Sustainable EV Market Incentives: Equitable Revenue-Neutral Incentives for Zero-emission Vehicles in the United States

August 2024

A White Paper from the National Center for Sustainable Transportation

Aditya Ramji, University of California, Davis

Lew Fulton, University of California, Davis

Daniel Sperling, University of California, Davis

National Center for Sustainable Transportation
A USDOT University Transportation Center

UC DAVIS Institute of Transportation Studies

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NCST-UCD-WP-24-14	N/A	N/A

4. Title and Subtitle Sustainable EV Market Incentives: Equitable Revenue-Neutral Incentives for Zero-emission Vehicles in the United States	**5. Report Date** August 2024 **6. Performing Organization Code** N/A
7. Author(s) Aditya Ramji, Ph.D., https://orcid.org/0000-0002-7614-6431 Lew Fulton, Ph.D., https://orcid.org/0000-0001-8292-3420 Daniel Sperling, Ph.D., https://orcid.org/0000-0002-8744-7651	**8. Performing Organization Report No.** UCD-ITS-RR-23-35
9. Performing Organization Name and Address University of California, Davis Institute of Transportation Studies 1605 Tilia Street, Suite 100 Davis, CA 95616	**10. Work Unit No.** N/A **11. Contract or Grant No.** USDOT Grant 69A3551747114
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590	**13. Type of Report and Period Covered** Final White Paper (October 2021 – December 2022) **14. Sponsoring Agency Code** USDOT OST-R

15. Supplementary Notes
DOI: https://doi.org/10.7922/G2SF2THB

16. Abstract
The United States (US), under the Biden Administration, has set a goal of reaching a 50% sales share for zero-emission vehicles by 2030. The administration is pursuing a combination of aggressive fuel economy and greenhouse gas performance standards along with tax credits for consumers who purchase electric vehicles (EVs). Given the anticipated high costs of the EV transition and limited public funds, policy mechanisms that generate extra-budgetary funding are enticing. Feebates—where a fee charged on some purchases is used to offer a rebate for others—can serve as a self-sustaining tool. Feebates have been attempted at the state and federal level in the US but did not pass legislatures due to a lack of political support for levying a fee on internal combustion engine (ICE) vehicles. However, as governments face increasing fiscal constraints, there is greater support for self-funding EV incentive programs. Feebate policies can provide certainty for both producers and consumers to facilitate a steady transition to sustainable transportation. This paper assesses the potential utility of feebates for shaping the US light-duty vehicle market. The analysis demonstrates that: (1) revenue-neutral incentive systems are possible and (2) revenue-neutrality can be achieved with relatively low fees on ICE vehicles to support economic equity among buyers. From an industry perspective, market certainty can be created by incorporating fuel economy targets into a fee schedule as pivot points and allocating fees to finance rebates. This would likely influence industry investment decisions in ways that increase EV production and model availability.

17. Key Words		18. Distribution Statement	
Sustainable incentives, market mechanisms, electrification, ZEV transitions, United States		No restrictions.	
19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	44	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Acknowledgments

This study was funded, partially or entirely, by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) through the University Transportation Centers program. The authors would like to thank the NCST and the USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project. The authors would like to thank Dr. Jacob Teter (Independent Advisor), Professor Lisa Ryan (University College Dublin), and Amber Manfree (University of California, Davis) for their significant review and inputs.

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EXECUTIVE SUMMARY

Strong policies are needed to accelerate the transition to zero emission vehicles (ZEV) at a pace that will be in line with international climate goals. Governments around the world are finding it increasingly difficult to finance electric vehicle (EV) purchase incentives in the long-term. Yet, there is a need for incentives because of: (1) financial challenges to lower-income consumers who may struggle to afford EVs; (2) cost uncertainties related to supply chain risks such as critical raw material procurement, and (3) high technology costs in the constrained timeline for achieving high EV adoption rates. Policymakers must find innovative ways to lower EV prices so that the transition to ZEVs is equitable and timely. Feebate policies offer a potential pathway.

The United States (US), under the Biden Administration, set a goal of reaching a 50% sales share for zero-emission vehicles by 2030 and is pursuing a combination of aggressive fuel economy and greenhouse gas performance standards along with tax credits for consumers who purchase EVs. Assuming average annual US light-duty vehicle (LDV) sales remain at historical levels of 16 million, the 50% market share target would translate to 8 million new EV sales in 2032, requiring EV sales to grow at a 20% compound annual growth rate after 2023.

Current allocated federal funding and policy structure for EV tax credits is likely inadequate to spur a large-scale transition to ZEVs. Assuming an average incentive of $3,750 USD per EV, present-day incentives will be able to offset consumer costs for 2 million EVs—only 5% of all EVs needed between 2023 and 2032 to achieve the 50% EV ambition. The amount of federal incentive funding for EVs does not come close to offsetting the additional cost to consumers buying, and producers selling, EVs. Moreover, federal incentives are limited by a variety of conditions, including the manufacturing source of the vehicle and batteries, the sale price of the vehicles, and the incomes of buyers. State incentives are limited in scope, their longevity is highly uncertain, and they are not always applicable at the point of purchase. State incentive funds are typically allocated one year at a time and often run out before the year ends.

Given the high costs of the EV transition and limited public funds, policy mechanisms that may overcome these challenges are enticing. Feebates—where a fee charged on some purchases is used to offer a rebate for others—can serve as a self-sustaining tool to shape the market. Feebates have been proposed at both the state and federal levels in the US. Examples include the Gas Guzzler Tax in 1978 and state-level legislative proposals in California, Massachusetts, and Vermont between 1990 and 2022. These proposals aimed at imposing a tax linked to fuel efficiency (measured in gCO_2/mi) of internal combustion engine (ICE) vehicles. As per the proposals, higher emission vehicles incurred a higher tax, and revenue funded EV purchase incentives.

This report examines feebates, a market-based mechanism that is self-financing. Feebate policies can provide certainty for both producers and consumers, thus facilitating a steady transition to sustainable transportation over many years. This analysis addresses a national focus for the US LDV market. It could also be applied in sub-national contexts, such as California and other states that follow California ZEV regulations.

The analysis demonstrates that: (1) revenue-neutral incentive systems are possible while supporting increasing sales of light duty EVs along the target path toward a 100% sales share by 2035 and (2) revenue-neutrality can be achieved with low fees—2% to 8% of purchase price—on ICE vehicles to ensure economic equity among buyers.

In this analysis, we test four scenarios to determine which ones may lead to revenue neutrality and how they might impact vehicle prices. The four scenarios are defined by EV adoption pathways, rebate options, and fee schedules (Table ES-1). Two special cases are also assessed: (1) increasing the fee schedule (F3) and (2) adjusting pivot points to reflect Phase 3 US Environmental Protection Agency (EPA) GHG regulations. Both special cases are applied to the HZEV scenario.

Table ES-1. Feebate scenarios evaluated in this paper with summary information. Scenarios include low carbon (LC) and high ZEV-adoption (HZEV) based on the Transportation Transitions Model and a version of HZEV in the context of US EPA Phase 3 regulations.

Scenario	Rebate	Fee per gCO_2		Revenue Status	Average Fee Impact by emission class		Average marginal fee rate
					Lowest 3	Highest 3	per gCO_2/mi
LC	Low	F1	\$2 - \$5 (2024 to 2027) \$2 - \$10 (2028 to 2031) \$2 - \$14 (2032 to 2035)	Surplus	1 – 2%	5 – 7%	\$7
	High						
HZEV	Low	F2	\$2 - \$14	Neutral	1 – 2%	7 – 9%	\$8
	High			Deficit			
HZEV	High	F3	\$8 - \$14	Neutral	1 – 2%	8 – 10%	\$11
HZEV (EPA)	Low	F2	\$2 - \$14	Neutral	1 – 2%	8 – 10%	\$8
	High			Deficit			

Key findings:

1. The low rebate cases, wherein all eligible EV purchases receive a rebate of $3,750, result in revenue-neutral feebate mechanisms in both LC and HZEV scenarios.
2. In the LC scenarios, the fee schedule (F1) increases from $450 per ICE vehicle subject to a fee in 2024 to $1,153 in 2030.
3. In the HZEV scenario, the fee schedule (F2) increases from $958 in 2024, and $1,400 in 2024 (for the high fee case, F3).
4. The highest fee impact ranges from $2,100 to $2,200 by the year 2034 across most scenarios, with the high fee schedule (F3) in the HZEV scenario reaching about $3,000 in 2034 (Figure ES-1).
5. The average fee on every ICE vehicle sold beyond the pivot point each year would be $7 to $8 per gCO_2 of deviation from the pivot point. In the HZEV scenario (HZEV-F3) with high rebate, the average fee would have to be $11 per gCO_2 to attain revenue neutrality (Table ES-1).
6. From an industry perspective, a feebate mechanism that incorporates fuel economy targets into a fee schedule as pivot points and self-finances a rebate program creates market certainty. This will likely influence investment decisions in ways that increase EV production and model availability.
7. From a consumer perspective, the certainty that the rebate program provides, combined with increased fees on ICE vehicles, will shift consumer decisions towards purchase of EVs instead of ICE vehicles.
8. Feebates could be used by individual automotive manufacturers to establish their own internal pricing mechanisms across ICE and EV products to ensure a profitable business pathway during the EV transition.

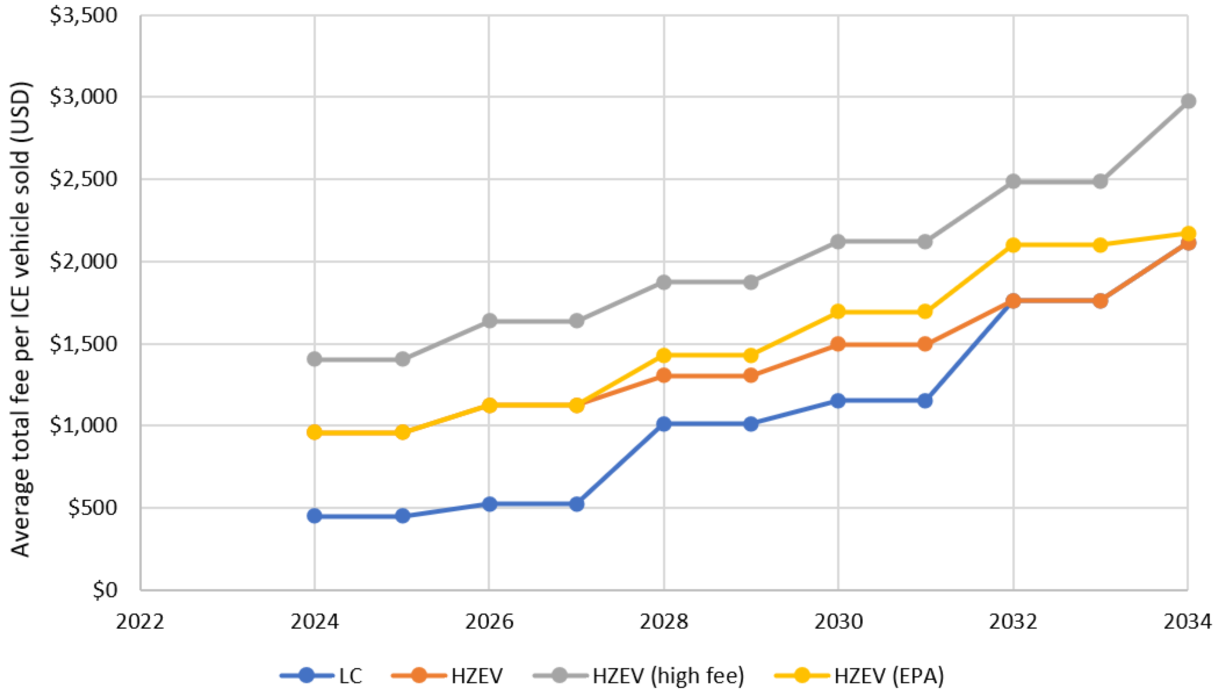

Figure ES-1. Average total fee per ICE vehicle sold above the pivot point each year.

