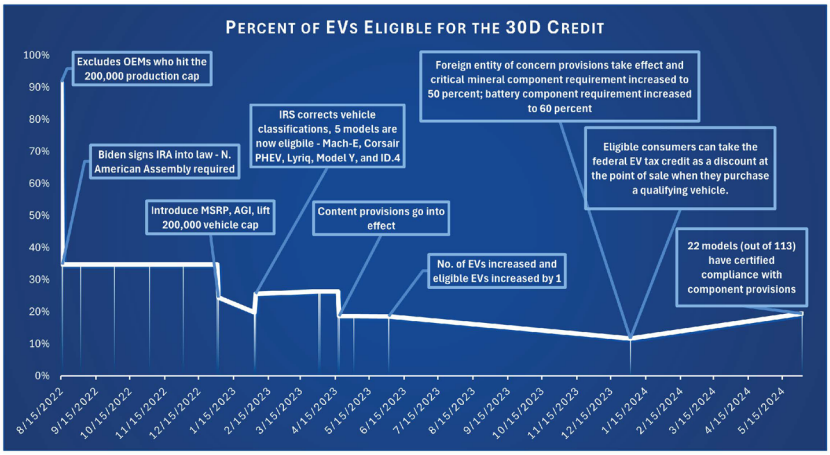
There are currently 113 available EV models for sale in the U.S. market, but only 22 (19 percent) are eligible for any part of the tax credit:

- 13 models fully eligible ($7500).
- 9 models partially eligible ($3750).

[24] Benchmark Minerals, Report, Q1 2023

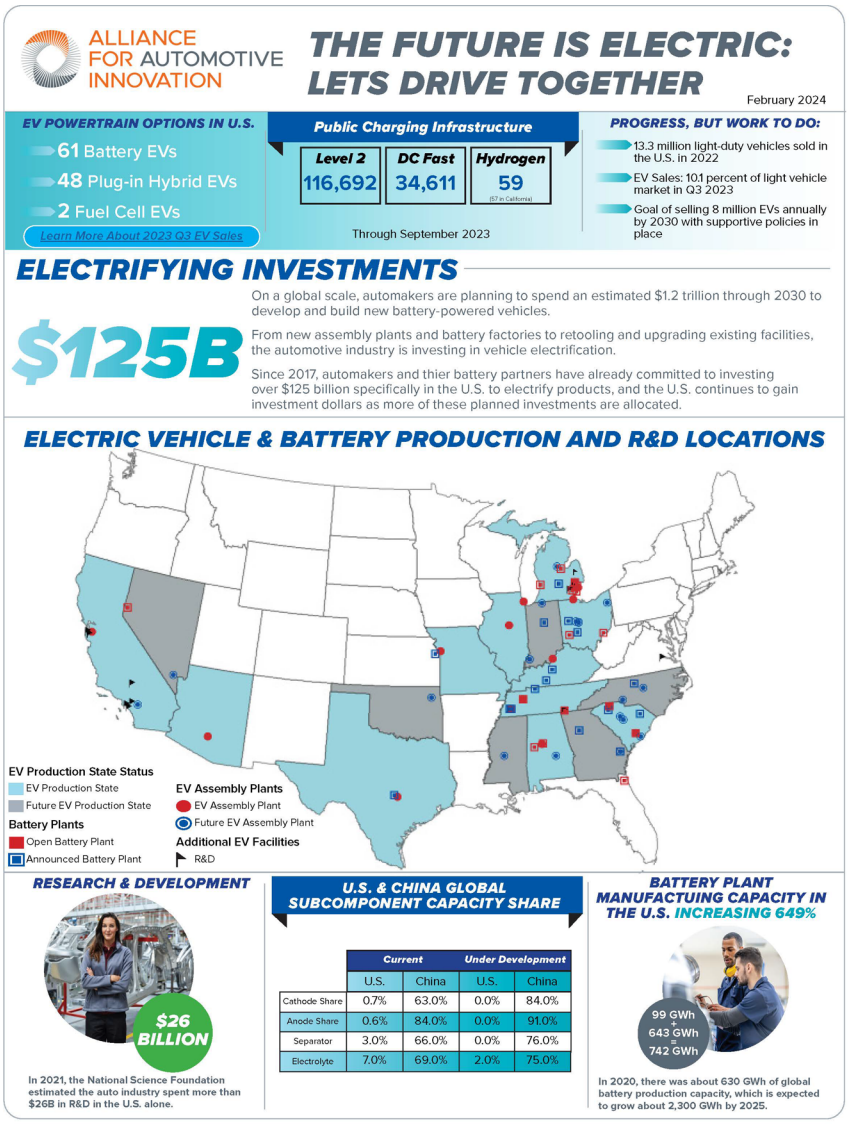
The ability of automakers to certify that certain vehicles qualify for the revised tax credit will largely hinge on meeting the increasing critical mineral and battery component cost thresholds, not to mention the foreign entity of concern requirements for both battery components (January 2024) and critical minerals (January 2025) – presuming a buyer is otherwise eligible to claim the corresponding tax credit.

