Final report

Study on the implications of EU policies for the affordability of car use in the future

Study for **FIA European Bureau**
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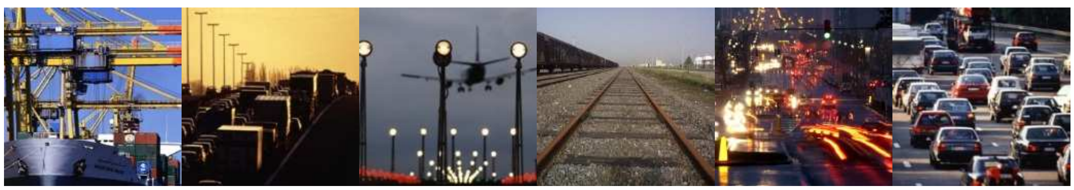

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Executive Summary

Background

In July 2021, the European Commission presented its Fit for 55 Package. The package contains legislative proposals and revisions of current EU legislation that should contribute to the 55% greenhouse gas emission reduction target by 2035, compared to 2005, and the 2050 climate neutrality objective.

The Fit for 55 Package measures will further stimulate the electrification of the passenger car fleet, pushing consumers to make the transition from fossil fuel cars to electric vehicles. These measures are expected to have an impact on prices of passenger cars and fuel. The following Fit for 55 Package proposals are specifically relevant for the passenger car market:

- More stringent greenhouse gas emission targets,
- Emission Trading System (ETS) for road transport
- Social Climate Fund.

The impact assessment of the European Commission found that the Fit for 55 policies would not threaten the affordability of a Battery Electric Vehicles (BEVs). In all scenarios considered by the Commission, BEVs will become affordable over time. However, for low-income households, new passenger cars are never affordable and can only afford purchasing used cars.

The European Commission's impact assessment was developed before the current energy crisis. Currently, energy prices in Europe are at an all-time high because of the Russian invasion of Ukraine. This raises concerns about the affordability of passenger car ownership and use, and the intended electrification.

In addition, Total Cost of vehicle Ownership (TCO) calculations assume a decrease of the BEV's purchase price due to declining production costs. Recent literature has challenged these assumptions. For instance, van Velzen et al. (2019) argue that many EVs are currently sold below production costs and that, even when production costs decline, manufacturers will keep prices high to recover the high investment costs. Therefore, to assess the future affordability of passenger cars, it is important to consider alternative scenarios with respect to the purchase price of electric vehicles.

Current state of the European market

The share of EVs in the total sales of new vehicles has increased rapidly in Europe in recent years. In 2021, the share of EVs in the total sales of new passenger cars was equal to 9% in the EU-27 region. High income countries have the highest share of EVs, with Norway, Iceland, the Netherlands, Sweden, and Austria leading the pack. In 2021, the top five countries with respect to BEV sales were Germany, the UK, France, Norway, and Italy. Germany clearly stands out with respect to new EV registrations, which is a consequence of the generous financial incentives provided by the German government; however, most of these incentives are scheduled to be phased out soon, therefore substantially impacting the TCO of EVs.

In most European countries, EV ownership is positively correlated with wealth, income, education and having solar panels. This is not surprising because new technologies are typically adopted first by the most affluent consumers. In countries where EVs are more established, the characteristics of electric car owners and fossil fuel car owners assimilate.

Study objectives

This study investigates the future affordability of car ownership and use in Europe in the context of the proposed EU policies and the current energy crisis. It compares the main determinants of the Total Cost of Ownership (TCO) of fossil fuel cars (ICEVs) compared to electric passenger cars (EVs) and identifies the driving factors behind affordability and equity.

Total Cost of Ownership of passenger cars in selected EU countries

To assess the impact of the electrification of the passenger car fleet that is the intended consequence of the Fit for 55 measures, we develop a Total Cost of Ownership (TCO) model for passenger cars in three EU countries, Denmark, Germany, and Italy. We calculate the TCO for small (segment B) and medium-sized (segment C) cars in Germany and Italy and for a medium-sized car and a SUV (segment L) in Denmark. Within each segment, we compare the TCO of a fossil fuel model with that of a comparable battery electric model. The TCO is consumer-oriented and uses actual sales prices instead of manufacturing costs. Cost items in the TCO are categorized as one-time costs, recurring variable costs and recurring fixed costs. For EVs, we also take the purchase, installation, and maintenance costs of charging infrastructure into account.

In the baseline analysis, we assume that the first owner drives 15 000 km per year and holds on to the vehicle for five years. The first owner of an EV is expected to be a regular Wallbox user, who chargers 90% privately (at home or at another private charging point) and 10% at public charging stations. The second owner is assumed to buy a five-year old vehicle with a cumulated mileage of 75 000km and hold on to this vehicle over its remaining lifetime. Because a higher proportion of second owners are assumed to be lower-income households that cannot install a private charging system, we assume that second owners charge 60% privately and 40% at public charging stations, on average. We test alternative charging profiles in a sensitivity analysis.

To understand the potential range of cost differences between EVs and ICEVs, we develop a Low EV-cost and a High EV-cost scenario, assuming favourable and unfavourable conditions for electric vehicles.

The main results of the TCO are shown in the tables below. We find that:

- In the base case, EVs are more affordable than comparable ICEVs for first owners in the three countries. The TCO gap between EVs and ICEVs is largest in Germany, that offers generous financial incentives for electric vehicles. The cost gap is the smallest in Italy, where small EVs are nearly at par with small ICEVs.
- The cost advantage of EVs over ICEVs is much smaller for second owners. This is because most financial incentives are limited in time or only applicable to first time registrations. In Italy, second owners of EVs face higher costs than used ICEV owners in each scenario. In Denmark, used EVs are cheaper than used ICEVs in each scenario.
- For first owners, the TCO vary significantly depending on the scenario. In the Low EV cost-scenario, electric cars are relatively cheap with TCO that can drop to 70% below those of a comparable ICEV. In the High EV cost-scenario, the opposite occurs and EVs may become up to 79% more expensive than ICEVs in the base case.

- The impact of the Low and High EV cost-scenarios is less extreme for second owners. This is because in the Low EV cost-scenario, EVs have a low depreciation rate, which benefits the first owner but increases the purchase cost for the second owner. Vice versa, in the High EV cost-scenario, first owners face a high depreciation rate, while second owners can benefit from a lower purchase price.

Next to the scenario analysis, we run several sensitivity tests to investigate the impact of some key assumptions in the TCO model. We find that the purchase price and the resale value (depending on the depreciation scheme) are key determinants of the TCO. The depreciation scheme has an important effect on the purchase price of used cars. If EVs depreciate at a slower pace than what is expected in the baseline scenario, used EVs will remain more expensive than used ICEVs at least until 2034. If EVs devalue more quickly than in the baseline, price differences between medium-sized used EVs and used ICEVs may become negligible by 2025 already. For small cars, the price gap persists much longer.

Table 0-1 TCO results small cars (Segment B) in euro per km

	First owner			**Second owner**		
	ICEV	EV	Cost gap	ICEV	EV	Cost gap
Germany						
Base case	€ 0.41	€ 0.28	-32%	€ 0.30	€ 0.24	-19%
Low EV cost		€ 0.13	-68%		€ 0.25	-15%
High EV cost		€ 0.61	+49%		€ 0.32	+9%
Italy						
Base case	€ 0.37	€ 0.36	-2%	€ 0.30	€ 0.31	+3%
Low EV cost		€ 0.22	-42%		€ 0.32	+8%
High EV cost		€ 0.66	+79%		€ 0.36	+18%

Source: own calculations

Table 0-2 TCO results medium-sized cars (Segment C) in euro per km

	First owner			**Second owner**		
	ICEV	EV	Cost gap	ICEV	EV	Cost gap
Germany						
Base case	€ 0.51	€ 0.34	-33%	€ 0.35	€ 0.27	-23%
Low EV cost		€ 0.15	-70%		€ 0.29	-19%
High EV cost		€ 0.71	+41%		€ 0.35	+0%
Italy						
Base case	€ 0.44	€ 0.40	-8%	€ 0.34	€ 0.35	+2%
Low EV cost		€ 0.24	-46%		€ 0.36	+7%
High EV cost		€ 0.73	+66%		€ 0.38	+11%
Denmark						
Base case	€ 0.53	€ 0.46	-12%	€ 0.36	€ 0.33	-8%
Low EV cost		€ 0.32	-39%		€ 0.34	-5%
High EV cost		€ 0.83	+59%		€ 0.35	-2%

Source: own calculations

Table 0-3 TCO results SUV (Segment L) in euro per km

	First owner			Second owner		
	ICEV	EV	Cost gap	ICEV	EV	Cost gap
Denmark						
Base case	€ 0.70	€ 0.61	-13%	€ 0.47	€ 0.41	-13%
Low EV cost		€ 0.39	-45%		€ 0.44	-8%
High EV cost		€ 1.16	+65%		€ 0.43	-8%

Source: own calculations

We also investigate the impact of the currently high energy prices on the affordability of passenger cars. The energy crisis affects petrol and electricity prices in a somewhat similar way. Therefore, the energy crisis has no significant impact on the cost gap between EVs and ICEVs. The costs for all vehicle types increase, affecting the overall affordability of passenger cars in Europe. We find that the currently high energy prices increase the TCO of passenger cars up to nearly 10%.

Strategies to help car users make the transition

We investigate financial and non-financial measures that authorities can take to support consumers in the transition towards electric passenger cars. With respect to financial policy measures, we find that purchase incentives such as subsidies have a larger TCO-reducing potential than recurrent financial incentives such as exemption of annual motor vehicle taxes. The main reason for this is that the latter are relatively low in the countries studied in this report. We show that the current financial incentives have a significant impact on the TCO of EVs. For example, if the German financial incentive package for EVs would be abolished, the TCO for small and medium EVs would increase by no less than 60% and 51%, respectively.

It is important to note that although financial incentives are important to support the uptake of EVs, special attention should be given to their design and implementation. Otherwise, the risk is that they only benefit the most affluent consumers. Currently, incentives to support the second-hand market of EVs are rare, while they are indispensable to develop this market and to support lower-income households.

With respect to non-financial measures, we find that the development of a dense, accessible, and high-quality charging network is the main determinant of electric vehicle uptake. Currently, there are significant differences between and within countries with respect to the availability and quality of the public charging network. Public charging points are predominantly available in more affluent areas and the share of fast and ultra-fast charging stations is low. As a result, charging of electric vehicles is predominantly done at home or at work. The lack of a dense and reliable charging network affects especially lower income households, which represent a larger share of consumers that have no opportunity to install a charging station at home.

Another non-financial measure that has the potential to further support the uptake of and affordability of EVs, is the development of car sharing services. By avoiding the high upfront costs, electric car sharing services may attract people who are interested in electric cars but cannot afford to buy one. However, currently the offer of car sharing services is limited in terms of location and time. The service is limited to highly populated areas and its users are mainly wealthy households. In addition, a successful deployment of car sharing services requires a strong mentality change from car ownership to car use.

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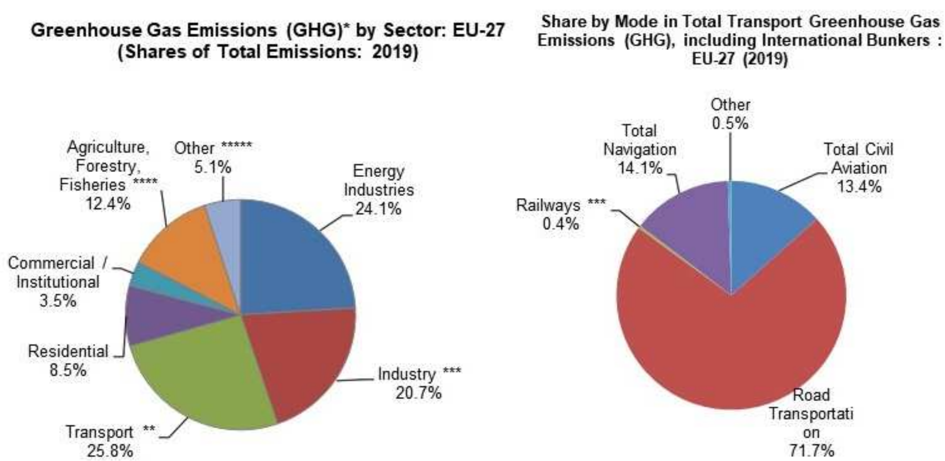
1 Introduction

1.1 Context

In 2019 transport accounted for 25.8 % of greenhouse gas emissions in the EU-27 (Figure 1-1). Within the transport sector road transport was responsible for 71.7 % of greenhouse gas emissions. Within road transport, passenger cars emitted more than 60 % of the greenhouse gas emissions. Heavy-duty vehicles (trucks and busses) accounted for 27 %. Apart from these so-called tank-to-wheel emissions, road transport also leads to indirect emissions related to the production, transport and transmission of the fuels and electricity that it consumes. These emissions are called well-to-tank emissions.

Figure 1-1 Greenhouse gas emissions in the EU-27 (2019) – left: by sector; right; share by mode in total transport GHG emissions



Source: EC (2021b), Statistical pocketbook 2021

Up to 2019 climate and energy policy in the EU resulted in significant greenhouse gas emission reductions in all sectors, except transport: total transport greenhouse gas emissions increased by more than 33 % between 1990 and 2019 and road transport emissions by almost 28 %. In 2020, due to the exceptional circumstances of the COVID-19 pandemic, transport emissions of greenhouse gases dropped by 19.7 % compared to 2019. Total energy related greenhouse gas in the EU-27 dropped by 12.1 % (EC, 2022). According to the Reference Scenario 2020 of the European Commission, which considers the existing policy measures, 2030 transport carbon dioxide (CO_2) emissions are expected to be 3.5 % above their 1990 level. They are projected to fall by 22 % in 2050 compared to 1990. This is far from the 90 % reduction for 2050 which is deemed to be needed for transport to contribute to the overall 2050 climate neutrality target that is set in the Climate Law.

In July 2021, the European Commission released the Fit for 55 Package. It contains proposals to deliver at least 55 % greenhouse gas emission reduction in 2030 and to pave the way to become climate neutral by 2050. Fit for 55 contains new legislative proposals as well as proposals for the revision of existing EU legislation. The following elements are relevant for road transport:

- A revision of the CO_2 standards for cars and vans
- A review of the Alternative Fuel Infrastructure Directive

- A revision of the Renewable Energy Directive
- The proposal for the introduction of an additional, separate ETS for the road transport and buildings sectors
- A revision of the Effort Sharing Regulation, Energy Efficiency Directive and Energy Taxation Directive
- A new Social Climate Fund.

If accepted these would have substantial implications for the GHG emissions of road transport. The legislative process concerning these proposals is currently ongoing. Chapter 2 presents the outcome of the recent steps in the legislative process.

On February 24, 2022, Russia invaded Ukraine. This has led to further initiatives by the European Commission to strengthen the EU's position, including the RepowerEU proposal, with even more ambitious targets for the share of renewable energy.

Even before the invasion of Ukraine, Europe was confronted with high energy prices. The invasion put even more pressure on them. The high energy prices and the indirect price effects across the economy are causing high inflation in the EU-27 and set economic challenges for households, firms, and governments. In a speech to the European Parliament end of September 2022 the head of the ECB said the economic outlook "is darkening" and that business activity is to "slow substantially" in the following months[1]. The question of affordability of car use needs to be seen in this light.

1.2 Aim of the study

Within this context, this study aims to investigate the implications of the proposed EU policies for the future affordability of car use in the EU. The analysis aims to support the FIA European Bureau and its member Clubs by contributing to the understanding of the factors determining the affordability for car users.

1.3 Structure of the report

The structure of the report is as follows. First, Chapter 2 sets the scene for the study. It presents information on the status of electric vehicles in Europe. Chapter 2 also provides an overview of the legislative context for this project, notably the current policy framework and the potential implications of the Fit for 55 package. Next, Chapter 3 presents the determinants of the total cost of ownership of different car types, today and how they are projected to evolve in the future. Finally, Chapter 4 discusses the pros and cons of various strategies that can be used to make the transition from combustion engines to electric vehicles easier for car users.

[1] https://abcnews.go.com/Business/wireStory/europes-outlook-darkening-ecb-head-hedges-recession-90526061

2 Setting the scene

Key messages

- The share of electric vehicles in the sales of new vehicles in the EU-27 has increased in recent years, reaching 9% in 2021. The five countries with the highest market share of battery electric vehicles are invariably high-income countries.
- Despite the increase in sales, the share of electric vehicles in the EU-27 car fleet remains small in 2021, below 1 %. Given the average lifespan of cars, it can be expected to take a while before the share of the new technologies becomes dominant.
- The share of transport expenditures and spending on vehicle purchases in household expenses increases with income. This is seen across countries with different income levels, as well across income quintiles in the same country.
- At the beginning of the uptake of battery electric vehicles, the ownership of these vehicles increases with income, wealth, and education. In Norway, where battery electric vehicles already are more common, the owners of such vehicles have become more like the owners of cars with combustion engines.
- Currently the legislative process is ongoing for proposals in the Fit for 55 package of the European Commission with relevance for road transport, cars in particular. This includes the proposal to reduce the CO_2 emissions of new cars and vans by 100% by 2035, as well as the proposal for an emissions trading scheme for road transport and buildings and the proposal for a Social Climate Fund.
- The European Commission's Impact Assessment of the Fit for 55 package assesses the affordability of different car types for the income quintiles. On the one hand no affordability issues were found for the two highest income groups (quintiles 4 and 5), for quintile 3 as second users, and for all quintiles as third users. On the other hand, all car types resulted unaffordable for the lowest income quintile as first users. Higher target levels also mean more restricted choices for specific powertrains. In all scenarios considered in the Impact Assessment, battery electric vehicles are affordable or become affordable over time.

In this chapter, we present the status of the market for electric vehicles across the European Union, and the average transport expenditures across countries. In addition, we provide an overview of the current policy framework with respect to emission standards and the European emission trading system (ETS). Next, we discuss the impact of the Fit for 55 (FF55) proposal on the expected costs and emissions, as well as the social impact of FF55.