Introduction

The transition to zero emission vehicles (ZEVs) will require a change in consumer purchasing behavior. The United States, under the Biden Administration, set an ambition of reaching a 50% sales share for ZEVs by 2030 (US Government, 2023) and is pursuing a combination of aggressive fuel economy and greenhouse gas performance standards[1] along with tax credits to encourage electric vehicle (EV) sales (Internal Revenue Service, 2023). Some states in the United States (US), led by California, have adopted ZEV sales mandates and purchase incentives to increase sales (CARB, 2022). The overall ZEV market share rose to 9.2% for the US in 2023 (EV Volumes, 2023).

Assuming average US light duty vehicle (LDV) sales remain at historically high levels of 16 million annually, the 50% market share target would translate to 8 million new EV sales in 2032, requiring EV sales to grow at a compound annual growth rate of 20% after 2023. With provisions in the Inflation Reduction Act of 2022 and the Infrastructure Investment and Jobs Act of 2021, the US Government has allocated $25.7 billion for EV purchase and infrastructure incentives, cumulatively, through 2032. Of this, about $7.54 billion are allocated towards EV tax credits for new sales between 2023 and 2032 (McCarthy, 2022; US Government, 2023a). Assuming an average incentive of $3,750 per EV, the funding will offset the costs of about 2 million EVs, which translates to about 5% of all EV sales needed between 2023 and 2032 to achieve the 50% EV ambition.

Further, the US Environmental Protection Agency (EPA) estimates an average cost to automotive manufacturers of $1,200 per vehicle (for ICE powertrains) in 2032 for corporate average fuel economy (CAFE) standards compliance under the Phase 3 regulations, amounting to an additional cost of $180 to $280 billion between 2026 and 2032 (NHTSA, 2023). These funds could potentially be diverted to EV investments.

Irrespective, the amount of federal incentive funding for EVs does not come close to offsetting the additional cost to consumers and producers of EVs. To qualify for federal incentives consumers and the vehicles they purchase must currently meet a variety of criteria, including domestic vehicle and battery manufacturing, sale price limits for vehicles, and a ceiling on the incomes of buyers (US Department of Energy, 2024).

State incentives are also sharply limited, highly uncertain, and not all apply at the point of purchase. State incentive funds are typically funded one year at a time, and often run out before the year ends (Alternative Fuels Data Center, 2023a; CARB, 2023b; Department of Environmental Quality, 2023; New Jersey, 2023).

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[1] On March 20, 2024, the US EPA adopted a CO_2 regulation for LDVs that aims to reduce the average fleet GHG emissions by 56% in 2032, relative to 2026 standards (target of 82 gCO_2/mile in 2032). In its regulatory analysis, the US EPA highlights two compliance pathways that include a 70% share of BEVs in 2032 across all LDV categories or a 40% BEV share in 2032 across medium duty vans and pickup trucks (NHTSA, 2023).

As of December 2023, 12 states have adopted the California Advanced Clean Cars (ACC) II regulation requiring manufacturers to meet increasing annual ZEV sales targets as a share of new LDV sales. Sales of ZEVs are mandated to increase from 36% in 2026 to 100% in 2035 in California. Targets vary by state (Alternative Fuels Data Center, 2023a) (Table 1). These 12 states represent 30 to 40% of total US LDV sales as of 2023 (California Air Resources Board, 2023a). However, ZEV sales mandates are imposed on automakers, not consumers. Consumers can delay new vehicle purchases and buy used vehicles. Another issue is that legal footing for state-administered sales mandates is tenuous, leading to outcomes that can be reversed in accordance with partisan politics (Friedman and Plumer, 2022). Given the uncertainty in costs of this transition and limited public funds, alternate policy mechanisms might be more stable (Lazo, 2023).

Table 1. EV sales targets and incentives for EV purchases in states that have adopted Advanced Clean Cars II rules.

<table>
<tr><th>State</th><th>2023 EV market share</th><th>EV sales target</th><th>Incentives</th></tr>
<tr><td>California</td><td>26%</td><td>New ZEV sales at 35% for model year 2026; increasing to 100% by model year 2035</td><td>Clean Vehicle Rebate Project; ended November 2023; yet to announce new program</td></tr>
<tr><td>Oregon</td><td>17%</td><td rowspan="10">Same as California; effective from model year 2027 (43% new sales)</td><td>Oregon Clean Vehicle Rebate Project; suspended May 2023 due to lack of funds</td></tr>
<tr><td>Washington</td><td>19%</td><td>EV tax exemption only</td></tr>
<tr><td>New York</td><td>8%</td><td>Rebates of up to $2,000</td></tr>
<tr><td>Massachusetts</td><td>12%</td><td>Rebates of up to $3,500</td></tr>
<tr><td>Vermont</td><td>10%</td><td>Rebates of up to $4,000</td></tr>
<tr><td>Virginia</td><td>10%</td><td>Rebates of up to $2,500</td></tr>
<tr><td>Colorado</td><td>14%</td><td>State tax credit up to $5,000</td></tr>
<tr><td>New Jersey</td><td>13%</td><td>Rebates of up to $4,000; temporarily suspended due to lack of funds</td></tr>
<tr><td>Maryland</td><td>11%</td><td>One-time excise tax credit up to $3,000 available from 2023 to 2027</td></tr>
<tr><td>Delaware</td><td>9%</td><td rowspan="2">Same as other states, but maxing out at 82% sales share in 2032</td><td>Rebates of up to $2,500</td></tr>
<tr><td>New Mexico</td><td>5%</td><td>No purchase incentives</td></tr>
</table>

Feebates offer a market-based mechanism that is self-financing and provides pricing certainty for both producers and consumers. To lay the groundwork for a long-term transition pathway, policymakers can: (1) design revenue-neutral incentive programs capable of rapidly increasing sales of light duty ZEVs to meet the goal of 100% sales share by 2035; and (2) specify policy designs that preserve revenue-neutrality with relatively low average fees on lower emission vehicles in ways that improve social equity among vehicle buyers. This report addresses a national focus for the US LDV market, but could be applied in sub-national contexts, such as California and states that follow California ZEV regulations.

Feebates: Command-and-control versus market-based mechanisms

Environmental policy has increasingly relied on the use of market-based mechanisms to meet policy goals, including in transportation. Policy often builds upon traditional command-and-control approaches (regulatory instruments) and sometimes moves beyond them to address externalities (Stavins, 2003). Market-based policies such as tradable development rights, industrial emissions control, and tradable credits have been used —especially in cases where abatement costs vary by polluter as regulators aim to shift the higher abatement burden on larger emitters (Lindsey and Santos, 2020; Neves et al., 2020; Peng et al., 2021; Xia et al., 2022; Zhang et al., 2020).

The shift to market instruments has been motivated by economic theory, which posits that they are more economically efficient and less costly than regulatory approaches (Beiser-McGrath et al., 2022; Swaney, 1992). In the case of road transport, performance-based standards in the form of fuel efficiency requirements for cars and light trucks have been the primary policy tool used to regulate vehicle CO_2 emissions in the US, as in many other countries (Congressional Research Service, 2021; Greene et al., 2020). While such performance standards have led to efficiency improvements, they are not sufficient for achieving near zero LDV fleet emissions in a short time frame spanning 2035 to 2040. This is because regulations on fuel efficiency or CO_2 emissions provide limited incentive for vehicle manufacturers to go beyond the minimum compliance requirements of the policy (Anderson et al., 2011). Further, the frequency of revision of fuel efficiency standards is time consuming, taking about two years to accomplish rulemaking and notification and another four years to become enforceable. At the same time, the European Union fuel economy target of 0 gCO_2/km by 2035 for the light duty segment is essentially the converse of imposing a ban on ICE vehicle sales or enacting a ZEV mandate (European Union, 2023). Politically, it is part of the larger 'Fit for 55' climate package agreed by the EU in 2023 (European Council, 2023). An approach similar to the EU is not tenable in the US due to different politics, strengthening the case for market-based policies to regulate US vehicle CO_2 emissions (Boasson and Tatham, 2023).

Various studies have compared the impact of market mechanisms such as feebates with performance standards such as fuel efficiency or CO_2 norms. A review of Japan's feebate policy found that it led to an economic surplus, but design deficiencies led to less-than-ideal improvements in the average fleet fuel efficiency (Konishi and Zhao, 2017). In a comparison of feebates and fuel economy standards, a simulation study in the US and France found that fuel economy standards lead to negative welfare effects that were about 1.7 times greater as compared to feebates (Durrmeyer and Samano, 2018). In Europe, major automotive markets such as France, Germany, Italy, and the UK have introduced feebates with a focus on driving ZEV transitions. Since feebates were introduced, EV sales share has rapidly increased in these countries, model availability has increased across segments, there are more affordable EV models on the market, and, in France, the mechanism is revenue-positive (Ramji et al., 2024) .

Overall, these and other studies find that market-based instruments can deliver significant cost savings while leading to desirable environmental outcomes such as zero tail pipe emissions. Moreover, such instruments also have the capability to provide greater flexibility, can be simpler for both producers and consumers to interpret, and can be monitored and enforced (Adamou et al., 2014; Rapson and Muehlegger, 2023).

Thus, a market-based tax-subsidy approach, such as feebates, can: (1) reduce the burden on government treasury and the average taxpayer, (2) address the limited certainty on compliance costs through its own revenue generation potential, (3) be designed to be revenue-neutral or revenue-positive, (4) provide greater certainty on emission reduction, (5) be linked theoretically to a carbon market, (6) allow for innovation in technology pathways, and (7) be expanded to cover other aspects of the transportation system (Greene et al., 2005; Kessler et al., 2023; Østli et al., 2022; Xing et al., 2021).

History of feebates in the US

Feebates have been attempted in the past at state and federal levels in the US. The gas guzzler tax, imposed in 1978, is perhaps the federal law most analogous to a feebate mechanism (US Environmental Protection Agency, 2012). The tax essentially imposed a fee only on passenger cars with a fuel economy rating below 22.5 miles per gallon (mpg). Light duty trucks were not taxed, as they were not popular when the rule was passed. But with very few contemporary cars below that fuel economy threshold and over two-thirds of the market being light duty trucks today, the tax does not result in any considerable economic impact to consumers, as it would cover a negligible share of vehicles sold today, thus also limiting the fuel efficiency gains (Vehicle Technologies Office, 2021). The gas guzzler tax, administered by the Internal Revenue Service (IRS) was essentially one half of a feebate, with just the fee and no rebate mechanism. It was most recently updated in 2012.

One of the earliest feebate proposals in the US was the Demand-based Reductions in Vehicle Emissions PLUS Improvements in Fuel Economy (DRIVE+) program in California. This would have enacted self-financing tax incentives for consumers willing to purchase cleaner and more fuel-efficient cars and trucks. The threshold was based on a combination of criteria pollutants and CO_2, with vehicles above the threshold facing a surcharge on sales tax, while those below would attract a sales tax reduction (Levenson and Gordon, 1990). The legislation was proposed as S.B. 1905 by California State Senator Hart (D-Santa Barbara) in 1990. After it passed the California State Assembly and Senate, it was vetoed by Governor Deukmejian (R-CA) on the basis that it would be unenforceable due to federal discretion over fuel economy standards (California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007, 2007).

In Maryland, a feebate law was enacted in 1991 but was never implemented (Motor Vehicle Administration Fees and Revenues, 1991). This was largely due to interpretation of the law by the US Department of Transportation that it conflicted with the federal government's authority to regulate fuel economy (Eilert et al., 2010).

Around the same time as California and Maryland, there were legislative proposals to create a feebate mechanism at the national level, none of which passed the US Congress. For example, Senator Wirth (D-CO) suggested a feebate in the proposed National Energy Efficiency and Development Act 1991 (S.1741), while the Clean Domestic Fuels Enhancement Act of 1991 (H.R. 2960), a bill by Representative Synar (D-OK), clearly stated the need to establish a fee and rebate program for vehicles. In 2003, Senator Durbin (D-IL) proposed the Senate Amendment 1385 to S.14, which suggested the provision of additional tax incentives for enhancing motor vehicle fuel efficiency and other purposes (US Congress, 2003; US Congress, 1991).

