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ANALYSIS

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Re-thinking procurement incentives for electric vehicles to achieve net-zero emissions

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Procurement incentives are a widely leveraged policy lever to stimulate electric vehicle (EV) sales. However, their effectiveness in reducing transportation emissions depends on the behavioural characteristics of EV adopters. When an EV is used, under what conditions and by whom dictates whether or not these vehicles can deliver emissions reductions. Here, we document that replacing gasoline powered vehicles with EVs may—depending on behavioural characteristics—increase, not decrease, emissions. We further show that counterfactual vehicle inventory—how many vehicles a household would own absent an EV purchase—is an important influencer of these effects. We conclude that achieving emissions reductions using EVs requires redesigning procurement incentive programmes in a manner that (re)distributes incentives towards the second-hand EV market. Doing so would not only facilitate emissions reductions but also address fiscal prudency and regressivity concerns associated with these programmes.

Can existing electric vehicle (EV) subsidy policies facilitate reductions in carbon emissions? If so, under what conditions? Vehicle electrification features prominently in environmental sustainability frameworks, a reflection of the presumed emissions advantage that EVs command over internal combustion engine vehicles (ICEVs)[1–3]. This presumption has merit. Studies show clear, consistent and compelling evidence of a superior emissions profile for EVs compared to ICEVs[4]. This profile persists even when emissions associated with EV production, extraction, processing, transportation and fuel distribution are accounted for[1,4].

Less clear, however, is the extent to which an EV's emissions advantage persists given heterogeneity in consumer behaviour. Leveraging EVs as a pathway towards carbon emissions reduction depends, in part, on behavioural parity: the manifestation of consumer actions and reactions when driving EVs that are analogous to ICEVs. However, it remains unclear, based on existing evidence, whether EV usage patterns and user behaviours differ from ICEVs[5–8]. The most notable potential difference is reduced vehicle utilization; that is, the accrual of fewer vehicle miles travelled in an EV relative to an ICEV. How might these differences impact an EV's ability to deliver an emissions advantage?

Answering this question is timely given the near global ubiquity of EV procurement incentives (subsidies). For example, the United States government provides tax credits (up to US$7,500 per vehicle) for qualified EV purchases. Similar programmes exist and have been adopted in countries like Germany, Japan and Australia (to name a few). Although these programmes vary regarding subsidy magnitude (how much financial relief is offered for procuring an EV), their underlying intent is homogenous: to incentivize fleet turnover as a pathway towards carbon emissions reduction. To what extent are these reductions realized given heterogeneity in EV usage patterns and behaviour?

Our work addresses this issue. We assess how diversity in consumer behaviour impacts an EV's ability to deliver an emissions advantage. Our efforts emphasize quantifying the extent to which behavioural precursors may disproportionally enable (or impede) emissions advantage delivery. We subsequently extrapolate the implications of our findings for EV procurement incentive policy. Our efforts are judicious given the need to achieve meaningful reductions in carbon emissions using pathways that (given political and fiscal constraints) do not further exacerbate deficit spending concerns[9].

Our work builds upon existing literature in three ways. First, whereas past studies have examined EV's potential emissions advantages given heterogeneity in behavioural patterns[6,7] or counterfactual vehicle fleets in isolation[10], the present study examines how the confluence of driving behaviour and choice of vehicle replacement impact EV's emissions benefits.

This distinction is a subtle yet important one. Previous estimates find that accounting for the higher-than-average fuel efficiency of most counterfactual vehicles reduces EV's emissions benefits by 39%—assuming EVs are driven between 136,328 and 164,323 miles over their lifetime[10]. However, emerging evidence suggests that EV mileage estimates (in both annualized and aggregate terms) may be far lower, the potential result of households' decision to purchase EVs as secondary, or complementary, vehicles[6].

This challenges the validity of presupposing that EVs demonstrate equivalent utilization to ICEVs and highlights the necessity for more precise analysis based on realistic household behaviour. By jointly analysing behavioural heterogeneity and counterfactual vehicle inventory (which vehicles a household would have owned or purchased were an EV not procured), our study demonstrates how the preconditions necessary to deliver an EV emissions advantage vary across households.