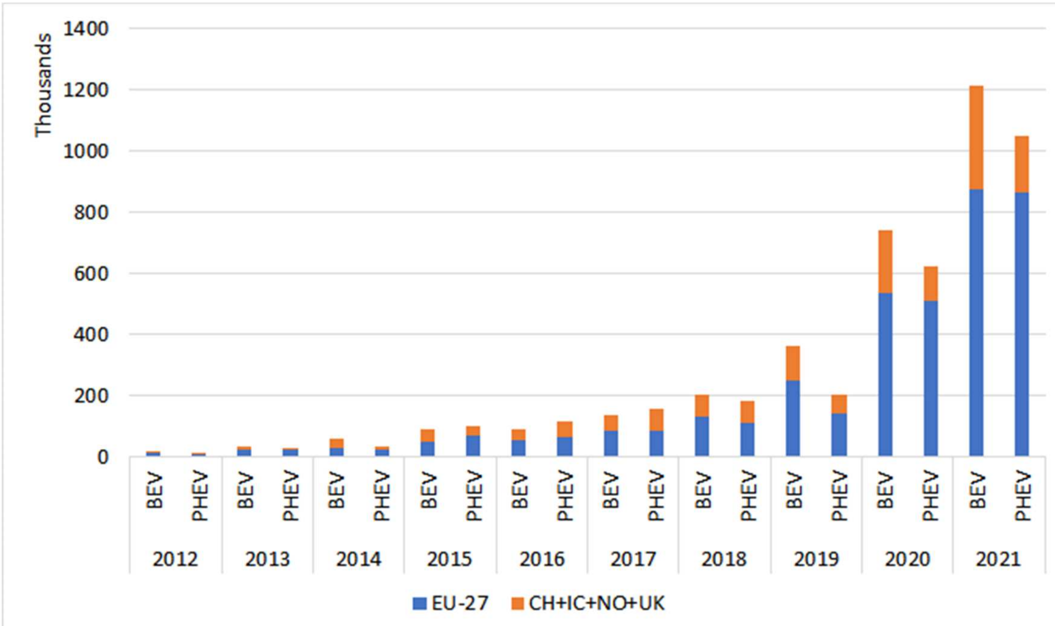
2.1 Status of electric vehicles in Europe

The European Alternative Fuels Observatory (EAFO) collects statistics on alternative fuel vehicles in the EU. Based on the EAFO data the following graphs present information on the status of electric vehicles in Europe.

Figure 2-1 presents the development of the number of new battery electric cars (BEV) and plug-in hybrid electric cars (PHEV) in the EU-27, and a selection of other European countries (Switzerland, Iceland, Norway, and the UK) between 2012 and 2021. This number increased significantly over time.

In 2015-2017 more PHEV were sold than BEV. In more recent years the opposite is the case considering the total of all countries. In the EU-27 the level of sales of the two types were comparable in 2020 and 2021.

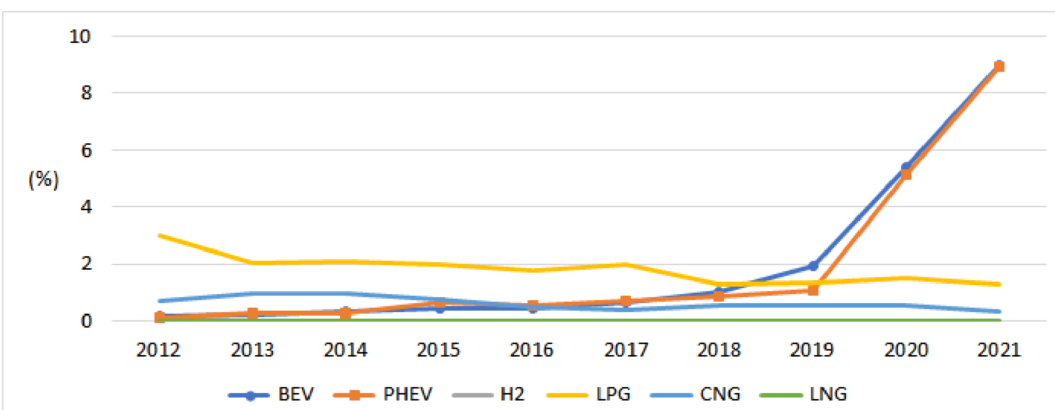
Figure 2-1 Registrations of new battery electric and plug-in hybrid electric cars in Europe – 2012-2021



Source: own elaboration based on EAFO (2022)

To put these sales in perspective Figure 2-2 shows how the EU-27 compare to the total number of new registrations. Before 2018 (in the case of BEV) and 2019 (in the case of PHEV) the share of these two technologies in the total sales of new cars was less than 1 %. After that their share increased, reaching about 9 % in 2021. The share of hydrogen powered cars was negligible (0.01 % in 2021).

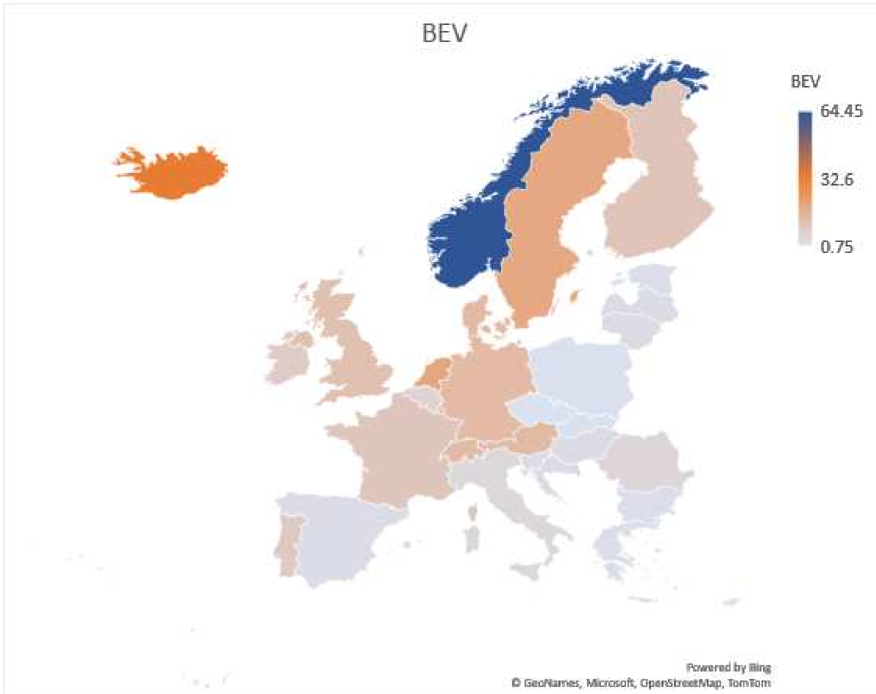
Figure 2-2 Market share of alternative fuel cars in registrations of new cars – EU-27, 2012-2021

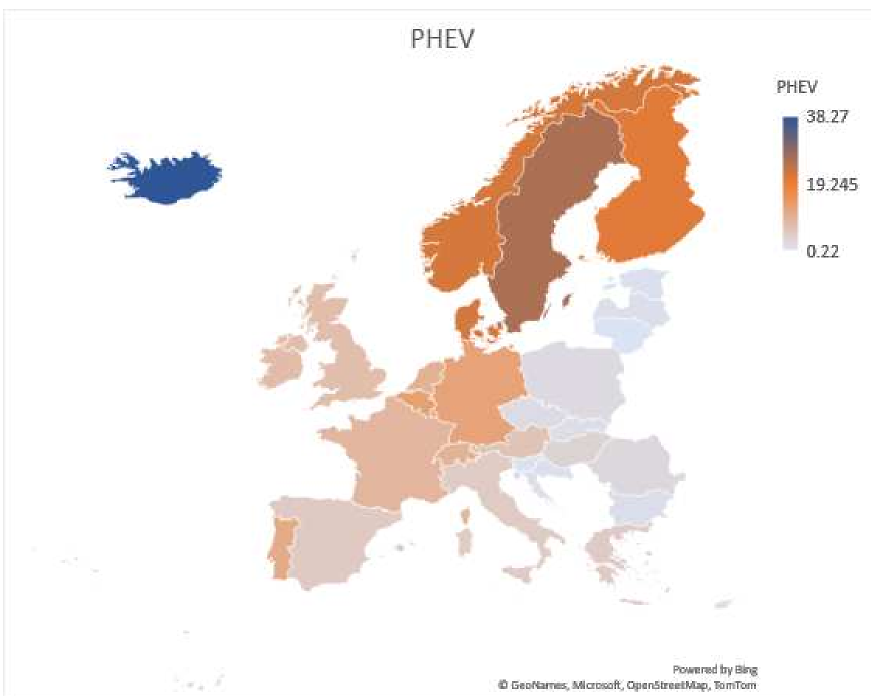


Source: own elaboration based on EAFO (2022)

The following maps present the variation across European countries in the share of BEV and PHEV in new car registrations in 2021. The five countries with the highest BEV share are all high-income countries (measured by income per capita): Norway, Iceland, the Netherlands, Sweden, and Austria. The countries with the lowest BEV shares are invariably countries with low-income levels. A similar pattern can be seen for the PHEV shares. Differences in BEV and PHEV shares across countries with similar income levels are due to a range of factors, including differences in policy measures regarding electric vehicles.

Figure 2-3 Share of BEV (top) and PHEV (bottom) in national registrations of new cars in European countries – 2021

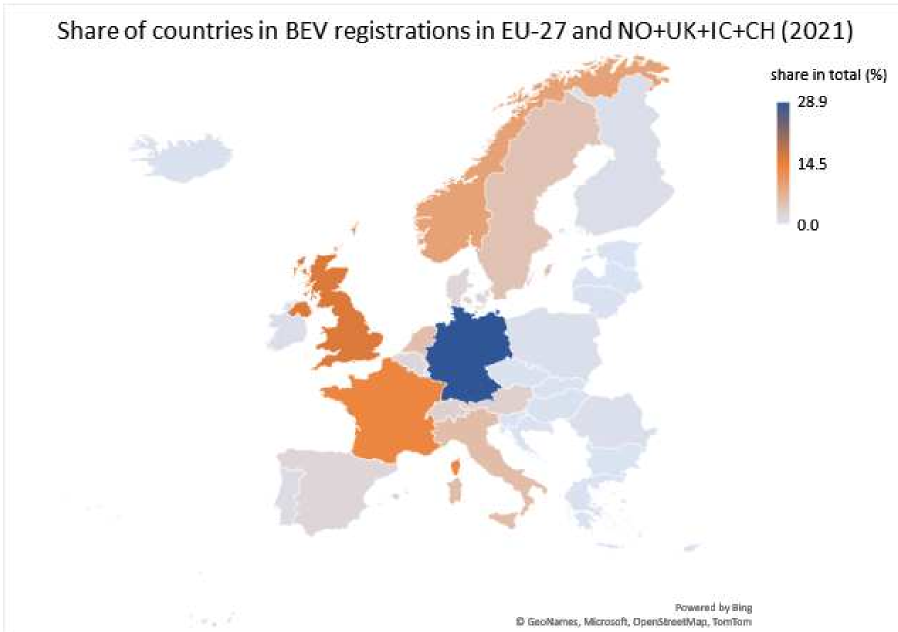


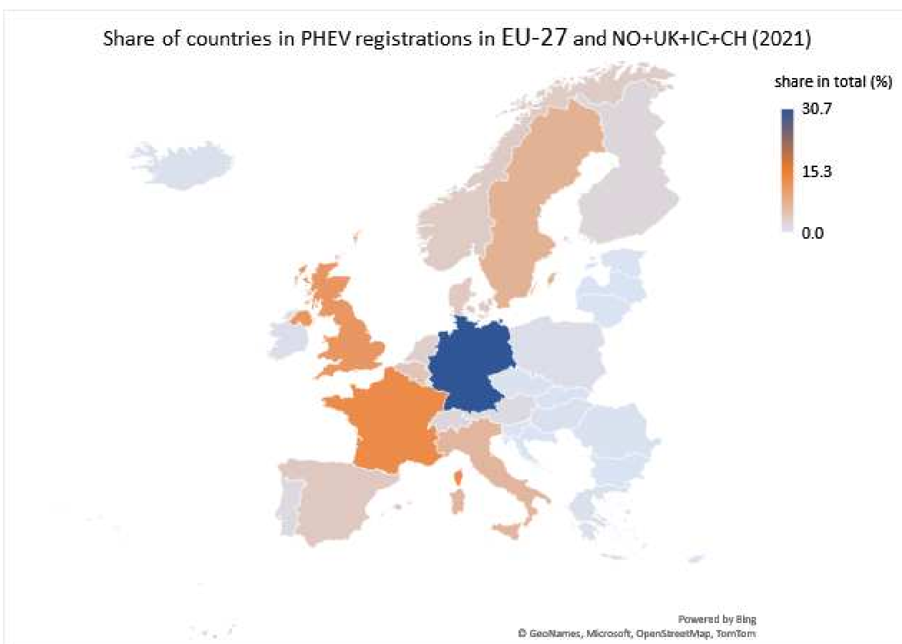


Source: own elaboration based on EAFO (2022)

Figure 2-4 shows the country share in the European sales of new BEV and PHEV vehicles. In 2021 the five most important European markets for BEVs were Germany, the UK, France, Norway, and Italy, in that order. For PHEVs the top five were: Germany, France, the UK, Sweden, and Italy.

Figure 2-4 Share of European countries in total registrations of new BEVs (top) and PHEVs (bottom) - 2021

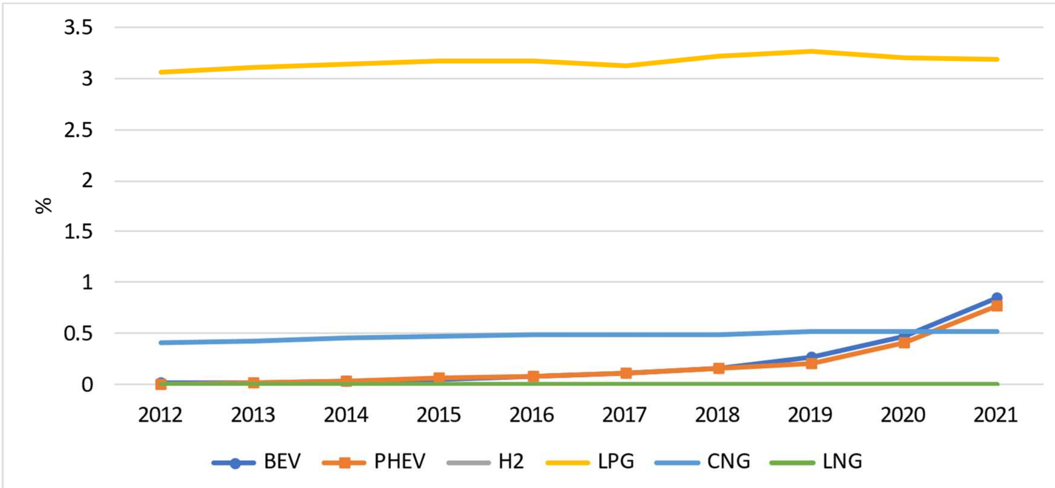




Source: own elaboration based on EAFO (2022)

Figure 2-5 shows the development of the share of the different alternative fuel vehicles in the EU-27 car fleet. While the sales of new BEV and PHEV have increased in recent years, their share in the entire car fleet remained very small in 2021, below 1 %. The mean lifespan of cars in Europe is estimated to be about 18 years in Western European countries and more than 28 years in Eastern European countries (Held et al., 2021). Therefore, it will take a while before the share of the new technologies in the car fleet increases. The share of hydrogen powered cars was negligible in 2021.

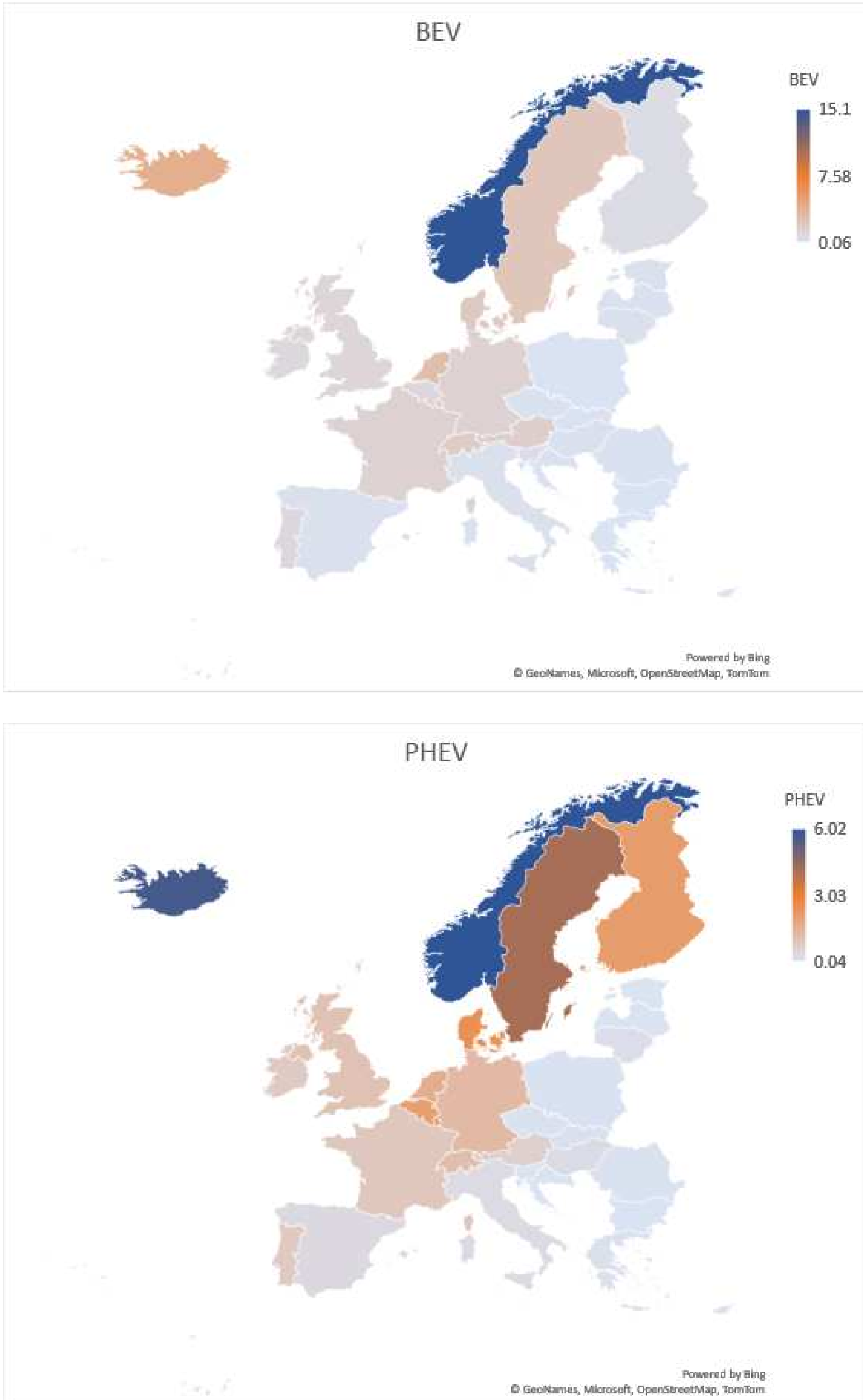
Figure 2-5 Share of alternative fuel cars in the car fleet – EU-27, 2012-2021



Source: own elaboration based on EAFO (2022)

There are significant differences in the shares of BEV and PHEV between European countries, as is shown in Figure 2-6. For BEV, the share ranges between 0.06 % (Cyprus, Greece, Poland) and 15.1 % (Norway). For PHEV, the share is also the highest in Norway (about 6 %) and the lowest in Bulgaria (0.04 %).