In Rhode Island, there were legislative efforts to establish feebate mechanisms in 2003 and 2004. Senate Bill 3024, also known as the Greenhouse Gas Vehicle Efficiency Act of 2004, proposed to introduce a feebate with an initial pivot point of 0.78 pounds of CO_2 per mile (corresponding with fuel economy of about 25 mpg), and an initial surcharge and credit incentive rate of $2,400 per pound, per mile (S3024, Rhode Island, 2004). The proposal further suggested annual revisions to the feebate structure and imposing the fee as a greenhouse gas surcharge used to fund credits or rebates for vehicles with emissions below the pivot point. The fee or credit was to be estimated by multiplying the incentive rate and the absolute difference between the zero-point and the carbon dioxide emissions rate for that vehicle.

In Washington DC, the DC Council approved legislation in 2004 that increased excise tax and registration fee on owners of large and luxury sport utility vehicles (SUVs) based on the premise that these contribute to air pollution and street damage (Yol and Woodlee, 2004). The legislation also provided a complete waiver of the excise tax and a 50% reduction in the registration fee to clean-air hybrid car owners.

In 2005, the state of Maine introduced the Act to Encourage the Use of Clean Fuel Vehicles (LD 305) proposing a 5% surcharge on the purchase or lease of new vehicles that did not achieve 27.5 mpg (Office of Policy and Legal Analysis, 2005). In the same year, the state of North Carolina introduced the Mobile Source Emissions Reduction Program (S.B. 1038), which proposed a sliding fee on vehicles purchased, based on a combination of miles travelled, pollutant emissions, and fuel consumption (SB1038, North Carolina General Assembly, 2005). Both bills in Maine and North Carolina failed in state legislatures.

In 2005, state of Massachusetts Bill 2438 adjusted the sales tax on vehicles relative to CO_2 emissions. It proposed that consumers who purchased vehicles with the lowest emissions would pay zero sales tax, while vehicles with better than average performance would attract a sales tax less than 5%, and purchasers of high polluting vehicles would pay a maximum tax of 10% (Langer, 2005).

In Connecticut, the state assembly directed the then-Commissioner of Environmental Protection (now, Department of Energy and Environmental Protection) to develop a feebate policy which was to be implemented from January 2006. The proposed policy included a decrease in sales tax by not more than 3% for new motor vehicles with greenhouse gas (GHG) emissions lower than a set threshold and an increase in sales tax by not more than 3% for new motor vehicles that have higher GHG emissions. The policy was never implemented. (SHB6908, Connecticut, 2005).

In 2022, the states of Vermont and New York pushed for the introduction of a feebate mechanism to accelerate EV transitions as a component of urgent climate action. In New York, the 2022 Scoping Plan for Climate Action encouraged legislators to consider measures such as a feebate program (State of New York, 2022). The plan states that the proposed feebate could be revenue-neutral and incorporate equity measures such as higher rebates or fee exemptions for low-income consumers.

In Vermont, Senate Bill 277, introduced in 2022 by State Senator MacDonald (D-Orange), proposed to implement a self-funded system of personal car registration fees and rebates based on vehicle efficiency (An Act Relating to Motor Vehicle Efficiency Feebates, 2022). The proposal included revenue-neutrality and linking the fee schedule to the US EPA fuel economy requirements. It included three levels of fees and rebates based on fuel economy classification, was applicable to purchase and lease of both new and used cars (with different schedules) and decreased proportionally with depreciation. It should be noted that two prior legislative attempts were made to introduce feebates in the state of Vermont, in 1999 and 2005 (H-444). This system was not yet implemented as of December 2023 (Vermont Agency of Transportation, 2019).

A detailed report prepared by Vermont's Transportation Agency for the Vermont State Legislature in 2021 provided insights into the current LDV market and feebate design (Vermont Agency of Transportation, 2019). The report assessed all LDV registrations in Vermont between 2016 and 2019 and found that: (1) the median fuel use was 25.3 mpg and median CO_2 emissions were around 352 grams per mile, (2) the majority of new vehicle purchases were clustered between 18 and 30 mpg, and (3) between model years 2016 and 2019, average fuel efficiency rates improved from 24.9 to 26.4 mpg. Further, the report examined five different feebate design alternatives and concluded that a feebate program applicable uniformly to all LDVs would be the most effective as it would incentivize a shift from large SUVs to more fuel-efficient cars. It also found that a sustainable, self-funded feebate or incentive program could be designed that provides a larger incentive for EVs in the short-term while also providing marginal incentives to shift to cleaner gasoline or diesel vehicles for consumers who may not be EV-ready. It also highlighted the role of CO_2 or mpg as the most efficient fee metrics and the need for both the fee and rebate to be implemented at the point-of-sale.

These findings resonate with the feebate design strategy proposed in our review of European feebates and are highlighted in the US feebate design methodology in the rest of this paper (Ramji et al., 2024).

Methodology and Data

To support a transition to ZEVs in the US, a feebate policy design should minimize taxpayer costs while ensuring sufficient incentives to shape the auto market.

To design an effective feebate, the current distribution of the US LDV market by CO_2 emission classes (gCO_2/mi), the sales-weighted price and fuel efficiency of each class must be known. Sales data of LDVs (2021) for the US from Marklines, IHS Markit, and EV Volumes are used to characterize the LDV market (EV Volumes, 2023; Marklines, 2023). The distribution of LDV sales across emission classes serves two purposes in the characterization: (1) it serves as the basic assumption for estimating the distribution of future ICE LDV sales across emission classes and (2) it defines a fee schedule for the feebate mechanism.

As a next step, we estimate future LDV sales scenarios for the US are estimated. This is done using the US Transportation Transitions Model (TTM), which is a stock turnover model developed by researchers at the University of California, Davis (Vijayakumar, 2022). TTM is based on the VISION model developed by Argonne National Laboratory (Argonne National Laboratory, 2022) with modifications to simulate low carbon scenarios for California and the US. Annual forecasts are produced up to the year 2035. They provide a detailed split of LDV sales by powertrain type, i.e., ICE, battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and fuel cell electric vehicles (FCEV). Market penetration scenarios are input as percentages of sales for all vehicle types and technologies. The model has three scenarios: (1) Business as Usual, where EV sales share reaches about 40% by 2035; (2) Low Carbon, where the EV sales share reaches around 80% by 2035; and (3) High ZEV where EV sales share reaches 100% by 2035.

This report suggests a design for a feebate mechanism that would help achieve EV sales shares defined in the TTM Low Carbon and High ZEV scenarios. To set parameters for the feebate policy, the following methodology is used:

a) ***Distribution of ICE LDV by emission classes:*** Based on the distribution of ICE LDVs sold in 2021 across emission classes (Figure 1), it is assumed that all ICE LDVs sold from 2022 to 2035 are distributed in the same shares across emission classes as in 2021. Since most sales in the US LDV market are SUVs and Pickups, with a consumer preference for larger LDVs, this assumption is expected to hold. For the purposes of this analysis, ZEVs include all BEVs and FCEVs with zero tailpipe emissions as well as PHEVs with emissions greater than zero and lower than 90 gCO_2/mi (EPA, 2023).Over 55% of 2021 LDV sales by emission classes are above 300 gCO_2/mi.

Figure 1. Distribution of US LDV sales by emission classes (gCO2/mi), 2021. Numbers in purple color indicate sales-weighted fuel economy for each emission class.

b) ***Estimating vehicle prices:*** First, we estimate the future trajectory of ICE prices. For this, historical vehicle price and inflation data are used. Based on US price inflation data (Bureau of Labor Statistics, 2023), an annual price increase of ICE vehicles by 2.46% is estimated**.** Based on an assessment of current vehicle prices between ICE and EV models across segments, it is found that the average BEV is about 1.7 times more expensive, while PHEVs are about 1.5 times more expensive than their ICE counterparts. Further, it is assumed that BEVs reach price parity with ICE vehicles by 2033, while PHEVs remain 5 to 7% more expensive than ICE vehicles in 2035 (Figure 2).

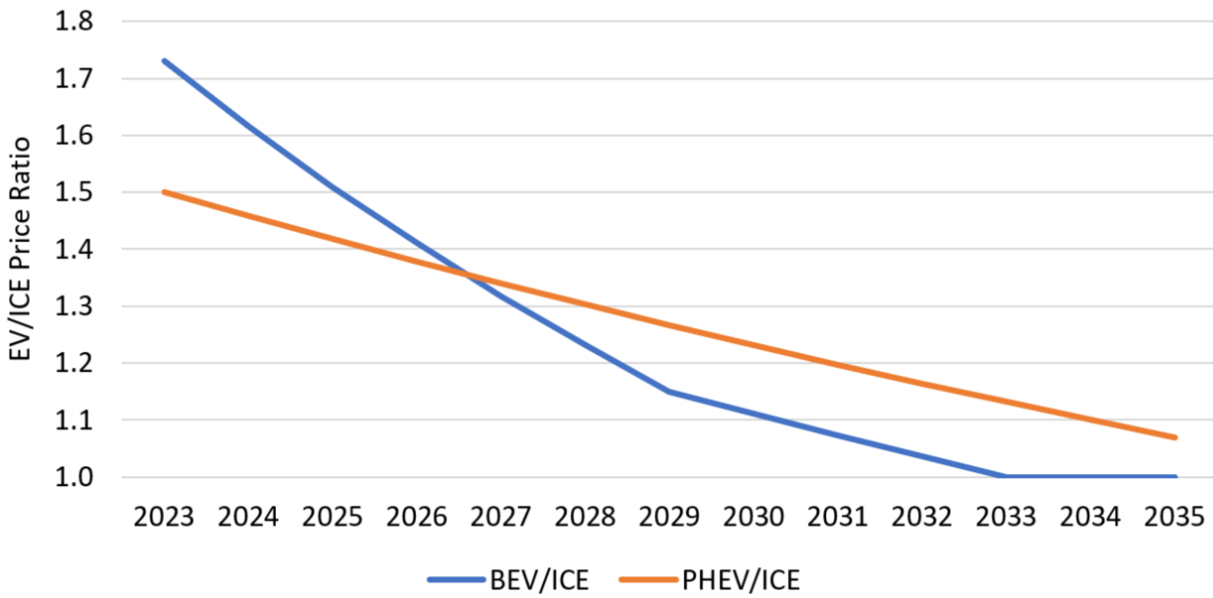

Figure 2. Electric vs. internal combustion engine price ratio (EV/ICE). Y-axis value is the multiplier for BEV or PHEV vs. ICE sales price.

c) ***Estimating the number of EVs receiving rebates:*** To estimate the cost of the ZEV transition, and to determine the fee schedule, the number of EVs that would receive a rebate must be estimated. A review of California EV sales shows that about half of the EVs sold between 2010 and 2022 received subsidies under the Clean Vehicle Rebate Project (Center for Sustainable Energy, 2022). Further disaggregation shows that about 75% of EVs sold in California in 2014 received a rebate, followed by 45% in 2018 and 10% in 2022.

   In the LC scenario, a similar trajectory is assumed for rebate eligibility in this analysis, going from 50% in 2024 to 10% in 2032 and remaining at that level until 2035. In the HZEV scenario, given the trajectory to 100% EV sales by 2035, it is expected that, in the latter years, a greater share of consumers would need incentive support to purchase EVs. Thus, the share of EVs receiving rebates goes from 50% in 2024 to 15% in 2032 and remains at that level until 2035.

d) ***Estimating the revenue required to finance the rebates:*** To design the “fee” for the feebates, it is essential to estimate the total amount required in rebates to finance the ZEV transition. We identify two rebate scenarios (Table 2). At this stage, having established the total revenue needed and the total ICE vehicle sales in each year, the total revenue is divided by the total ICE sales each year to get an average fee per ICE vehicle in each year. This is then divided by the estimated average ICE vehicle manufacturer's suggested retail price (MSRP) to find the percentage increase in price due to the fee. The overall price elasticity for new vehicle sales defined as: with every 1% increase in vehicle prices, sales decline by 0.5%. This relationship is used to adjust the future year market size (Leard and Wu, 2023). Rebate values are drawn from the current incentive structure for EVs in the US, which offers $3,750 or $7,500 depending on certain criteria (Internal Revenue Service, 2023).