Moreover, whereas other studies assume static and homogenous consumer behaviour as a precursor to assessing (and realizing) EV's emissions advantage[10], we quantify requisite EV mileage needed to achieve an emissions advantage given documented behavioural heterogeneity in how vehicles are used in multi-vehicle households[6,7]. This facilitates greater precision when ascertaining the effectiveness of EV procurement incentives. This is particularly relevant given the increasing number of households that own more than one vehicle.

Third and finally, unlike previous studies[10], our counterfactual scenarios do not assume that vehicle procurement in households

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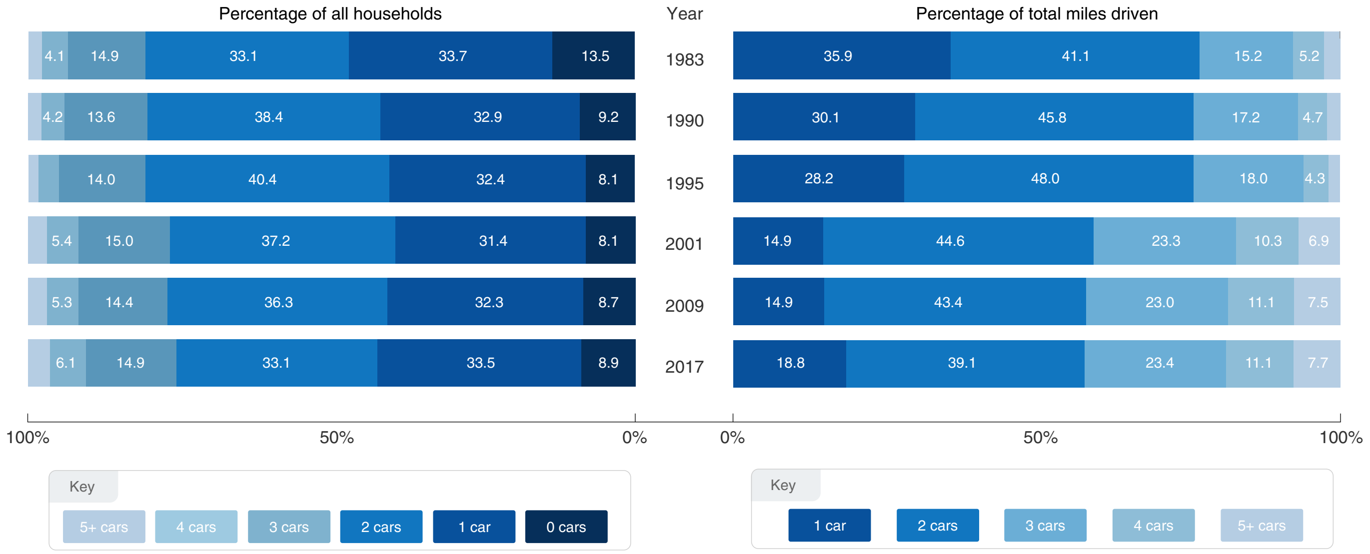

Fig. 1 | Auto procurement and utilization trends analysis based on NHTS data. Historical automotive trend data.

will occur regardless of EV availability. Instead, our counterfactuals allow for the possibility that some households would (absent EV procurement) continue driving existing vehicles in household inventory. Put simply, were these households not to purchase an EV, they would continue driving the vehicle they already own. Consideration of this counterfactual accounts for diversity in consumer behaviour and facilitates, we suggest, a more comprehensive assessment of the financial prudency of EV procurement incentives.

Results and discussion

To analyse the impact of EV utilization patterns and household behaviour on potential emissions advantages, we first leverage a nationally representative dataset to quantify household vehicle ownership trends and aggregate utilization levels. After determining the number of vehicles owned by households, as well as the proportion of miles travelled by single- and multi-vehicle households, we analyse emergent procurement and utilization patterns and construct four representative scenarios (Fig. 1 and Table 1). Given existing policy's emphasis on incentivizing new, rather than used, EV purchases, we focus our analysis on households procuring new EVs.

We subsequently use existing data (Methods and Supplementary Information) to inform our model of requisite behaviours to achieve an EV emissions advantage. Specifically, we estimate the aggregate utilization (miles travelled over the vehicle's lifetime) and longevity (measured in years of ownership) required for EVs to reduce emissions relative to each counterfactual, considering vehicle status and existing utilization trends. Additional details of our approach are available in Methods and Supplementary Information.

