Electric Cars: Calculating the Total Cost of Ownership for Consumers

***Final report** for BEUC (The European Consumer Organisation)*

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Executive Summary

Reducing passenger car CO_2 emissions is a fundamental part of achieving the EU's climate ambitions, including reaching net zero by 2050. Despite recent growth in zero emission vehicle sales, real-world reductions of car emissions have stalled since 2015, raising the question of whether stronger manufacturer CO_2 targets for 2025 and 2030 are required to meet the EU's climate goals[1]. The Total Cost of Ownership (TCO) of different powertrains are an important part of this discussion and will determine how consumers can benefit from, and the ways policy should support, the decarbonisation transition.

This report forecasts the costs and efficiencies of petrol & diesel internal combustion engine (ICE) and full hybrid vehicles, as well as low & zero emission powertrains, such as plug-in hybrids (PHEVs), battery electric vehicles (BEVs) and H2 fuel cells (FCVs)[2]. The TCOs for different powertrains are calculated for first, second and third owners for vehicles bought new between 2020-30.

The structure of this report is based around 5 key themes that have emerged from our analysis:

- Affordable BEVs are just around the corner
- BEVs bring most benefits to second and third owners
- Maximising the opportunities for BEV uptake
- Mitigating the risks to BEV uptake
- The importance of European CO_2 emission standards and national supportive schemes

Affordable BEVs are just around the corner

At an EU level, which excludes purchase subsidies and tax incentives, BEVs are already the cheapest powertrain on a lifetime TCO basis for medium cars bought today, which is illustrated in Figure 1, and will become cheapest for small and large cars in 2024 and 2026 respectively. This means that with suitable financing schemes available to consumers, medium BEVs can provide financial savings from day 1. While lifetime TCO may not dictate the overall mix of vehicles bought in a market, it shows the long-term cost optimal solution for consumers.

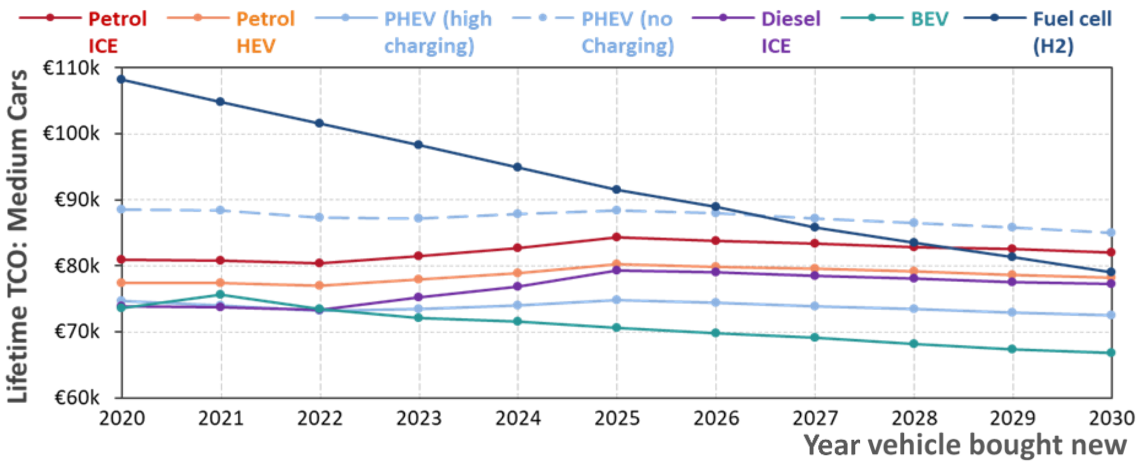

Figure 1: Lifetime TCO comparison between different powertrains for a medium car. Note that the year indicates when the car is first bought new.

A significant barrier to BEV market growth is high upfront purchase prices driving greater depreciation costs for first owners. This is especially important as first owners determine the market stock mix and

[1] ICCT 2021 pocketbook http://eupocketbook.org/

[2] LPG and CNG have been excluded due to low market share, very limited growth potential & OEM investment and because they achieve minimal emission reductions.

therefore the vehicles available for eventual used car buyers. BEVs do not become the cheapest powertrain for first owners for small and medium cars until 2025 and large cars in 2026, and should be supported, in the short term, by government upfront purchase subsidies and tax incentives.

BEV supply has become increasingly less constrained, with manufacturers representing over 30% of 2019 EU sales having announced plans for a fully electrified model line-up by 2030[3], and additionally VW Group[4] and BMW[5] are forecasting 60% and 50% BEVs in 2030 respectively, with VW group abandoning development of new combustion engines[6]. In 2020, Volkswagen was the market leader in terms of BEV sales, driving significant category growth through the new ID.3, with major brands including Mercedes and Opel gaining share by launching BEV models (see Appendix 6.1). The introduction of mainstream, lower specification models continues to drive down costs for consumers, which will be key to realising the TCO savings projected, for example, for medium cars in Figure 1.

BEVs bring most benefits to second and third owners

BEVs offer better financial value to used car buyers than any other powertrain. A medium BEV bought new today will save a total of almost €9,000 for its second & third owners over a Petrol ICE, which is illustrated in Figure 2. Improvements to local air quality in urban areas, due to consumers switching to BEVs, typically most benefits the least affluent consumers. Few used car owners currently benefit from the financial savings discussed, due to limited availability of BEVs in the used car market. Tightening emission standards and encouraging OEMs to sell more BEVs, will increase the available stock of used BEVs.

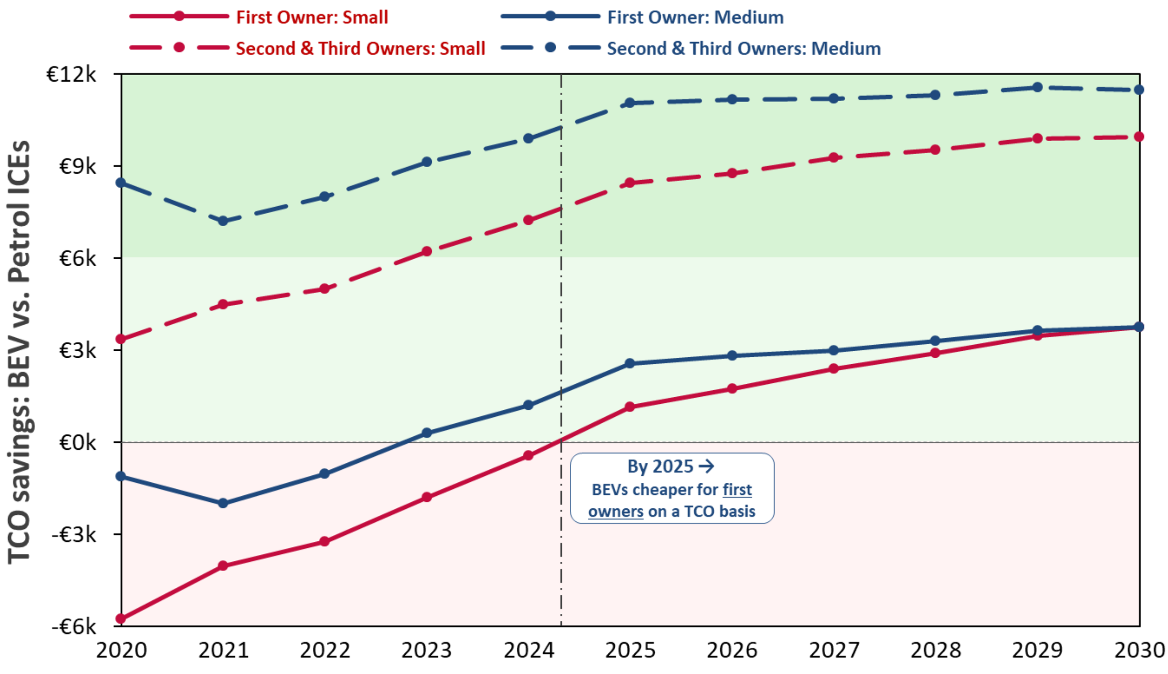

Figure 2: BEV TCO savings over a Petrol ICE for a medium car for first and used car owners

Figure 3, which presents cost savings vs. Petrol ICE and equity index (defined as first owner / lifetime TCO) for different powertrains, shows medium BEVs driving the highest market equity as the first owner, who is most able to afford it, pays a higher proportion of the lifetime TCO. While purchase subsidies benefit first owners, even with an upfront subsidy of €7,000, a medium BEV would still drive greater market equity over its lifetime than a Petrol ICE due to the lower running costs offered to second and

[3] 30% fully-electrified (including PHEVs and HEVs): PSA, Jaguar Land Rover, Ford, Volvo & Tesla
[4] www.just-auto.com/news/vw-group-platform-strategy-key-to-e-mobility-rollout_id200799.aspx
[5] www.cnbc.com/2021/03/17/bmw-has-no-plans-to-produce-its-own-electric-vehicle-batteries.html
[6] www.electrive.com/2021/03/22/vw-brand-joins-audi-in-ending-combustion-engine-development/

third owners. Annual tax breaks benefit all consumers, regardless of ownership period, and when BEVs are fully available in the used car market, tax incentives will actually increase market equity.

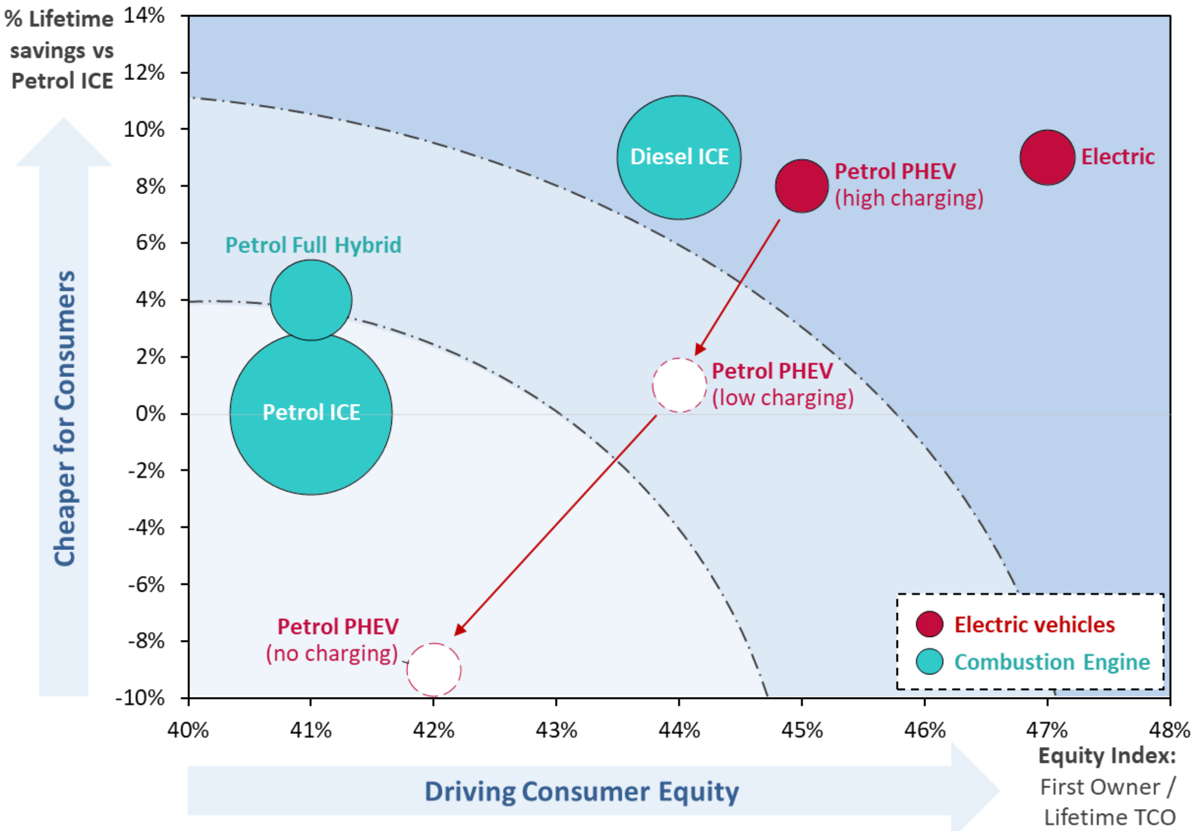

Figure 3: Market equity for medium cars bought new in 2020 (bubble size represents 2020 sales)

Maximising the Opportunities for BEV uptake

50% of total passenger car CO_2 emissions are produced by the 25% of consumers with the highest average annual mileages [7]. As BEVs provide the largest savings for high mileage users, there is a clear opportunity to maximise emission reductions while driving high TCO savings. Figure 4 summarises the year that BEVs for first owners, averaged over all car sizes, become cheaper than Petrol ICEs on a TCO basis for several of the sensitivities considered in this report. BEVs are already the cheaper option for first owner company car drivers (38,000km mileage) today, 4 years before the baseline scenario, and reduce carbon emissions by over x3 times that of an average consumer (average 12,000km annual mileage over car's lifetime) who switches to a BEV. Due to their shorter ownership periods, BEVs owned by high mileage first owners also offer an opportunity for a rapid uptake into the second and third hand markets, driving market equity and bringing savings for lower-income consumers.

Despite anxiety over BEV range still impacting consumer attitudes, range is no longer a "real" barrier to uptake, with an average WLTP range of 479km in 2021 for medium cars, and models with ranges that exceed 600km currently available. Entry of models such as the VW ID.3, with WLTP ranges up to 550km[8], into the mainstream market meet the requirements of high mileage consumers. Indeed, if the highest mileage consumers were the first to switch to BEVs, for a 60% BEV uptake scenario by 2030, a 75% reduction in new fleet emissions would be achieved by 2024, which is 4 years earlier than the

[7] Analysis based on mileage data from: Ricardo-AEA (2014): Improvements to the definition of lifetime mileage of light duty vehicles
[8] 77 kWh version: https://www.volkswagen.co.uk/electric/electric-cars/id3.html

baseline case. Investment in en-route rapid charging infrastructure is essential to maximising the number of high mileage users that switch to BEVs over the next five years.

Many European consumers have off-street parking and can potentially access cheaper off-peak electricity tariffs for charging. As illustrated in Figure 4, off-peak tariffs only have a secondary impact for first owners, where depreciation is the dominant cost component, however, for second and third owners, where running costs become more crucial, BEVs are cheaper by 2021 (car bought in the second-hand market in 2025), two years earlier than for consumers who use average domestic electricity tariffs. For consumers that rely exclusively on fast (11-22kW) or rapid (50kW) charging, representative of some city and sub-urban user groups without off-street parking, the year that BEVs become cheaper than Petrol ICEs is delayed by only one and two years later respectively than the baseline scenario.

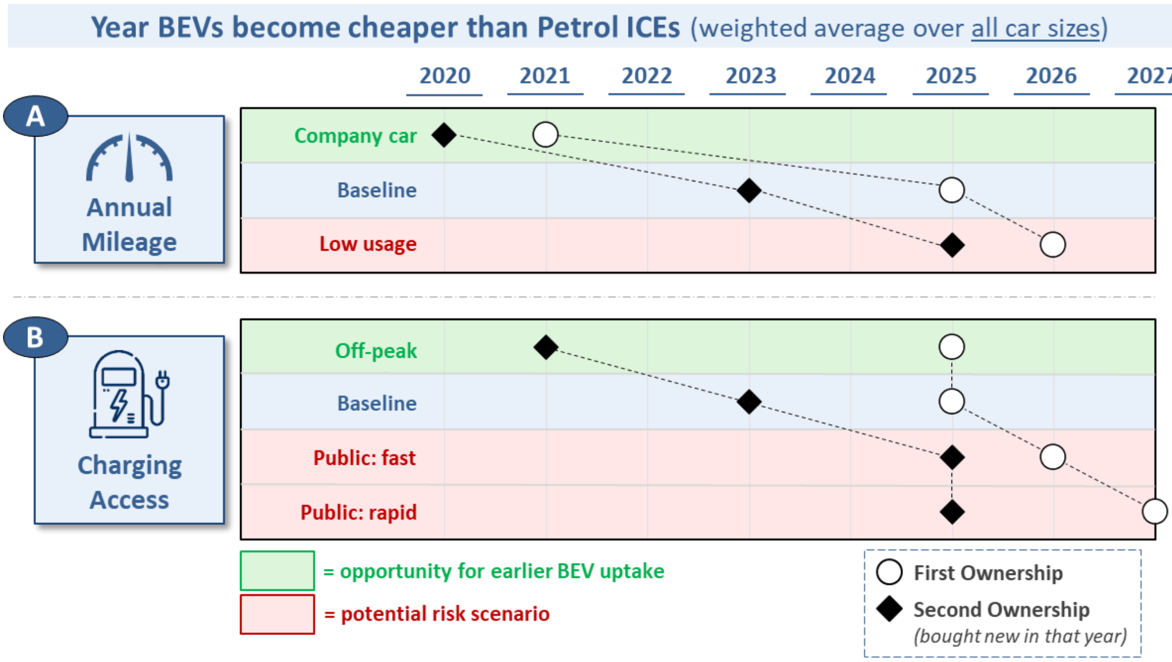

Figure 4: sensitivities showing when BEVs become cheaper than Petrol ICEs for first & second owners

One of the major advantages of BEVs over internal combustion engine vehicles (ICEVs)[9] is that they provide consumers with an additional flexibility to save cost by choosing a smaller battery with a lower maximum range. This allows consumers to find an optimum balance between convenience and cost, with a vehicle to meet their driving needs and priced accordingly.

Figure 5 shows the average number days per year a BEV driver will exceed WLTP range and require an additional en-route charge each year, across different battery size scenarios. Indeed, results show that almost 50% of consumers would be suited by a BEV with only a 200km range and would only need to use en-route charging up to 5 times per year. Consumers should think in terms of the cost savings per additional trip each year that they are likely to use en-route public charging. In 2021, an average medium car first owner with a 15,000km annual mileage could save €2,450 (excluding VAT) off the purchase cost by choosing a smaller 300km range battery and would only need to use en-route charging an additional 3 times per year (vs. 2021 average medium car with WLTP range of 479km). Investment into rapid charging infrastructure will allow consumers to trade down into smaller batteries, allowing significant cost savings and driving additional emission reductions from lower demand of battery raw materials.

[9] ICEVs include Petrol and Diesel ICEs, and HEVs

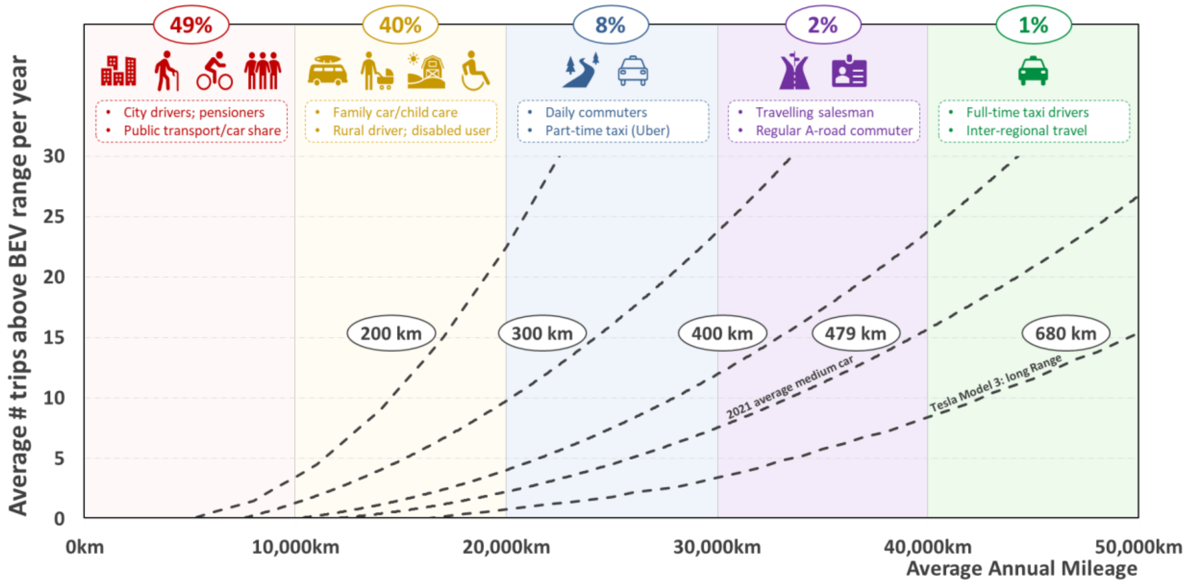

Figure 5: average number of days per year a BEV driver will exceed maximum WLTP range and require an additional en-route charge across different battery size scenarios. Bubbles at the top of the chart show the proportion of consumers in each mileage band.

Indeed, an average medium car first owner with a 15,000km annual mileage could save an additional €3,650 (excluding VAT) off the purchase cost by choosing a 200km battery (compared to the current medium BEV range of 479km). This makes the TCO of such a car competitive with its petrol equivalent today, a few years earlier than the TCO-parity baseline scenario for first owners. New models, such as the Dacia Spring (with a range of 200km WLTP), offer very competitive upfront costs and provide an opportunity for a mass market (which may include user groups such as city/suburban drivers, pensioners and household second cars) that buys smaller and cheaper vehicles but are still willing to buy new.

Mitigating the Risks to BEV Uptake

BEVs provide a clear path to maximise value for consumers and to reduce carbon emissions. Figure 6, which shows the financial cost & tailpipe CO_2 impact of buying a powertrain other than a BEV in 2025 against the likelihood of each powertrain to grow, summarises the varying risk profiles. Full Hybrids (HEVs) have a strong current growth trend, which has been exacerbated by misleading language such as “self-charging”, and risks locking in long-term high carbon emissions into the market stock. Consumers will be 14% financially worse off on a lifetime TCO basis for each medium HEV that enters the market in 2025 over a BEV.

Unless PHEVs are charged every day, they increase costs and emissions for consumers. This is particularly important as many PHEVs sales are driven by company car fleets for tax purposes, without granting access to home charging or a “charging card” to employees. The risk is even greater for second and third hand users which are less likely to have access to off-street parking, driving long-term market inequity. Indeed, for a medium PHEV bought in 2020, the lifetime TCO difference between high and no charging is almost €14,000. Under a low charging scenario, representing a consumer that uses weekly destination charging, consumers will only achieve around 50% CO_2 of the reductions compared to WLTP values, which are the official figures provided to consumers. Given that it is impossible to ensure that PHEVs will only ever be used by consumers that have adequate charging access and that, even in the most optimistic charging scenario, PHEVs offer increasingly worse value to BEVs, it is critical to consider PHEVs as a risk to consumers rather than a “stepping stone” to fully electric vehicles.

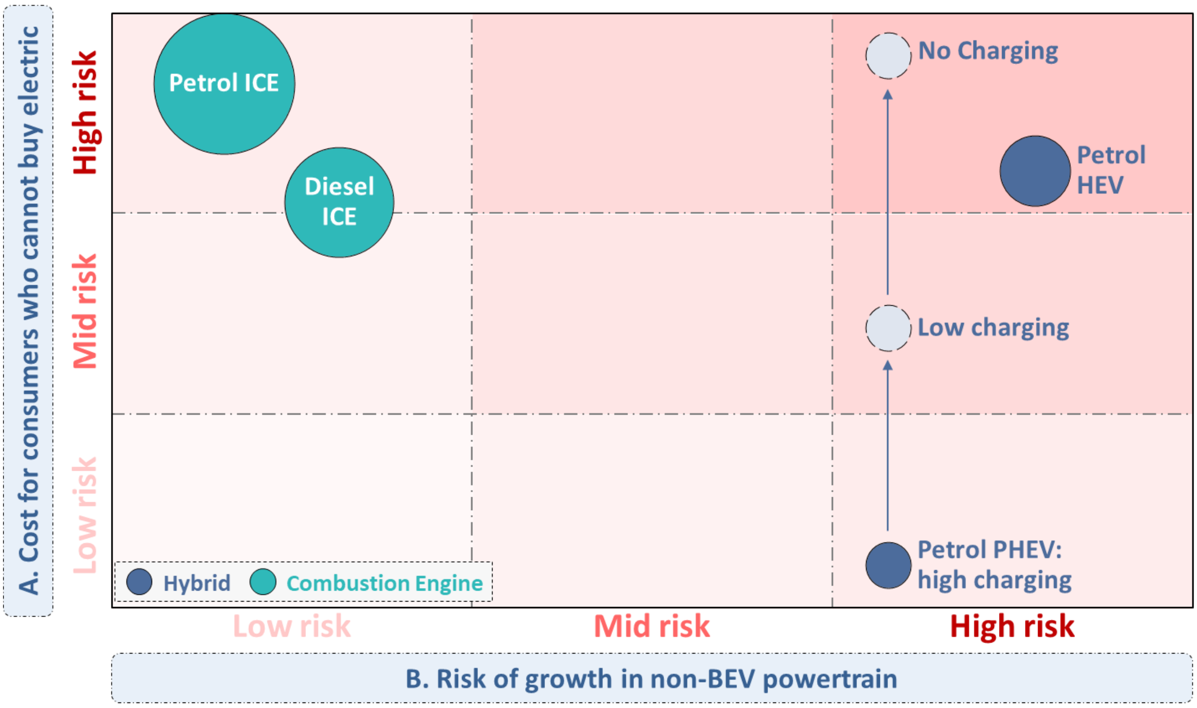

Figure 6: overall risk assessment of non-BEV powertrains in 2025 for a medium car. Bubble size represents current powertrain share of total European passenger car registrations

E-fuel[10] market entry would be financially detrimental for consumers. Even under optimistic projections (relying on Middle East solar PV for cheap production), E-fuels do not reach price parity to petrol until 2037 and currently consumers would need to pay premiums of over 80%. For medium cars bought anytime between 2020-30, BEVs will always cost consumers over 20% less than ICEVs running on E-fuels on a lifetime TCO basis. Any push for the use of E-fuels in passenger cars risks diverting investment (with significant subsidies required to bring E-fuels to mass market) away from improving charging infrastructure & accelerating BEV uptake, with no clear long-term benefits to consumers.

Euro 7 is essential to ensure air quality improvements in urban environments and reduce the harmful effects of pollution. To meet Euro 7 requirements, currently forecast to come into force between 2022-24, OEMs are expected to pass increased costs onto ICEV consumers, which brings forward when BEVs reach parity to ICEVs for first owners. Alongside the serious implications for air quality, delays to Euro 7 would mean that governments would need to continue to subsidise BEVs for several years longer to achieve the high growth necessary for decarbonisation.

The importance of European CO_2 emission standards and national supportive schemes

Analysis shows that for a European country in line with the EU average, purchase subsides could be phased out between 2022-26, with annual tax breaks no longer needed by 2030. Long-term subsidies risk OEMs focusing supply towards highly subsidised markets, being able to artificially maintain inflated pricing, while limiting BEV supply in European countries without subsidies. This shows the need for EU wide policy to ensure that BEVs become available for all European consumers.

TCOs for 9 specific European markets[11] were analysed within the scope of this project, with detailed findings to be published in 9 additional reports (country results include tax incentives and purchase subsidies). Significant variation is seen in terms of the TCO savings available to BEV first owners vs.

[10] E-fuels including carbon-neutral synthetic fuels made from renewable electricity that can power internal combustion engines (ICEs) without the environmental impact of traditional fossil fuels
[11] Belgium, Cyprus, France, Germany, Italy, Lithuania, Portugal, Slovenia, Spain

an equivalent Petrol ICE. Figure 7 shows an overview of the BEV share of new sales in 2020 against first owner TCO savings for BEVs vs. Petrol ICEs for a weighted average of small and medium cars.