Table 2. Rebate schedules for eligible EVs including high and low rebate scenarios.

Scenario	Rebate schedule
High	[(60% of eligible EVs) * $3,750] and [(40% of eligible EVs) * $7,500]
Low	(All EV's eligible for rebate) * $3,750

The total cumulative rebates required in each scenario are estimated based on the below two equations:

$$Total\ Rebates\ Required\ (Low) = \sum_{k=2022}^{2035} \left(BEV_{ik} + PHEV_{jk}\right) * \$3{,}750 \quad (1)$$

where i = %BEVs eligible in year k; and j = %PHEVs eligible in year k.

$$Total\ Rebates\ Required\ (High) = \sum_{k=2022}^{2035} (0.6 * EV_{ik} * \$3750) + (0.4 * EV_{ik} * \$7{,}500) \quad (2)$$

where i =%EVs eligible in year k.

e) ***Choosing the pivot point for the fee:*** The US EPA has set a fuel economy target for the LDV fleet at 40.6 mpg for 2024, which is equivalent to about 218 gCO_2/mi. Thus, based on the emissions classes for the US LDV fleet (Figure 1), the first pivot point of the feebate is set at 220 to 240 gCO_2/mi in 2024 (Figure 3). The pivot point is revised every two years, shifting by one emission class each revision, eventually reaching 110 gCO_2/mi in 2034.

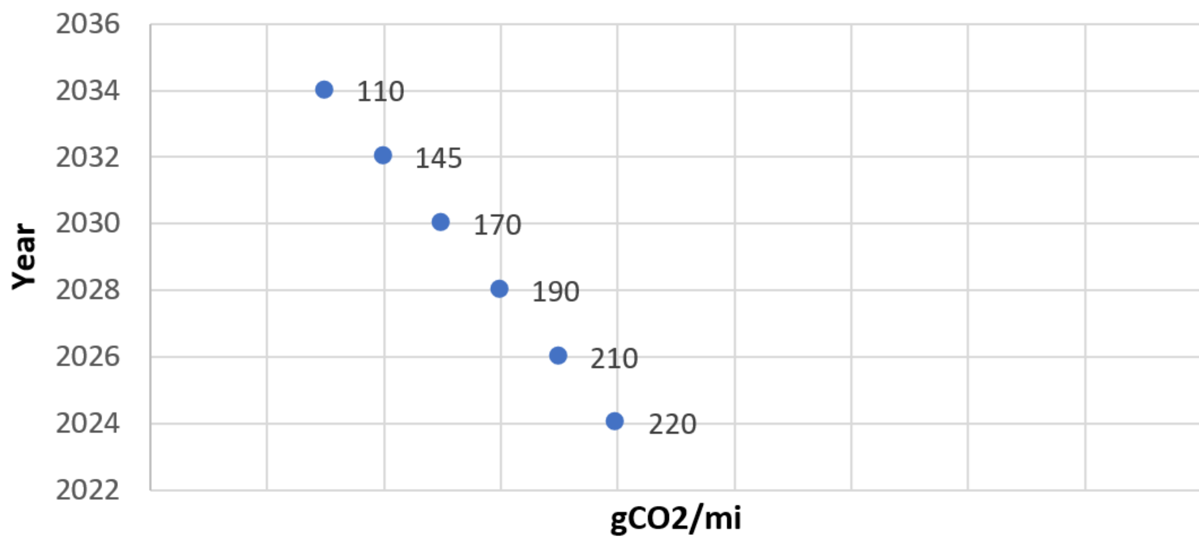

Figure 3. Periodic revisions to pivot point (gCO_2/mi) every two years.

f) ***Estimating the CO_2 penalty matrix:*** With the pivot point set for each year, the CO_2 penalty matrix is defined, i.e., the amount of CO_2 emissions per mile that the vehicle emits above the pivot point, resulting in a financial ("fee") penalty. The CO_2 penalty is calculated based on the deviation or difference of the mid-point of the emission class from the pivot point. For example, in year 2024, if the pivot is at 220 gCO_2/mi, and if a vehicle falls in the emission class 260 to 300 gCO_2/mi, then the CO_2 penalty is the difference between the mid-point of the emission class, i.e., 280 gCO_2/mi and the pivot point of 220 gCO_2/mi, which amounts to 60 gCO_2/mi. From covering nine emission classes in 2024, with bi-annual revisions, the feebate covers fourteen emission classes by 2034. A matrix of fee levels by emission class and year prepared for the fee schedule (Table 3).

Table 3. Matrix of fees (USD) for deviation from pivot point by emission class and year.

Emission Class	*Emission Class mid-point*	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0													
1-90													
90-130	*110*											**20**	**20**
130-160	*145*									**15**	**15**	55	55
160-180	*170*							**10**	**10**	40	40	80	80
180-200	*190*					**10**	**10**	30	30	60	60	100	100
200-220	*210*			**10**	**10**	30	30	50	50	80	80	120	120
220-240	*230*	**10**	**10**	30	30	50	50	70	70	100	100	140	140
240-260	*250*	30	30	50	50	70	70	90	90	120	120	160	160
260-300	*280*	60	60	80	80	100	100	120	120	150	150	190	190
300-340	*320*	100	100	120	120	140	140	160	160	190	190	230	230
340-380	*360*	140	140	160	160	180	180	200	200	230	230	270	270
380-420	*400*	180	180	200	200	220	220	240	240	270	270	310	310
420 - 460	*440*	220	220	240	240	260	260	280	280	310	310	350	350
460 - 500	*480*	260	260	280	280	300	300	320	320	350	350	390	390
> 500	*550*	330	330	350	350	370	370	390	390	420	420	460	460

g) ***Estimating the CO_2 fee matrix:*** In the LC scenario, the fee schedule per gCO_2 is the same as typical EU CO_2 emission taxes, which are about $2 per gCO_2 for values closest to the pivot point, increasing exponentially as a continuous upward sloping curve. The fee schedule remains fixed for a period of two years before it is revised. The highest fee is $5 per gCO_2 up to 2027, going up to $10 per gCO_2 up to 2031, and then $14 per gCO_2 from 2032 onwards. In the HZEV scenario, a different fee schedule is used. It has the same starting point of $2 per gCO_2, but the highest fee is $14 per gCO_2 across all emission classes (Figure 4).

The below equations describe the fee schedule for the LC and HZEV scenarios.

$$\text{LC 2024: } y = 0.0211x^2 - 0.1352x + 1.743 \quad (3)$$

$$\text{LC 2035: } y = 0.064x^2 - 0.3339x + 2.6688 \quad (4)$$

$$\text{HZEV 2024: } y = 14.023x^2 - 369.37x + 2348.3 \quad (5)$$

$$\text{HZEV 2035: } y = -2.5947x^3 + 85.771x^2 - 873.28x + 2668.7 \quad (6)$$

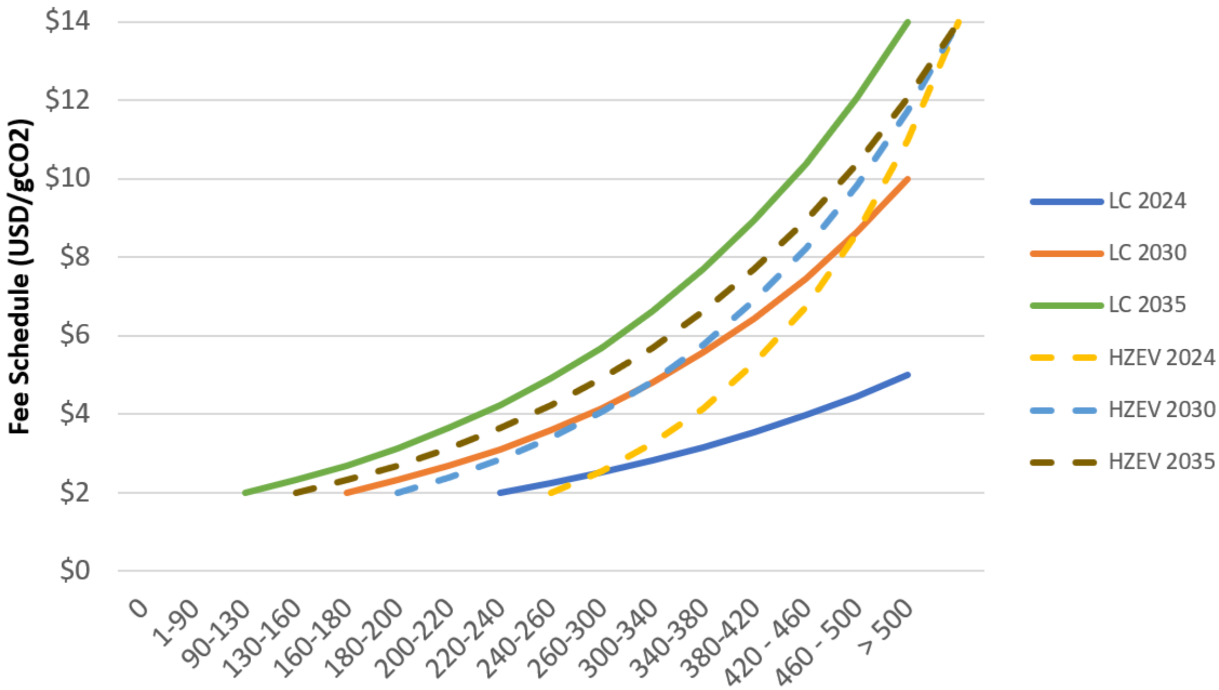

Figure 4. Fee schedule ($) per gCO_2 in LC scenarios by emission class and year.

Designing a Feebate for the US

In this analysis, four scenarios are identified. They are defined by LC and HZEV adoption scenarios from the TTM model and low and high rebates. Further, two separate fee schedules (F1 and F2) for the LC and HZEV scenarios are incorporated (Table 4). The analysis tests which of these scenarios lead to revenue surplus, neutrality, or shortfall and consider impacts on vehicle MSRP.

Table 4. Four feebate scenarios. Two rebate levels and two rates of EV adoption are considered.

<table>
<tr><th rowspan="2">Rebate</th><th colspan="2">EV Adoption</th><th rowspan="2" colspan="2">Fee Schedule per gCO$_2$</th></tr>
<tr><th>Low Carbon (LC)</th><th>High ZEV (HZEV)</th></tr>
<tr><td>Low</td><td>LC1</td><td>HZEV1</td><td>F1</td><td>$2 - $5 (2024 to 2027)
$2 - $10 (2028 to 2031)
$2 - $14 (2032 to 2035)</td></tr>
<tr><td>High</td><td>LC2</td><td>HZEV2</td><td>F2</td><td>$2 - $14</td></tr>
</table>

LC Scenarios

In the LC scenarios, the cumulative revenue required from 2024 to 2035 to finance the low (LC1) and high (LC2) rebates is $59.9 billion and $83.8 billion, respectively, a difference of nearly 30% (Figure 5).