Our analysis yields two key findings. First, like previous work, we find that acquiring an emissions advantage requires that EVs exceed specific aggregate utilization thresholds[11]. However, building on previous work, we document that the stringency of these thresholds—how many miles the EV must cover over its lifetime to attain and maintain a 'green lead'—depends on the specific counterfactual considered. Our model estimates that less stringent utilization thresholds (28,069 miles) are required of households that either (1) do not currently own a vehicle and would (absent an available EV) purchase an ICEV (scenario 1, Fig. 2a) or (2) currently own an ICEV and would (absent an available EV) purchase another ICEV as a second, complementary vehicle (scenario 3, Fig. 2c).

Conversely, more stringent thresholds (68,160 miles) are required in households that either (1) currently own an ICEV and would (absent replacing that vehicle with a new EV) continue to drive the ICEV (scenario 2, Fig. 2b) or (2) currently own two ICEVs and would (absent replacing the second ICEV with an EV) drive the ICEVs already in inventory (scenario 4, Fig. 2d). More stringent utilization profiles are attributable to counterfactual-specific characteristics: absent EV procurement, the household would drive their existing ICEV(s). Since emissions associated with manufacturing that/those ICEV(s) have already been produced, their presence is realized in both the EV procurement scenario and the counterfactual. During comparative analysis, these emissions cancel out, producing a 'write off' for ICEV-specific manufacturing emissions.

Counterfactual decisions to either purchase a new ICEV or continue to drive an existing one do not necessarily describe two separate demographics. A household may, over time, transition from one group to another. For example, if an ICEV has not yet reached the end of its usable life, the household may choose to continue driving it were a new EV unavailable. However, once that ICEV can no longer satisfy any portion of the household's travel demand, the household would seek out a new EV and (absent an available EV) purchase a new ICEV. By considering both decisions, we show how the stringency of our thresholds also partially depends on when the incentive is realized and how it coincides with the current lifespan(s) of the household's existing vehicle(s).

Our second finding is that counterfactual vehicle inventory (a seldom discussed parameter to our knowledge) influences the likelihood of achieving the aforementioned thresholds. Consider that although the requisite utilization threshold imposed by scenario 1 is identical to scenario 3 (28,069 miles), the requisite longevity (how many years the EV must remain in service to deliver an emissions benefit) is different: 2.73 versus 4.32 yr, respectively. Similarly, scenarios 2 and 4 impose different requisite longevity requirements (6.62 and 10.49 yr, respectively) despite having the same utilization threshold (68,160 miles). Increased requisite longevity in scenarios 3 and 4 reflects lower annual (versus aggregate) utilization of the second vehicle.

Our model does not specifically discern why 'second vehicle' longevity thresholds are higher. This lack of specificity is intentional. Second vehicles may be driven less because they are EVs[5,6]. But lower mileage may also be the product of vehicle status[12]. Our analysis of the US Department of Transportation's National Household Travel Survey (NHTS) data (Fig. 1) further supports this claim, as additional vehicles are associated with declining marginal

Table 1 | Scenario summary

	EV procurement scenario	Counterfactual procurement scenario	Requisite aggregate utilization threshold (miles)	Requisite longevity threshold (yr)
Scenario 1	Household owns no vehicles and will purchase a new EV	Household owns no vehicles and will purchase a new ICEV	28,069	2.73
Scenario 2	Household currently owns one ICEV and will replace that ICEV with a new EV	Household currently owns one ICEV and will continue to drive that ICEV	68,160	6.62
Scenario 3	Household currently owns one ICEV and will purchase a new EV as a second, complementary vehicle	Household currently owns one ICEV and will purchase a new ICEV as a second, complementary vehicle	28,069	4.32
Scenario 4	Household currently owns two ICEVs and will replace the second ICEV with a new EV	Household currently owns two ICEVs and will continue to drive those ICEVs	68,160	10.49

miles travelled (Supplementary Table 1). Households with more vehicles in inventory also not only travel more but they often put more miles on their most-used (primary) vehicle compared with households with fewer vehicles[13]. Consequently, even if EVs demonstrated equivalent annual utilization as ICEVs[14], a reflection of envisioned improvements in battery technology and recharging infrastructure, EVs would—when relegated to secondary vehicle status—still need to remain in service for longer than their primary vehicle counterparts.