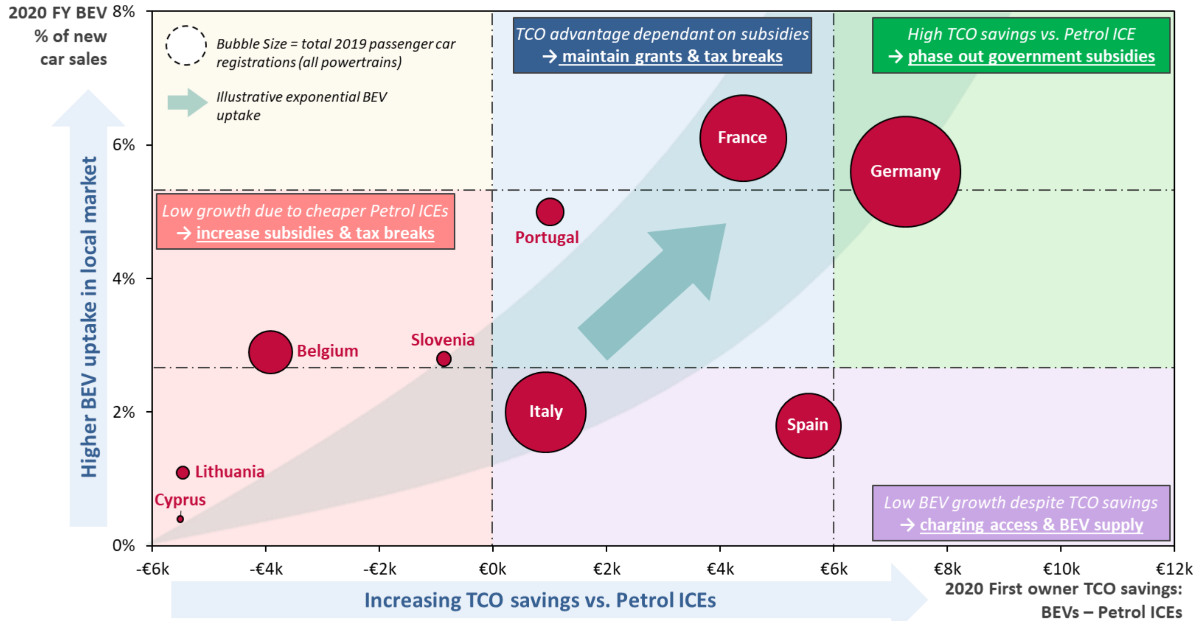

Figure 7: small & medium cars BEV % of 2020 market sales vs first owner Δ TCO to Petrol ICEs

Position on this landscape correlates with country specific strategies to accelerate BEV uptake. Located in the purple segment, there is strong evidence that limited access to off-street charging and expensive public electricity tariffs are already limiting BEV growth in some focus markets, such as Spain, emphasizing the need for immediate action to improve charging infrastructure. As lifetime costs are increasingly no longer a barrier to BEV uptake (which must be communicated clearly to consumers), European and national policy must focus on ensuring: (1) consumers can access convenient and affordable charging points (2) OEMs supply affordable BEVs to meet the requirements of different consumer groups. The evolution of first owner TCO savings for BEVs vs. Petrol ICEs over 2020-30 for a weighted average of small and medium cars is showing in Figure 8.

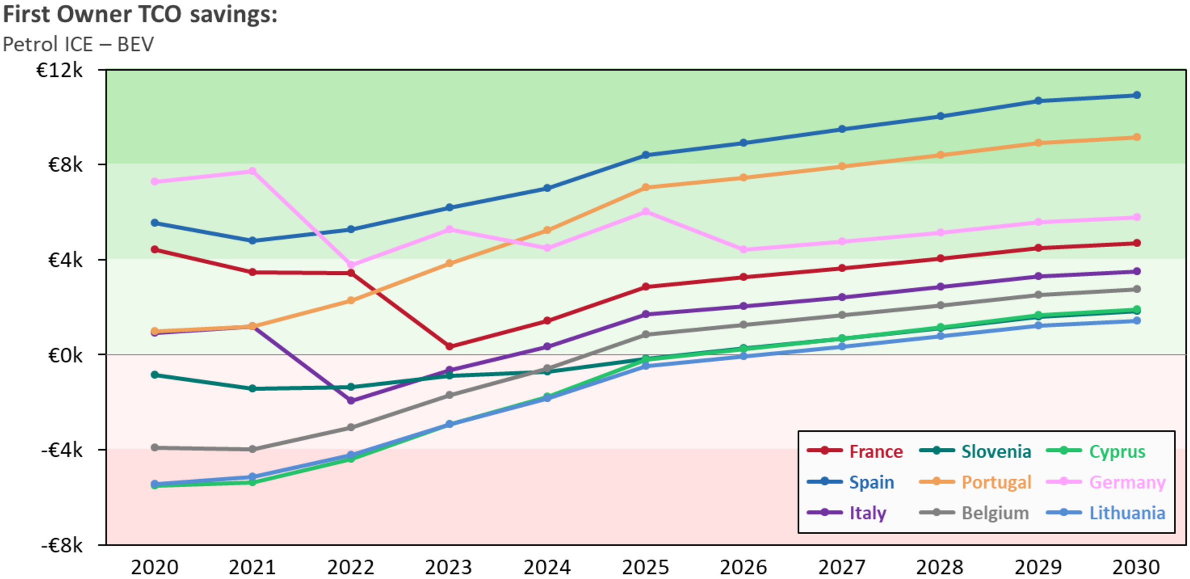

Figure 8: evolution of first owner TCO Δ between Petrol ICEs and BEVs for a weighted average of small and medium cars across European focus markets. Year indicates when car bought new.

Short-term TCO differences between markets from 2020-23 are largely driven by the size of government subsidies and their projected phase out. Savings for first owners that buy a BEV increase sharply from 2023-25 due to the prevalence of cheaper, more mainstream electric vehicle models entering the market and costs from additional Euro 7 requirements for Petrol ICEs being passed onto consumers. Additional savings flatten between 2026-30 and country variation is a function of different running costs, with Spain and Portugal providing the highest savings due to longer ownership periods.

EU vehicle manufacturer CO_2 emission targets have been the main mechanism for the decarbonisation of the European passenger car fleet. Figure 9 illustrates forecast WLTP emissions between 2020-30 under different BEV uptake scenarios (EU emission targets converted to WLTP[12]). This demonstrates that the current targets are not stringent enough to drive sufficient growth of BEV sales, in line with providing the lowest cost and emission transport option to as many consumers as possible, with the current 2030 emission target achievable with less than a 40% BEV EU uptake by 2030. For example, to reach a more ambitious target of 60% BEV market share by 2030[13], a WLTP target of below 26gCO_2/km would be appropriate. Higher BEV uptake will reduce long-term costs for consumers, especially those on lower incomes buying used cars.

However, the timing of BEV uptake is just as important as the final percentage of market share reached by 2030. For a 60% BEV market share of new sales by 2030, an early adoption scenario, akin to the uptake seen in markets such as Norway, would achieve a total passenger car fleet (old and new sales) CO_2 reduction of 52% by 2030 compared to 2020 levels, whereas a late adoption strategy only leads to a 34% reduction, risking increased costs and emissions for consumers. Emissions targets should reflect a continual decrease over the next decade, to avoid the risk of OEMs peaking sales to meet 2025 & 2030 targets. Moreover, a delayed BEV uptake has substantial consequences for the total car fleet (old and new cars) make-up in 2030, with ICEVs remaining in the market stock much longer with later BEV adoption. It is essential that targets reflect the fact that the earliness of BEV uptake is just as important as the final percentage of BEV sales reached by 2030.

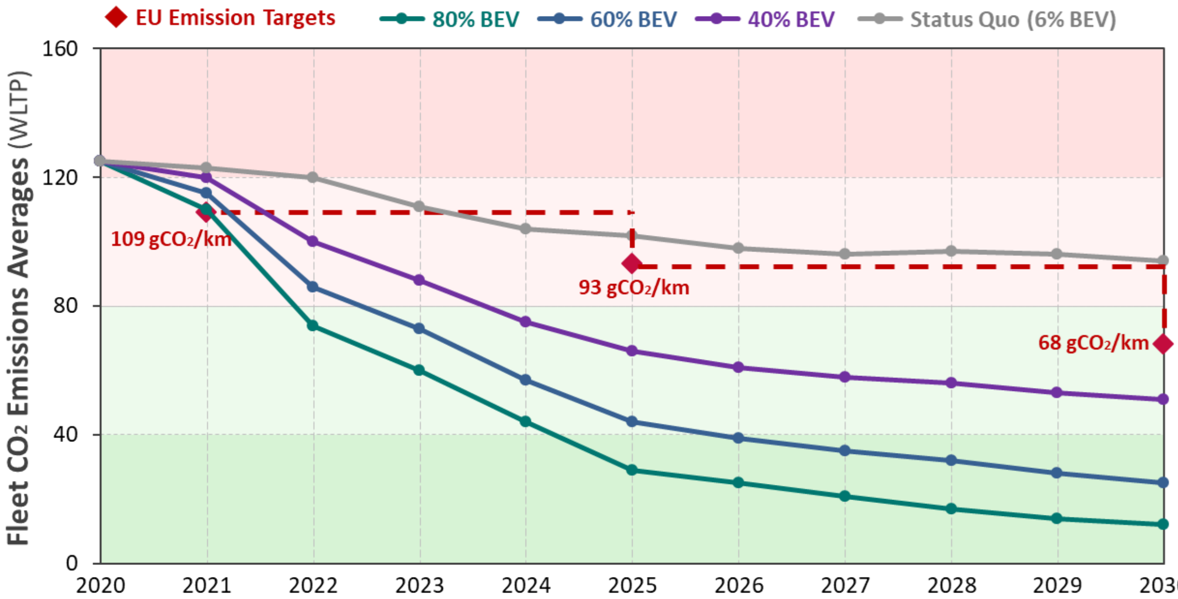

Figure 9: new fleet WLTP CO_2 emissions for BEV uptake scenarios compared to current EU targets

12 Using a x1.15 conversion factor from NEDC based on: https://theicct.org/sites/default/files/publications/ICCT_EU-CO2-stds_2020-30_brief_nov2016.pdf
13 A 60% BEV market share by 2030 is the preferred option in this study as it maximises financial and environmental benefits under an early adoption scenario while leaving room for BEV supply by OEMS.

Contents

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Acronyms

ACEA	European Automobile Manufacturers' Association
BEUC	The European Consumer Organisation
BEV	Battery electric vehicle
EE	Element Energy
EU	European Union
EV	Electric vehicle
FCV	Fuel cell vehicle
HEV	(Full) Hybrid electric vehicle, non-plug in
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
LDV	Light duty vehicle
LED	Light emitting diode
NEDC	New European Driving Cycle
OEM	Original equipment manufacturer
PHEV	Plug-in hybrid electric vehicle
TCO	Total cost of ownership
ULEV	Ultra-low emission vehicle
VAT	Value added tax
WEO	World Energy Outlook (IEA)
WLTP	Worldwide harmonized Light vehicles Test Procedure

1 Introduction

In order to achieve decarbonisation in the passenger car sector required by EU timelines, a rapid transition to electric vehicles will be required. There are several factors that will impact the rate at which decarbonisation happens, including: the cost to consumers, provision of charging and the supply of EVs.

This study explores the cost aspect of the transition, by analysing the TCOs of different car powertrains at an EU and national level. It is important that electric vehicles are cost effective for consumers and, where required, government policy is put in place to make decarbonisation affordable. This is essential to deliver a just and equitable decarbonisation transition for all European consumers.

1.1.1 Background & Context

In 2018, the transport sector made up 24% of EU-27 (+EFTA +UK +Turkey) Greenhouse Gas Emissions (GHG), of which road vehicles (cars, vans, heavy duty trucks and buses) are the most significant contributors, representing 94% of transport emissions, with cars making up the biggest share at 57%[14]. Reducing emissions is essential to achieve the EU climate goals, which currently aims to realise a 55% reduction in GHG from 1990 levels by 2030, and through the European Green Deal, reach net zero emissions by 2050. The transport sector has a long-term target to achieve 90% reductions from 1990 levels by 2050.

The EU vehicle manufacturer CO_2 emission targets, which now cover cars, vans and trucks, have been the main policy mechanism for decarbonising the vehicle fleet. Manufacturers must ensure that the average CO_2 emissions across the fleet of vehicles they sell in a year meet specific emission targets. These targets have mostly been set at 5-year intervals and designed so that the targets fall significantly over time. Car targets Regulation (EU) 443/2009 and 2019/631 - introduced in 2009 and updated subsequently, has set EU wide CO_2 targets for car manufacturers of:

- 130gCO2/km on average across the fleet by 2015; 95gCO2/km on average by 2021 (specific emission targets for manufacturers take into account the average test mass of a manufacturer's newly registered vehicles).
- 15% reduction in fleet average CO_2 emissions between 2021-25; 37.5% reduction between 2021-30.
- Several mechanisms have been put in place to ease manufacturers' efforts to reach their targets: 95% phase-in for 2020 (excluding 5% most emitting new cars), granting of super-credits for zero and low emission vehicles, counting of eco-innovations and emissions pooling between OEMs.

Despite emissions targets and growth of low and zero emission vehicles, new fleet passenger CO_2 emissions have actually increased between 2016-19[15]. This has been driven by a number of factors including stalling efficiency improvements to ICEVs, sales mix shift to larger SUVs and limited growth of electric vehicles.

The recent surge in EV sales for compliance purpose is a reminder that the EU vehicle manufacturer CO_2 emission standards can be a strong market force, countering their historical inability to force manufacturers to introduce low emission vehicles at the rate needed to meet the ambitious carbon reduction targets. This has left countries with strong national decarbonisation commitments to find additional policies to accelerate the decarbonisation of the fleet (these include policies such as large grants for purchasing BEV in many countries and national commitments to end of the sale of petrol,

[14] European Environment Agency (EEA) (2018), Greenhouse Gas – Data Viewer
[15] https://www.eea.europa.eu/data-and-maps/daviz/average-emissions-for-new-cars-6#tab-chart_1

diesel, hybrid and plug-in hybrid cars between 2030-2040). The future European CO_2 reduction targets are being reviewed and are expected to be made more stringent (than the current 37.5% reduction by 2030 for passenger cars). This will ensure a steady reduction in average fleet emissions, increasing long-term BEV supply, while putting an end to existing testing and regulatory loopholes.

1.1.2 Aims of this Study

As policy discussions continue within Europe about the level of ambition needed for new vehicle emissions in the 2020s and the mechanisms to be used to deliver them, it is timely to assess the future cost impacts of zero emissions vehicles on private and fleet vehicle users, and in particular whether the lower running costs will outweigh higher upfront costs. This report by Element Energy was commissioned by BEUC (The European Consumer Organisation), to explore the Total Costs of Ownership (TCO) of cars sold in the 2020s. Specifically, the study aims were as follows:

- Synthesise the latest evidence on future costs and performance of new cars, covering incremental improvements to petrol and diesel cars as well as low and zero emission powertrains.
- Develop a robust set of assumptions for the other components of vehicle ownership costs, such as depreciation rates, fuel costs, maintenance and insurance, and how these are likely to evolve in the future for each powertrain.
- Calculate and compare the Total Costs of Ownership for different powertrains between 2020-30. This includes an assessment of how costs are likely to vary for first, second and third owners. Complete TCO analysis for an EU baseline and consider 9 European focus markets (Belgium, Cyprus, France, Germany, Italy, Lithuania, Slovenia, Spain, Portugal).
- Explore wider implications for consumer equity and impact of CO_2 emissions on consumers from the purchase of different powertrains.
- Examine the sensitivity of the results to changes in input assumptions, including different average annual mileages, battery sizes, Euro 7 timings, E-fuels & electricity tariffs.
- Draw conclusions on the implications of the results for consumers and post-2020 policy mechanisms to drive decreases in new vehicle emissions and improved cost-effective consumer mobility.

1.1.3 Report Structure

In Section 2, the methodology is detailed with an overview of vehicle scope and cost & performance modelling. The ongoing ownership assumptions, including: fuel & electricity pricing, average annual mileages, depreciation rates, insurance and maintenance costs, are also discussed.

Baseline TCO results for cars bought new between 2020-30 for different ownerships are outlined in Section 3, which includes an overview of country-by-country differences for 9 scope European markets and a discussion of the implications for consumer equity and CO_2 emissions.

Section 4 shows TCO sensitivities that explore different user groups of consumers where there may be opportunities for earlier adoption of Battery Electric Vehicles (BEVs) or specific risks to consumer uptake of low emission vehicles. Overall conclusions and implications for EU CO_2 emissions targets are given in Section 5.

2 Project Methodology

In this Section, the methodology is detailed with an overview of vehicle scope and cost & performance modelling. The ongoing ownership assumptions are discussed, which includes: fuel & electricity pricing, average annual mileages, depreciation rates, insurance and maintenance costs, as well as assumptions around PHEV charging scenarios.

2.1 TCO Overview

Figure 10 shows the make-up of the total cost of ownerships (TCO) in terms of its individual cost component. This includes both upfront purchase cost (including VAT) and vehicle running costs.

Figure 10: breakdown of the TCO cost components

2.2 Vehicle Scope

The TCO work presented here focuses on generalised cars of specific size segment and powertrain types, rather than predicting future TCO for any individual car makes or models. By taking this approach the TCO of an ‘average’ vehicle is shown which is readily comparable across different European markets.

In this report we consider 3 car size segments: small; medium; large, based broadly on ACEA segmentation[16], and 6 powertrains: petrol and diesel internal combustion engines (ICE); petrol hybrid (HEV) electric vehicles; petrol plug-in hybrid (PHEV) vehicles; battery electric vehicles (BEV); and hydrogen fuel cell vehicles [17]. A brief description of each powertrain is included below. Figure 11 shows a graphic representation of the powertrain components included in each powertrain.

[16] Specialist Sport and Luxury Car are excluded from the large segment, to best reflect the choice for an average consumer

[17] Please note: LPG and CNG have been excluded due to low market share, very limited growth potential & OEM investment and because they achieve minimal emission reductions

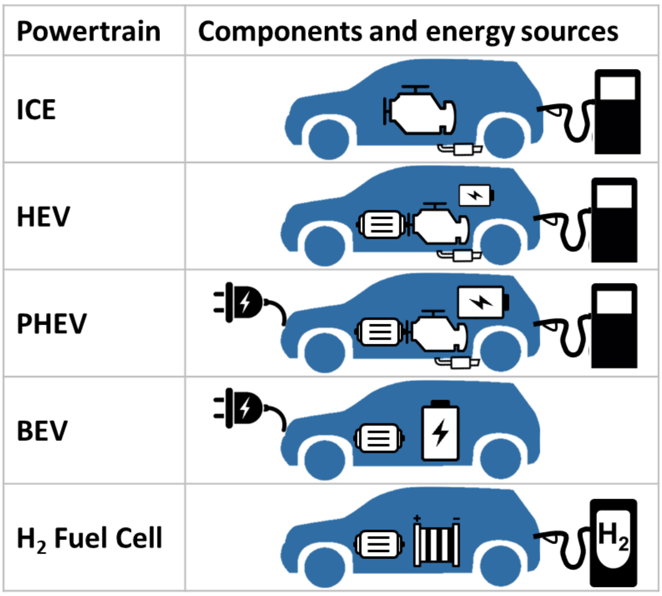

Figure 11: Graphic representation of the powertrain components included in each powertrain.

Internal Combustion Engine (ICE)

Conventional vehicle comprising of an internal combustion engine and a fuel tank for fuel storage. Note that this powertrain can incorporate start-stop technology and micro-hybridisation, such as belt driven starter generators and 48V electrical systems.

Full Hybrid Electric Vehicle (HEV)

Similar to an ICE but supplemented with an electric motor and battery pack allowing it to drive short distances at low speed under electric-only power. The battery is charged by the engine, rather than an external power source. This configuration improves the fuel consumption relative to a conventional ICE, at the expense of additional capital cost.

Plug-in Hybrid Electric Vehicle (PHEV)

A hybrid electric vehicle with a larger battery which can be recharged by plugging into an external source of power, as well as by the engine. This enables a portion of overall energy consumption to be provided by electricity, rather than fuel. Recent analysis has shown that the real-world fuel consumption and emissions of PHEVs can be quite different to the WLTP values[18], principally due to significant differences in the charging frequency assumed in official test cycles and how consumers appear to be behaving. In this report we present TCO findings for both PHEVs which are charged regularly (following the assumptions included in the WLTP specification[19]) and for PHEVs which are never charged, and therefore drive under ICE power at all times, and PHEVs which are charged at destination charge points a few times a week. These three approaches are included to cover the range of values we expect consumers to fall within.

Battery Electric Vehicle (BEV)

Uses electric motors for propulsion, which are powered entirely by electricity stored in a battery. The battery is charged by plugging into an external electricity source.

H_2 Fuel Cell (FCEV)

Powered by a hydrogen fuel cell, which converts the chemical energy in hydrogen to electricity through an electrochemical reaction in order to power an electric motor.

[18] Transport & Environment (2020) Plug-in hybrids: Is Europe heading for a new Dieselgate?
[19] UN/ECE Regulation 101, Annex 8, pg. 74
https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/r101r2e.pdf [Accessed 12/03/2021]

2.3 Cost and Performance Modelling

The TCO forecasts presented in this report are derived from projections for future vehicle attributes from Element Energy's Cost and Performance Model. This model takes a bottom-up approach to forecasting future vehicle attributes out to 2030, whereby powertrain components are added onto a blank chassis and their associated vehicle attributes (such as cost, weight, and efficiency) are aggregated to the vehicle level.

Figure 12 outlines the basic calculation structure of the Cost and Performance Model. Blank chassis are identified by removing components from known archetype vehicles, and future vehicles are constructed by adding back the required components for each powertrain. The cost, mass, and efficiency for each component is added together to create the overall vehicle characteristics, and individual projections for each component allow for very granular insight into the effect on overall vehicle performance.

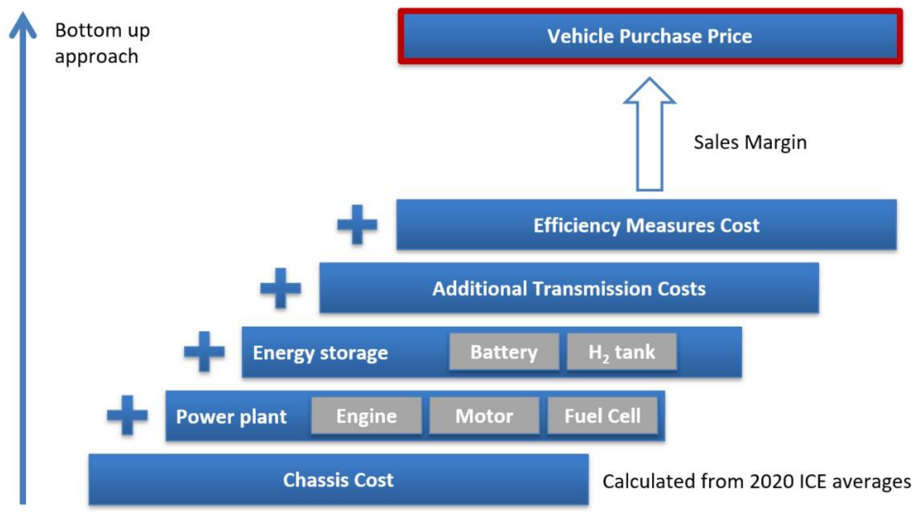

Figure 12: Outline of the methodology applied in the Cost and Performance Model

In addition to the required powertrain components, each vehicle has a suite of efficiency measures deployed which change the overall vehicle characteristics, with an associated efficiency, weight and cost impact. 45 individual efficiency technologies are applied to vehicles, each with an individual cost curve and deployment projection which are taken from Ricardo-AEA's 2016 cost curve study for the European Commission[20].

Vehicles are constructed from the drivetrain components required to move the vehicle (engine, motor, battery, etc), and the chassis which forms the remainder of the vehicle (outer body of the vehicle, seats, windows, air-conditioning system etc). Drivetrain components define the powertrain and vary between vehicle types, whilst the chassis is common between powertrains. Detailed forecasts of component cost, mass, and efficiency are input into the model, so these can be defined accurately. The blank chassis however is treated as a black box: the model does not explicitly consider what materials go into the chassis or how these change over time; instead, the model considers how the chassis evolves as a whole. It is assumed that the chassis is common between related powertrains in the same size segment. Figure 13 shows a more detailed view of the modelling approach employed.

[20] Ricardo-AEA. Improving understanding of technology and costs for CO_2 reductions from cars and LCVs in the period to 2030 and development of cost curves. 2016.

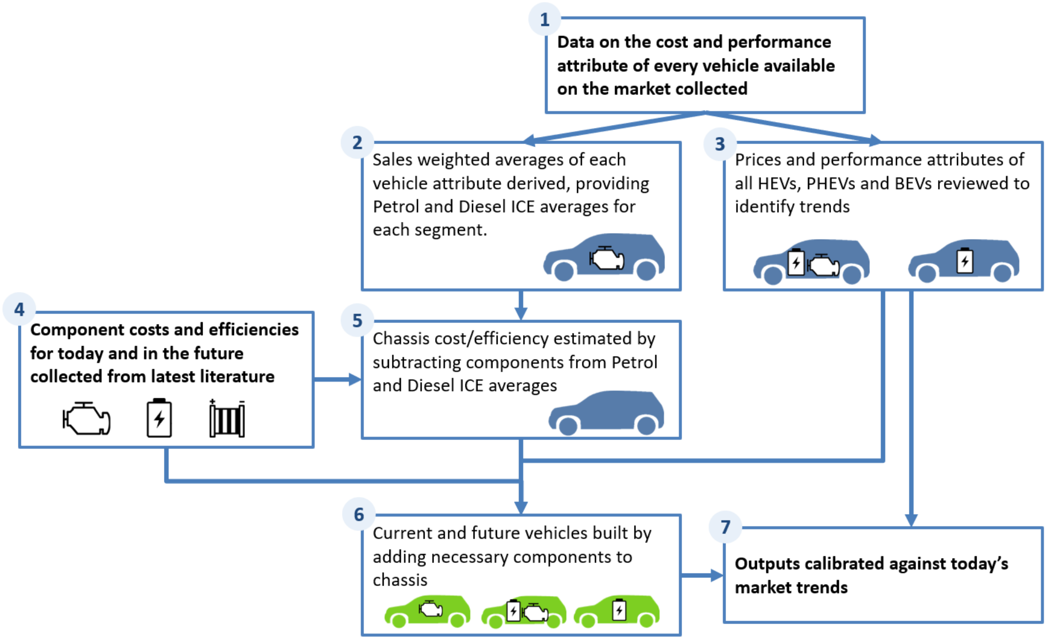

Figure 13: Overview of steps taken to construct future vehicles. Numbers indicate modelling order.

Once the overall manufacturing cost of each vehicle has been calculated, a margin is applied to calculate the purchase price a consumer would see in a showroom. The margins used are based on literature review[21,22,23,24] and market research conducted by Element Energy.

In order to have a representative baseline off which to base future vehicles, 2020 archetype vehicles are identified for each segment and powertrain. These archetypes represent a sales-weighted average of ICEs and were determined by an analysis of the over 9,000 vehicle models on sale in October 2020. The ICE archetypes generated are used to determine the basic properties of the vehicle chassis which are assumed to be common amongst vehicles of the same size segment. An analysis of all HEV, PHEV, and BEV vehicles on sale was also undertaken in order to identify representative 2020 archetypes which are used for the purpose of model calibration.

2.4 Ongoing Ownership Assumptions

2.4.1 Fuel and Electricity Projections

Future EU-average petrol and diesel pricing was derived using the IEA World Energy Outlook (WEO) 2019's Stated Policies forecast global oil prices[25], and based on a historic correlation modelled between oil and petrol & diesel prices between 2010-20, with VAT and fuel duty taken as population weighted average of each EU member state. Price at pump for hydrogen sources from Hydrogen Council (2020) Pathway to Hydrogen Competitiveness using the Gaseous Trucking scenario[26]. Residential electricity forecasting has been taken from World Energy Outlook 2019 Stated Policies scenario[27]. Please note

[21] Roland Berger (2014) Global Automotive Supplier Study
[22] KPMG (2013) Automotive Now, Trade in crisis
[23] Holweg, Matthias, and Pil (2004) The Second Century: Reconnecting Customer and Value Chain through Build-to-Order – Moving Beyond Mass and Lean Production in the Auto Industry
[24] Cuenca, Gaines, Vyas (1999) Evaluation of Electric Vehicle Production and Operating Costs
[25] International Energy Agency (2019) World Energy Outlook: Global Oil Forecast
[26] Hydrogen Council (2020) Pathway to Hydrogen Competitiveness
[27] International Energy Agency (2019) World Energy Outlook: Residential Energy

that no off-peak discount has been included in the baseline results. Full fuel and electricity pricing assumptions are detailed in Appendix 6.2.1.

2.4.2 Depreciation and Residual Values

Analysis of real world vehicle residual value data, for varying vehicle ages and mileages, was completed for over 9,000 models of cars, which was used to correlate depreciation rates for different powertrains and car sizes. An example of the depreciation rates found across different powertrains are shown for a 4-year-old vehicle having completed 64,000km in Appendix 6.2.2. In general, analysis revealed that there is minimal difference in depreciation rates across powertrains, with more minor trends including:

- Smaller cars depreciate faster than large and medium cars
- Diesel ICEs depreciate slightly faster than Petrol ICEs
- Petrol HEVs and PHEVs show similar depreciation to Petrol ICEs
- BEVs are similar to Petrol ICEs, except Large BEVs which depreciate much slower. This is because this segment is currently dominated by Tesla Model X and S which have low depreciation.

Please note that no additional savings have been included for BEVs for the sale of end-of-life batteries.

2.4.3 Insurance and Maintenance

Price comparison websites were used to gather insurance cost data for top selling car models. Insurance costs were found to be strongly correlated with vehicle purchase price and are largely independent of powertrain.

Analysis of annual maintenance data, based on “real world” costs paid by consumers, shows a strong correlation with vehicle purchase price, with differences observed across powertrains. Maintenance is generally required most often for Petrol ICEs and least for BEVs. However, as BEVs are currently more expensive than ICEVs, requiring higher specification parts, this difference is largely offset and overall maintenance costs are similar.