Figure 2-6 Share of BEV (top) and PHEV (bottom) in the car fleet in Europe – 2021



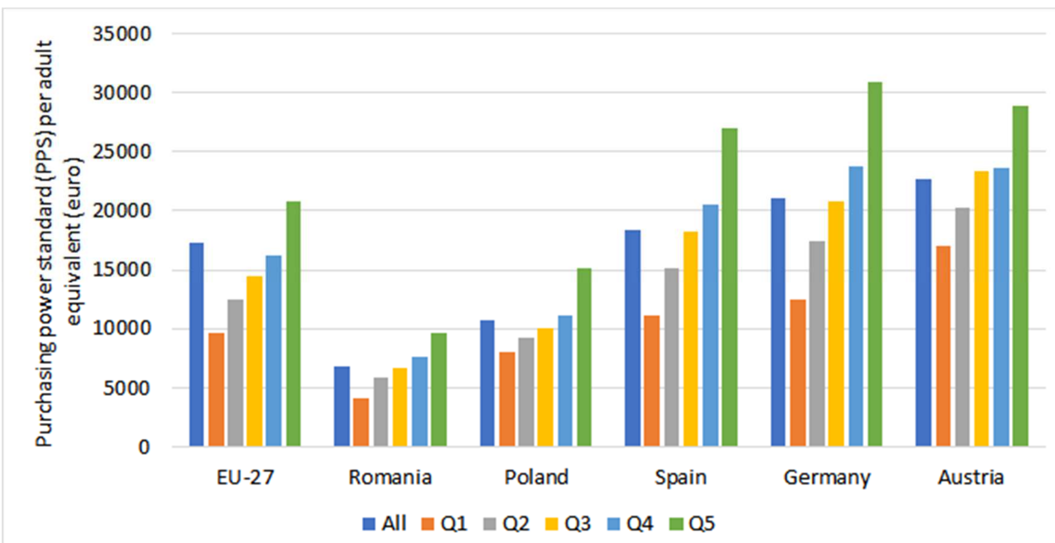
Source: own elaboration based on EAFO (2022)

2.2 Transport share in household spending

The share of transport in household expenses differs across countries and across household income groups. Based on household budget surveys in the EU Member States, Eurostat reports the structure of consumption expenditure by income quintile and consumption purpose (Eurostat indicator hbs_str_t223). The most recent data that are published by Eurostat refer to 2015.

Within income quintiles the households are divided into 5 income groups (from the lowest income group Q1 to the highest income group Q5) so that approximately 20% of the households are in each group. To give an idea of the purchasing power of people belonging to the different quintiles, Figure 2-7 shows information for the EU-27 and a selection of five European countries with lower to higher average purchasing power. The indicator takes differences in price levels across countries as well as the size and composition of the households into account[2]. The average purchasing power standard in the EU-27 was about € 17 400 per adult equivalent in 2015, with large differences across the quintiles: from a value of about € 9 700 for the first quintile to about € 21 000 for the fifth quintile. The graph also shows that there are large differences across EU countries. The average purchasing power in Romania was 39 % of the EU average, that of Poland 62 %, that of Spain 106 %, that of Germany 121 % and that of Austria 130 %.

Figure 2-7 Purchasing power standard per adult equivalent (euro) – EU-27 and five EU Member States – 2015



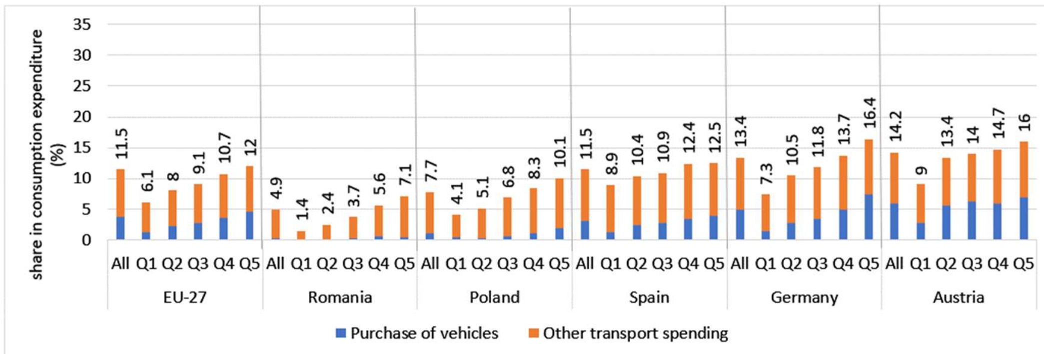
Source: own elaboration based on Eurostat (indicator hbs_exp_t133)

The share of transport in spending also varies across households in different quintiles. This is shown in Figure 2-8 for the EU-27 and the five countries included in the previous graph. Transport spending includes spending on the purchase of vehicles (in blue) and other transport expenditures, which cover

[2] The concept of "adult equivalent" is used. This way, expenditures can be compared between households of different sizes. The first adult in the household gets a weight of 1, each adult thereafter (aged 14 and over) a weight of 0.5 and each child a weight of 0.3.

spending for the operation of the personal transport equipment (e.g., fuel, maintenance, …), as well as spending on transport services (e.g., public transport)

Figure 2-8 Share of transport spending in consumption expenditure by income quintile in the EU-27 and a selection of EU countries - 2015



Notes:
Eurostat notes that reliability for the quintiles in the EU-27 estimates is low.
The numbers above each bar give the share of transport spending in household consumption expenditure.
Source: own elaboration based on Eurostat (indicator hbs_exp_t223)

In general, the share of transport spending in household consumption increases with income. This is seen across countries with different income levels, as well as across quintiles in the same country. It also holds for the share of spending on vehicle purchases (indicated in blue).

Evidence for Norway, which has a relatively high share of EVs, shows that BEV ownership increases with wealth, income, and education. However, over time as BEVs became more common, BEV owners share more characteristics with other car owners (Fevang et al., 2021). A survey by KfW in Germany shows that households owning a BEV mostly have a high income, live in detached or semi-detached houses and more than average live in rural regions[3]. Based on an EU-wide survey analysis,[4] Gezelius and Mortazavi (2022) show that there is a significantly positive correlation between having solar panels and owning a battery electric vehicle. More specifically, the researchers find that, all else being equal, having solar panels increase the probability of having a BEV by 34 percentage points.

2.3 Current Policy Framework

In July 2021, the European Commission presented the Fit for 55 package with a set of new legislative proposals and updates to existing legislation. The aim of this policy package is to deliver the Green Deal which, in terms of greenhouse gas (GHG) emissions, sets as targets 55% GHG reduction by 2030 with respect to 1990 and climate neutrality by 2050 (European Commission, 2021a). These targets are set into law in the European Climate Law ((EU) 2021/1119) and are therefore legally binding. The law does not set sector-specific targets, however, the Green Deal states that a 90% reduction in the transport sector is necessary to achieve climate neutrality by 2050 (EEA, 2022).

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[3] https://www.kfw.de/About-KfW/Newsroom/Latest-News/Pressemitteilungen-Details_651072.html
[4] www.enable-eu.com

There is a broad set of legislations that supports the reduction of GHG emissions in transport for which an overview can be found in the TERM report (EEA, 2022). One corner stone policy is the CO_2 emission performance standards regulation, for which the Fit for 55 package includes a proposal for revision. The Commission has also proposed a new emission trading system addressing transport (and residential) emissions. We address these policies in the following sections, first outlining the current legislation and then providing further information on the corresponding proposals in the Fit for 55 package as well as their expected impacts, including the social dimension. Finally, we briefly introduce the new Social Climate Fund proposed by the Commission to address social impacts arising from the Fit for 55 package.

2.3.1 CO_2 Emission performance standards

Since January 2020, CO_2 emission performance standards for new passenger cars and light commercial vehicles are set into a new regulation ((EU) 2019/631) which respectively replaces the two previous regulations for cars ((EC) 443/2009) and vans ((EU) 510/2011). This new regulation sets targets for each manufacturer's average fleet of newly registered vehicles within the EU. For the period 2020-2024 the targets are the same as in the previous regulations, notably 95 gCO_2/km for cars and 147 gCO_2/km for vans. Targets become more restrictive for the 2025-2030 period with a percentage reduction defined from the 2021 starting point. For cars the reduction target is 15% from 2025 and 37.5% from 2030 on. For vans the reduction target is 15% from 2025 and 31% from 2035 on.[5]

The emission standard regulation (EU) 2019/631 includes an incentive mechanism for zero and low emission vehicles (ZLEV). For the years 2020 to 2022 a super-credits system applies where ZLEV, with emissions between 0 and 50 gCO_2/km according to the now obsolete New European Driving Cycle (NEDC), credit multiple times for the calculation of the average fleet emissions. After 2025, ZLEV are defined with the same emission limits but according to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) and a new credit system is introduced. The WLTP test procedure is introduced to address the discrepancy between emissions measured with the former NEDC laboratory test procedure and real-world emissions.[6] The new credit system is based on the benchmarks set for manufacturers: The benchmarks are set for cars at 15% ZLEV after 2025 and up to 35% ZLEV after 2030. For vans the benchmarks are set at 15% ZLEV after 2025 and up to 30% ZLEV after 2030. Manufacturers that, during a given year, exceed the benchmark set for newly registered ZLEV can relax their specific emission target. Manufacturers that exceed these benchmarks by one percentage point will increase their CO_2 target (in gCO_2/km) by one percent, to a maximum of 5%.

Manufacturers are flexible in how they reach the targets: by increasing the fuel efficiency of cars with an internal combustion engine, by increasing the share of ZLEV, by increasing the share of smaller and more fuel-efficient cars or by pooling with other manufacturers.

The regulation also includes an exemption from the targets for manufactures registering fewer than 1 000 cars or fewer than 1 000 vans. Small volume manufacturers (with fewer than 10 000 cars or less than 22 000 vans newly registered per year) and niche car manufacturers (with between 10 000

[5] https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

[6] https://ec.europa.eu/clima/system/files/2017-11/qna_proposal_post-2020_co2_targets_en.pdf

and 300 000 cars newly registered per year) may apply for a derogation to the targets, the latter only up until 2028 included. Provisions encouraging eco-innovations and requirements for in-service verification of CO_2 emissions are also included.[7]

The revision of the emission standard regulation (EU) 2019/631 as proposed in the Fit for 55 package has recently been approved by the European Parliament.[8] The revision sets more ambitious targets for both new cars and vans. The reduction targets, with respect to the 2021 target, are set to 55% for cars and 50% for vans after 2030 and 100% for both cars and vans after 2035. The revision also removes the incentives for ZLEV from 2030 onwards and lifts the derogation for small manufacturers from 2029.[9] After 2030, only manufacturers with fewer than 1000 new vehicle registrations would be able to apply for a derogation.

2.3.2 Emission Trading System

The EU Emission Trading System (EU ETS) was introduced in 2005 with Directive 2003/87/EC and it is now in its fourth trading phase (2021-2030). It has undergone several revisions to ensure its alignment with the EU climate policy objectives and it was last amended in 2018 by Directive (EU) 2018/410. It operates in all EU member states, Iceland, Liechtenstein, and Norway. The United Kingdom stopped participating with the end of EU membership and established its own system, whereas Switzerland's ETS has been linked to the EU one since January 2020.[10]

The EU ETS is a "cap and trade" system where a cap limits the total amount of certain GHGs that can be emitted by the facilities covered by the scheme. The cap represents the total emission allowances and is reduced over time, in the current phase at a rate of 2.2% per year. The allowances are partly auctioned and partly distributed free of charge depending on the industries' risk of carbon leakage. After each year, the companies must surrender enough allowances to cover their emissions, else heavy fines apply. If an installation reduces its emissions and has spare allowances, it can keep them to cover future emissions or sell them to another business. The number of allowances is limited through the Market Stability Reserve (MSR, Decision (EU) 2015/1814), which allows for a better matching of the supply of allowances to be auctioned and the demand. The price of EU carbon permits has increased considerably over the past years, going from below € 10/ton in the beginning of 2018, to an average price of about 80 €/ton in the beginning of 2022.[11]

The EU ETS includes power generation in its scope, and it addresses therefore part of the well-to-tank GHG emissions of road transport such as electricity generation for electric vehicles and emissions associated to fuel production by regulated refineries. As mentioned in Chapter 1, these are indirect emissions and they do not count towards the total direct emissions attributed to transport as a sector but are part of the life cycle emissions.

[7] https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

[8] https://www.consilium.europa.eu/en/press/press-releases/2022/10/27/first-fit-for-55-proposal-agreed-the-eu-strengthens-targets-for-co2-emissions-for-new-cars-and-vans/

[9] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-co2-emission-standards-for-cars-and-vans-post-euro6vi-emission-standards?sid=6101

[10] https://www.europarl.europa.eu/legislative-train/package-fit-for-55/file-revision-of-the-eu-emission-trading-system-(ets)

[11] https://tradingeconomics.com/commodity/carbon

The ETS is currently aligned with the previous 2030 target to reduce EU emission by 40% compared to 1990 levels. The Fit for 55 proposal aims, as for the emission standards, to align the target with the 55% reduction by 2030 target. The main changes the proposal would bring are:

- a reduction of the cap;
- revised rules for free allocation and the MSR;
- extension of the ETS to maritime transport;
- a separate ETS for buildings and transport, called ETS2;
- an increase in the Innovation and Modernisation Funds and new rules governing ETS revenues.[12]

ETS2 would be a separate self-standing scheme for fuel distribution for road transport and buildings and would start in 2025 with a cap set for 2026 gradually decreasing to 43% reduction in 2030 compared to 2005. An overview of the functioning and impact of such a system, and a comparison across different designs of such a system can be found in Ochelen et al. (2021). The system is conceived to regulate fuel distributors rather than the consumers (households and vehicle drivers). In the proposal all allowances are auctioned, none are free. The fuel distributors need to obtain enough allowances and surrender them to cover the CO_{2e} emissions from the combustion of the fuel they placed on the market.[13] The financial incentive is given by the CO_2 ETS price which would be reflected in the fuel price depending on its carbon intensity. The intention is to provide additional financial incentives to use energy-efficient vehicles, low carbon fuels, and to make more sustainable mobility choices (EEA, 2022).

The EU ETS revision proposal has been referred to the ENVI Committee (Committee on Environment, Public Health, and Food and Safety) and the corresponding report was adopted in the June II plenary in Parliament, after an initial rejection (Parliament I). Concerning ETS2 the adopted text sets 2024 as a starting date for commercial buildings and road transport for reporting and 2026 as the first year for which corresponding allowances should be surrendered. Residential buildings and private road transport would be included only after 2029 and are subject to a thorough impact assessment and new legislative proposal.[14] At the end of June 2022, the Council maintained the overall ambition proposed by the Commission and agreed to create a new, separate ETS for the buildings and road transport sectors. However, it delayed the implementation by one year, with the auctioning of allowances from 2027. Afterwards, the first trialogue was held in July 2022.

As mentioned earlier, EU ETS includes power generation ensuring that electricity used in zero-emission vehicles (ZEV) is decarbonised over time. Depending on its value, the carbon price within the EU ETS can therefore impact the operating cost of ZEV. By establishing ETS2, the Commission aims to further internalize climate externalities in transport and level the playing field between fossil fuelled vehicles and electric ones (EC, 2021a).

2.3.3 *Impact Assessment and social dimension*

The impact assessment for amending the CO_2 emission performance regulation (EU) 2019/631 (EC, 2021a) considers significantly strengthening the CO_2 targets for cars and vans as of 2030 the preferred

[12] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698890/EPRS_BRI(2022)698890_EN.pdf
[13] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698890/EPRS_BRI(2022)698890_EN.pdf
[14] https://www.europarl.europa.eu/legislative-train/package-fit-for-55/file-revision-of-the-eu-emission-trading-system-(ets)

option. This would allow reducing transport emissions by 32-33% in 2030, 56-66% in 2035 and 83-89% in 2040 in comparison to 2005 levels.

The Commission also carried out an assessment on economic savings from an end-user and societal perspective, considering capital costs, fuel or electricity costs and operation and maintenance (O&M). These costs are estimated with the DIONE modelling suite developed by the Joint Research Centre.[15] Capital costs are estimated based on average marginal vehicle manufacturing costs, weighted on the % sales and including manufacturers profit margins. Energy costs and O&M costs are based on corresponding PRIMES and PRIMES-TREMOVE (the energy system and transport model used in the Commission impact assessment) scenarios (EC, 2021a).

End user savings are estimated in terms of TCO savings, averaged over the EU-wide new vehicle fleet, from the perspective of the first user (first 5 years) and second user (next 5 years). Taxes are included and an 11% discount rate is used. The residual value of the vehicle is also considered.

Societal savings include the external Well to Wheel CO_2 costs and are estimated throughout the vehicle lifetime (15 years). Taxes are not considered and a discount rate of 4% is applied.

The baseline scenario for the assessment is the Reference Scenario 2020 (REF scenario) which represents the current legislation. It is however considered more appropriate to evaluate different target levels for CO_2 emissions within a scenario consistent with the other policies in the Fit for 55 package. This scenario is referred to as the MIX scenario and considers different target levels: low, medium, and high (for more detailed information, we refer to the impact assessment (EC, 2021a)). TCO results for cars show that in a MIX policy scenario, more ambitious target levels offer net savings for the first owner in 2030 of about € 330-600, which increase to € 2 800-3 100 in 2040. Results are similar for the second owner, going from savings around € 450-800 in 2030 to € 2 800-3 000 in 2040. The savings are explained by the fact that less fuel expenditure compensates higher upfront capital costs. Throughout a lifetime net saving amount to € 860-1 600 in 2030 and € 4 600-5 100 in 2040 from a societal perspective.

