Electric Cars in Germany: Calculating the Total Cost of Ownership for Consumers

Final Report (v2) *for VZBV & BEUC*

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Executive Summary

This Germany report has been developed in parallel with an overall EU level report (Electric Cars: Calculating the Total Cost of Ownership For Consumers) and eight additional European country specific reports on the total cost of ownership (TCO) of cars for consumers from 2020-30.

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 TCOs 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 (HEVs), as well as low & zero emission powertrains, such as plug-in hybrids (PHEVs), battery electric vehicles (BEVs) and H_2 fuel cells (FCEVs)[2]. The TCOs for different powertrains are calculated for first, second and third owners for vehicles bought new between 2020-30 in Germany.

This report explores how TCOs in Germany vary from the EU average case and what consequences this has for consumers. "Real world" examples, representing specific user groups in Germany, reflect how decarbonisation will affect various consumers differently, an essential consideration for policymakers.

Battery electric vehicles are just around the corner in Germany

In Germany (including purchase subsidies and tax breaks), BEVs are already the cheapest powertrain on a lifetime TCO basis for small and medium cars bought new today, which is illustrated in Figure 1 (for medium cars). Large cars become the cheapest powertrain on a lifetime TCO basis from 2025, which is one year earlier than EU averages (excluding taxes and subsidies). 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.

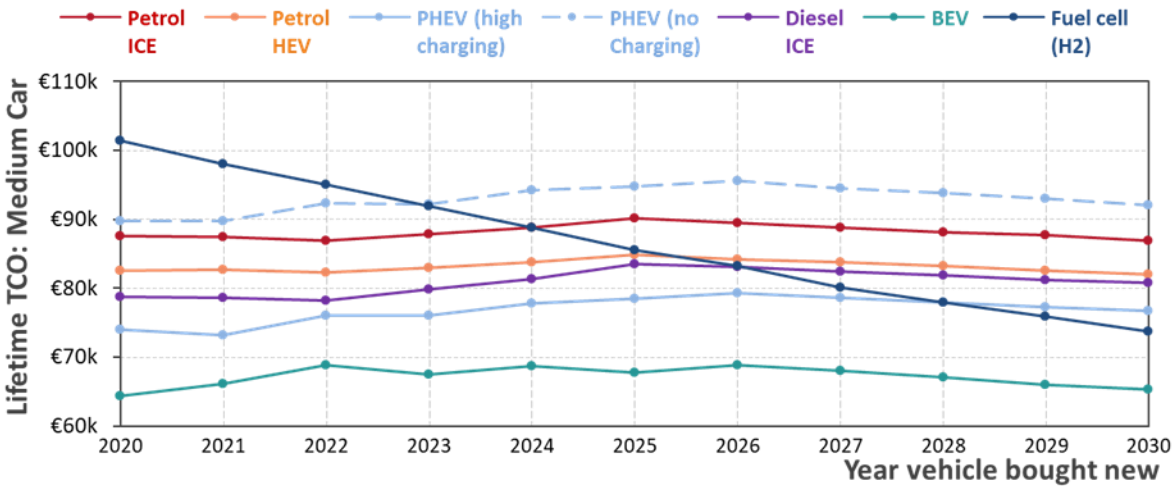

Figure 1: lifetime TCO comparison between different powertrains in Germany.

[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.

It is important that policymakers in Germany consider the significant benefits that BEVs offer to less affluent consumers when compared to other powertrains. A medium BEV bought new today will save a total of almost €12,100 for its combined second & third owners 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 targets and encouraging OEMs to sell more BEVs will most benefit the least affluent consumers by increasing the available stock of used BEVs more quickly.

The Umweltbonus should be phased out between 2021-25

A significant barrier to BEV market growth is high upfront purchase prices, which drive greater depreciation costs for first owners. This is especially important as first owners determine the market stock mix and therefore the vehicles available for eventual used car buyers. Figure 2 illustrates the first owner TCO saving for a BEV over a Petrol ICE with and without a €6,000 purchase subsidy (which represents the remaining Umweltbonus once the €3,000 Innovationsprämie is removed). Without upfront subsidies, small cars do not become cheaper than Petrol ICEs until 2025, however, a medium BEV would already be cheaper even without any support from the Umweltbonus. Purchase subsidies, which in the short term remain important for the uptake of small BEVs, should be phased out between 2021-25, to ensure government investment is spent where it is most needed to achieve decarbonisation and does not subside consumers who would have bought a BEV regardless.

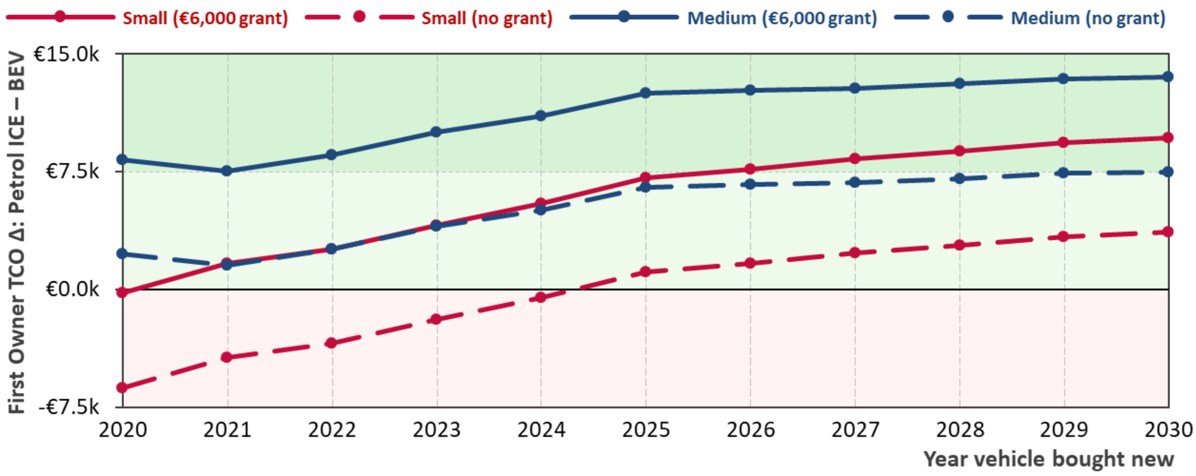

Figure 2: first owner TCO savings for a BEV over a Petrol ICE with and without a €6,000 upfront purchase grant

Germany has achieved high BEV growth due to strong first owner TCO savings

As shown in Figure 3, Germany has achieved the second highest BEV percentage of total 2020 car sales of the 9 European markets covered in this study, with small and medium BEVs currently cheaper than Petrol ICEs for first owners. Upfront cost has been the most important barrier to BEV uptake, with 57% of consumers surveyed in Germany in 2018 saying that this was their main reason to not buy an electric or fuel cell car[3]. It is essential to educate consumers about the savings already available from buying a BEV and provide financing mechanisms to best unlock these TCO savings. To fully eliminate growth barriers, alongside reducing the costs of BEVs for consumers, it is essential for policymakers to also consider other factors such as building suitable charging infrastructure and securing OEM supply to meet the driving needs of all consumers in Germany.

[3] Transport & Environment (2018): Consumer attitudes to low and zero-emission cars (sample size of 500 consumers)

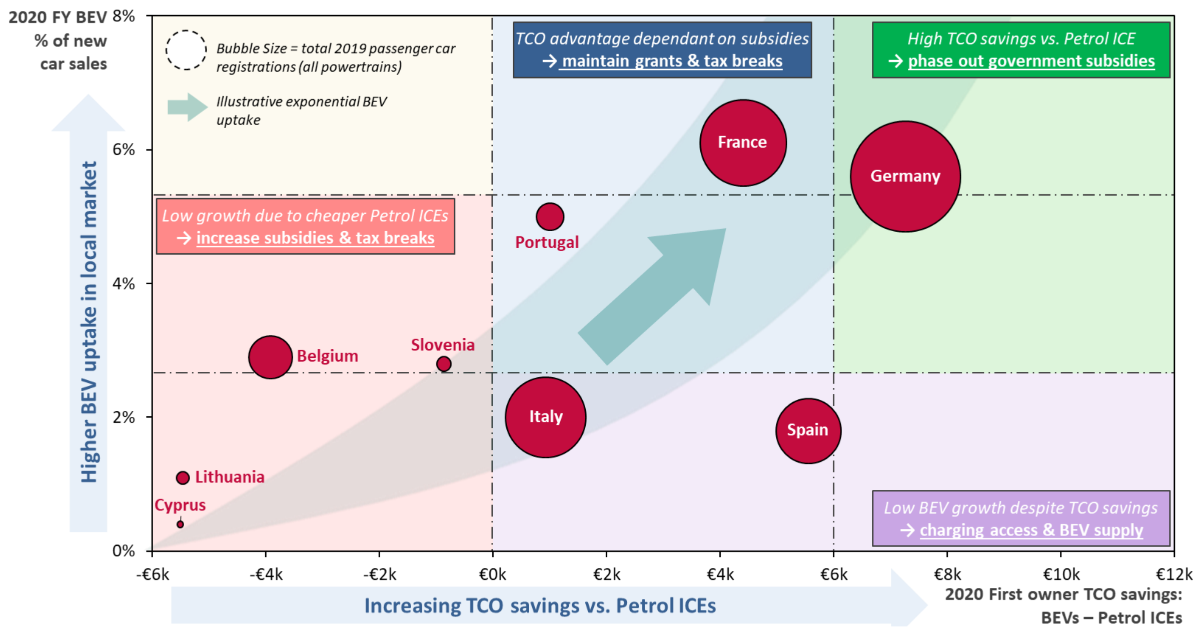

Figure 3: weighted average for small & medium cars showing BEV 2020 share of market sales vs BEV first owner TCO savings over Petrol ICEs

Specific User Groups in Germany

TCO sensitivities for specific groups of German consumers have been considered for (1) a daily commuter (2) a part time employee that relies exclusively on public charging and (3) a pensioner/ retiree. The 2020 first owner TCO results for a high annual mileage daily commuter (25,000km) are illustrated in Figure 4, where the BEV model is assumed to be a Tesla Model 3 (Long Range) and is compared to the upper-medium sized segment averages of the other powertrains. The Model 3 provides a consumer from this user group with total savings of €16,700 and €12,800 compared to a Petrol and Diesel ICE respectively over the first ownership. High mileage drivers should be considered a top priority group for educating about the benefits of switching to BEVs. This user group benefits the most on a TCO basis while also being the largest producer of CO_2 tailpipe emissions.

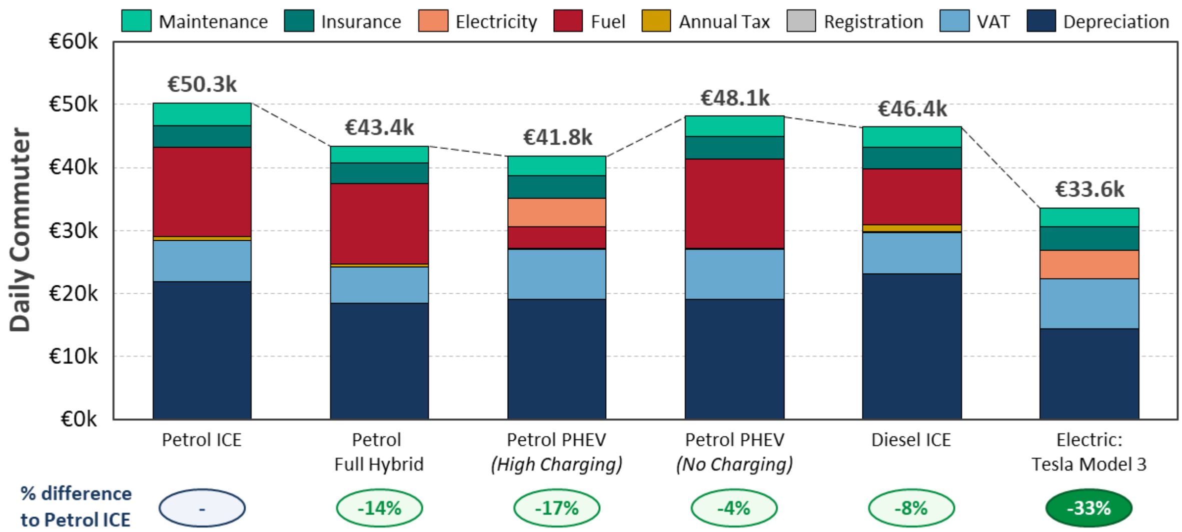

Figure 4: first owner TCO for a new car bought in 2020 by a daily commuter. Tesla Model 3 (Long Range) compared against the upper-medium sized segment averages of other powertrains.

