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Article

Rethinking the electric vehicle tax policy: prioritizing affordable solutions for environmental impact

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SUMMARY

Car emissions present significant risks to both the environment and human health. To reduce greenhouse gas emissions and promote energy-efficient transportation, the United States (U.S.) government introduced a tax credit policy to incentivize income-eligible individuals to purchase electric vehicles (EVs). While the use of EVs reduces carbon emissions, they are expensive, and households that earn at least $200,000 are the primary consumers of EVs. In this study, we propose reallocating tax credit funds to encourage the purchase of hybrid vehicles, which are cheaper than EVs and thus more accessible to lower-income families. Lower-income households often own older, inefficient vehicles, and replacing these with hybrids could significantly reduce emissions. We hypothesized that this new policy would achieve higher fuel economy and reduce carbon emissions more effectively than the current policy. To test our hypothesis, we collected vehicle data from 2022 in the U.S. and analyzed the potential outcomes of fuel efficiency and greenhouse gas emissions of both the current policy and proposed policy changes under different assumptions. Our analysis supported this hypothesis, showing that the proposed policy could yield better outcomes in terms of fuel efficiency, measured in miles per gallon and carbon dioxide emissions. We also suggested that the U.S. government develop a list of eligible vehicles for tax credits, contingent on the trade-in of older, high-emission cars, to maximize environmental benefits. Redirecting EV tax credits towards incentives for hybrids could be a more effective strategy to achieve greater environmental benefits and promote accessibility in sustainable transportation.

INTRODUCTION

In the current world, cars are an important mode of transportation, but their emissions pose significant risks to both the environment and human health (1). Car emissions are a major contributor to the build-up of greenhouse gases in the atmosphere, with substantial amounts of carbon dioxide (CO_2) being released from the increasing number of gasoline-powered vehicles; on average, a typical vehicle emits approximately 400 grams of CO_2 per mile (2). Each year, they emit billions of metric tons of CO_2, trapping heat from the sun and driving climate change (3). These atmospheric changes often lead to severe weather events and other consequential changes to the natural environment, such as melting ice caps, rising sea levels, and destruction of natural habitats (4).

Additionally, car emissions contain pollutants like carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbons (HC), which can lead to serious health issues and further environmental degradation (5). While modern-day cars are equipped with aftertreatment devices designed to reduce harmful pollutants, these systems may not function effectively in older vehicles, leading to significantly higher emissions (6). Therefore, identifying strategies to improve vehicle efficiency and reduce emissions is essential for mitigating climate change and protecting public health.

To encourage the adoption of more energy-efficient transportation and reduce greenhouse gas emissions, the United States (U.S.) government has implemented a tax credit policy that incentivizes income-eligible individuals to switch to electric vehicles (EVs), including plug-in hybrid or battery EVs, which use electricity as their primary energy source. Introduced as part of the Energy Improvement and Extension Act of 2008, this policy offers financial incentives for consumers to purchase EVs, promoting environmental sustainability and reducing harmful greenhouse gas emissions (7). This credit expired in 2014 and was replaced by new EV tax incentives under the Inflation Reduction Act of 2022, which expired on September 30, 2025.

The amount of tax credit provided depends on the vehicle's battery capacity, with a maximum credit of $7,500 available for qualifying EVs. For example, under the Inflation Reduction Act of 2022, single filers must have a modified adjusted gross income of no more than $150,000, and married couples' modified adjusted gross income must not exceed $300,000 (8). Moreover, data shows that households with annual incomes exceeding $200,000 are more likely to buy EVs (9). These income levels are notably higher than the median household income of $74,580 in 2022 (10). In this study, we defined higher-income households as those with an annual gross income greater than $200,000, and lower-income households as those with incomes at or below this threshold.