The CO_2 emission performance standards regulation interacts with other policies which are part of the Fit for 55 package, as for example the EU ETS for cars (discussed in the following section), the increase of renewable fuels required under the Renewable Energy Directive (RED, Directive 2018/2001/EU) and additional capital costs for ICEVs due to stricter Euro 7 emissions standards tackling air pollution.[16] The analysis of the TCO and societal savings also including these policies show that stricter emissions standards mitigate the effect of the higher fuel prices due to other policies and lead to savings by 2035 except for the TCO in the lowest emission target level considered in the assessment.

In terms of social impact, the Commission considers both affordability (the variety of affordable vehicle choice available per consumer group) and subjective TCO. Consumer groups are divided into five income quintiles (with the 5th quintile (Q5) representing the highest income group). The

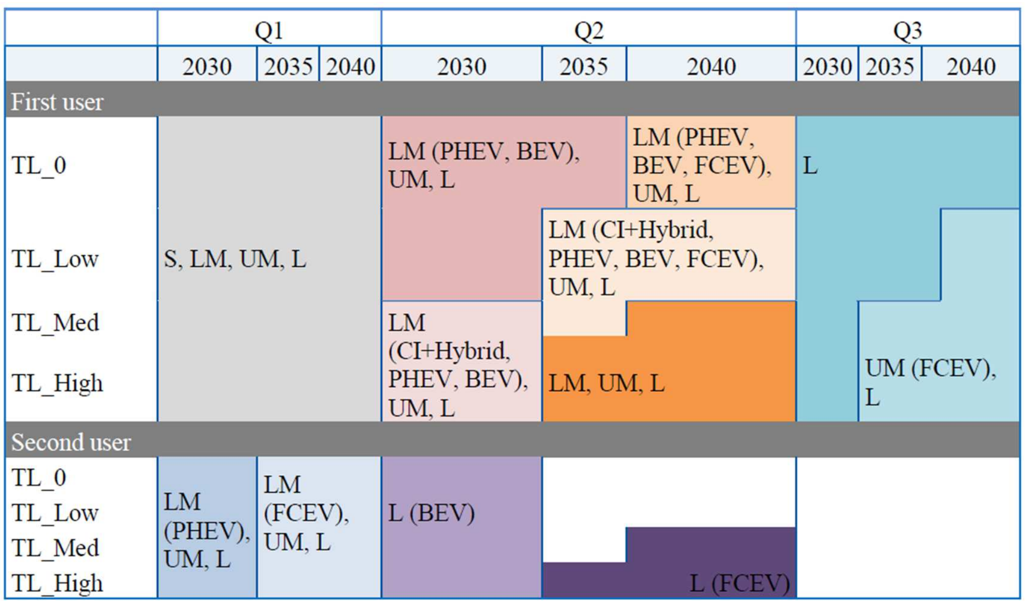
[15] https://publications.jrc.ec.europa.eu/repository/handle/JRC108725

[16] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12313-European-vehicle-emissions-standards-Euro-7-for-cars-vans-lorries-and-buses_en

subjective TCO includes purchase price or loan payments and other group-specific parameters in the total cost of ownership. For passenger cars, a mark-up factor of 1.4 is used to convert manufacturing costs to prices.

Results for affordability are summarized in Figure 2-9 which shows the "unaffordable car types" per consumer segment, per target level and over time. On the one hand, no affordability issues were found for Q4 and Q5, for Q3 as second users, and for all quintiles as third users. On the other hand, all car types resulted unaffordable for the Q1 as first users and higher target levels mean more restricted choices for specific powertrains. In all scenarios, BEVs are affordable or become affordable over time.

Figure 2-9 Overview of unaffordable car types (powertrains) and segments for income groups Q1 to Q3 under the baseline (TL_0) and different target level options in 2030, 2035 and 2040.



Notes:
Segments: S: Small, LM: Lower Medium, UM: Upper Medium, L: Large
CI: Compression Ignition
Source: EC Impact assessment – Revision of emission standards Part I (EC, 2021a).

Results in terms of subjective TCO show that more stringent emission standards translate into higher savings for the lower income groups, relative to their annual income. In this regard the International Council on Clean Transportation (ICCT) warns that there are still relatively few EVs on the market and many are marketed as luxury vehicles that typically go to affluent households (Bauer et al. (2021)). Goetzel et al. (2022), referring to the German market, also show that price parity for small cars will not be achieved before 2030 whereas luxury and midsized EVs are already close to price parity. These studies show the importance of reducing the purchase cost of used and small EVs to enable lower-income household access to the cost savings associated to EVs with substantial equity benefits.

Whereas the main instrument tackling emissions from road transport is the emission performance standard regulation, the ETS2 should be considered as a complementary measure. Performance emission standards are expected to secure long term emission reductions, which will come at the cost of the required investments and will in turn put downward pressure on ETS2 allowances prices

(Ochelen, 2021). The carbon price would support the shift towards low carbon fuels, modal shifts, efficiency improvement as well as incentivise the switch to zero-emissions vehicles. A carbon price would however also increase the energy and transport expenditure for households, which represents an important share of total final expenditure for the lower and middle-class. Auction revenues could be used for the Innovation Fund but also to address social and distributional concerns. With the aim to shield vulnerable households as well as micro-businesses and transport users from the costs of ETS2, the Fit for 55 package also includes a new Social Climate Fund.

2.3.4 Social Climate Fund

The Social Climate Fund (SCF) is proposed to provide funding to Member States to support a socially fair energy and climate transition. It is being introduced as part of the Fit for 55 package to address any social impact arising from ETS2. Its objectives are to help citizens finance investments in energy efficiency, new heating and cooling systems, and cleaner mobility and, in certain cases, to finance temporary direct income support for vulnerable households.

The future SCF would use 25% of the expected revenues from the auctioning of allowances under the ETS2 system. It is expected to provide € 72.2 billion of funding to Member States for the period of 2025-2032. To obtain the funding, the Member States will have to prepare and submit to the Commission their Social Climate Plans (SCPs), and at least match the funding through own resources. This will ensure the alignment and complementarity of national and EU spending priorities.[17]

The Parliament referred this file to the Committee on Environment, Public Health, and Food Safety (ENVI) and the Committee for Employment and Social Affairs (EMPL). The joint report by ENVI and EMPL prioritizes investments and limits direct income support to 40% of the fund expenditure with a phase out by 2032. The Council set up an ad hoc working party and decided to apply a ceiling of 35 % of the estimated total SCP costs as a limit to temporary direct income support. In its general approach it also decided not to retain the co-financing (match of the funding) intended in the Commission proposal.[18]

[17] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698777/EPRS_BRI(2021)698777_EN.pdf
[18] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-social-climate-fund

3 The determinants of the total cost of ownership

Key messages

- With current car taxes and subsidies, the EVs considered in the baseline Total Cost of Ownership (TCO) analysis for Germany, Italy and Denmark all have a smaller TCO than their ICEV counterpart. While this cost advantage is relatively large in Germany (32%) and Denmark (12%), it is much smaller in Italy (2 to 8%). The car tax and subsidy systems (including the suppliers' reactions to these) explain a large part of these differences.
- The sensitivity analyses for Germany, Italy and Denmark show a few similar patterns: the relative cost advantage of EVs grows with the resale value of the EVs and as the difference in purchase costs between the EVs and ICEVs falls. The relative cost advantage of EVs falls in a significant way if the EVs are charged at the higher rates of public charging, rather than those of home charging.
- The impact of the annual mileage is different in Germany, on the one hand, and Italy and Denmark, on the other. In Germany, the relative cost advantage of the EVs falls as the annual mileage increases, whereas the opposite can be observed in the two other countries. This is due to the different cost structure (influenced by taxes and subsidies) in Germany compared to Denmark and Italy.
- In the Low EV cost-scenario, that assumes favourable conditions for EVs, the TCO of EVs for first owners can fall up to 70% below those of ICEVs, and the EV's TCO is reduced by half compared to the base case. On the contrary, in a High EV cost-scenario, first owners of EVs are faced with up to 79% higher costs than ICEV owners. Compared to the base case, EVs can become up to 80% more expensive in the High EV cost-scenario.
- For second owners, the impact of the Low EV cost and High EV cost-scenarios is mitigated by a respectively higher and lower purchase cost. In Italy, second owners of EVs face higher costs than second owners of ICEVs in all scenarios. This finding implies that there is currently low potential for a strong development of a used EV market in Italy.
- In the baseline in which EVs and ICEVs have a similar depreciation rate, a model-2022 used EV can be expected to reach purchase price parity with a comparable ICEV in 2030 for a mid-sized car and in 2036 or later for a small car. If EVs depreciate faster than ICEVs, the current models may become more affordable as second-hand cars soon, especially for mid-sized cars, which might then already reach price parity by 2025. However, if EVs depreciate at a slower pace than ICEVs, the price difference between used EVs and ICEVs remains large for a long time.

In this chapter, we use a Total Cost of Ownership (TCO) model to compare the costs of electric (EV) and internal combustion engine (ICEV) vehicles from the point of view of the car owners (i.e.,, their private costs). We first explain the concept of a TCO model and discuss the relevant elements of TCO for ICEVs and EVs. In Section 3.4 we present the TCO results for three countries with different tax regimes, notably Germany, Italy, and Denmark.

3.1 TCO model specifications

The Total Cost of Ownership (TCO) of a passenger car is defined as the discounted sum of all the costs during the lifespan of the vehicle, minus the residual value. The costs include upfront costs such as the purchase price and registration taxes, but also all running costs (maintenance & repair, recurrent taxes, fuel costs, …). Because a TCO model considers all costs occurring during the lifespan of the vehicle, it is a commonly used tool to compare the costs of different vehicles.

More specifically, the TCO of vehicle c over a holding period of T years is equal to:

$$TCO_{c,T} = UC_c - \frac{RV_{c,T}}{(1+i)^T} + \sum_{t=1}^{T} \frac{RC_{i,t}}{(1+i)^t}$$

where UC_c represents the upfront costs, RV is the resale value at the end of the holding period and RC represents the recurrent costs (comprised of fixed recurring costs and variable costs). i is the (real) discount rate and t is an index for the years during the vehicle holding period.

By comparing the TCO of different passenger cars, we can assume that vehicles with the lowest TCO will be preferred by consumers. However, a disadvantage of TCO is that it does not consider non-monetary attributes of cars, which can also influence the consumer choice. Examples of such attributes are the brand, the driving range of the vehicle or the availability of charging infrastructure. Another disadvantage of a TCO model is that the analyst needs to make assumptions about the driving habits of the consumer such as the annual mileage and the holding period. Because these assumptions have an important influence on the outcome of the TCO, researchers typically allow for different user profiles in the analysis.

In this study, the main aim is to assess the affordability of passenger cars for European households. Therefore, comparing the TCO of different cars is the appropriate approach. We only look at the monetary attributes of different cars and we consider different driver profiles. More particularly, in the baseline scenario we assume an average annual mileage of 15 000 km/year. In the sensitivity analysis we consider both short and long annual mileages.

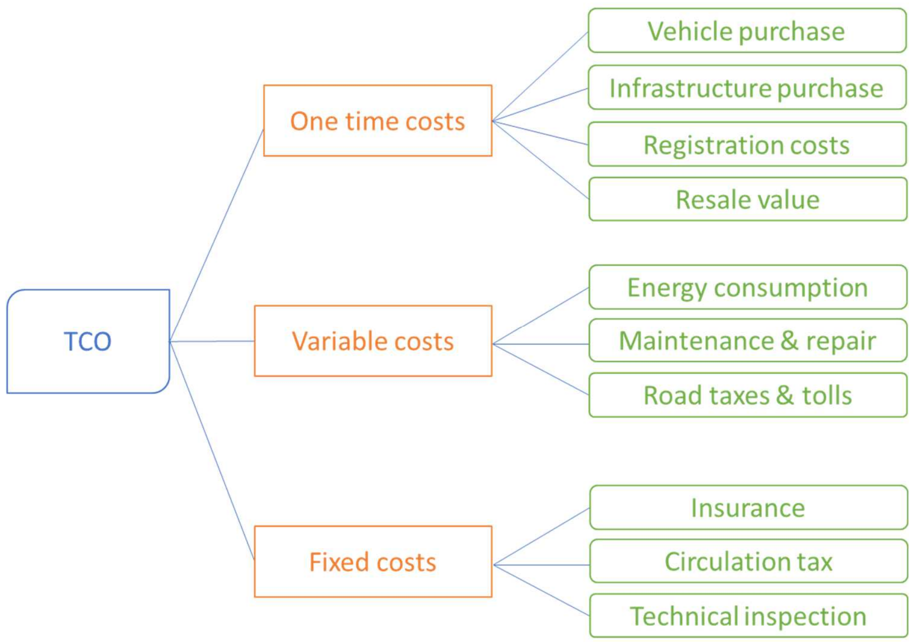
The different elements in our TCO model are visualized in Figure 3-1. We consider three cost categories: (1) one-time costs, (2) variable recurrent costs, and (3) fixed recurrent costs. The one-time costs consist of the expenditures to purchase the vehicle and necessary accessories and infrastructure, as well as registration costs (registration taxes, license plate, …). Another item in the one-time costs is the resale value of the vehicle. This costs item enters with a negative sign.

The variable recurrent costs are use-dependent costs such as energy consumption, maintenance and repair costs and potential road taxes, parking fees and tolls.

Fixed recurrent costs include the annual insurance and car circulation tax as well as mandatory technical inspection.

We discuss each of the TCO components in more detail in the subsections below.

Figure 3-1 Components of the TCO model



3.2 TCO cost components

3.2.1 *One-time costs*

One-time cost items include the vehicle's purchase cost, as well as the expenditures for charging infrastructure (in case of EVs) and registration costs. When the vehicle is sold before the end of its lifespan, it will have a resale value that has to be considered.

3.2.1.1 Vehicle purchase cost

The purchase cost of a passenger car is one of the main elements in the TCO model. The literature distinguishes two types of TCO-models, production cost-based and consumer-oriented TCO models.

Production cost-based TCO

In a production cost-based model, the vehicle's purchase price is computed bottom-up. More specifically, the purchase price is determined based on the production costs of the different vehicle attributes. The total production cost of the vehicle is then marked up with a sales margin. Examples of studies that apply the production cost-based approach are BEUC (2021), BloombergNEF (2021) and van Velzen et al. (2019).

Most production cost-based studies imply a decrease in the purchase price of EVs based on the expected decline in production costs due to learning effects, economies of scale and lower battery costs. As an example, the study by BloombergNEF (2021) predicts the prices of EVs to be at par with the price of conventional cars by 2026. In their most recent Electric Vehicle Outlook, BloombergNEF (2022) nuances this statement to "unsubsidized price parity between Evs and ICEVs is achieved in the late 2020s".

The problem with using the production cost as a proxy for the purchase price is that it does not consider the varying profit margin of manufacturers (van Velzen et al, 2019). A decrease in future production costs for Evs does not necessarily imply that the purchase price will decline as well. Based on interviews with experts and manufacturers, van Velzen (2019) documents that most electric cars are currently sold below production costs. For ICEVs, the retail price is typically a factor 1.6 higher than the production costs (Kolwich, 2013). When the production costs of electric vehicles decrease, it is to be expected that manufacturers will first recover the high investment costs. Hence, retail prices may not decline as fast as the production costs.

In addition, the recent soaring prices for lithium, nickel and cobalt, key components in the batteries in electric cars, can put pressure on a potential decline in sale prices for electric vehicles. The prices of these commodities are expected to drop when supply meets demand, but this might take a few years.[19]

Consumer-oriented TCO

A consumer-oriented TCO model uses actual sales prices as vehicle purchase cost. Examples of studies that use a consumer-oriented approach are Crist (2012), The New Drive (2021), Letmathe and Suares (2017) and Steinbuch (2014).

The advantage of a consumer-oriented TCO is that empirical data on purchase expenses is used to feed the TCO model. A disadvantage is that actual sales prices are not always available. Therefore, most studies rely on catalogue prices, which can sometimes differ considerably from the actual purchase expense.

In this study, we use a consumer-oriented approach to determine the vehicle's purchase cost. Purchase prices are obtained from the respective national automotive sector organisations. More specifically,

- for Germany: ADAC,
- for Denmark: FDM,
- for Italy: ACI

Purchase prices include VAT.

3.2.1.2 Infrastructure purchase and installation costs

Many studies do not include the costs of charging infrastructure (such as a Wallbox) in the analysis because it is not a necessary condition for owning an EV. An EV can be charged in any household outlet with a regular cable. However, fast charging is not possible with a regular household outlet and fully charging the battery will typically take longer than 8 hours. Therefore, most EV owners who charge at home will prefer to install a Wallbox, provided that their electric installation allows it. Prices of Wallboxes vary significantly. Lanz et al. (2022) provide a database containing prices for 230 home, commercial and mobile charging installations in Europe. The price of charging equipment ranges from € 338.23 to € 4 719, with an average price of € 1 415.73 (excluding VAT).

[19] https://www.abc.net.au/news/2022-06-09/electric-cars-lithium-price-batteries-credit-suisse/101135860

The true cost of charging infrastructure may be very variable and case specific. First, there are several car owners whose housing situation will not permit the installation of a Wallbox. This is the case for people who don't have a private parking spot or garage. These EV owners do not pay for the installation of charging infrastructure. Instead, they need to rely fully on public charging points or on landlords who must install charging points for their tenants. Hence, for these EV owners, the upfront costs will be lower while the running costs will be higher than what is assumed in the base case analysis.

If the electric network at home is insufficiently powerful, the installation of charging infrastructure will require an upgrade of the electric installation. In that case, the costs of charging infrastructure may increase to a multiplication of costs of the equipment. Unfortunately, low-income households will be overrepresented in the share of people who will have to upgrade their electricity network. This is because a larger proportion of these households lives in older buildings.

Lanz et al. (2022) distinguish equipment costs, installation costs and annual maintenance costs and collect these data per country and per type of installation. We use this dataset and compute the average equipment and installation cost for home charging infrastructure in Denmark, Germany, and Italy. The annual maintenance costs of the infrastructure equipment are considered in the fixed recurrent costs.

Table 3-1 Residential charging equipment and installation costs

	Cost equipment	Cost installation	Total
Denmark	€ 868.75	€ 1 886.72	€ 2 755.47
Germany	€ 827.05	€ 1 475.41	€ 2 302.46
Italy	€ 847.90	€ 1 359.16	€ 2 207.06

Source: Lanz et al. (2022)

3.2.1.3 Registration costs

Car registration costs include several elements such as registration taxes, the purchase of emission certificates or labels and license plates. The car registration tax can also take the form of a subsidy, in which case it enters the model with a negative sign.

