Sustainable EV Market Incentives: Lessons Learned from European Feebates for a Zero Emissions Future

August 2024

A White Paper from the National Center for Sustainable Transportation

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16. Abstract

Strong policies are needed to accelerate the zero-emission vehicle (ZEV) transition so that it occurs at a pace in line with international climate goals. The purchase price of new vehicles tends to be the variable that most affects consumer decisions. With urgency for a ZEV transition, fiscal pressure for governments can be high as rebates for consumers and incentives supporting manufacturers in the switch to ZEV technologies will be needed for a mass-market transition. Fees on high-polluting vehicles—and rebates on clean ones—have become an effective and increasingly common strategy in European countries. The feebate mechanism can raise the necessary capital for financing a ZEV transition in combination with other regulatory mechanisms. This paper reviews and assesses feebate design types, issues, and implementation strategies in France, Germany, Italy, Sweden, and the United Kingdom. These examples show that feebates can be designed in a variety of ways to meet unique policy objectives and that periodic adjustments are helpful in achieving goals. Among twelve design considerations for an effective feebate, the authors find that: (1) focusing on a single fee parameter, such as CO_2 emissions, can be a simple yet effective mechanism; (2) a continuous functional form for the fee and a stepwise rebate are likely to be most effective in driving EV adoption; and (3) pure feebates, where fee revenue funds EV incentives by program design, provide certainty for manufacturers, regulators, and consumers.

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Disclaimer

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TABLE OF CONTENTS

List of Tables

List of Figures

Sustainable EV Market Incentives: Lessons Learned from European Feebates for a Zero Emissions Future

EXECUTIVE SUMMARY

The transition to zero-emission vehicles (ZEVs) to reduce greenhouse gas and air pollutant emissions is underway in California, Europe, China, and other regions. Strong policies are needed to accelerate the ZEV transition so that it occurs at a pace in line with international climate goals. In addition to top-down requirements such as ZEV sales mandates, bottom-up financial incentives are needed to push markets in the right direction. The purchase price of new vehicles tends to be the most important variable for affecting consumer decisions. In this regard, fees on high-polluting vehicles—and rebates on clean ones—have become an effective and increasingly common strategy in European countries. Whether called "feebates," "bonus-malus," "revenue-neutral incentives," or other names, these policies have the appeal of creating strong price signals without imposing a cost on taxpayers, unlike direct subsidies.

A feebate policy instrument can:

(i) be equitable and revenue neutral by redistributing revenue among consumers with no burden on taxpayers,

(ii) drive adoption of a more fuel efficient and lower-polluting fleet, thereby serving as a powerful tool in mitigating climate change,

(iii) offer a flexible and cost-effective model that can be superimposed on existing funding and tax mechanisms,

(iv) avoid reliance on budgeting or appropriations decisions by legislatures and policy makers to increase certainty for consumers and manufacturers by providing a steady funding stream.

For these reasons, feebates are compelling and may gain support across the political spectrum.

This paper reviews and assesses feebate design types, issues, and implementation strategies in France, Germany, Italy, Sweden, and the United Kingdom (UK). These five European countries are leading the way on feebate-type pricing strategies. The role of EV incentives and the impact of the feebate mechanism in each of these countries provides insights on achieving a ZEV transition.

We focus on these five countries as they are global leaders with rapidly evolving vehicle tax and rebate systems. Their policies have been updated since 2017, allowing an assessment of how markets have responded over the past few years. These countries accounted for over 63% of new vehicle sales in Europe in 2022 and have shown significant growth in electric vehicle (EV) sales, especially since 2018.

Feebates have been applied to incentivize both battery electric vehicle (BEV) and Plug-in Hybrid Electric Vehicle (PHEV) sales in Europe. However, the mechanism will need to be calibrated as

conditions change to achieve a rapid ZEV transition in the accelerated timelines to meet climate goals. Addressing equity concerns for consumers and producers should be a priority in this process.

Based on our review of European countries and general feebate design considerations, we identify these elements of good design to facilitate a ZEV transition in the next decade (Figure ES-1):

1. **Transition to a pure feebate structure.** Feebates can be classified as pure or partial based on whether the "fee" and "rebate" parts of the mechanism were introduced under one mechanism (as in France and Sweden) or instituted separately (as in Germany and the UK). If fee revenue is not mandated to finance rebates either by regulation or legislation, there is a risk of sub-optimal funding allocation towards EV purchase incentives and charging infrastructure (as in the UK).
2. **Categorize vehicles by emission classes.** Identifying the distribution of vehicles sold by emissions (gCO_2/km) is a key first step in the feebate design strategy, followed by an understanding of prices within each emission class, and then choosing the feebate design. Components include functional form, efficiency, design, and/or pollutant emissions parameter(s), and the pivot point.
3. **Focus on a single fee parameter.** Having a single parameter can be efficient, easy to interpret, monitor, and implement within the feebate design. A CO_2 emissions-based fee mechanism should form the basis of vehicle taxes, as it will provide manufacturers the flexibility around adjusting other vehicle attributes if they meet the emissions reduction targets.
4. **Adopt a continuous functional form for fees and step-functions for rebates.** We recommend a continuous function, rather than a step function, for levying fees for every unit increase in CO_2 emissions (g/km). A non-linear fee function, with a steep rise in fees for higher emission values, is preferrable. This approach is the best way to avoid system gaming and ensure continuous incentives to build and purchase vehicles with lower CO_2 emissions. With rebates, there is evidence that a stepwise function will be more efficient than a continuous fee function. Stepwise functions can be structured to incentivize PHEVs with higher all-electric range requirements in the interim and target greater rebates towards ZEVs.
5. **Choose a pivot point that will maximize impact.** Policies can specify a single "pivot point" at which fees shift to rebates across the range of vehicles or a "donut hole" where neither a fee nor rebate is applied to vehicles within a central range. The choice should be based on an analysis of the type of vehicles being sold in the market. A percentile approach based on vehicle prices and/or emissions may be relevant.
6. **Revise feebates periodically.** Periodic revisions in the slope of the curve and the pivot point can help ensure a revenue-neutral system. Further, providing a two-year horizon on the functional form for the fee results in changes in the composition of new vehicle sales. Designing the feebate scheme to be updated at regular intervals ensures that it is

responsive to changes in the market and advances in vehicle technologies. This also assists in achieving design goals such as efficiency, stringency, equity, and revenue neutrality. The slope of the fee curve, which will impact both producer and consumer decisions, can be based on various parameters, such as upfront purchase price or Total Cost of Ownership (TCO).

7. **External policy support key to feebate mechanisms.** Feebate design must be supported by external policy choices such as a vehicle price caps for incentive eligibility for EV purchases and all-electric range requirements for PHEVs. Overall, as a basic principle, rebates need to be reduced over time, while fees increase. This will compel automotive manufacturers and consumers to make different choices.

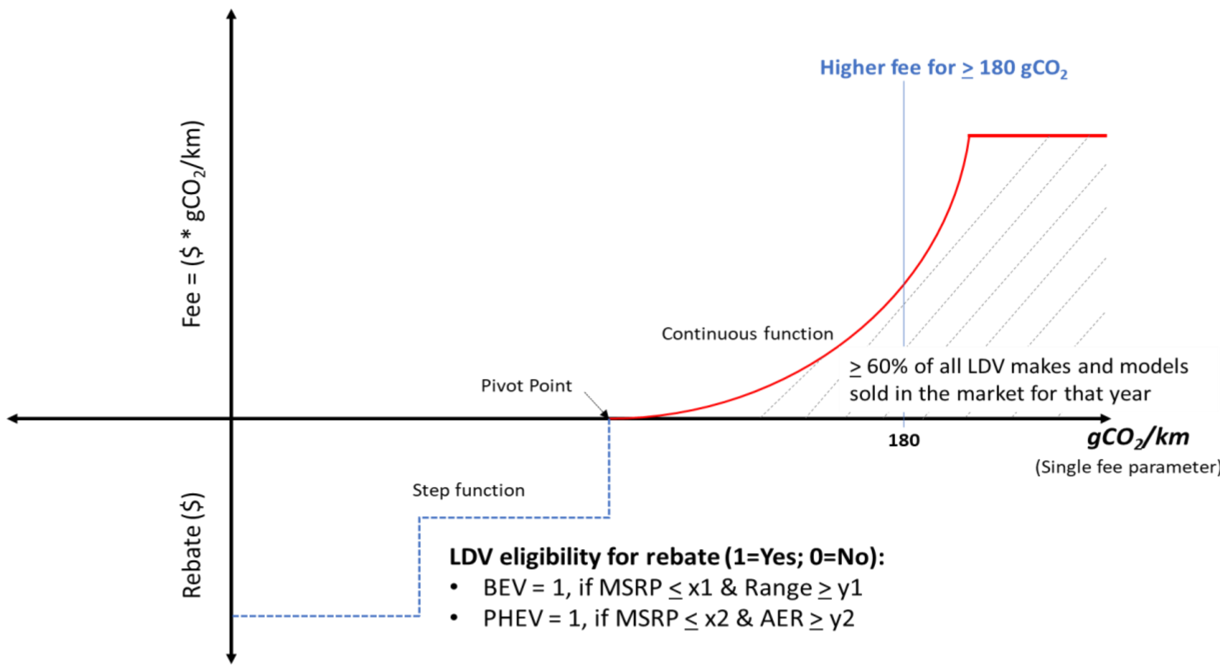

Figure ES-1. A summary of insights one through seven. A well-structured feebate includes a continuous functional form for fees and step-functions for rebates and a carefully chosen pivot point. Periodic revisions sustain impact, and external policy support can bend markets effectively.

8. **Upfront impact of fee or rebate at point-of-purchase is critical for affecting consumer choices.** We find that the point-of-collection of emissions-based fees matters to consumers and will likely play a role in the transition to ZEVs. A higher one-time fee collected at point-of-purchase is expected to be more effective than an annual fee, given consumer discounting of future cash flows.

9. **Model availability alone may not be sufficient to drive higher adoption rates of EVs.** Adoption rates will depend on factors including vehicle prices, (dis)incentives, and the feebate mechanism. Policymakers should consider EV price points, how they compare to internal combustion engine (ICE) vehicles, and other attributes.

10. **Consumer choice can be preserved with feebate designs.** In the cases of five European countries, we find that arguments that "feebates constrain consumer preferences for larger vehicles" or "are pro-small cars" do not hold true. Between 2015 and 2021, all five countries saw an overall convergence to C-segment EVs. These are similar to ICE vehicle options, without any disincentive related to vehicle footprint. Instead of vehicle type, this shift was driven by fees and the market response from both producers and consumers. Feebates can also be designed by policymakers to pivot consumer choices for reasons such as safety or resource efficiency.
11. **Equity considerations are key for a mass transition to EVs.** Equity considerations for those in low-income groups and other disadvantaged communities will be critical in ensuring a mass transition to EVs. Benefits should apply across society, over and above the price caps in place for vehicle eligibility for general rebates. Across Germany, Sweden, and the UK, we do not find explicit support for low-income households to purchase EVs. Possible remedies are used-EV schemes, EV car-sharing, and vehicle trade-in programs. Low-income and disadvantaged communities can be supported to transition to PHEVs before a move to BEVs, given limited access to charging infrastructure. Feebate equity can be addressed by considering household income levels and prices of vehicles purchased when determining the functional form, slope of the curve, and pivot point.
12. **Robust data monitoring frameworks enable self-sustaining feebate programs.** For each program, it is essential to maintain a strong database of vehicle sales, pricing, and emissions to facilitate periodic adjustments of feebate mechanisms.

To achieve an equitable ZEV transition, countries will have to implement or re-align feebate mechanisms in a manner that charges fees for most ICE vehicles sold while supporting those in low-income groups and other disadvantaged communities. Reaching the goal of a ZEV transition will likely happen in phases with a mix of PHEV and BEV sales at the outset followed by a shift to only BEV and other ZEV technologies. As the benefits for ZEVs are realized at-scale in the market, they will lead to an overall reduction in new vehicle prices and a more robust market for used ZEVs. This will improve accessibility and affordability for consumers on the lower end of the income spectrum.

Introduction

Emissions from the transportation sector must decline dramatically to achieve net-zero greenhouse gas goals in the next few decades (IEA, 2021; UNFCCC, 2021a). Vehicle electrification is widely considered the most important strategy to dramatically reduce GHG emissions from transport (Ramji et al., 2021;Brown et al., 2021; IEA, 2021; Miller et al., 2021; Sperling et al., 2020; UNFCCC, 2021b).

The shift to very low emission vehicles, referred to as zero emission vehicles (ZEVs) below, requires changes in vehicle supply and demand. Given the widespread expectation of both policymakers and the automotive industry that ZEVs, especially electric vehicles (EVs) will dominate in the future (Hall et al., 2018; Muratori et al., 2021), this paper focuses on policies to effectively facilitate the transition (Boasson & Tatham, 2023). Given these expectations, the declining costs of EVs (Goetzel and Hasanuzzaman, 2022; Rapson and Muehlegger, 2023), and government commitments to significantly reduce GHG emissions, it is now widely perceived that aggressive performance standards (including stringent fuel efficiency norms and ZEV sales mandates) are the most important policy to accelerate EV sales, more so than consumer incentives. This is already being demonstrated in China, the world's largest EV market (Deng & Tian, 2020; S. Li et al., 2020; Xiao et al., 2020); the EU, the second largest EV market (Dornoff, 2023; Dornoff et al., 2021); and in the US, where EV sales are greatest in states with ZEV sales mandates (Woody et al., 2023).

Even with a policy that sets performance standards, consumers still need to purchase low emission vehicles and, thus, consumer incentives are widely seen as essential to smooth the transition process (European Council, 2023). Since 2015, governments have provided purchase incentives for EVs in all major car markets. The sustainability of incentives has come into focus, as they put significant fiscal pressure on governments. Through 2022 and 2023, several governments have announced reductions in subsidies (e.g., California, UK) or phase-outs of subsidies (e.g., Germany, China) (CARB, 2023a; EV-Volumes, 2022; Li and Lee, 2023; Reuters, 2022; Times of India, 2023). These entities cite a lack of public funds as the reason for reducing subsidies. Incentive programs are subject to annual budgetary appropriations and are thus likely to be unfunded when politics or resources change.

This paper addresses feebates, a form of consumer incentive that has gained acceptance in several European countries. It provides a comprehensive review of feebate mechanisms in Europe, their evolution, and their impact on EV sales between 2015 and 2022. Previous reviews assessed these mechanisms between 2010 and 2015, in their initial stages of implementation. It also presents a unique vehicle make-model-powertrain analysis. Here, we identify key elements of feebate design and implementation, discuss how feebates can be sustainable and cost-effective for governments, and give examples of feebates contributing to policy objectives. Our findings suggest that feebates can accelerate a ZEV transition.

Role of feebates and design considerations

A feebate mechanism imposes a tax above a defined threshold value and offers a rebate below the threshold. Feebates can be an effective tool to reinforce a level of carbon pricing across products and activities in sectors including transportation, industry, electricity generation, electric appliances, and land use, and others (Batini et al., 2020; Scholz & Geissler, 2018).

Feebates for vehicles are typically designed with three components: (a) a fee on the sale of vehicles that have higher-rated CO_2 emissions than an identified threshold level (sometimes using proxy metrics such as engine size or pollutant emissions); (ii) a rebate for the purchase of vehicles with emissions below this threshold; and, (iii) a pivot point or zero point, defined as the threshold above or below which fees or rebates would apply, with the fee estimated based on an efficiency or CO_2 criterion but also possibly adjusted by other vehicle attributes such as weight or footprint (German & Meszler, 2010).