While incentivizing individuals to replace their current cars with EVs is a positive step toward improving transportation emission efficiency, it may not be the most effective approach when considering various practical factors. First, EVs cost more than gas-powered and conventional hybrid cars on the market, which cannot be charged externally and cannot operate purely on electricity. In 2022, the typical transaction price for an EV in the U.S. was approximately $65,108, while conventional hybrid vehicles, such as Toyota Prius,

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had manufacturer's suggested retail price (MSRP) of about $27,950 (11). As a result, even with the tax credit, EVs are still more accessible to higher-income households. These individuals may purchase new cars more frequently, meaning the vehicles they replace with EVs are often newer models that have improved fuel efficiency. Additionally, a tax credit may have limited influence on the purchasing decisions of wealthier individuals, who would likely buy EVs regardless of any financial incentives due to their abundant discretionary income (12). Moreover, a recent study in Finland found that EV owners tend to drive more, leading to higher overall carbon emissions compared to lower-income individuals (13). In this study, we propose an alternative policy that reallocates tax credit funds to incentivize the purchase of low-cost, fuel-efficient cars. Currently, conventional hybrid vehicles represent a better option, as they occupy a middle ground between conventional gasoline vehicles and EVs in terms of cost and emissions. For instance, the Toyota Prius is rated at 55 miles per gallon (MPG) with a manufacturer's suggested retail price (MSRP) of $27,950, less than half of the cost of a typical EV (14). Overall, hybrid cars are more affordable than EVs for lower-income households below the median income level (15). Additionally, lower-income households often own older, less efficient vehicles compared to their higher-income counterparts due to financial constraints (16). Replacing these older, inefficient cars with hybrid models could lead to reduced emissions and improved sustainability.

Previous studies have examined the impact of various government incentives on the demand for eco-friendly vehicles, including conventional hybrid vehicles and EVs (17–25). The majority of this research has focused on EVs, while one study published in 2009 examined the effects of tax credits on conventional hybrids, at a time when such incentives were available prior to the introduction of EVs in the U.S. market (20). A few of these studies specifically investigated the effects of tax credit incentives on carbon emissions, with a primary focus on plug-in hybrid EVs (17, 19). Although these studies found that tax incentives contributed to reductions in carbon emissions, they relied on data collected prior to 2020 (17–25). In contrast, we utilized more recent data from 2022 to evaluate and compare two tax incentive policies: one targeting conventional hybrid vehicles, hereafter referred to as hybrids, and the other focused on plug-in hybrid or battery EVs, hereafter referred to as EVs. We hypothesized that the tax incentive policy for hybrids would yield better outcomes in terms of emission reductions and overall fuel efficiency than the current policy focused on promoting EVs.

We collected vehicle data from 2022 and assessed the potential outcomes of both the current and proposed policies in terms of overall vehicle efficiency and greenhouse gas emissions, under various assumptions regarding the number of EV and hybrid vehicle purchases. Our analysis indicated that the proposed policy could lead to improved car efficiency and deliver greater environmental benefits. Moreover, our data suggests that a tax incentive policy for hybrids could allow lower-income households to support sustainable transportation without the financial barriers of EVs. This increased accessibility helps unite society in reducing emissions and building a cleaner future. By improving affordability and access to hybrid vehicles, this policy can accelerate the replacement of older, less fuel-efficient cars among lower-income households. This shift could contribute to measurable reductions in overall carbon emissions and increase the availability of cost-effective, lower-emission transportation options to a broader population.

RESULTS

To test our hypothesis that incentivizing the purchase of less expensive hybrid vehicles leads to better outcomes regarding fuel efficiency and greenhouse gas emissions compared to the current policy of incentivizing EV purchases, we made the following five assumptions.