2.4.4 Ownership Periods

The TCO results in this study are given for first, second and third owners of passenger cars, with ownership periods of 4, 5 and 7 years in length respectively. This reflects the tendency for ownership periods to increase with vehicle age. Correspondingly, annual vehicle driving distance is also known to decrease with vehicle age[28], and as such annual mileages of 15,000 km, 12,000 km and 10,000 km are applied to the TCO calculation of average EU-27 first, second and third hand owners respectively.

2.4.5 Plug-in Hybrid Charging

Three charging scenarios have been considered for PHEVs to reflect the significant variation in driver charging behaviour[29]:

1. **High Charging** – typical of a driver that has access to daily home charging. Utility factors are sourced from European Commission regulation regarding WLTP testing of PHEVs[30].
2. **Low Charging** – representative of a driver who does not have access to daily home or work charging and relies on destination charging (e.g. at a supermarket) a couple times per week.
3. **No Charging** – a driver who does not charge their PHEV and relies 100% on combustion fuel

[28] Ricardo-AEA (2014) Improvements to the definition of lifetime mileage of light duty vehicles
[29] Fraunhofer-Institut für System- und Innovationsforschung ISI (2020), Real-world usage of plug-in hybrid electric vehicles. Fuel consumption, electric driving, and CO2 emissions
[30] European Commission, COMMISSION REGULATION (EU) 2017/1151 of 1 June 2017, Sub-Annex 8, Appendix 5

3 Vehicle TCO Results: Consumer Cost Saving in the Decarbonisation Transition

In this Section, EU Baseline TCO results are discussed for cars bought new between 2020-30 for different ownerships (first, second & third), and includes an overview of country-by-country differences for 9 scope European markets with discussion around the implications for consumer equity and CO_2 emissions from different powertrains.

3.1 Overall TCO Results

This sub-section looks at: (A) the lifetime (16 years) TCOs of different vehicle powertrains purchased between 2020 and 2030 to show the total costs that will be faced by consumers for car ownerships in the decarbonisation transition and (B) the first ownership (4 years), which is especially important as it dictates the long-term market stock. Equivalent graphs detailing the second (5 years) and third ownerships (7 years) can be found in Appendix 6.3.

Please note that these charts do not include BEV subsidies or tax breaks, which are available for consumers in many European markets.

3.1.1 Lifetime TCO

Figure 14 compares the TCOs between different powertrains on a total lifetime basis. Each data point illustrates the TCO over the 16-year lifetime of the car, starting from the year that the car was bought new, which is shown on the x axis. Separate trends are considered for small, medium and large cars. While lifetime TCO may not dictate the overall mix of vehicles bought in a market, it shows the cost optimal solution for consumers.

The key finding is that BEVs are already the cheapest powertrain for medium cars bought today, with small and large cars following in 2024 and 2026 respectively. Petrol PHEVs cost broadly the same on a TCO basis as BEVs in the large segment, but this is due to a high share of driving assumed under electric power. Without charging (as it is the case for many company cars), Petrol PHEVs become the most expensive powertrain. The introduction of Euro 7 requirements between 2022-24 has a significant impact on petrol and diesel lifetime TCOs because VAT is paid on these capital costs three times.

BEVs still have the appearance of being unaffordable for many consumers, largely due to the fact that a majority of BEVs are currently concentrated in the first owner market. However, the emergence of specific electric car financing schemes, such as Onto and elmo[31], which structure pricing largely on a TCO basis, by including insurance, maintenance, annual car tax and breakdown cover, alongside a wider leasing market increasingly available to consumers, provide opportunities to unlock the lifetime benefits of BEVs over other powertrains from day one.

[31] https://www.theguardian.com/money/2021/mar/14/first-there-was-netflix-now-you-can-subscribe-to-an-electric-car?CMP=Share_iOSApp_Other

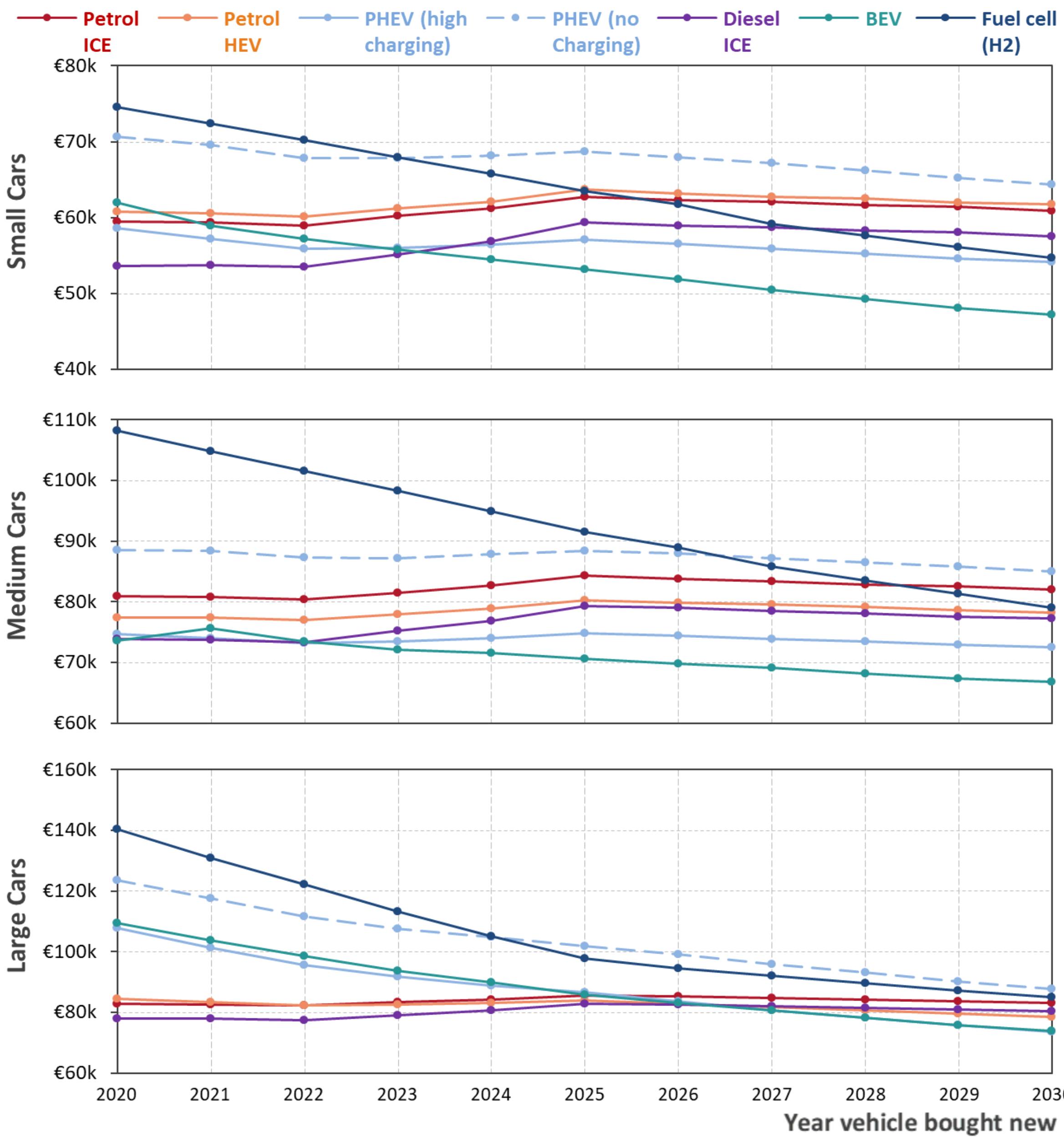

Figure 14: Lifetime TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

3.1.2 First Owner TCO

The relative first owner TCOs are forecast for the various powertrains in
Figure 15. The TCOs for BEVs and FCEVs will drop significantly over the next decade, driven by falling battery and fuel cell costs, leading to a lower upfront price, which removes a strong psychological barrier

to consumers. BEVs become cheaper on a TCO basis for all car sizes by 2026. Note the slight increase to costs for medium BEVs in 2021 is due to models with larger battery sizes entering the market.

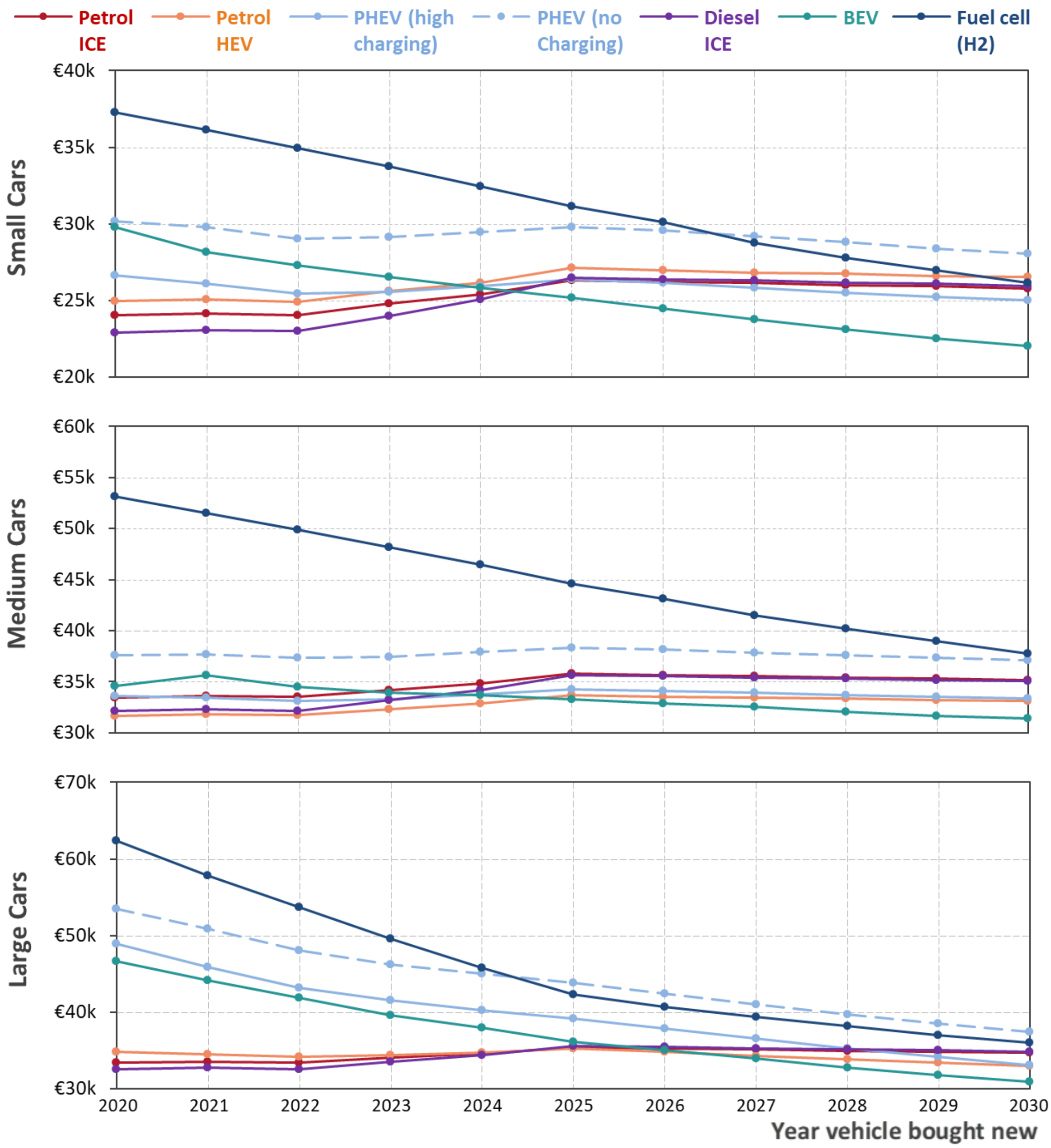

Figure 15: First owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

Although BEVs bought new today will provide significantly better value for second and third owners, it is especially important to consider the first ownership as it impacts new buyer purchasing decisions, which in turn determines the long-term market stock. Small BEVs become the cheapest powertrain a year before medium and large cars, and will provide savings of around €4,000 by 2030. This provides an opportunity for a mass market that buys smaller and cheaper vehicles, and it is crucial for small BEV models, which have historically been limited, be made available for consumers by OEMs. With new models equipped with smaller batteries (see Section 4.1.2), the potential for lower-income consumers to participate in the decarbonisation transition as first owners is even greater. As seen in the case of lifetime TCOs, PHEVs which are not charged provide the worst financial value to consumers.

All of the 9 European countries within the project scope offer either purchase grants and/or tax incentives for BEVs. Subsidies help make BEVs cheaper for first owners and encourage higher market share of new sales. This builds up the overall long-term BEV market stock, which unlocks substantial savings for second and third owners, while reducing carbon emissions. Figure 16 shows the differences in first owner TCOs between a small BEV and Petrol ICE, for both the baseline case and with the addition of a purchase grant (limited to €5,000) and an annual tax break (up to €500 per year), which is representative of many European markets, such as the Annual circulation tax (ACT) in Belgium. The bottom chart shows the phase out of the purchase grant and tax breaks that can be achieved while still maintaining a +€4,000 first owner TCO advantage for BEVs over Petrol ICEs (which is shown by the red line in the top chart) to drive uptake growth.

This scenario demonstrates that, for a country in line with EU average parameters, it is essential to maintain full BEV subsidies until 2022, however, it will be possible to phase out purchase grants between 2022-26 and tax breaks from 2026-30 while still achieving an additional +€4,000 saving for consumers over the first ownership period. The timeline over which specific policymakers should remove BEV subsidies for first owners varies from country to country, with significant variation due to different vehicle pricing, average annual mileage and fuel & electricity costs. A country specific overview is discussed in detail in Section 3.2.

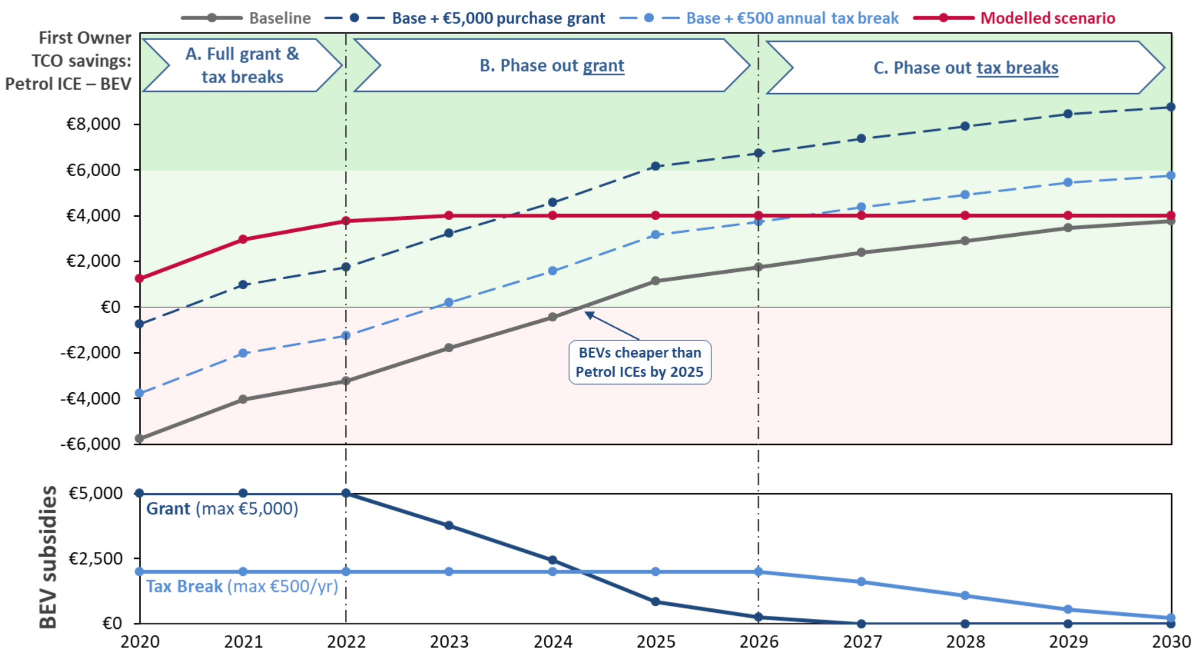

Figure 16: first owner TCO savings for small BEV vs. Petrol ICE with addition of BEV subsidies (top graph) & subsidies needed to maintain the modelled scenario marked in red (bottom graph)

It is best practice to phase out subsidies before tax breaks, as policy costs can quickly escalate as higher proportions of first owners buy BEVs. There is an increasing risk of subsidising first owners who would have likely bought a BEV anyway, especially by the time BEVs become cheaper than Petrol ICEs in 2025. Furthermore, this may drive market inequity, which is discussed in detail in Section 3.4. Long-term subsidies also risk OEMs focusing supply towards highly subsidised markets, being able to artificially maintain inflated pricing, while limiting BEV supply in European countries without subsidies. This shows the need for EU wide policy, with Euro 7 and manufacturer CO_2 emissions standards essential to ensure that BEVs, and their associated financial and carbon benefits, become available for all European consumers.

3.1.3 TCO component Evolution between Ownerships

Purchase price differences between ICEVs and BEVs become smaller for used owners, which means that savings will be available to the eventual second and third owners of medium BEVs bought new today.

First Owners

Figure 17 shows the TCO cost component break out – depreciation, VAT, fuel/electricity, insurance & maintenance – for the first owners of different powertrains for a medium car bought new in 2025. For first owners, depreciation is the largest single TCO component, with variation by powertrain largely a result of differences in purchase price. However, by 2025, as the purchase prices of BEVs become much more comparable to ICEVs, fuel/electricity costs become the deciding factor in which powertrain is cheapest on a TCO basis for consumers.

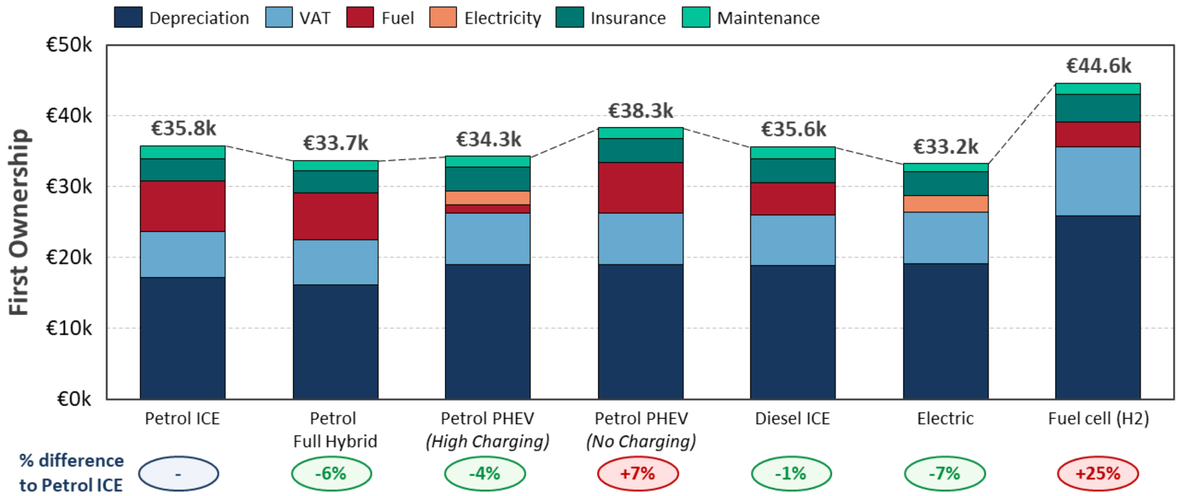

Figure 17: first owner TCOs for different powertrains for a medium car bought new in 2025

The 2025 first owner TCO for PHEVs varies by around €4,000 depending on charging behaviour and, even under a high charging scenario, PHEVs will cost over €1,000 more than a fully electric car. A BEV bought new in 2025 will be €2,600 and €2,500 cheaper over the first ownership than a Petrol and Diesel ICE respectively. The component differences are shown for a BEV vs. Petrol ICE in Figure 18. Depreciation is slightly lower for Petrol ICEs, however, this is outweighed by fuels cost being significantly higher than electricity.

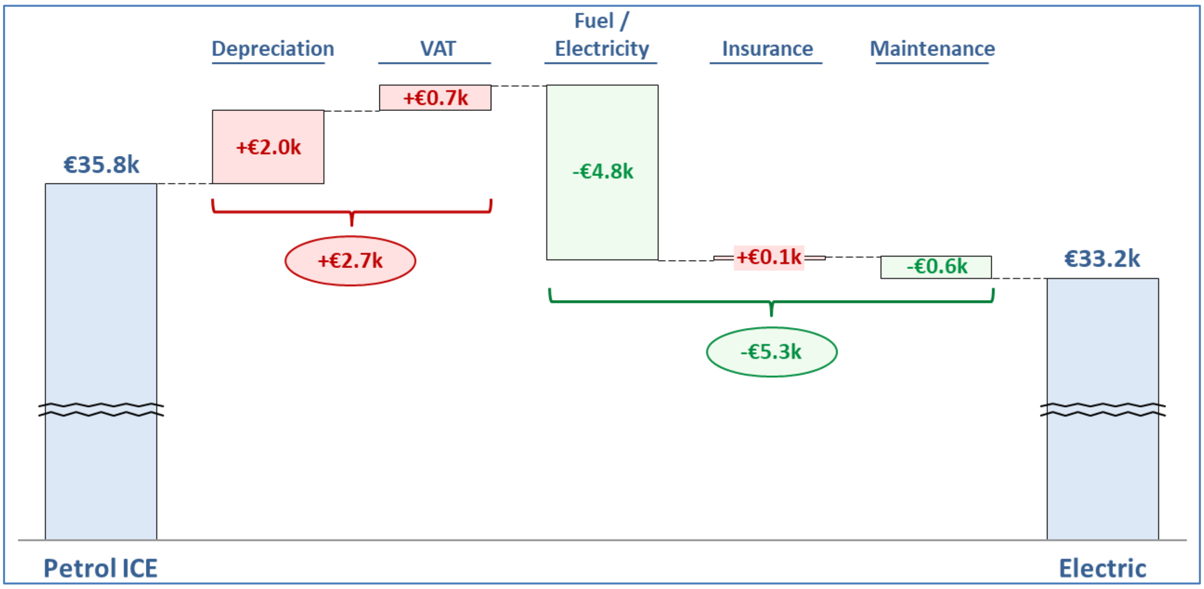

Figure 18: first owner TCO cost components compared for a medium car between Petrol ICEs and BEVs bought new in 2025

Second Owners

As shown in Figure 19, for a second-hand medium car, that was originally bought new in 2025 (and therefore the second owner bought in 2029), depreciation makes up a much smaller proportion of the overall TCO for second owners, with variation between vehicle powertrains driven largely by differences in fuel/electricity costs. A medium BEV, originally bought new in 2025, will provide a €4,100 saving for its second owners over a Petrol ICE, which has fuel costs making up 30% of the overall TCO.

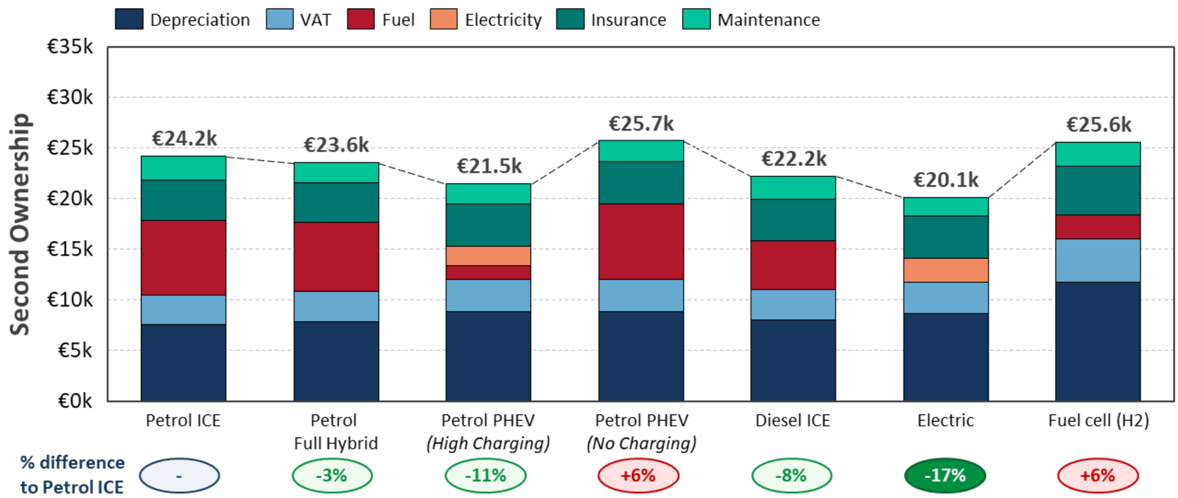

Figure 19: second owner TCOs compared for different powertrains for a medium car bought new in 2025

The relative difference between a medium BEV vs. Petrol ICE bought new in 2025 and sold in the second-hand market in 2029, is shown in Figure 20. As the impact of depreciation becomes significantly less, the electricity vs. fuel savings available for BEVs drive additional savings worth €5,000 for consumers. For third owners, the running costs continue to become increasingly important, and drive additional value for consumers (see Appendix 6.3.4).

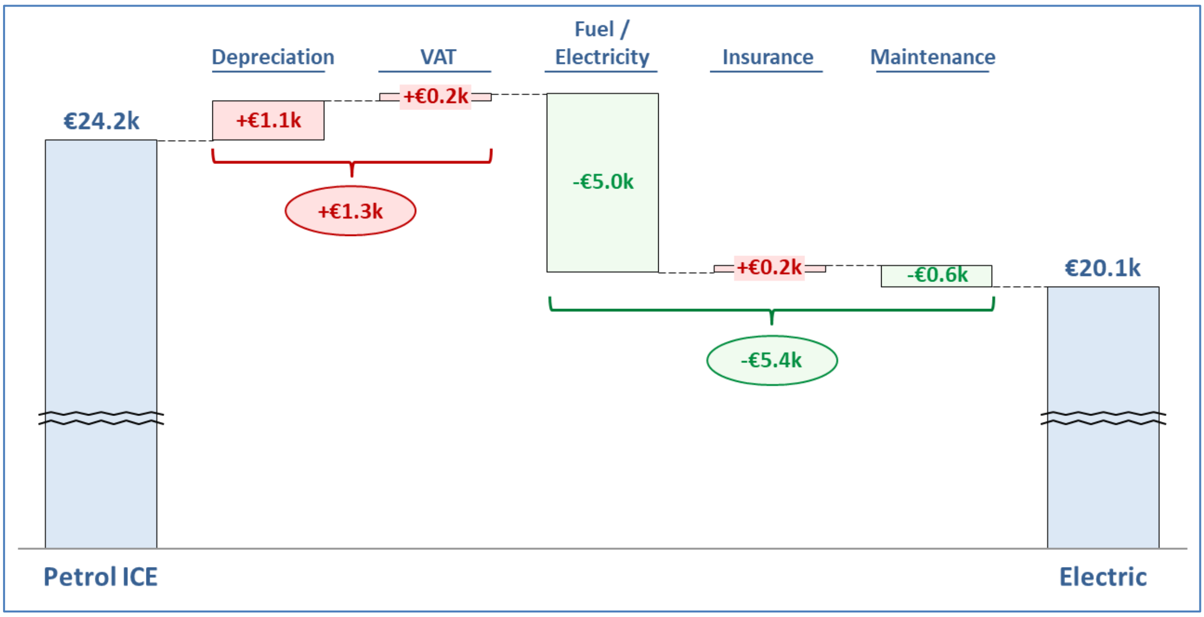

Figure 20: second owner TCO cost components compared for a medium car between Petrol ICEs and BEVs bought new in 2025

3.2 Country Specific Overview

In this sub-section, the variations from the baseline EU TCO results are compared for nine European focus markets: Belgium, Cyprus, France, Germany, Italy, Lithuania, Slovenia, Spain and Portugal. The drivers of country-by-country relative TCO differences and the consequences for BEV growth in each market are discussed.

There is significant variation between the different European markets in scope for the year that BEVs become cheaper than Petrol ICEs for first and second owners. However, BEVs are already the cheapest option in all focus countries for their eventual third owners if bought new in 2020. Differences in the year each country reaches parity, which is averaged over all car sizes, is shown in Figure 21 for each ownership. Countries are compared to the EU baseline which excludes tax breaks & subsidies.