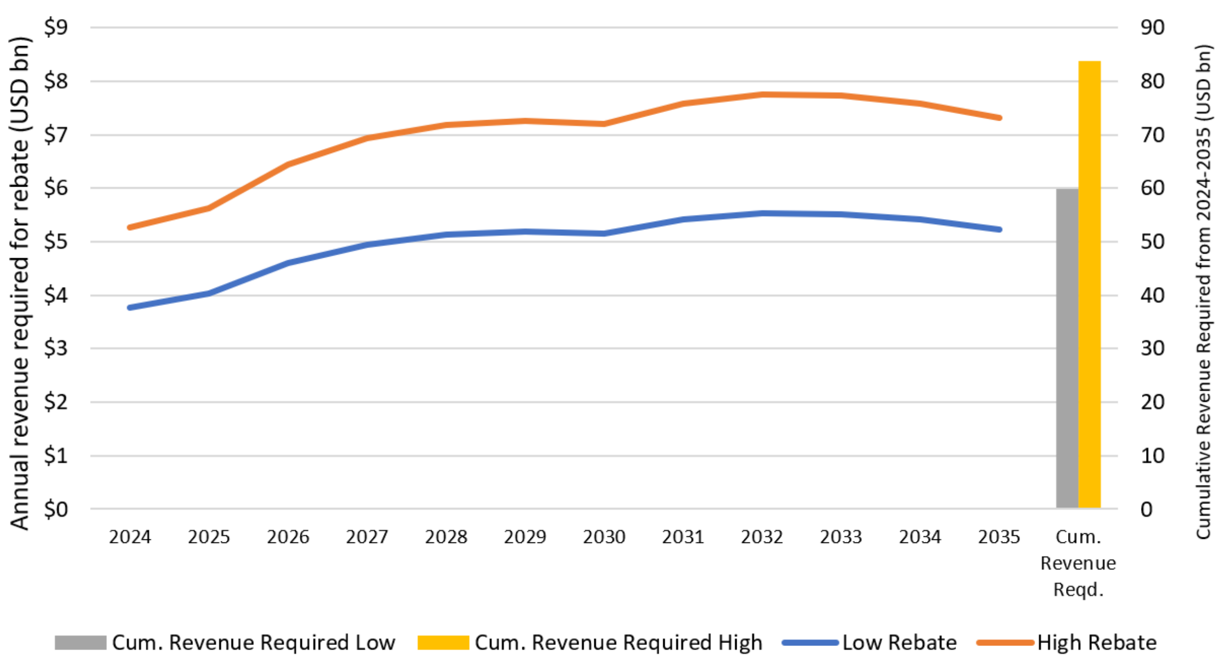

Figure 5. Revenue required to finance EV rebates in low and high LC scenarios.

The analysis finds that the fee schedule generates surplus revenue to fund the rebate requirements up to 2035 (Figure 6). There is a cumulative surplus of $33 billion and $57 billion, for the high (LC2) and low (LC1) rebate cases, respectively. The fee program is essentially revenue neutral immediately from 2024 to 2027, after which it results in a gross surplus (not accounting for any administrative costs for implementing the program). This is due to an excess of funds collected relative to the declining share of EVs that receive a rebate, over time.

The impact of fees on consumers is important to consider because of equity concerns, especially on the lower-priced end of the vehicle market (Figure 7). The sales weighted average MSRP was about $26,000 for the lower emission classes between 200 gCO_2/mi and 340 gCO_2/mi (Figure 1). In the higher emission classes, the average MSRP was around $36,000 dominated by large pickup trucks.

In 2024, the first year modeled for the feebate mechanism, the fee results in a 1 to 3% increase on vehicle prices within the highest emission class (>500 gCO_2/mi). The fee amount ranges from as low as $67 for an average emission of 250 gCO_2/mi to $1,650 for vehicles emitting more than 500 gCO_2/mi.

Even in 2030, as the fee schedule changes, the impact is highest on emission classes above 420 gCO_2/mi, ranging from 5 to 8%. In absolute terms, the fee for the top three emission classes—420 gCO_2/mi and higher — ranges from $2,090 to $3,900.

In 2035, the fee impact is greater for vehicles emitting more than 380 gCO_2/mi. They will incur an additional impact of 6 to 12%. As the fee schedule increases in 2035, the fee ranges from $3,632 to $6,440 for the top three emission classes (≥420 gCO_2/mi).

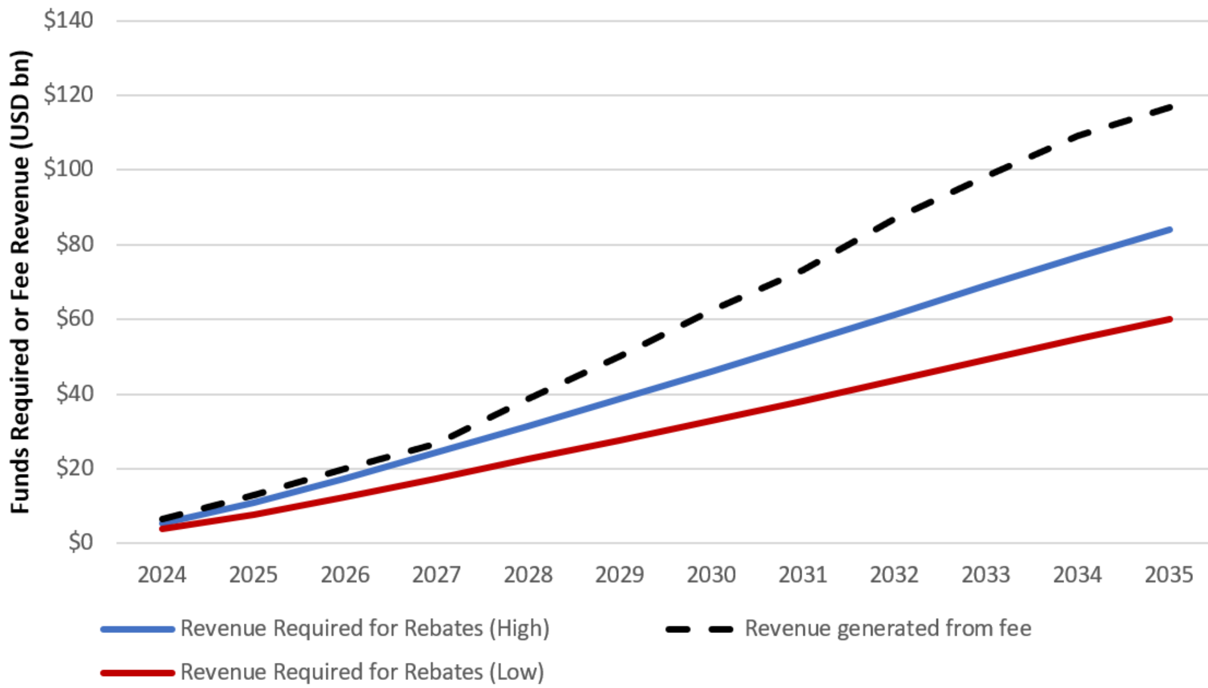

Figure 6. Funds required to finance rebates and revenue generated by fees for the LC scenarios.

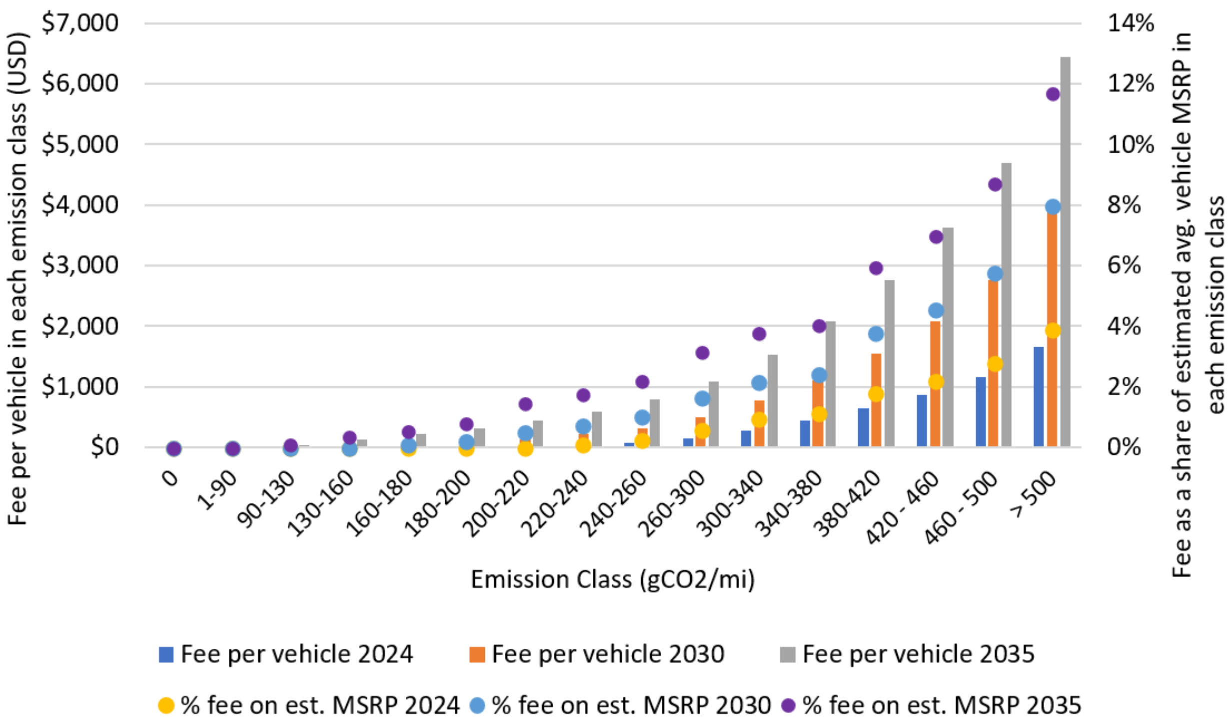

Figure 7. Fee impact on estimated vehicle MSRP in each emission class over time for LC scenarios.

HZEV Scenarios

In the HZEV scenarios, the share of EVs reaches 100% by 2035 increasing at a faster pace as compared to the LC scenario. This is means that, while the total cost of transition will be higher, there will be lower revenues from fees given the lower sales of ICE vehicles in each year, compared to the LC scenario. The revenue required to finance the two rebate scenarios ranges from $96.1 billion to $134.5 billion over the same period (Figure 8). If the same fee schedule (F1) as in the LC scenario is assumed, the fee revenue is only $62 billion, resulting in a significant shortfall.

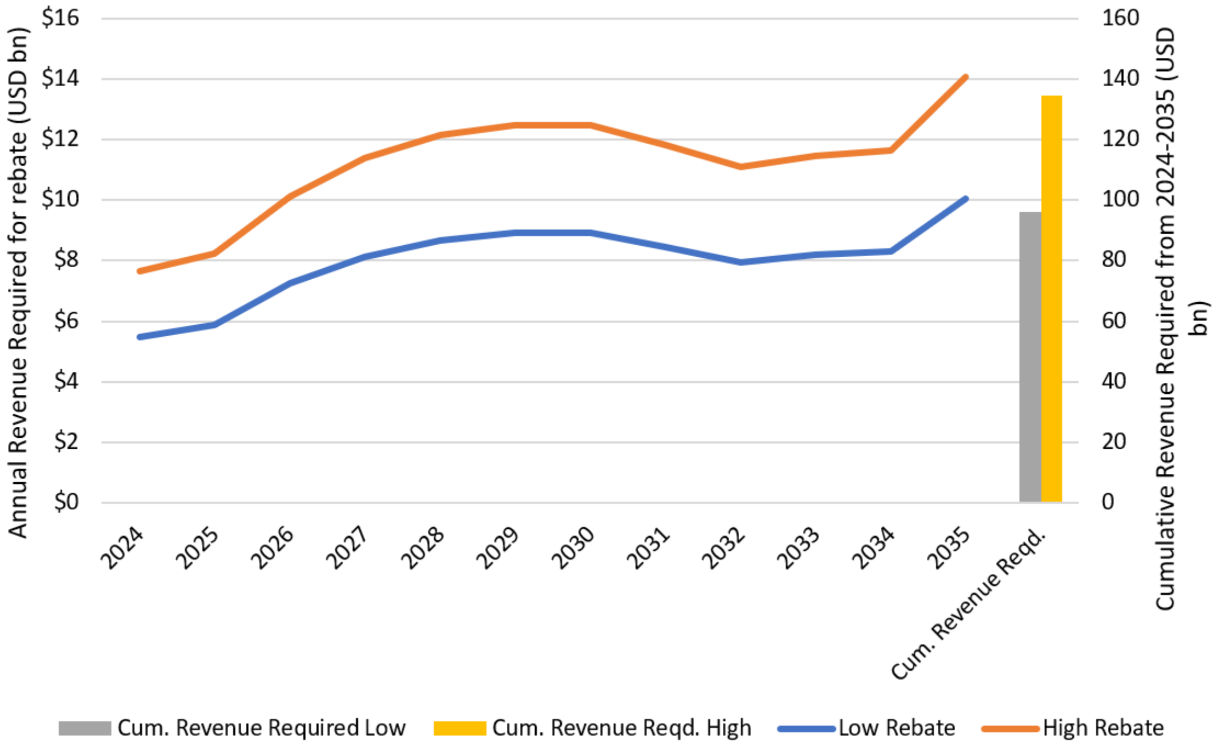

Figure 8. Revenue required to finance the EV rebates in HZEV scenarios.