Our first assumption was that each hybrid vehicle or EV purchased replaced an older gas-powered vehicle. This assumption reflected the idea that a household typically uses a fixed number of vehicles. In other words, every new car a household buys retired one of their current cars. Our second assumption was that the vehicles being replaced by hybrid vehicles were generally older than those replaced by EVs. EVs are relatively expensive. In 2022, the typical transaction price for an EV in the U.S. was approximately $65,108, compared to the Toyota Prius hybrid, which had an MSRP of

Model Year	Percentage of Total Vehicles (%)	Vehicle Age (Years)	Average Fuel Economy (MPG)
≤2003	11.0	≥20	19.58451
2004	2.0	19	19.2986
2005	2.5	18	19.88375
2006	3.0	17	20.1333
2007	3.3	16	20.6039
2008	3.6	15	20.96833
2009	4.0	14	22.40281
2010	4.3	13	22.59206
2011	5.0	12	22.28844
2012	5.1	11	23.56593
2013	5.2	10	24.17888
2014	5.2	9	24.11047
2015	4.0	8	24.64986
2016	4.8	7	24.70826
2017	4.8	6	24.86173
2018	5.8	5	25.10552
2019	6.5	4	24.90835
2020	6.7	3	25.38325
2021	7.0	2	25.42454
2022	6.2	1	25.99349

Table 1: U.S. Vehicle Data in 2022. This table includes vehicle data on the road in 2022 (27, 28). These data were used to simulate counterfactual outcomes, including the average fuel economies and CO2 emissions for the current EV policy and the proposed hybrid policy. The "Model Year" refers to the year a car was produced, "Vehicle Percentage" represents the percentage of vehicles on the road in 2022 by model year. "Vehicle Age" indicates the age of the vehicle in 2022, based on its model year. For analysis purposes, vehicles older than the 2003 model year were grouped together and categorized as "2003 or older" (i.e., ≤2003). "Average MPG" refers to the average miles per gallon (MPG) of vehicles for each model year. This data was used in simulating the average fuel economies and CO2 emissions under the current electric vehicle policy and the proposed hybrid policy.

$27,950 (11, 14). As a result, EVs were primarily accessible to higher-income households. We believed that these individuals tended to purchase new cars more frequently, meaning that the vehicles replaced with EVs were more likely to be newer models with improved fuel efficiency. Our third assumption was that some individuals would still purchase EVs even without tax credit incentives. Tax credits were likely to have limited influence on wealthier individuals. First, wealthy individuals typically did not qualify for the EV tax credit, meaning the policy did not impact their decision-making (8). Second, these individuals were likely to purchase EVs regardless of financial incentives (12). Our fourth assumption was that a reduced tax credit, lower than the current $7,500 tax credit for EVs, would be sufficient to incentivize the purchase of hybrid vehicles. Since hybrid vehicles were generally more affordable than EVs, costing roughly half of typical EVs, a smaller credit would likely be sufficient to encourage their purchase. For example, if a tax credit equal to 10% of the vehicle's sale price was enough to motivate a purchase, a proportionally smaller credit would likely suffice for a hybrid vehicle. The lower upfront cost of hybrids means that even a reduced incentive could meaningfully influence buyer decisions. Our fifth assumption was that the total government budget for tax credits remained constant. We collected vehicle data for 2022, including information on a total of 283 million vehicles on the road, 800,000 EV sales, vehicle age distribution, and the average MPG for each age group (**Table 1**) (26–29). Then, we used this data to simulate the potential outcomes of both the current EV tax credit policy and our proposed hybrid vehicle tax credit policy based on the assumptions above (**Figure 1**).

In the current EV policy, the tax credit was $7,500 for purchasing an EV, which uniformly replaced 800,000 old gas-powered cars of ages one to ten years old. In the new policy, we reduced the current $7,500 tax credit by half, reallocating it into $3,750 tax credits for hybrid cars (based on Assumption 4). With the same total budget, the government would now be able to provide incentives for 1,600,000 hybrid cars (based on Assumption 5). Furthermore, 50% of individuals may still purchase EVs without the tax credit (based on Assumption 3), keeping 400,000 EV replacements, which were evenly distributed across cars aged one to ten years. For this analysis, we used a fuel economy of 100 MPG for EVs and 55 MPG for hybrid cars and calculated the average fuel economy measured in MPG and total CO_2 emissions (in billion tons) for 2022 under both the current and proposed policies. The new policy incentivized 1.6 million hybrids and 400,000 EVs, compared to the current policy only incentivizing 800,000 EVs (**Figure 2**).