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This study was carried out using a continuous peer review process, during which local market experts, from a number of different organisations working on automotive affairs, provided contributions. The **information and views set out in this report are those of the author(s) and do not necessarily reflect the opinions of those individuals or their organisations involved during the peer review process.**

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
VZBV	Verbraucherzentrale Bundesverband
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 the EU, a rapid transition to electric vehicles will be required. There are several factors that will impact the rate at which decarbonisation occurs, 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 Total Cost of Ownership (TCO) of different car powertrains in Germany. 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 consumers.

1.1 EU Level Report

This Germany TCO report is part of a wider study that looked into TCOs at an EU level.

The future European CO_2 reduction targets are being reviewed and are expected to be made more stringent that the current target of a 37.5% reduction between 2021 and 2030 for new passenger cars[4]. 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.

Our EU-level report, which has been released in parallel with this report (and equivalent results for 8 additional European countries), is structured around 5 key messages that have emerged from our analysis:

- The inevitability of battery electric vehicles (BEVs)
- The importance of European emissions standards
- BEVs driving consumer market equity
- Opportunities to maximise the consumer value available through BEVs
- Mitigating the risks to BEV uptake and unlocking consumer benefits

While these themes are common across all European markets, it is important to consider how the decarbonisation transition will impact consumers differently across specific countries. This Germany-specific report provides policymakers with tailored TCO results and "real word" examples to support arguments for strengthening European CO_2 reduction targets and inform consumers in Germany about the opportunities from decarbonisation and associated cost savings.

1.2 Aims of this Study

This report by Element Energy was commissioned by VZBV and BEUC (The European Consumer Organisation), to explore the Total Costs of Ownership (TCO) of cars sold in the 2020s in Germany. 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 fuel & electricity costs, taxes and subsidies, and how these are likely to evolve in the future for each powertrain.

[4] https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en

- Calculate and compare the Germany-specific 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.
- Explore sensitivities for “real world” specific user groups to identify the impact of decarbonisation on different consumers.

1.2.1 Report Structure

In Section 2, the methodology is detailed with an overview of vehicle scope and cost & performance modelling. The Germany-specific ongoing ownership assumptions, including differences to the EU average baseline, covering: fuel & electricity pricing, average annual mileages and taxes & subsidies, are also discussed. Germany specific TCO results for cars bought new between 2020-30 for different ownership periods are outlined in Section 3, which includes a comparison to the EU baseline and other European markets covered in the study. Section 4 shows TCO sensitivities that explore different “real world” specific user groups for BEV models currently available in the market today. Overall conclusions and implications are provided in Section 5.

2 Project Methodology

This Section details the project methodology, providing an overview of vehicle scope and cost & performance modelling. The ongoing ownership assumptions are discussed, which include: fuel & electricity pricing, average annual mileages, depreciation rates, insurance and maintenance costs, taxes and subsidies, as well as assumptions around PHEV charging scenarios.

2.1 TCO Overview

Figure 5 shows the make-up of the Total Cost of Ownership (TCO) in terms of individual cost components. This includes both upfront purchase costs (including VAT) and vehicle running costs.

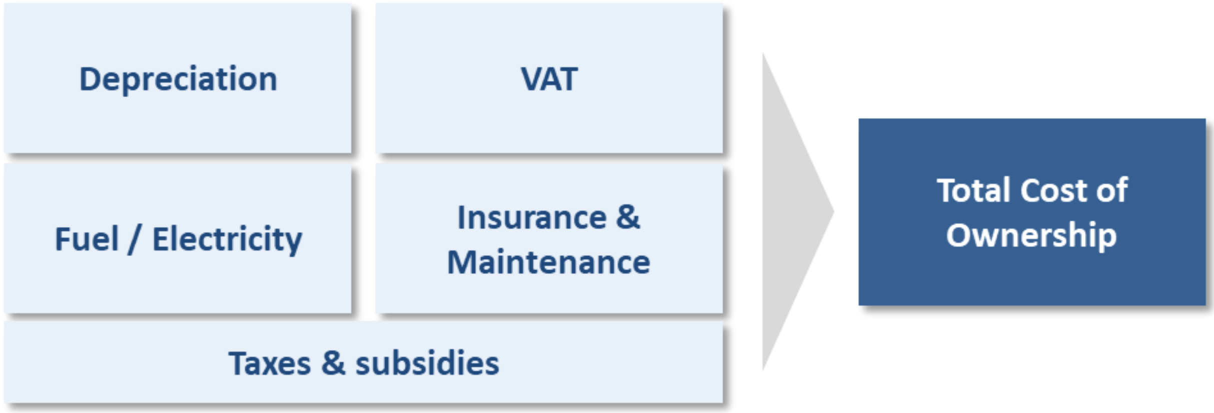


Figure 5: breakdown of the TCO cost components

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. This approach gives the TCO of an 'average' vehicle, which can be readily compared across different European markets.

In this report we consider 3 car size segments: small; medium; large, based broadly on ACEA segmentation[5], 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[6]. A brief description of each powertrain is included below. Figure 6 shows a graphic representation of the powertrain components included in each powertrain.

[5] Specialist Sport and Luxury Car are excluded from the large segment, to best reflect the choice for an average consumer
[6] LPG and CNG have been excluded due to low market share, very limited growth potential & OEM investment and because they achieve minimal emission reductions.

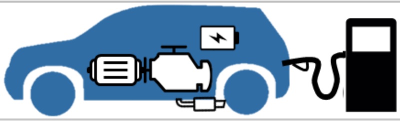
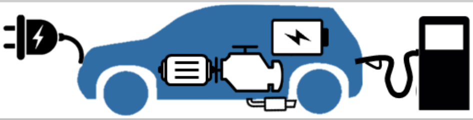
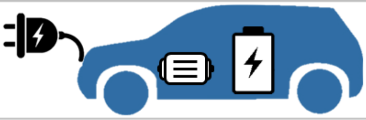
Powertrain	Components and energy sources
ICE	
HEV	
PHEV	
BEV	
H_2 Fuel Cell	

Figure 6: 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 from the WLTP values[7], 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[8]) and for PHEVs which are never charged, and therefore drive under ICE power at all times. These two approaches are included to represent extreme values which bookend the range of values we expect consumers to fall within and can be viewed as a 'worst-case' and a 'best-case' scenario. Please note that an additional "low charging" scenario is included in the EU-level report based on destination charging, for example at a supermarket, a couple times each week.

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.

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

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 charge a small battery and power an electric motor.

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 7 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 highly granular insight into the effect on overall vehicle performance.

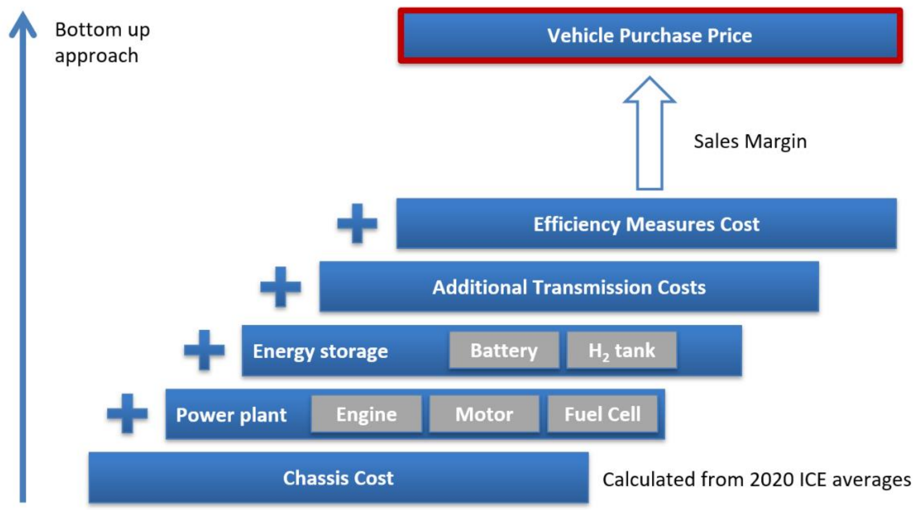


Figure 7: outline of the methodology applied in the Cost and Performance Model

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[9].

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 8 shows a more detailed view of the modelling approach employed.

[9] Ricardo-AEA. Improving understanding of technology and costs for CO2 reductions from cars and LCVs in the period to 2030 and development of cost curves. 2016.

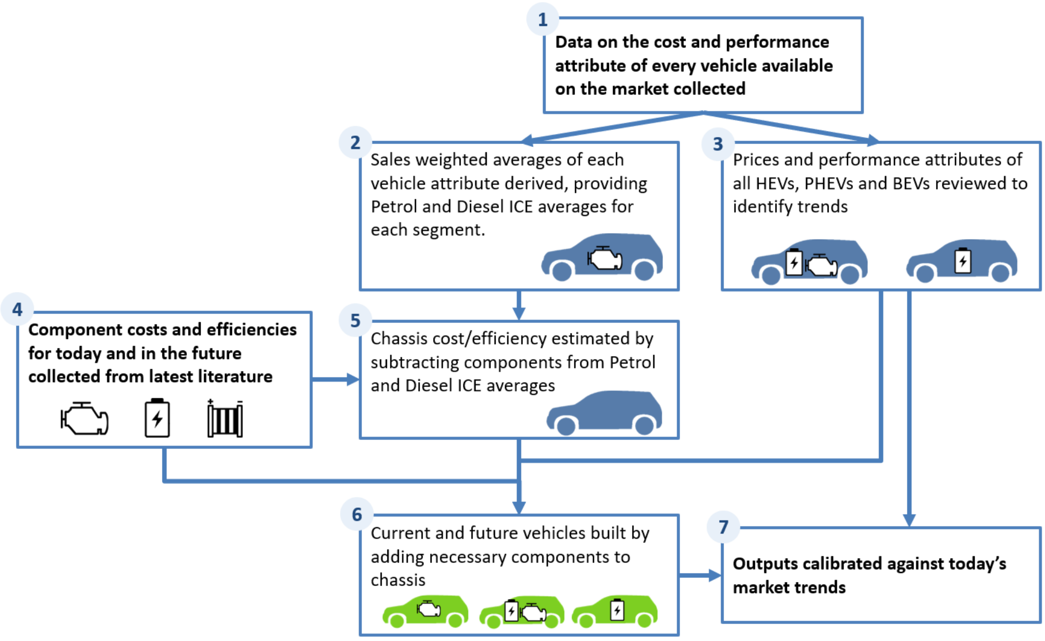


Figure 8: overview of steps taken to construct future vehicles. Numbers indicate modelling order.

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[10,11,12,13] and market research conducted by Element Energy.

In order to have a representative baseline on which to base future vehicles, 2020 archetype vehicles are identified for each segment and powertrain. These archetypes represent a sales-weighted average ICE vehicles and were determined by an analysis of the 9,000+ vehicle models on sale in October 2020, with adjustment factors to convert from EU averages to Germany-specific pricing modelled using data gathered from a local market vehicle price comparison website[14]. 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.

[10] Roland Berger (2014) Global Automotive Supplier Study
[11] KPMG (2013) Automotive Now, Trade in crisis
[12] 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
[13] Cuenca, Gaines, Vyas (1999) Evaluation of Electric Vehicle Production and Operating Costs
[14] https://www.adac.de/

2.4 Ongoing Ownership Assumptions

Please note that insurance, maintenance & PHEV charging assumptions have been set in line with the methodology set out in the EU level report.

2.4.1 Depreciation

Depreciation rates for Germany were adjusted from the EU baseline using depreciation cost projection data sourced from ADAC price comparison website[15].

There is significant uncertainty around forecasting the relative residual value of ICE versus BEV cars in the short term. While many more EVs will enter the used car market, demand will also considerably increase; at the same time there is a potential for a fall in ICEVs resale value due to local and national policies limiting their popularity. This uncertainty is particularly important when considering the impact of first owner purchase subsidies on the residual value of EVs. In this study we have assumed that purchase subsidies do not change EVs' residual value at the end of the first ownership.

2.4.2 Fuel and Electricity Projections

Historic German fuel prices (ex VAT and fuel duty) were sourced from the European Commission's Weekly Oil Price Bulletin[16] and correlated with historic oil prices. These were then projected forward using the same oil price scenario that has been used at an EU level (see EU Level Report for full details). From 2021, the price for petrol will rise by 7.5 cent/litre (with a CO_2 price of 25€/ton) and for diesel by ca. 8 cent/litre. In 2025, the CO_2 price will be 55€/ton, with the cost for petrol and diesel increasing proportionately.

2020 domestic electricity prices for Germany were taken from Eurostat[17]. The wholesale, network, CO_2 and tax cost components were then projected forward based on the World Energy Outlook 2019 Stated Policies scenario[18]. Full fuel and electricity pricing assumptions are detailed in Appendix 6.1.