Thus, the fee schedule would need to be adjusted to fully fund incentives for higher rates of EV adoption, if that is the goal, which is reflected by the fee schedule, F2. The cumulative revenue generated by the higher fee (F2) schedule (Figure 9) between 2024 and 2035 is $97.2 billion. The revenue generated by the higher fee schedule (F2) just about achieves revenue neutrality in the low rebate case but leaves a shortfall of $37.3 billion in the high rebate case (Figure 9).

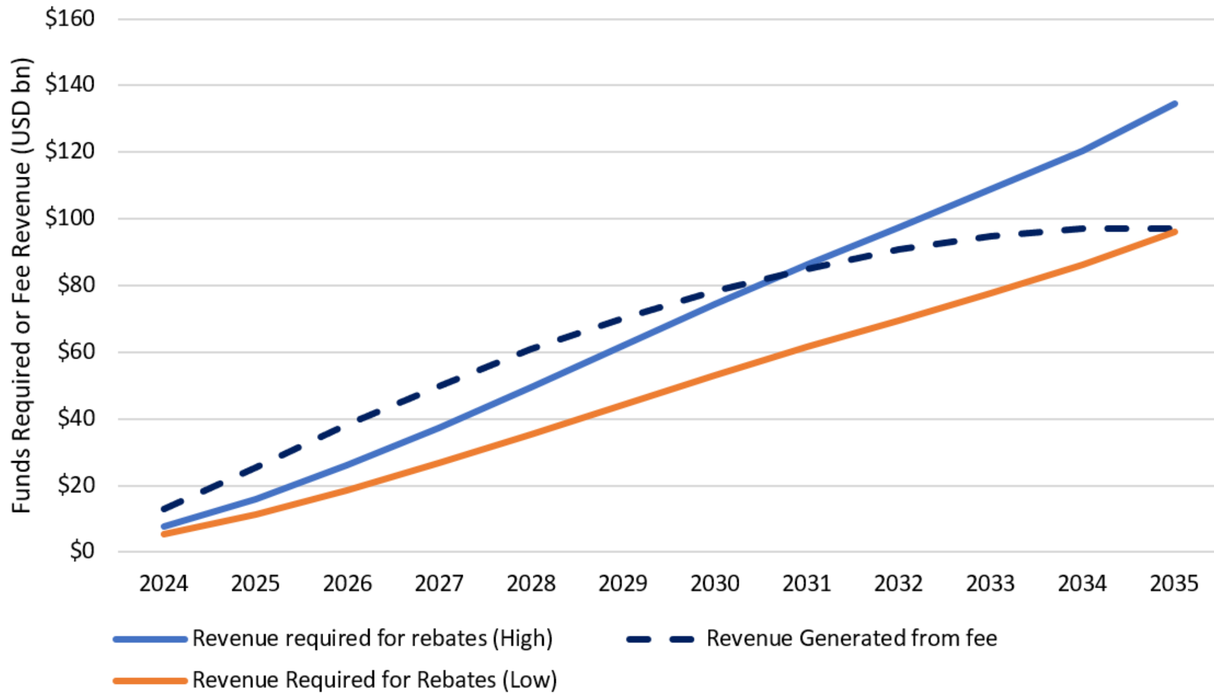

Figure 9. Funds required to finance the rebates and revenue generated by fees for HZEV scenarios.

In terms of impact on estimated vehicle MSRP (Figure 10), in the first year of the feebate mechanism (2024), the fee increases on vehicle prices by 7 to 11% in the two highest emission classes (≥460 gCO_2/mi). The fee amount ranges from as low as $77 for an average emission of 250 gCO_2/mi to $4,620 for vehicles emitting more than 500 gCO_2/mi.

In 2030, the impact is highest on emission classes 420 gCO_2/mi and higher, ranging from 6 to 11% of vehicle price. In absolute terms, the fee for the top three emission classes (≥420 gCO_2/mi) ranges from $2,752 to $5,460.

In 2034, vehicles emitting 380 gCO_2/mi or more—the four highest-emitting classes—incur an additional impact of 6 to 12% on their estimated MSRP. As the fee schedule increases in 2035, the fee ranges from $3,632 to $6,440 for the top three emission classes (≥420 gCO_2/mi). This is the same as the impact on vehicle MSRP in 2035 in the LC scenario. This is because, in 2035, there are no ICE sales in the HZEV scenario and thus zero revenue from fees.

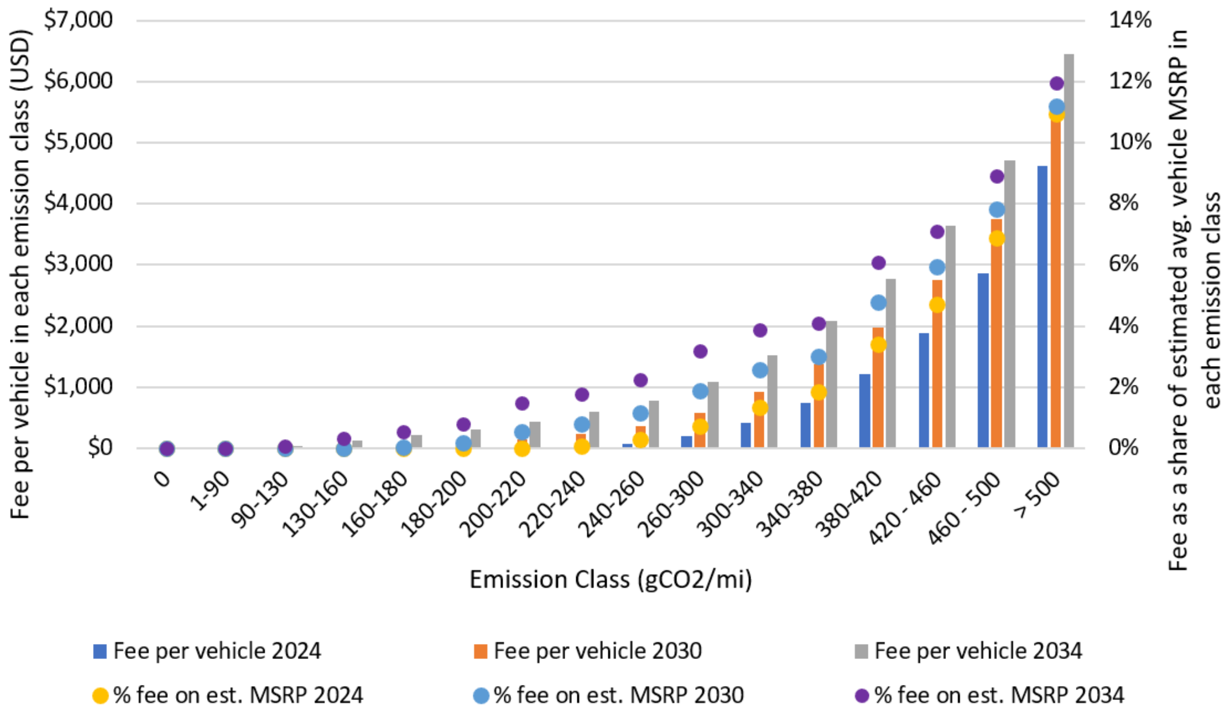

Figure 10. Fee impact on estimated vehicle MSRP for HZEV scenarios in each emission class over time.

Revenue neutral fee schedule for high rebate case in HZEV scenario

As seen in the previous section, given the revenue shortfall for the high rebate case within the HZEV scenario, finding an alternative fee schedule that will achieve revenue-neutrality would be helpful. Below, a fee schedule is determined that equals the revenue required to cover the rebate costs and its potential impacts on estimated vehicle MSRP are analyzed. While there can be multiple different fee schedules that can achieve revenue-neutrality, in this case, the impact of one possible fee schedule (defined as F3) is explored (Figure 11). The base fee starts at $8 per gCO_2 from the pivot point for each year—significantly higher than the $2 per gCO_2 base fee applied in the HZEV scenario fee schedule (F2). The highest rate remains at $14 per gCO_2. The cumulative revenue generated from this fee schedule (F3) is $140.1 billion, compared to the requirement of $134.5 billion (Figure 12). The higher fee schedule has a significantly higher impact by 2034 in terms of additional costs to consumers over the estimated vehicle MSRP.

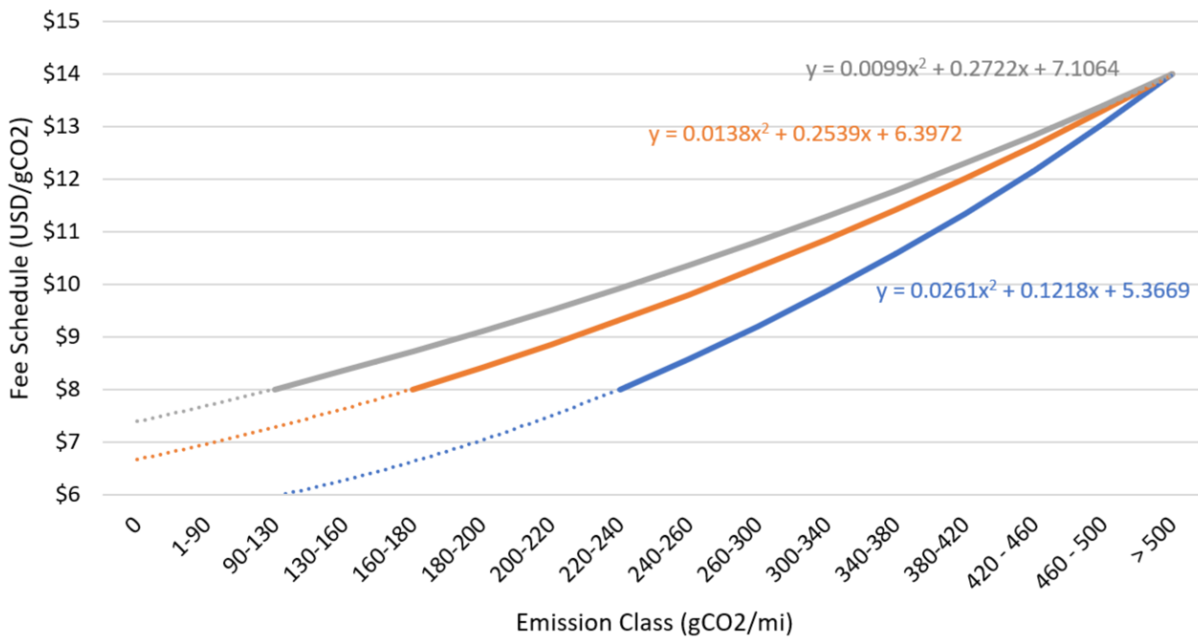

Figure 11. Revised fee schedule for revenue neutrality in the high rebate HZEV scenario.