3.2.1.4 Resale value

The vehicle´s resale value depends on the annual mileage and its holding period. There are several approaches to determine the depreciation scheme and corresponding residual value of the vehicle. BEUC (2021) uses empirical data on the resale value of 9,000 models of used cars to determine the relationship between depreciation rates, powertrains, and car sizes. The study concludes that there is a minimal difference in depreciation rates across fuel types and that the resale value is mainly dependent on the vehicle's mileage. Similarly, Steinbuch (2014) and The New Drive (2021) calculate the vehicle residual value based on its mileage.

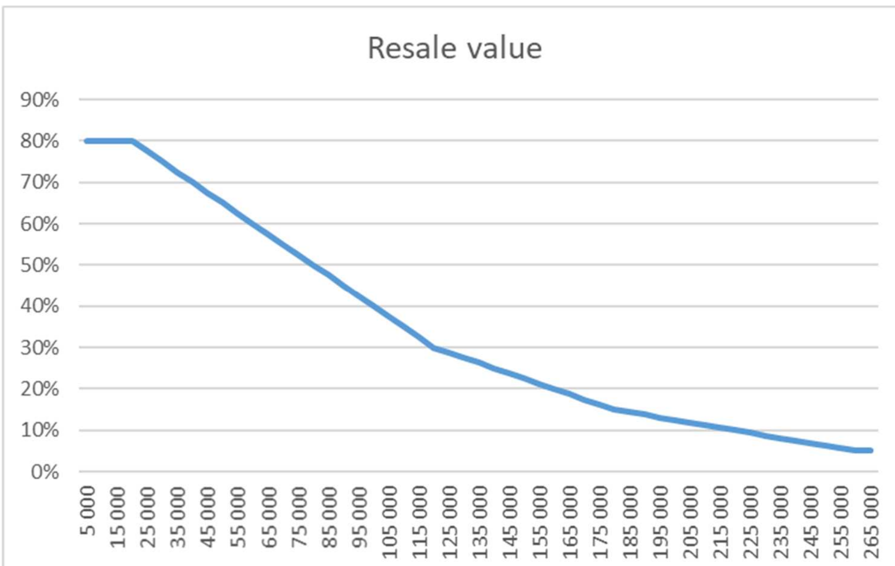
In line with the studies discussed above, we calculate the residual value of the vehicle based on the total mileage of the car.

More specifically, we follow the approach as suggested by Steinbuch (2014).[20] The resale value is X% of the vehicle's purchase price, with X equal to:

- 80% (up to 20 000 km) to 30% (120 000 km) with a step size of 10% per 20 000 km,
- 30% (120 000 km) to 15% (180 000 km) with a step size of 5% per 20 000 km,
- 15% (180 000 km) to 5% (260 000 km) with a step size of 2.5% per 20 000 km,
- 5% for a mileage above 260 000 km.

The next figure shows the resale value of the vehicle (as a percentage of the initial purchase costs) relative to the accumulated mileage over the vehicle's lifespan.

Figure 3-2 Resale value of the vehicle as a percentage of the purchase price relative to the total mileage in km



Source: Own calculations based on Steinbuch (2014)

There is no consensus on the residual value of EVs in the literature. Some authors argue that EVs depreciate faster than ICEVs because their new technology is subject to rapid technological depreciation (Danielis et al., 2018; Bauer et al., 2021). Other studies find that EVs hold their value better than equivalent ICEVs because of the strong demand for these vehicles (Naylor, 2021). A study by Forbes (2019) reveals that while EV resale values were below average levels a few years ago, they are currently on a rise. This is because an increasing number of vehicles with a long driving range are entering the used car market. The demand for this type of EVs is very high and drives up the cars' resale value.

To account for these contradicting views, we allow for different scenarios with respect to the EV resale value in a sensitivity analysis (see Section 3.3).

[20] https://maartensteinbuch.com/2014/11/04/elektrisch-rijden-voor-zzp-en-bv-aanschaf-2016/

3.2.2 Recurring variable costs

The recurring variable costs of a passenger car are use-dependent costs and include energy consumption, maintenance and repair costs and use-dependent tax items (road taxes, tolls, parking fees, …).

3.2.2.1 Energy consumption

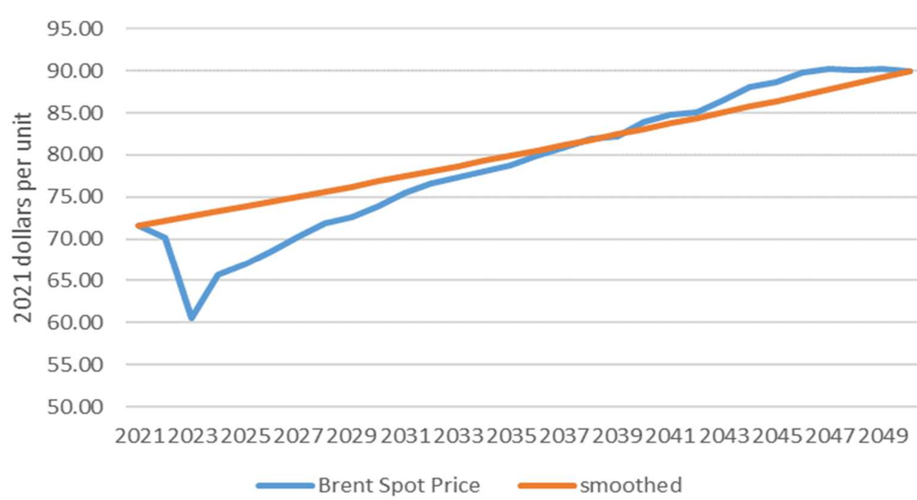
Total energy consumption costs are equal to the product of the fuel efficiency of the vehicle (in l/km for gasoline cars and kWh/km for BEVs) and the energy price per litre or kWh. For the energy consumption of the vehicle, we rely on the actual consumption based on test driving, if available. Alternatively, we use reported electricity consumption based on WLTP.

Energy prices have been rising significantly in 2022 because of the Russian invasion of Ukraine. A communication by the European Commission on March 8, 2022, revealed that energy prices are expected to remain high and volatile over the next few years.[21]

In May 2022, the price of a barrel Brent crude oil was approximately equal $113. In its short-term energy outlook, the U.S. Energy Information Administration (EIA) predicts that the Brent price could decrease slightly to $ 108/b by the end of the year and would further fall to $ 97/b (-14%) in 2023.[22]

With respect to the longer term, the EIA predicts oil prices to increase steadily over time in its reference scenario. After the price correction in 2023, Brent crude oil prices will hit about $ 90/b by the end of the 2040s, after which the price increase is expected to top off (Figure 3-3).

Figure 3-3 Long term oil price projections



[21] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN

[22] https://www.eia.gov/outlooks/steo/report/prices.php#:~:text=Winter%20Fuels%20Outlooks-,Prices,potential%20for%20oil%20price%20volatility.

Source: Annual Energy Outlook 2022, EIA

To project future gasoline prices, we start from the average 2021 price per litre (excluding excise duties and VAT) for Super 98 in the countries under consideration and apply the smoothed annual percentage price change (orange line) as implied by the Brent oil spot price projection in Figure 3-3. This corresponds to an annual price increase of 0.79%.[23]

Electricity prices for medium households in Europe are obtained from Eurostat.[24] The Eurostat price is the electricity price charged to final consumers. It includes all taxes and levies for the first semester of each year for households with an annual consumption between 2 500 and 5 000 kWh.

With respect to future electricity prices, research shows that they are expected to remain high until the end of 2023. As of 2024, a robust growth of the production of renewable energies will push prices down.[25] Similarly, in the EU Reference Scenario, the PRIMES model predicts electricity prices to drop by 2.09% in the period 2030 to 2040 and by 6.79% between 2040 and 2050.

The table below shows the average energy prices for 2021 that are used as starting values for the TCO analysis.

Table 3-2 Average energy prices in 2021 (including all taxes)

	DE	**DK**	**IT**
Petrol Euro 98 (€/litre)	€ 1.69	€ 1.74	€ 1.92
Electricity price (€/kWh)	€ 0.32	€ 0.29	€ 0.23

Source: Eurostat, it.fuelo.net
Prices for Denmark are converted to euro at an exchange rate of 7.44 krone per euro.

In the sensitivity analysis, we test the impact of higher energy prices on the TCO.

3.2.2.2 Maintenance and repair costs

There is a no agreement in the literature regarding the difference in maintenance and repair costs between ICEV cars and EV cars. Several authors argue that maintenance and repair costs for electric vehicles are significantly lower than those for vehicles with a combustion engine because an electric engine has fewer moving parts. For example, based on a large consumer survey in the U.S., Harto (2020) finds that maintenance and repair costs for EVs are 40% to 50% lower than those for ICEVs. Van Velzen et al. (2019) also assume maintenance costs for EVs to be 50% lower than those for ICEVs in their TCO model. In Breetz and Salon (2018), the difference in maintenance costs based on fuel types is much lower. They use maintenance costs based on actual expenditures by consumers and find that the costs to maintain and repair EVs are on average 8.2% below those of ICEVs.

In contrast, some other studies argue that maintenance and repair for electric vehicles is more expensive than for petrol-driven cars. For example, a study by the Allianz Centre for Technology

[23] Price projections are in real terms.
[24] https://ec.europa.eu/eurostat/databrowser/view/ten00117/default/table?lang=en
[25] https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/080521-european-power-forecast-to-hold-near-record-levels-to-2023-platts-analytics

(AZT, 2022) finds that the costs for repairs on electric cars are about 10% higher than those for ICEV cars. The reason for this is that parts of electric cars (such as the battery and the high-voltage cable) are very expensive in case they must be repaired or replaced.

In the TCO-model by Steinbuch (2014), maintenance and repair costs are independent of the vehicle's fuel type. Instead, they are based on the car's catalogue price and the accumulated mileage. Because EVs are currently more expensive in terms of purchase costs than ICEVs, this implies that maintenance costs for EVs are higher in this model.

In contrast to the studies discussed above, some TCO models argue that there are no meaningful differences in maintenance and repair costs between EV and ICEVs. In the TCO model by BEUC (2021), the analysts conclude that although maintenance is more often required for ICEVs, the replacement and repair of EV parts are more expensive. Therefore, the difference in costs is largely offset and maintenance and repair costs are considered similar across fuel type.

We follow the approach by Lethmathe and Suares (2017) who use the German ADAC vehicle cost database as input for maintenance and repair cost calculations. They compute the average maintenance and repair costs per vehicle type for different driver profiles, ranging from occasional drivers to high-mileage drivers. We use these average costs per vehicle and driver profile type and convert the costs to prices for the year 2022. Maintenance and repair costs in euro per kilometre are shown in Table 3-3. Depending on the driver profile, maintenance, and repair costs for BEVs are 10% to 16% lower than those for ICEVs.

Table 3-3 Maintenance and repair costs in € per km, €_2022 prices

	Driver profile				
Vehicle type	5 000 km/year	10 000 km/year	15 000 km/year	20 000 km/year	30 000 km/year
BEV	€ 0.119	€ 0.074	€ 0.060	€ 0.056	€ 0.051
PHEV	€ 0.134	€ 0.083	€ 0.067	€ 0.066	€ 0.065
ICEV	€ 0.135	€ 0.083	€ 0.066	€ 0.064	€ 0.061
% difference of BEV compared to ICEV	-12%	-11%	-9%	-12.5%	-16%

Source: Own calculations based on Lethmathe and Suares (2017)

3.2.2.3 Road taxes and tolls

A third recurrent use-dependent cost item are road taxes and tolls. For example, Italy and France charge tolls on motorways and for the passage of specific tunnels.

3.2.3 Recurring fixed costs

Recurring fixed costs are use-independent costs such as insurance premia, recurrent vehicle ownership taxes and period technical inspection.

3.2.3.1 Insurance costs

BEUC (2021) analyses the relationship between insurance premia and vehicle attributes. The study concludes that insurance premia mainly depend on the vehicle purchase price and are not closely related to the fuel type of the vehicle.

Note that some insurance companies offer use-dependent insurance. In our model, we assume insurance costs to be fixed. Annual insurance premia per car model are provided by ADAC, FDM, and ACI.

3.2.3.2 Vehicle ownership taxes

Vehicle ownership taxes are recurrent taxes that are charged to owners of passenger cars, irrespective to the amount of use. These taxes can vary based on the vehicle attributes such as the powertrain, CO_2 emission, size or weight of the vehicle. The design of the vehicle ownership tax differs considerably by country and will therefore be discussed on a by country basis in section 3.4.

3.2.3.3 Operating and maintenance costs charging infrastructure

The users of EVs that have a charging point installed at home, face annual operating and maintenance costs (Lanz et al., 2022). These costs are relatively low but should be considered. For Denmark, Germany and Italy, the annual O&M costs for residential charging infrastructure is equal to € 17.38, € 16.54, and € 16.96 respectively (Lanz et al., 2022).

3.2.4 Discount rate

The TCO model captures the total discounted costs of a vehicle during its lifecycle. Costs that occur in the future are discounted to the present to account for the timing of these costs. This means that the impact of recurring costs on the TCO increases with the holding period and decreases with the discount rate. Differently put, the higher the discount rate (which reflects the opportunity cost of the consumer), the lower the relative importance of recurring costs compared to upfront costs.

Discount rates differ greatly depending on the source consulted:

- Franckx (2019) uses a discount rate of 1.5% (consistent with rates for car loans in Belgium at that time).
- BEUC (2021) do not mention the use of discounting in their model
- Letmathe and Suares (2017) use a discount rate of 4.99% (consistent with the interest rate on consumption loans to households with a maturity of up to five years).
- Breetz and Salon (2018) use a discount rate of 7% in their baseline analysis and conduct a sensitivity analysis with discount rates of 0, 5, 10 and 15%. They also report that TCO studies typically use a discount rate in the range of 5 to 8%.
- In a TCO for the German passenger car market, Goetzel and Hasanuzzaman (2022) use a discount rate of 6%, which corresponds to the interest rate on consumer loans with a maturity exceeding five years.

We use a real discount rate of 1.5% in the baseline analysis. Note that the discount rates applied by Goetzel and Hasanuzzaman (2022) and Letlathe and Suares (2017) are nominal interest rates, which explains the large difference.

3.2.5 Driver's profile

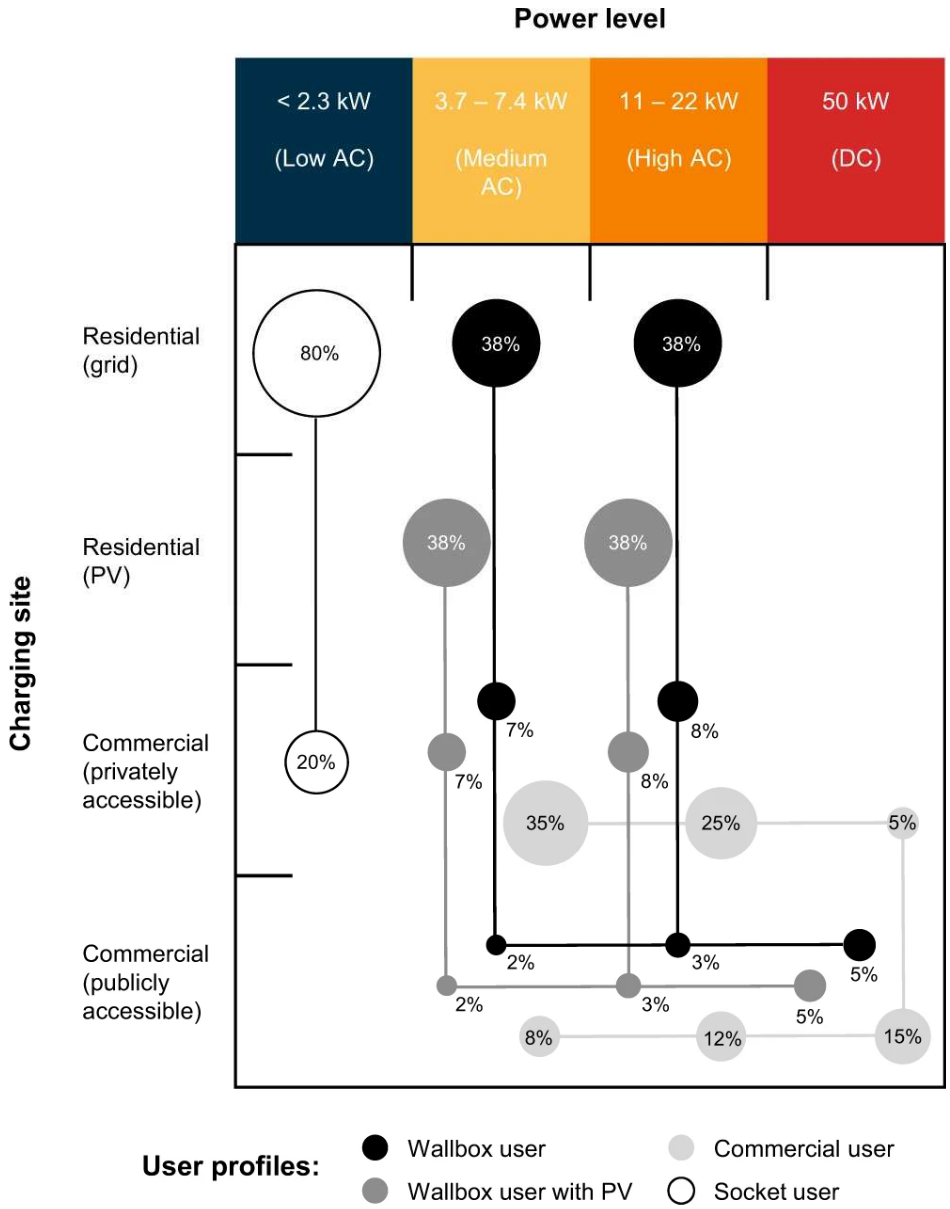
In the baseline scenario, we assume the purchase of a new vehicle by an average household. The first owner drives 15 000 km per year and the car is held for five years. Second owners buy a five-year-old vehicle with a total mileage of 75 000 km. Second owners are assumed to hold on to the vehicle for its remaining lifespan, which we assume to be 10 years. The share of lower-income households is higher in the group of second owners than in the group of first owners. Within this group, we expect that more car users will have to rely on public charging. Therefore, for the second owners, we use an average energy cost, composed of a 60% home charging tariff and a 40% public charging rate.