Collectively, these results hint at a paradoxical finding: using EVs as substitutes, not complements (particularly in multi-vehicle households) may produce more onerous preconditions for realizing an emissions advantage. This finding challenges the efficacy of existing EV policy proposals, whose underlying intent is to incentivize EV purchases as substitutes.

Implications for policy. Our findings have important implications for EV-dependent sustainability frameworks. A key tenet of these frameworks are procurement incentives, government-sponsored financial programmes, directed in large measure towards non-commercial vehicle owners to encourage 'electrification'. Intuitively, such policies may make sense. In the United States, for example, privately owned cars, vans and light-duty trucks are responsible for most vehicle miles travelled and, by consequence, the greater part of transportation-related emissions[15]. Incentivizing these owners to use EVs instead of ICEVs offers substantial carbon emissions reduction opportunities. However, our model estimates that achieving 'green leads' could—under certain conditions—be challenging.

We observe that using EVs as the non-primary vehicle increases the longevity thresholds required for these vehicles to deliver an emissions benefit. This finding is noteworthy because the number of multi-vehicle households in the United States has increased substantially over the years[16]. Although this increase has been accompanied by rising vehicle ownership duration, the observed length of new vehicle ownership (6.61 yr) falls far short of the requisite longevity (10.49 yr in scenario 4) for EVs to deliver an emissions benefit during its first ownership period[17]. Moreover, because our requisite longevity estimates denote the number of years that must elapse before an EV can deliver an emissions advantage over the counterfactual procurement scenario (namely, driving an ICEV), failing to achieve these estimates could make driving an EV worse than driving an ICEV.

Given these findings, how should governments respond? Existing EV procurement incentive programmes direct sizable financial relief towards first adopters. A willingness to purchase a new EV is almost universally accompanied by government support, a reflection of the belief that incentives should be applied at the initial point of sale, not afterwards[18]. Our results suggest a more targeted approach is warranted, one that considers EV usage patterns and user behaviours. Incentive programmes should, where possible, account for counterfactual vehicle inventory and adjust incentive magnitudes accordingly. This may be achieved by transitioning away from incentive programmes that reward EV adoption to programmes that reward utilization, such as subsidized charging costs and/or vehicle maintenance fees.

Such an approach is timely given that governments have limited capital and must, given competing priorities, judiciously allocate that capital. In the United States alone, publicly held debt is projected to rise from 102% of gross domestic product in 2021 to 202% in 2050[19]. Similar debt accumulation—and by consequence, fiscal anxiety—is projected globally without changes in current tax rates or government benefit programmes. Consequently, taxpayer-funded investments must prioritize return maximization. Our approach reflects this reasoning, with an emphasis placed on revenue-neutral adjustments to existing EV procurement incentive policies. Our model estimates that this outcome is more likely to be realized when counterfactual household inventory is considered over the current one-size-fits-all approach.

A more targeted vehicle electrification policy may be viewed as a weakened response to the threat posed by transportation-related emissions. We caution against the adoption of such reasoning. While there is broad consensus on the need to reduce carbon emissions, financing these efforts entirely using taxpayer funds remains unlikely due to the worsening debt outlook, capital intensity of indefinite subsidies and public resistance towards federal subsidies[20]. Hence, it is important—for reasons of political practicality—that public spending programmes be diligent and deliberate, maximizing emission benefits per dollar spent.

Adjusting the magnitude of EV procurement incentives also matters for reasons of socioeconomic equity. Our model estimates higher requisite longevity thresholds in multi-vehicle households. These households are typically characterized by high income and, by consequence, are less likely to keep new vehicles in inventory for long periods of time[21]. As the requisite longevity threshold among households in scenario 4 exceeds current first ownership durations[17], realizing an EV's emissions advantage in these households necessitates dependence on secondary EV adopters, individuals who are more likely to belong to low-income households[21]. EV procurement incentive programmes should reflect this reality, with some government support—initially targeted toward first adopters—being explicitly (re)directed towards second-hand EV owners[22]. Doing so would also alleviate concerns surrounding the regressive nature of existing EV procurement incentive programmes[23].

Limitations. We conclude by acknowledging that our analysis has limitations. Uncertainties regarding the phasing out of fossil fuel-powered electricity grids, reductions in EV production emissions and projected changes in vehicle energy consumption profiles (to name a few factors) can (and will) affect the stringency of our estimates.