Feebate functions can be stepped or continuous. Continuous functions can be linear or non-linear with slopes changing at different threshold values, or as a hybrid of these. Parameters can be targeted at specific vehicle segments, such as cars or SUVs, or apply uniformly (German and Meszler, 2010).

The selection of a pivot point requires good forecasting of consumer choices and market behavior. The specification of the pivot point and slope of the curve for fees should account for consumers' valuation of fuel economy, which is typically only the first three years of savings, and not the entire life cycle of vehicle ownership (D.L. Greene et al., 2005).

A feebate policy instrument is compelling for a number of reasons: (i) it can be designed to be equitable and revenue neutral, with no burden on taxpayers or governments; (ii) it provides strong incentives to mitigate GHG emissions (Brand et al., 2013; Fazeli et al., 2017; Fridstrøm and Østli, 2017; Liu et al., 2012, 2011); (iii) it is flexible and is usually designed to be readily adjusted over time usually without legislative intervention, increasing certainty for both consumers and manufacturers (Kley et al., 2010); (iv) it harnesses market forces by adjusting price signals to consumers; and (v) tends to be supported across much of the political spectrum because it does not require taxes and yet is a market instrument. Feebates show promise, for all these reasons, to accelerate a ZEV transition (Antweiler & Gulati, 2013; Usher et al., 2015).

Feebate policies are sometimes seen as small-car subsidies (Berthold, 2019; Kley et al., 2010). This view is accurate when mostly ICE vehicles are targeted. Feebates can be adjusted to reflect whatever goal is desired. For instance, cars can be incentivized while sport utility vehicles (SUVs) and pickup trucks can be discouraged. Feebates currently do not account for CO_2 emissions generated by EV charging through the electricity grid. Instead, they relate to tail-pipe emissions from vehicles. Feebates could be extended by including grid-related emissions.

Data and methodology

Feebate mechanisms are compared across five countries, namely, France, Sweden, Germany, Italy, and the United Kingdom (UK). For automotive sales, data are obtained from Marklines, IHS Markit, and EV-Volumes (EV Volumes, 2023; EV-Volumes, 2022; Marklines, 2023). For vehicle emission data, the European Environment Agency database monitoring CO_2 emissions from passenger cars is used (EEA 2023). Further, the European Automobile Manufacturers' Association Tax Guide from multiple years is referred to obtain data on vehicle taxation and EV incentives in European countries (ACEA 2021, ACEA 2022). Information about feebate regulations is obtained from the regulatory authority that administers each program. The measurement of CO_2 emissions in this report is restricted to tail-pipe emissions and does not account for EV emissions from the electricity grid.

A comprehensive dataset that includes automotive light duty vehicle (LDV) sales by make-model, powertrain (ICE, BEV, PHEV), and CO_2 emission has been created for this analysis. This yields unique country profiles for the years 2010 through 2021. Country profiles are overlaid with feebate design mechanisms to better understand feebate implementation and best practices for policy design to support a ZEV transition.

Review of Feebate Mechanisms in Five European Countries

In the European region, 23 of 31 countries have some form of emission-based taxation on vehicle ownership, acquisition, or both (European Automobile Manufacturers' Association, 2021; OICA, 2023). There are five European countries – France, Germany, Italy, Sweden, and the United Kingdom – that have implemented either a full or partial feebate mechanism and form the core of the review in this paper. Sweden's and Italy's program began in 2019 while all others began before 2015 with significant design changes in 2017.

An overview of feebate policy design elements is presented below (Table 1), followed by a detailed review of feebate mechanisms. The French feebate policy also known as the Bonus-Malus, was a pioneering policy tool introduced in January 2008, and has been considered a strong success, being replicated in other countries. With the need to accelerate EV deployment, feebate policies have been revised since 2017. Common changes include: (i) non-linear fee functions featuring a steep rise in fees for higher emission values, (ii) flexibility in adjusting rebates with limited fiscal impacts (i.e., revenue in-flow from fees), (iii) donut-hole[1] feebate structures, and (iv) meeting more stringent PHEV performance thresholds to qualify for rebates. Combined, these policy mechanisms give a clear signal to consumers to purchase ZEVs (Bose Styczynski & Hughes, 2019; D'Agostino et al., 2022.

[1] A "donut-hole" is a vehicle emission range (gCO_2/km) without any fee leveed or rebate offered.

Table 1. Summary of feebate mechanisms across key European countries in 2021 (European Automobile Manufacturers' Association, 2021).

Country	Feebate type	Functional form and parameter	Pivot point	Fee structure	Rebate structure
France	Pure	Continuous function for fee, step function for rebate CO_2 emissions (gCO_2/km) and vehicle weight	133 gCO_2/km	CO_2-based (non-linear curve) and vehicle weight (€10 per kg beyond 1,800 kg)	€6,000 for BEV with purchase price < €45,000 and emissions < 20 gCO_2/km €3,000 additional for low-income households
Sweden	Pure	Non-linear, piece-wise continuous function for fee, continuous function for rebate CO_2 emissions (gCO_2/km)	90 gCO_2/km	~€10 (SEK 107) per gCO_2 if emission is between 90 and 130 gCO_2/km ~€12.8 (SEK 132) per gCO_2 if emission > 130 gCO_2/km	Graded rebates offered for all vehicles with emission < 90 gCO_2/km Maximum rebate of SEK 70,000, not exceeding 25% of the vehicle price
Germany	Partial	Non-linear, piece-wise continuous function for fee, step function for rebate Engine displacement and CO_2 emissions	95 gCO_2/km	Tax on engine displacement and CO_2 tax (€ 2 per gCO_2 > 95 gCO_2/km up to 116 gCO_2/km Increases up to € 4 per gCO_2/km for emissions > 195 gCO_2/km)	Annual tax bonus of €30 for emissions from 1 to 95 gCO_2/km €6,000 for BEVs and FCEVs, if purchase price < €40,000, else, €5,000 In case of PHEVs, bonus will be €4,500 if purchase price < €40,000, else, €3,750
Italy	Pure	Step function for fee, discrete rebates CO_2 emissions	160 gCO_2/km	Stepped CO_2 tax from €1,100 to €2,500	€8,000 for 0 to 20 gCO_2/km with scrapping; €4,500 for 21 to 60 gCO_2/km with scrapping; € 2,000 for 61 to 135 gCO_2/km; purchase price < €50,000 or <€40,000 if > 61 gCO_2/km

Country	Feebate type	Functional form and parameter	Pivot point	Fee structure	Rebate structure
UK	Partial	Step function for fee, single rebate structure CO_2 emissions	50 gCO_2/km	~€12 (GBP 10) for gasoline vehicles with emissions < 10 gCO_2/km; up to €264 (GBP 220) for vehicles emitting 150 gCO_2/km; up to €1,614 (GBP 1,345) for vehicles emitting 200 gCO_2/km	€1,800 (GBP 1,500) for vehicles with emissions < 50 gCO_2/km, and at least 112 km of all-electric range; purchase price < €42,000 (GBP 35,000)

Assessing functional forms and impact of fees and rebates

In France, the feebate mechanism *(bonus-malus)* was initially structured as a step function, with discrete fee amounts based on classification of vehicle emissions. Automotive manufacturers took advantage of the step functions by making marginal improvements in CO_2 emissions to qualify vehicles for lesser fees or greater rebates (Kessler et al., 2023). After multiple corrections of the step function, France made an important change to the bonus-malus scheme in 2017, wherein, the 'fee' was converted to a continuous non-linear function (every marginal change in CO_2 emissions had a cost associated with it) while the 'rebate' was maintained as a step function (Figure 1). An additional fee of €10 fee for every additional kilogram of vehicle weight over 1800 kg took effect in 2022.

Italy introduced a feebate mechanism in 2019 (Figure 2) structured as a step function (Asadollahi, 2021), even though the disadvantages of a step function were well established. While there was a significant jump in EV sales in 2020 and 2021, with EVs reaching 8.6% of new sales after the feebate was introduced (compared to less than 1% in 2019), sales share remained flat around 8% in 2022 and 2023 (EV-Volumes, 2022). It is yet-to-be-seen how the feebate will incentivize adoption of ZEVs in Italy. A possible complication is that rebates apply to ICE vehicle purchases with emissions up to 135 gCO_2/km when older ICE vehicles are being scrapped.

Germany, on the other hand, does not have a pure feebate mechanism, as the incentive and fee are authorized by separate legislation. The German fee function is essentially non-linear and piece-wise continuous, with a graded fee per gCO_2 (Figure 3). From 2020, Germany changed the "Umweltbonus" policy, increasing the subsidy for EVs from the 2016 policy. Starting 2021, Germany has also imposed a revised CO_2-based vehicle tax, along with an existing tax based on engine displacement. The linear CO_2-based emission fee has now been amended with effect from 2021 to a non-linear, more stringent CO_2-based emissions fee, which ranges from €2 to €4 per additional gCO_2 above 95 gCO_2 (Bieker, 2019).

The UK also has a partial feebate mechanism, with the CO_2-based taxes being higher for diesel cars, like Germany (UK Government, 2023). The UK emission fee follows a step function (Figure 4).

Sweden introduced the feebate mechanism on 1st July 2018, replacing a rebate-only program for green cars. The Swedish feebate follows a non-linear, piecewise continuous function for the emission fee, and is the only country among those being reviewed in this analysis to have a continuous rebate function (Figure 5). Prior to the feebate, ZEVs received a rebate of €3,800 while PHEVs received a flat rebate of €1,800.

In addition, all countries have a higher fee on diesel vehicles, include price caps on EVs eligible for incentives, minimum all-electric range requirements for PHEVs and provide sales tax exemptions for EV purchases.

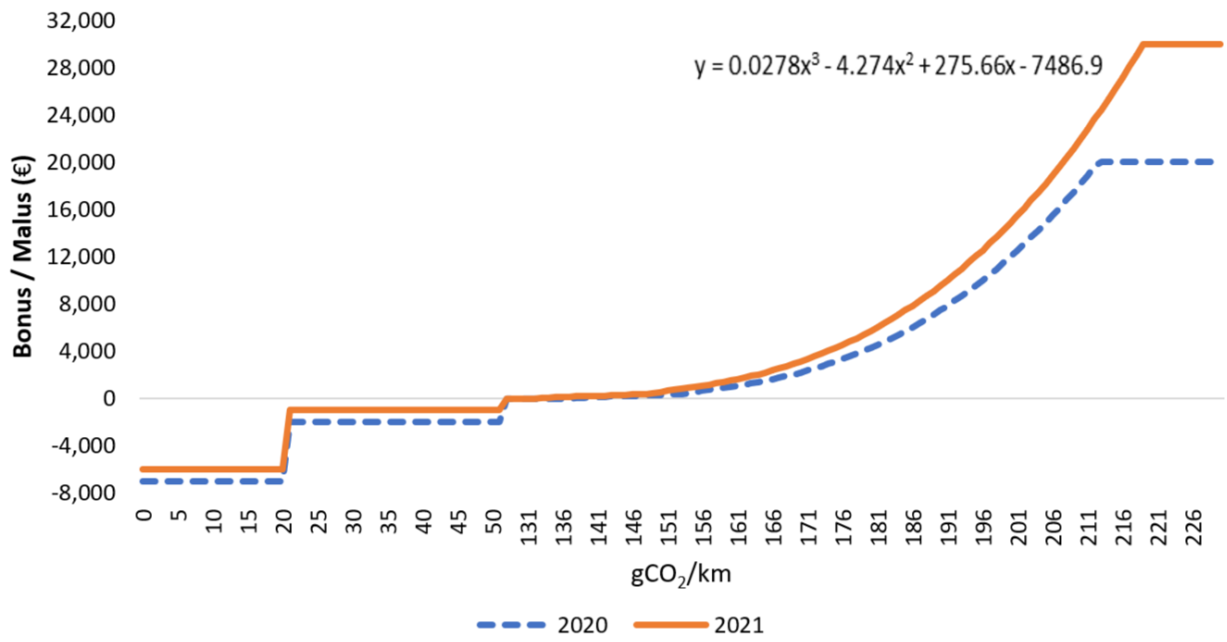

Figure 1. Feebate functional form in France for 2020 and 2021.

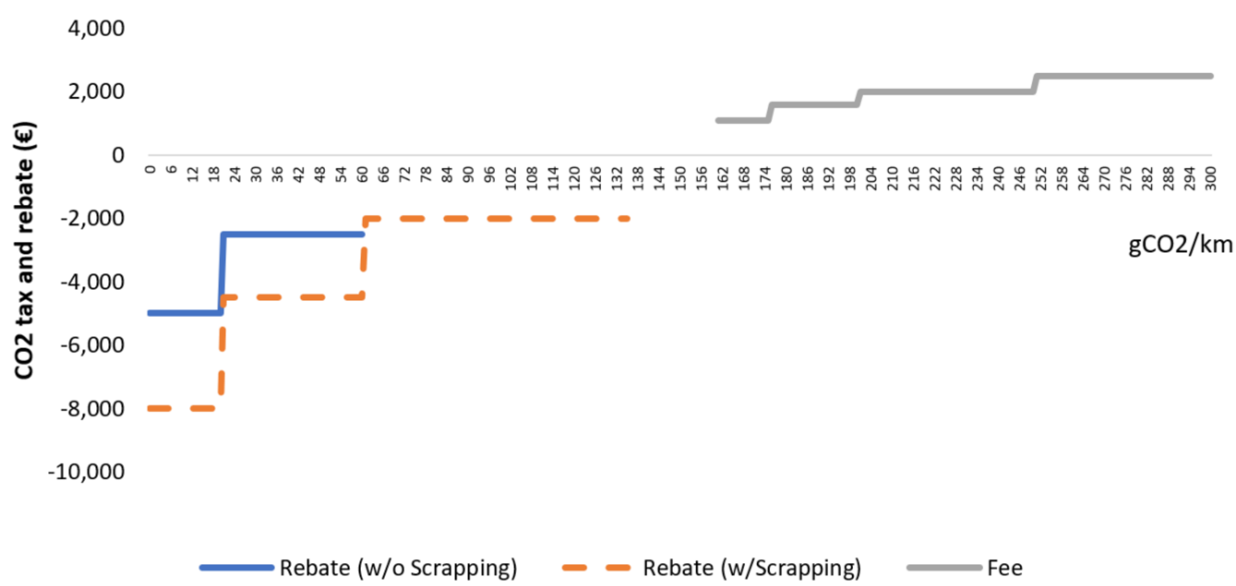

Figure 2. Feebate functional form for Italy in 2021.