For a list of EVs that qualify for the federal government's new clean vehicle tax credit of up to $7,500 *click here*.



[25] Note: eligible vehicles under 30D also require an eligible buyers adjusted gross income under $300,000 for married couples filing jointly, $225,000 for heads of households, and $150,000 for all other filers; MSRP below $80,000 for vans, sport utility vehicles and pickup trucks and $55,000 for other vehicles. Additional restrictions apply. View qualifications here: https://fueleconomy.gov/feg/tax2023.shtml#requirements




ALLIANCE FOR AUTOMOTIVE INNOVATION
THE FUTURE IS ELECTRIC: LETS DRIVE TOGETHER
February 2024
EV POWERTRAIN OPTIONS IN U.S.
61 Battery EVs
48 Plug-in Hybrid EVs
2 Fuel Cell EVs
Learn More About 2023 Q3 EV Sales
Public Charging Infrastructure
Level 2
116,692
DC Fast
34,611
Hydrogen
59
(57 in California)
Through September 2023
PROGRESS, BUT WORK TO DO:
13.3 million light-duty vehicles sold in the U.S. in 2022
EV Sales: 10.1 percent of light vehicle market in Q3 2023
Goal of selling 8 million EVs annually by 2030 with supportive policies in place
ELECTRIFYING INVESTMENTS
$125B
On a global scale, automakers are planning to spend an estimated $1.2 trillion through 2030 to develop and build new battery-powered vehicles.
From new assembly plants and battery factories to retooling and upgrading existing facilities, the automotive industry is investing in vehicle electrification.
Since 2017, automakers and thier battery partners have already committed to investing over $125 billion specifically in the U.S. to electrify products, and the U.S. continues to gain investment dollars as more of these planned investments are allocated.
ELECTRIC VEHICLE & BATTERY PRODUCTION AND R&D LOCATIONS
EV Production State Status
EV Production State
Future EV Production State
Battery Plants
Open Battery Plant
Announced Battery Plant
EV Assembly Plants
EV Assembly Plant
Future EV Assembly Plant
Additional EV Facilities
R&D
RESEARCH & DEVELOPMENT
$26 BILLION
In 2021, the National Science Foundation estimated the auto industry spent more than $26B in R&D in the U.S. alone.
U.S. & CHINA GLOBAL SUBCOMPONENT CAPACITY SHARE
Current
Under Development
U.S.
China
U.S.
China
Cathode Share
0.7%
63.0%
0.0%
84.0%
Anode Share
0.6%
84.0%
0.0%
91.0%
Separator
3.0%
66.0%
0.0%
76.0%
Electrolyte
7.0%
69.0%
2.0%
75.0%
BATTERY PLANT MANUFACTUING CAPACITY IN THE U.S. INCREASING 649%
99 GWh + 643 GWh = 742 GWh
In 2020, there was about 630 GWh of global battery production capacity, which is expected to grow about 2,300 GWh by 2025.

ELECTRIC VEHICLE & BATTERY PRODUCTION AND R&D LOCATIONS

STATE	PLANT TYPE	COMPANY	MODEL	CITY	STATUS
Alabama	Battery	Mercedes-Benz U.S. International		Woodstock	Open
		Accumotive		Vance	Open
	Assembly	Hyundai	Genesis GV70	Montgomery	On Sale Now!
		Mercedes-Benz U.S. International	EQE SUV	Vance	On Sale Now!
			EQS SUV	Vance	On Sale Now!
Arizona	Battery	American Battery Factory		Tuscon	Announced
		KORE Power		Phoenix	Announced
	Assembly	Lucid	AIR	Casa Grande	On Sale Now!
California	Battery	Statevolt		Imperial Valley	Announced
	Assembly	Fisker/Karma		Moreno Valley	Coming Soon
		Tesla Motors	MODEL 3	Fremont	On Sale Now!
			MODEL S	Fremont	On Sale Now!
			MODEL X	Fremont	On Sale Now!
	R&D	BMW Technology Office		Mountain View	Open
		Hyundai America Technical Center, Inc. (California Proving Grounds)		California City	Open
		Hyundai-Kia Technical Center		Irvine	Open
		Hyundai America Technical Center, Inc. (Chino)		Chino	Open
		Mazda R&D		Irvine	Open
		Mitsubishi Motors R&D of America, Inc.		Cypress	Open
		Subaru Research & Development, Inc.		Cypress	Open
		Volkswagen: Innovation and Engineering Center California (IECC)		Belmont	Open
Florida	Battery	SAFT		Jacksonville	Open