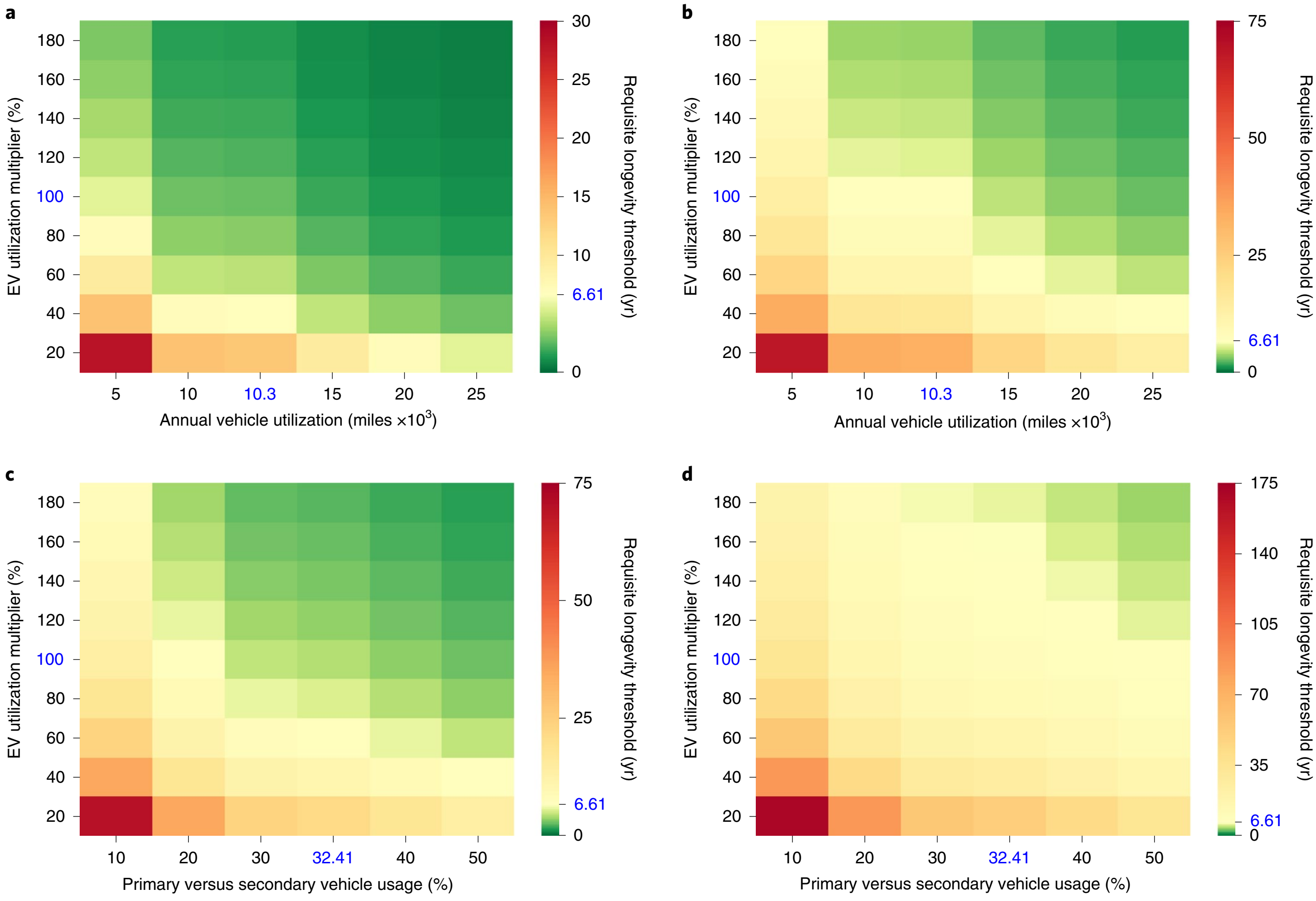

Fig. 2 | Requisite EV longevity thresholds. a, Scenario 1: requisite EV longevity threshold (yr) to achieve the 28,069 mile requisite aggregate utilization threshold. Blue text represents current EV utilization multipliers (the proportion of miles EVs cover compared to equivalent ICEVs), annual vehicle utilization and new vehicle ownership duration. Red shades denote conditions wherein estimated requisite longevity exceeds trends observed today. **b**, Scenario 2: requisite EV longevity threshold (yr) to achieve the 68,160 mile requisite aggregate utilization threshold. Blue text represents current EV utilization multipliers (the proportion of miles EVs cover compared to equivalent ICEVs), annual vehicle utilization and new vehicle ownership duration. Red shades denote conditions wherein estimated requisite longevity exceeds trends observed today. **c**, Scenario 3: requisite longevity threshold (yr) to achieve the 28,069 mile requisite aggregate utilization threshold. Blue text represents current EV utilization multipliers (the proportion of miles EVs cover versus equivalent ICEVs), primary versus secondary vehicle utilization percentage and new vehicle ownership duration. Red shades denote conditions wherein estimated requisite longevity exceeds current trends. **d**, Scenario 4: requisite longevity threshold (yr) to achieve the 68,160 mile requisite aggregate utilization threshold. Blue text represents current EV utilization multipliers (the proportion of miles EVs cover versus equivalent ICEVs), primary versus secondary vehicle utilization percentage and new vehicle ownership duration. Red shades denote conditions wherein estimated requisite longevity exceeds current trends.

Regarding phasing out of fossil fuel-powered electricity grids, existing literature demonstrates that future reductions in electricity grid carbon intensity are plausible[24–26]. However, our sensitivity analysis (Supplementary Section V) demonstrates that the resulting reductions in EV fuel production emissions may, all other things being equal, prove insufficient in facilitating an emissions advantage among certain households. Realizing emissions benefits from EVs instead probably requires—our analysis suggests—reducing emissions from both fuel production and vehicle manufacturing, as simultaneous improvements to both factors generate highly elastic reductions to the requisite longevity and aggregate utilization thresholds of EVs.