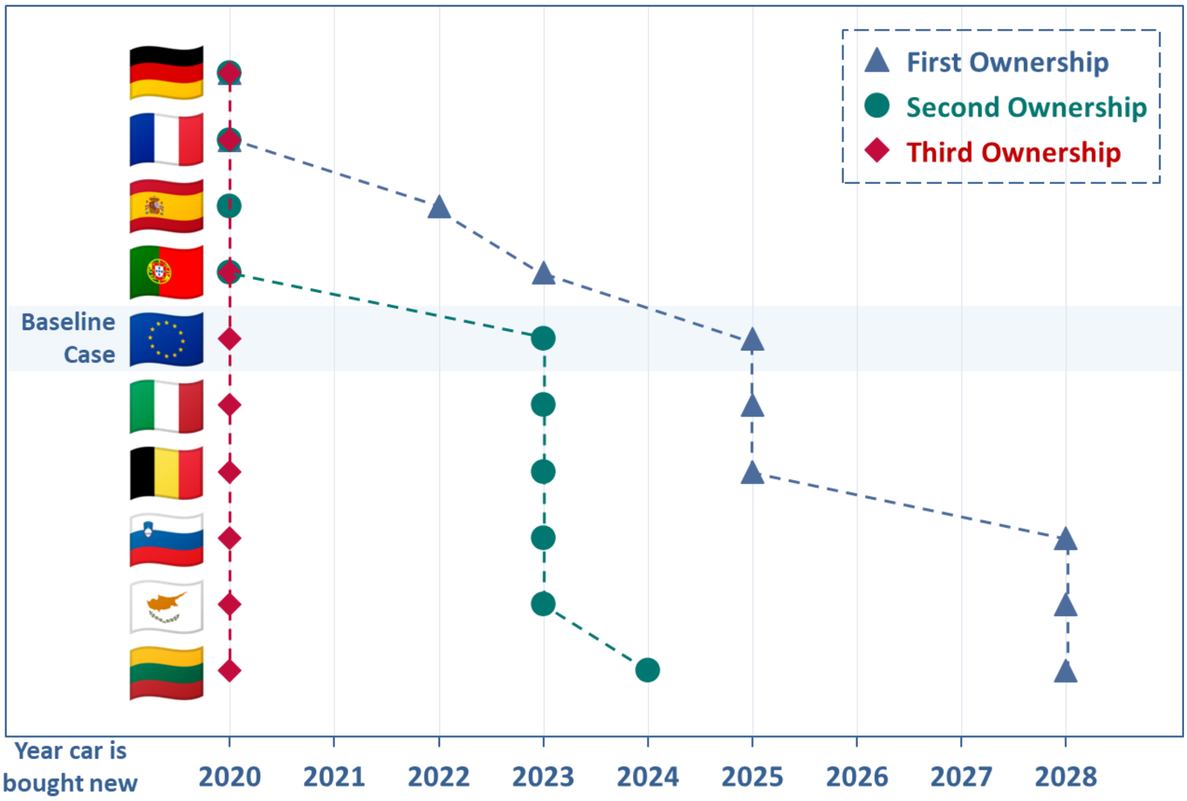

Figure 21: year that BEVs become cheaper than Petrol ICEs, averaged over all car sizes. Note the year indicated when the vehicle is bought new

In France & Germany, which have the highest BEV subsidies available to consumers, BEVs are already cheaper than Petrol ICE for first owners on a TCO basis. BEVs in Spain reach first owner parity to Petrol ICEs three years earlier than EU average, which is driven by a significantly longer 11 year first ownership period that increases the running cost savings. Belgium, which has no purchase subsides, is in line with the EU baseline, as is Italy, where there is a lower average annual mileage of 12,000km. BEVs in Slovenia, Cyprus & Lithuania are shown to become cheaper on a TCO basis several years later, due to the more limited government financial support and prevalence of cheaper Petrol ICEs.

Figure 22 shows a case study of what drives differences between the EU baseline and France for the relative TCO of a medium Petrol ICE & BEV for first owners. Medium BEVs, based on EU averages and excluding taxes & subsidies, are on average around €1,100 more expensive than Petrol ICEs for first owners bought new in 2020. The impact of marginally more expensive BEVs is outweighed by Petrol ICEs in France being ca. 5% more expensive. Running cost savings are increased in France due to longer mileages, cheaper electricity & higher petrol prices. Without grants or tax breaks, BEVs in France already save €440 for first owners, increasing to over €7,100 with government support.

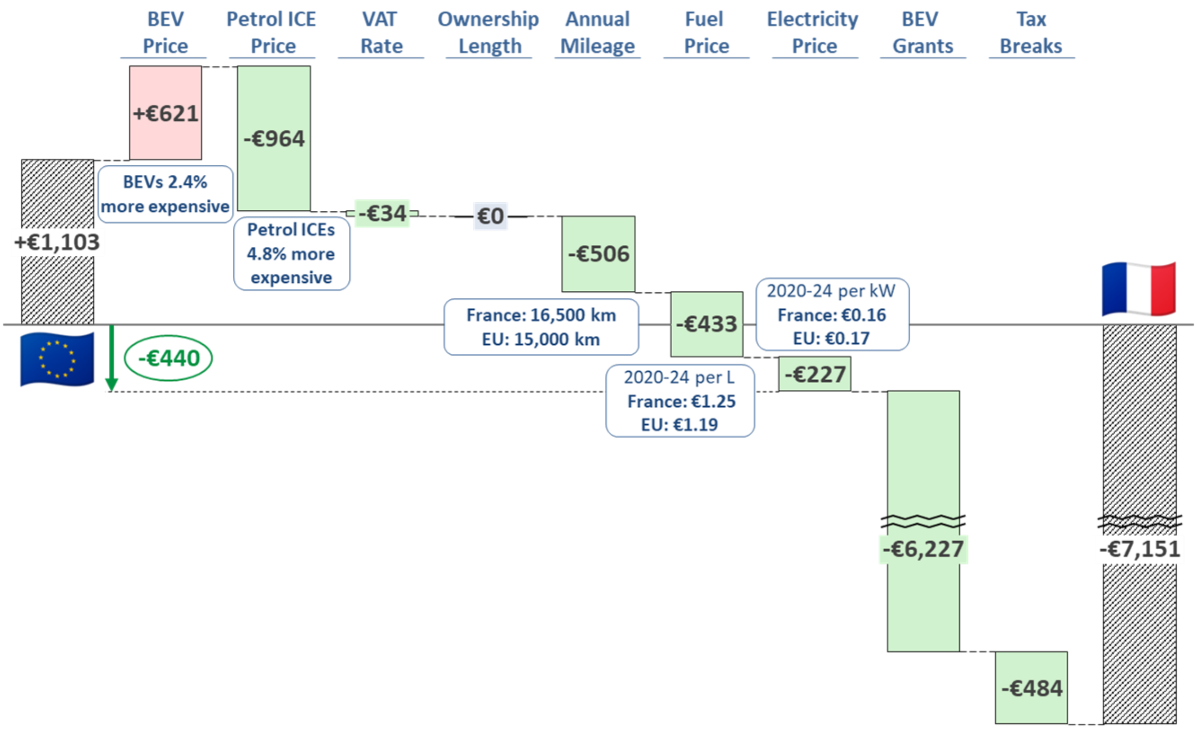

Figure 22: drivers of change in BEV vs. Petrol ICE relative first owner TCOs between EU average & France. Fuel & electricity prices in the graph exclude VAT.

The evolution of first owner TCO savings vs. Petrol ICEs for small and medium cars, and how this differs between countries, is explored in Figure 23. Short-term differences between markets within 2020-23 are largely driven by the size of government subsidies and their projected phase out. Germany provides the best value to first owners in 2020 due to post-Corona grants of up to €9,000. Savings for first owners that buy a BEV increase sharply from 2023-25 due to the prevalence of cheaper, more mainstream electric vehicle models entering the market and costs from additional Euro 7 requirements for Petrol ICEs being passed onto consumers. BEV savings between 2026-30 flatten and country TCO variation is largely a function of different running costs, with Spain and Portugal providing the highest savings due to longer ownership periods.

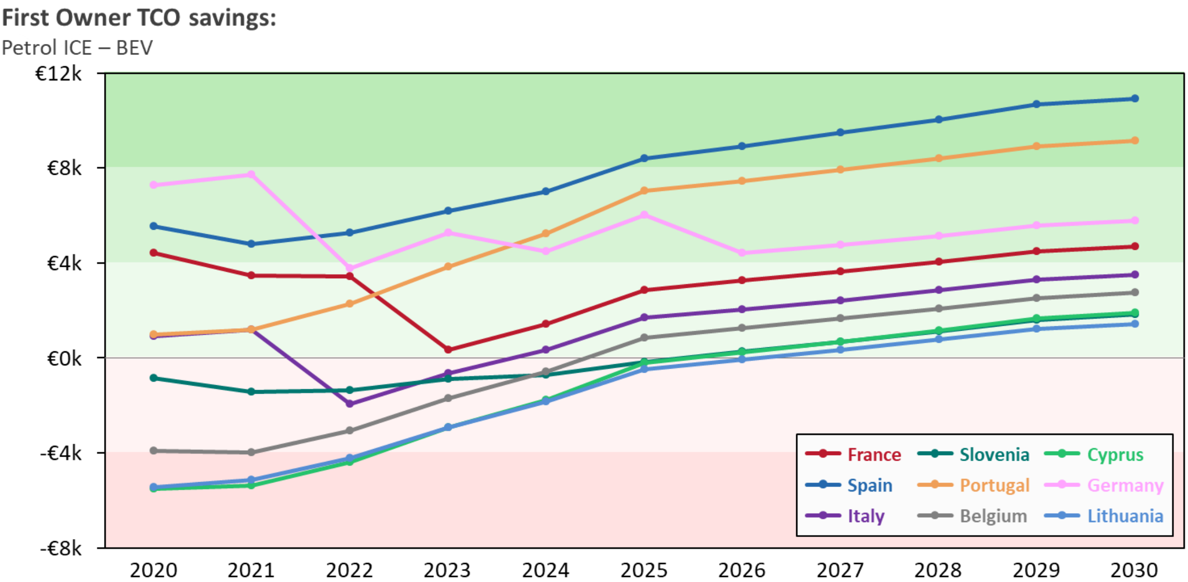

Figure 23: evolution of first owner TCO Δ between Petrol ICEs and BEVs for a weighted average of small and medium cars across European focus markets

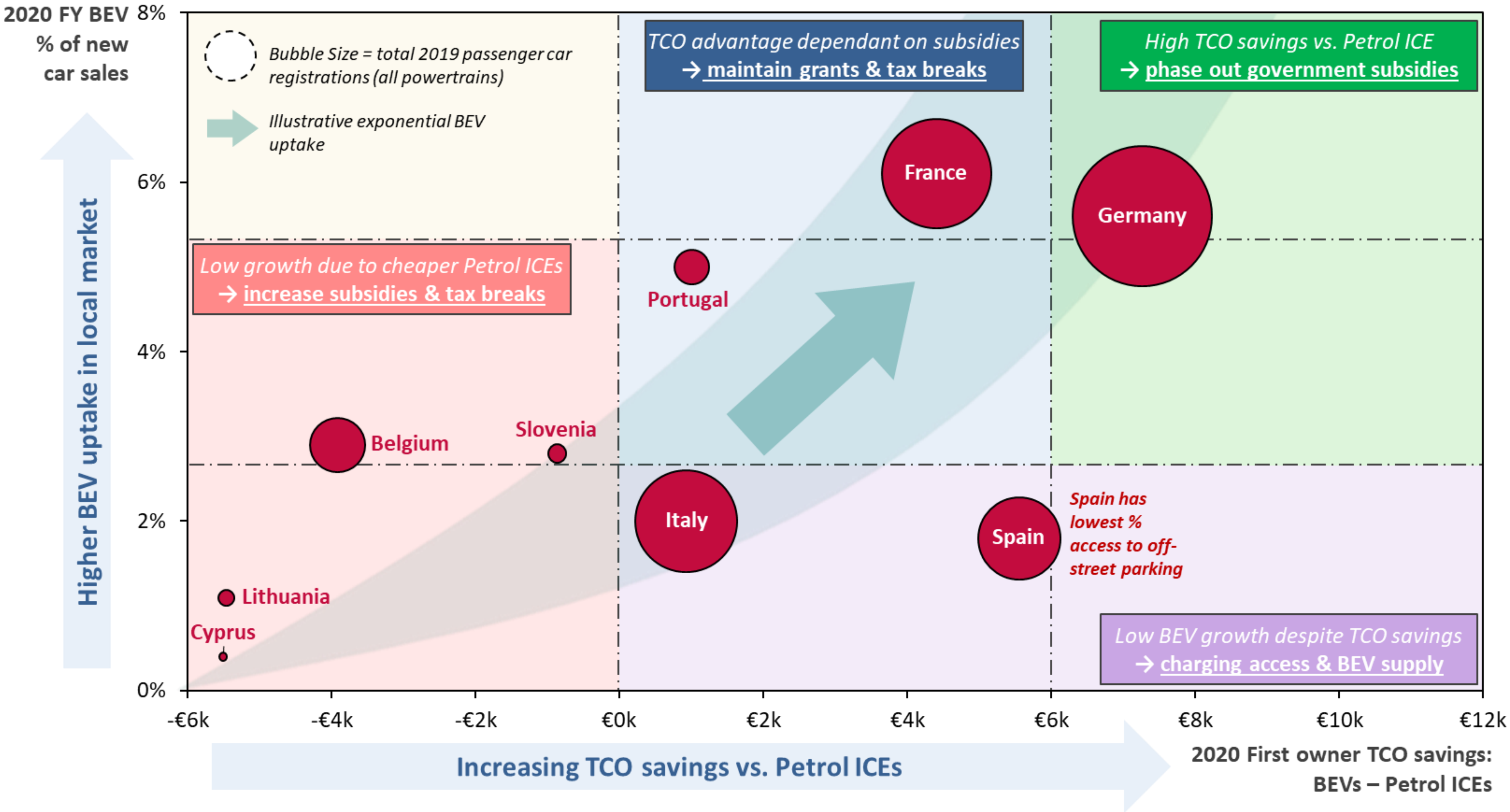

Figure 24: weighted average for small & medium cars showing BEV 2020 share of total market sales vs BEV first owner Δ TCO to Petrol ICEs

For each country assessed, the 2020 first owner TCO difference between BEVs vs. Petrol ICEs are plotted against current BEV sales[32] in Figure 24. There is a broad exponential correlation between Δ first owner TCO and BEV uptake, with the strongest growth seen in Germany and France. Each market's position on this landscape should translate into a specific strategy to improve BEV uptake. The red shaded area indicates markets where BEVs are more expensive for first owners than Petrol ICEs on a TCO basis and government investment is required to stimulate growth. For France and Portugal, in the blue section, strong ongoing uptake is dependent on the continuation of government support. Germany has the highest BEV TCO advantage vs. Petrol ICEs and can look to start phasing out BEV subsidies. In the purple segment, Spain and Italy have not experienced strong BEV growth despite being cheaper on a first owner TCO basis than Petrol ICEs. This highlights the limitations of considering markets from purely a TCO perspective. To fully understand growth barriers and how to change consumer attitudes, it is essential to consider other factors such as charging infrastructure (which should nonetheless be seen as a global need to increase consumer convenience and tackle range anxiety) and the OEM supply of BEVs available. This is considered in more detail for Spain in a case study in Section 4.2.3.

[32] European Alternative Fuels Observatory (EAFO): EV Market Share of New Registrations (M1)

3.3 Implications for CO_2 Emissions of New Cars

In this sub-section, the carbon cost of different vehicle powertrains is discussed and how different BEV uptake scenarios impact the rate of tailpipe CO_2 emissions reductions between 2020-30. Please note that no emissions from the vehicle manufacturing supply chain or the production and supply of fuel and electricity are included in the results. This is in line with the scope of the report, which focuses on EU manufacturer regulation and CO_2 emission targets, but lifecycle emissions are an essential part of wider debate.

3.3.1 Powertrain Landscape

Figure 25 compares the Lifetime TCO savings vs Petrol ICEs (y axis) and the total WLTP tailpipe CO_2 saving vs. 2020 baseline (x axis) across different powertrains for a medium car bought new in 2020. BEVs provide considerable CO_2 savings while driving lifetime financial value for consumers. PHEVs provide significant risk, and only provide value to consumers who can charge their vehicle regularly and maximise the distance driven in electric mode - this is discussed in Section 4.2.2. While Fuel Cells (H2) drive carbon savings, but they do not currently offer strong financial value to consumers.

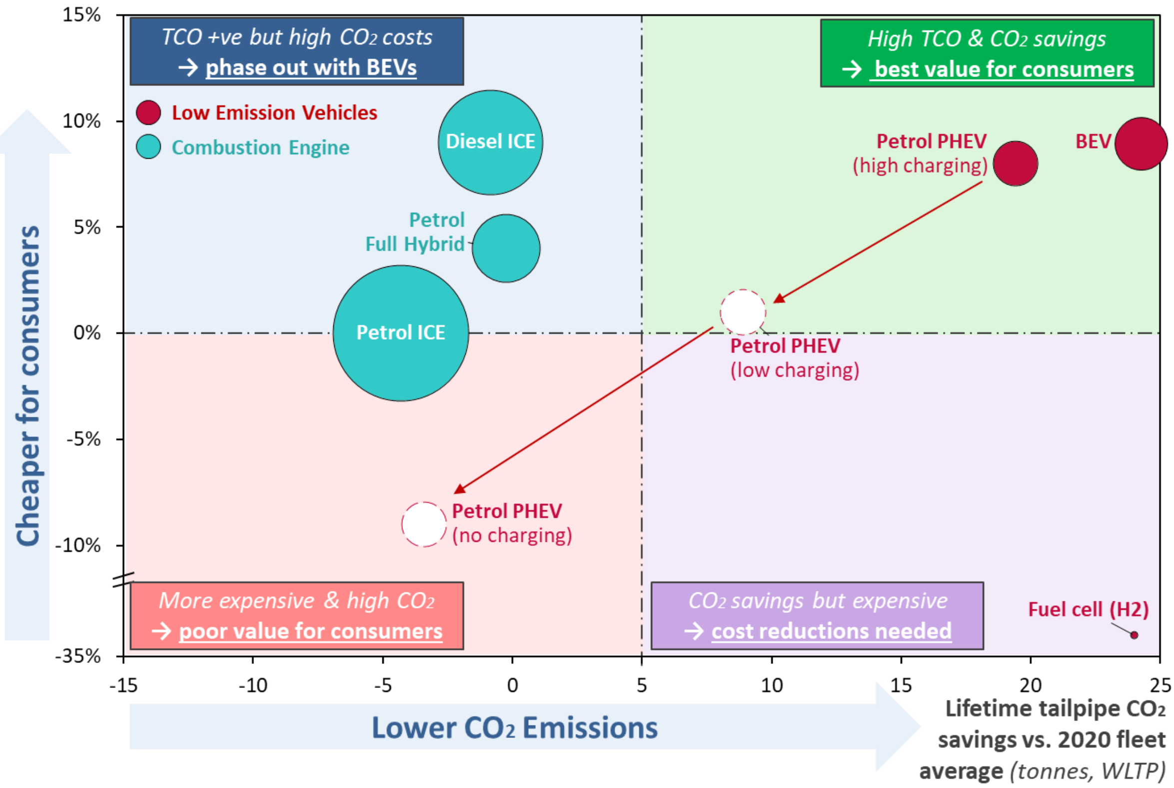

Figure 25: lifetime TCO savings over a Petrol ICE and total lifetime WLTP tailpipe CO_2 savings vs. 2020 baseline (125gCO_2/km) per vehicle for a medium car bought new in 2020. Bubble size represent current share of sales in 2020.

3.3.2 BEV Uptake Scenarios

Figure 26 shows projected WLTP passenger car fleet average tailpipe CO_2 emissions under 4 scenarios where BEV sales reach 40%, 60% & 80% (and Status Quo - 6% BEV) by 2030 while ICEVs show further incremental improvements and PHEVs play a limited role[33]. These are compared to a

[33] PHEVs reach a peak of 18% new sales share in 2026 before declining in 60% BEV uptake scenario

109gCO_2/km EU target (using ICCT conversion to WLTP[34]) in 2021, and further 15% and 37.5% reductions by 2025 and 2030 respectively. This shows that (even excluding additional credits for the sale of zero or low emission vehicles) 2025 & 2030 emissions targets would be easily achieved even by the lowest 40% BEV uptake scenario, and that these targets would need to be significantly tightened to stimulate higher BEV sales. Bearing in mind that BEVs bought new today already provide almost €9,000 TCO savings over Petrol ICEs for their eventual used owners, stringent OEM emissions targets must ensure sufficient supply of BEV to allow consumers to benefit from the cost and emissions savings.

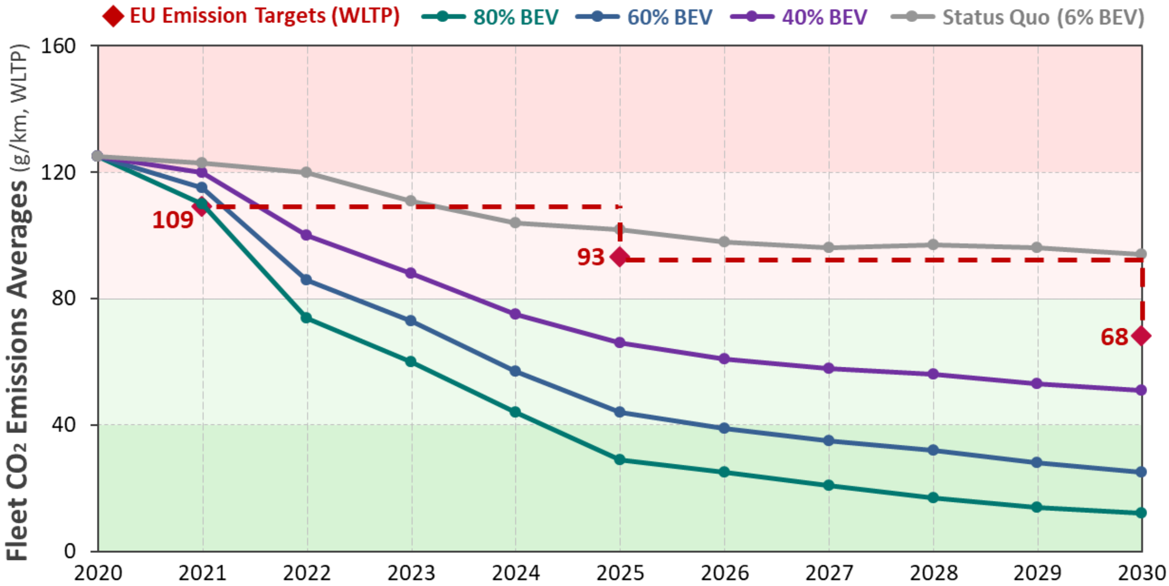

Figure 26: new fleet WLTP CO_2 tailpipe emissions for BEV scenarios compared to current EU targets

Figure 27 shows the breakdown in terms of the drivers of average tailpipe CO_2 emission reductions per km for the 60% BEV uptake scenario by 2030. This scenario is favoured due to the environmental and financial benefits brought about by early uptake (discussed further on the next page). BEV growth is responsible for a 74gCO_2/km reduction, by far the most substantial decrease, with PHEV and Fuel cell uptake reducing emissions by an additional 18gCO_2/km. Fuel efficiency improvement across ICEVs, contribute only to around a 7gCO_2/km reduction. This highlights the crucial role fully electric cars will play in the decarbonisation of the EU's car fleet and shows again the importance of enabling and driving the adoption of BEVs as quickly as possible.

[34] x1.15 conversion factor from NEDC emission targets based on: https://theicct.org/sites/default/files/publications/ICCT_EU-CO2-stds_2020-30_brief_nov2016.pdf

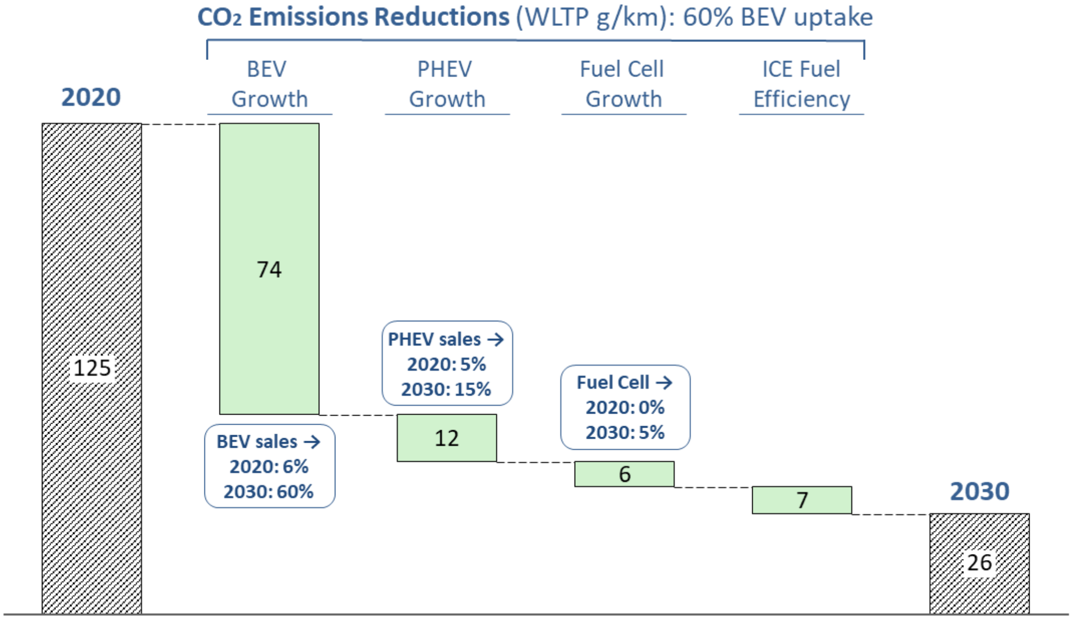

Figure 27: breakdown of WLTP tailpipe emission reductions (new cars) for 60% uptake by 2030

Focusing policy exclusively on long-term 2025 and 2030 targets, risks OEMs delaying BEV supply before peaking in these years to meet targets. Alongside EU-wide emission targets, national authorities thus play a key role in the coming years to favour early adoption via supportive financial measures. Two additional scenarios are modelled in Figure 28 to represent early and late BEV adoption, while still reaching 60% BEVs of total new sales by 2030.

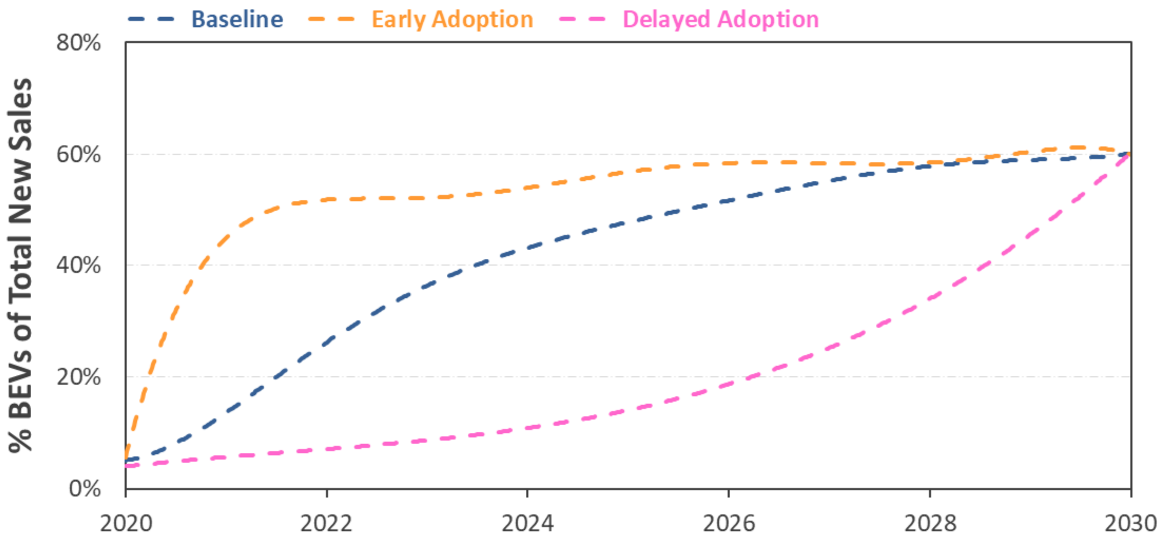

Figure 28: BEV share of total new sales for 60% uptake by 2030 for different adoption speeds

The impact on fleet emissions is shown in Figure 29 for different adoption speeds for a 60% BEV uptake by 2030. For the delayed adoption scenario, CO_2 emissions flat line between 2020-22 and drop significantly in 2028-30 to reach a 60% BEV uptake. In contrast, an early adoption strategy, representative of trends seen in markets such as Norway[35], is able to achieve over 50% reduction in total CO_2 emissions of new car sales by 2022. However, it should be noted that the early adoption scenario on an EU-wide level would be constrained by current BEV production limits.