We used CO_2 as a measure of car emissions because it directly indicates the contribution of vehicle emissions to the greenhouse effect, representing a significant form of pollution and a threat to environmental sustainability. Additionally, CO_2 emissions can be more effectively derived and converted from fuel economy data than other pollutants.

We calculated the overall fuel economy as described in the Materials and Methods. Under the current policy, we determined a weighted average by multiplying the average MPG by the vehicle percentage for each age group and summing the results. We then added the average MPG of the 800,000 EVs adopted under the tax credit policy and subtracted the average MPG of the 800,000 gas-powered

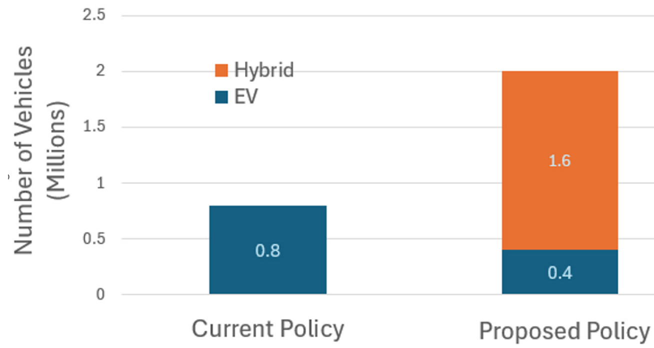

Figure 1: Number of electric vehicles (EVs) and hybrid vehicles purchased in the United States under the current and proposed new policy. Under the current policy, there were 0.8 million EVs in 2022 (17). In contrast, the proposed policy for hybrid tax credits would result in 0.4 million EV sales, assuming 50% of households still purchase EVs without incentives, and 1.6 million hybrid vehicle sales, assuming that a halved tax credit could support incentives for twice as many cars.

cars aged one to ten years that were replaced by EVs. The resulting overall fuel economy was 23.516 MPG, which equals 1.07 billion tons of CO_2 emissions in one year.

We did a similar calculation for our proposed policy when replaced cars were evenly distributed from 1–20 years under scenario (a), 10–20 under scenario (b), and older than 20 years under scenario (c). Under scenario (a), the average fuel economy increased to 23.59 MPG and CO_2 emissions decreased to 1.0666 billion tons, representing a reduction of 3.4 million tons of CO_2 emissions over the course of one year compared with the current EV policy. Under scenario (b), the replaced cars were older than (a), and the average fuel economy increased to 23.60 MPG and CO_2 emissions decreased to 1.0661 billion tons, leading to an additional reduction of 0.5 million tons of CO_2 emissions. Under scenario (c), the cars replaced were even older, and the average fuel economy rose further to 23.61 MPG and CO_2 emissions further decreased to 1.0657 billion tons, achieving an additional reduction of 0.4 million tons of CO_2 emissions compared to scenario (b) (**Figure 3**). Thus, the total CO_2 emission reductions were larger if the replaced old cars were older.

In the calculation above for our proposed policy, we used a median MPG value for hybrid cars. To investigate how CO_2 emissions would change with varying hybrid MPG, we calculated the total CO_2 emissions for a range from 40 to 60 MPG under scenario (a). The total CO_2 emissions decreased as hybrid fuel efficiency increased from 40 to 60 MPG. When a fuel economy was larger than 43 MPG, which was well below the median value for hybrid cars on the market, our new policy outperformed the current policy, as evidenced by dramatically reduced total CO_2 emissions (**Figure 4**). These data suggested that our new policy could increase the average fuel economy of vehicles on the road and achieve a greater reduction in total CO_2 emissions in the U.S..