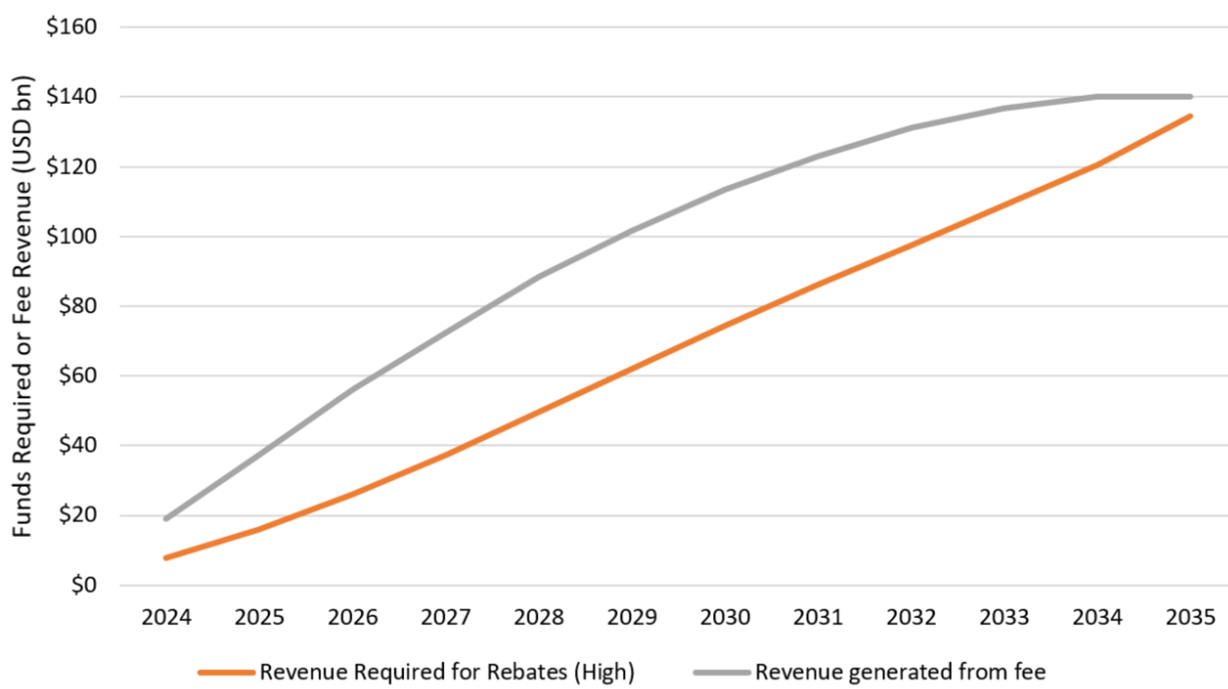

Figure 12. Revenue needed for rebates and generated from fees under revised fee for the high rebate HZEV scenario.

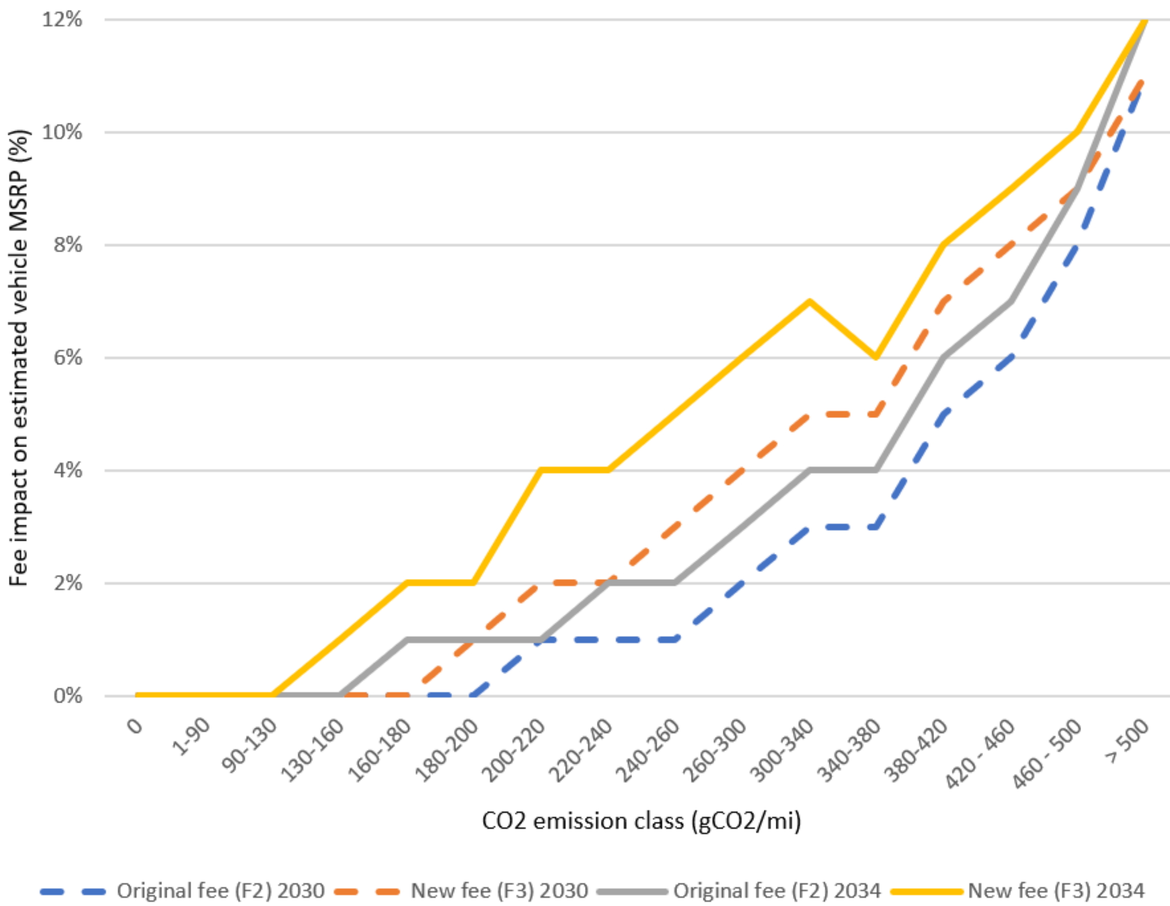

Figure 13. Comparison of fee impact on estimated vehicle MSRP for the high rebate HZEV scenario.

The average impact of the fee on estimated vehicle MSRP increases by about 2.5 times for the five emission classes covering the range between 200 and 340 gCO_2/mi in 2030, while the impact is about 2.3 times for the same emission classes in 2035, when compared to the F2 fee schedule. The average fee impact across emission classes increases to 6% compared to 4% in the original fee (F2) schedule for the HZEV scenario (Figure 13).

Change in pivot points for US EPA Phase 3 GHG regulation: Case of the HZEV scenario

The US EPA has implemented a new phase of CAFE regulations up to model year 2032, which puts the 2032 threshold at 82 gCO_2/mi (Final Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 2024). With the pivot points of the feebate mechanism linked to the thresholds as defined by the CAFE regulations, this special case updates the pivot points to be aligned with the new CO_2 thresholds aligned to the updated Phase 3 US EPA GHG standards for LDVs. The new pivot point schedule (indicated with blue dots in Figure 14), is assessed for the HZEV scenario with the F2 fee schedule.

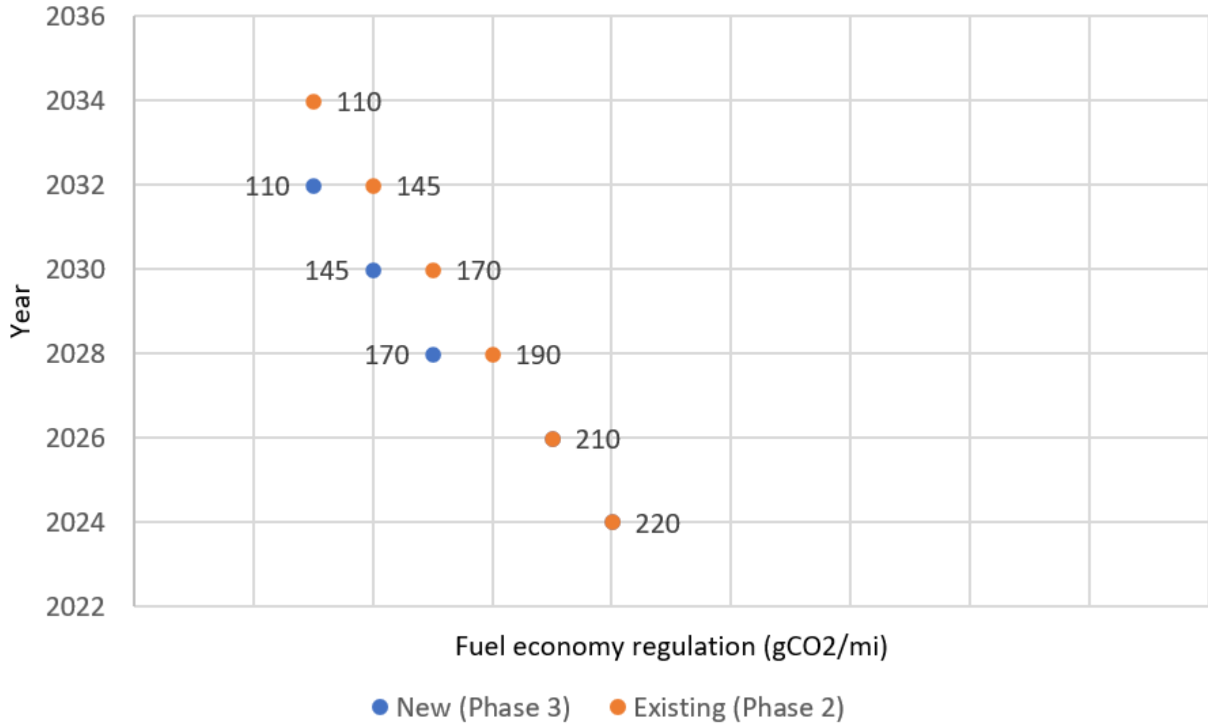

Figure 14. US EPA CO_2 regulation pivot points. Values based on Phase 2 and Phase 3 regulations are shown.

With the new pivot points, the revenue from the fee schedule (F2) increases by 6% to $103.1 billion (Figure 15). While this still yields a revenue surplus for the low rebate case, the shortfall remains for the high rebate case. Although, it can be observed (Figure 15), that the fee schedule generates surplus revenue in the high rebate case up to 2030, becoming revenue neutral in 2031, after which it results in a deficit. Thus, a marginal adjustment to the fee for the years 2032 to 2034 could help achieve revenue neutrality even in this case.

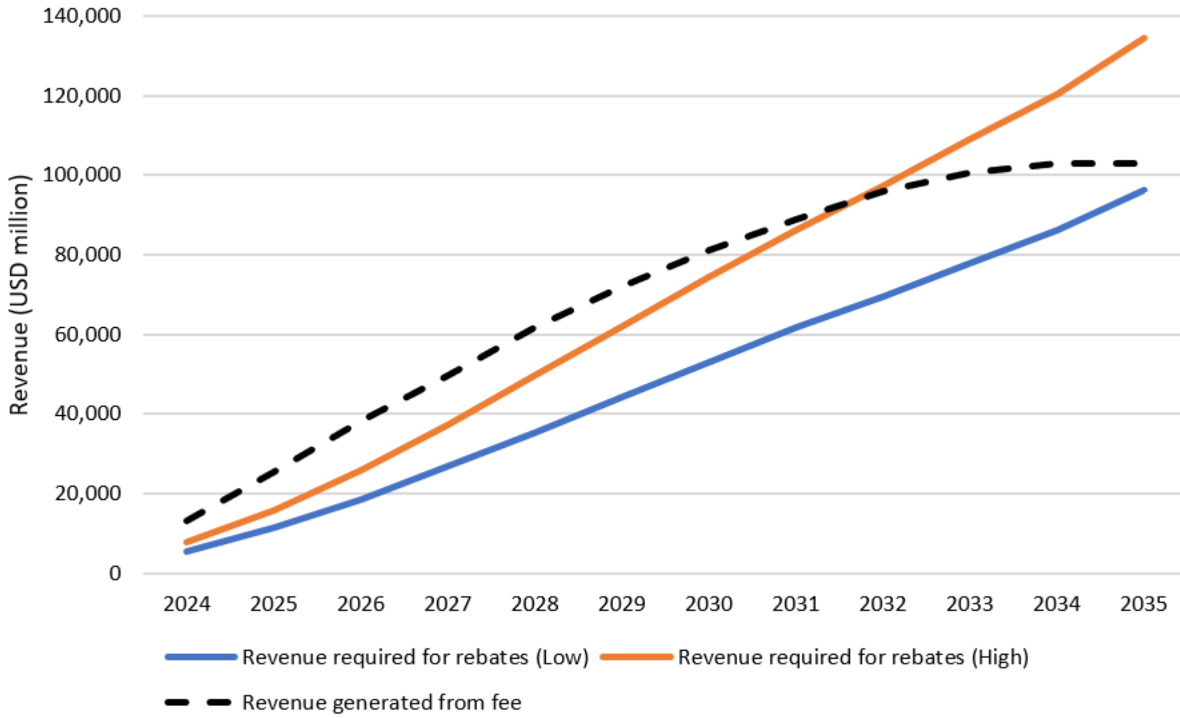

Figure 15. Funds required to finance rebates and revenue generated by fees in low and high HZEV rebate scenarios with pivot points as per Phase 3 US EPA GHG regulations.