[35]Norway had 51.6% BEVs of new car sales in 2020 according to the European Alternative Fuels Observatory (EAFO): EV Market Share of New Registrations (M1)

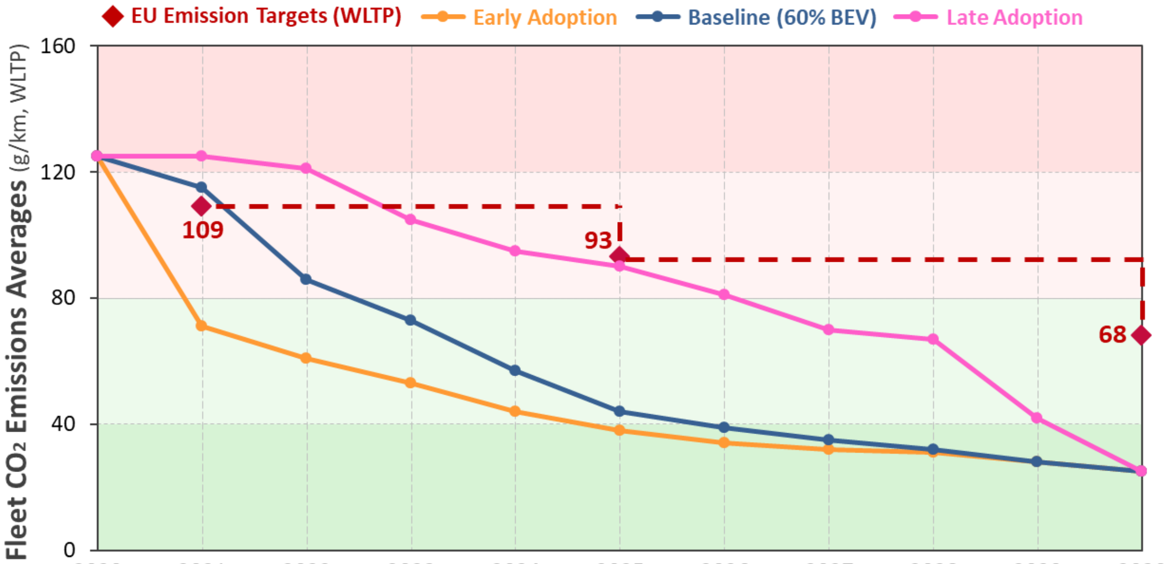

Figure 29: WLTP new car emissions for different adoption speeds for 60% BEV uptake by 2030

The relative speed of uptake has substantial consequences for the passenger car fleet make-up in 2030, with ICEVs remaining in the market stock much longer with later BEV adoption. In Figure 30, the reduction of total fleet CO_2 emissions (old and new passenger cars) is shown for 2030 under various uptake scenarios compared to 2020 levels. WLTP CO_2 tailpipe emission have been assumed, however, "real world" emissions are likely to be higher, underestimating the emission reductions achievable. Please note that we have assumed that European passenger car sales post-2021 return to 2019 levels and remain relatively flat between 2022-30. This shows that late adoption, with a 60% uptake by 2030, actually leads to a 4% lower decrease in the total 2030 fleet emissions than if only 40% BEVs was reached by 2030 but with a baseline uptake. Indeed, an 80% uptake by 2030 and a 60% uptake with early adoption both achieve above 50% total passenger car CO_2 reductions over the next 10 years. It is essential that EU targets, combined with effective national measures, reflect the fact that the earliness of BEV uptake is just as important as the final percentage of BEV sales reached by 2030.

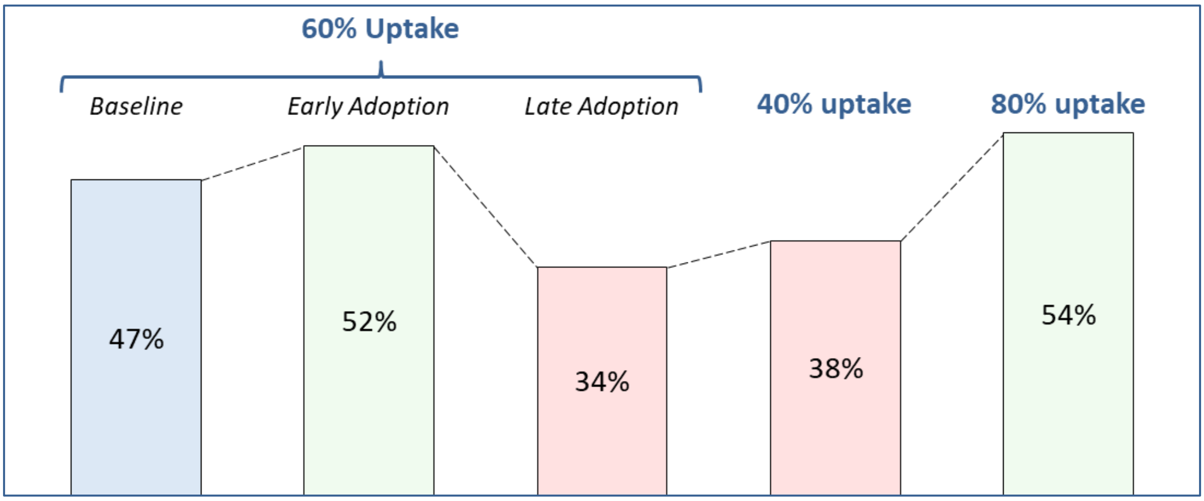

Figure 30: reduction in total fleet tailpipe CO_2 emissions in 2030 compared to 2020 levels

Another important criterion for considering in these scenarios is the additional cumulative tailpipe CO_2 emissions from passenger cars between 2020-30. Figure 31 shows the reduction from 2020 levels for different scenarios (excluding reduction in average annual mileages due to Covid 19). Here the risk of late adoption is particularly poignant, achieving only a 17% reduction in cumulative emissions, compared to almost a 28% reduction for the early adoption scenario. Indeed, on the basis of cumulative emissions, the early adoption scenario with 60% uptake in 2030 actually realises greater savings than the higher 80% scenario with a baseline uptake curve.

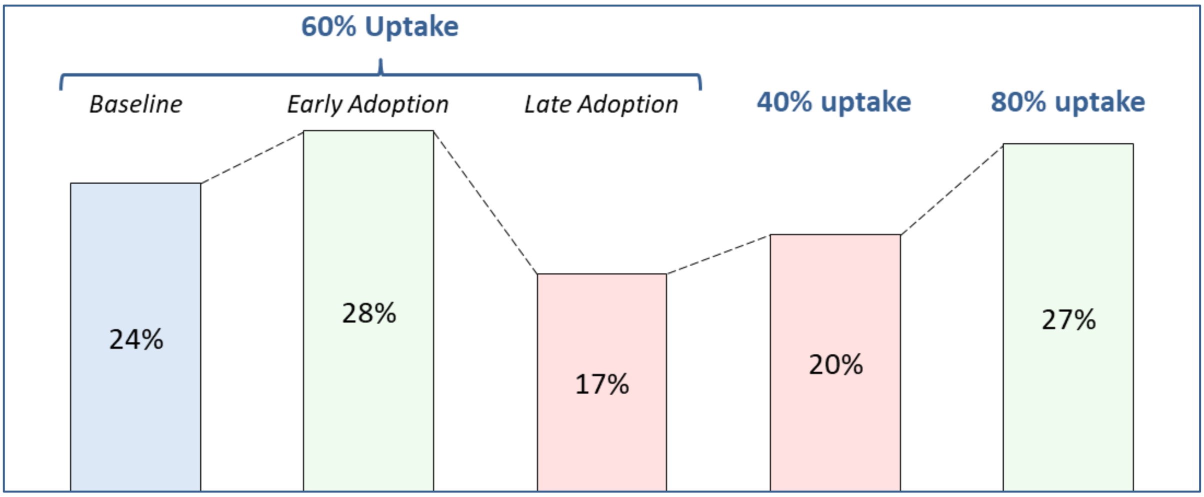

Figure 31: reduction in cumulative 2020-30 CO_2 tailpipe emissions compared to 2020 levels

3.4 Implications for Consumer Equality

Affluent user groups are much more likely to buy new cars, with less wealthy consumers buying used cars, which are cheaper due to lower depreciation costs. It is important to consider the impact that different powertrains have on overall market equity. **For this study, the equity index has been defined as the percentage of a vehicles' lifetime cost that is paid by the first owner**. Figure 32 shows that BEVs, which provide significantly better value than other powertrains for second-hand owners, drives the most market equity, with over 47% of lifetime costs paid by the first owner. Petrol HEVs and ICEs, which currently provide best value for first owners on a TCO basis, drive financial inequity, alongside having the highest CO_2 emissions and increasing air pollution, which disproportionately impacts urban areas that have higher proportions of less affluent user groups[36].

[36] Science for Environment Policy (2016): Links between noise and air pollution and socioeconomic status

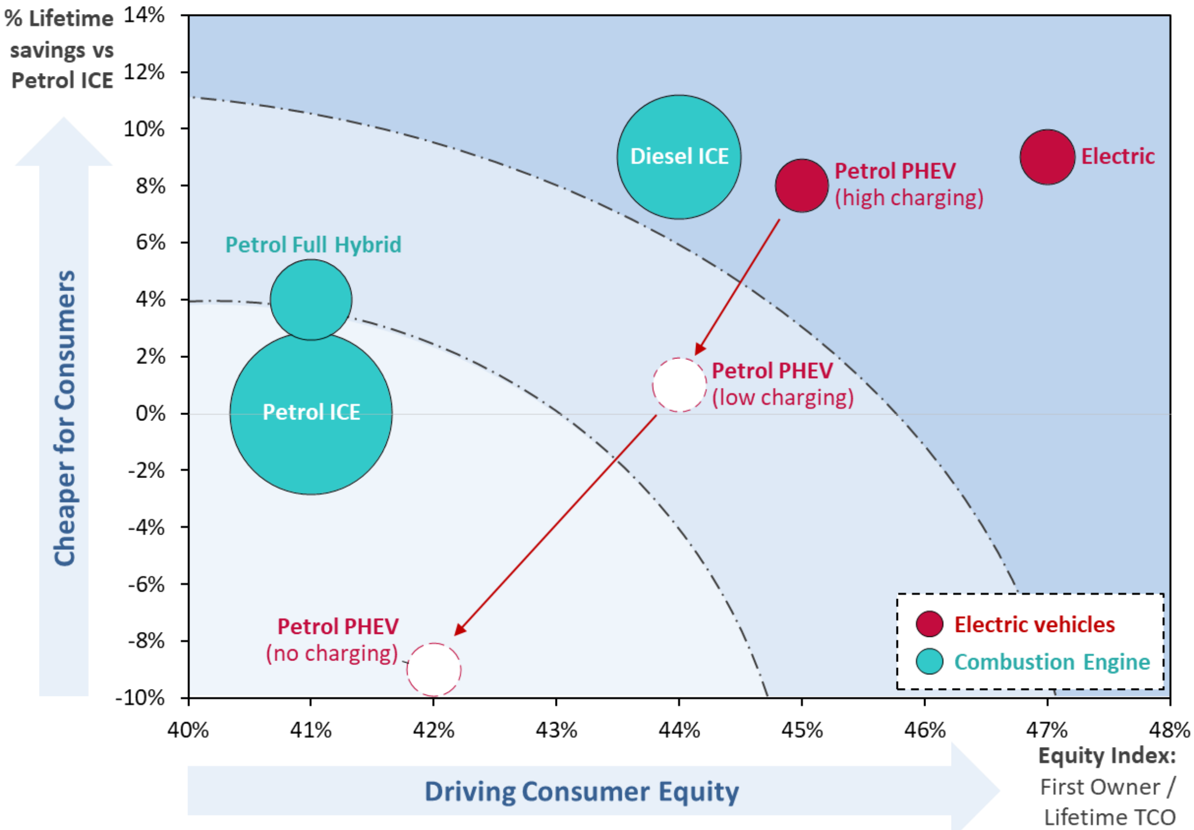

Figure 32: market equity and lifetime TCO savings vs. Petrol ICE for a medium car bought new in 2020 for different powertrains. Bubble size represents 2020 sales.

One of the major criticisms of BEVs is that purchase grants, which are required to drive first owner market uptake, in effect, subsidise only the most affluent users. However, as demonstrated in Figure 33, which shows the market equity index (first owner / lifetime TCO) for BEVs with different government purchase subsidies or tax breaks (for a country in line with EU average parameters), BEVs still drive higher market equity over their lifetime vs. Petrol ICEs even when they have a first owner purchase subsidy up to around €7,000; with only Germany (from the nine European markets in the project scope) exceeding this amount.

An alternative method of subsidising the uptake of BEVs is through annual tax breaks. This better maintains BEVs' equity advantage over other powertrains, as tax breaks apply to all users and not just to first owners. However, due to current limitations of supply within the BEV second-hand market, this impact is likely to be more limited in the short term. It is important for government to use a mix of subsidies and tax breaks to incentivise all users to switch to electric. With the prevalence of cheaper BEVs increasingly available to consumers, subsidies should have a maximum vehicle price limit to ensure that governments do not subsidise overly premium vehicles and, by focusing on mainstream models, maximise the number of consumers who can benefit from purchase incentives.

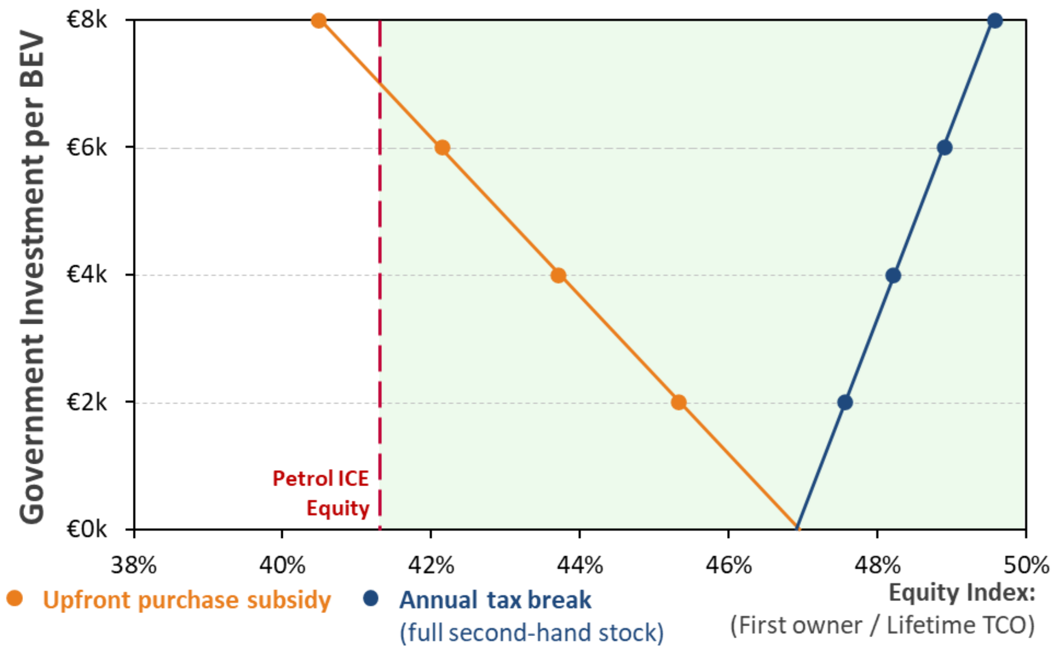

Figure 33: BEV equity index for a medium car bought new in 2020 and changes due to purchase subsidies and tax grants (for a country in line with EU average parameters)

Overall a major incentive to subsidise BEVs for consumers is to increase the second-hand market stock and unlock the substantial savings for less affluent consumers. As illustrated in Figure 34, for every medium BEV that is bought in 2020 instead of a Petrol ICE, the second and third owners will save almost €9,000 over the lifetime of the car. Tightening European emission standings thereby encouraging OEMs to promote earlier BEV adoption, will most benefit the least affluent consumers.

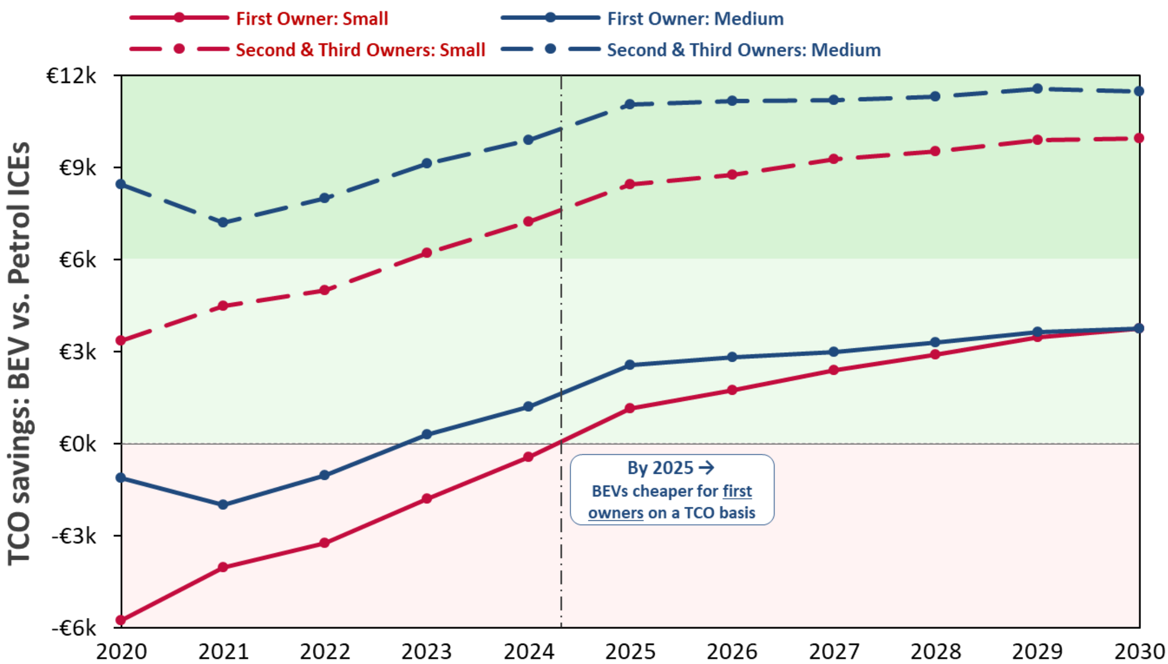

Figure 34: BEV lifetime TCO savings over a Petrol ICE for a medium car bought new by year

4 Sensitivities: Analysis of Specific User Groups

This Section looks at TCO sensitivities that explore different user groups of consumers where there may be opportunities for earlier adoption of BEVs, such as high mileage groups, or specific risks to consumer uptake of low emission vehicles, including consumers that rely on public charging tariffs.

4.1 Opportunities to Maximise TCO Savings Available from BEVs

The TCO results in Section 3 considered the financial and carbon savings from switching to a BEV for an "average consumer". However, TCOs depend largely on a specific consumer's driving requirements, and it is essential that consumers who benefit more from the decarbonisation transition, due to high mileages or being able to trade into smaller batteries, do not wait unnecessarily to replace their ICEV.

4.1.1 High Mileage Users

The top 25% of consumers with the highest annual mileages produce almost 50% of total CO_2 emissions, as shown in Figure 35, based on Ricardo-AEA data[37]. To ensure the greatest carbon reduction impact, it is essential high mileage user groups are early adopters of BEVs. This is particularly important where the supply of BEVs is limited. This must be supported by strong local policies, as seen in London, where a delicensing grant of up to £10,000 is offer to drivers of older taxis on top of the national grant (up to £7,500) to switch to Zero Emission Capable (ZEC) vehicles. Furthermore, Transport for London has not granted new licences to diesel taxis since 2018.

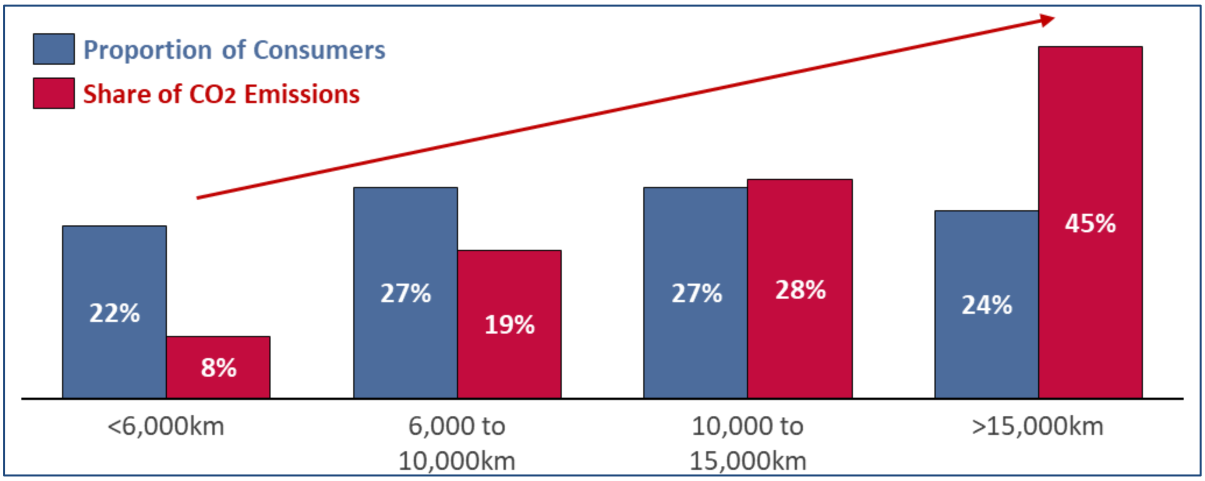

Figure 35: percentage of consumers and their share of total CO_2 tailpipe emissions by mileage band

Encouraging BEV uptake by high mileage consumers is particularly achievable as they unlock substantial TCO savings. The first owner TCO for BEVs relative to Petrol ICEs for different mileage consumer groups is shown in Figure 36. Company car owners, with an annual mileage of 38,400km[38], that buy a medium BEV today already access savings of over €6,000, which increases to almost €12,000 by 2030. A more moderate high usage scenario (20,000km) already results in BEV being cheaper for first owners compared to Petrol ICEs.

[37] Ricardo-AEA (2014): Improvements to the definition of lifetime mileage of light duty vehicles
[38] Mileage multiples of baseline from (2020) Data on Vehicle Mileage and Occupancy, Department of Transport, UK

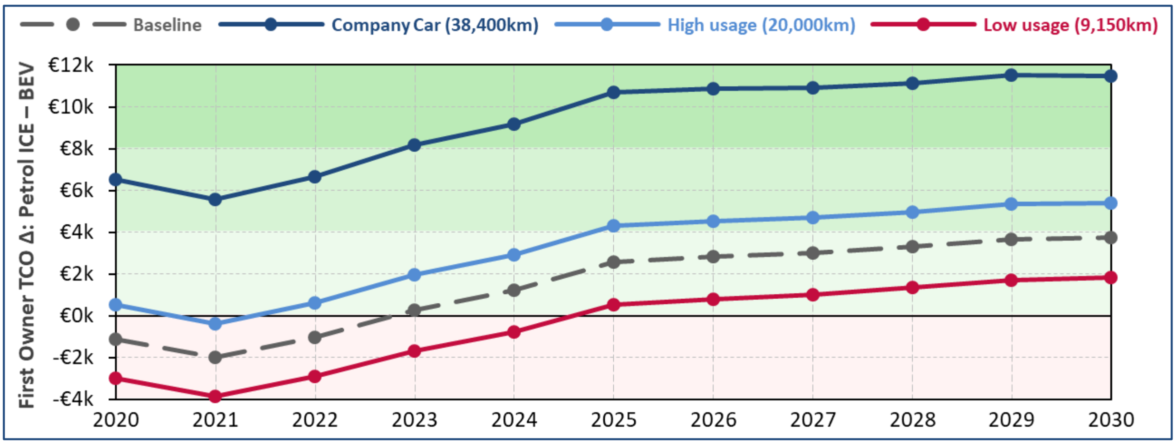

Figure 36: first owner Δ Petrol – BEV TCO for a medium car by mileage scenario

The full landscape of first owner TCO savings and carbon impact is shown for increasing mileages in Figure 38 on the following page. The % of consumers that fall into each mileage band and examples of users in each group are detailed. A user, with a 30,000km average annual mileage, that buys a BEV saves around €4,000 and reduces carbon emissions by 2.5 times that of an average consumer (with a baseline of 12,000km) that switches to Electric. A full-time taxi driver who has an average annual mileage of 50,000km, will have a CO_2 emissions of over 4 times an average consumer and will save €10,000 over a 4 year ownership, which may even be further increased by some European cities offering free public charging. It must be the first priority to encourage the highest mileage drivers to switch to BEVs and unlock the most financial savings while bringing about the fastest reduction to CO_2 emissions. High range BEVs, such as the 77kWh VW ID.3, with a WLTP range of 550km[39], are now meeting the driving needs of high mileage consumers at an affordable price (discussed further in Section 4.1.2). However, additional investment into rapid charging infrastructure is essential to not discourage these users groups.

Figure 37 considers the reduction in new passenger car WLTP emissions for a 60% BEV uptake scenario, as discussed in Section 3.3.2. The baseline is compared to a scenario where the highest mileage users are the first consumers to switch to BEVs. This significantly impacts the rate of new fleet emission reductions, achieving a 75% decrease by 2024, a milestone not reached until 2028 for the baseline. This reinforces the impact of prioritising high mileage user groups to switch to electric.

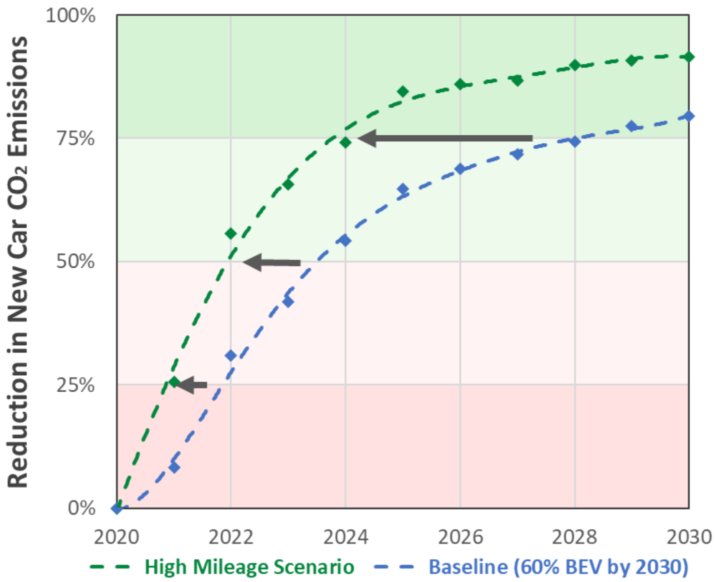

Figure 37: reductions in WLTP new fleet tailpipe CO_2 emissions for 60% BEV uptake by 2030

[39] https://www.volkswagen.co.uk/electric/electric-cars/id3.html

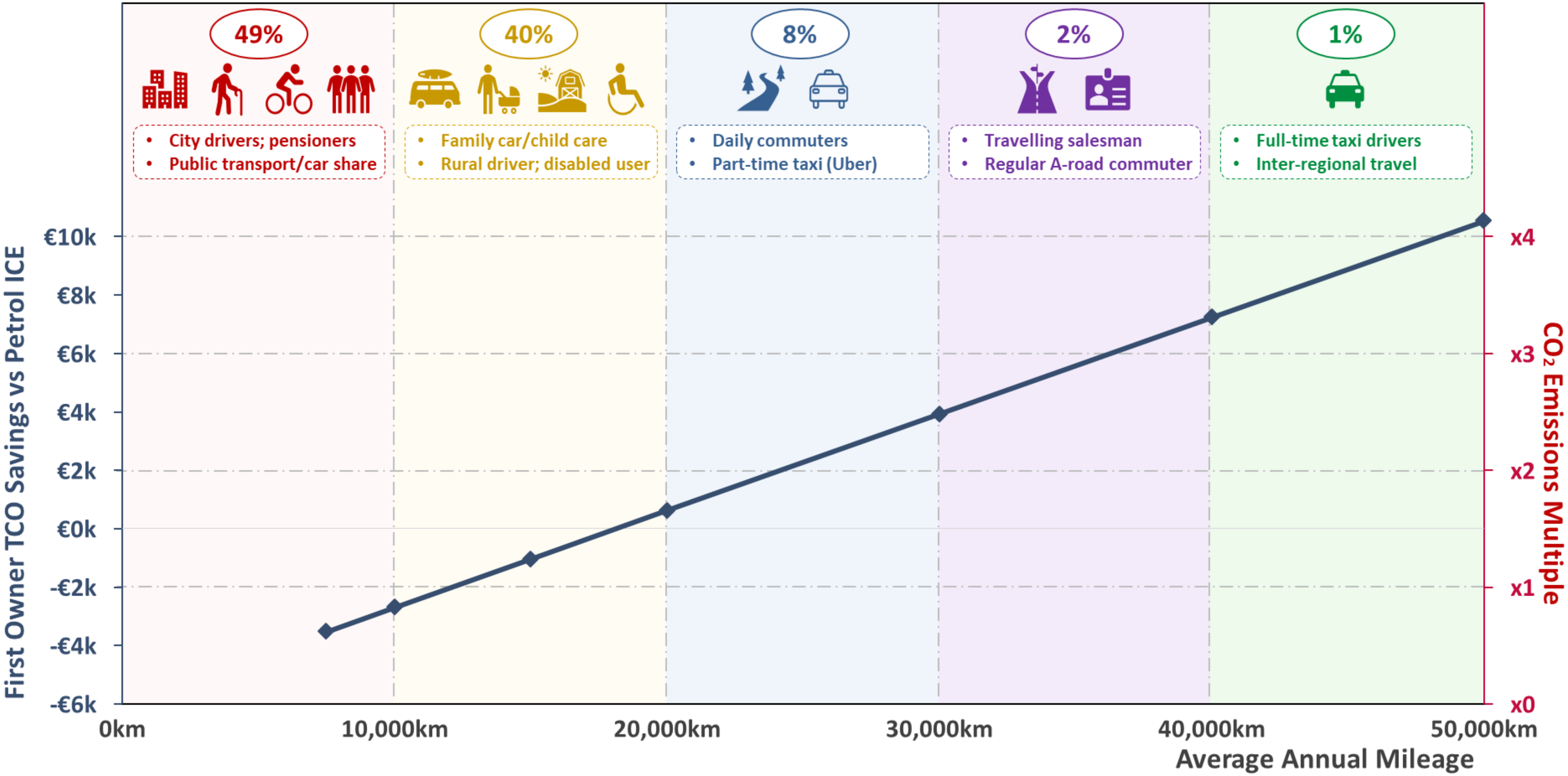

Figure 38: first owner TCO savings plotted against the multiple of tailpipe CO_2 emission reductions over an average consumer (12,000km) for a medium car bought new in 2020. The percentage of total consumers in each mileage band and representative user groups are shown at the top of the graph.