For EV users, Lanz et al. (2022) distinguish four profiles based on charging behaviour:

- Socket user: charges 80% at home and 20% at privately accessible commercial point (e.g., at work). Charging is done without designated charging equipment at a regular socket (slow charging, AC < 2.3 kW)
- Wallbox user: charges 75% at home, 15% at a privately accessible commercial charging point, and 10% at public charging points.
- Wallbox user with PV: similar charging behaviour as the regular Wallbox user but has photovoltaics (PV) panels. This reduces the energy cost by 15 to 17% compared to a regular Wallbox user.
- Commercial user: cannot charge at home. Charges 65% at privately accessible commercial charging points and 35% at public charging points.

The charging shares per power level and type of charging point are shown in Figure 3-4.

Figure 3-4 Charging profiles and charging options



Source: Comparing the levelized cost of electric vehicle charging options in Europe, Lanz et al. (2022)

In our TCO analysis we do not consider a socket user, because exclusively slow charging at a regular household outlet is inconvenient (extremely long charging cycles) and not recommended due to safety concerns. In our baseline analysis, we consider the profile of a regular Wallbox user who charges 75% at home, 15% at privately accessible commercial charging points, and 10% at public charging points. In the scenario and sensitivity analysis, we consider alternative charging profiles.

Our model allows for different driver profiles. Therefore, we assess the impact of the assumptions with respect to the annual mileage, holding period and charging profile in a sensitivity analysis.

3.3 Scenario and sensitivity analysis

To understand the impact of the assumptions made by the TCO modeller and the potential impact of policy interventions, we conduct several sensitivity analyses. More specifically, we investigate the impact on the baseline results for variations in the following costs elements:

1. The depreciation scheme for EVs (hence, the car's resale value)
2. Purchase prices for EVs and ICEVs
3. Energy costs: different charging profiles and energy prices
4. Different driver profiles
5. Discount rate

The sensitivity analysis enables to assess the impact of a single element in the TCO model. In addition, we build two scenarios to get an understanding of the potential range of the cost gap between ICEV and EV passenger cars.

3.3.1 Sensitivity analysis depreciation scheme

In the baseline scenario, we consider the depreciation scheme of the car to be irrespective of its fuel type. However, in practice a car's resale value depends on many factors such as brand, segment, fuel type, market demand, etc. For fossil fuel cars, sufficient historical data exist to predict the resale value. This is not the case for EVs, for which the depreciation rate is highly uncertain.

We consider two alternative scenarios, where we assume the EV's resale value to be 20% higher (EV_high) or lower (EV_low) than that of a comparable ICEV.

3.3.2 Sensitivity analysis purchase price

As a second sensitivity analysis we assume alternative purchase prices for Evs. As discussed in section 3.2.1.1, there is no consensus among analysts and researchers with respect to the future price path of Evs. Some believe that Evs will become cheaper soon as a consequence of economies of scale and efficiency gains. Others argue that purchase prices may remain high or even increase because car manufacturers want to recover investment costs or demand surpasses supply.

Not only the future price of Evs is uncertain. The EU is planning to impose new air pollutant emission standards on ICEVs, the EURO 7 standard as of 2025. Several analysts believe that this emission standard will result in a higher purchase cost for diesel and petrol cars. On the other hand, under the influence of restrictive measures targeting ICEVs, like the introduction of low emission zones, the market demand for these vehicles may drop considerably. This may trigger a price decrease for ICEVs.

We run several sensitivity tests with respect to the purchase price of the vehicles, each time assuming a 20% higher or a 20% lower purchase price for the EV or the ICEV, holding all other assumptions constant.

3.3.3 Sensitivity analysis energy costs

We run two sensitivity analyses with respect to energy costs. First, we consider the impact of having to rely on the public charging network, that implies higher electricity prices than the household electricity price. Second, we calculate the impact of the current high energy prices for fuel and electricity on the TCO.

Public charging

In the baseline analysis, we used electricity prices charged to average households. This implies that EV owners charge at home. In general, charging costs at public charging stations are considerably higher than household electricity prices. This means that people who have no charging availability at home face higher energy costs for an EV.

Table 3-4 shows the average electricity prices for 2021 charged to households compared to the rates applicable at public charging stations. Recharging the battery of an electric vehicle at a public charging station is very costly, especially in Denmark and Italy.

Table 3-4 Average rates at public charging stations in €/kWh

	DE	DK	IT
Household electricity price	0.32	0.29	0.23
Normal power recharging (up to 22 kW)	0.48	NA	0.58
High power recharging (> 22 kW)	0.58	NA	0.75
Average public charging	**0.53 (+66%)**	**0.67 (+132%)**	**0.66 (+188%)**

Source: Eurostat, European Alternative Fuels Observatory (2020), Spirii, Sperto

We calculate the change in TCO if an EV driver does not have access to home charging and thus exclusively relies on public charging. In this case, the EV owner does not have the upfront costs for installing charging infrastructure.

High energy prices

In the wake of the Russian invasion in Ukraine, energy prices have increased considerably. All forecasts assume that prices will remain high for the next coming years, although there is a lot of uncertainty. Therefore, we compute the impact of the current high energy prices on the affordability of passenger cars for the three countries in this study.

We have no data with respect to the most recent public charging rates, but we assume that public charger providers pass through electricity price changes to their customers to a large extent. Therefore, in the high energy price case, we apply a 20% increase in public charging rates with respect to the base case.

Table 3-5 Energy prices October 2022 and percentage change wrt base case

	DE	DK	IT
Petrol Euro 98	€ 2.09 (+24%)	€ 2.15 (+23%)	€ 2.02 (+5%)
Household electricity price (€/kWh)	€ 0.44 (+38%)	€ 0.47 (+60%)	€ 0.31 (+36%)
Public charging electricity price (€/kWh)	€ 0.64 (+20%)	€ 0.80 (+20%)	€ 0.79 (+20%)

Source: Globalpetrolprices.com, de.fuelo.net, it.fuelo.net

3.3.4 Sensitivity analysis driver profiles

In the baseline analysis, we assume an annual mileage of 15 000 km and a holding period of 5 years, after which the car is sold. These assumptions have an important impact on the total TCO and on the relative importance of the several components. Therefore, we investigate the impact of different driving profiles considering low mileages (5 000 and 10 000 km/year) and high mileages (20 000 and 30 000 km/year) drivers. We also calculate the TCO for a holding period of 10 years.

3.3.5 Sensitivity analysis discount rate

In the baseline analysis, we assumed a real discount rate of 1.5%. We run a sensitivity test in which we assume a real discount rate of 3%. A higher discount rate implies that upfront costs become comparatively more important than yearly recurrent costs.

3.3.6 Low EV cost versus High EV cost scenario

We develop two scenarios for electric vehicles that impact the affordability of these cars. In the "low EV cost" scenario, we consider beneficial conditions for EV uptake with respect to several cost items. Similarly, the "high EV cost" scenario assumes accommodating conditions for EVs. The assumptions made in each scenario are shown below.

Low EV cost	**High EV cost**
Purchase price EV 20% lower than base case	Purchase price 20% EV higher than base case
All tax advantages and subsidies remain	No tax advantages or subsidies
Energy prices as in base case	High (based on current) energy prices
Wallbox users with PV	100% public charging
Resale value 20% EV higher than base case	Resale value 20% EV lower than base case

Lanz et al. (2022) compute that Wallbox users with PV incur significantly lower energy costs than Wallbox users that don't have solar panels. For German car users, the average cost reduction is 17%, in Italy the average energy costs are 15% lower. The dataset contains no country specific energy costs for Denmark. Therefore, we assume a similar cost reduction as in Italy, i.e., 15% lower energy costs for Wallbox users with PV.

3.4 TCO model for selected countries

We apply our consumer-oriented TCO model to three EU countries with a different tax scheme, notably Denmark, Germany and Italy. Annex 1 shows the car taxation schemes in these three countries. For Italy and Germany, we compute the TCO for a popular ICEV and EV in the B and C segment. In Denmark, SUVs are very common. Therefore, we compute TCO for cars in segments C and L. The specific car models used for the calculations are shown in Table 3-6.

Table 3-6 Car models considered in the TCO model

	ICEV	EV
Segment B		
Germany	Opel Corsa 1.2 DI Turbo GS Line Automatik 5-türig, 96 kW	Renault Zoe R110 Z.E. 50
Italy	Peugeot 208 1.2	Peugeot e-208 100 kW
Segment C		
Denmark	VW Golf Variant 1.5 TSI Life DSG	VW ID.3 Pure (45 kWh)
Germany	VW Golf 2.0 TSI	VW ID.3 Pro S (77 kWh)
Italy	VW Golf 1.5 TSI	VW ID.3 150 kw
Segment L (SUV)		
Denmark	Volvo XC40 T3 aut. Momentum	Audi Q4 e-tron Attitude

The selection of countries is motivated by the different vehicle tax systems. As such we can compare and evaluate the affordability of electric passenger cars under various tax systems. Germany and Denmark have the most favourable tax regime for EVs, although the implementation is different. In Germany, people who buy an EV currently benefit from a significant purchase subsidy. As of 2023, the purchase subsidy will decrease gradually, until it's completely phased out by 2026.

In addition to this one-time financial incentive, EV owners receive an annual premium based on their GHG quota and are exempt from the annual motor vehicle tax during the first ten years. At the same time, Germany has implemented disincentives for the use of fossil fuel cars such as the ETS system for road transport. In Denmark, the relative advantage for EVs is mainly implemented through high taxes on ICEVs. EVs are partially exempt from registration taxes and pay a significantly lower environmental tax.

In Italy, fewer fiscal incentives for EVs are in place compared to the two other countries in our study. Purchase subsidies are in place, but they are much lower than the subsidy granted by the German government. In addition, the Italian government also grants a purchase subsidy to low emission ICEVs (passenger cars with CO_2-emissions up to 135g/km).

For each country we present the results of our baseline analyses and the impact of the sensitivity tests on the results.

3.4.1 Germany

3.4.1.1 TCO Germany – baseline results

As a result of the German government's policy to subsidize EV purchase and use (see Annex 1), electric passenger cars in Germany are currently more affordable than ICEV cars in terms of total costs of ownership. Table 3-7 shows that over a holding period of five years, an EV from segment B is expected to incur € 9 850 lower costs than an ICEV. For an EV in the C segment € 12 592 less than for a comparable ICEV are expected to incur. For both car segments, the EV to ICEV ratio is well below unity. The TCO of the selected electric cars are 32% lower than for comparable fossil fuel driven cars.

Table 3-7 TCO results Germany (annual mileage 15,000 km, holding period 5 years)

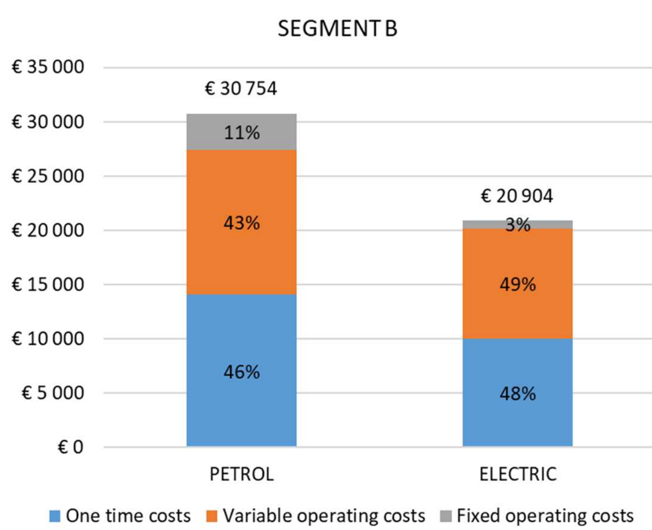
	Segment B			**Segment C**		
	ICEV	**EV**	**% difference (EV vs. ICEV)**	**ICEV**	**BEV**	**% difference (EV vs. ICEV)**
TCO_total (€)	30 754	20 904	**-32%**	37 950	25 359	**-33%**
TCO (€/km)	0.41	0.28		0.51	0.34	

Source: own calculations

The different components of the TCO are shown in Figure 3-5 and Figure 3-6. The figures show that for the smallest car segment, the one-time costs represent an equal share of the TCO across fuel types. In absolute terms, the one-time costs for EVs are significantly lower than for ICEVs. This is a result of the generous purchase subsidy for EVs. The large difference in fixed recurrent costs is mainly explained by the GHG quota that EV drivers receive.

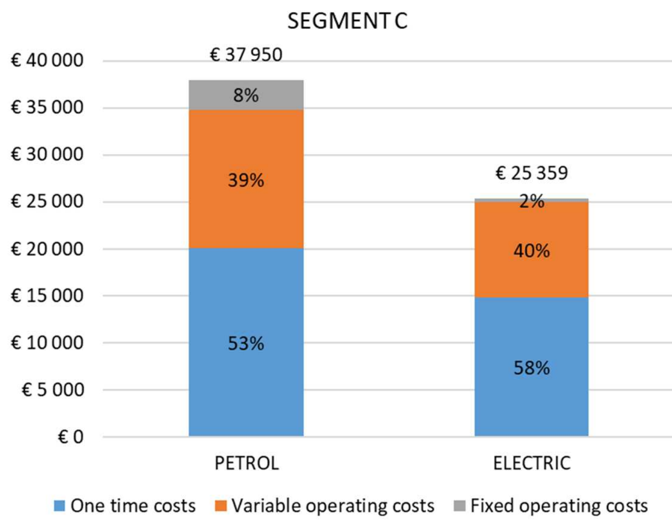
For medium-sized cars (segment C), upfront costs represent the majority of the TCO. Although in absolute terms the one-time expenses for EVs are significantly lower than those for a comparable ICEV, one-time costs still represent 59% of the TCO for an EV.

Figure 3-5 TCO passenger car segment B – Germany



Source: own calculations

Figure 3-6 TCO passenger car segment C – Germany



Source: own calculations

3.4.1.2 Germany – scenario and sensitivity analysis

We ran several sensitivity analyses to investigate the impact of the assumptions that we made regarding depreciation rates, purchase prices, energy prices, driver profiles and discount rates. The results of these sensitivity tests are presented in Table 3-8. TCO are expressed in € per km so that different holding periods and mileages can be compared with the baseline analysis. The baseline results are shown in the first row of the table for comparison.

The results of the sensitivity analysis show that EVs in Germany remain the cheapest vehicle type, irrespective of the assumptions we made. If we assume a stronger depreciation of electric vehicles, resulting in a 20% lower resale value, the TCO increase from € 0.28/km to € 0.32/km (segment B) or from € 0.34/km to € 0.40/km (segment C). Still, these costs are 24% lower than the TCO for a corresponding ICEV. The same conclusion holds when we allow purchase prices of EV to be 20% higher than their current price or when we assume a 20% drop in the purchase price of ICEVs.

If drivers are constraint exclusively to public charging, the running costs of an electric vehicle increase, but remain well below those of an ICEV. Different driver profiles have a significant impact on the TCO of ICEV, but they impact the costs of EVs to a lesser extent.

The current high energy prices have a significant impact on the TCO of both EV and ICEV vehicles. The price gap between the vehicle types remains consistent. However, it is important to emphasize that higher energy prices impact the overall affordability of passenger cars. For small sized EVs, the TCO increased from € 0.28 to € 0.30 per km, a price increase of 8.5%. A similar price increase is observed for medium-sized cars.

The impact of the discount rate on the TCO is minimal.

Table 3-8 Sensitivity analysis results – Germany

	SEGMENT B			SEGMENT C		
	ICEV €/km	**EV €/km**	**% difference**	**ICEV €/km**	**EV €/km**	**% difference**
Baseline	€ 0.41	€ 0.28	-32%	€ 0.51	€ 0.34	-33%
Resale value EV +20%		€ 0.23	-43%		€ 0.28	-44%
Resale value EV -20%		€ 0.32	-21%		€ 0.40	-22%
Purchase price EV +20%		€ 0.33	-21%		€ 0.40	-21%
Purchase price EV -20%		€ 0.23	-44%		€ 0.28	-45%
Purchase price ICEV +20%	€ 0.45		-38%	€ 0.56		-40%
Purchase price ICEV -20%	€ 0.37		-25%	€ 0.45		-25%
Public charging		€ 0.30	-27%		€ 0.36	-29%
High energy prices	€ 0.44	€ 0.30	-31%	€ 0.54	€ 0.36	-33%
High mileage (30 000km/year)	€ 0.34	€ 0.26	-23%	€ 0.42	€ 0.31	-26%
High mileage (20 000km/year)	€ 0.38	€ 0.25	-34%	€ 0.47	€ 0.31	-34%
Low mileage (10 000km/year)	€ 0.55	€ 0.37	-33%	€ 0.68	€ 0.46	-33%
Low mileage (5 000km/year)	€ 0.96	€ 0.63	-34%	€ 1.20	€ 0.81	-33%
Long holding (10 years)	€ 0.35	€ 0.27	-22%	€ 0.42	€ 0.32	-25%
Discount rate (3%)	€ 0.41	€ 0.29	-30%	€ 0.52	€ 0.35	-31%

Baseline assumptions: annual mileage of 15 000 km/year, 5 year holding period, discount rate 1.5%.
Source: Own calculations

Next to the sensitivity analysis, we calculate the TCO for a "low EV cost" and a "high EV cost" scenario to estimate the expected range for the TCO and the relative cost gap with ICEV passenger cars. The results of this scenario analysis are shown in Table 3-9.

Assuming optimal conditions for electric vehicles (i.e.,, a lower purchase cost and low depreciation rate, the persistence of financial incentives, Wallbox charging with PV and energy prices at the 2021 price level) would further benefit EVs over fossil fuel cars. The TCO of electric passenger cars can become even up to 68% lower than that of comparable ICEV cars. On the contrary, if conditions for electric cars become unfavourable (higher purchase prices combined with faster depreciation, cancellation of all financial incentives for EVs, exclusively public charging at high energy costs), EVs become considerably more expensive than ICEVs. For small cars, the cost gap is equal to 49%, medium-sized EVs will be 41% more expensive than ICEVs.

The impact of the scenarios is less extreme for the second owner. This is because a low depreciation rate is beneficial for the first owner, but increases the purchase cost for the second owner and vice versa. This means that in the "High EV cost"-scenario, the impact of higher energy costs and omitted financial incentives is partly compensated by a lower purchase price for the used vehicle. In the "Low EV cost" scenario, the TCO for used EV owners is even higher than in the base case.