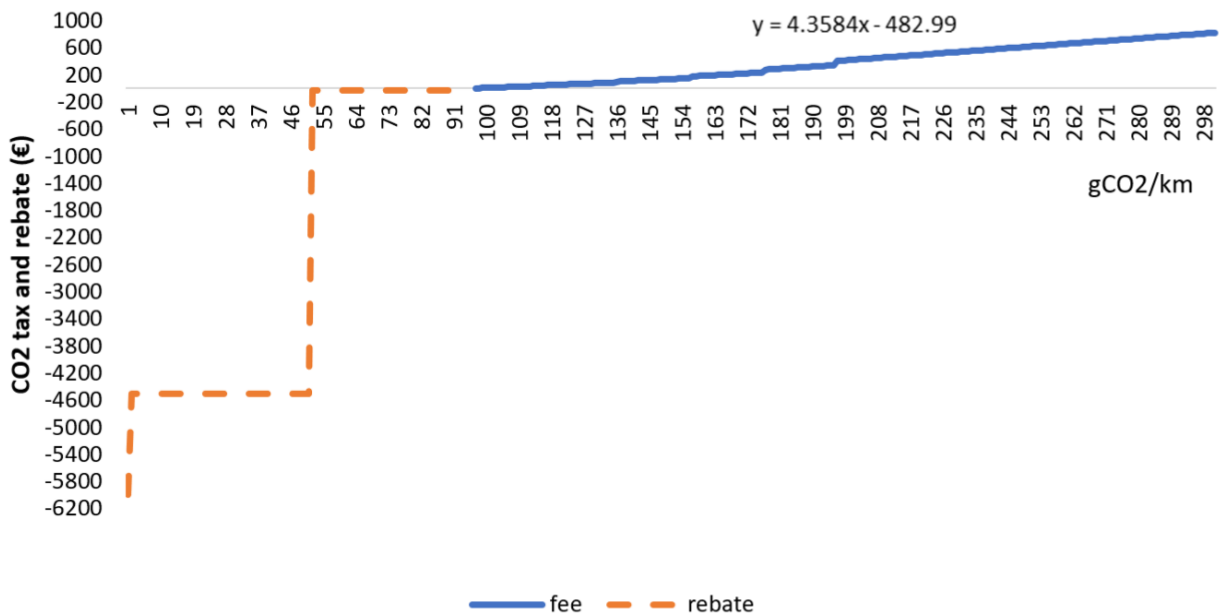

Figure 3. Feebate functional form for Germany in 2021.

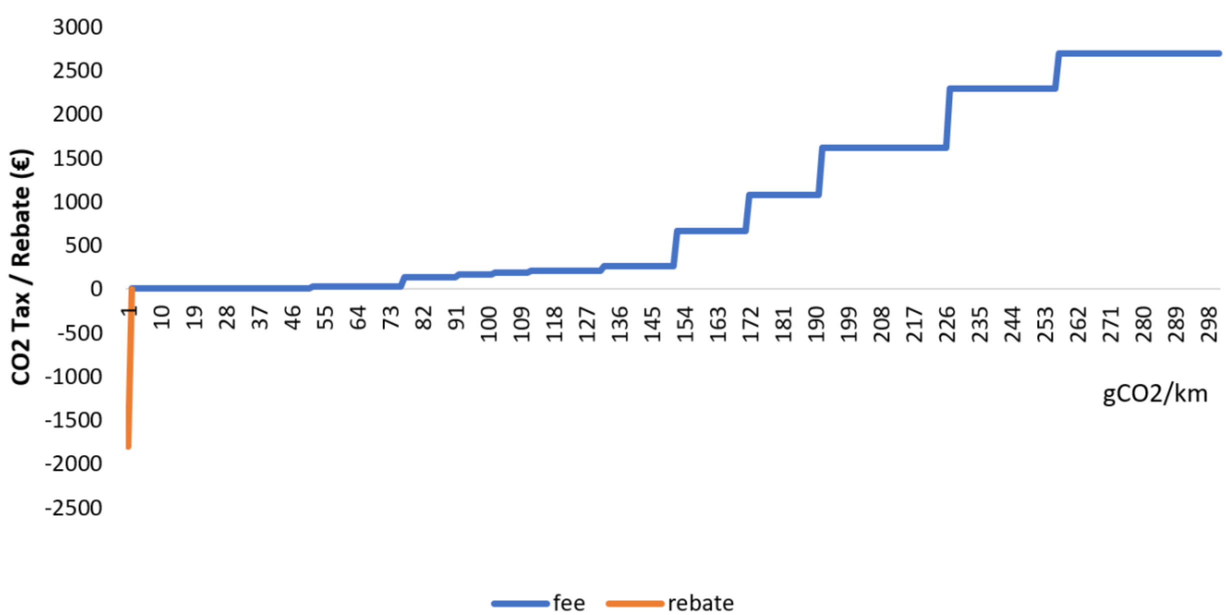

Figure 4. Feebate functional form for the UK (1 GBP = 1.2 EUR) in 2021.

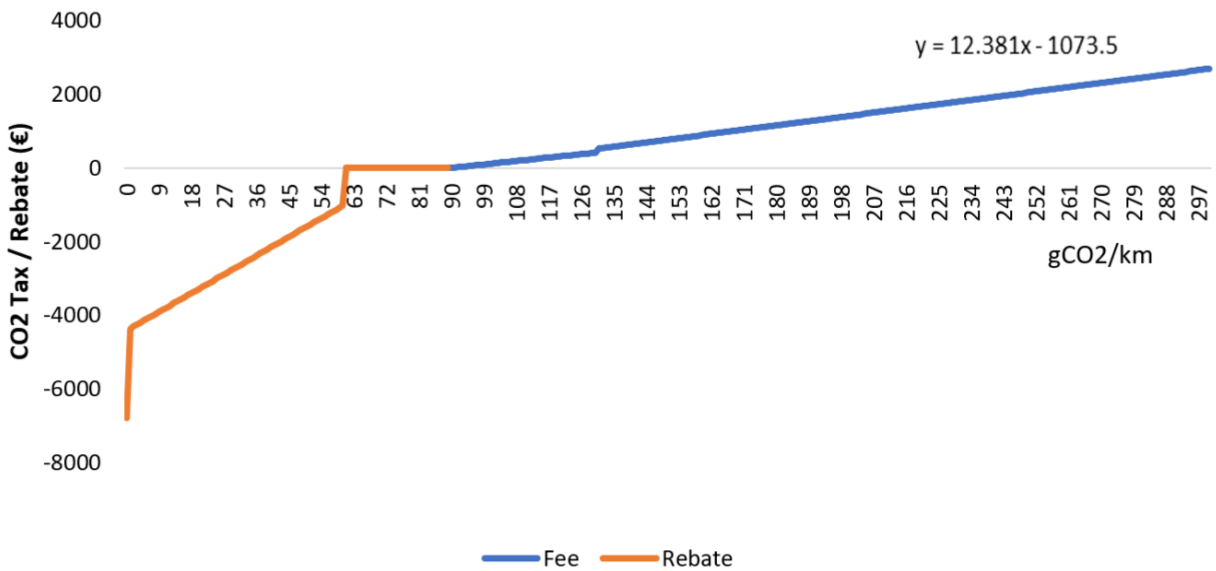

Figure 5. Feebate functional form for Sweden (1 SEK = 0.097 EUR) in 2021.

To understand the impact of the CO_2 fee on purchase prices for consumers in the respective countries, the emission values based on 2020 WLTP[2] estimates for a reference ICE vehicle are considered (Table 2). The emission values for the reference vehicle in each country as provided in the European Environment Agency database (EEA 2023). While the average rated CO_2 values for any vehicle is typically the same across the EU, the CO_2 values for the Volkswagen (VW) Golf are different in each country as it is based on the most selling variant of the VW Golf 2021 in that country.

Table 2. CO_2 fees across countries with a 2021 Volkswagen Golf as a reference vehicle. Manufacturer's Suggested Retail Price (MSRP) is the maximum sales retail price; all monetary values are adjusted to Euros as per reference exchange rate.

	France	UK	Germany	Sweden	Italy
MSRP* *(€)*	25,445	31,640	25,445	34,510	25,445
CO_2 fee - Year 1 *(€)*	0	1,074	70	91	0
CO_2 Fees - Year 2 to 4 *(€)*	0	0	210	216	0
% fee on MSRP	0.0%	3.4%	1.1%	0.9%	0.0%
gCO_2/km (WLTP)	119	171	127	102	121

The analysis shows that the VW Golf 2021 model attracts no emission fee in France and Italy, as the vehicle emission value falls in the donut-hole of the feebate mechanism in both countries

[2] The worldwide harmonized light vehicles test procedure (WLTP) is a global standard for determining levels of pollutants, CO_2 emissions, and fuel consumption of internal combustion engine, hybrid, and fully electric vehicles (Worldwide Harmonised Light-Duty Vehicles Test Procedure (WLTP) and Real Driving Emissions (RDE), 2017).

(Table 2). The emission fee is the highest in the UK, followed by Germany and Sweden, as a share of the MSRP, which is due to the differential in the WLTP emission factor of the VW Golf in each country. Germany and Sweden both impose an annual emission-based fee, while other countries impose an upfront fee at the time of purchase. A one-time higher fee at the time of purchase may have a different impact on consumer choices than an annual fee. Consumers tend to discount subsequent cash flows, so an initial higher one-time emission fee can be the difference between consumers choosing an EV or an ICE vehicle.

Table 3. Purchase rebate for Tesla Model 3 BEV and Ford Kuga PHEV 2021 across five European countries.

		France (€)	UK (£)	Germany (€)	Sweden (SEK)	Italy (€)
Tesla Model 3 BEV	MSRP (before rebate)	43,800	40,490	39,990	440,000	35,331
	Rebate	6,000	1,500	6,000	70,000	5,000
	MSRP (after rebate)	37,800	38,990	33,990	370,000	30,331
	% rebate of MSRP	14%	4%	15%	16%	14%
	MSRP (after rebate) in €	*37,800*	*46,285*	*33,990*	*35,980*	*30,331*
Ford Kuga PHEV	MSRP (before rebate)	40,950	35,915	39,300	51,2700	36,350
	Rebate	1,000	0	4,500	31,552	2,500
	MSRP (after rebate)	39,950	35,915	34,800	481,148	33,850
	% rebate of MSRP	2%	0%	11%	6%	7%
	MSRP (after rebate) in €	*39,950*	*42,660*	*34,800*	*46,720*	*33,850*

Except for the UK, BEV rebates are 14 to 16% of MSRP across countries, while there is a wide variance with regards to rebates for PHEVs (Table 3). The PHEV rebate is highest in Germany at 11% of the MSRP, compared to about 6 to 7% in Sweden and Italy. The comparison shows that France, Sweden, and Italy are focused on incentivizing BEVs over PHEVs, especially given that the top selling BEV and PHEV models compared are in comparable price ranges.

Choice of efficiency parameter for feebates

Efficiency parameters that are currently being used or considered to determine the feebate mechanism in the five countries assessed are CO_2 emissions, vehicle weight, engine capacity or displacement, and vehicle length (Table 4). For ease of comparison, the New European Driving Cycle (NEDC)[3] test cycles for 2015 and 2020 are used, as the CO_2 emission testing standards shifted from NEDC to WLTP from 2021 (Mian et al., 2023; Worldwide Harmonised Light-Duty Vehicles Test Procedure (WLTP) and Real Driving Emissions (RDE), 2017).

[3] The NEDC was last updated in 1997 and was phased out in 2017. It collected data under ideal conditions and thus did not reflect real world driving emissions.

First, average emissions from the NEDC tests have improved considerably across countries for all new cars sold between 2015 to 2020. Sweden shows a significant reduction at 6% CAGR compared to an average of about 2% CAGR reduction in other countries.

Second, all countries have shown an increase in vehicle mass in the range of 1 – 1.5% CAGR on average. Sweden and the UK have had the greatest increase in average vehicle mass, while Italy continues to have the lowest average vehicle mass among the five countries (Figure 6). While France and Italy have comparable vehicle parameters, the average emission reductions have been greater in France and can probably be attributed to the longer running bonus-malus scheme and—more significantly—the higher malus component compared to Italy.

Table 4. Country comparison across key efficiency parameters for feebate (European Environment Agency, 2023).

Country	***Year***	**Avg NEDC (gCO_2/km)**	**Avg. Mass (kg)**	**Avg. Engine Capacity (cm^3)**	**Vehicle Length (mm)**
France	2015	111	1,315	1,481	2,609
	2020	98.5	1,360	1,404	2,613
Germany	2015	128.4	1,447	1,710	2,643
	2020	113.6	1,534	1,698	2,680
Italy	2015	115.6	1,300	1,464	2,400
	2020	108.6	1,351	1,420	2,573
Sweden	2015	126.3	1,530	1,773	2,697
	2020	93.5	1,656	1,735	2,733
UK	2015	121.3	1,393	1,635	2,620
	2020	111.5	1,510	1,591	2,678

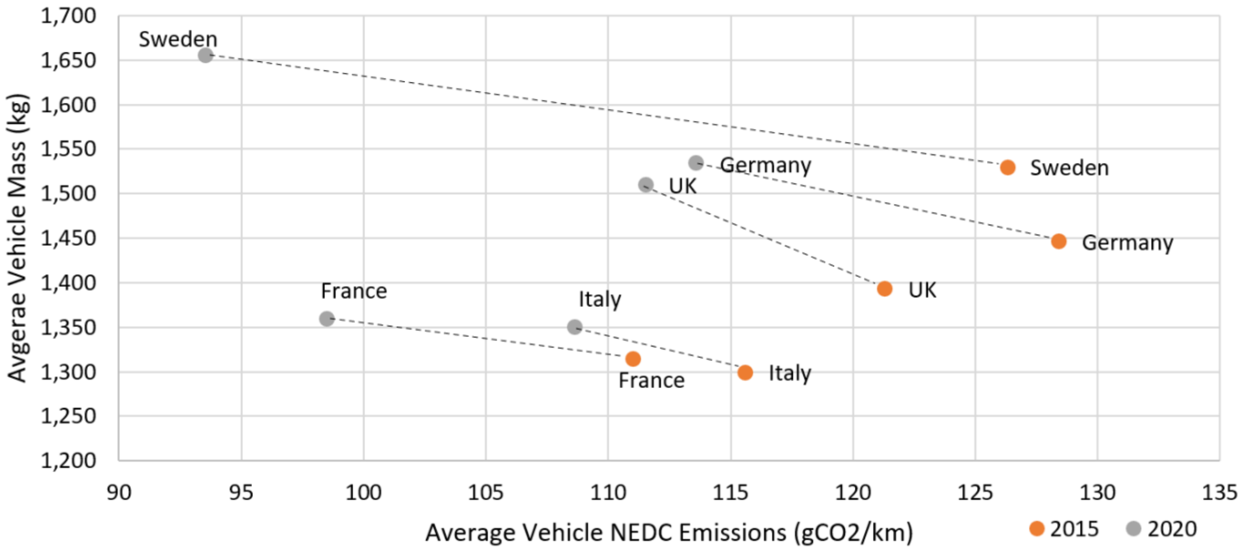

Figure 6. Average vehicle mass and NEDC emissions across countries, 2015 to 2020.

In France, the average vehicle mass was 1,360 kgs in 2020. The additional weight-based penalty introduced in 2022 will impact less than 5% of new vehicles sold and is a disincentive towards purchase of heavier and larger SUVs. France had the highest average increase in vehicle mass (kg) to vehicle length (mm) ratio of 11.3 kgs/mm between 2015 and 2020, compared to an average of 2.6 kgs/mm among other countries in the same period. This may have pushed French regulators to pre-empt automotive trends and introduce weight-based taxation measures.

Third, average engine displacement volume has decreased between 2015 and 2020 across all countries, even though average vehicle mass and length increased (Table 4). The power-to-weight ratio of an automobile, defined as the ratio of engine displacement (as a proxy for engine power) and vehicle weight is a good indicator of engine performance, speed, and acceleration. Germany had the highest engine displacement-to-vehicle mass ratio for both 2015 and 2020 among the five countries considered. Germany has been using engine displacement taxes since 2009 yet has shown the least reduction in power-to-weight ratio between 2015 to 2020. Since the ultimate objective is to reduce CO_2 emissions, having only a CO_2-based fee structure would have greater merit and efficiency.