4.1.2 Battery Size Flexibility

One of the major advantages of BEVs is that they provide consumers with the additional flexibility to save cost by choosing a smaller battery with a lower maximum range. Consumers that purchase BEVs will be able to find the optimum balance between price and range, choosing a vehicle range to meet their own personal requirements and priced accordingly. This is already becoming a market reality, with the VW ID.3[40], which offers three battery sizes, with WLTP ranges from 330-550km.

A consumer choice study in Ireland by GreenCar[41] on 2,000 new car buyers estimated that, from a baseline of 70% of consumers buying BEVs if they had a 500km range and were at purchase price parity to Petrol ICEs, only 4% of consumers switched away when offered a BEV with a lower 400km range, which increased to 19% switching for a 200km range. These results indicate that (1) the current BEV range for Medium BEV, which is projected at 479km (WLTP) in 2021, is acceptable for vast majority of consumers (2) many consumers are still willing to buy an EV with a significantly lower range. Indeed, the Dacia Spring, with maximum WLTP range of 200km[42], entering the market in 2021 provides an example of OEMs tailoring new models for specific user groups (such as city/suburban drivers, pensioners, second car of a household).

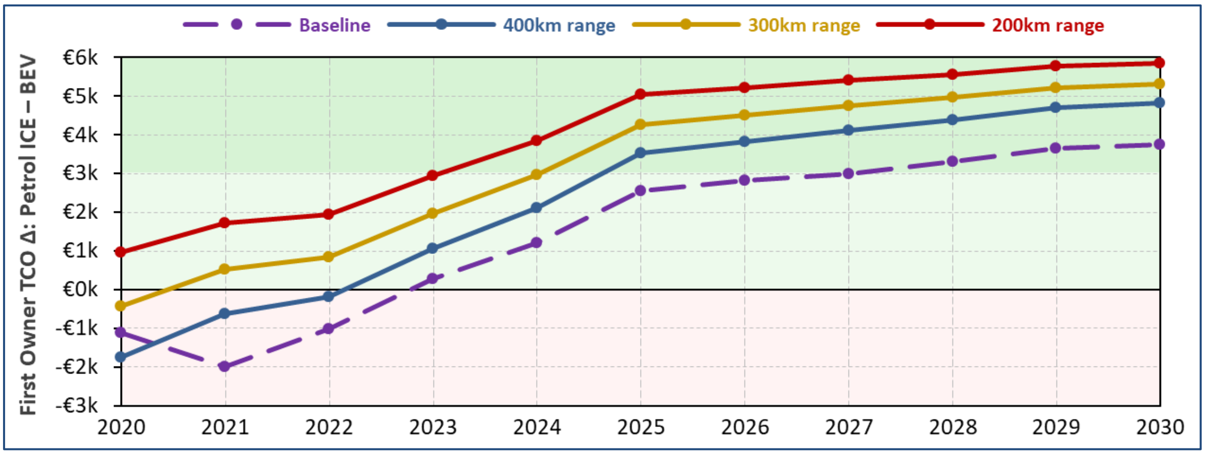

Figure 39: first owner Δ Petrol – BEV TCO for a medium car for smaller battery sizes. Baseline average annual mileage (15,000km) assumed for all scenarios.

Figure 39 shows the additional first owner TCO cost savings vs. Petrol ICEs available for consumers that do not require as high a maximum BEV range. Both the 200km and 300km range batteries are cheaper on a TCO basis by 2021, showing the potential uptake of electric cars in lower mileage consumers if more models were deployed by car manufacturers. Upfront BEV purchase price savings vs. the baseline case for the battery scenarios in 2021, based on varying maximum range, are provided in Table 1.

Table 1: forecast BEV purchase price savings (excluding VAT) in 2021 for lower maximum range batteries[43]

Baseline (479km)	400km	300km	200km
-	€1,350	€2,450	€3,650

[40] https://www.volkswagen.co.uk/electric/electric-cars/id3.html
[41] GreenCar (2020) EV Labelling: what Types of Information will Increase the Switch?
[42] https://press.dacia.co.uk/en-gb/releases/264
[43] Element Energy Cost and Performance estimates

The most important criteria, except cost, when consumers select a battery size is the number of days each year that they are likely to exceed the BEV's maximum range and need to rely on en-route charging. Research from Plotz et. al[44] shows that daily driving distance distribution is correlated to drivers' average annual mileage. We have modelled a log-normal distribution, based on data from the German Mobility Panel[45], to predict the spread of consumers' daily driving distances with different average annual mileages and estimated the proportion of drivers that fall into each mileage band based on Ricardo-AEA data gathering[46]. From this analysis, we have predicted the number of days a BEV driver will, on average, exceed their maximum WLTP range each year for different battery sizes and require en-route charging[47]. Drivers are assumed to fully charge BEVs once per day. The underlying probability density functions for each battery scenario are shown in Appendix 6.4.

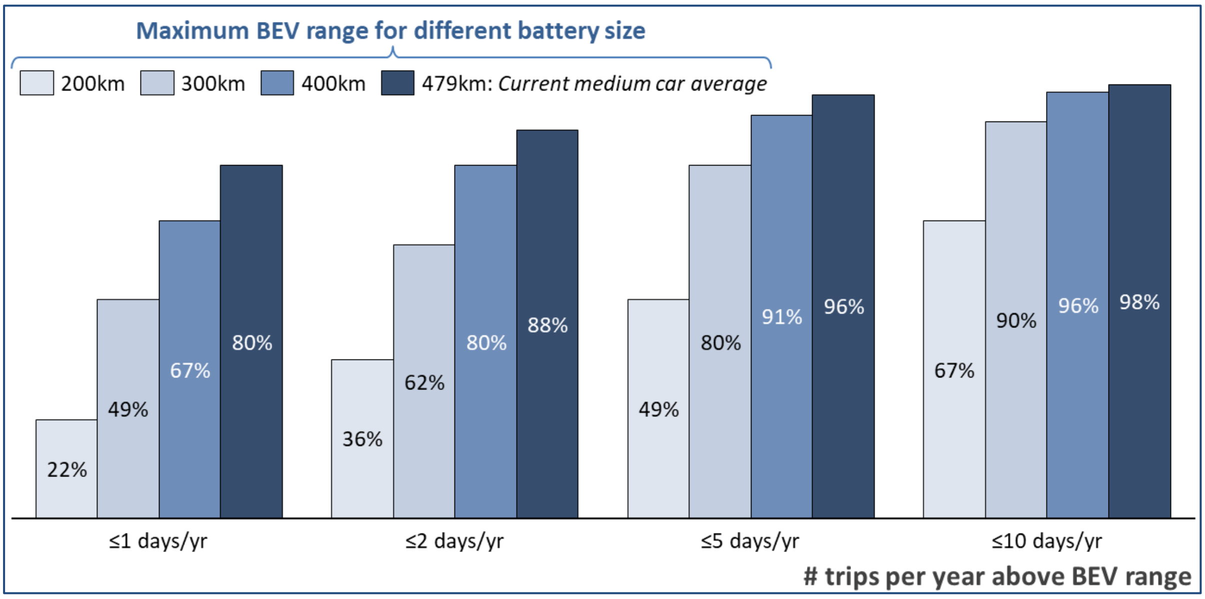

Figure 40: estimated days that consumers surpass their maximum BEV WLTP range for different battery range scenarios

Figure 40 illustrates, across different battery range scenarios, the proportion of consumers that are likely to need to use en-route charging no more than a certain number of days each year. For the 200km battery scenario, 22% of drivers will on average require an en-route charging session on no more than one day per year, and 49% will exceed their maximum driving range less than five times a year, which shows that smaller batteries are suitable for the needs of many consumers. Only 2% of drivers are likely to exceed the baseline range (479km) on more than 10 days each year. Investment in rapid charging infrastructure and greater charging power will encourage consumers to trade down into smaller batteries, unlocking further cost savings while providing additional emissions reductions from lower demand of the raw materials used within battery production.

The average number of times a driver is likely to exceed their maximum range a year for each battery size scenario is shown across a full distribution of average annual mileages in Figure 41. Different specific user groups are likely best suited by different battery sizes, for example, a full-time taxi driver will likely need a long-range BEV, as shown with the example of the Tesla Model 3: Long Range. However, the needs of many lower mileage consumers would be met by a 200km range battery.

[44] Plotz et al. (2017) On the Distribution of Individual Daily Driving Distances
[45]MOP (2010) Mobilitätspanel Deutschland 1994–2010
[46]Ricardo-AEA (2014): Improvements to the definition of lifetime mileage of light duty vehicles
[47]Note that "real world" ranges have been estimated to be up to 25% lower than WLTP figures, which may increase yearly en-route charging stops required

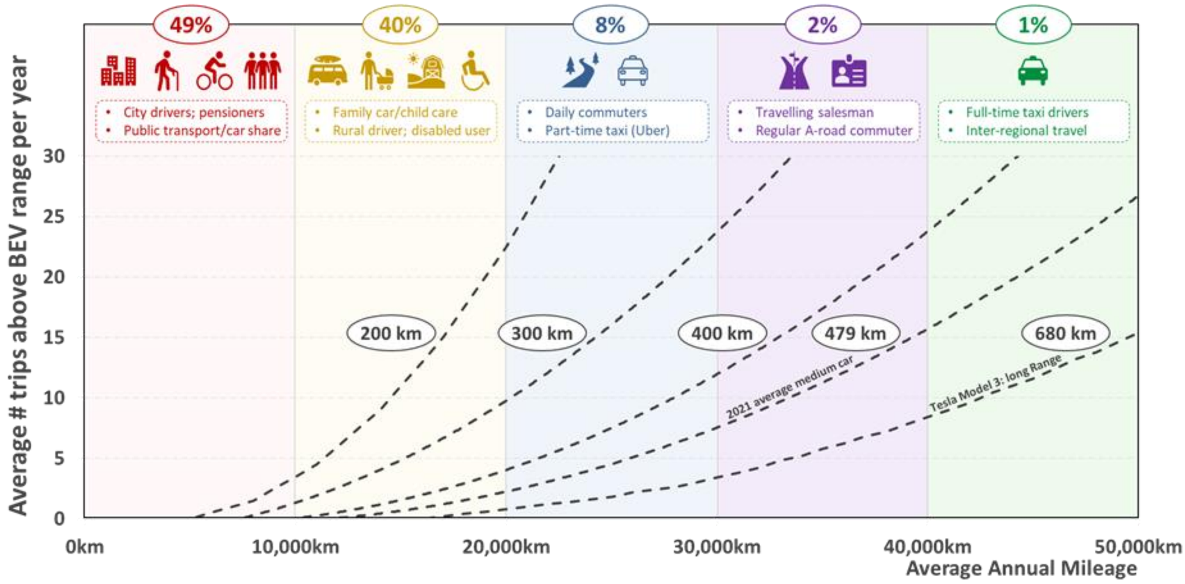

Figure 41: average number of days per year a BEV driver will exceed maximum WLTP range and require an additional en-route charge across different battery size scenarios. Bubbles at the top of the chart show the proportion of consumers in each mileage band and representative user groups.

Consumers should think in terms of the cost savings per additional trip each year that they are likely to use en-route public charging. In 2021, an average medium car first owner with a 15,000km annual mileage could save €2,450 (excluding VAT) off the purchase cost by choosing a smaller 300km range battery and would only need to use en-route charging an additional 3 times per year (vs. medium car with WLTP range of 479km

4.2 Risk to Consumer Benefits within the Decarbonisation Transition

This section considered different risk factors that might impact or delay unlocking consumer benefits through BEVs. These includes: (1) an analysis of the risk profiles from ICE and hybrid powertrains to future consumers, with a deep-dive on the impact of PHEV charging behaviour (2) additional costs for consumers that rely on public charging tariffs and (3) consumer risk from scaled E-fuel investment.

4.2.1 Overview of the Risks from Non-Electric Powertrains

At an EU-level, BEVs become the cheapest powertrain on a lifetime TCO basis in 2020 for medium cars, with small & large vehicles following in 2023 and 2025 respectively. Any other powertrain bought subsequently poses both a financial and carbon risk to consumers. In Figure 42, the relative severity of the impact a medium non-BEVs bought new in 2025 has on consumers is shown for different powertrains. Petrol HEVs and Petrol & Diesel ICEs pose similar risk, with high CO_2 emissions and cost between 12-19% more than BEVs on a lifetime basis. The risk profile of PHEVs varies drastically with consumer charging access, amplified by the uncertainty and the variable nature of driving behaviour. PHEVs that are not charged become the most damaging powertrain to consumers. This is particularly important for second and third owners, who are less likely to have access to off-street parking and therefore home charging due to living in more densely populated areas, and will be more impacted by significantly higher running costs, providing an additional risk to consumer equity. Furthermore, policy makers have little control over PHEV charging after the vehicle is purchased.

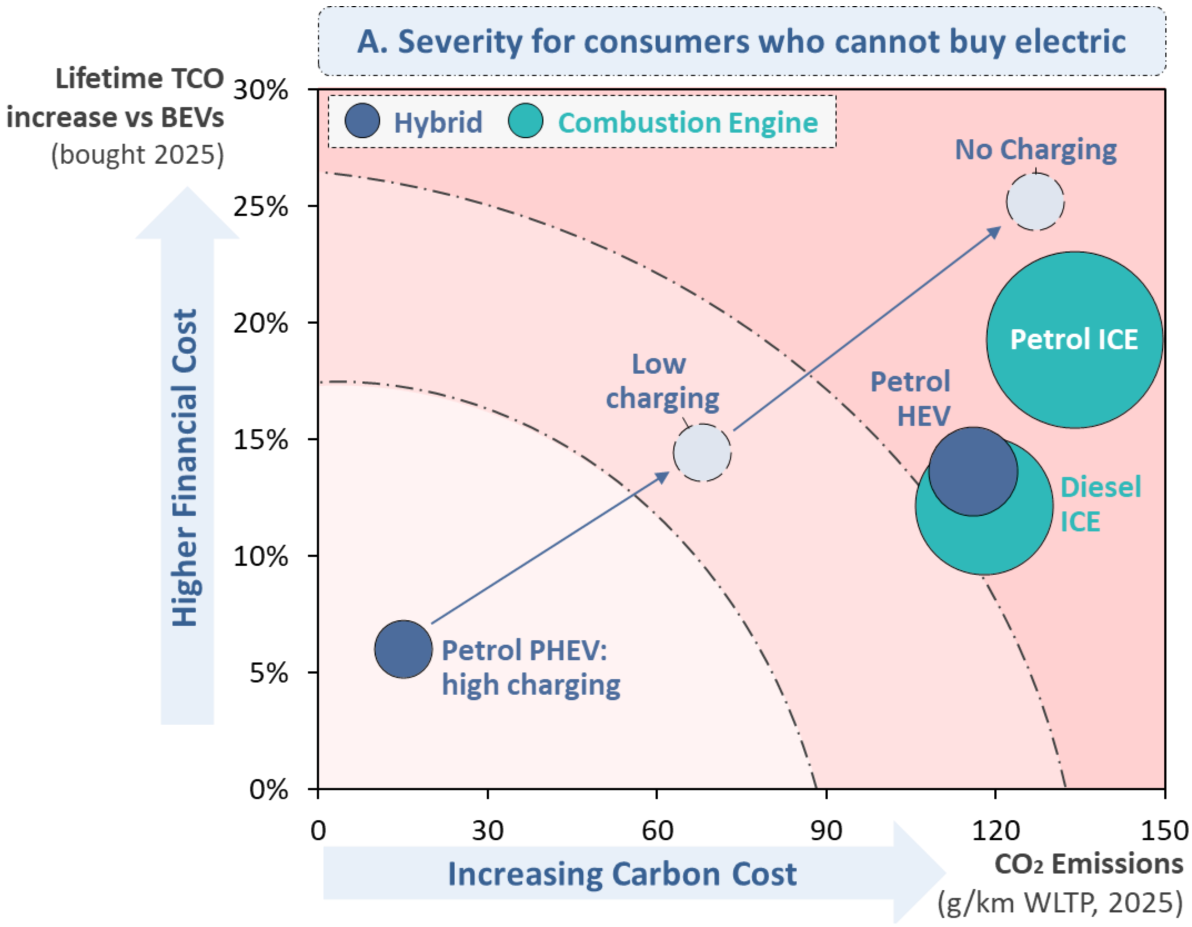

Figure 42: relative financial and carbon risks to consumers for a medium car bought new in 2025. Bubble size represents current share of total European passenger car registrations.

OEM supply of BEVs is essential to mitigating risks to consumers from non-electric powertrains after 2025. The likelihood of additional sales growth for each non-electric powertrain is shown in Figure 43, based on the current 2019-20 growth trajectory[48], alongside the relative value for first owners in 2025, who will dictate the market stock and availability of different powertrains for second and third owners. Hybrids provide significant risk of growth, with HEVs gaining +6% additional market share in 2020 and providing the best value to first owners, in 2025 on a TCO basis after BEVs. HEV growth would lead to long-term CO_2 emissions and greater financial costs, especially for second and third owners. While Petrol and Diesel ICEs represent the largest powertrains, their likelihood of growth is much more limited.

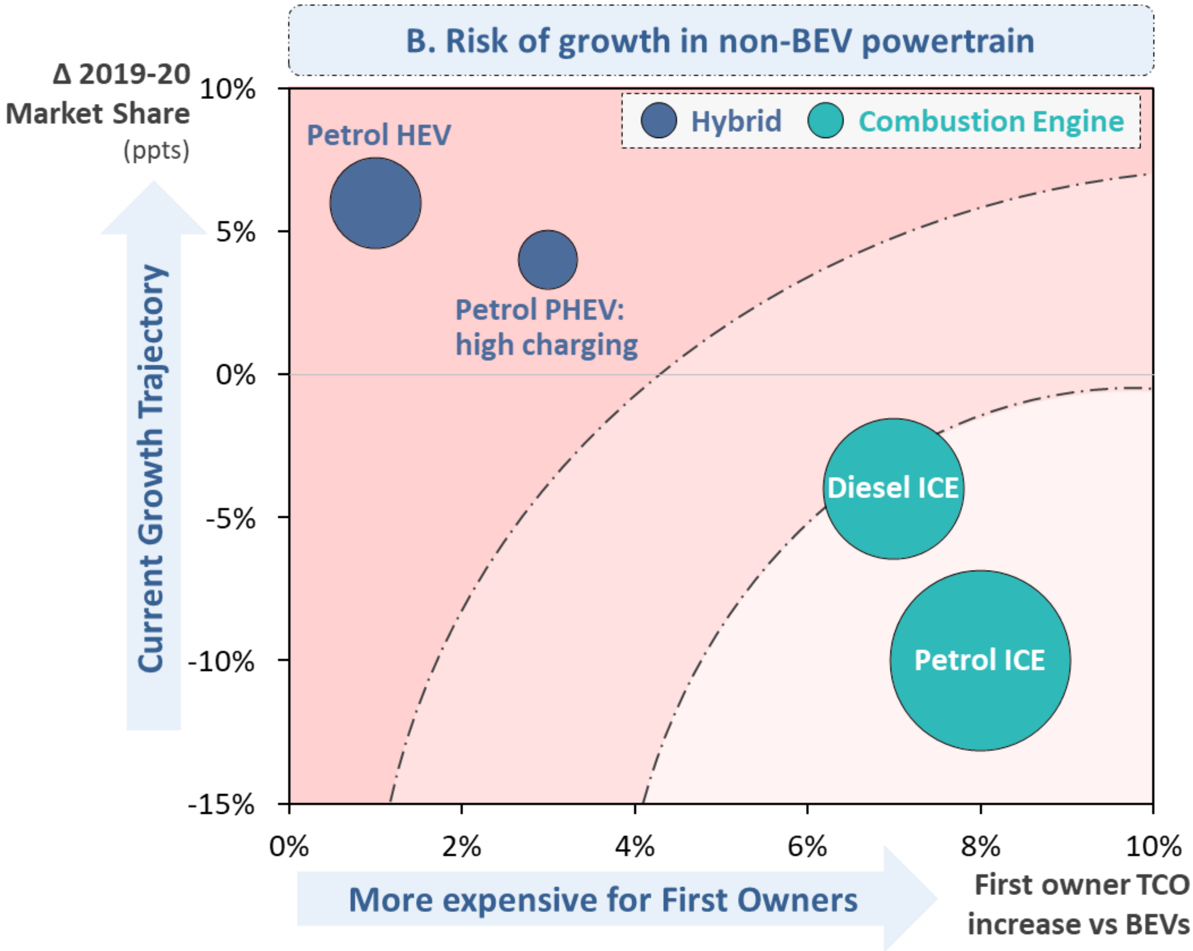

Figure 43: likelihood of growth in non-BEV powertrain for medium cars. Bubble size represents current share of total European passenger car registrations.

Figure 44 quantifies the overall risk to consumers, combining severity and likelihood of growth. Petrol HEVs provide the largest future risk to consumers, which have a significant probability of market growth and impose high carbon costs and TCO premiums on consumers over their lifetime. This is reinforced by OEMs continuing to market HEVs using misleading terms, including "self-charging" and "charging without the plug". It is essential for regulators to ban advertising that mislead consumers into believing that HEV and PHEV might offer the cost and emissions saving of a BEV without the range drawbacks. It is estimated that 75% of consumers are not clear about the differences between a BEV and hybrids [49], and it is becoming increasingly essential to educate consumers about the financial and carbon costs as a result of buying a Petrol HEV instead of a BEV.

[48] ACEA (2020) New Passenger Car Registrations By Fuel Type in the European Union
[49] Ford (2020) Go Electric Consumer Survey: 2,000 UK-based participants

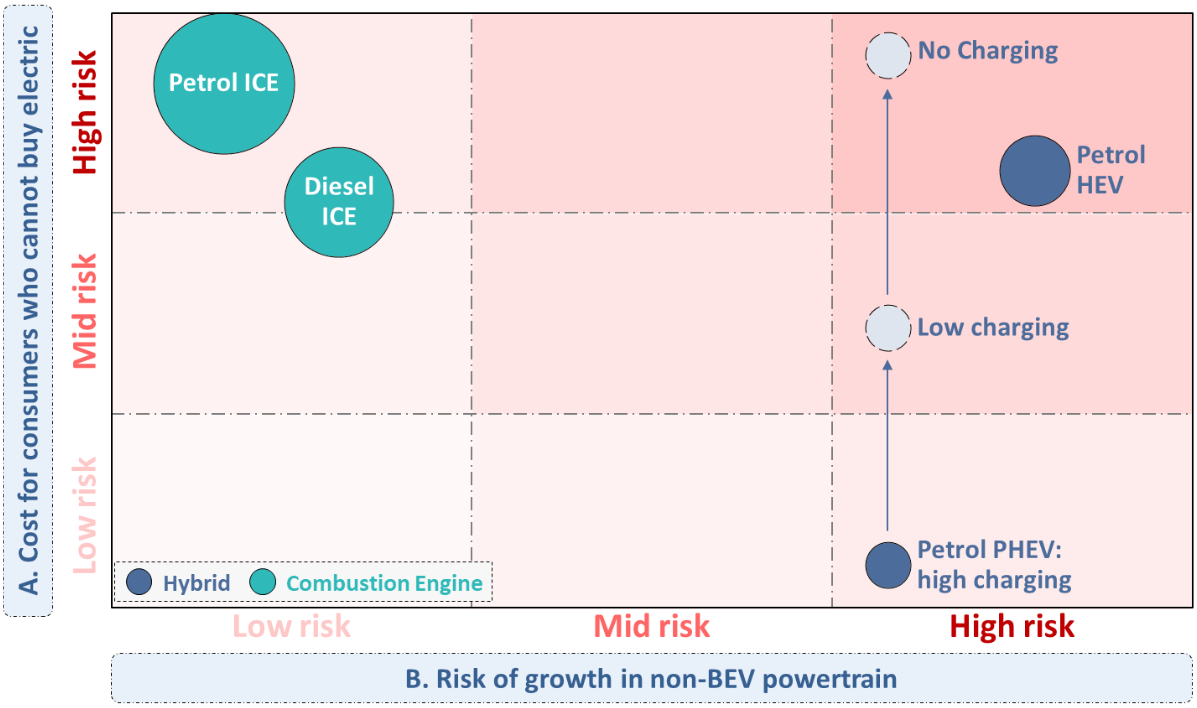

Figure 44: overall risk assessment of non-BEV powertrain uptake in 2025 for a medium car. Bubble size represents current share of total European passenger car registrations

4.2.2 Risks associated with PHEV Charging Behaviour

The lifetime TCOs of PHEVs relative to BEVs is shown for different charging behaviour scenarios in Figure 45. Even under high charging, which requires full charging at least once per day, PHEVs are more expensive than BEVs in 2020, which increases to almost 10% more expensive when bought new in 2030. These additional costs escalate significantly with lower charging, with PHEVs being 17% and 27% more expensive than BEVs in 2030 for low and no charging respectively. This is due to the additional upfront cost of the battery and the high running costs of using petrol if not charged.

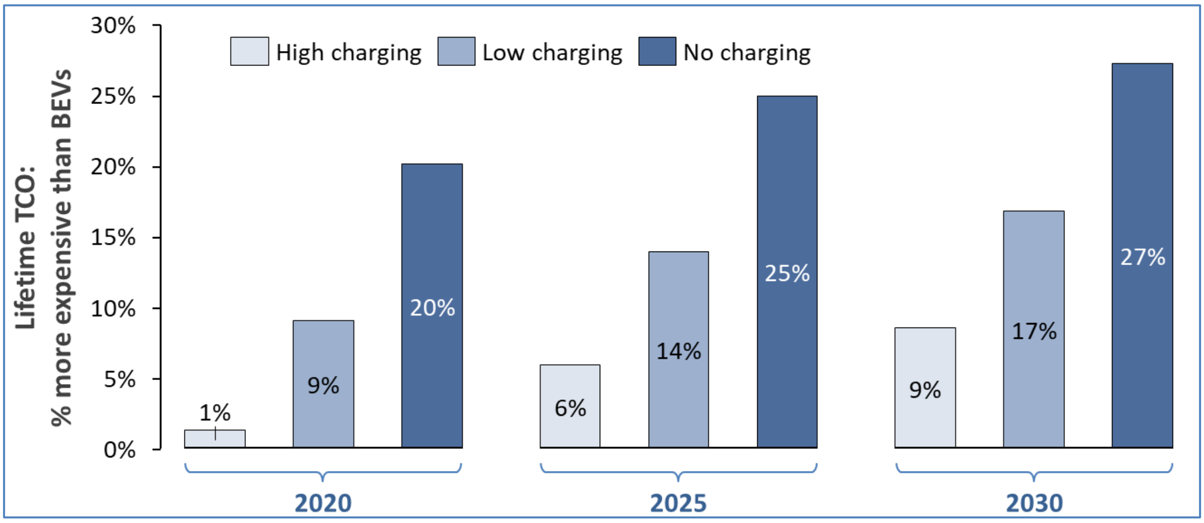

Figure 45: percentage higher lifetime TCO vs. BEVs for a new PHEV bought in 2020, 25 & 30

The reduction in new car WLTP CO_2 emissions for PHEVs vs. ICEVs reduces drastically with lower charging, as shown for different PHEV market shares, modelled for the 2020 new fleet, in Figure 46. Assuming an equal split between charging scenarios, which may be realistic in many markets, including

Belgium where no charging of company cars is a significant issue[50], only ~50% the projected WLTP CO_2 savings from PHEVs would be achieved. Each PHEV that is not charged in 2020 actually increases CO_2 emissions from current levels, due to lower fuel efficiencies than ICEVs. Given that it is impossible to ensure that PHEVs will only ever be used by consumers that have adequate charging access and that, even in the most optimistic charging scenario, PHEVs offer increasingly worse value to BEVs, it is critical to consider PHEVs as a risk to consumers rather than a "stepping stone" to fully electric vehicles.

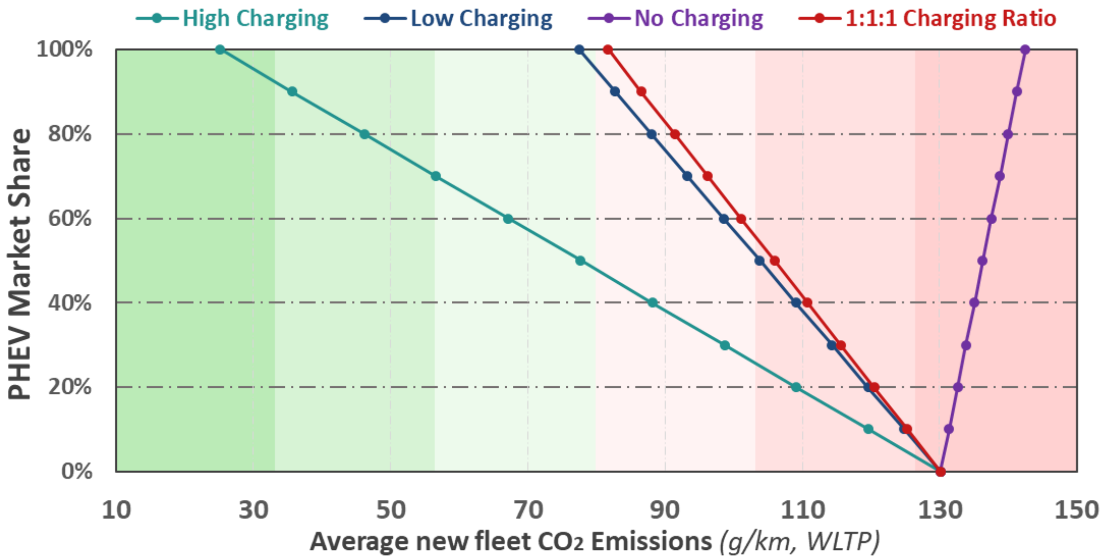

Figure 46: reduction to new fleet WLTP average tailpipe CO_2 emissions from 2020 levels with different market shares of medium PHEVs

4.2.3 Consumer using Off-peak and Public Charging Tariffs

Many consumers have access to overnight off-street parking and have the potential to access cheaper off-peak tariffs. For example, 75% of consumers in Germany are estimated to have access to off-street parking[51]. An off-peak scenario, assuming an electricity cost reduction from 0.21 to 0.10 €/kWh in 2020, has been modelled in Figure 47 and compared to sensitivities considering public charging scenarios [52].

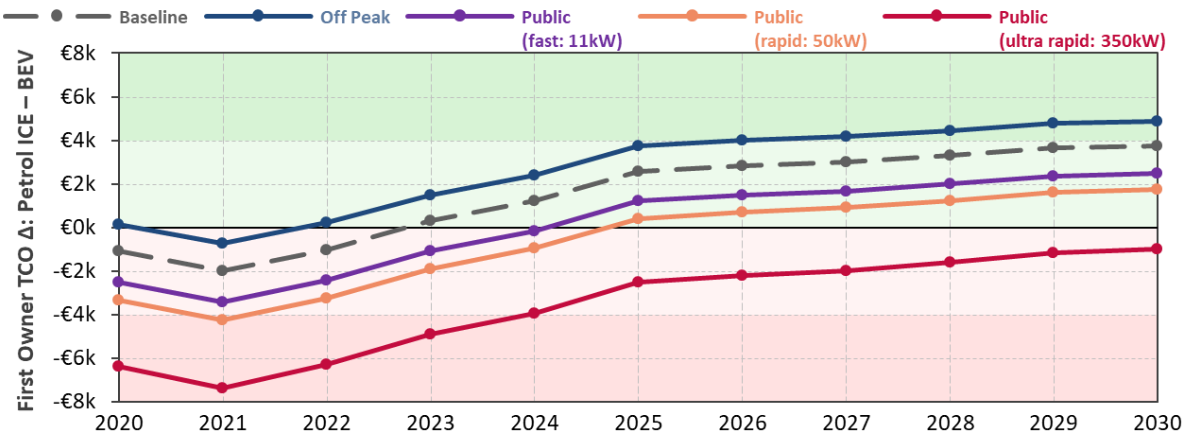

Figure 47: medium car first owner BEV – Petrol ICE TCO savings for different charging scenarios

[50] Based on discussions with market experts at Test-Achats and ACEA's data for 2020 showing that Belgium recorded 31 000 new PHEV sales (4th biggest market in EU27+EFTA): https://www.acea.be/uploads/press_releases_files/20210204_PRPC_fuel_Q4_2020_FINAL.pdf
[51] Dena (2020): Private Charging Infrastructure Potential in Germany
[52] Public charging tariffs based on an extensive Element Energy review of European markets. Prices of 0.33, 0.40 & 0.66 €/kWh are assumed for fast, rapid & ultra rapid charging respectively

For a medium BEV car, first owners with access to off-peak tariffs will already have a cheaper TCO compared to a Petrol ICE. These BEV owners can access savings of up to €4,000 over the first ownership period for vehicles bought new in 2025 vs. a Petrol ICE.

It is important to note that medium BEVs will become cheaper than Petrol ICEs by 2025 even for consumers that rely exclusively on rapid (50kW) public charging. This is particularly relevant in markets such as Spain, where it is estimated that only 35% of consumers have access to off-street parking[53]. Indeed, according to a consumer attitude survey by Transport & Environment (T&E)[54], 46% of respondents in Spain stated a main reason that their next car will not be an EV was due to lack of charging points, which compares to only 36% of consumers in France. Charging tariffs vary between countries, and estimations in Spain of €0.50-0.83 per kWh, by market experts at Organización de Consumidores y Usuarios (OCU), for rapid (50kW) public charging costs are significantly above comparable European markets.

There is evidence that lack of access to home charging and expensive public charging is already limiting BEV growth in Spain. Figure 48 plots the % BEV sales vs. Δ BEV – Petrol ICE first owner TCO costs for a weighted average of small and medium cars over the past five years. France has had a strong exponential uptake of BEVs as relative first owner TCO value over Petrol ICEs has increased, which has been driven recently by increased subsidies, whereas the trend in Spain has been much more linear. The current BEV mix of new sales in Spain is 7.1% lower than expected had it been following the uptake trajectory in France. This potentially shows the risk of subsidising BEVs without supporting consumers with the necessary infrastructure. However, it is also important to consider the impact of OEM supply, with historically only a limited range of BEV models have been made available for consumers by leading in-market brands such as SEAT.

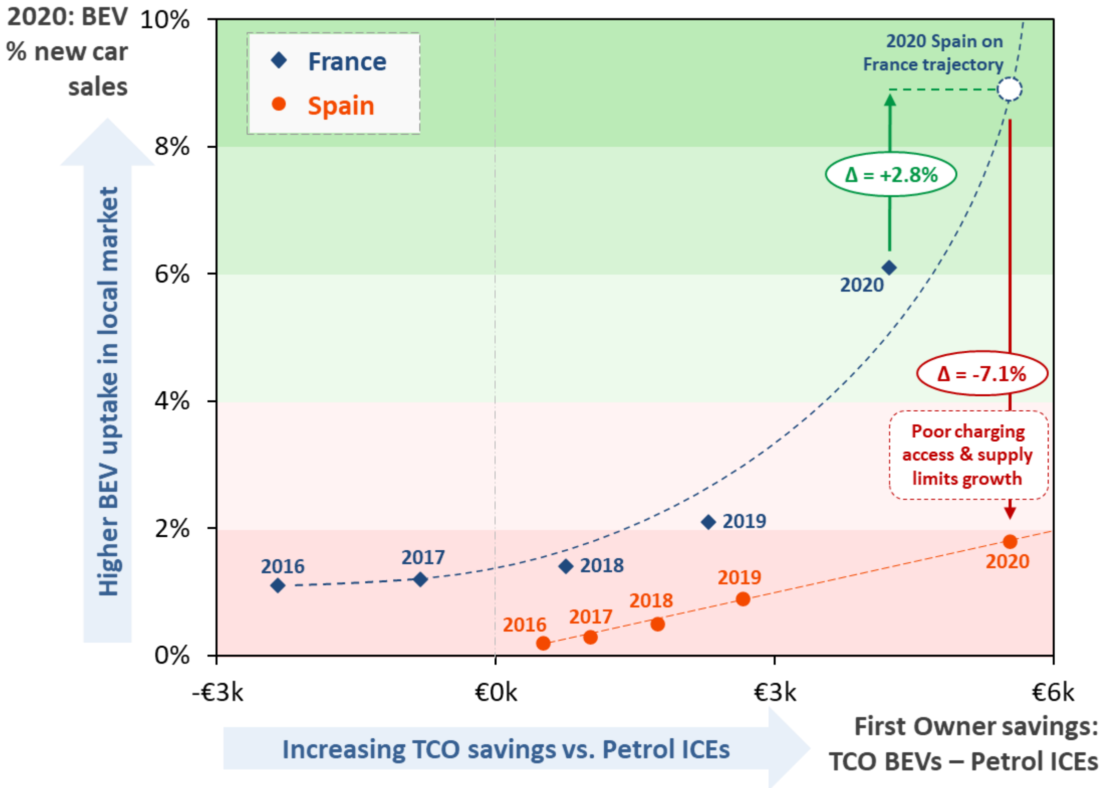

Figure 48: small & medium BEV 2020 market share vs BEV first owner Δ TCO to Petrol ICE

[53]https://www.idealista.com/news/inmobiliario/vivienda/2017/06/14/746871-solo-el-35-de-las-viviendas-en-venta-en-espana-tienen-plaza-de-garaje
[54]Transport and Environment (2018) Consumer attitudes to low and zero-emission cars

4.2.4 E-fuels

E-fuels present a significant financial risk to European consumers. Even based on the most optimistic projections, which relies on Middle East PV production with no additional fuel duty, E-fuels are currently 80% more expensive than petrol and do not reach price parity until 2037, E-fuel forecasting and assumptions shown in Appendix 6.5. The costs of E-fuels entering the market would be passed directly or indirectly (through government subsidisation) onto consumers, with no long term benefits emerging for European drivers.

Figure 49 shows that, on a lifetime TCO basis, E-fuels would be 20% more expensive than a medium BEV in 2020, which compares to 10% more expensive for a Petrol ICE. Even by the time the TCO for E-fuels is similar to that for petrol, for a vehicle lifetime between 2030-46, they remain 23% more expensive for consumers than buying a BEV.

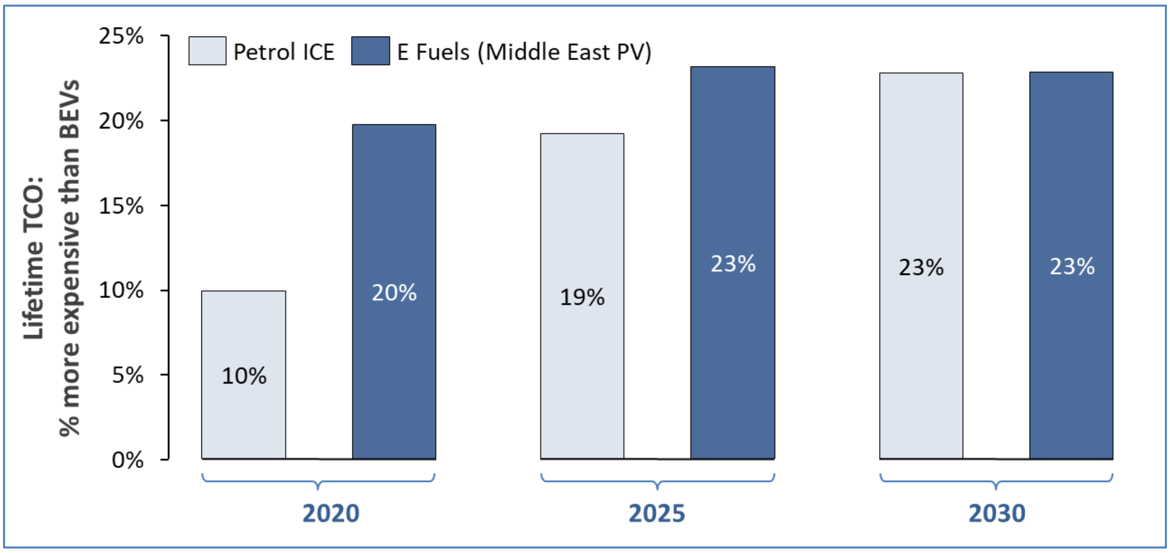

Figure 49: percentage higher lifetime TCO vs. BEVs for a new car bought in 2020, 25 & 30

On a first owner TCO basis, E-fuel cost parity to Petrol is not reached by 2030, as shown for a medium car in Figure 50, which provides a very strong barrier to market entry without significant subsidies. And even as E-fuels approach price parity to Petrol, BEVs offer significantly better long-term value for consumers. As reported by Transport & Environment (T&E)[55], Volkswagen Group, which has the largest market share in Europe, describes how the "so-called potential of these alternatives for liquid fuels is [...] massively overestimated," as well as “complex, cost-intensive, not very climate-efficient and with low efficiency.” It is essential that national & European investment and regulatory focus is not diverted away from securing BEV uptake across Europe and building the nessessary charging infrastructure, which is the clear path forward to reducing costs for consumers, while meeting net zero ambitions.

[55]https://www.transportenvironment.org/news/vw-breaks-german-auto-industry-over-efuels

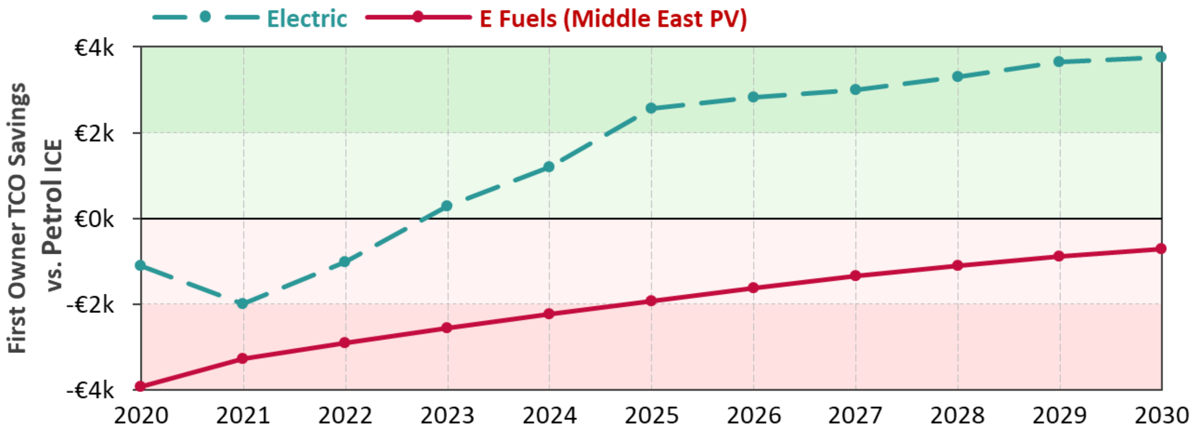

Figure 50: first owner TCOs savings vs. Petrol ICEs for a medium car. Note: E-fuel price forecasting is based on the most optimistic Middle East solar PV scenario & excludes fuel duty

4.2.5 Euro 7 Regulation

As shown in Figure 51, a two-year delay to Euro 7, which is forecast to come into the market between 2022-24, results in BEVs not reaching cost parity to Petrol ICEs until 2025. This would mean that governments would need to maintain first owner BEV subsidies for several years beyond currently forecast in order to drive necessary uptake. Preventing delays to Euro 7 is essential to share transition costs evenly between governments and OEMs and maximising the supply of BEVs in the market stock to unlock the substantial benefits to consumers in the used market. The health consequences of delaying Euro 7, which is essential to reducing air pollution, especially in local urban areas, would be highly damaging for consumers. BEVs will eventually become cheaper for first owners in 2026 for medium cars, even without Euro 7, however, this would lead to a much slower uptake of BEVs and would lead to additional long-term financial and pollution costs for consumers.

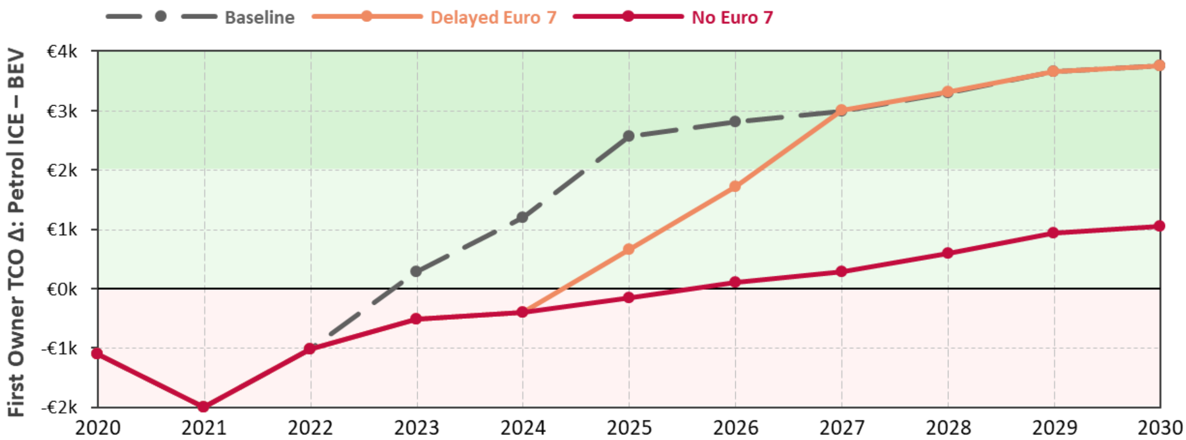

Figure 51: relative BEV first owner TCOs to Petrol ICEs for a medium car under Euro 7 scenarios. Note: a 2 year delay is modelled to Euro 7, which is forecast between 2022-24 for the baseline

5 Conclusions

This study has assessed forecast TCOs for different powertrain cars in Europe in the 2020s. We have used the latest evidence on trends in technology costs and efficiency improvements, and modelled different scenarios for a range of ownership costs to represent a variety of specific user groups. The results have wide-ranging implications for European consumers as well as policymakers responsible for leading the decarbonisation transition. The main implications of the TCO findings are summarised within 5 key themes below.

Affordable BEVs are just around the corner

BEVs are already the cheapest powertrain on a lifetime TCO basis for medium cars bought today, and will be for small & large cars in 2024 & 2026 respectively. Based on these forecasts, BEVs are likely to become the dominant powertrain for new car sales within the next decade. The transition to BEVs has the potential to rapidly reduce new car fleet emissions, while unlocking significant long-term savings for consumers.

With BEV TCOs increasingly no longer a barrier to consumer uptake, policymakers must focus on ensuring that BEV supply is sufficient to meet the needs of all consumers. While more mainstream BEVs are now entering the market, OEMs should make adequate investment to meet the required pace of the decarbonisation transition that they have previously failed to meet.

It is also essential that consumers are able to unlock the lifetime TCO savings available from BEVs through appropriate financing schemes, which allow consumers to spread higher depreciation costs over an entire ownership. Increased policy supervision may be required to ensure that consumers receive best value from financing schemes and are appropriately protected in a market that currently has limited regulation across many European countries.

BEVs bring most benefits to second and third owners

It is important that policymakers consider the significant benefits BEVs offer to less affluent consumers compared to other powertrains. A medium BEV bought new today will save almost a total of €9,000 for its second & third owners combined over a Petrol ICE and achieve reductions to CO_2 emissions, crucial for decarbonisation, while reducing the adverse health impacts from air pollution in urban areas. Tightening EU manufacturer emission standards and encouraging OEMs to sell more BEVs, will most benefit the least affluent consumers by increasing the available stock of used BEVs more quickly.

Maximising the opportunities for BEV uptake

High mileage drivers should be considered a top priority group to incentivise to switch to BEVs. This user group benefits the most financially from switching while also being the largest producer of CO_2. For example, a full-time taxi driver, with an average annual mileage of 50,000km, that switches from a medium Petrol ICE to a BEV, will save x4 times the CO_2 emission of an average consumer, as well as saving over €10,000 over the first ownership. By effectively targeting high mileage consumers, it would be possible to achieve up to a 75% reduction in new car fleet emissions by 2024 (based on a 60% BEV uptake by 2030) from 2020 levels. Particular focus on investment into en-route rapid charging infrastructure is an essential part of maximising the number of high mileage users that switch to BEVs over the next five years.

By giving consumers the confidence that they can access affordable and quick en-route charging, many drivers would have the possibility to trade down into smaller batteries and unlock considerable savings. For a smaller battery with a lower driving range of 300km (significantly below the 479km medium car average WLTP range in 2021), and assuming all drivers have access to reliable daily charging (home or public), 90% of drivers would require less than 10 public charging sessions (typically en-route) per year and would benefit from €2,450 savings (excluding VAT) in upfront costs vs. a BEV with the market average battery size (of 479km range). This shows that it is essential OEMs provide adequate supply of different battery sizes – and especially lower range models (200-300km range) – so that consumers can find the optimum balance between cost and flexibility. By encouraging the prevalence of smaller battery models through adequate charging infrastructure, additional emission savings will be achieved through reduced production of battery raw materials, while unlocking considerable TCO savings for consumers.

Access to cheaper off-peak charging tariffs has a significant impact on the savings available for consumers that switch to a BEV, this is especially important for used car buyers where running costs become the most important TCO cost component. Smart charging mechanisms (on both public and private charging points) to encourage consumers towards off-peak charging times will become increasing important through the decarbonisation transition in managing peak loads, while allowing consumers to access additional savings.

Mitigating the risks to BEV uptake

The TCO assessment completed shows that Full Hybrids risk becoming increasingly damaging to consumers over the next five years, both in terms of additional financial costs and locking in long term carbon emissions. This highlights the importance of ensuring that policymakers regulate misleading language, such as “self-charging”, and educate consumers about the differences between HEVs and BEVs.

PHEVs provide considerable risk to consumers as their value, in terms of TCO and carbon emissions, depends entirely on charging behaviour and access. Without any charging, PHEVs become financially the worst powertrain for consumers. For example, a medium sized PHEV bought new in 2020 that is never charged would cost around €15,000 more over its lifetime than a BEV (€7,500 more than a Petrol ICE) on a TCO basis. Given that charging behaviour is highly variable and is difficult to influence with policy (outside the company car context) once the vehicle is sold into the market, the role of PHEVs in the decarbonisation transition is limited. It is critical to consider PHEVs as a risk to consumers rather than a “stepping stone” to fully electric vehicles. Government investment and European policy is better targeted at ensuring the wide-spread uptake of BEVs.

Analysis completed sugggests that it is essential that investment into charging infrastrucure and BEV uptake is not diverted into E-fuels, which provides substantial short term cost and no clear long term benefits to passenger car consumers. In addition, policy makers should ensure that there are no delays to the introduction of Euro 7, which is crucial to reducing the impact of harmful emissions on local air quality, and would lead to governments needing to subsidise first owners for several years longer to ensure BEV growth.

The importance of European CO_2 emission standards and national supportive schemes

The analysis shows that upfront subsidies should continue in the short-term across European markets, with BEVs not becoming the cheapest powertrain for first owners until 2024-26 depending on car size. However, our analysis shows that, for a European country in line with the EU average, purchase subsidies could be phased out between 2022-26, with tax incentives no longer needed after 2030. It is important that governments do not continue to subsidise BEVs for first owners once the market reaches the stage where the vast majority of consumers would already choose to buy a BEV regardless of incentives being available. While subsidies remain, there is a risk that OEMs may keep BEV prices artificially high which would limit additional savings made available to consumers. A price limit for BEV grants can encourage OEMs to reach lower purchase price points and ensures that the grant is used by consumers that need it most.

It is important that national policymakers find a balance between encouraging earlier BEV adoption, while making sure that investment is spent where most needed in maximising electromobility, and, in particular, does not compromise the immediate roll out of charging infrastructure.

Evidence shows that in some European markets, such as Spain, there has been limited BEV growth despite high first owner TCO savings available for consumers, which is likely due to a lack of charging infrastructure. It is important that policymakers adjust charging strategies to meet the specific needs in their own countries, for example, with high variation seen in the percentage of consumers that have access to off-street charging in different European markets. Charging investment should also be tailored to the requirements of various socio-economic groups and acknowledge the differences in charging behaviour between first hand and user car buyers, with used car owner less likely to have off-street parking. A comprehensive and strategically located charging network offering attractive tariffs (which may include preferential pricing for frequent users, smart charging, EV charging linked to domestic electricity tariffs and roaming agreements with charging operators) is crucial to ensure drivers have confidence in publicly available infrastructure as this will encourage consumers to switch to BEVs more quickly.

Evidence presented within this report demonstrates that EU vehicle manufacturer CO_2 emission targets should be significantly tightened in order to achieve BEV growth necessary for strong decarbonisation. Achieving a 60% BEV share of new sales by 2030 would likely require 2030 CO_2 emission targets of 26gCO_2/km. Given a growing share of OEMs that have pledged to be fully BEV, including Ford which will only launch its first fully electric model in 2021[56], this indicative target should not be considered unfairly ambitious for OEMs.

The analysis completed shows that it is essential targets do not focus exclusively on a 2030 uptake percentage. Scenario modelling has shown that the timing of BEV uptake is as important as the final share of new car sales that are BEVs at the end of the decade. Based on a scenario of 60% BEV market share by 2030, early adoption would achieve a 52% reduction in total fleet emissions (old and new sales) whereas late adoption only allows a 34% reduction. On a basis of additional cumulative CO_2 emissions this effect is exacerbated, with an early adoption of 60% BEVs reached by 2030 providing lower cumulative emissions between 2020-30 than an 80% share reached in 2030 with a baseline uptake. Without the necessary policy, there is a significant risk of OEMs peaking BEV supply late in the 2020s to meet EU emission targets.

[56] 2021 Ford Mustang Mach-E

6 Appendix

6.1 2020 OEM BEV Landscape

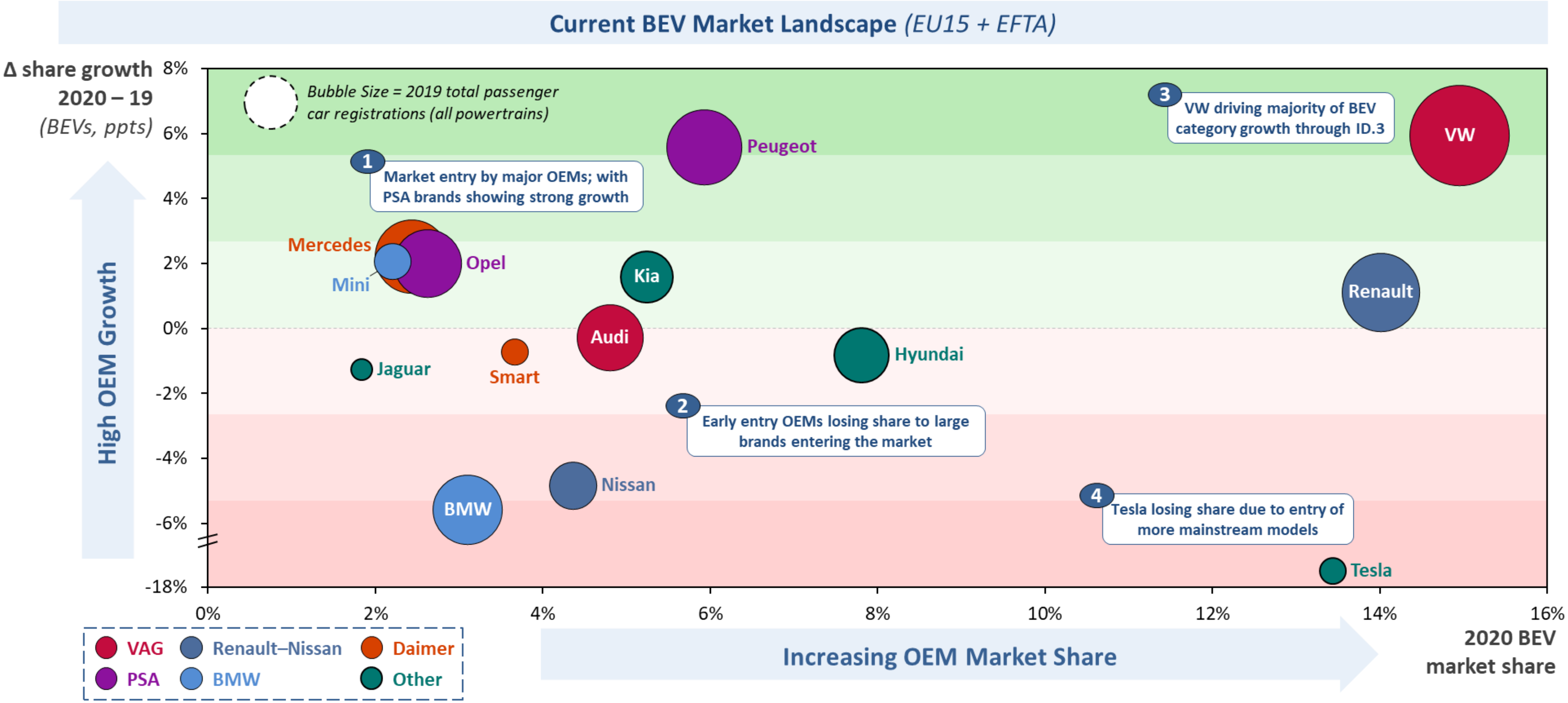

Figure 52: 2020 OEM landscape for BEV sales with Δ share growth between 2019 & 20 against 2020 BEV market share (Schmidt Automotive Research)

6.2 Methodology Assumptions

6.2.1 Fuel & Electricity Forecasting

In this Appendix Section, the full fuel and electricity inputs for the baseline scenario modelling are detailed based on the methodology laid out in Section 2.4.

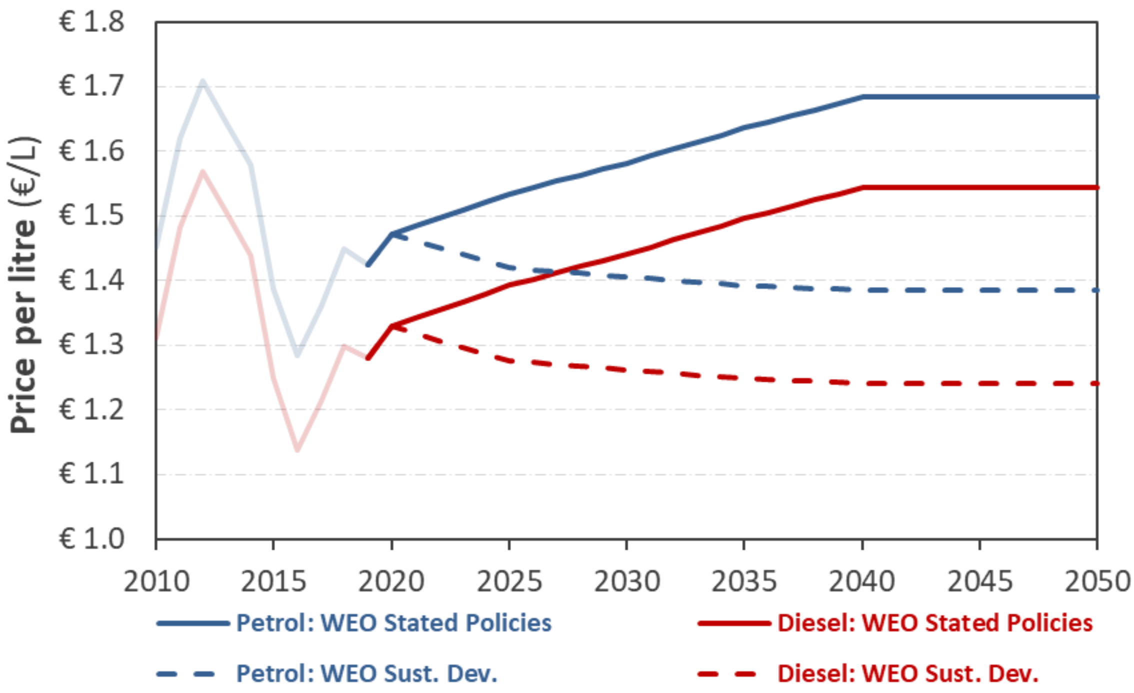

Figure 53: petrol & diesel price forecasting between 2020-50. Two World Economic Energy (WEO) scenarios are shown: (1) State Policies & (2) Sustainable Development

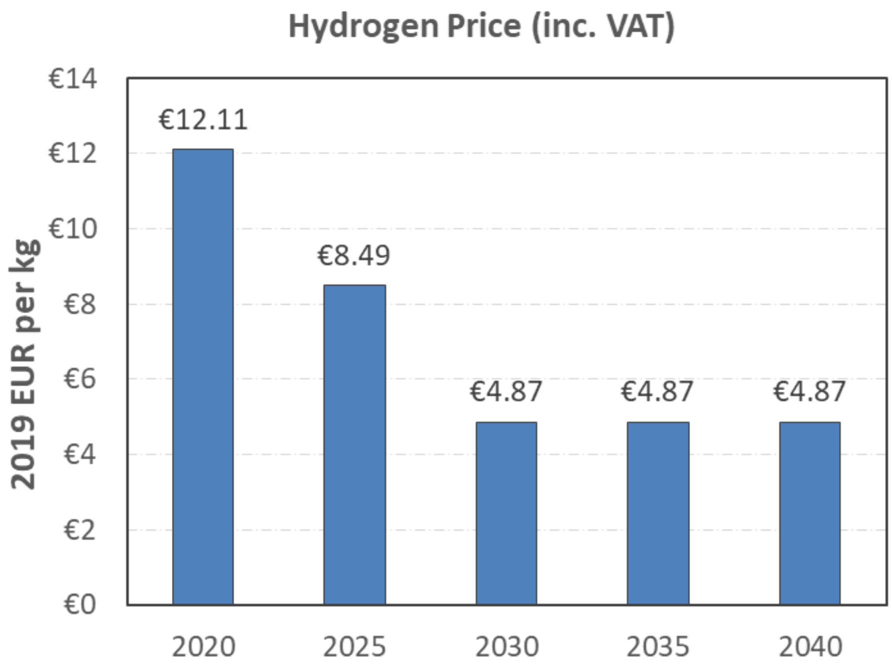

Figure 54: Hydrogen price forecasting between 2020-40

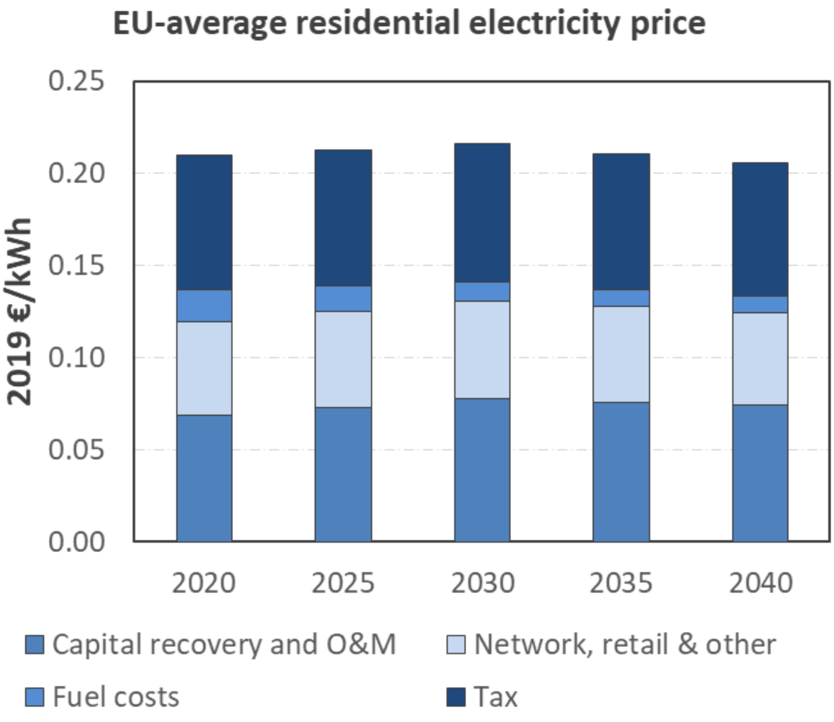

Figure 55: Electricity price forecasting between 2020-40 broken down by cost components

6.2.2 Depreciation Rates example

The following example compares the depreciation rates for a snapshot vehicle age and mileage (4 years; 64,000km) between different powertrains as discussed in Section 2.4.

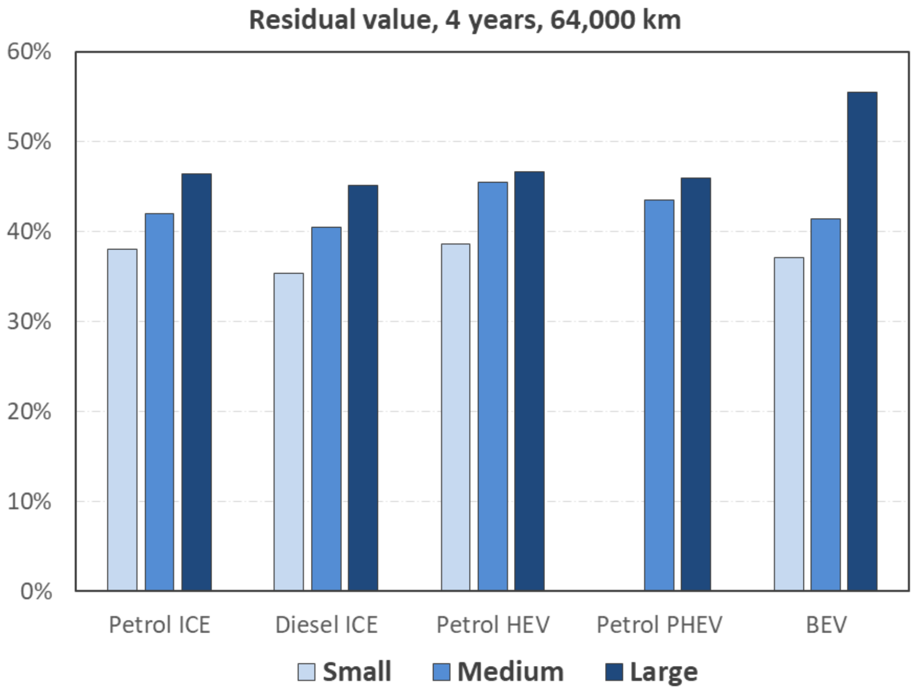

Figure 56: residual value of different powertrains for a 4 year old vehicle at 64,000km lifetime mileage

6.3 Additional TCO Results

6.3.1 Second Owner TCOs

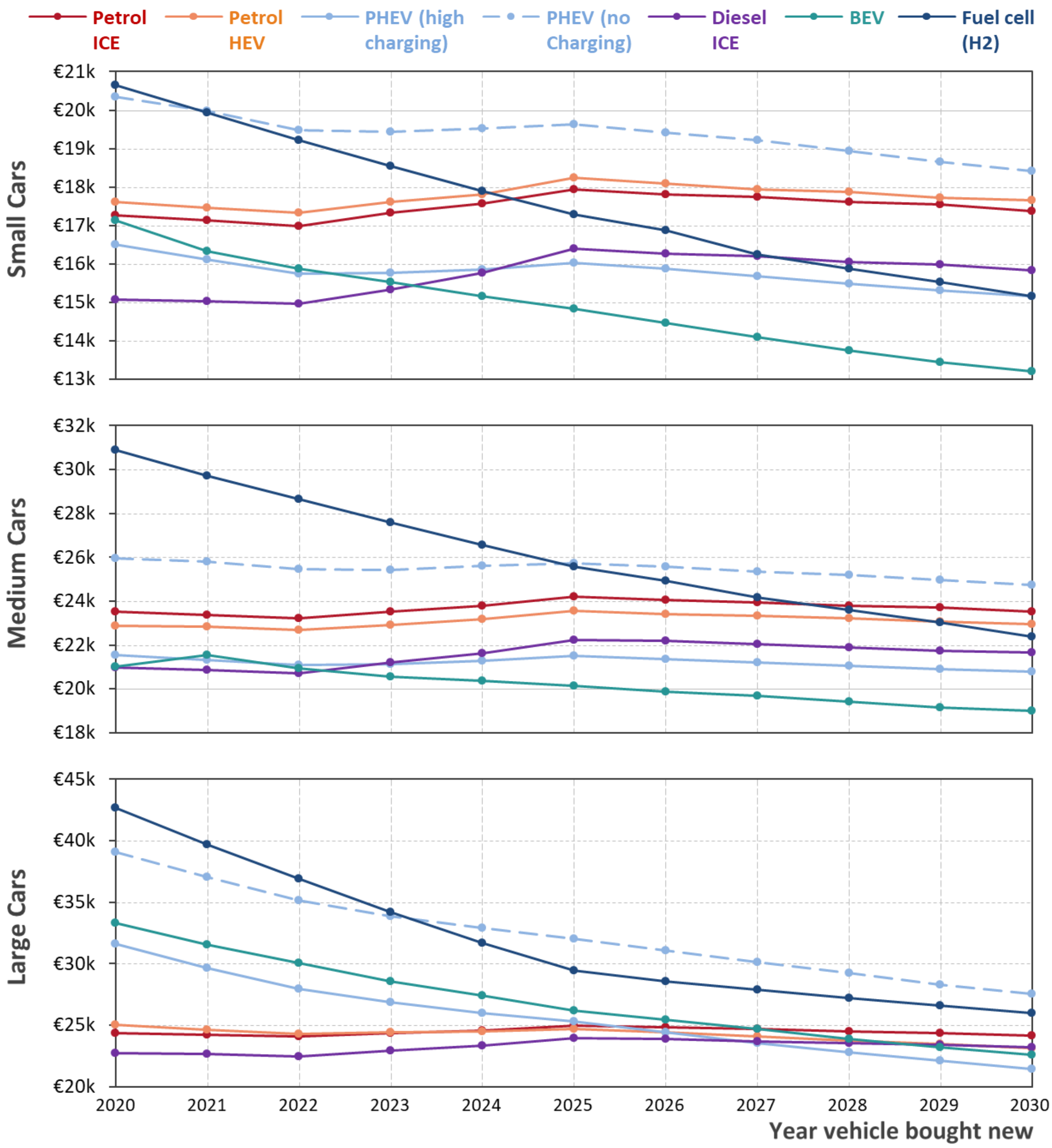

Figure 57: Second owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

6.3.2 Third Owner TCOs

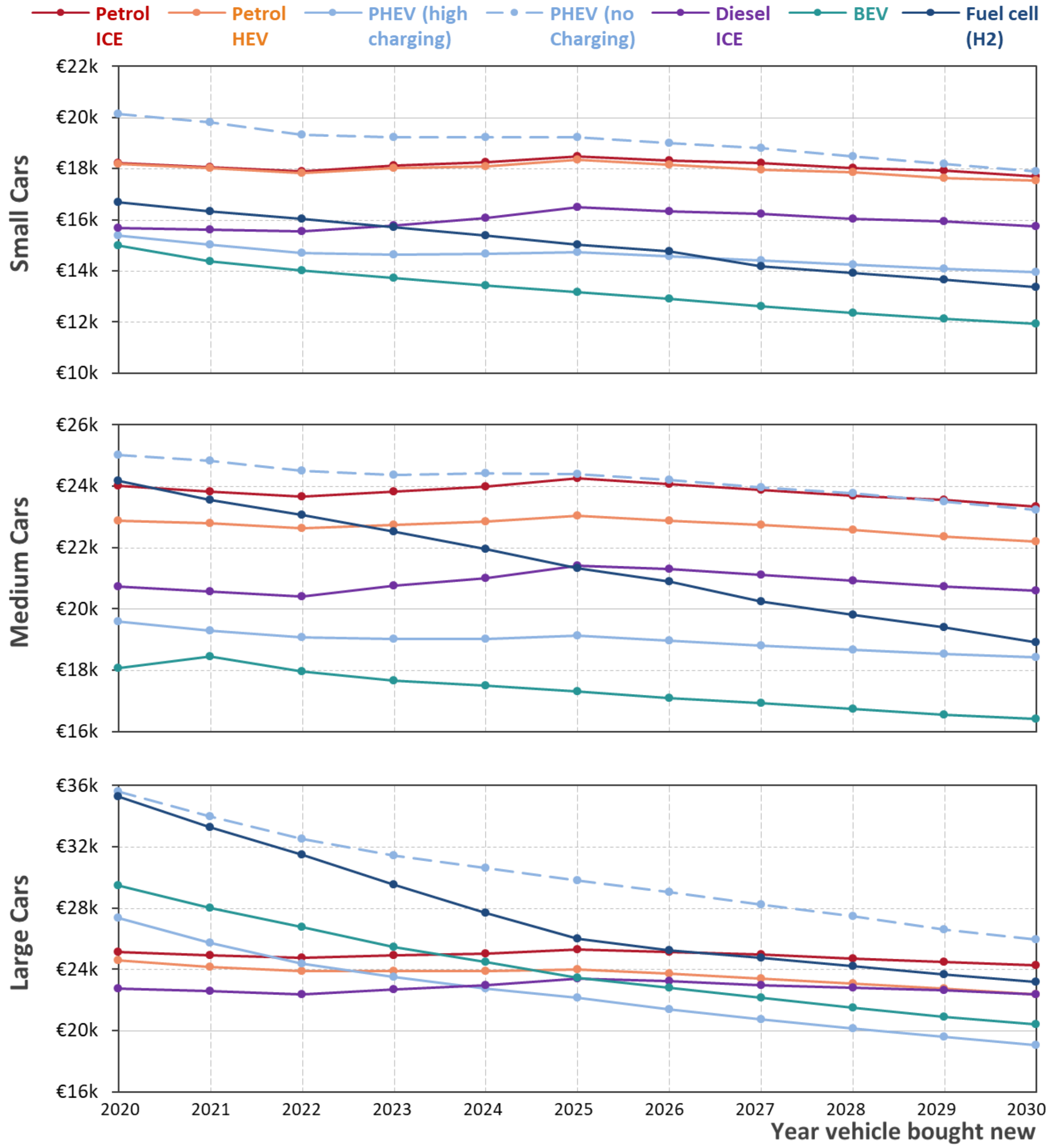

Figure 58: Third owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

6.3.3 Medium Car Cost Components 2020

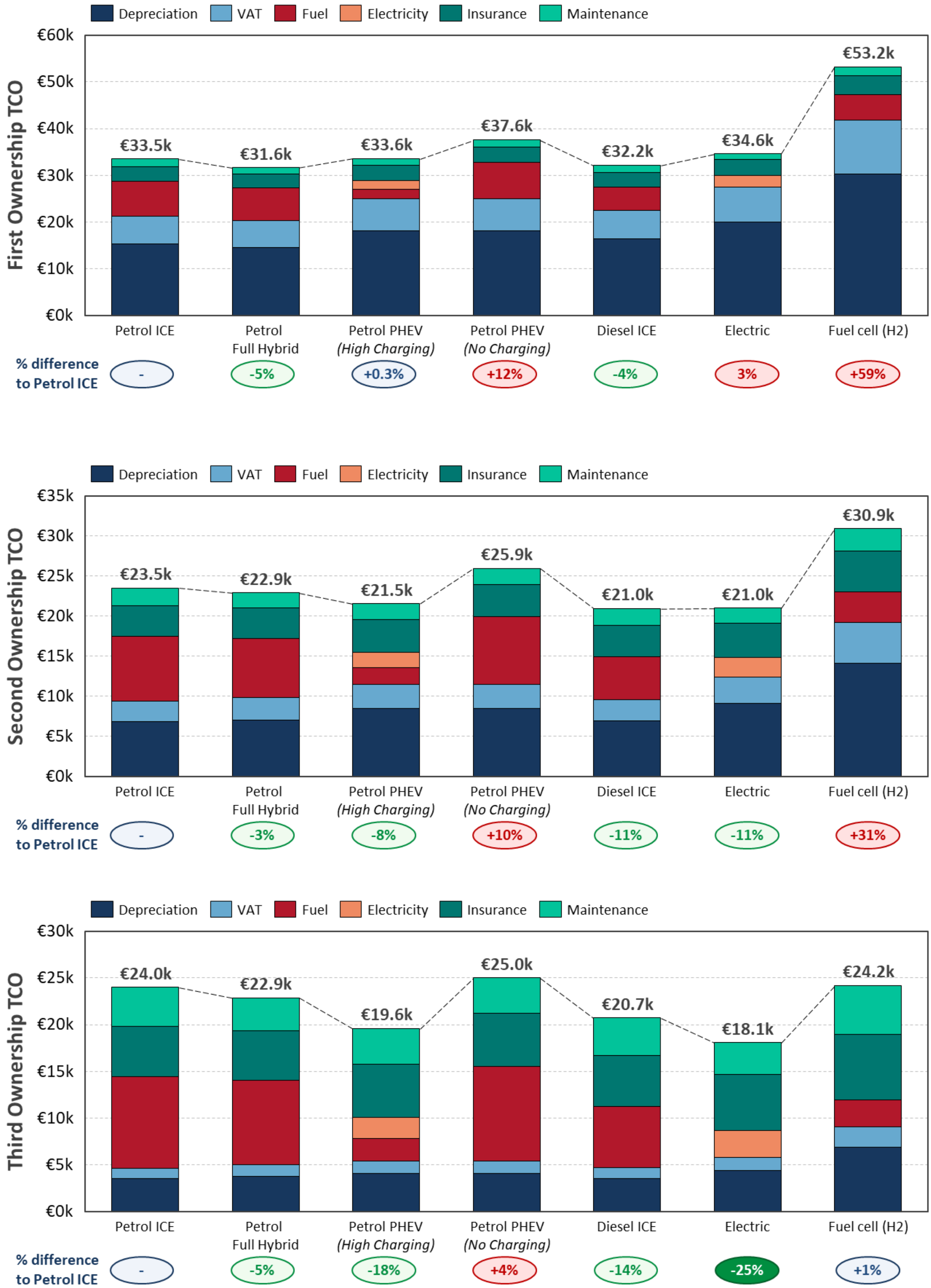

Figure 59: TCOs on a cost component level for different powertrains bought new in 2020

6.3.4 Medium Car Cost Components 2025

Please note that equivalent graphs for the first and second ownership are shown in Section 3.1

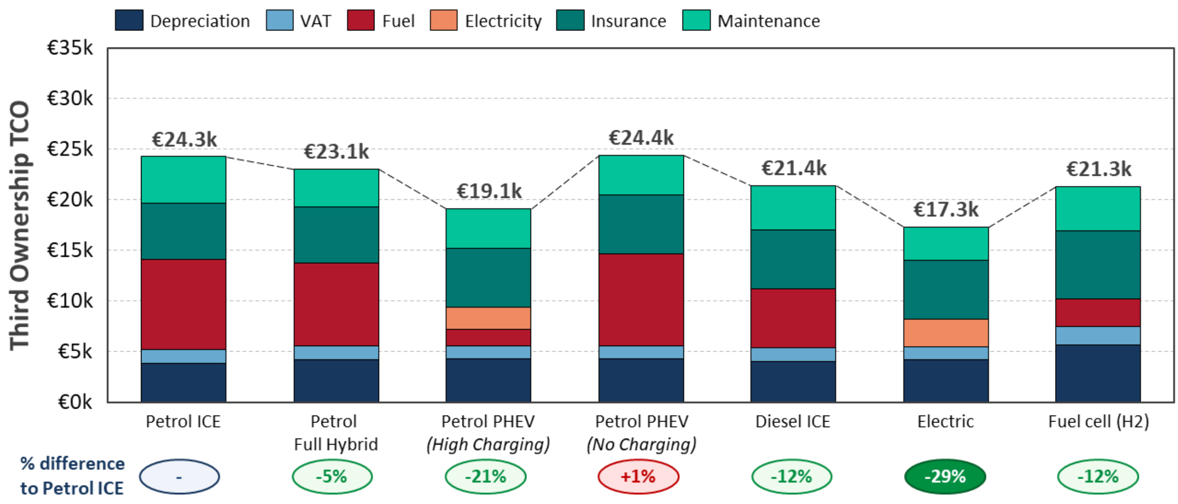

Figure 60: third owner TCOs on a cost component level for different powertrains bought new in 2025

6.3.5 Medium Car Cost Components 2030

Figure 61: TCOs on a cost component level for different powertrains bought new in 2030

6.4 Additional Battery Scenario Distributions

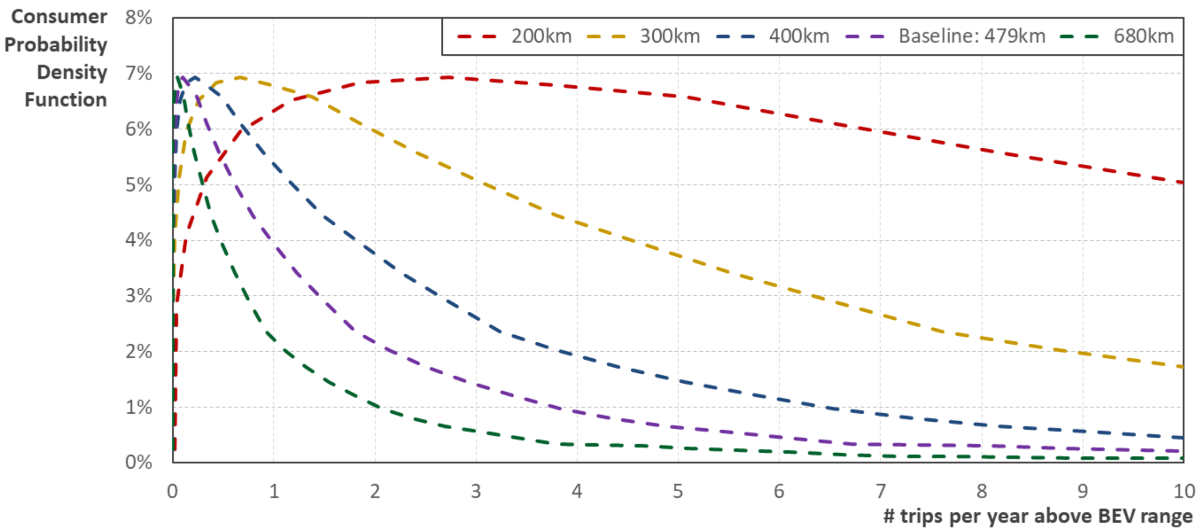

Figure 62: consumer probability density functions for different battery size scenarios

6.5 E-fuel Forecasting

E-fuel cost component based on an estimation by Frontier Economics[57], and excludes fuel duty to provide an optimistic scenario for the future E-fuel market entry.

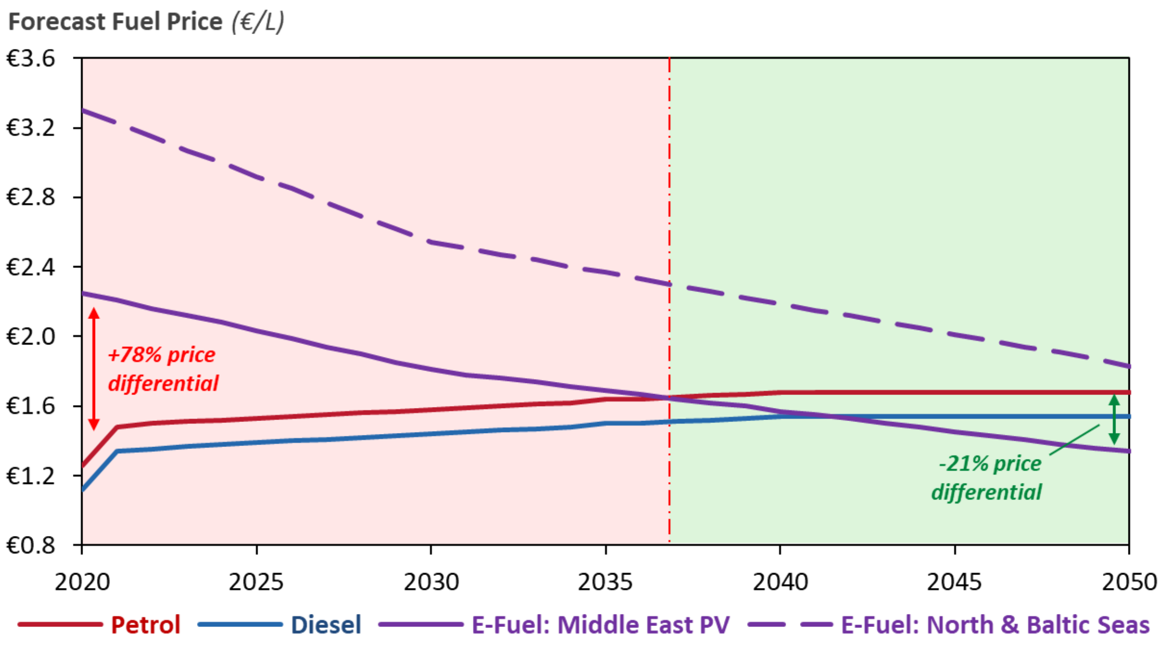

Figure 63: E-fuel price scenario forecasting between 2020-50 compared to petrol & diesel

[57]Frontier Economics (2018): The Future Cost of Electricity-Base Synthetic Fuels