Our longevity threshold estimates also depend on the annual utilization of EVs. Given uncertainties about utilization of EVs relative to that of ICEVs[5,6,8,27], some caution is warranted when interpreting our findings. Increased EV utilization (relative to equivalent ICEVs) would produce less stringent longevity thresholds and vice versa. Likewise, increases in annual vehicle utilization (a potential consequence of improvements to charging infrastructure and EV range) would produce less stringent longevity thresholds (Fig. 2a–d). However, there is little evidence suggesting that EVs are used as primary vehicles in households that also own ICEVs. Conversely, a lack of consistent evidence persists with regard to fuel efficiency changes across a vehicle's lifespan[28,29]. Hence, our model assumes a constant fuel efficiency throughout the lifespans of EVs and ICEVs.

These parameters warrant consideration when assessing the effectiveness of EV procurement incentive programmes, as does the extent to which our findings generalize across other markets.

Nevertheless, the robustness of our results suggests that existing incentive programmes should—given limited capital—be redesigned to realize EV-related emissions benefits more fully. We argue that the existing structure of EV subsidies, which predominantly favours new vehicle adoption, is not only less likely to deliver envisioned emission benefits than policies that incentivize longer EV retention but may also produce regressive results, directing financial relief away from households that are (1) more likely to need it and (2) more likely to facilitate realization of an EV's emissions advantage. Failure to acknowledge and address this reality risks further exacerbating climate and societal inequities.

Methods

To begin, we specify our market focus, clarify our terminology and highlight key parameters of our model. We focus on the United States, a key vehicle market that is a notable contributor to global carbon emissions. EVs refers to vehicles solely powered by electricity obtained from the power-generating electric grid (estimated to generate 436 $gCO_2e\,kWh^{-1}$, ref. [4]); counterfactual vehicle inventory refers to the number of vehicles a household would own were an EV not procured; utilization refers to EV mileage (considered on aggregate and annualized bases); and longevity refers to how long an EV remains in service (expressed in years).

To assess how EV usage patterns and user behaviour impact its emissions advantage, we execute a three-step process. First, we analyse historical automotive procurement and utilization trends. Second, we leverage this insight to construct representative automotive procurement and utilization scenarios. Third, we develop and leverage a model to estimate (for each of the aforementioned scenarios) the behavioural conditions under which an EV's emissions advantage is preserved/lost. Emissions estimates reflect (in contrast to previous work) homogeneity in vehicle range and size between EVs and ICEVs to ensure greater precision[4,30–34].