Table 3-9 Scenario analysis - Germany

	Segment B			**Segment C**		
First owner (holding period 5 years)						
ICEV	€ 30 754	€ 0.41		€ 37 950	€ 0.51	
EV Low cost	€ 9 777	€ 0.13	**-68%**	€ 11 468	€ 0.15	**-70%**
EV Base case	€ 20 904	€ 0.28	**-32%**	€ 25 359	€ 0.34	**-33%**
EV High cost	€ 45 845	€ 0.61	**+49%**	€ 53 367	€ 0.71	**+41%**
Second owner (holding period 10 years)						
ICEV	€ 44 461	€ 0.30		€ 52 829	€ 0.35	
EV Low cost	€ 37 734	€ 0.25	**-15%**	€ 43 054	€ 0.29	**-19%**
EV Base case	€ 35 979	€ 0.24	**-19%**	€ 40 459	€ 0.27	**-23%**
EV High cost	€ 48 667	€ 0.32	**+9%**	€ 52 714	€ 0.35	**0%**

Source: own calculations

3.4.1.3 TCO Germany – Summary

- For both car models that are compared for Germany, the TCO is lower for the EV than the ICEV. In the baseline the TCO of the EV is 32 % lower than that of the ICEV. In the sensitivity analyses the magnitude of the cost advantage changes, but for all individual cases considered, there is a cost advantage for the EV.
- The sensitivity analysis shows that the cost advantage of the EV can be increased significantly if the resale value of the EV is higher or if the price premium of the EV compared to the ICEV falls. The cost advantage also depends significantly on the price of charging: the more expensive charging gets, the lower the cost advantage of the EV.
- A consequence of the tax structure in Germany with the high upfront subsidy for EVs is that the cost advantage of an EV falls as the annual mileage or the holding period increases.
- The TCO of a small EV varies between € 0.13/km to € 0.61/km in a low-cost versus a high-cost scenario. This represents a cost gap between the TCO of a fossil fuel car ranging from -68% to +49%. For a medium-sized EV, the costs gap ranges between -70% in the most favourable scenario to +41% in the most pessimistic scenario.

3.4.2 Italy

3.4.2.1 TCO Italy – baseline results

The results of the baseline TCO analysis for Italy are shown in Table 3-10. These take the car taxation scheme summarized in Annex 1 into account. For the B segment, we estimated the TCO of a Peugeot 208 1.2 (74 kw) and a Peugeot e-208 (100 kw), the electric alternative. In the C segment, we compared the TCO of a Volkswagen Golf 1.5 TSI (96 kw) with the electric Volkswagen ID.3 (150 kw). Recall that in the baseline analysis, we assume a yearly mileage of 15 000 km and a holding period of 5 years.

The TCO results for Italy show that the costs to own and operate an electric passenger car are similar to the TCO of an ICEV for market segment B. For cars in the mid-size range, the TCO for an EV are 8% lower than those of a comparable ICEV.

Table 3-10 TCO results Italy (annual mileage 15,000 km, holding period 5 years)

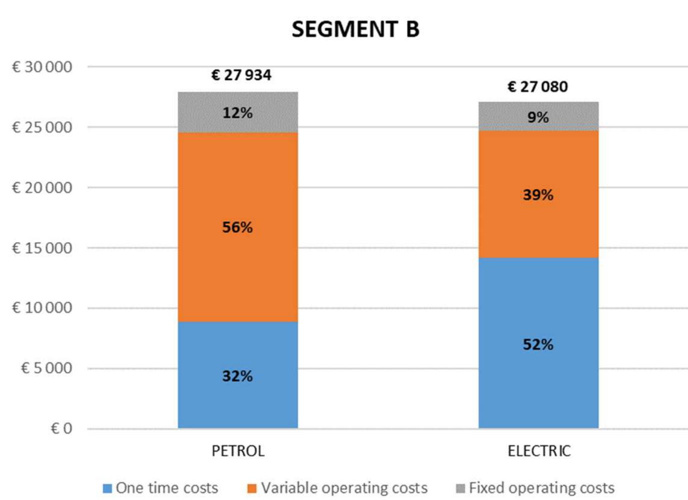
	Segment B			**Segment C**		
	ICEV	**EV**	**% difference (EV vs. ICEV)**	**ICEV**	**EV**	**% difference (EV vs. ICEV)**
TCO_total (€)	27 934	27 080	-3%	33 111	30 343	-8%
TCO (€/km)	0.37	0.36		0.44	0.40	

Source: own calculations

When we look at the composition of the TCO, which is depicted in Figure 3-7 and Figure 3-8, a different picture than for German car owners emerges. For petrol cars, the one-time cost represents only 32% (segment B) to 41% (segment C) of the TCO. Most of the costs is caused by use-dependent factors such as energy consumption. For EVs, this is not the case. More than half of the TCO consist of one-time costs.

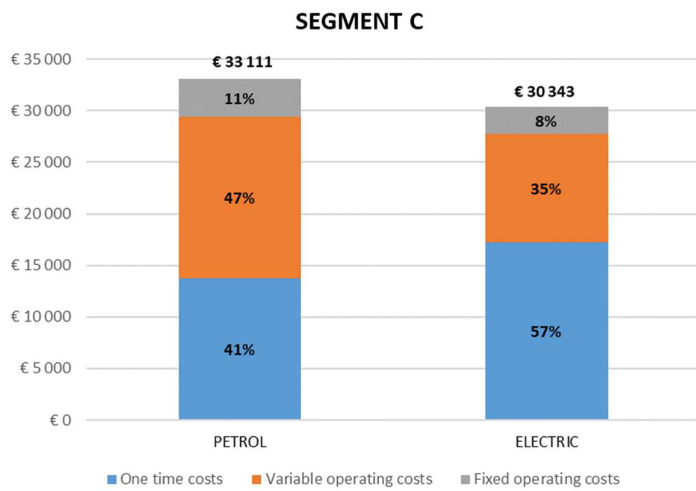
In absolute numbers, the one-time costs for a small electric car exceed those of a petrol car by € 5 259. For a medium-size car, the price difference is € 3 486. Because upfront costs are an important barrier for lower income households, this difference may be a hurdle in the affordability of EVs. It also explains the relatively low popularity of EVs among Italian consumers. Especially for low mileage drivers, the higher purchase expenses for an EV may represent an important barrier.

Figure 3-7 TCO passenger car segment B – Italy



Source: own calculations

Figure 3-8 TCO passenger car segment C – Italy



Source: own calculations

3.4.2.2 TCO Italy – sensitivity analysis

Table 3-11 presents the results of the various sensitivity tests. According to the baseline analysis, electric passenger cars are currently slightly cheaper than ICEVs. However, this finding only holds for the assumptions that were made in the baseline analysis.

If we assume a lower resale value for electric cars, the total costs are 9% or 3% higher than those for a corresponding ICEV in segment B and C. Similarly, if electric vehicles are sold at higher prices, their TCO is significantly higher.

If drivers need to rely on public charging, the TCO for an electric car increase from € 0.36/km to €0.42/km (segment B) or from € 0.40/km to € 0.47/km (segment C), making them more expensive than ICEVs.

A different driving profile affects the costs of ICEVs and EVs in a somewhat similar way. Intuitively, high mileage drivers face lower per km costs and vice versa. The longer the car is in use, the lower are the per km costs. For low mileage drivers, an electric vehicle is considerably more expensive than for high mileage drivers.

Assuming a higher discount rate increased the costs per km for passenger cars, the upfront costs become relatively more important. This is especially relevant for electric vehicles that come at a relatively high purchase price. At a real discount rate of 3% ICEV and EV in segment B are at par. Electric vehicles in the C segment remain somewhat cheaper than their ICEV equivalent.

Table 3-11 Sensitivity analysis results – Italy

	SEGMENT B			SEGMENT C		
	ICEV €/km	EV €/km	% Difference	ICEV €/km	EV €/km	% difference
Baseline	€ 0.37	€ 0.36	-2%	€ 0.44	€ 0.40	-8%
Resale value EV +20%		€ 0.32	-15%		€ 0.35	-20%
Resale value EV -20%		€ 0.41	+9%		€ 0.46	+3%
Purchase price EV +20%		€ 0.41	+10%		€ 0.46	+4%
Purchase price EV -20%		€ 0.31	-16%		€ 0.35	-21%
Purchase price ICEV +20%	€ 0.40		-9%	€ 0.48		-16%
Purchase price ICEV -20%	€ 0.34		6%	€ 0.40		1%
Public charging		€ 0.42	+13%		€ 0.47	+5%
High energy prices	€ 0.38	€ 0.38	0%	€ 0.45	€ 0.42	-6%
High mileage (30 000km/year)	€ 0.32	€ 0.30	-6%	€ 0.37	€ 0.34	-10%
High mileage (20 000km/year)	€ 0.35	€ 0.34	-3%	€ 0.41	€ 0.38	-8%
Low mileage (10 000km/year)	€ 0.47	€ 0.49	+3%	€ 0.57	€ 0.55	-3%
Low mileage (5 000km/year)	€ 0.78	€ 0.87	+12%	€ 0.99	€ 1.00	+2%
Long holding (10 years)	€ 0.33	€ 0.32	-2%	€ 0.38	€ 0.35	-7%
Discount rate (3%)	€ 0.37	€ 0.37	0%	€ 0.45	€ 0.42	-6%

Baseline assumptions: annual mileage of 15,000 km/year, 5 year holding period, discount rate 1.5%.
Source: Own calculations

The TCO in a Low EV cost and High EV cost scenario compared to the base case are shown in Table 3-12. For the first owner, the Low EV cost scenario leads to significantly lower TCO for segment B and segment C electric passenger cars. The cost gap with comparable ICEV cars is equal to 42% and 46%. Similarly, in High EV cost scenario, EVs become much more expensive than in the base case. The costs of an EV compared to an ICEV are 79% and 66% higher for small and medium-sized cars. Compared to the base case, the costs of an electric passenger car nearly double in a high-cost scenario.

Table 3-12 Scenario analysis - Italy

	Segment B			Segment C		
First owner (holding period 5 years)						
ICEV	€ 27 934	€ 0.37		€ 33 111	€ 0.44	
EV Low cost	€ 16 281	€ 0.22	**-42%**	€ 17 864	€ 0.24	**-46%**
EV Base case	€ 27 080	€ 0.36	**-3%**	€ 30 343	€ 0.40	**-8%**
EV High cost	€ 49 871	€ 0.66	**+79%**	€ 55 074	€ 0.73	**+66%**
Second owner (holding period 10 years)						
ICEV	€ 45 248	€ 0.30		€ 50 790	€ 0.34	
EV Low cost	€ 48 669	€ 0.32	**+8%**	€ 54 509	€ 0.36	**+7%**
EV Base case	€ 46 625	€ 0.31	**+3%**	€ 51 872	€ 0.35	**+2%**
EV High cost	€ 53 274	€ 0.36	**+18%**	€ 56 619	€ 0.38	**+11%**

Source: own calculations

The conditions for a used EV car owner are not favourable in Italy. This is partly because the financial incentives for BEVs are exclusively for new cars. In addition, owners of used BEVs face higher running costs due to a higher reliance on public charging. This has two consequences. First, the cost difference between new and used BEVs in Italy is relatively low. Second, used ICEVs are cheaper than used BEVs.

Used electric cars in Italy are more expensive than used ICEVs in all scenarios. Because the Low EV cost scenario assumes a low depreciation rate for electric vehicles, the purchase price for second owners increases, which drives up the TCO of used cars. In the High EV cost scenario, the opposite occurs, but the lower purchase costs are more than compensated by higher use costs due to public charging at high energy prices. The results of the scenario analysis for second owners provides a pessimistic view on the development potential for the used EV car market in Italy.

3.4.2.3 TCO Italy – Summary

- For the car models that are compared for Italy in the two car segments, the TCO of the EV is similar to that of an ICEV in segment B, and 8% lower in segment C. Given the relatively small (if any) cost advantage of EVs in Italy, the sensitivity analyses lead in several cases to a cost disadvantage for EVs.
- The sensitivity analysis shows that the cost advantage of the EV can be increased significantly if the resale value of the EV is higher or if the price premium of the EV compared to the ICEV falls. The cost advantage also depends on the charging cost: with public charging rates, the EV has a much higher TCO than the ICEV counterpart.
- As the annual mileage falls, the EV become less interesting from a TCO perspective. This is most pronounced for the shortest annual mileage and market segment B. This pattern of change in the relative TCO of EVs w.r.t. changes in the annual mileage is similar as for example, was found in Crist (2012).
- In a Low EV cost scenario, TCO of small and medium-sized EVs may become 42% and 46% lower than those of a comparable ICEV. In a High EV cost scenario, the opposite occurs, with EV costs increasing 79% and 66% above ICEV costs.
- The TCO for used EVs is higher than the TCO for used ICEVs in all scenarios considered. The cost gap varies between 2% and 18%. The fact that used EVs remain more expensive than used ICEVs may be an important barrier to the development of the second-hand EV market in Italy.

3.4.3 Denmark

3.4.3.1 TCO Denmark – baseline results

Because of the high popularity of SUVs in Denmark, we calculate the TCO for two cars from the SUV segment (segment L), notably a Volvo XC40 T3 Momentum (ICEV) and an Audi Q4 e-tron Attitude (EV). In the C segment, the respective ICEV and EV vehicles under consideration are the Volkswagen Golf 1.5 TSI and the Volkswagen ID.3 with a battery capacity of 45 kWh. The car taxation scheme in Denmark is summarized in Annex 1.

The TCO for the respective cars are shown in Table 3-13. The TCO for the ICEV in the C segment is equal to DKK 293 027, which is 12% higher than the TCO for the corresponding electric vehicle, DKK 258 067. In the SUV segment, there is a similar cost difference, with the EV being more affordable than the comparable ICEV model.

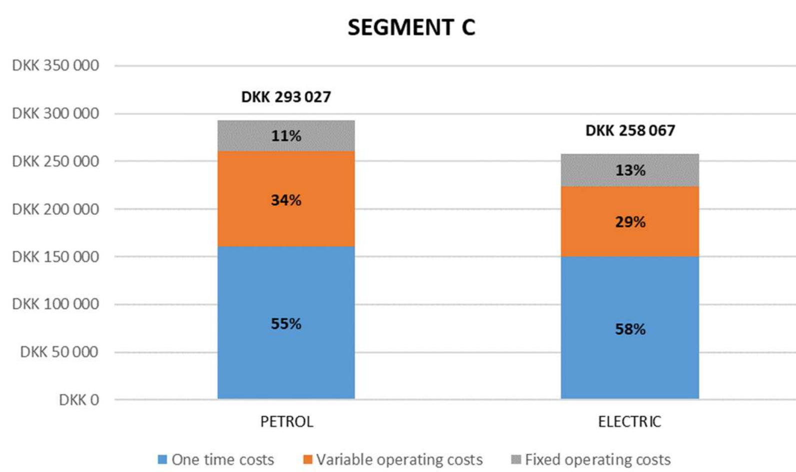
Table 3-13 TCO results Denmark (annual mileage 15,000 km, holding period 5 years)

	Segment C			**Segment SUV**		
	ICEV	EV	% difference (EV vs. ICEV)	ICEV	EV	% difference (EV vs. ICEV)
TCO_total (DKK)	293 027	258 067	**-12%**	392 717	340 146	**-13%**
TCO (DKK/km)	3.91	3.44		5.24	4.54	
TCO (€/km)	0.53	0.46		0.70	0.61	

Source: own calculations

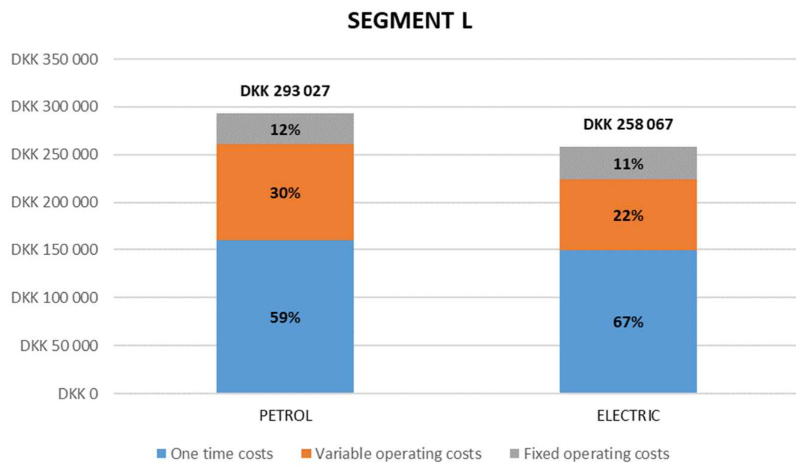
The different components of the TCO are shown in Figure 3-9 and Figure 3-10. In both segments, the one-time costs represent the largest part of the TCO, ranging from 55% for a medium-sized petrol car to 67% the TCO for the electric SUV.

Figure 3-9 TCO passenger car segment C – Denmark



Source: own calculations

Figure 3-10 TCO passenger car segment L – Denmark



Source: own calculations

3.4.3.2 TCO Denmark – sensitivity analysis

The results from the different sensitivity analysis in Table 3-14 show that the TCO (in DKK/km) for electric vehicles are lower than those for comparable ICEVs in all scenarios considered. The difference in costs between the two fuel types is always significant except for people who must rely on public chargers. As also confirmed by other studies (for example Uswitch (2020)), public charging in Denmark is very expensive compared to home charging. If consumers do not have the possibility to charge their electric vehicle at home, TCO increase from DKK 3.44/km to DKK 3.66/km for a segment C vehicle, representing a cost increase of 6%. For SUVs, the TCO under a fully public charging scenario increase from DKK 4.54/km to DKK 4.78/km (+5%).