STATE	PLANT TYPE	COMPANY	MODEL	CITY	STATUS
Georgia	Battery	SK Innovation		Atlanta	Open
					Announced
		Hyundai Motor Group (Hyundai, Kia, Genesis)		Bryan County	Announced
	Assembly	Kia	EV9	West Point	Coming Soon
		Hyundai Motor Group (Hyundai, Kia, Genesis)		Bryan County	Announced
Illinois	Assembly	Ford	AVIATOR	Chicago	On Sale Now!
		Rivian	R1S	Normal	On Sale Now!
			R1T	Normal	On Sale Now!
			EDV	Normal	On Sale Now!
Indiana	Battery	Stellantis/Samsung SDI		Kokomo	Announced
		General Motors/ Samsung SDI		New Carlisle	Announced
	Assembly	Electric Last Mile Solutions (ELMS)		Mishawaka	Coming Soon
		Toyota	SUV	Princeton	Coming Soon
Kansas	Battery	Panasonic		De Soto	Announced
Kentucky	Battery	Envision AESC		Bowling Green	Announced
		Ford		Glendale	Two Plants Announced
	Assembly	Ford	CORSAIR	Louisville	On Sale Now!
			ESCAPE	Louisville	On Sale Now!
Michigan	Battery	Ford		Rawsonville	Open
				Marshall	Announced
		General Motors		Brownstown	Open
		General Motors/LG Energy Solution		Lansing	Announced
		LG Energy Solution		Holland	Open
		AKASOL		Hazel Park	Open
		JCI Brookfield		Holland	Open
		Samsung SDI		Auburn Hills	Open
		Xalt Freudenberg		Midland	Open

STATE	PLANT TYPE	COMPANY	MODEL	CITY	STATUS
	Assembly	Ford	F-150	Dearborn	On Sale Now!
		General Motors	Chevrolet Silverado	Detroit - Hamtramck & Orion Township	Coming Soon
			Cadillac CELESTIQ	Warren	Coming Soon
			BOLT EUV	Orion Township	On Sale Now!
			GMC Sierra	Detroit - Hamtramck & Orion Township	Coming Soon
			Hummer EV Edition 1 Pickup	Detroit - Hamtramck	On Sale Now!
			Hummer EV Edition 1 SUV	Detroit - Hamtramck	Coming Soon
			BOLT EV	Orion Township	On Sale Now!
		Stellantis	Grand Cherokee 4xe	Detroit	On Sale Now!
	R&D	Hyundai America Technical Center, Inc.		Superior Township	Open
		Mitsubishi Motors R&D of America, Inc.		Ann Arbor	Open
		Nissan Technical Center North America		Farmington Hills	Open
		Subaru Research & Development Inc.		Van Buren Township	Open
Mississippi	Assembly	Nissan		Canton	Coming Soon
Missouri	Assembly	Ford	E-Transit	Kansas City	On Sale Now!
Nevada	Battery	Panasonic/Tesla		Sparks	Open
		Tesla Motors		Sparks	Announced
New York	Battery	Imperium3		Endicott	Open/Expanding
North Carolina	Battery	Toyota		Greensboro	Announced
	Assembly	Arrival		Charlotte	Coming Soon
		Vinfast		Chatham County	Coming Soon
Ohio	Battery	American Battery Solutions		Springboro	Open
		General Motors/LG Energy Solution		Warren	Open
		Honda (battery case)		Anna	Announced
		Honda/LG Energy Solution		Jeffersonville	Announced
	Assembly	Honda	New EV	East Liberty	Announced
			New EV	Marysville	Announced
			New FCEV	Marysville (PMC)	Coming Soon
		Lordstown Motors	Endurance	Lordstown	Coming Soon
		Stellantis	WRANGLER 4xe	Toledo	On Sale Now!

STATE	PLANT TYPE	COMPANY	MODEL	CITY	STATUS
South Carolina	Battery	BMW (assembly)		Spartanburg	Open
		BMW (assembly)		Woodruff	Announced
		Envision AESC		Florence	Announced
		Volvo		Ridgeville	Open
	Assembly	Arrival		Rock Hill	Coming Soon
		BMW	BMW XM	Spartanburg	On Sale Now!
			X5 xDrive45e	Spartanburg	On Sale Now!
		Volvo	Polestar 3	Ridgeville	Coming Soon
			VOLVO S60	Ridgeville	On Sale Now!
			VOLVO EX90	Ridgeville	Coming Soon
		Mercedes-Benz Vans	eSprinter	North Charleston	Coming Soon
		Scout Motors		Columbia	Announced
Tennessee	Battery	Envision AESC		Smyrna	Open
		Ford		Stanton	Announced
		General Motors/LG Energy Solution		Spring Hill	Announced
		LG Chem (Cathode Manufacturing)		Clarksville	Announced
		Volkswagen		Chattanooga	Open
		Microvast		Clarksville	Announced
	Assembly	Ford		Stanton	Coming Soon
		General Motors	Cadillac LYRIQ	Spring Hill	On Sale Now!
		Nissan	LEAF	Smyrna	On Sale Now!
		Volkswagen	ID.4	Chattanooga	On Sale Now!
	R&D	Volkswagen		Chattanooga	Open
Texas	Battery	Tesla Motors		Austin	Announced
	Assembly	Tesla Motors	Model Y	Austin	On Sale Now!
			Cybertruck	Austin	On Sale Now!
Virginia	R&D	Mitsubishi Motors R&D of America, Inc.		Arlington	Open