2.4.3 Ownership Periods & Average Annual Mileage

Data from Kraftfahrt-Bundesamt (KBA)[19] revealed that annual mileages in Germany are around 20% higher than EU averages, we have assumed mileages of 18,000km; 14,000km & 11,000km for the first (4 years), second (5 years) and third ownerships (7 years) respectively. Ownership periods have been assumed to be in line with EU averages.

2.4.4 Taxes and Subsidies

Engine and CO_2 components of vehicle tax were sourced from the ACEA tax guide 2020[20]. Based on discussion with local market experts at VZBV, the Innovationsprämie subsidy is assumed to finish at the end of 2021 with the Umweltbonus reduced in two steps (2022 & 2024) before finishing at the end of 2025; complete assumptions are detailed in Appendix 6.2. A VAT rate of 19% is applied for both new cars only, and is excluded for used car buyers.

[15] https://www.adac.de/
[16] https://ec.europa.eu/energy/data-analysis/weekly-oil-bulletin_en?redir=1
[17] https://ec.europa.eu/eurostat
[18] International Energy Agency (2019) World Energy Outlook: Residential Energy
[19] Kraftfahrt-Bundesamt (2019) https://www.kba.de/SharedDocs/Publikationen/DE/Statistik/Kraftverkehr/VK/2019/vk_2019_xlsx.xlsx?__blob=publicationFile&v=4
[20] https://www.acea.be/publications/article/acea-tax-guide

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

3.1 Germany 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.

3.1.1 Lifetime TCO

Figure 9 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 is useful for showing the long-term cost optimal solution for consumers.

BEVs are already the cheapest powertrain on a lifetime TCO basis for small and medium cars bought today, and will become the cheapest option for large cars in 2025. This is four years earlier for small cars and one year earlier for large cars than EU averages (excluding taxes and subsidies), which is driven by upfront purchase subsidies and a higher average annual mileage (which increases BEV running cost savings vs. ICEVs).

It should be noted that the introduction of Euro VII requirements between 2022-24 has a significant impact on petrol and diesel lifetime TCOs, with additional cost passed onto ICEV consumers. 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. Furthermore, preventing delays to Euro 7 is essential to share transition costs evenly between governments and OEMs and maximise the supply of BEVs in the market stock to unlock the substantial benefits to consumers in the used market.

PHEVs are only slightly more expensive on a TCO basis than BEVs for large cars, however, this is only the case with high charging behaviour. If not charged at all, Petrol PHEVs become significantly more expensive, providing the worst financial value of any powertrain on a lifetime TCO basis. This is particularly important for second and third owners, who are less likely to have access to off-street charging and therefore will be more impacted by significantly higher running costs, providing an additional risk to consumer equity[21]. Furthermore, policymakers have little control over PHEV charging after the vehicle is purchased. Please note that an additional low charging PHEV scenario has been considered in the EU-level report, based on destination charging, for example at a supermarket, a couple times each week.

[21] Charging access is also an important concern for BEV drivers and this is discussed through specific user group analysis in Section 4.1

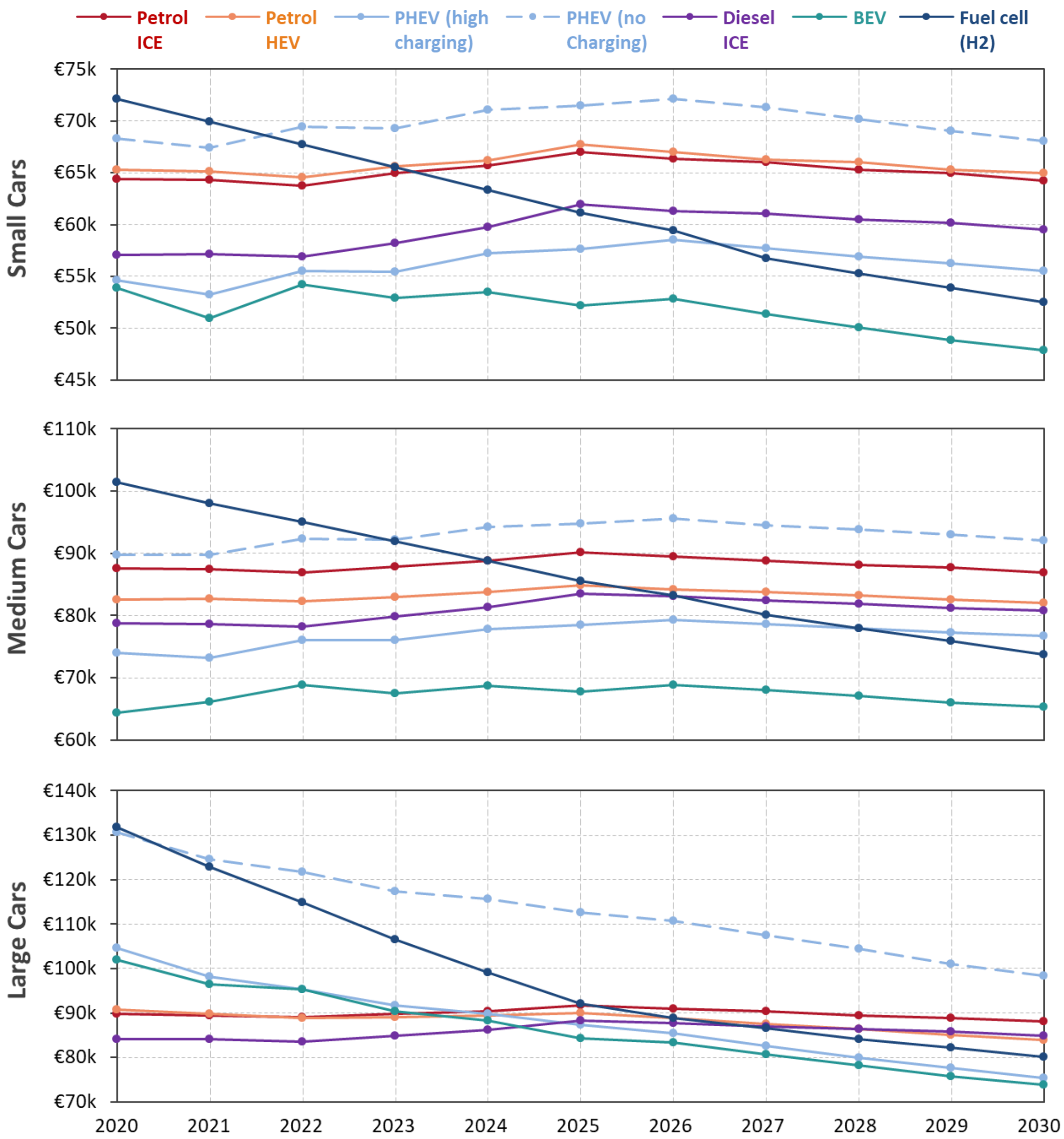


Figure 9: lifetime TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

3.1.2 First Owner TCO

Although BEVs provide significantly better value for second and third owners, it is especially important to consider the first ownership period. This impacts new buyer purchasing decisions, which in turn determines the long-term market stock and thus used car availability. The relative first owner TCOs are forecast for the various powertrains in Figure 10. The TCOs for BEVs and FCEVs will drop significantly over the next decade, driven by falling battery and fuel cell costs, however, this is counterbalanced by the phase out of subsidies between 2021 and 25. The TCO increase for medium BEVs in 2021 is due to models with significantly larger batteries entering the market.

BEVs are already the cheapest powertrain on a first owner TCO basis for medium cars and become the cheapest for small cars in 2023. It is crucial that small BEV models, which have historically been limited, be made available for consumers by OEMs to ensure early BEV adoption for a mass market that buys smaller and cheaper vehicles. Flexibility over battery size (which is discussed at length in the EU-level report) allows consumers to elect to purchase smaller battery model variants and unlock additional cost savings. This enables consumers to find an optimum balance between convenience and cost, with a vehicle to meet their driving needs and which is priced accordingly.

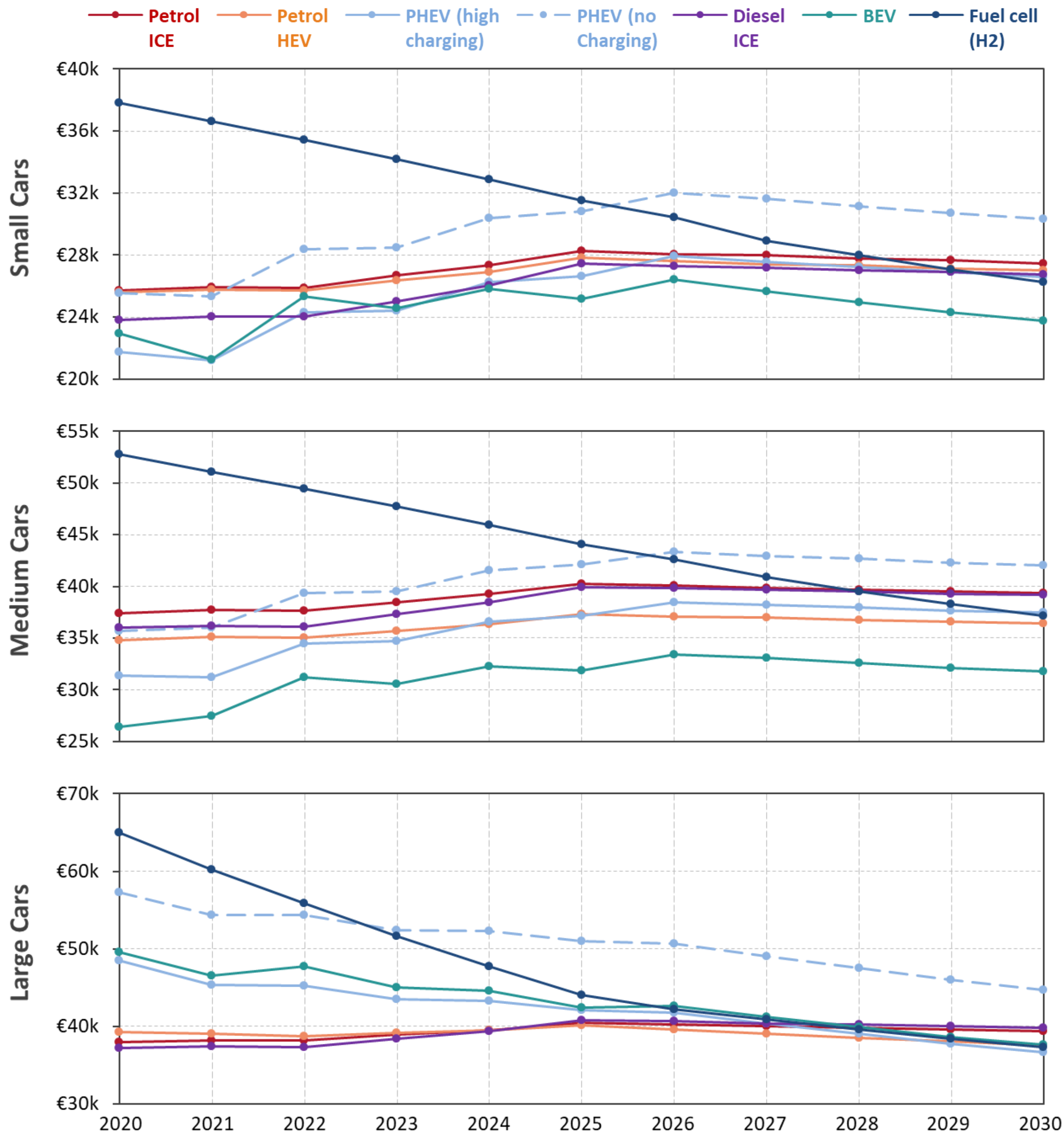


Figure 10: first owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

Figure 11 illustrates the first owner TCO saving for a BEV over a Petrol ICE with and without a €6,000 purchase subsidy. This represents the Umweltbonus currently available to consumers once the Innovationsprämie (which amounts to €3,000 of the €9,000 subsidy available in 2021) is removed. Without upfront subsidies, small cars do not become cheaper than Petrol ICEs until 2025, however, with a €6,000 grant, small BEVs are already cheaper. Medium BEVs are already cheaper than Petrol ICEs even without the Umweltbonus. While purchase subsidies continue to be necessary in the short term to ensure that there is strong uptake a small BEVs, policymakers should start to phase out support over next 5 years.

There is an increasing risk of subsidising first owners who would have likely bought a BEV anyway, especially with medium BEVs being already cheaper than a Petrol ICE without subsidies. Furthermore, this may drive market inequity, with tax breaks a better option as they benefit all consumers and not only first owners, who are typically more affluent. Long-term subsidies also risk OEMs focusing supply in specific 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 targets essential to ensure that BEVs, and their associated financial and carbon benefits, become available for all European consumers.

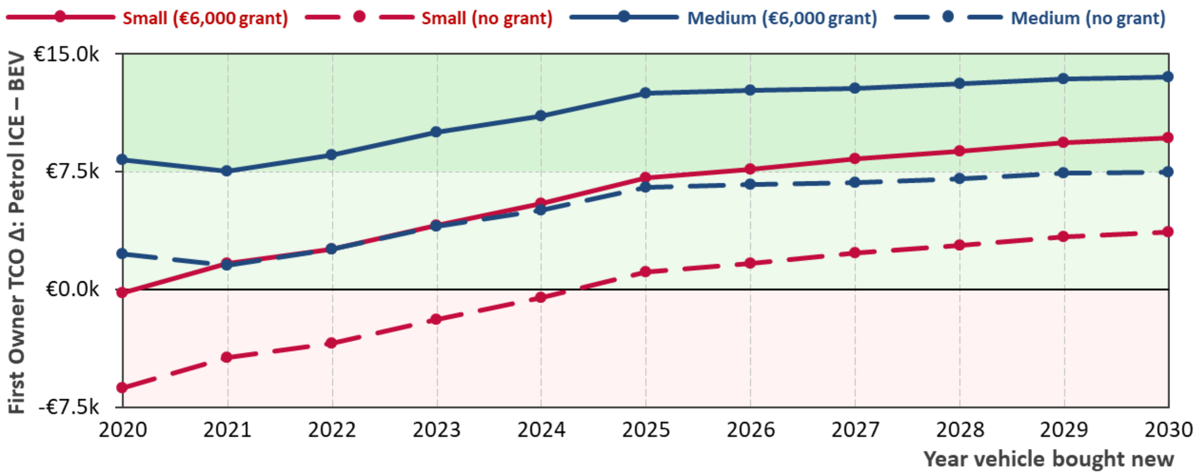


Figure 11: first owner TCO savings for a BEV over a Petrol ICE with and without a €6,000 upfront purchase grant

3.1.3 TCO component evolution between Ownerships

This section considers TCO on a cost component level for first, second and third ownerships. Purchase price differences between ICEVs and BEVs become smaller for used-car owners, which means that savings will be available to the eventual second and third owners of medium BEVs bought new today.

First Owners

Figure 12 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 2020. For first owners, depreciation is the largest single TCO component. Depreciation costs are higher for BEVs, due to a more expensive upfront purchase price, however, this is significantly reduced in Germany due to the Umweltbonus and Innovationsprämie subsidies. Consumers that buy a medium BEV currently save €11,000 and €9,600 over a Petrol and Diesel ICE respectively on a TCO basis. The 2020 first owner TCO for PHEVs varies by around €4,300 depending whether there is high or no charging and, if a PHEV is not charged at all, representative of consumers, for example, that have access to and use a company fuel card, PHEVs will cost over €9,300 more than a fully electric car.

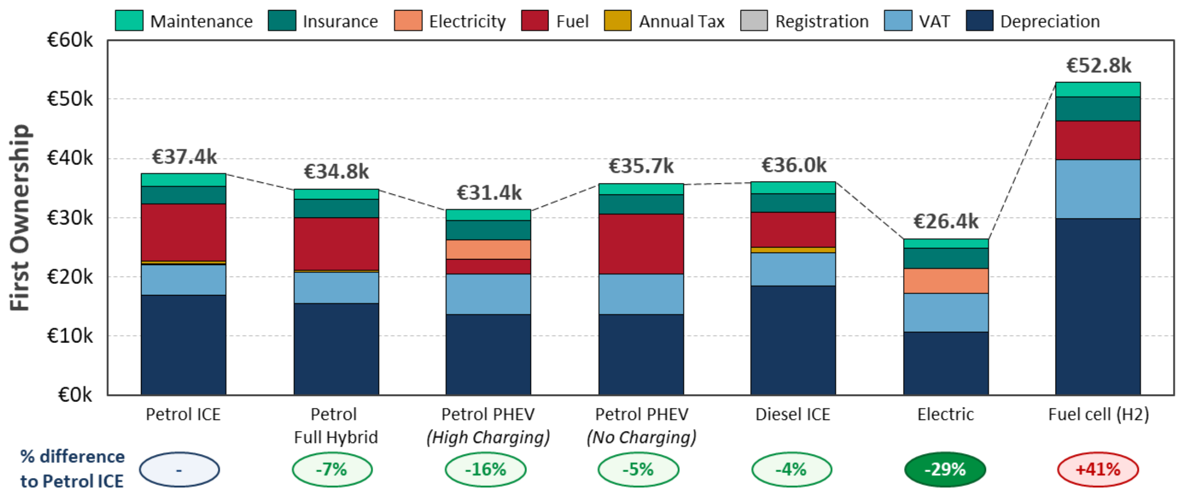


Figure 12: first owner TCOs for different powertrains for a medium car bought new in 2020

Second Owners

As shown in Figure 13, for a second-hand medium car that was originally bought new in 2020 (and therefore bought by the second owner in 2024), depreciation makes up a smaller proportion of the overall TCO, with variation between vehicle powertrains driven largely by differences in fuel/electricity costs. It should be noted that VAT is not included for used-car owners in Germany. A medium BEV, originally bought new in 2020, will provide a €4,400 saving for its eventual second owners over a Petrol ICE, which amounts to a 19% cost saving.

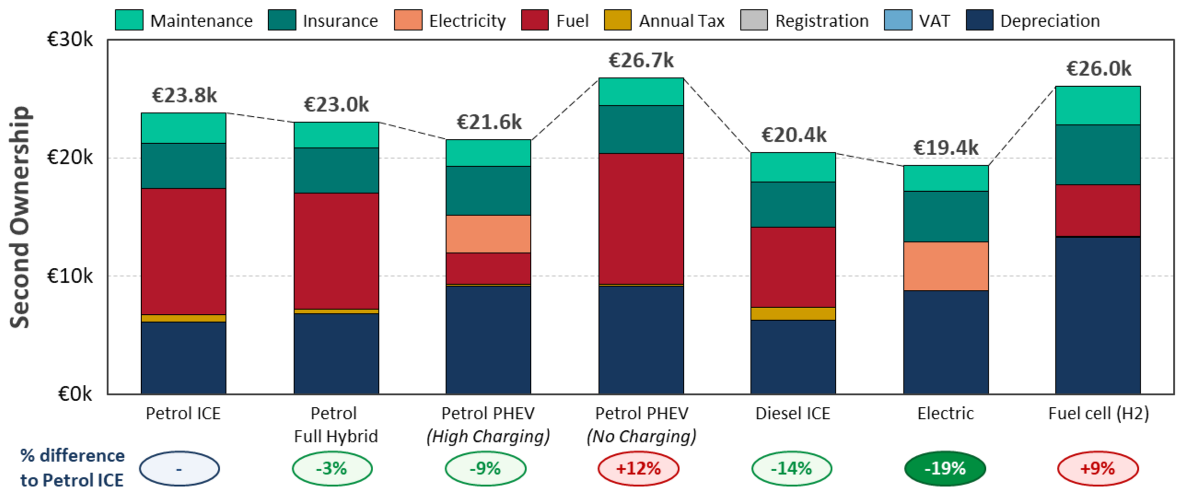


Figure 13: second owner TCOs for different powertrains for a medium car bought new in 2020

Third Owners

A third-hand medium car that was originally bought new in 2020 (bought by third owner in 2029) is shown in Figure 14. Once different powertrains have significantly depreciated, running costs determine TCO savings vs. the Petrol ICE baseline. BEVs offer best value to consumers, with almost €7,700 and €3,700 savings against a Petrol and Diesel ICE respectively. BEVs drive market equity as they unlock savings for the used-car owners, who are typically less affluent. For every medium BEV that is bought in 2020 instead of a Petrol ICE, the second and third owners combined will save almost €12,100 over the lifetime of the car. This shows that tightening European emission targets, thereby encouraging OEMs to promote earlier BEV adoption, will most benefit the least affluent consumers.

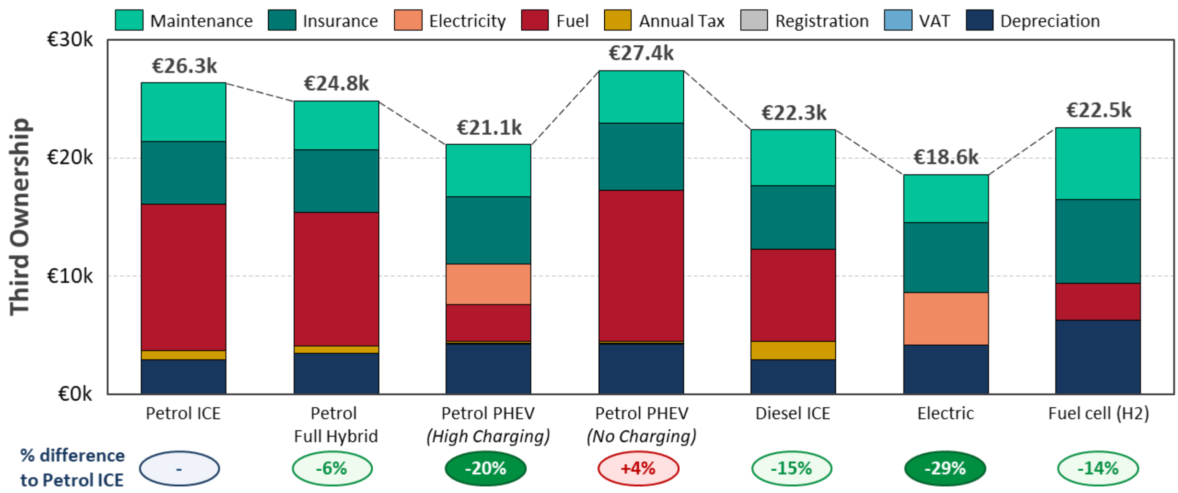


Figure 14: third owner TCOs for different powertrains for a medium car bought new in 2020

3.2 Germany compared to other European Focus Markets

For each of the nine European countries assessed in this project, the 2020 first owner TCO difference between BEVs and Petrol ICEs is plotted against current BEV sales[22] in Figure 15. There is a broad exponential correlation between Δ first owner TCO and BEV uptake, with the strongest growth seen in Germany and France where BEVs provide best value to consumers. Each market's position on this landscape should translate into a specific strategy in order to improve BEV uptake. In the green segment in the Figure, Germany has experienced strong growth due to small and medium BEVs currently being significantly cheaper than Petrol ICEs on a TCO basis for first owners. Policy makers should start to phase out purchase subsidies over the next four years, with small BEVs becoming cheaper than Petrol ICEs on a first owner TCO basis in 2025 without the Umweltbonus.

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

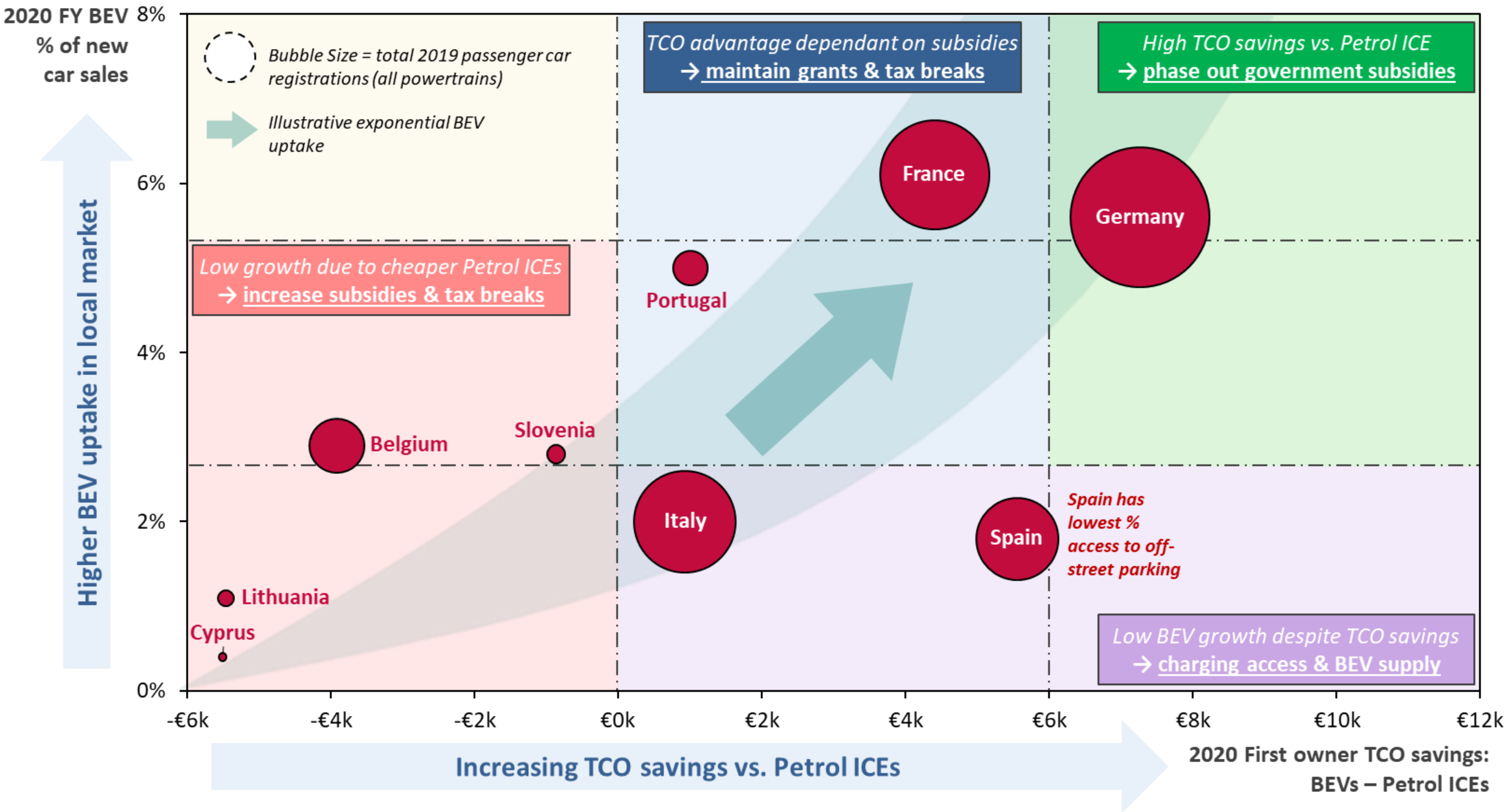


Figure 15: weighted average for small & medium cars showing BEV 2020 share of market sales vs BEV first owner Δ TCO to Petrol ICEs

4 Germany Specific User Groups

There is high variation in the driving behaviour and needs of consumers, and the TCOs different powertrains offer will change significantly due to factors including annual mileage and charging access. Specific user groups are detailed in this section in order to give “real world” examples of the relative TCOs for different consumer groups for a new car bought in 2020. The BEV in each scenario is based on a real model available today, and is compared to the segment averages of the other powertrains.

4.1 First Ownership Scenarios

Figure 16 shows the input parameters that test a first ownership sensitivity for (1) a daily commuter and (2) a part-time employee. The daily commuter has been modelled to have a significantly higher average annual mileage (25,000km). Based on discussions with local market experts at VZBV, the Tesla Model 3 (Long Range) was chosen as the representative BEV model for this specific user group, and is compared to the upper-medium car (ACEA segment D) segment averages for the other powertrains. The part-time employee has a first owner annual mileage (15,000km), slightly below the German national average (18,000km), which is representative of a consumer that provides childcare and uses their vehicle for limited work travel. This scenario tests a sensitivity around charging access and tariffs, with two scenarios modelled considering a user that relies exclusively on either (a) public DC charging and (2) public AC charging. The Nissan Leaf (40kWh) is compared to the lower-medium car (ACEA segment C) segment averages for the other powertrains in this sensitivity. The BEVs in these scenarios are assumed to get the Umweltbonus and Innovationsprämie, however, additional graphs without any purchase subsidies are provided in Appendix 6.3.5.

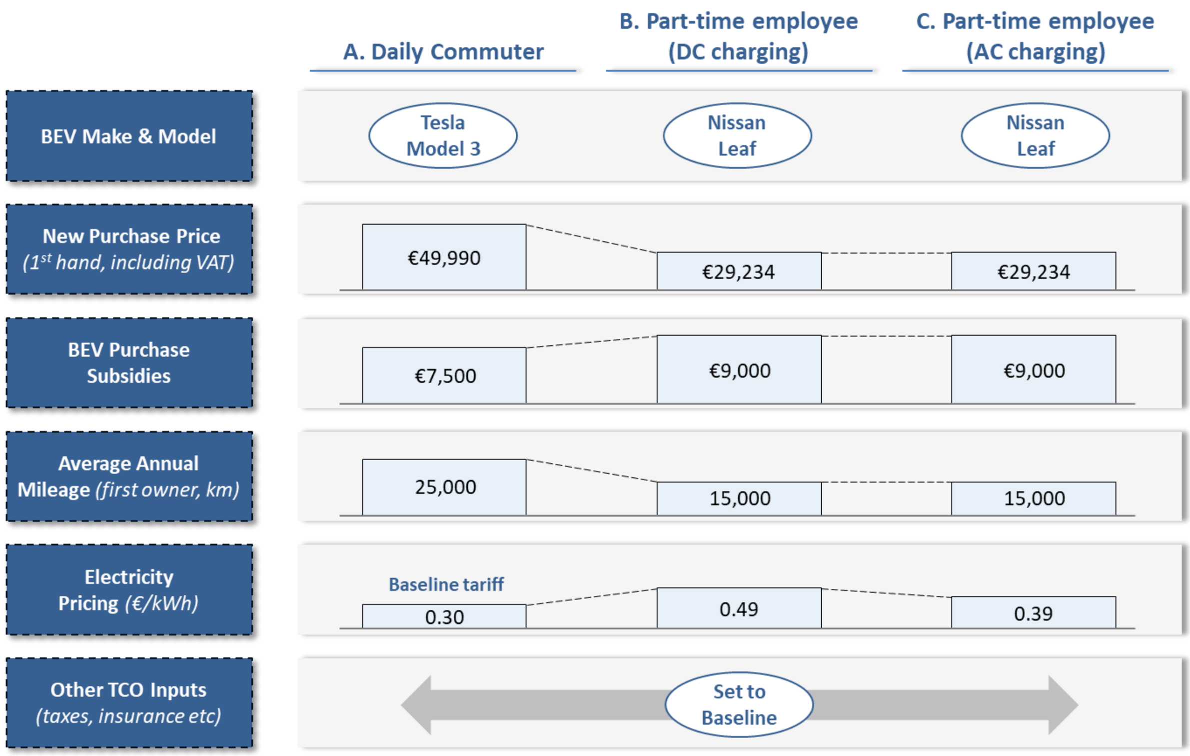


Figure 16: input parameters for a first owner daily commuter and part-time employee buying a new car in 2020

4.1.1 Daily Commuter

The first owner TCO results for a new car bought in 2020 for the daily commuter sensitivity are shown in Figure 17. The Tesla Model 3 (Long Range) provides consumers with savings over a Petrol and

Diesel ICE of €16,700 and €12,800 respectively. This means that with appropriate financing options, a Tesla Model 3 (Long Range) could provide these consumers with significant savings from day one. High mileage drivers should be considered a top priority group to incentivise to switch to BEVs. Financially, this user group benefits the most from switching, while also being the largest producer of CO_2. 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. Please find a version of this Figure for a Tesla Model 3 (Standard Range) in Appendix 6.3.6.

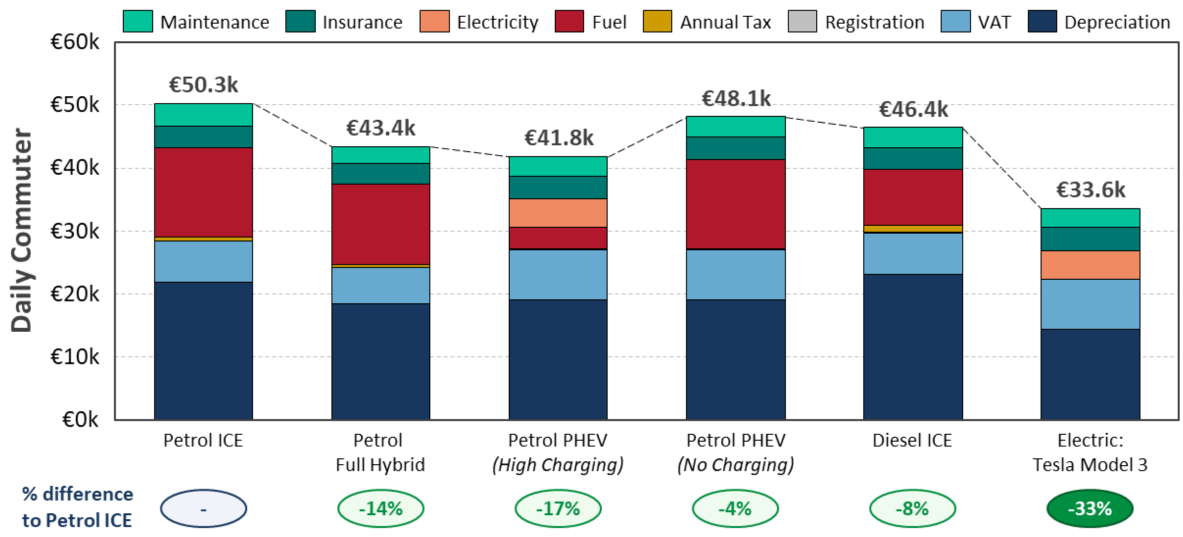
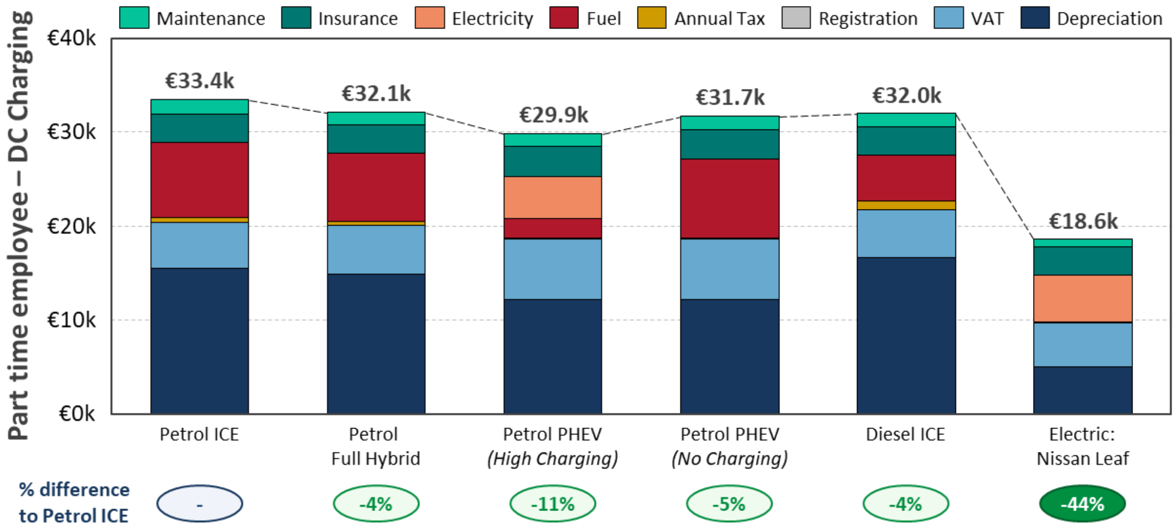


Figure 17: first owner TCOs for a new car bought in 2020 for a daily commuter. The Tesla Model 3 (Long Range) is compared against the upper-medium segment averages of the other powertrains.

4.1.2 Part-time Employee

Figure 18 illustrates the first owner TCO results for a new car bought in 2020 for consumers that use exclusively more premium public charging. The Nissan Leaf saves consumer 44% and 47% over a lower-medium Petrol ICE even when relying on DC and AC public charging respectively. Even when the Umweltbonus and Innovationsprämie are removed, the Nissan Leaf still provides savings of 17% for DC charging and 21% for AC charging tariffs over an equivalent Petrol ICE, with full graphs shown in Appendix 6.3.5.

These scenarios, show greater savings available to consumers than the medium car baseline case discussed in Section 3.1.2 despite more premium charging tariffs. This is because the Nissan Leaf is a more mainstream model than the average medium BEV, which is typically of a significantly higher specification than the average medium ICEV. This demonstrates that where OEMs provide more equivalent and cheaper models to consumers, significant TCO savings can already be achieved for BEVs over ICEVs.



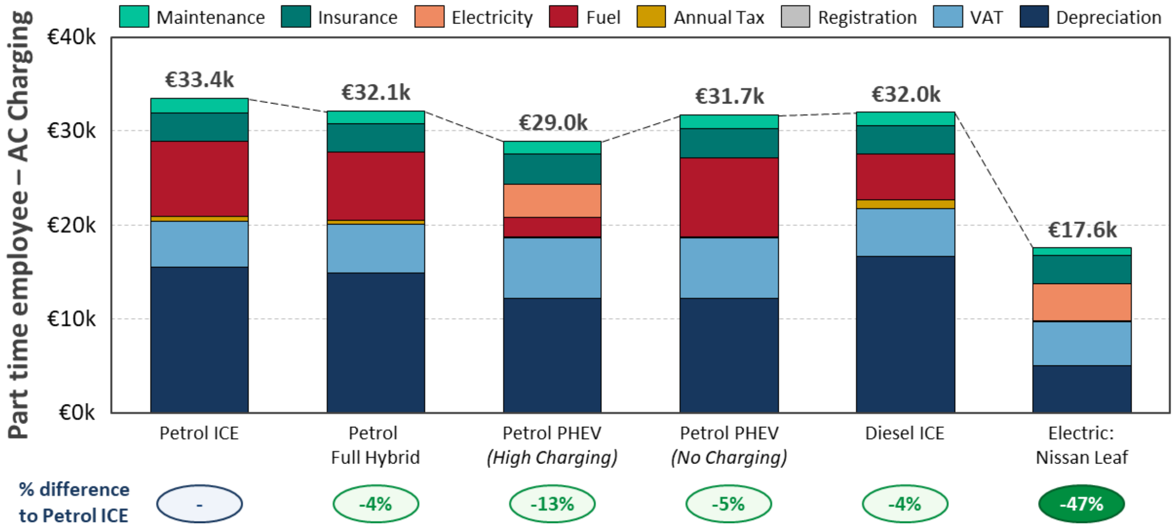


Figure 18: first owner TCOs for a new car bought in 2020 for a part-time employee. The Nissan Leaf is compared against the lower-medium segment averages of the other powertrains.

4.2 Used Car Sensitivities

4.2.1 Pensioner / Retiree

Figure 19 shows the input parameters for a scenario considering a pensioner / retiree that has a significantly lower average annual mileage. These parameters may also represent a sub-urban or city-based used car buyer. The Renault Zoe is assumed to be a typical model for this user group, which is compared to supermini (ACEA segment B) segment averages for the other powertrains. This consumer is assumed to have a lower average annual mileage and typically buys cars second-hand. Please note that no second-hand purchase subsidies have been assumed to be available for this user group in this scenario. The Renault Zoe bought new in 2020 is estimated to cost its eventual second and third owners ca. €9,000 and €3,500 respectively in terms of upfront purchase price.

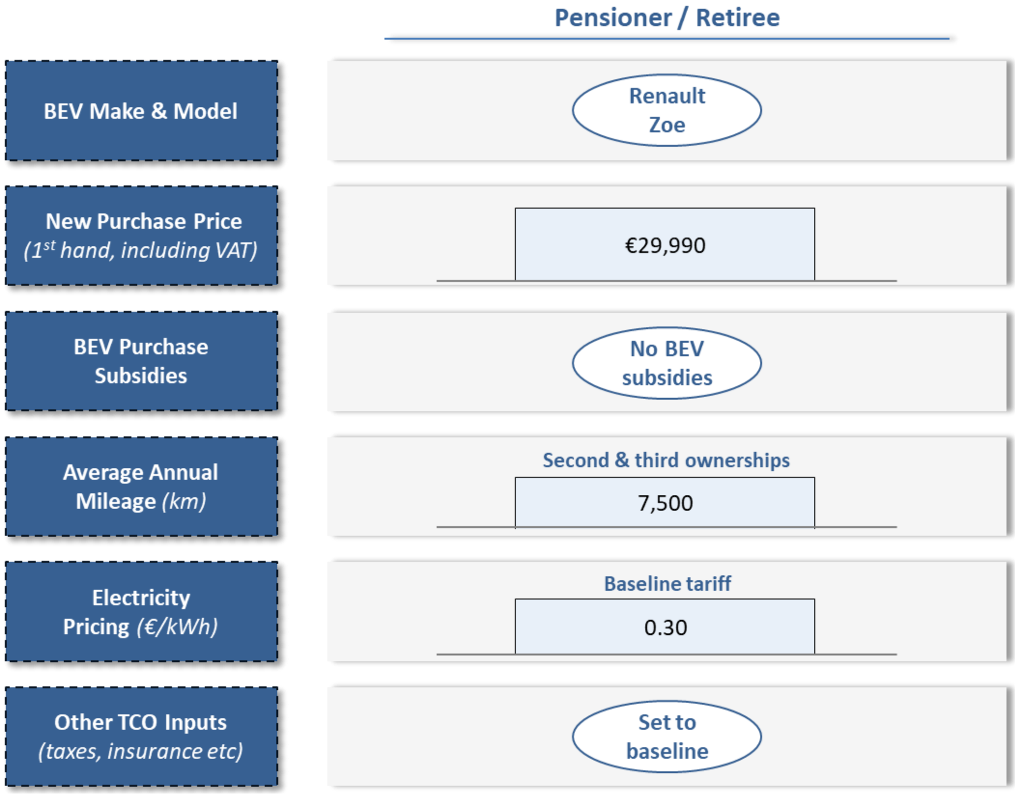


Figure 19: input parameters for a second & third owner pensioner / retiree

Figure 20 shows the second and third owner TCO results for a pensioner / retiree for a car originally bought new in 2020. The Renault Zoe allows consumers to achieve 11% and 26% TCO savings compared to an equivalent Petrol ICE for its eventual second and third owners, which amounts to total savings for its combined used owners of €5,800 over the car's lifetime. This demonstrates that BEVs provide a cost competitive option for a wide range of consumer groups and, where OEMs have provided sufficient mainstream models, BEVs can already meet the different driving needs of German consumers.

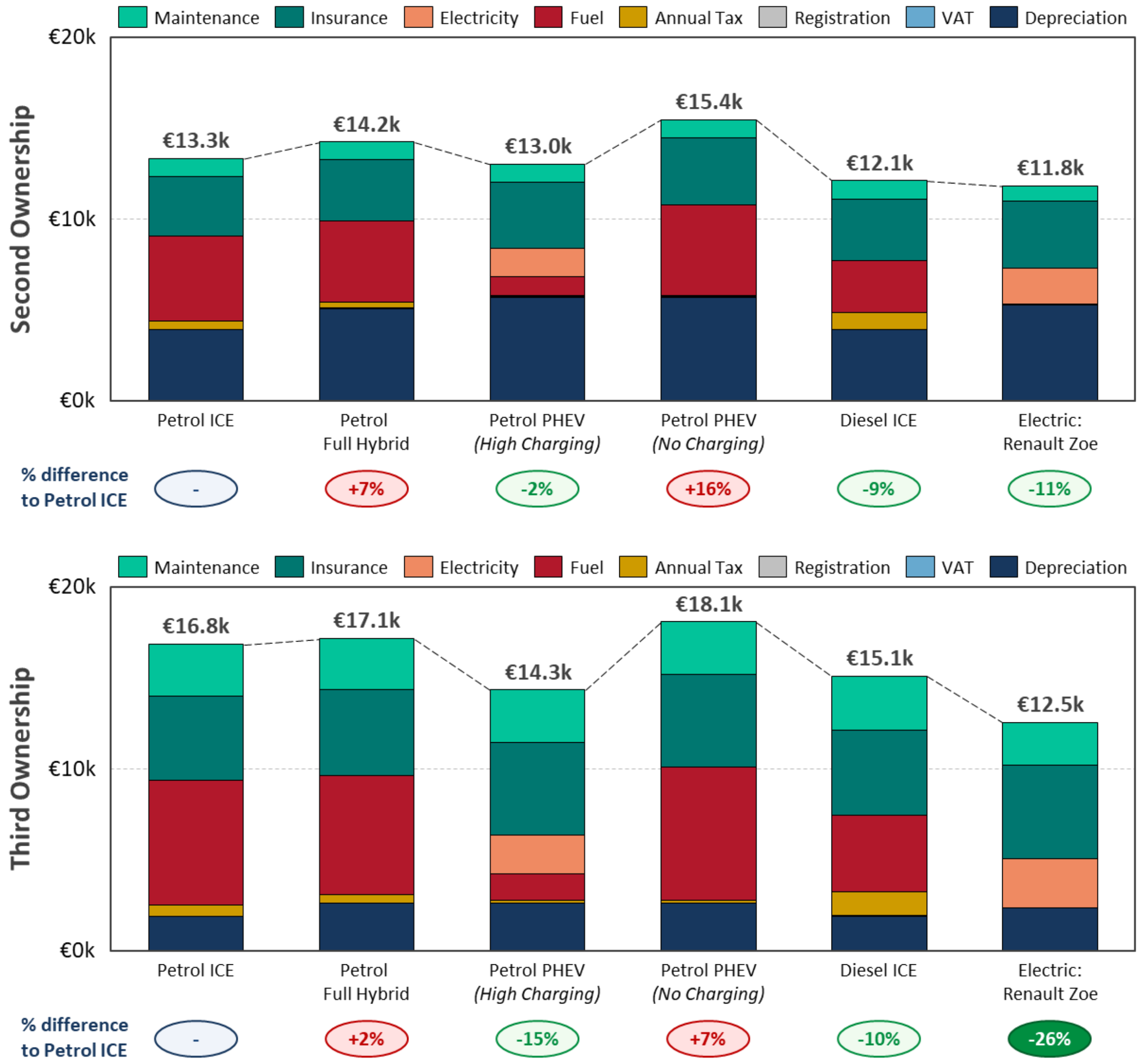


Figure 20: second and third owner TCOs for a car originally bought new in 2020 for a pensioner / retiree

5 Conclusions

This study has assessed forecasted TCOs for different powertrain cars in Germany 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 German consumers as well as policymakers responsible for leading the decarbonisation transition.

BEVs are already the cheapest powertrain for small and medium cars on a lifetime TCO basis bought new today, and will become the cheapest for large cars by 2025. This is four years earlier for small cars and one year earlier for large cars than EU averages (excluding taxes and subsidies).

BEVs offer most savings to less affluent consumers. A medium BEV bought new today will save almost a total of €12,100 for its eventual second & third owners combined compared to a Petrol ICE. Switching to BEVs is essential for decarbonisation but also for reducing the adverse health impacts from air pollution in local urban areas. Tightening EU manufacturer emission targets will most benefit the least affluent consumers by increasing the available stock of used BEVs more quickly. This will also promote a higher variety of BEV models, such as increasing the range of small and large vehicles, which has historically been limited, in order to meet the driving needs of all consumers in Germany.

Petrol PHEVs that are not charged become the most expensive powertrain for consumers. Second and third owners, who are less likely to have access to off-street parking and therefore home charging risk being impacted by higher running costs. Furthermore, Petrol PHEVs pose a potential competitive risk to the uptake of BEVs rather than being a “stepping stone” to fully electric cars, and will not necessarily bring the expected emissions savings.

Umweltbonus should be phased out between 2021-25

Strong BEV growth in Germany has been achieved due to significant TCO savings over a Petrol ICE being available to first owners for small and medium cars. In Germany, without upfront subsidies, small cars will not become cheaper than Petrol ICEs until 2025, however, medium cars would already be cheaper today even without the Umweltbonus.

While maintaining purchase subsidies for small cars is necessary until 2025, it is important that governments do not continue to subsidise BEVs for first owners once the market reaches the stage where many consumers would already choose to buy a BEV regardless of incentives being available, which is expected to happen in in Germany by the mid-2020s. While subsidies remain, there is a risk that OEMs may keep BEV prices artificially high which would limit additional savings made available for consumers. Purchase price limits for subsidies are important to maximise the benefits for consumers from government investment. It is important that policymakers in Germany find a balance between encouraging earlier BEV adoption, while making sure that investment is targeted where most needed in maximising electromobility, and, in particular, does not compromise the immediate roll out of charging infrastructure.

Removing barriers to BEV uptake in Germany

It is essential that policymakers address the two most important barriers to BEV consumer uptake: (1) access to reliable and affordable charging (2) adequate OEM supply of BEV models. While strengthening manufacturer emission targets is the most impactful way to support BEV supply, policymakers should adjust charging strategies to meet the specific needs of various socio-economic groups and acknowledge the differences in charging behaviour between first-hand and used-car buyers, with used-car owners less likely to have off-street parking. A comprehensive and strategically located charging network offering attractive tariffs (via preferential pricing for frequent users, smart charging or EV charging included in electricity contracts and roaming agreements with charging operators) is crucial to ensure drivers have confidence in publicly available infrastructure, which will encourage consumers to switch to BEVs more quickly.

Specific user groups: BEVs provide cost savings for a wide range of different consumers

There are many German consumers who have high average annual mileages, which significantly increases the savings offered by BEVs, due to their lower running costs. The 2020 first owner TCO was considered for a daily commuter (annual mileage of 25,000km), where the BEV model is assumed to be a Tesla Model 3 (Long Range). The Model 3 provides high mileage consumers savings of €16,700 over an equivalent Petrol ICE, and tailpipe CO_2 emission savings ca. 40% higher than for an "average first owner" (annual mileage of 18,000km) that switches to a BEV. This user group benefits the most on a TCO basis while driving the highest savings of CO_2 emissions. Therefore, it must be considered a top priority group for policymakers. Particular focus on investment, especially in urban areas, 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.

Specific user group analysis for a part-time employee showed that a Nissan Leaf saves consumers 44% and 47% over a lower-medium Petrol ICE even when relying exclusively on public DC and AC charging respectively. This demonstrates that on-street public charging, which will likely become typical in urban and sub-urban areas, where consumers do not have access to off-street parking, provides a cost effective option for consumers.

Many consumers in Germany have access to off-street parking, with a DENA report in 2020 estimating that 80% of German vehicle owners living in a single-family home have parking in their garage/carport, with 55% of users living in a multi-household building having access to a parking space[23]. Potential opportunities to access cheaper off-peak charging tariffs can have 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 increasingly important through the decarbonisation transition in managing peak loads, while allowing consumers to access additional savings.

Sensitivity modelling, based on a Renault Zoe bought new today, for a pensioner with a significantly lower average annual mileage (7,500km) showed that consumers could access 11% and 26% TCO savings compared to an equivalent Petrol ICE for its eventual second and third owners respectively, which amounts to total savings for its used owners of €5,800. This demonstrates that the decarbonisation transition, and specifically the market shift to fully electric cars, will benefit a wide range of consumers with different driving needs.

[23]https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2020/dena-STUDIE_Privates_Ladeinfrastrukturpotenzial_in_Deutschland.pdf

6 Appendix

6.1 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.

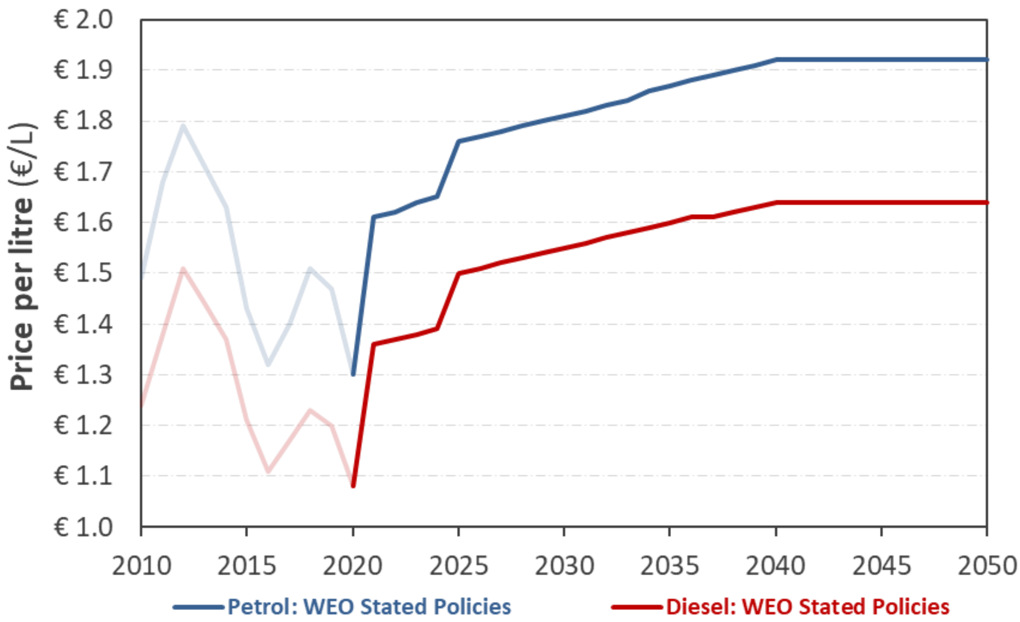


Figure 21: petrol & diesel price forecasting between 2020-50

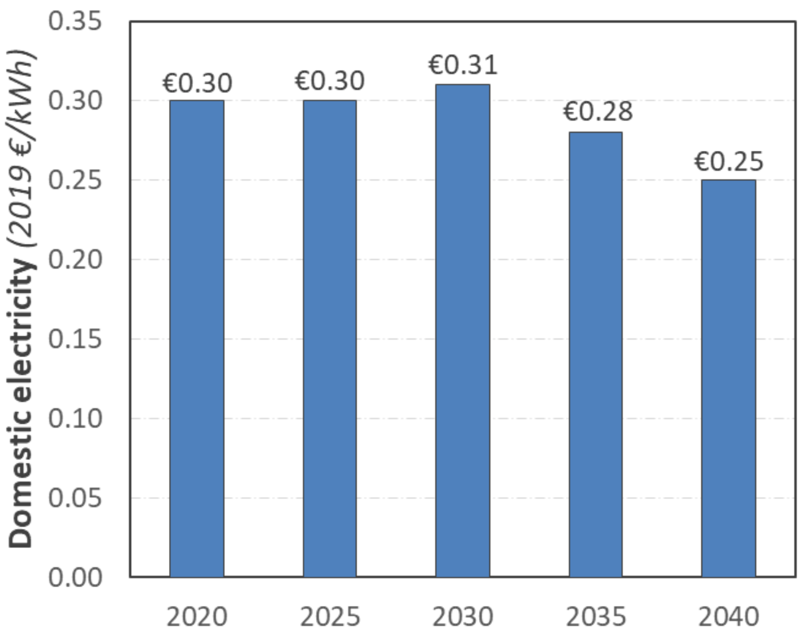


Figure 22: electricity price forecasting between 2020-40

6.2 Taxes & Subsidies

A. **Registration Fee:** €26.30 at the start of each ownership

B. **Annual Vehicle Tax:**

Table 1: Vehicle tax – CO_2 component

CO_2 emissions per km	€ / g CO_2 > lower bound
<95	-
95-115	2.00
115-135	2.20
135-155	2.50
155-175	2.90
175-195	3.40
>195	4.00

Table 2: Vehicle tax – engine capacity component

Petrol	Diesel
€2.00 per 100cc	€9.50 per 100cc

Note: BEVs & Fuel Cell (H2) are assumed exempt

C. **EV First Owner Subsidies:**

Table 3: EV purchase subsidies

EV Type	Umweltbonus	Innovationsprämie	Conditions
Fully-electric	€6,000	€3,000	Max list price €40,000
Fully-electric	€5,000	€2,500	List price above €40,000
Plug-in Hybrid	€4,500	€2,250	Max list price €40,000
Plug-in Hybrid	€3,750	€1,875	List price above €40,000

6.3 Additional TCO Results

6.3.1 Second Owner TCOs

The year on the x-axis shows when the car was originally bought new, with the vehicle entering the second-hand market 4 years after this date.

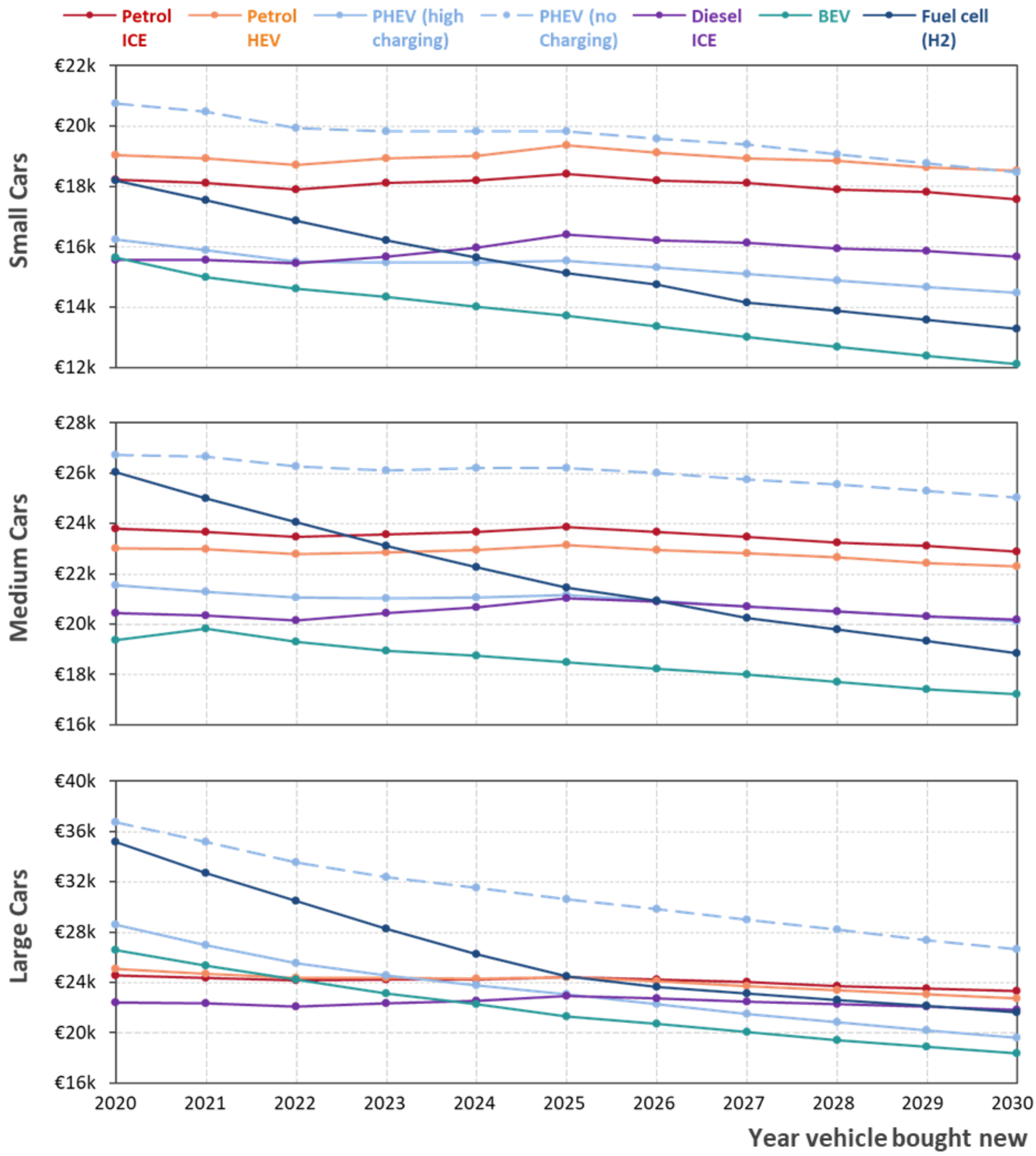


Figure 23: second owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

6.3.2 Third Owner TCOs

The year on the x-axis shows when the car was originally bought new, with the vehicle entering the third-hand market 9 years after this date.

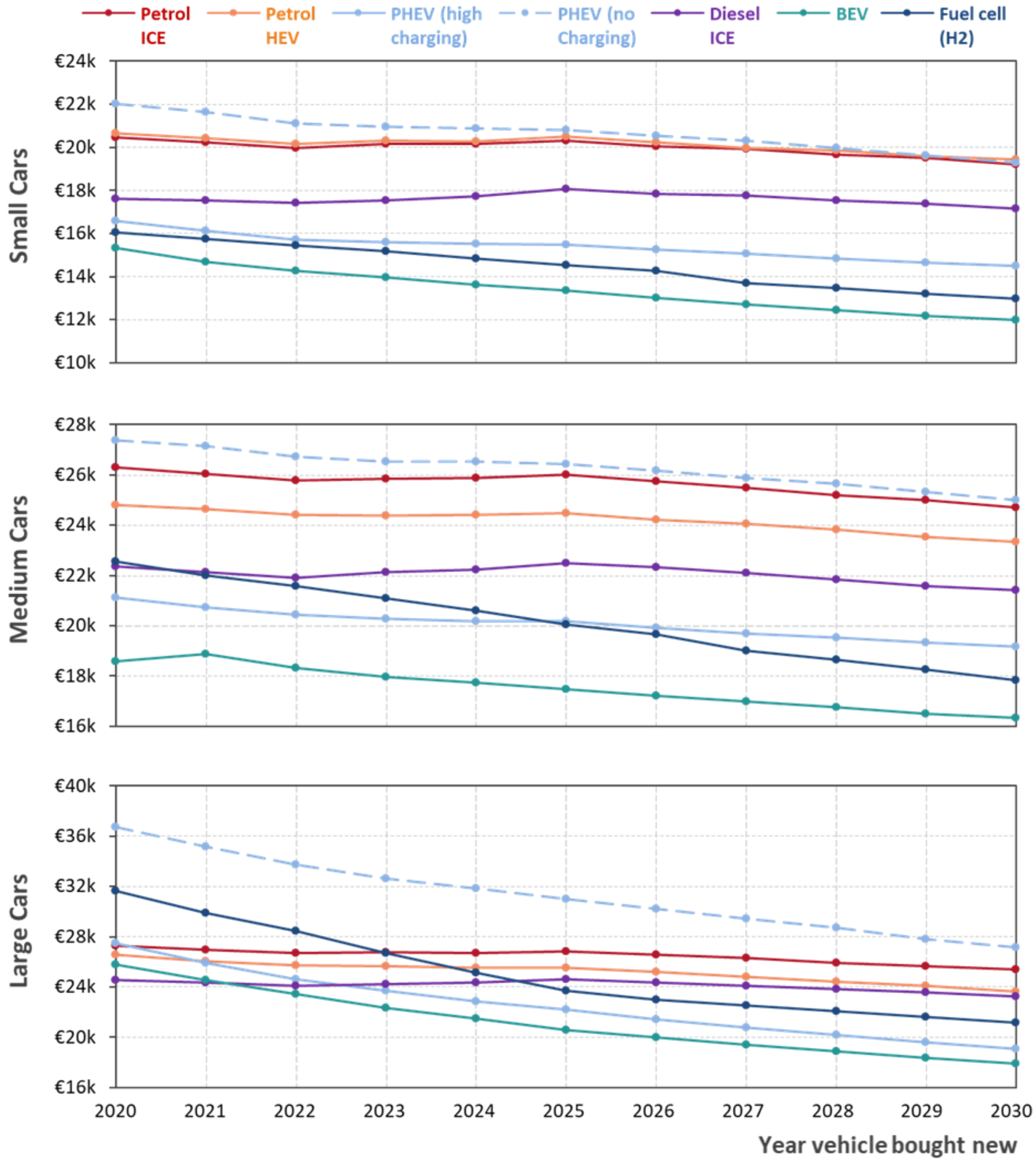


Figure 24: third owner TCO comparison between different powertrains. Note that the year indicates when the car is first bought new.

6.3.3 Medium Car Cost Components: vehicle originally bought new in 2025

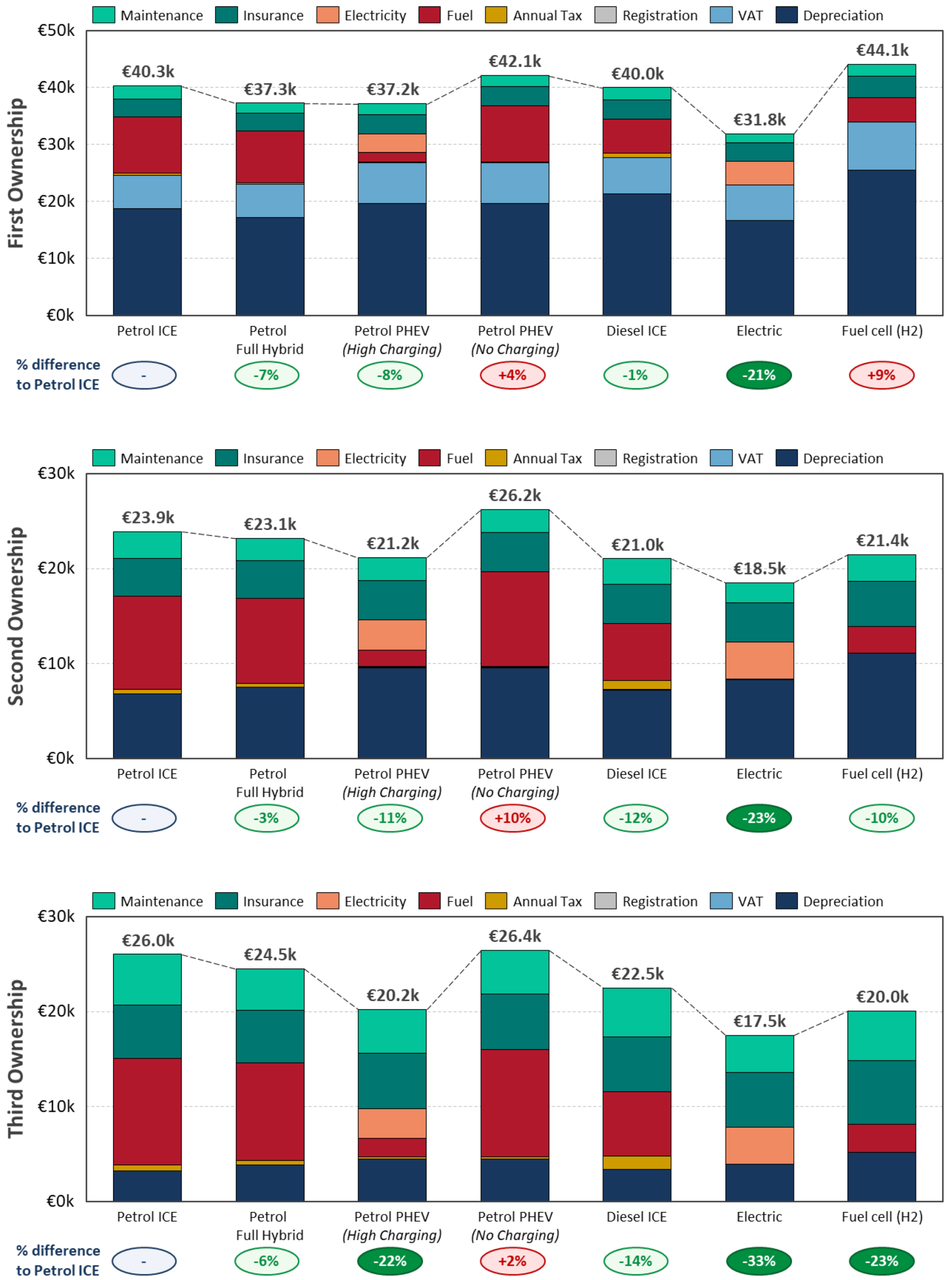


Figure 25: TCOs on a cost component level for different powertrains bought new in 2025

6.3.4 Medium Car Cost Components: vehicle originally bought new in 2030

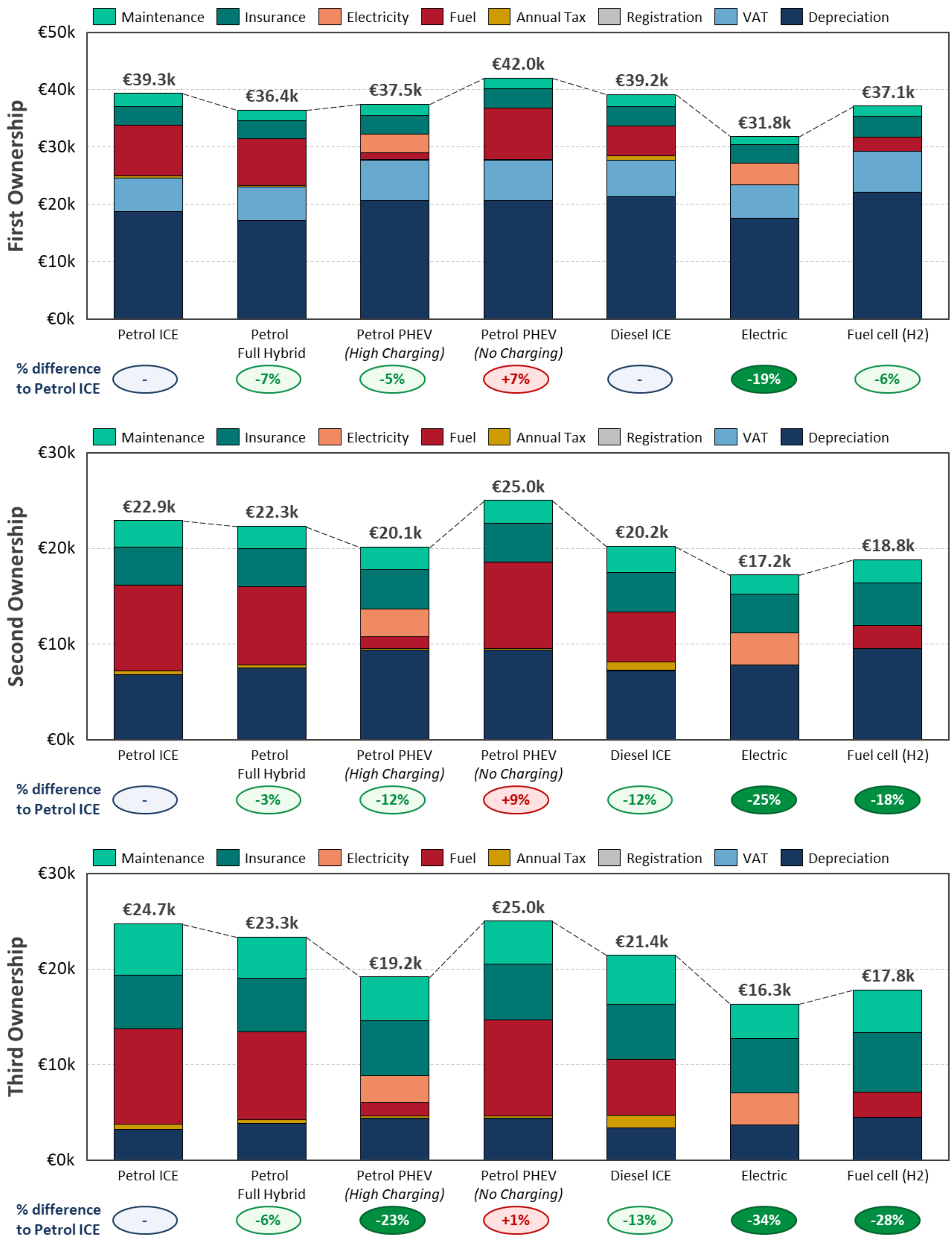


Figure 26: TCOs on a cost component level for different powertrains bought new in 2030

6.3.5 First Owner Specific User Group Scenarios: excluding subsidies

Figure 27: first owner TCOs on a cost component level for different powertrains bought new in 2020 excluding purchase subsidies

6.3.6 Daily Commuter: Tesla Model 3 Standard Range

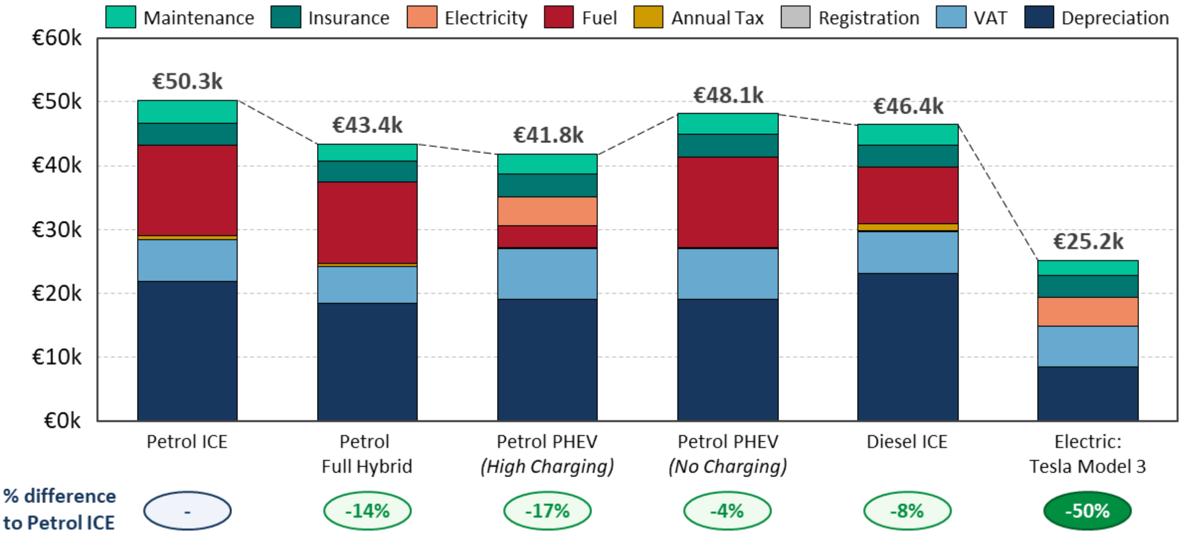


Figure 28: first owner TCOs for a new car bought in 2020 for a daily commuter. A Tesla Model 3 Standard Range is compared against the upper-medium sized segment averages of the other powertrains.