Fourth, vehicle length has increased across all countries in varying magnitudes. France has seen an average increase of only 4mm in vehicle length between 2015 and 2020, whereas Italy has seen the highest increase of 173mm, followed by the UK with 58mm, and Germany and Sweden with about 36mm.

This raises the following questions:

(i) would CO_2-based taxation with a large penalty amount, in lieu of fees based on other attributes, be equally or more effective for supporting a ZEV transition; and

(ii) would taxation on attributes other than CO_2 serve as a hedonic pricing mechanism for emissions externalities where CO_2 taxation is difficult to implement.

Choice of pivot point and donut-hole

In the French Bonus-Malus scheme, the donut hole has been revised frequently (European Automobile Manufacturers' Association, 2022):

- in 2008, the donut hole was between 125 gCO_2/km and 160 gCO_2/km;
- in 2016, it was between 110 gCO_2/km and135 gCO_2/km;
- in 2021, it was between 50 gCO_2/km and 133 gCO_2/km, with significantly more stringent vehicle penalties, capped at €30,000 above 219 gCO_2/km;
- in 2022 it was between 128 gCO_2/km and 224 gCO_2/km with a penalty cap of €40,000; and
- in 2023, the upper threshold of the donut hole decreased to 123 gCO_2/km, and a €50,000 penalty cap for emissions over 226 gCO_2/km).

Other countries have made fewer adjustments to their fees, rebates, and donut holes:

- In Italy, the 2022 donut hole was between 136 gCO_2/km to 160 gCO_2/km. The fee is a step-function for vehicles emitting above 160 gCO_2/km, with the highest fee at €2,500 for all vehicles emitting more than 250 gCO_2/km.
- In Sweden, the "donut hole" is between 60 and 90 gCO_2/km, above which a fee applies, and below which a rebate applies.
- In Germany, there was a donut hole up to 2021. There were no taxes for vehicles with emissions below 95 gCO_2/km, which has been replaced with a flat annual tax bonus of €30 for emissions between 1 and 95 gCO_2/km. This can be considered a flat rebate "donut hole."
- In contrast, the UK has no donut hole, however there is no taxation for hybrids with emissions below 50 gCO_2/km and an all-electric range of at least 112 kms.

The following section reviews the potential impacts of feebates on vehicle registrations, emissions, and consumer choices.

Sales shares of EVs in relation to feebates

The choice of the functional form, efficiency parameter, and pivot point determine which vehicles are taxed, which benefit from a rebate, and which are excluded from the feebate altogether. In France, while ICE vehicles were initially eligible to receive rebates, the scheme was revised in 2018 to make only EVs eligible for rebates. In Sweden, Germany, and the UK only EVs are eligible.

Sales shares of EVs vary by country and by year (Figure 7). The year 2019 is observed as an inflexion point across all five countries, with EV sales rising significantly in subsequent years. France, Germany, and the UK follow a similar trajectory up to 2019. Then, from 2020 to 2021, Germany saw a sharp increase in EV market share compared to France and the UK.

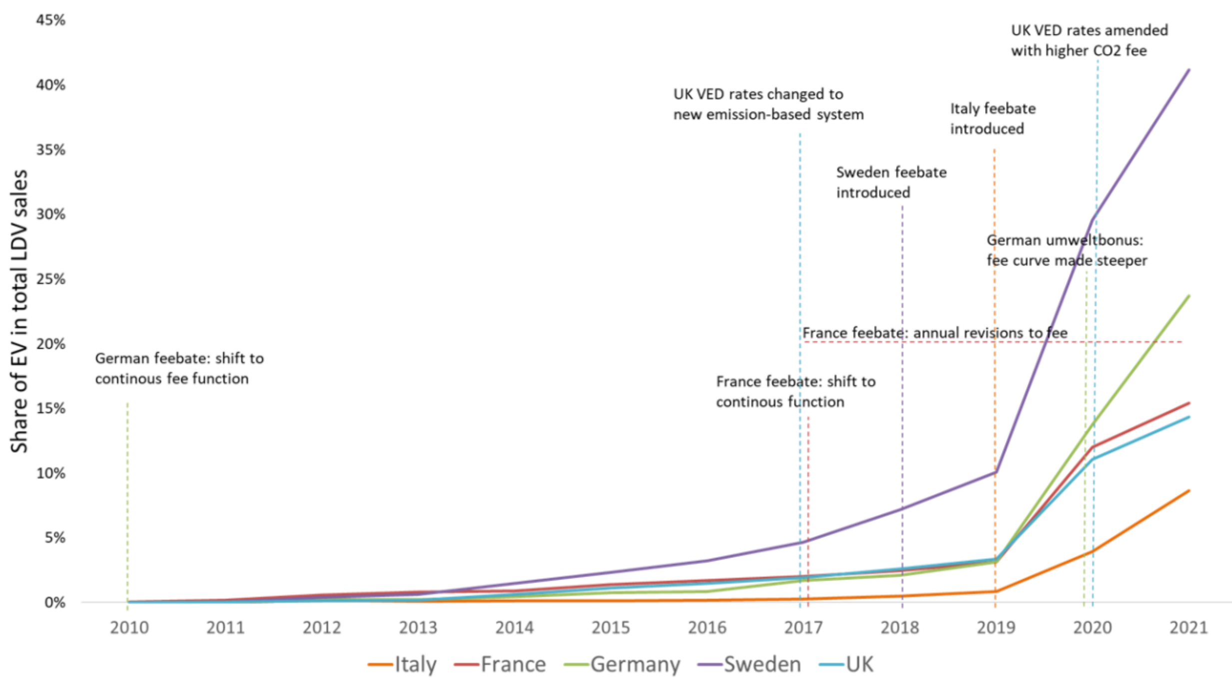

Figure 7. Share of EV sales and changes in feebate mechanisms in five European countries, 2010 to 2021.

While the EV share of total LDV sales reached around 15.4% in France and 14.4% in the UK in 2021, the share in Sweden jumped to around 41.2% in 2021. Sweden's jump was driven by continued momentum in PHEV sales since 2020 and a significant increase in BEV sales in 2021. Italy has shown a doubling of market share in new EV sales for 2021, reaching 8.6%, compared to 4.3% in 2020, also driven by a greater increase in PHEV sales. In Germany, the EV market share reached 23.7% in 2021, compared to 13.7% in 2020.

France and the UK are the only two countries with dominant BEV shares in 2020 and 2021, while PHEV sales have been increasing as well (Figure 8 and Figure 9). In Germany, there has been a moderation in the growth of BEVs compared to PHEVs in total EV sales, although BEVs were marginally dominant in 2021 (Figure 10). There was an inflexion point in 2020, where the BEV and PHEV shares are equal in Germany, with Italy not being very different (Figure 11). A recent study by ICCT indicates that the tax benefits introduced in 2019 for low and zero-emission company cars has boosted PHEV sales in Germany in 2019 and 2020 (Bieker, 2019; Bieker et al., 2022; Transport and Environment, 2022). Sweden, on the other hand, remains the only country among the five to have dominant PHEV sales since 2011, although BEV sales have grown steadily since 2018 (Figure 12).

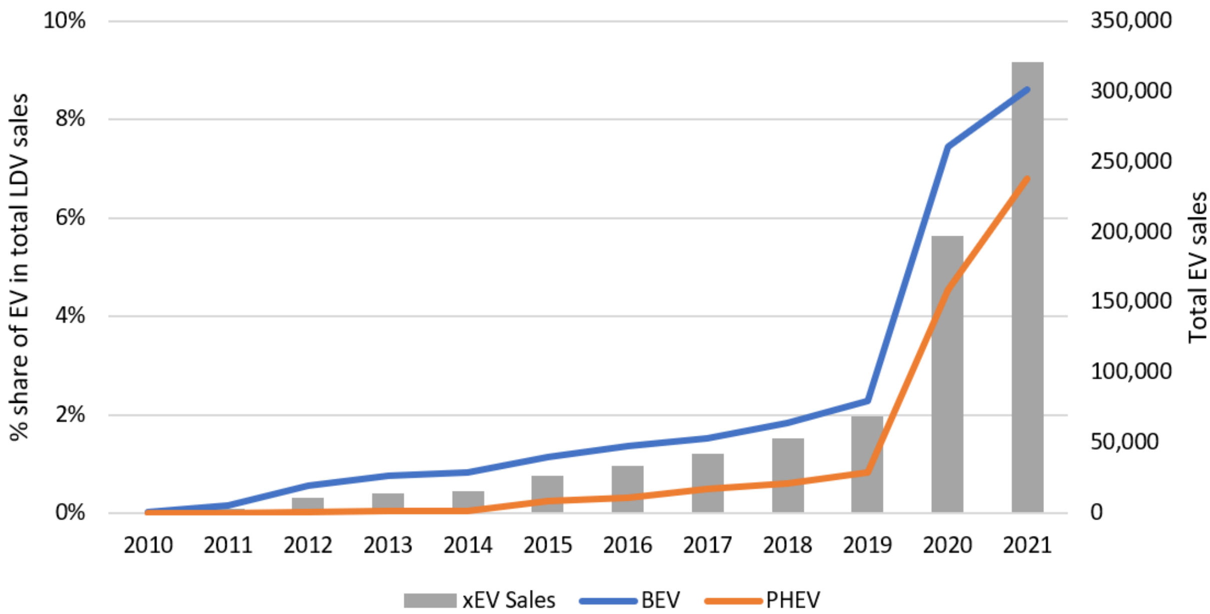

Figure 8. Total EV sales and share of EV sales in total LDV sales in France, 2010 to 2021.

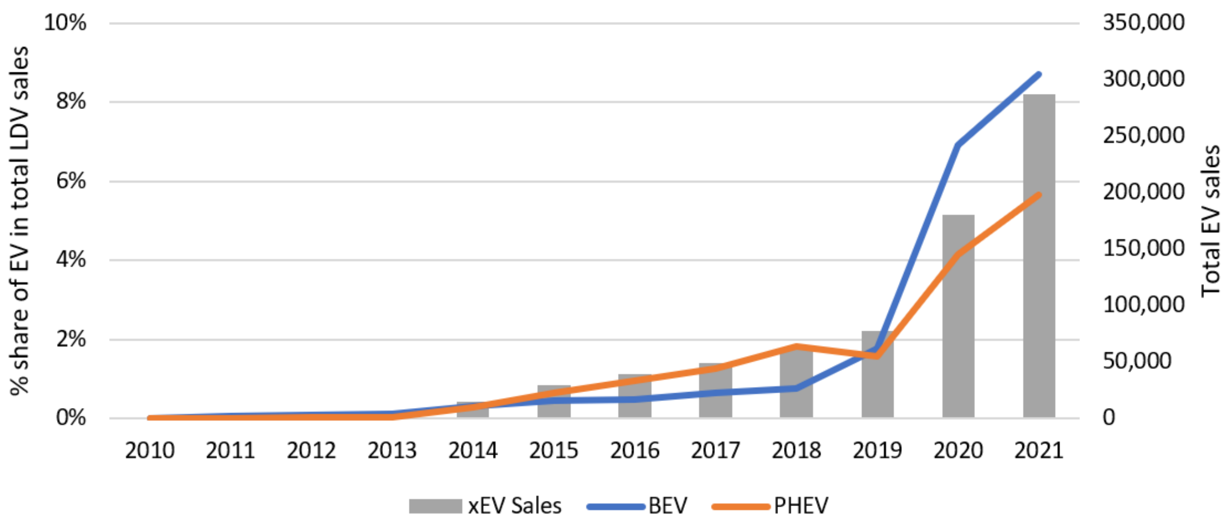

Figure 9. Total EV sales and share of EV sales in total LDV sales in the United Kingdom, 2010 to 2021.

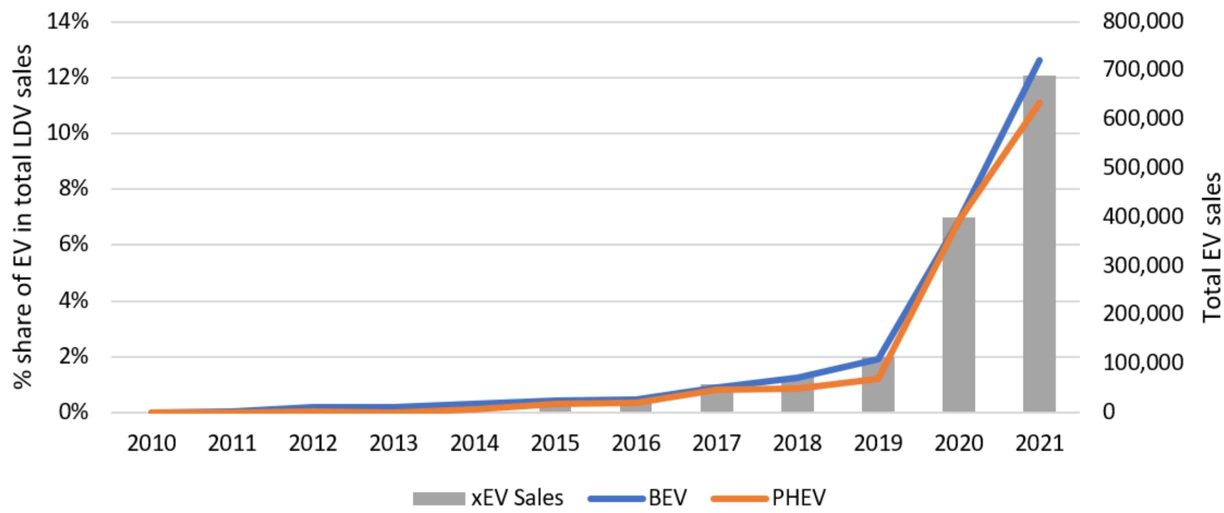

Figure 10. Total EV sales and share of EV sales in total LDV sales in Germany, 2010 to 2021.

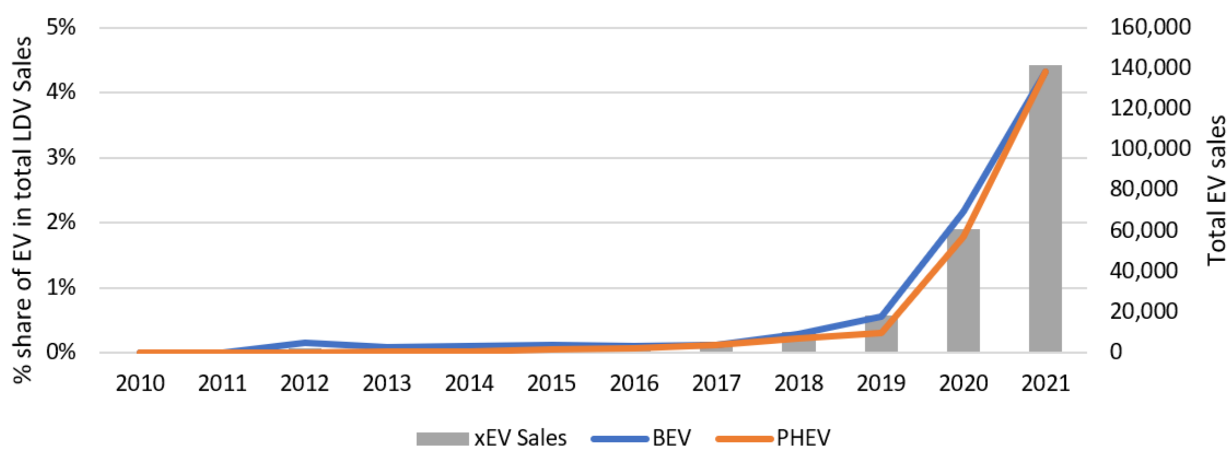

Figure 11. Total EV sales and share of EV sales in total LDV sales in Italy, 2010 to 2021.