DISCUSSION

In this study, we proposed a new policy to incentivize the purchase of affordable cars with efficient fuel economy, using hybrid cars as an example to evaluate the impact of

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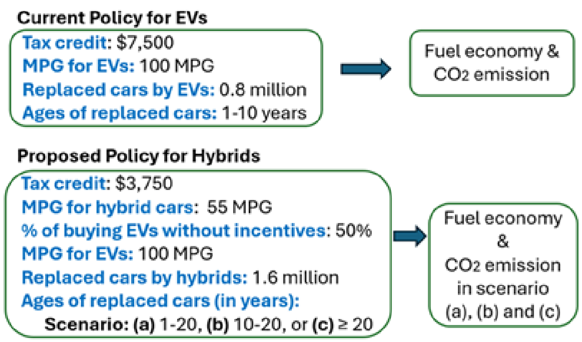

Figure 2: Input values used for hypothesis testing under the current and proposed new policy. Under the current policy, the $7,500 tax credit supports 0.8 million EVs with 100 MPG, replacing 0.8 million old cars aged 1–10 years. In the proposed policy, 50% EV buyers still buy EVs (100 miles per gallon (MPG)) without incentives, while the $3,750 tax credit supports 1.6 million hybrids with 55 MPG, replacing 1.6 million old gasoline-powered cars with age distributions based on scenarios (a)–(c). MPG, miles per gallon.

this policy on overall gas mileage and CO_2 emissions in the U.S. We determined that a hybrid tax credit may lead to decreased overall CO_2 emissions, compared to the current EV tax credit policy. Our findings support the hypothesis that such policy would lead to an improvement in fuel efficiency and a significant reduction in pollution, as measured by CO_2 emissions.

Our estimates are based on five key assumptions, including that many high-income individuals would still purchase EVs even without a tax credit and that hybrids will replace vehicles older than those replaced by EVs under the current policy. While these assumptions are reasonable and allow for meaningful comparisons across different policies, they remain theoretical and may not fully capture the complexities of reality. For instance, we assumed that purchasing a hybrid or EV would replace an older gas-powered vehicle, but some families may choose to keep their gas-powered vehicles. Additionally, the age distribution of vehicles may not be evenly spread throughout a time period, and a more complex distribution may better reflect reality. We also assumed that 800,000 EVs were purchased under the tax credit, although it is likely that a certain percentage would have been purchased regardless of the credit. However, this does not affect our comparison of the two policies. Despite these limitations, we believe our estimates provide valuable insights for evaluating the potential impacts of different policies, suggesting that a new policy incentivizing the purchase of hybrid cars could lead to improved fuel efficiency and reduced CO_2 emissions compared to the current policy of promoting EVs. Additionally, this new policy has the potential to more effectively benefit lower-income individuals, as hybrid cars typically have lower costs compared to EVs (11, 14). Under the current EV tax credit policy, many lower-income households may be unable to afford an EV even with the tax credit incentive, limiting the policy's reach. By reallocating tax credits to hybrids, a greater number of households can access fuel-efficient vehicles, allowing lower-income individuals to participate in making transportation more sustainable. As a result, our new policy has the potential to benefit more households overall, particularly those with lower income, compared to the current policy focusing on EVs.