Results

This paper evaluates six feebate cases, four as described in Table 5, and two special cases: (1) increasing the fee schedule (F3) and (2) adjusting the pivot points to the new Phase 3 US EPA GHG regulations, both applied to the HZEV scenario. The analysis finds that there are numerous pathways to designing feebate policies that are revenue-neutral or generate a revenue surplus. It is possible to build-in equity considerations with fee structures. Feebates are a self-funding market-shaping tool that can be leveraged to shift consumer purchasing behavior.

1. The use of fees on ICE vehicles to support rebates on EVs can be achieved with relatively low average fees per vehicle, on the order of 2 to 8% of MSRP. Only at very high CO_2 levels do the fees rise above this for ICE vehicles and, even in those cases, the highest fee impact does not exceed 12%.
2. The low rebate cases, wherein all EVs eligible to receive a rebate are given $3,750 and the fee schedule has a base of $2 and a maximum of $14, results in a revenue neutral feebate mechanism across both the LC and HZEV scenarios.
3. In the LC scenarios, the feebate results in a revenue surplus, with the impact on the highest emission classes in the range of 5 to 7%. In the HZEV scenarios, the average fee impact on the highest emission classes ranges from 7 to 10%, depending on the fee schedule.

4. If a flat fee schedule were to be considered in each of the scenarios, the average fee on every ICE vehicle sold beyond the pivot point each year would be around \$7 to \$8 per gCO_2 of deviation from the pivot point. In the HZEV scenario with high rebate, the average fee would have to be \$11 per gCO_2 to attain revenue neutrality, as shown in Table 5, with all other cases resulting in a revenue deficit.

Table 5. Feebate scenarios evaluated in this paper with summary information.

<table>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Rebate</th><th rowspan="2" colspan="2">Fee</th><th rowspan="2">Revenue Status</th><th colspan="2">Average Fee Impact by emission class</th><th>Average marginal fee rate</th></tr>
<tr><th>Lowest 3 classes</th><th>Highest 3 classes</th><th>per gCO_2/mi</th></tr>
<tr><td rowspan="2">LC</td><td>Low</td><td rowspan="2">F1</td><td rowspan="2">$2 - $5 (2024 to 2027)
$2 - $10 (2028 to 2031)
$2 - $14 (2032 to 2035)</td><td rowspan="2">Surplus</td><td rowspan="2">1 – 2%</td><td rowspan="2">5 – 7%</td><td rowspan="2">$7</td></tr>
<tr><td>High</td></tr>
<tr><td rowspan="2">HZEV</td><td>Low</td><td rowspan="2">F2</td><td rowspan="2">$2 - $14</td><td>Neutral</td><td rowspan="2">1 – 2%</td><td rowspan="2">7 – 9%</td><td rowspan="2">$8</td></tr>
<tr><td>High</td><td>Deficit</td></tr>
<tr><td>HZEV</td><td>High</td><td>F3</td><td>$8 - $14</td><td>Neutral</td><td>1 – 2%</td><td>8 – 10%</td><td>$11</td></tr>
<tr><td rowspan="2">HZEV (EPA)</td><td>Low</td><td rowspan="2">F2</td><td rowspan="2">$2 - $14</td><td>Neutral</td><td rowspan="2">1 – 2%</td><td rowspan="2">8 – 10%</td><td rowspan="2">$8</td></tr>
<tr><td>High</td><td>Deficit</td></tr>
</table>

5. The highest fee impacts range from \$2,100 to \$2,200 by the year 2034 across scenarios, with the high fee schedule in the HZEV scenario reaching about \$3,000 in 2034 (Figure 16).
    - In the LC scenarios, the fee schedule assesses \$450 per ICE vehicle above the pivot point in 2024 and increases to an assessment of \$1,153 by 2030.
    - In the HZEV scenario (high fee), the fee schedule assesses \$958 per ICE vehicle in 2024 and \$1,400 by 2024 for the high fee case.

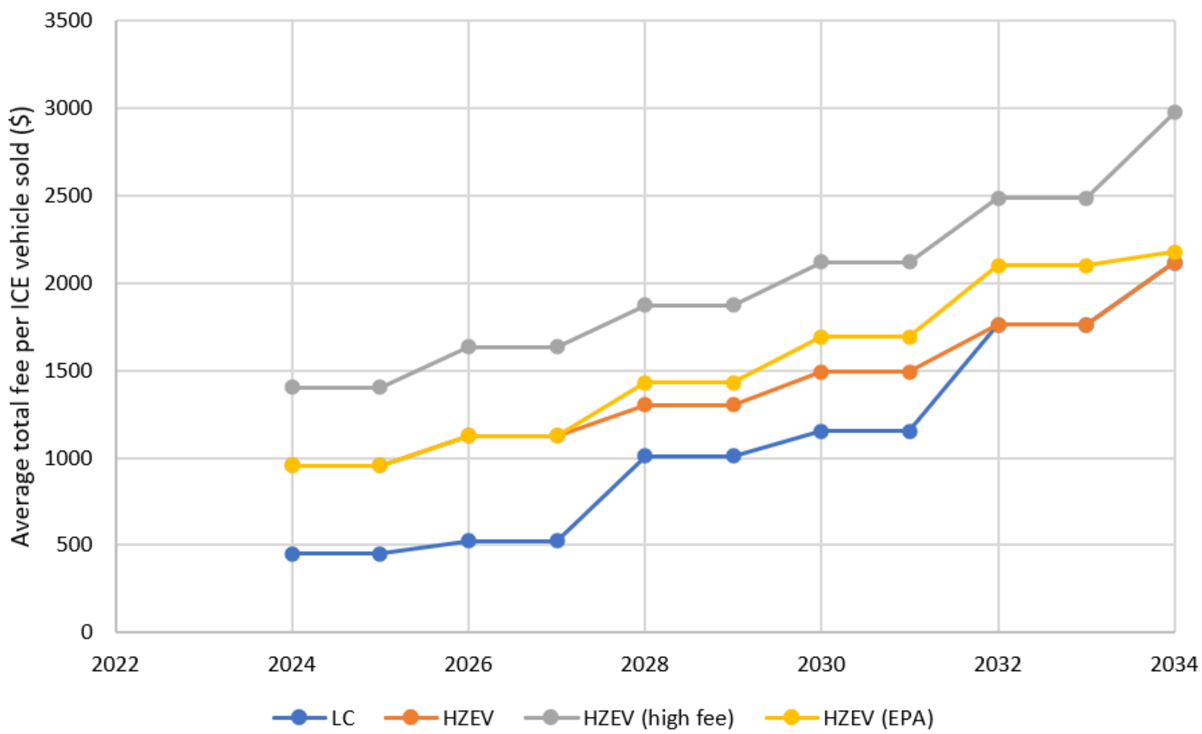

Figure 16. Average fee per ICE vehicle sold above the pivot point each year.

Discussion

Beginning in 2024, the EV tax credit will be offered upfront, functioning like a purchase subsidy, instead of being credited to the buyer the following year when they file their tax returns. This is expected to drive consumer choices toward EVs. However, overall budgetary allocations are limited for the incentive program.

Governments around the world are finding it increasingly difficult to finance subsidies for EV purchase incentives in the long term (International Energy Agency, 2023). There are uncertainties around the rate at which EVs will achieve price parity with ICE vehicles, putting pressure on policymakers to find innovative solutions that can support the costs of the transition to EVs on a timeline that will mitigate GHG emissions to achieve climate goals.

There is a need for some level of incentives in the long run because:

1. Until price parity between EVs and ICE vehicles is reached, consumers buying lower-priced vehicles may need subsidies to make EVs affordable and therefore attainable,
2. Cost uncertainties driven by supply chain risks, such as critical raw material procurement and regulatory changes, such as the US Inflation Reduction Act or the EU Critical Raw Materials Act, increase the costs of EV investments, and

3. Achieving technology cost reductions to substantially lower EV prices in the constrained timeline of achieving climate goals is unlikely to occur without subsidies, given the observed pace of necessary EV deployment and capital investments.

Further, the US EPA Phase 3 GHG regulations for LDVs with more stringent CO_2 regulations will likely lead to automotive manufacturers increasing sales of EVs to meet the regulatory requirements. It is anticipated that this will lead to an increase in EV model availability. These advances will come at a cost to manufacturers, especially in the early years as they invest in both technological fuel efficiency improvements and facilities for EV production. These considerations make the case for a market-based policy mechanism that can self-finance rebates and reduce fiscal pressure on government(s).

From an industry perspective, a feebate mechanism that incorporates fuel economy targets into the fee schedule as pivot points, and has the capability of self-financing, creates strong market certainty for choosing to invest in EV production and increasing model availability. From a consumer perspective, the certainty of the rebate program and the increased fees on ICE vehicles will result in shifting consumer decisions towards purchasing more EVs.

Typically, an analysis like this should also account for demand elasticities across gasoline and EV buyers. However, given the relatively low sales share of EVs in the auto market at present, and considering that most EV buyers are from relatively higher income households, accurate estimates of price elasticities of demand for EV buyers are difficult to make. This is a limitation on estimating fluctuations in the impact of fees and rebates on consumer choices. However, the feebate designs presented here provide clarity on EV sales trends and the financial feasibility of the feebate mechanism.

While not explored in the purview of this analysis, a feebate mechanism can have exogenous features, such as price caps on EVs eligible for incentives, thresholds on household income above which incentives do not apply, rebates for used EVs, and/or ICE vehicle scrappage programs. Related support mechanisms such as these can be considered when defining the fee schedule and estimating its net impacts on vehicle prices and consumer choice.

This report advances knowledge about feebates in the US. It shows that:

1. Revenue-neutral incentive systems are possible while supporting increasing sales of light duty EVs along the target path toward a 100% sales share by 2035; and
2. Revenue-neutrality can be achieved with relatively low average fees on entry level ICE vehicles, at the very least, maintaining economic equity among vehicle buyers.

While this paper has discussed feebates in the context of government policy development, the government is not the only entity that could apply them. With strong fuel economy regulations as in the Phase 3 GHG emissions final rule by the US EPA, individual automotive manufacturers could use feebates as a tool to establish their own internal pricing mechanisms across ICE and EV products, an area of future research. For automotive companies, internal feebates could facilitate an internal cost-benefit analysis of investing in ICE vs EV production, and external pricing decisions in terms of vehicle MSRPs for consumers, thus, ensuring a profitable business pathway during the EV transition.

Feebates as a tool could also be utilized to create sufficient disincentives from car dependency to finance shift to other lower emission multimodal and mass transit alternatives, with the fee revenue being used to invest in public transit and multimodal infrastructure. The role of feebates or emission pricing as a tool to achieve different transportation decarbonization outcomes remains an area of research, especially to leverage limited government resources to achieve low carbon transportation pathways.

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Data Summary

Products of Research

The data collected for the study include the following:

- Automotive sales data for light duty vehicles in the European Union (specifically for France, Germany, Italy, Sweden), the United Kingdom (UK) and the United States (US)
- The sales data was model-wise by manufacturer, and included parameters such as powertrain type (internal combustion, plug-in hybrid, and battery electric), fuel efficiency rating (measured as miles per gallon, kilometers per litre), CO2 rating (measured as gCO2/km or gCO2/mi).
- Average vehicle prices for the year 2021-2022 were also collected.

Data Format and Content

The data is stored as MS excel files. Two files have been created, one with data for Europe and one for the US. Each file has the following data:

- Model-wise LDV sales
- Powertrain type
- Fuel efficiency / CO2 rating for each model
- Avg. sales price

Data Access and Sharing

The final dataset has been created using five different data sources. Of these, two data sources are public, while the other three are restricted due to being paid subscriptions. The general public can request aggregated descriptive statistics for the data, which will be shared after due consideration for data sharing restrictions.

Reuse and Redistribution

The data provided in the paper can be reused and redistributed directly with due citations. Any background data not presented in the paper will be considered by individual requests and shared within the limitations imposed by the nature of the data sources.