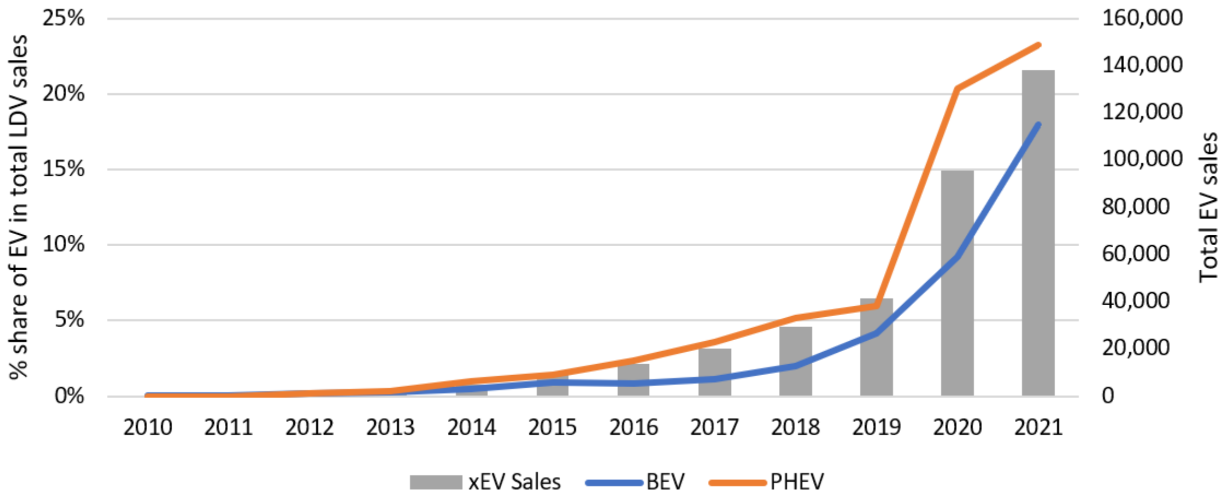

Figure 12. Total EV sales and share of EV sales in total LDV sales in Sweden, 2010 to 2021.

Model availability

Given the differences in EV sales across the five countries, this analysis further investigates model availability across BEVs and PHEVs, to understand the market transformation in the period concurrent with feebate policy changes. Between 2010 and 2017, the total number of EV models and variants sold across the five countries are similar (Figure 13). The number of EV models are estimated if, in any given year, the volumes sold in that year are greater than zero (EV-Volumes, 2022). It is only in 2018 that differences are observed in model availability across countries, the year after revisions in the feebate mechanisms. The availability of models alone does not drive higher shares of EV adoption and will depend on the other factors including vehicle prices, (dis-)incentives, and others such as feebate mechanism design, in this case.

Germany leads in model availability since 2014 with a significant increase from 2018 to 2020, while France and Italy move similarly to each other between 2017 and 2020. In 2021, Sweden has a lower availability of EV models compared to others but has the highest market share with 41.2% of EV sales in that year. The UK, which has the lowest number of EV models in 2021, has an EV market share of 14.4% in 2021. This is much higher than the 8.6% EV market share in Italy for 2021, even though Italy has a higher number of EV models sold for that year. The Italian feebate has a larger donut-hole than the UK, impacting a lesser share of ICE vehicles within the scope of the emission tax, potentially impacting the rate of EV adoption.

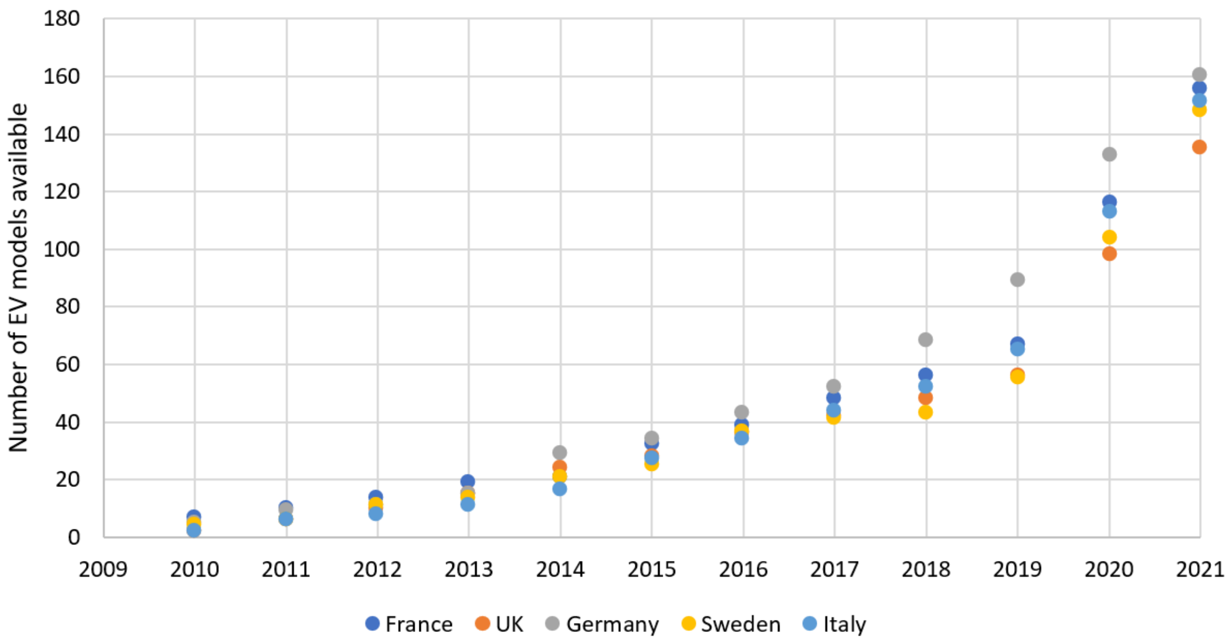

Figure 13. EV model availability by country, 2010 to 2021.

Table 5. Country-wise availability of BEV and PHEV models between 2010 and 2021. (Green highlighted cells indicate the dominant share of powertrain type driving EV sales.)

Country	EV	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
France	*BEV*	*7*	*10*	*10*	*13*	*14*	*16*	*17*	*17*	*21*	*27*	*48*	*66*
	PHEV	0	0	4	6	7	15	20	29	32	38	66	87
UK	*BEV*	*2*	*5*	*7*	*10*	*12*	*12*	*13*	*14*	*16*	*21*	*32*	*54*
	PHEV	0	1	3	4	11	14	21	26	31	33	64	79
Italy	*BEV*	*2*	*5*	*7*	*8*	*12*	*14*	*16*	*17*	*20*	*28*	*47*	*68*
	PHEV	0	1	1	3	3	12	18	27	31	35	64	82
Germany	*BEV*	*5*	*7*	*8*	*11*	*16*	*14*	*15*	*18*	*26*	*29*	*51*	*68*
	PHEV	0	2	3	4	12	19	26	31	39	57	78	89
Sweden	*BEV*	*4*	*4*	*6*	*8*	*13*	*9*	*13*	*11*	*15*	*20*	*37*	*60*
	PHEV	0	2	5	6	8	15	22	28	27	34	66	86

More BEV models are becoming available in automotive markets across the five countries, causing the average ratio of PHEV to BEV models to decline. From an average ratio of 1.6 PHEV to BEV models sold between 2017 and 2020, the ratio declined to 1.35 in 2021, marking a rise in BEV model availability (Table 5).

A further analysis of the sensitivity of EV sales to model availability shows that, for every additional model available, BEV sales indicate higher growth propensity compared to PHEV sales among all countries, except in Sweden (Figure 14 through Figure 18). Further, in Sweden, model availability to additional EV sales is similar for both BEV and PHEVs. For every additional model available, the response ratio of BEV sales to PHEV sales is highest for the UK and France, followed by Germany and Italy (Table 6).

Table 6. Country-wise EV sales and model availability from 2015 to 2021.

Country	BEV sales per additional model	PHEV sales per additional model	Sensitivity difference *(BEV per model /*
France	2,457	1,191	2.1
UK	2,860	1,275	2.2
Germany	4,138	2,375	1.7
Sweden	889	871	1.0
Italy	792	566	1.4

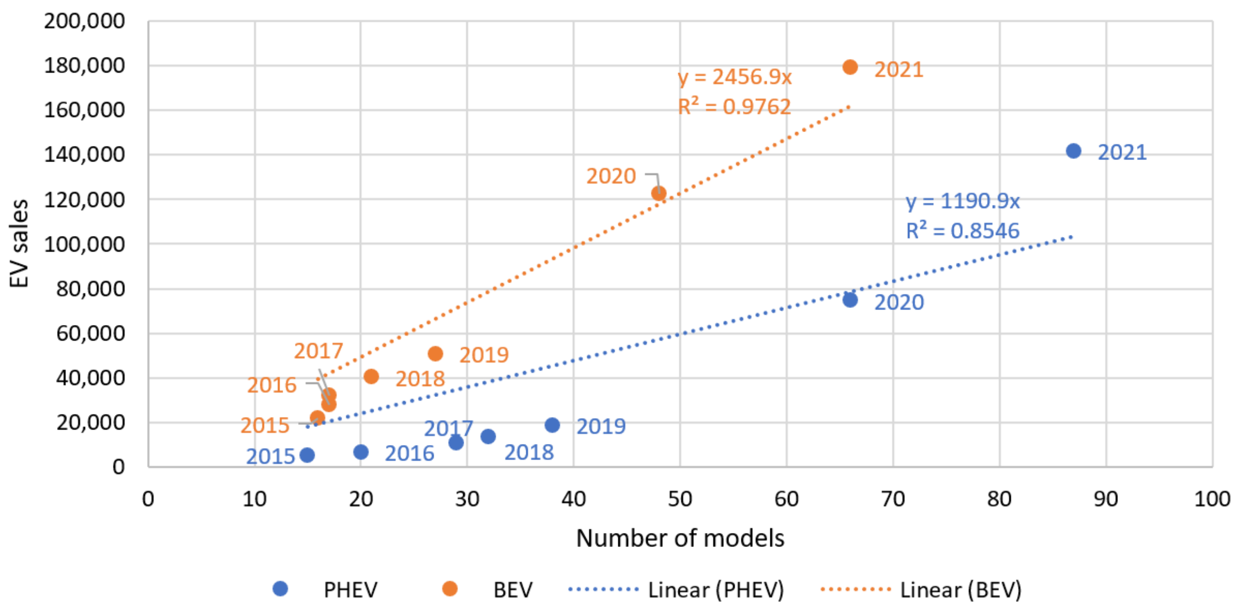

Figure 14. EV sales vs. model availability sensitivity in France, 2015 to 2021, fitted with a linear trendline to show the correlation between model availability and EV sales. No causality is implied.

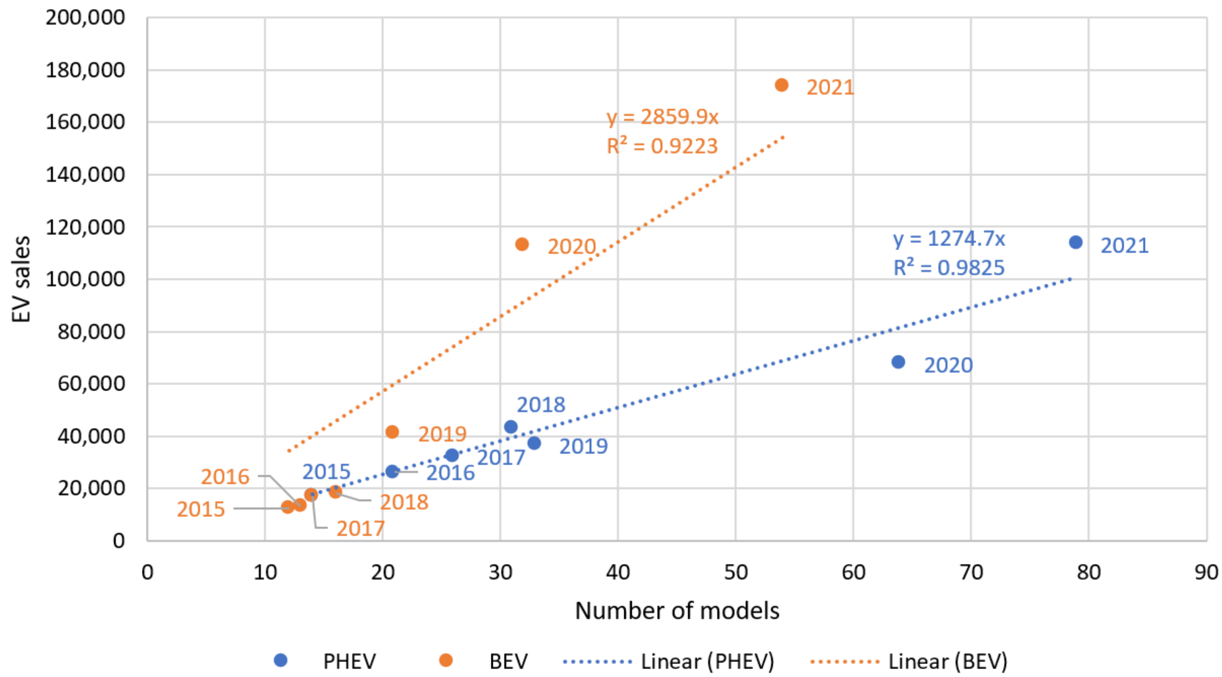

Figure 15. EV sales vs. model availability sensitivity in the UK, 2015 to 2021.

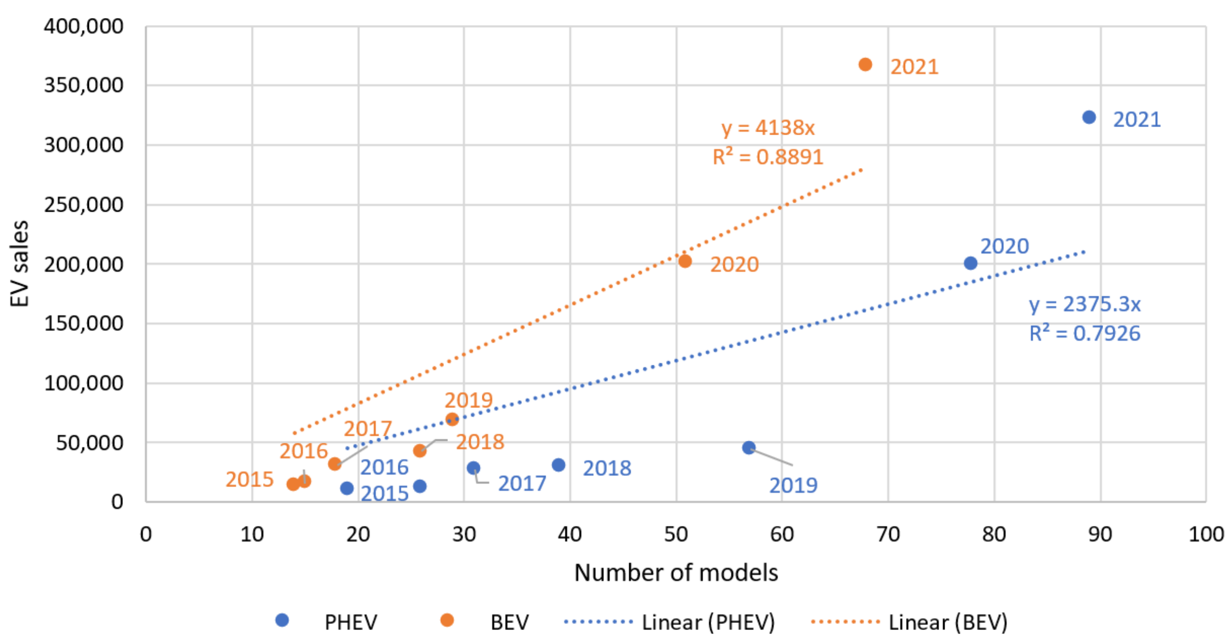

Figure 16. EV sales vs. model availability sensitivity in Germany, 2015 to 2021.

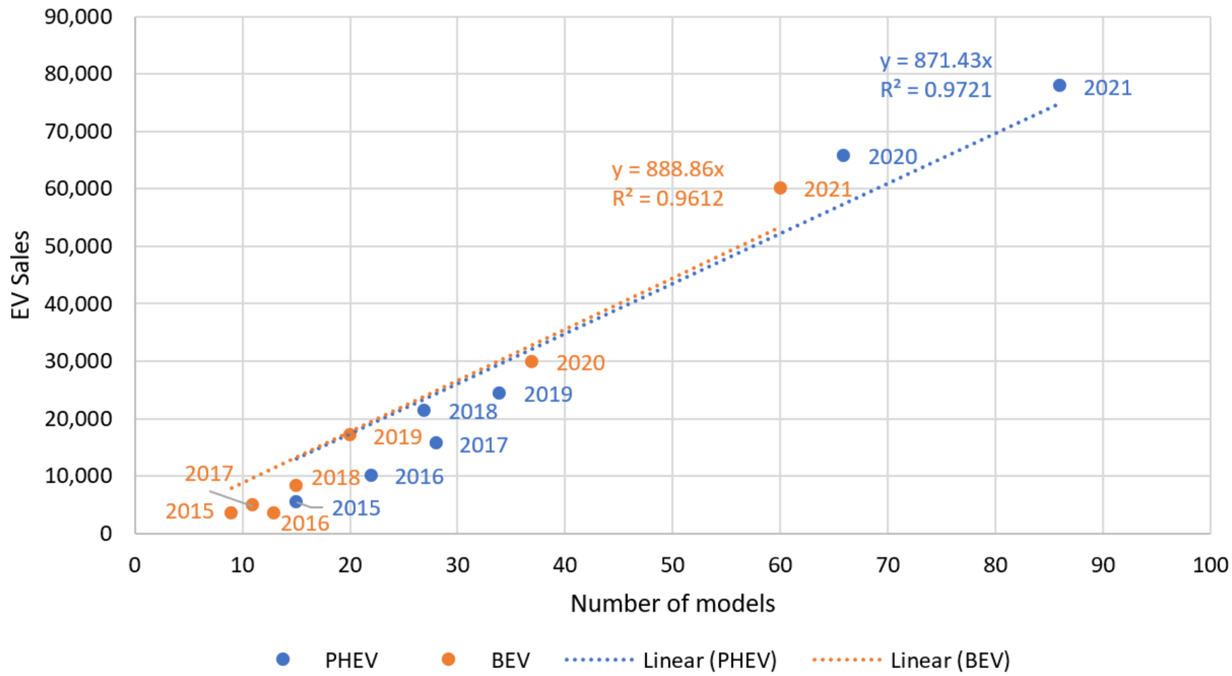

Figure 17. EV sales vs. model availability sensitivity in Sweden, 2015 to 2021.

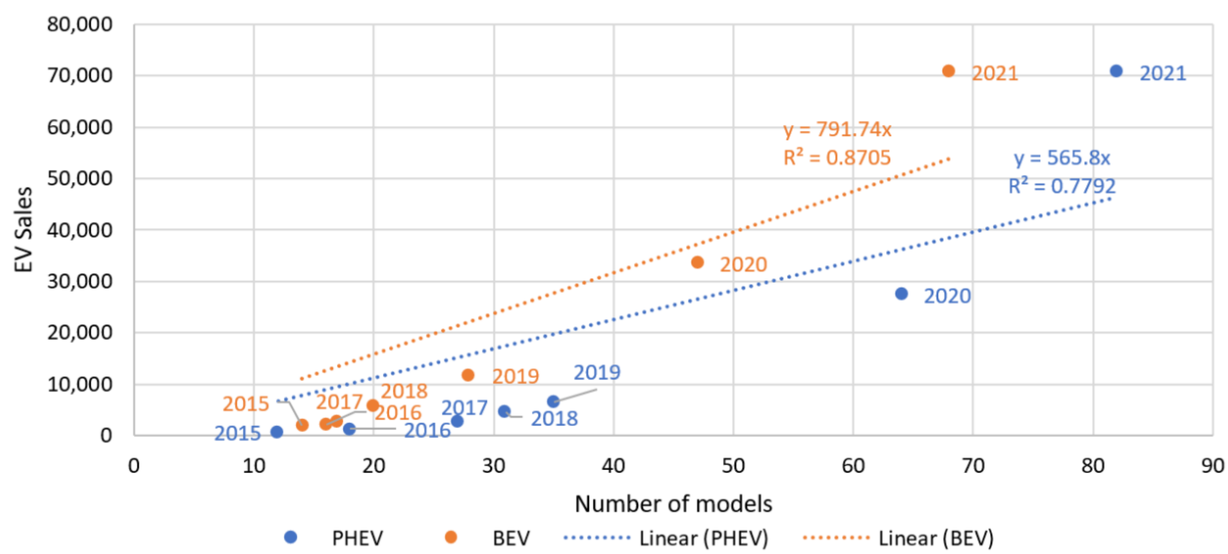

Figure 18. EV sales vs. model availability sensitivity in Italy, 2015 to 2021.

Vehicle registrations

To understand the distribution of vehicle registrations in the context of the feebate mechanisms, this section analyzes vehicle registrations and parameters for the year 2020 (European Environment Agency, 2023). We considered emissions cycle estimates from NEDC for this analysis, as not all reporting had transitioned to WLTP in 2020. Based on the EU emission target in 2020, we considered three emission classes: 0-95 gCO_2/km, 96-130 gCO_2/km, and greater than 130 gCO_2/km (Table 7).

Table 7. Country-wise vehicle parameters by emissions class for the year 2020.

Country	Avg. CO_2 (NEDC)	% of total registrations	Avg. WLTP	Avg. Mass (kg.)	Avg. Engine Capacity (cm^3)
France	0-95	28%	75.8	1,398	1,481
	96-130	66%	135.3	1,315	1,330
	> 130	6%	175.9	1,678	1,935
Germany	0-95	19%	45.6	1,629	1,632
	96-130	50%	137.8	1,367	1,452
	> 130	31%	188.9	1,749	2,123
Sweden	0-95	40%	42.8	1,799	1,775
	96-130	35%	139.2	1,415	1,475
	> 130	26%	180.7	1,759	2,018
UK	0-95	21%	64.0	1,566	1,498
	96-130	53%	137.3	1,354	1,367
	> 130	26%	187.0	1,776	2,068
Italy	0-95	23%	102.3	1,239	1,298
	96-130	63%	135.2	1,315	1,351
	> 130	14%	179.7	1,695	1,904

Sweden has the highest share of vehicle registrations in the 0-95 gCO_2/km NEDC range, which translates to an average of 43 gCO_2/km (WLTP), which is in line with the dominant PHEV sales. In this segment, Sweden has the highest average mass per vehicle (1,800 kg) and average engine capacity (1,775 cm^3), indicating the dominance of gasoline-electric hybrids. The Swedish CO_2 tax is low compared to the rebates being offered (Figure 6), thus, it does not serve as a strong disincentive for larger cars.

In the case of France, the 96-130 gCO_2 range has 66% of the vehicle registrations in 2020, which has remained relatively the same when compared to the 2015 data at NEDC test levels. In this segment, while the average vehicle mass has increased by about 2% between 2015 and 2020, the average engine capacity has declined by about 6.5%. The average WLTP emission value for over two-thirds of the vehicles registered in France is 135 gCO_2/km, which is near the low end of the malus (132 gCO_2/km).

Italy has a similar distribution as France, with two-thirds of the registration in the 96-130 gCO_2/km category and having similar average WLTP emission values. To incentivize a ZEV transition, **Italy would likely need to adopt a policy similar to France's, re-calibrate its malus curve to be more stringent,** and include more vehicles within its scope.

The UK, Germany, and Sweden have almost one-third of vehicle registrations in the highest emissions bracket. These countries could likely have a significant impact on EV adoption if

they were to raise emission-based taxes sufficiently for all vehicles with emissions above at least 180 gCO_2/km (WLTP), and then gradually increase the fee rate for all vehicles. Germany has the highest weighted average engine displacement, and it will be interesting to see how engine displacement-based taxation, in addition to the CO_2 tax, will play a role in consumer choices.

Emissions

Average CO_2 emissions of new passenger cars declined between 2010 to 2019 in France as EV sales increased (Figure 19). The early benefits of increasing EV sales are a rapid decline in average emissions, but average emissions increase between 2016 to 2018. This was likely a consequence of the feebate policy revisions not being aligned to the overall EU CO_2 regulations.

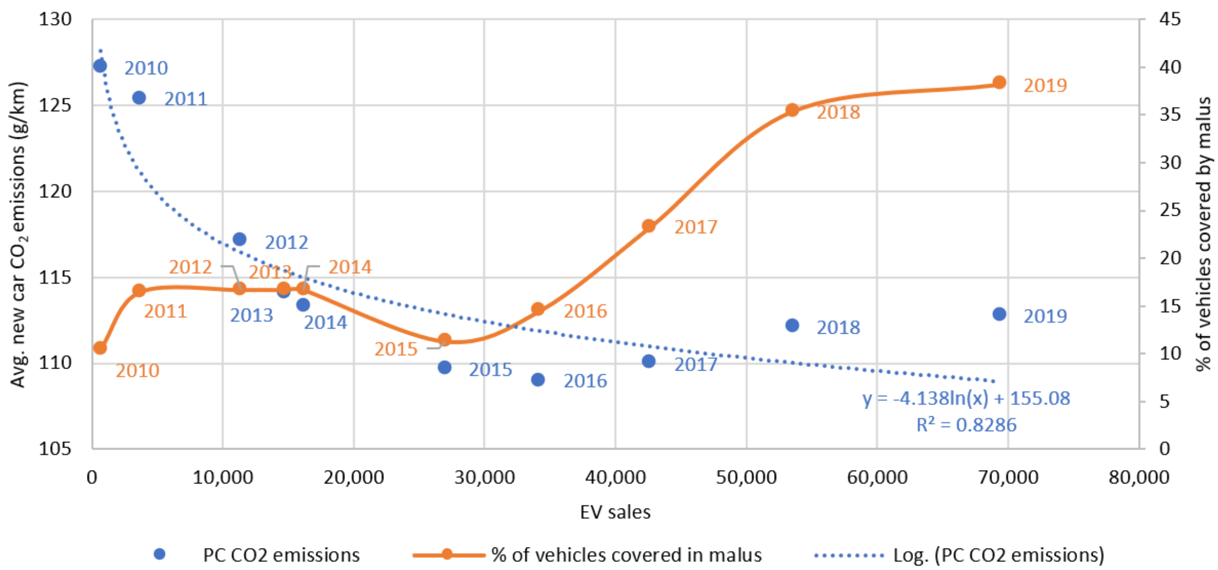

Figure 19. EV sales by average new car CO_2 emissions and malus applicability in France, 2010 to 2021. A logarithmic curve fitted with R-squared values highlights trends. CO_2 emissions are g/km (NEDC).

Sweden and Germany are the only two countries that have most registrations within the coverage of the emission fee (Figure 20 through Figure 23). In the UK, the slope of the fee curve becomes much steeper after the 150 gCO_2/km threshold, covering over two-thirds of the registrations below that. In Italy, the malus curve only covered 13% of vehicle registrations in 2020.

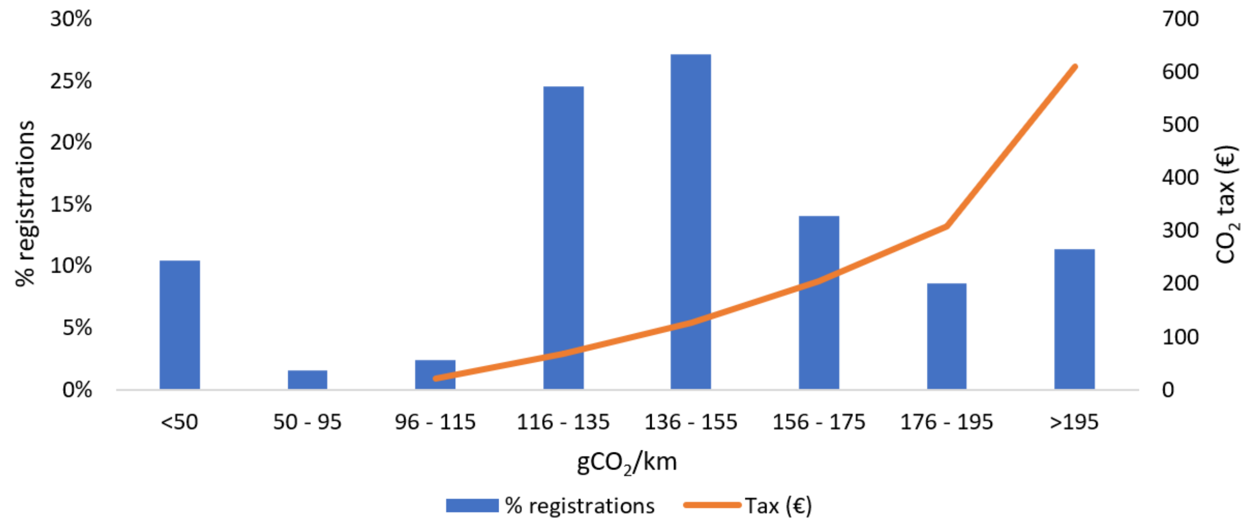

Figure 20. Share of vehicle registrations by emissions categories in Germany in 2020. Emission classes are defined by the country's emission tax regulation. The secondary axis plots the emission tax for the mid-point in each emission class with eh highest emission class measured up to 300 g/CO_2/km.

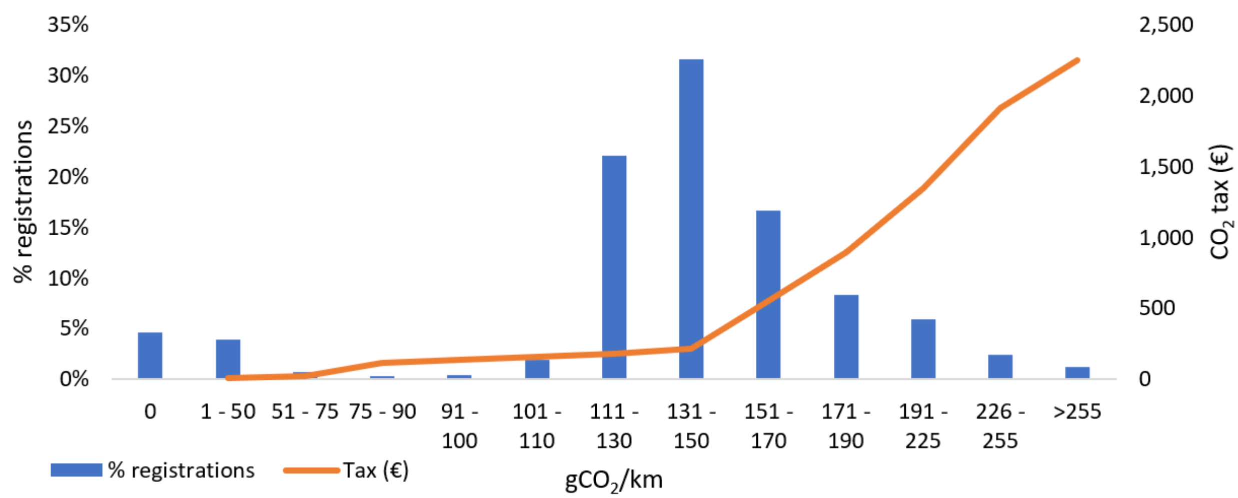

Figure 21. Share of vehicle registrations by emission categories in the UK in 2020.

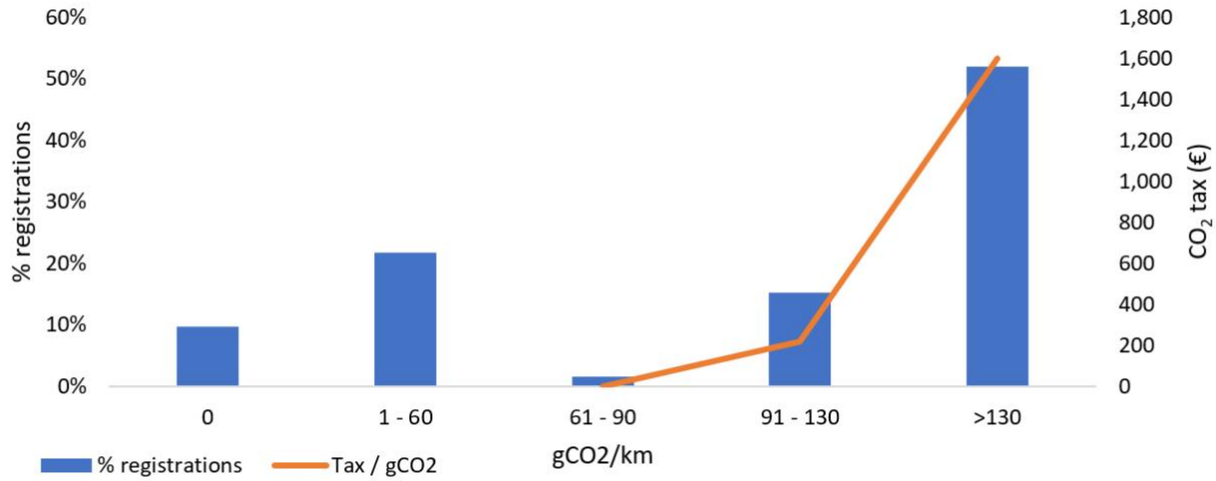

Figure 22. Share of vehicle registrations by emission categories in Sweden in 2020.

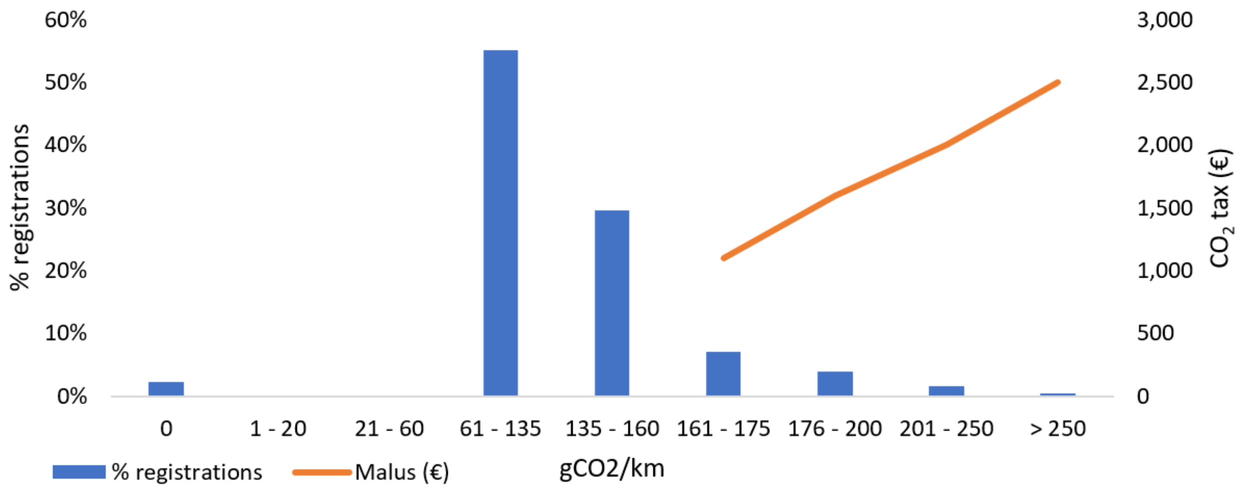

Figure 23. Share of vehicle registrations by emission categories in Italy in 2020.

Other Considerations in Designing a Feebate System

The above analysis informs two other important aspects of a feebate mechanism: consumer preferences and revenue neutrality.

Preserving consumer preferences

Policymakers can design feebate mechanisms to preserve consumer choice by imposing a fee and rebate within a range of vehicle sizes and types preferred by car buyers in any given market. If there is a fuel efficiency standard with multiple vehicle types, a feebate can have separate functions for each vehicle type (Gillingham, 2013). However, a feebate system that treats all vehicles equitably, without any attribute adjustments across categories would be ideal (German & Meszler, 2010). Challenges of a size-neutral design would most likely include differential impacts on automakers based on vehicle portfolios, although studies find that feebates can lead to enhanced manufacturer revenues, given the higher value-add for new-technology vehicles (Changzheng et al., 2012; Greene et al., 2005; Liu et al., 2011).

In 2007, the French government underestimated the response to the feebate scheme. The demand for smaller and more fuel-efficient cars and, subsequently, EVs rose rapidly in the early years of bonus-malus. While the fees were increased over years, the bonus eligibility included a price-cap on EVs (as in most countries), thus, in part, pressuring automakers towards production of mid-sized, cost-effective EVs for consumers. Given the urgency for a shift to EVs, it was imperative that the slope of the fee line be adjusted to accelerate EV adoption. EV sales saw a significant increase in France from a 3.1% share in 2019 to 15.4% in 2021. During this time, they also extended the 2020 purchase bonus to 2021 instead of phasing it down, keeping demand robust during the pandemic.

European consumer preferences for vehicle segments[4] across passenger cars and SUVs have varied since 2015 (Figure 24 and Figure 25). There is a general shift to D-segment EVs in most countries, except Italy, where there is a clear shift to A-segment EVs. Similar trends in SUVs are emerging with (1) all countries moving to C-segment EVs, (2) with France, Germany and Italy moving upwards in size, (3) and Sweden and the UK moving downwards in size. Overall, in case of EVs, transitions in France and Germany are similar and so are Sweden and the UK.

Comparing the EV consumer choice trends to overall LDV sales in these countries, a similar trend is seen, wherein LDV sales have essentially been dominated by C-segment in most countries. Germany, Sweden, and the UK are all dominant C-segment markets for LDV sales, while Italy and France are dominant B-segment markets (Figure 26).

Two key insights evolve: (1) between 2015 and 2021, all five countries have seen an overall convergence to C-segment EVs being the dominant share and, (2) consumers are tending to preserve their choices in case of EV purchases as well. In the early years of the EV transition, consumer choices were likely constrained by model availability and affordability

[4] The European Commission classifies cars as follows: (A) mini cars, (B) small cars, (C) medium cars, (D) large cars, (E) executive cars, (F) luxury cars, (J) sport utility cars, (M) multipurpose cars, and (S) sport coupés (UAFO 2024). For this analysis, MPVs are included within the SUV segment.

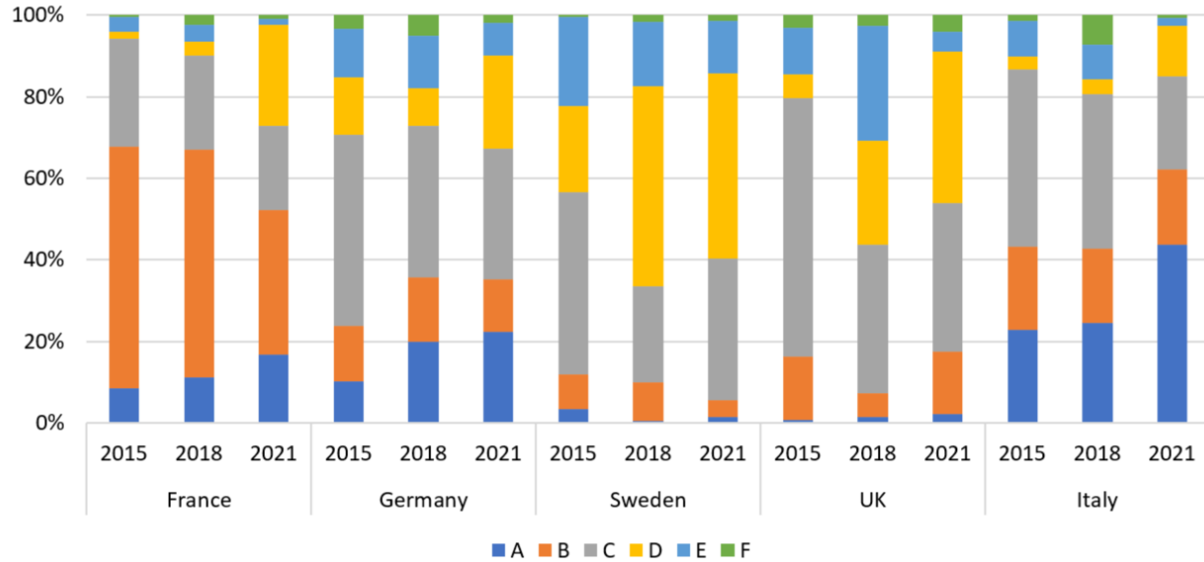

Figure 24. Share of EV car sales by segment size.

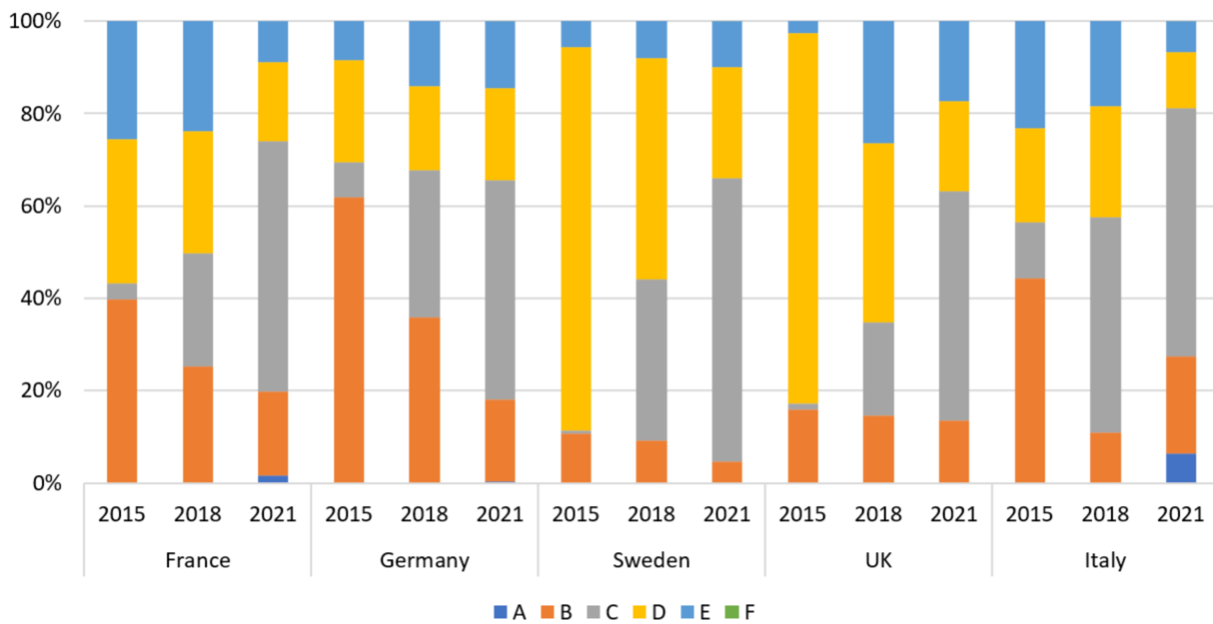

Figure 25. Share of EV SUV and MPV sales by segment size to understand trends in an increasingly popular vehicle segment of consumer choice.

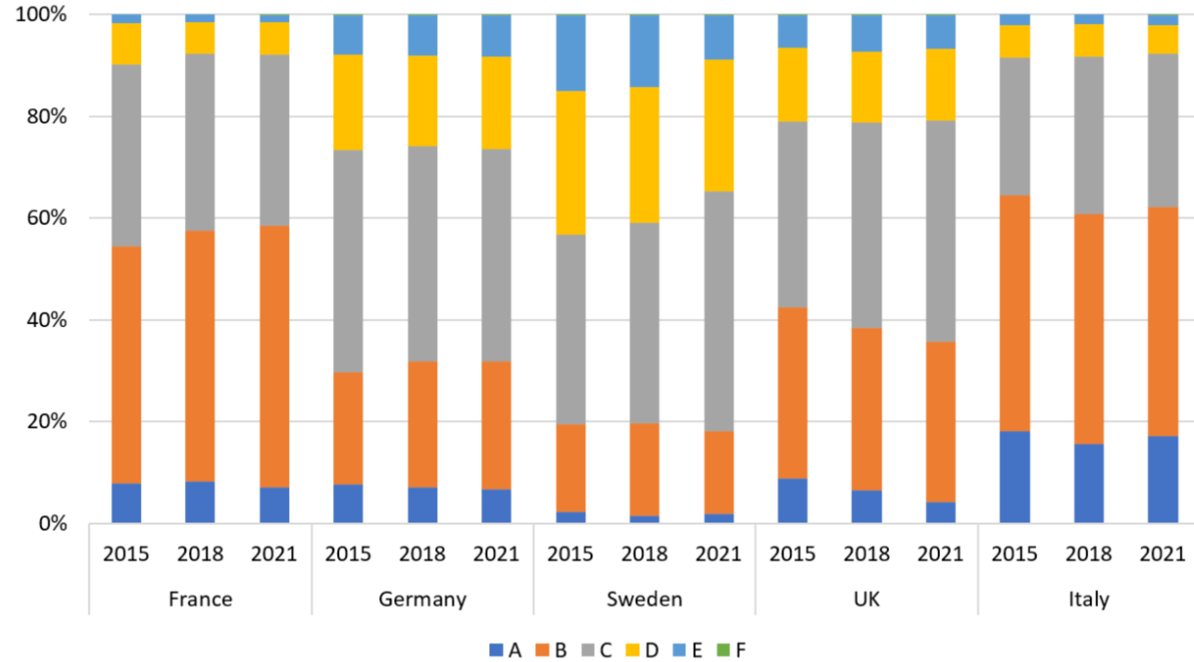

Figure 26. Transition of predominant vehicle segment choices for total LDV sales, 2015 to 2021.

Political acceptability and revenue-neutrality

In the US, a feebate for clean vehicles would almost instantly redistribute the tax revenue gained from higher emitting vehicles to reward consumers purchasing efficient or low emission vehicles. This is a meaningful alternative to general tax revenue, which is often appropriated in congressional or legislative approved budgets. Given its potentially redistributive nature, a feebate need not be seen as a tax, but rather a carbon dividend to society (Ramseur & Leggett, 2019). Feebates can also have strong public support if they are deemed to be fair, which is where the lessons for an effective feebate design play a critical role (Martin et al., 2014).

Another important feature of feebates is revenue-neutrality. They can be designed such that fees levied can be equal to or greater than the rebates offered, plus administrative costs. From a fiscal perspective, this has worked for France and Sweden. It took France a few years to forecast and manage the feebate to balance the flow of revenues. France has achieved surplus revenue each year since 2014. In Sweden, the government expected a surplus of SEK 0.43 billion (~€42 million) in 2018, SEK 0.09 billion (~€9 million) in 2019, and SEK 0.58 billion (~€56 million) in 2020 (European Commission, 2024). In Germany, given the hybrid nature of the policy, it is yet to be analyzed how much of the revenue collection will help co-finance the EV rebates. As per the German government, €2.09 billion have been earmarked from 2020 onwards to fund the EV rebates program through at least 2025 (Germany, 2023). In Italy, the government allocated €60 million for 2019 and €70 million for 2020 and 2021 for rebates towards BEVs and PHEVs. However, given that the Italian bonus-malus scheme was launched in 2019, the revenue flows are not yet available.

Ensuring equity to minimize the distributional impacts of the feebate

It will be critical to make EVs more affordable to all middle- and lower-income consumers while ensuring equity. For example, by minimizing any adverse short-term impacts of ICE vehicle fees to achieve a scaled and effective ZEV transition for people at all income levels. Various countries have made efforts to address aspects of equity, by way of additional rebates for EV purchases by low-income households, used-EV schemes, or vehicle trade-in programs (European Automobile Manufacturers' Association, 2021, 2022).

For 2021, France provided a maximum combined rebate of € 12,000 for the purchase of used or new BEVs and PHEVs for scrapping an older ICE vehicle subject to household income. They also have a bonus of €1,000 if an individual lives or works in a low emission zone. The low-income rebate conditionality also distinguishes between vehicle buyers as 'average commuters' or 'heavy drivers,' based on their home-to-work commute distance. In Italy, the bonus-malus scheme includes a provision for low-income households who purchase new EVs with a power of less than 150kW and a list price less than €30,000 (excluding VAT).

Germany does not have a specific low-income grant for purchase of EVs but provides incentives on purchase of used EVs, although, the second-hand EV should not have received any federal rebate on original purchase. This could be a potential barrier for low-income households to access EVs and could be amended to ensure that a new EV sold with a rebate cannot be resold for at least 2 years from the date of original purchase.

The UK illustrates potential equity impacts arising out of changes to the feebate design. While it increased the CO_2 based taxation in 2020, the UK reduced the EV purchase rebate, with no safeguards for low-income vehicle buyers.

It will be imperative that policies are designed in a manner that helps shift middle- and higher-income households to EVs while still addressing issues around range anxiety and reliable infrastructure.

Key Insights and Considerations of Feebate Design for a ZEV Transition

As seen in earlier sections, various EU countries continue to use feebates as an effective policy tool to achieve transitions towards low and zero emission vehicles. Feebate mechanism impacts in each country provide important insights into the larger goal of achieving of a ZEV transition.

While there are key elements of a feebate mechanism that should be considered while designing it for implementation, there is no one single or 'optimal' design. Different policy objectives can be served by a feebate mechanism. These objectives would influence its design and effectiveness. This section highlights policy objectives that feebates can play a role in achieving and discusses conditions under which feebates would work.

A fundamental policy objective is to shift consumers to purchasing more fuel-efficient ICE vehicles. For example, in Italy, the government imposed a fee on less than 15% of the vehicles sold among the highest emission classes. The possible reasons for this policy design include protecting Italy's domestic automotive industry balanced with a commitment to climate action.

Using feebates to facilitate a shift to EVs is a more recent strategy. Feebates can be amended over time to meet differing policy goals, as in the case of France and Germany. France's initial objective was to shift the market to more fuel-efficient ICE vehicles and, over time, the feebate design has been revised to facilitate a shift to EVs. A more constrained version of the policy objective would be to use feebates to shift to ZEVs only.

At a global level, using feebates to shift to more fuel-efficient vehicles could be well-placed in countries—especially developing economies—where leapfrogging to EV technology is challenging. Countries, like India, which have not set national EV targets, could benefit from a feebate mechanism designed to meet the ZEV transition objective. Moreover, the financial sustainability of stand-alone EV incentive programs has come into question, and thus, a self-financing market mechanism could be the 'need of the hour' solution.

Irrespective of the policy goals, a feebate will impact both the supply and demand side because an ICE vehicle becomes cost-prohibitive for sale from an industry viewpoint and/or purchase from a consumer viewpoint. In accordance with the feebate design, the industry will shift its strategy towards more policy-compliant vehicles. This is likely to increase EV model availability and bring down technology costs. With the fee effectively imposed on consumers, it creates an equilibrium in the market by recalibrating supply and demand objectives. Feebates could also be used to address policy goals such as curtailing the sales of certain kinds of vehicles, for example, very large SUVs.

Based on feebate mechanisms in major European countries as presented in this paper, **twelve key insights are offered on how to design feebate policy that can facilitate an inclusive ZEV transition in the next decade** (Figure 27).

1. **Pure feebates, where fee revenue funds EV incentives, provide certainty.** A clear mandate for funds allocation provides certainty for manufacturers and consumers in the market and flexibility for the government in budgeting.
2. **Identify the distribution of vehicles sold by emissions (gCO_2/km).** To decide the fee schedule, functional form, and pivot point, it is important to first understand average prices and vehicle type (SUVs or cars) across different emission classes. A further optional step can be to better understand household income levels and prices of vehicles purchased.
3. **The choice of having a single pivot point or a donut-hole should be based on an analysis of the type of vehicles being sold in the market.** A percentile approach based on vehicle prices and/or emissions is possible. This will define which of the vehicles being sold in the market will be taxed, receive a rebate, or be excluded from the feebate mechanism with a donut-hole. The pivot point is chosen based on prevailing fuel efficiency norms.

4. **Focus on a single fee parameter such as CO_2 emissions can be a simple yet effective mechanism.** A CO_2 emissions-based fee mechanism should form the basis of vehicle taxes. It provides manufacturers with flexibility to adjust other attributes as long as emissions reduction targets are met. Having a single parameter, i.e., CO_2 emissions can be efficient and easy to interpret, monitor, and implement. Where introducing emission taxes can be a challenge, there may be a case for attribute-based taxation as an alternative. However, it may still not lead to a transition to EVs, and even less so for ZEVs, as attribute-based taxation may not serve as a strong hedonic pricing mechanism for emissions externalities. Vehicle attributes increasingly have non-linear relationships to vehicle emissions.

   Reducing CO_2 emissions from the electricity grid will be increasingly important, beyond tailpipe emissions, and ensuring efficiency for EVs will be part of the solution. A well-calibrated feebate mechanism can continue to generate revenue, even with high EV adoption.

5. **A continuous functional form for the fee and a stepwise rebate are likely to be most effective in driving EV adoption.** A continuous fee function—preferably a non-linear fee function with a steep rise in fees for higher emission values—for every increase in CO_2 emissions (g/km), rather than a step function, provides the best way to avoid system-gaming. A piece-wise linear fee function can be designed to generate sufficient revenues by imposing the highest tax burden on high-emission vehicle buyers as compared to the middle 50th percentile of vehicle buyers. Further, in case of rebates, a stepwise function can be structured to incentivize PHEVs with higher all-electric range requirements in the interim and target greater rebates towards ZEVs.

6. **Periodic revisions in the slope of the curve and the pivot point can help ensure a revenue-neutral system.** Providing a clear horizon on the functional form for the fee gives positive market signals, as seen in France. A shorter frequency of feebate design revisions (e.g., every 2 to 3 years) are likely to result in more favorable policy outcomes. Longer revision periods may lead to either under- or over-estimating the potential for technology and market developments.

7. **The feebate design needs to be supported by external policy choices.** Ancillary policies such as vehicle price caps for incentive eligibility for EV purchases and all-electric range requirements for PHEVs will make feebates more effective. Overall, as a basic principle, rebates need to decrease over time while the fees increase, forcing automotive manufacturers and consumers to reconsider their choices.

8. **Feebate policy parameters can be adjusted to drive a transition towards BEVs.** BEV sales indicate a higher growth sensitivity than PHEVs for every additional model made available in the market. Model availability could provide a basis for future feebate design focused on a ZEV transition. The pivot point, fees, and external policy variables such as all-electric range requirements for PHEVs can be adjusted to preferentially drive the market towards BEVs.

9. **The differences in the point of collection of the emissions-based fee for the consumer will likely play a key role in the transition to ZEVs.** A higher one-time fee collected at point-of-purchase is expected to be more effective than an annual fee, given consumer discounting of future cash flows, and fee timing could well make the difference between a consumer choosing an ICE or electric vehicle. Similarly, applying rebates at point-of-sale are likely to be more effective than income tax rebates or staggered incentive payments. Direct monetary benefits at the point-of-purchase have a stronger influence on consumer choice than annual tax refunds.
10. **Feebates can be designed to shift consumer preferences towards more efficient EVs.** Current feebate policies do not necessarily constrain consumer preferences for vehicle segment types, such as SUVs or mid-sized cars. Between 2015 and 2021, all five countries analyzed in this paper see an overall convergence to C-segment EVs, similar to ICE vehicle choices. Fee parameters can incorporate additional criteria related to vehicle footprint.
11. **Equity considerations for those in low-income groups and other disadvantaged communities will be critical in ensuring a mass transition to EVs, as well as distribution of benefits across society.** Support can be offered through used-EV schemes and vehicle trade-in programs, for example. Low-income and disadvantaged communities can be supported to transition to PHEVs before a move to BEVs, given constraints of access to charging infrastructure.
12. **It is important to have a robust monitoring framework so that feebates can be calibrated on a periodic basis to achieve intended policy objectives.** It is essential to maintain a holistic database of vehicle sales, pricing, emissions portfolio, and so on, to facilitate a periodic revision of the feebate mechanism so that it is self-sustaining. Forecasting responses to feebates has been challenging given the lack of literature on relevant elasticities (Berthold, 2019).

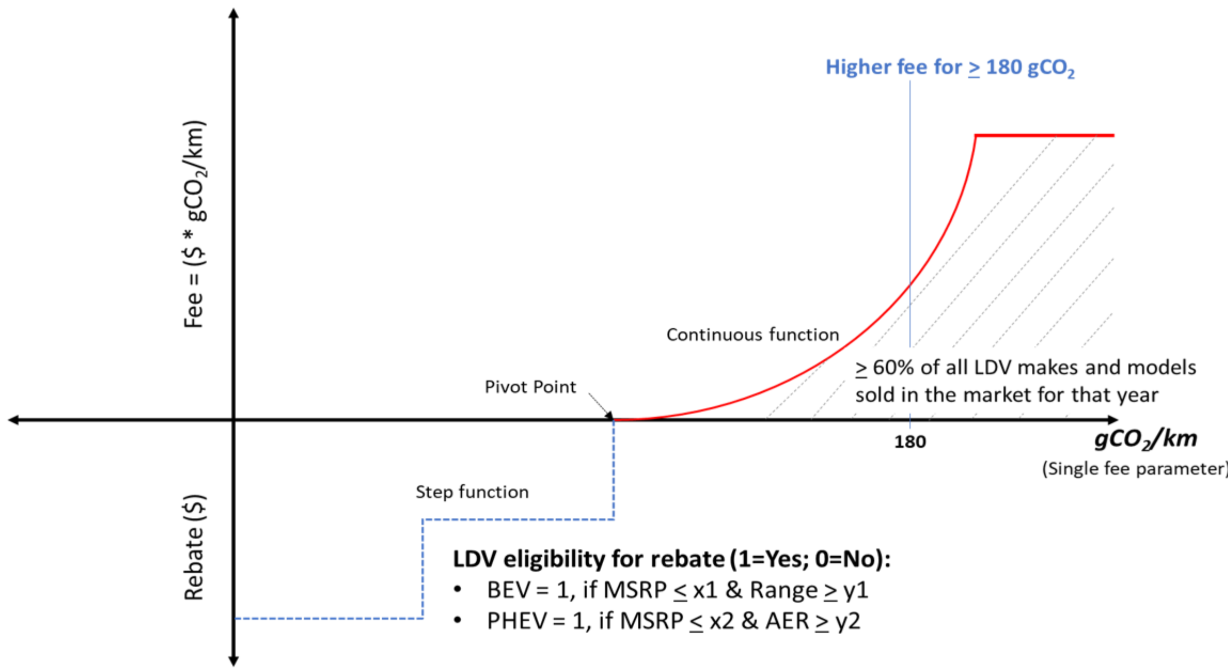

Figure 27. Key elements of a feebate mechanism supporting an inclusive EV transition.

Conclusions

Effectively, to achieve a ZEV transition, countries will have to re-align their feebate mechanisms in a manner that targets most ICE vehicles sold, while keeping in mind equity considerations for those in low-income groups and other disadvantaged communities. A ZEV transition will likely happen in phases, with a mix of PHEV and BEV sales as in present conditions followed by a shift to only BEV and other ZEV technologies.

With the growing urgency for a ZEV transition, the fiscal pressure for many countries can be significantly higher, given potentially long-term rebate requirements to sustain the transition and higher technology costs for alternate ZEV technologies. The feebate mechanism is a good approach to raise the necessary capital for financing a ZEV transition in combination with other regulatory mechanisms. Feebates can play a critical role in pushing manufacturers towards investing in ZEVs, thus bridging the gap between TCO and price parity between EVs and ICE vehicles.

Feebate design can be revenue-neutral or revenue-positive. The latter offers opportunities to utilize the additional funds to achieve even more. For example, surplus funds could be spent on public charging infrastructure or subsidies for public transit or other active travel modes.

Feebates are redistributive in nature and adhere to the fundamental principle of taxation, which is to create a public good to the best extent possible. Namely, a tax on higher polluting vehicles can fund rebates targeted towards assisting middle and low-income households for EV purchases.

Feebates need not be used in perpetuity. Once price parity between EVs and ICE vehicles is achieved as the feebate pushes EV sales volumes to a critical mass by impacting consumer choices and manufacturer strategies, the rebate burden will decline significantly. At this point, rebates can be limited to low-income households to support equity objectives and a complete transition.

In the future, innovations in feebate design can be adopted to meet specific transportation goals. In a high-EV scenario, feebates could be adapted to target VMT (Greene, 2011; Musti & Kockelman, 2011; Paz et al., 2014; Zhang et al., 2009). At the same time, VMT-based feebates could have equity considerations as lower income households tend to travel longer distances out of compulsion and not voluntarily.

Future analysis could include: (i) an econometric evaluation to estimate the effect of feebates on EV sales compared to other vehicle parameters and market conditions and, (ii) evaluating a feebate designs to facilitate an EV transition in other leading automotive markets such as the US or India.

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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.