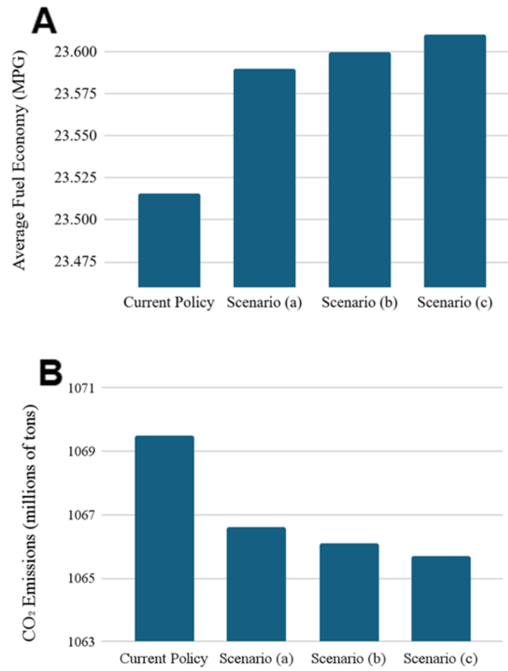

Figure 3: Average miles per gallon (MPG) and total carbon dioxide (CO_2) emissions estimated under current and proposed policies in 2022. The ages of the replaced vehicles in the current policy are evenly distributed between one and ten years. Three scenarios were considered for the age distribution of replaced cars under the proposed new policy: (a) evenly distributed between 1 and 20 years, (b) evenly distributed between 10 and 20 years, and (c) 20 years or older. (A) Average fuel economy in MPG was calculated by summing the product of the average MPG and the percentage of vehicles for each model year, from 2003 through 2022. This weighted average gave us a representative MPG for all cars on the road. When we applied our EV and hybrid tax credit policies, we updated this calculation by adjusting the percentage of gas-powered cars, hybrids, and EVs. (B) CO_2 emissions were estimated by dividing 8,887 grams (the CO_2 per gallon of gasoline) by average MPG to get emissions per mile, then multiplying by 10,000 miles and the number of vehicles for total annual emissions.

Although EVs produce virtually no tailpipe emissions, the production of electricity may still generate significant CO_2 emissions (30). This is primarily due to the reliance on fossil fuels, like coal, oil, and natural gas, for the generation of electricity. According to U.S. Energy Information Administration data in 2022, about 60% of U.S. electricity generation comes from fossil fuels, leading to substantial greenhouse gas emissions associated with their combustion (31, 32). In our studies, we focused solely on direct emissions from vehicles, not considering the upstream emissions associated with electricity production. This omission highlights the complexity of assessing the overall environmental impact of EVs. While they offer significant reductions in direct emissions compared to conventional gasoline or diesel vehicles, the benefits can be diminished if the underlying electricity generation is heavily reliant on fossil fuels (33). To provide a more comprehensive evaluation, future studies should incorporate an analysis of the electricity generation mix and its associated emissions. This would allow for a clearer understanding of the overall environmental benefits of incentivizing hybrids over EVs.

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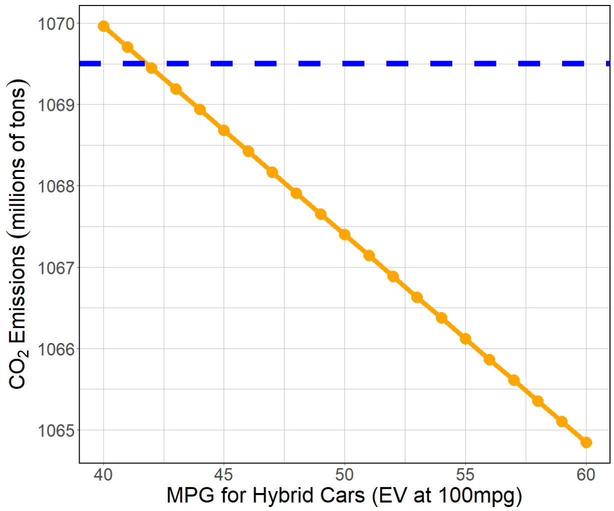

Figure 4: Estimated total CO_2 emissions for hybrid cars with varying miles per gallon (MPG). The orange line represents total CO_2 emissions under the proposed new policy in scenario (a), where replaced vehicles are evenly distributed between 1 to 20 years and MPG of hybrids ranges from 40 to 60 MPG. The blue line represents the total CO_2 emissions calculated under the current policy.