Historical automotive procurement/utilization analysis. We source data from the NHTS to assess historical automotive procurement and utilization trends. Administered in 1983, 1990, 1995, 2001, 2009 and 2017, the NHTS is a nationally representative data sample which provides individual and household level insight on travel behaviour[35]. Respondents provide information on demographic factors, socioeconomic status, vehicle ownership, vehicle attributes and travel-related data.

Our analysis uses vehicle ownership and usage pattern data provided by respondents for every year the survey was administered. Specifically, we analyse responses regarding household vehicle ownership magnitude (how many vehicles a household has) and the total vehicle miles travelled by those vehicles annually. We subsequently estimate (1) the proportion of households nationwide that have zero, one, two, three and four or more vehicles in household inventory and (2) their contribution (expressed as a percentage) to total vehicle miles (VMT) travelled. Zero vehicle households are excluded when estimating VMT contributions and total VMT estimates exclude trips that involve non-personally owned vehicles (public transit, rental vehicles, commercial operators and so on).

Scenario construction. Analysis of historical automotive procurement/utilization trends yields three results (Fig. 1). First, vehicle ownership rates have increased over time, from 86.47% in 1983 to 91.1% in 2017. This effect highlights increasing public preference for vehicle ownership. Second, although there has been some growth in the number of households with at least three vehicles, one and two vehicle households still constitute the majority of vehicle ownership (66.64%). Third, these households also constitute the majority of VMT (57.91%).

On the basis of these findings, we assemble four scenarios (Table 1). Each scenario presupposes a pre-existing household inventory of between zero and two vehicles (given the consistent importance of this household inventory profile) and reflects a household's decision to either acquire an EV (complement) or replace an existing ICEV with an EV (substitute). For each scenario, we analyse potential EV usage patterns among 'first adopters', defined here as being households in which an EV is purchased new. This approach is intentional, as most current EV procurement programmes target first adopters by virtue of these programmes' focus on new, rather than used, EV purchases. Using pre-existing data and applicable assumptions (Supplementary Sections I and II), we develop and leverage a model to estimate the behavioural conditions under which an EV's emissions advantage is preserved/lost.

Model estimation. Our model considers heterogeneity in behavioural parameters to estimate an EV's ability to deliver an emissions advantage. Estimates (provided at the household level) consider applicable counterfactuals (what the emissions impact would be in a household absent EV adoption) (Supplementary Sections II, III and IV). Counterfactuals assume household preference for vehicle ownership over non-ownership and over public transit/non-motorized mobility options. This assumption is informed by consumer preference for vehicle ownership (regardless of powertrain type)[10], longer-than-average commute times associated with public transit[36] and the strong relationship between vehicle ownership and economic mobility[37].

Due to a lack of available evidence supporting policy-induced changes to a household's quantity of vehicles owned, we further assume that households' vehicle ownership decisions are based primarily on exogenous factors, the most notable being travel demand. That is, regarding the procurement of EVs, we assume that EV procurement incentives alone do not induce a household to purchase a greater number of vehicles than it otherwise would. Were this assumption inaccurate, the result would almost certainly be higher emissions. In the counterfactual scenario, households satisfy equivalent travel demand, albeit with fewer vehicles, thus producing a net emissions reduction owing to the absence of manufacturing emissions from an added vehicle.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The authors present all data and sources supporting this work in the Supplementary Information.

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Author contributions

All authors contributed extensively to the work presented in this paper. A.N., L.W. and P.R. conceived the project. A.N. supervised the project. L.W. developed analytical tools. All authors analysed data and wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

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☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☒	☐	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	No software was used
Data analysis	Microsoft excel and R were used in assembling and executing our model

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

Data generated during the study
available in a public repository

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Study quantitatively assesses conditions under which electric vehicles attain and maintain 'green leads' compared to gasoline powered vehicles. Assessment is based on publicly available and peer reviewed data sets
Research sample	Data sample leverages emissions estimates from the MIT Mobility of the Future Initiative and the University of California at Davis
Sampling strategy	Data sample is unrestricted. Sensitivity analysis is further applied to address concerns over imprecision
Data collection	Analysis leveraging existing emissions estimates for ICEVs and EVs for environmental impact projections. Data is publicly available.
Timing	N/A
Data exclusions	No data was excluded from our analysis
Non-participation	N/A
Randomization	N/A

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Human research participants
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging