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Budget Committee

United States Senate

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

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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.

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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.*

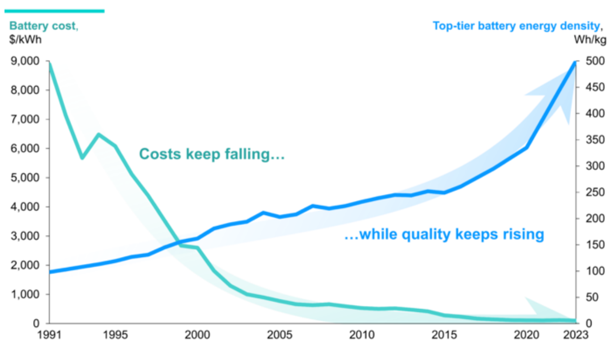

Figure 1. Battery Cost and Energy Density Since 1990
Source: RMI, https://rmi.org/the-rise-of-batteries-in-six-charts-and-not-too-many-numbers/

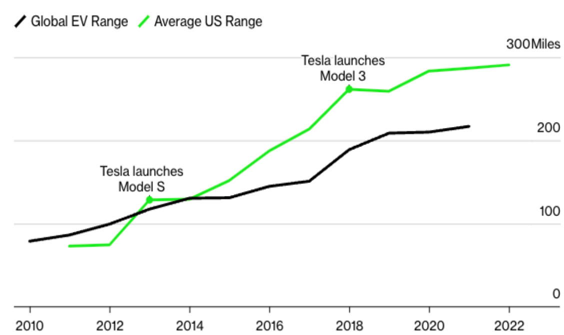

Figure 2. Average EV Range Approaches 300 Miles in U.S.
Source: Bloomberg, https://www.bloomberg.com/news/articles/2023-03-09/average-range-for-us-electric-cars-reached-a-record-291-miles

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]

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[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…

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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).

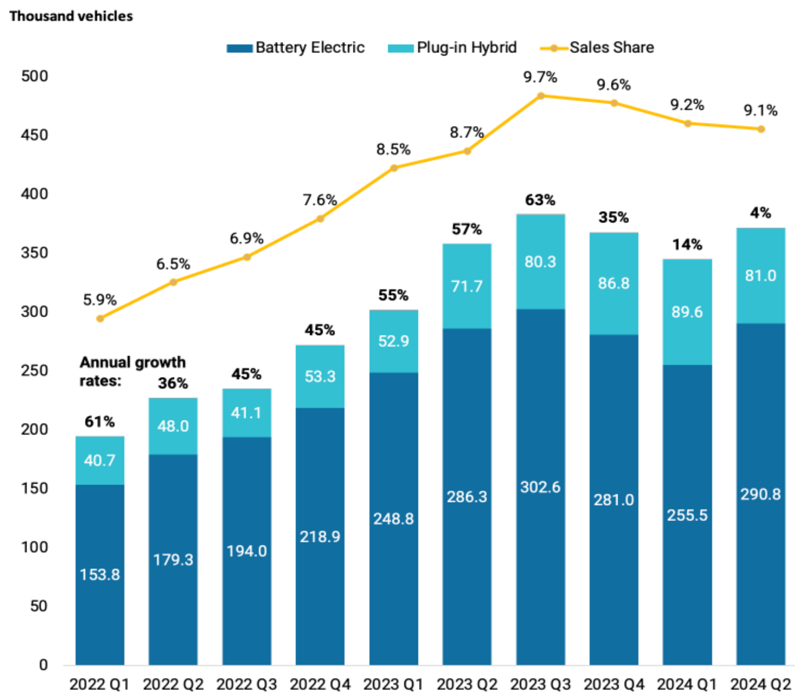

Figure 3. Quarterly U.S. Battery Electric and Plug-in Hybrid Electric Vehicle Sales
Data source: Argonne National Laboratory, "Light Duty Electric Drive Vehicles Monthly Sales Updates - Historical Data." *https://www.anl.gov/esia/reference/light-duty-electric-drive-vehicles-monthly-sales-updates-historical-data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

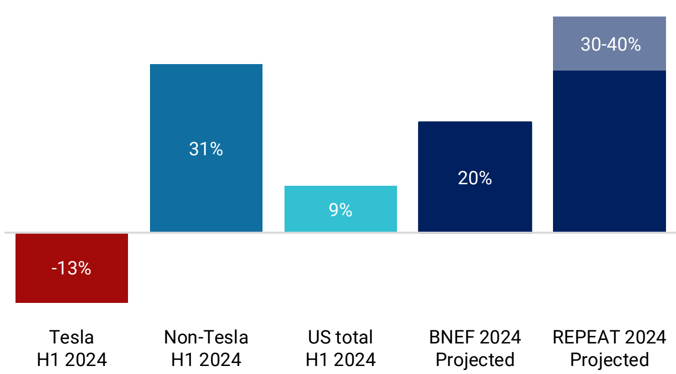

Figure 4. Comparison of Actual vs Projected Year-on-Year Growth Rates for 2024 U.S. Battery Electric and Plug-in Hybrid Electric Vehicle Sales
Data source: Historical data for overall market from ANL (full citation see Figure 3 above) and for Tesla from Marklines, *https://www.marklines.com/en/statistics/flash_sales/automotive-sales-in-usa-by-month.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

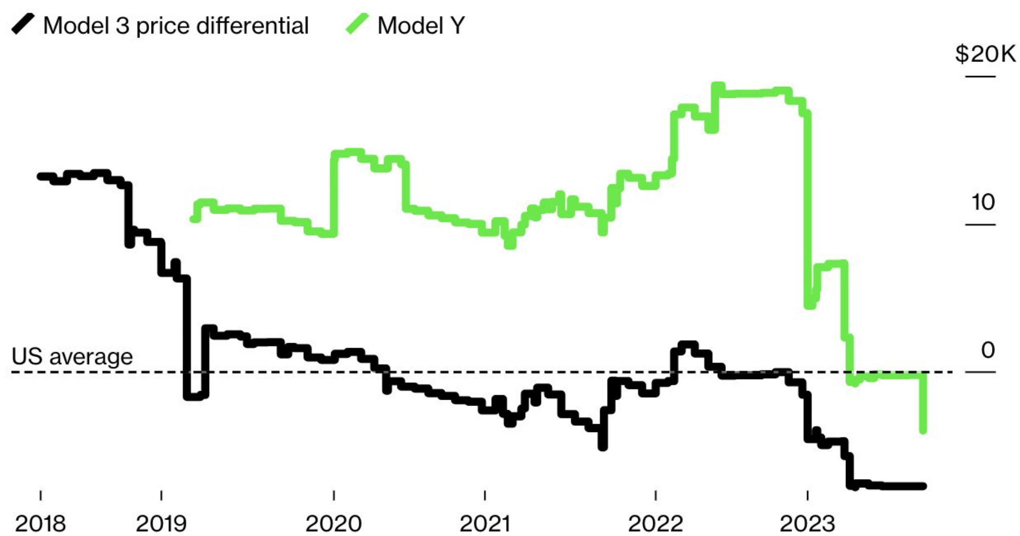

Figure 5. Tesla Prices Now Compete with the Average New Car
Starting prices fall below the U.S. benchmark transaction price
Source: Bloomberg, https://www.bloomberg.com/news/articles/2023-10-05/where-is-tesla-s-ev-competition

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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/1wiNeeKfpT73YIhpgdaqvCe1wyMue5wX0STSpcy-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

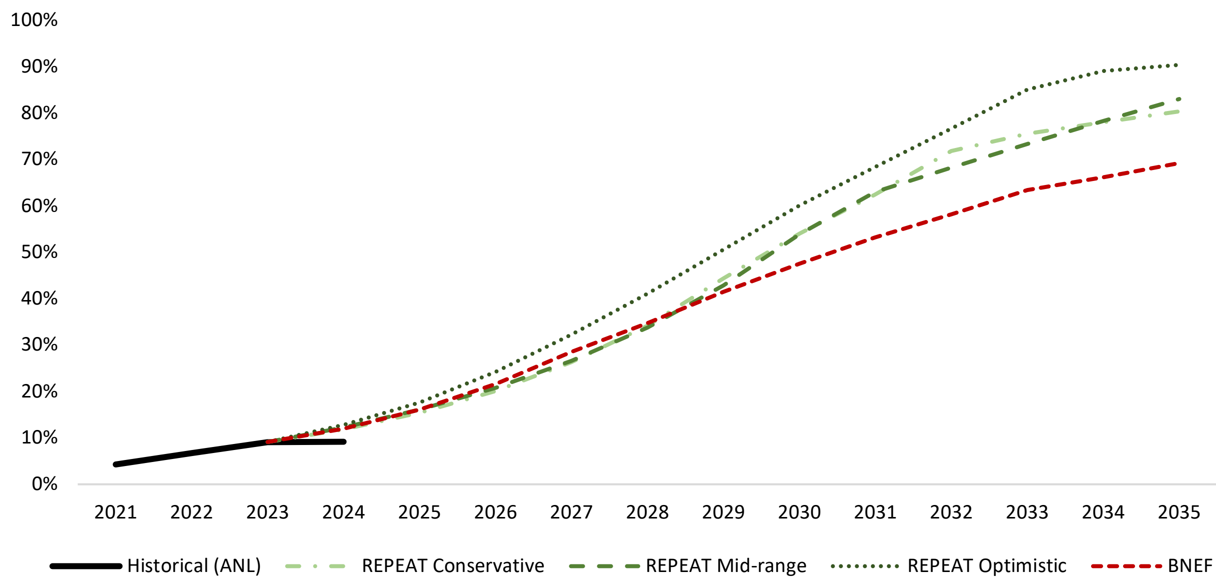

Figure 6. Historical vs Projected Battery Electric and Plug-in Hybrid Electric Vehicle Sales Shares
Share of light duty vehicle sales
Source: Historical data for overall market from ANL (full citation see Figure 3 above). Projected growth rates from Bloomberg NEF Global EV Outlook 2024 *and REPEAT Project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

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[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.

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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.

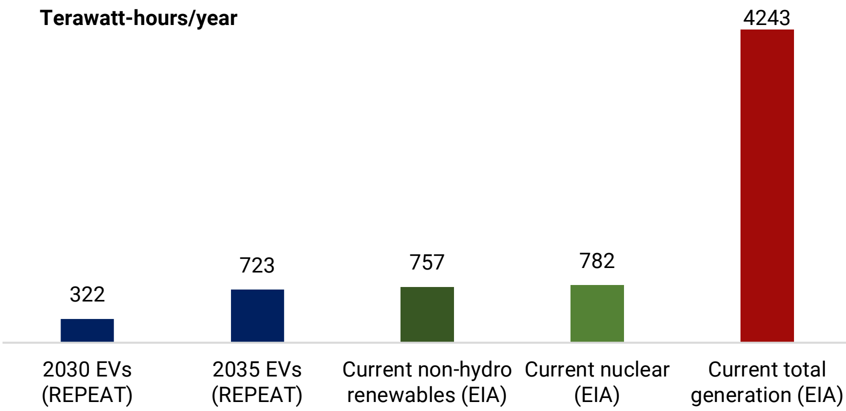

Figure 7. Projected Electricity Demand From Battery Electric and Plug-In Hybrid Electric Vehicles vs Current U.S. Electricity Generation

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