The purpose of this study was not to endorse any particular type of vehicle, but to explore effective government policies for creating inclusive environments for reducing CO_2 emissions. Currently, due to cost considerations, we believe that hybrids are often more practical than EVs for the majority of households in the U.S., especially for lower-income families. However, we recognize that in the future, EVs may become more affordable and accessible. Therefore, an ideal approach would be for the government to establish a list of qualifying vehicles for tax credits, which should be associated with the trade-in of older, high-fuel-consumption cars. This would encourage the adoption of more efficient vehicles while effectively reducing overall emissions, protecting the environment through accessible sustainable transportation.

This study offers a practical framework for evaluating different tax incentive policies by explicitly accounting for vehicle affordability and household-level vehicle replacement patterns. By simulating the potential outcomes of different tax credits, our findings provide actionable insights for policymakers aiming to reduce emissions while promoting equitable access to fuel-efficient vehicles across different income groups.

MATERIALS AND METHODS

Vehicle data from 2022 from the U.S. was collected (**Table 1**) (25–26). The data included the total number of vehicles in use, the vehicle age distribution (i.e. percentage of vehicles for each age group), and the average fuel economy, measured in miles per gallon (MPG), for each vehicle age group.

Determination of MPGs for EVs and hybrid cars

MPG varies depending on the type of EVs and hybrid cars. In the calculation, for EVs, a fuel economy of 100 MPG was used, based on the MPG of the popular 2022 Tesla Model X (32,34). For hybrid cars, we used Toyota Prius's value of 55 MPG, which is around the median MPG value for hybrid vehicles (13).

Calculation of the overall fuel economy in 2022

The average MPG for all vehicles on the road in 2022 under a tax credit policy (EV or hybrid) was calculated based on the vehicle age distribution, average MPG for the cars on the road, MPG values for the EV (EV MPG) and hybrid (hybrid MPG), and the number of EV and hybrids purchased under the tax credit policy (EV Num and Hybrid Num, respectively). We calculated the overall fuel economy (AveMPG) using the formula below,

$$AveMPG = \sum_{2003}^{2022}(average\ MPG \times adjVehicle\ Num) + EV\ MPG \times EV\ Num + \ Hybrid\ MPG \times Hyrbrid\ Num)$$

where "adjVehicle Num" was the number of vehicles after subtracting the gas-powered cars replaced by EVs and hybrids.

Under the current policy, we first multiplied the average MPG by the adjusted vehicle number (adjVehicle Num) after subtracting the 800,000 gas-powered cars aged one to ten years that were replaced by EVs, and then summed these products over all age groups. We then added the average MPG of the 800,000 EVs adopted under the tax credit policy to obtain the overall average MPG. Under our proposed policy, we added the average MPG of the 1,600,000 hybrids adopted under the tax credit policy and 400,000 EVs sold without tax credits, then subtracted the average MPG of the 1,600,000 gas-powered cars replaced by hybrids. For the age distribution of the 1,600,000 replaced vehicles in the new policy, we considered three scenarios, each with an older age range of gas-powered vehicles replaced by hybrid vehicles.

(a) The vehicles were evenly distributed between 1 to 20 years. We extended the age range to include vehicles up to 20 years old based on the second assumption that those replaced by hybrids were generally older than those replaced by EVs.

(b) The vehicles were evenly distributed from 10 to 20 years. In this scenario, the cars being replaced were, on average, older than those in scenario (a).

(c) The vehicles were 20 or more years old, which were older than scenarios (a) and (b).

Calculation of CO2 emission in 2022

$$CO_2\ \text{emissions}\ (g) = \frac{8.887}{AveMPG} \times \ Vehicle\ Num \ \times 10{,}000\ (miles)$$

To evaluate the impact of car emissions on the environment, the MPG values were converted into CO2 emissions by dividing 8,887 by the respective MPG to obtain grams (g) of CO2 emitted per mile driven (35). To measure the overall impact of CO2 emissions on the environment, we calculated the total CO2 emissions in 2022 by summing the CO2 emissions for all vehicles in that year (Vehicle Num), assuming an average mileage for each car is 10,000 miles/year (36).

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