Table 3-14 Sensitivity analysis results – Denmark

	SEGMENT C			SEGMENT L		
	ICEV DKK/km	EV DKK/km	% difference	ICEV DKK/km	EV DKK/km	% difference
Baseline	DKK 3.91	DKK 3.44	-12%	DKK 5.24	DKK 4.54	-13%
Resale value EV +20%		DKK 3.12	-20%		DKK 4.02	-23%
Resale value EV -20%		DKK 3.77	-4%		DKK 5.06	-3%
Purchase price EV +20%		DKK 3.78	-3%		DKK 5.12	-2%
Purchase price EV -20%		DKK 3.10	-21%		DKK 3.99	-24%
Purchase price ICEV +20%	DKK 4.33		-21%	DKK 5.85		-22%
Purchase price ICEV -20%	DKK 3.48		-1%	DKK 4.63		-2%
Public charging		DKK 3.66	-6%		DKK 4.78	-9%
High energy prices	DKK 4.10	DKK 3.69	-10%	DKK 5.49	DKK 4.80	-13%
High mileage (30 000km/year)	DKK 3.16	DKK 2.61	-17%	DKK 4.19	DKK 3.45	-18%
High mileage (20 000km/year)	DKK 3.58	DKK 3.05	-15%	DKK 4.79	DKK 4.05	-16%
Low mileage (10 000km/year)	DKK 5.34	DKK 4.79	-10%	DKK 7.22	DKK 6.42	-11%
Low mileage (5 000km/year)	DKK 9.62	DKK 8.85	-8%	DKK 13.16	DKK 12.08	-8%
Long holding (10 years)	DKK 3.26	DKK 2.77	-15%	DKK 4.34	DKK 3.64	-16%
Discount rate (3%)	DKK 3.99	DKK 3.50	-12%	DKK 5.36	DKK 4.67	-13%

Baseline assumptions: annual mileage of 15,000 km/year, 5 year holding period, discount rate 1.5%.
Source: Own calculations

The results of the Low EV cost and High EV cost scenario provide a cost corridor for EVs relative to ICEVs (Table 3-15). The scenarios have a different impact on the first and second owner. For the first owner, a Low EV cost-scenario implies that EVs are significantly cheaper than comparable ICEVs, with a TCO up to 45% lower. However, in the High EV cost-scenario, the costs of EVs exceed that of ICEVs with 65%. The scenarios only have a moderate impact on the second owners. In all scenarios, owners of used EVs face lower costs than owners of used ICEVs.

Table 3-15 Scenario analysis – Denmark

	Segment C			**Segment L**		
First owner (holding period 5 years)						
ICEV	DKK 293 027	DKK 3.91		DKK 392 717	DKK 5.24	
EV Low cost	DKK 178 306	DKK 2.38	**-39%**	DKK 215 463	DKK 2.87	**-45%**
EV Base case	DKK 258 067	DKK 3.44	**-12%**	DKK 340 146	DKK 4.54	**-13%**
EV High cost	DKK 465 678	DKK 6.21	**+59%**	DKK 646 807	DKK 8.62	**+65%**
Second owner (holding period 10 years)						
ICEV	DKK 402 715	DKK 2.68		DKK 527 332	DKK 3.52	
EV Low cost	DKK 382 118	DKK 2.55	**-5%**	DKK 486 278	DKK 3.24	**-8%**
EV Base case	DKK 368 684	DKK 2.46	**-8%**	DKK 457 810	DKK 3.05	**-13%**
EV High cost	DKK 394 453	DKK 2.63	**-2%**	DKK 484 221	DKK 3.23	**-8%**

Source: Own calculations

3.4.3.3 TCO Denmark – Summary

- For the car models that are compared for Denmark the TCO of the EV in the two car segments is always lower than that of comparable ICEVs, both in the baseline and in the sensitivity analyses.
- From the sensitivity analysis consequently follows that the cost advantage of the EV can be increased significantly if the resale value of the EV is higher or if the price premium of the EV compared to the ICEV falls. The cost advantage also depends significantly on the price of charging: with public charging rates, the cost advantage of the EVs falls substantially.
- As the annual mileage falls, the relative cost advantage of the EV remains, but gets smaller. This pattern of change in the relative TCO of EVs w.r.t. the annual mileage is similar as was found for Italy and, for example, the analysis by Crist (2012).
- In a Low EV cost scenario, TCO of medium-sized EVs may become 39% lower than those of a comparable ICEV. The TCO of an electric SUV is even 49% lower than that of its ICEV counterpart. In a High EV cost scenario, the opposite occurs, with EV costs increasing 59% and 65% above ICEV costs.
- For second owners, second hand electric passenger cars are cheaper than used ICEVs in all scenarios considered.

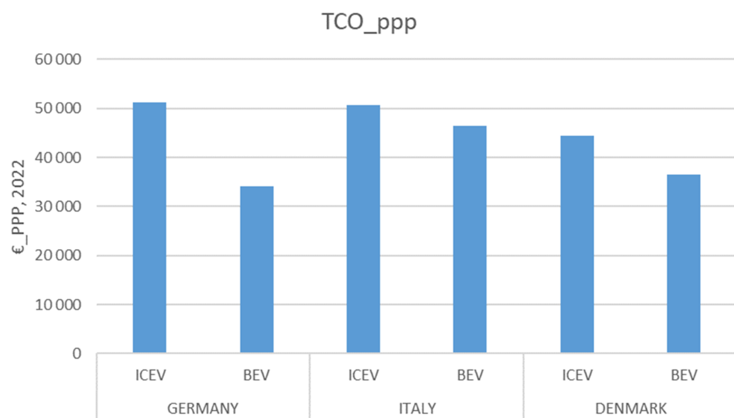
3.5 Country comparison

In this section, we compare the TCO of ICEVs versus EVs across countries. Because we calculated the costs for different car models per country, we only use the mid-sized cars in this comparison (segment C) because this is the segment for which car models were studied in the three countries.

To compare costs across countries, we rescale the original TCO from the baseline analysis using purchasing power parity exchange rates. This approach corrects expenditures for differences in purchasing power between countries. The resulting TCO_ppp are shown in Figure 3-11.

The figure shows that, when corrected for differences in purchasing power, ICEV vehicles are most expensive in Germany and Italy. Electric vehicles are available at the lowest cost in Germany. In this country, the cost gap between ICEVs and EVs is the largest. Electric vehicles are most expensive in Italy, where the cost difference between ICEVs and EVs is the smallest.

Figure 3-11 Purchasing power parity corrected TCO – Segment C passenger cars



Source: Own calculations based on analysis in Section 3.4 and OECD PPP exchange rates

3.6 Outlooks for future development of TCO components

In this section, we provide an overview of cost projections of different TCO components. We discuss how the expected cost evolutions may impact the total TCO and investigate the potential influence of EU-wide or national measures.

3.6.1 Purchase costs

A consensus among researchers and analysts is that the purchase price of electric vehicles remains the main hurdle to a widespread adoption of these zero-emission vehicles (Goetzel and Hasanuzzaman, 2022); therefore, most public authorities focus on incentives that reduce the purchase costs.

While nearly all studies agree that the average purchase price of electric vehicles will decrease in the future, there is no consensus on how soon electric vehicles and ICEVs will reach price parity. While studies like BloombergNEF (2021) estimate price parity to be achieved in the mid 2020's, other studies are more conservative and argue that price parity will not be reached before the end of the decade (Miller, 2020). A recent TCO by BEUC (2021) estimates BEVs to become cheaper than ICEVs by 2026. Small cars could become more available at an even faster pace, while medium and large BEVs are expected to become cheaper than ICEVs by 2030, according to the study.

Difference in purchase price projections across studies may be caused by several factors. First, because the EV market is evolving at a very fast pace, the timing of the study has an impact on the forecasted outlook. The technology evolves constantly, therefore the most recent studies are expected to be the most reliable. Second, the methodology on which price projections are based differs across studies. Most purchase price projections are based on a production cost-model and the underlying techno-economic assumptions are not always clearly specified.

Production cost-based models derive the purchase price of an electric vehicle bottom-up, making assumptions about technology advances and sales margin. In contrast, a learning rate model, as used by Goetzel and Hasanuzzaman (2022) follows a top-down approach, comparing actual sales prices of electric vehicles to those of comparable fossil fuel cars. This approach offers more reliable purchase price estimates and allows to make projections over all vehicle segments. In a study for the German market, Goetzel and Hasanuzzaman (2022) show that price parity depends on the vehicle size. Large and upper-class passenger cars (segment E/F) are expected to already reach price parity by 2023, even without subsidies. Midsize vehicles (segment C/D) will reach price parity by 2026, but small passenger cars (segment A/B) will only achieve price parity by 2030.

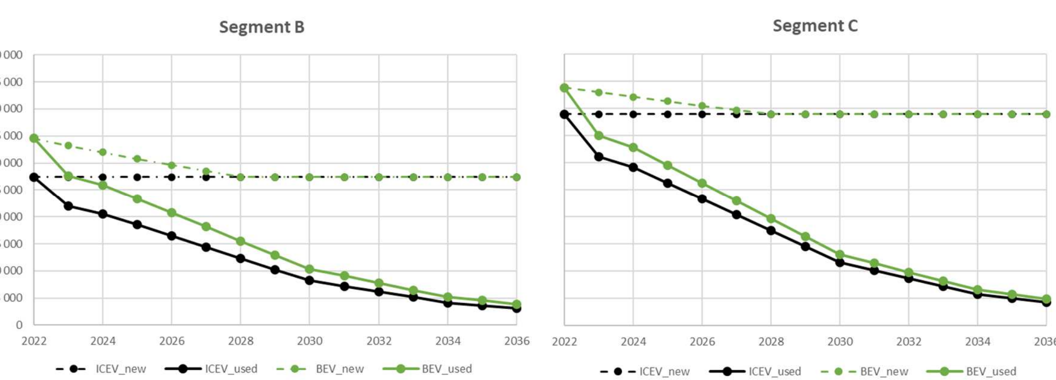
3.6.2 Resale value

As discussed in section 3.2.1.4 there is still no consensus and a lot of uncertainty about the depreciation scheme of electric vehicles relative to ICEVs. The earliest findings on EV resale value showed high depreciation rates because of the rapidly changing technology and the entry of new models onto the market. More recent data on the second-hand market for EVs indicate the opposite. Under the influence of a shortage of supply in the new car market, demand inflation occurs, which drives up prices on the used-car market.

To illustrate the impact of the depreciation rates on the evolution of the purchase price of second-hand ICEVs and BEVs soon, we apply a similar approach as Bauer et al. (2021) for the US. The purchase price includes VAT but excludes subsidies or registration taxes.

Figure 3-12 shows the purchase price projections of new ICEVs and BEVs by a dashed line, assuming price parity by 2028. The full lines show the evolution of the used 2022-model's price, assuming a yearly mileage of 15 000 km. First, the figure shows that the price gap between EVs and their ICEV equivalent is currently 26% for a small car, and 12.6% for a medium-sized car. Second, while new cars reach purchase cost parity by 2028, used cars do not reach cost parity before 2036. The purchase cost gap for mid-sized cars (segment C) is negligible as of 2030. For small used cars (segment B), price parity is expected only by 2036 or later.

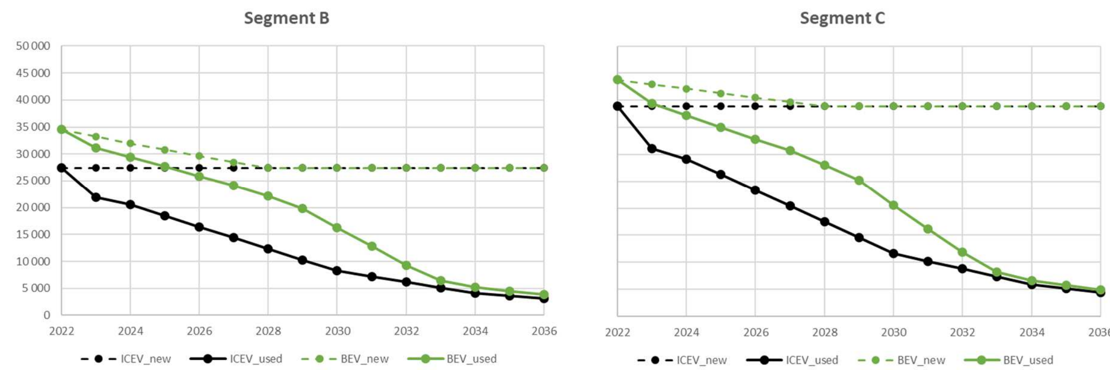
Figure 3-12 Purchase price of new (dashed) and used (full) cars by fuel type – Baseline scenario



Source: own calculations

In Figure 3-13 and Figure 3-14 we analyse respectively the impact of a lower and a higher depreciation rate for BEVs on the purchase prices for used models in the coming years. In the low depreciation scenario (Figure 3-13) we assume that the BEV retains 90% of its purchase value in the first year. The resale value drops to 80% of the original price only after three years (and a cumulated mileage of 45 000 km). For comparison, in the baseline scenario, after three years the resale value is equal to 68% of the original purchase price. It is clear from the figure that this scenario implies that used EVs remain expensive for a long time. The price gap with used ICEVs is significant, especially in the segment for small cars. In 2030, a 2022-model with a total mileage of 120 000 km would still cost € 16 234, which is nearly twice as much as a comparable fossil fuel car that costs only € 8 222. A similar but smaller price gap exists for medium-sized cars. In the low-depreciation scenario, an 8-year-old medium-sized BEV will cost € 20 600, while a comparable used fossil-fuel car costs € 11 681.

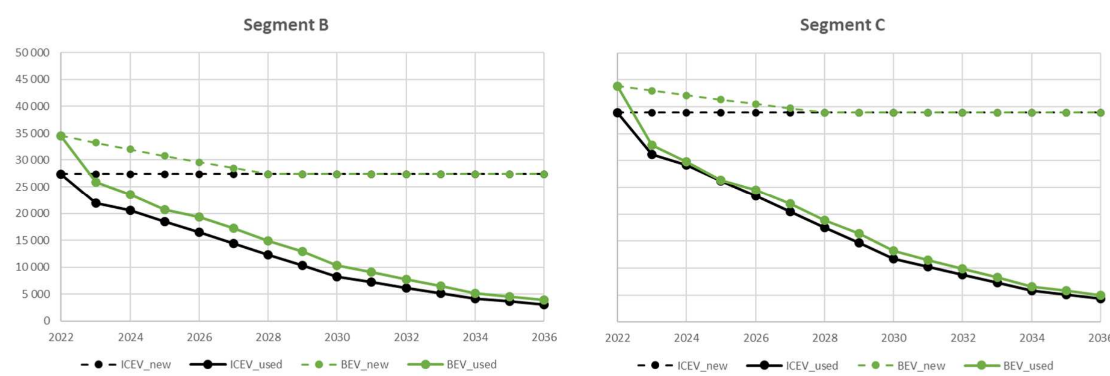
Figure 3-13 Purchase price of new and model-2022 cars – Scenario low depreciation BEV



Source: own calculations

In the scenario with a higher depreciation rate for BEVs (Figure 3-14), we assume a 25% loss of value for the electric car in the first year. After three years, the BEV's resale value has dropped to 60% of its original price, versus 68% for the ICEV. A higher depreciation rate of electric cars implies that the current models will be more affordable in the coming years than what is assumed in the baseline scenario. This is especially the case for medium-sized cars. The current 2022 model will cost the same as a comparable ICEV in three years' time (2025). For smaller cars, the price gap persists, although it has narrowed considerably. An eight-year-old EV model-2022 will cost € 10 362, compared to € 8 222 for the fossil-fuel alternative.

Figure 3-14 Purchase price of new and model-2022 cars – Scenario high depreciation BEV



Source: own calculations

4 Strategies to help car users make the transition

Key messages

- The development of a dense, accessible, and high-quality charging network is found to be the main driver to boost electric vehicle use. A high-quality public charging network with a harmonized payment system provides access to more affordable (shorter driving range) electric cars while alleviating range anxiety.
- Although purchase incentives for electric vehicles such as rebates and subsidies help to support the EV market uptake, these financial incentives are not the most economically efficient measure. In addition, if they are not targeted to lower-income households, they risk leading to equity concerns.
- Access to cheap financing sources and investments in car sharing services can improve the affordability and accessibility of electric vehicles.
- Recurrent tax incentives have a relatively limited impact on the total costs and therefore on the affordability of electric vehicles. This is because, in the countries studied in this report, annual vehicle taxes represent only a small part of a passenger car's total ownership costs.

4.1 Flanking measures and their impact

To achieve a substantial reduction in CO_2-emissions in the passenger transport sector, a widespread transition to zero-emission vehicles is indispensable. Because the purchase cost of these vehicles remains an important hurdle for many households, most European countries provide **financial incentives** such as subsidies, rebates and/or tax benefits. Financial incentives alone are insufficient to stimulate a nationwide adoption of EVs. The uptake of EVs also depends on other factors such as the availability of charging infrastructure, range anxiety and public acceptance. Hence, government support should also include **non-financial incentives, regulatory measures, charging infrastructure development and raising awareness**.

In this section, we investigate the economic and equity impact of the flanking measures that are in place or could be considered by public authorities.

Purchase subsidies

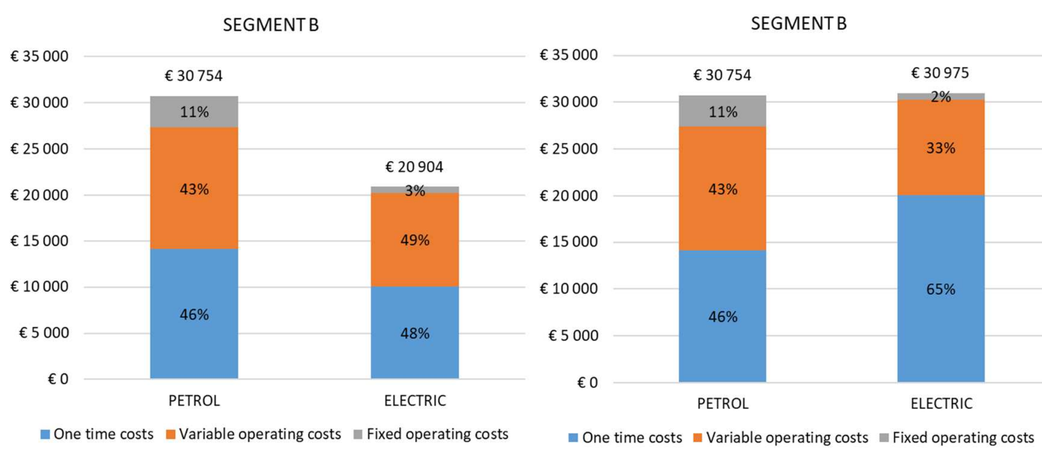
Since 2020, Germany provides the most generous financial support with purchase subsidies up to € 9 000, as well as a grant for the installation of charging infrastructure and a recurrent premium based on GHG quota. These incentives had an immediate market impact: sales of BEV and PHEV vehicles rose by more than 200% in 2020 (Wittich, 2021). According to EAFO data, Germany was market leader in terms of EV shares in new sales in the year 2021. No less than 28.9% of all new passenger cars were BEV, while 30.7% were PHEVs. The German purchase subsidies are only a temporary measure to stimulate EV market uptake. As of 2023 the amount of the subsidy will be reduced to € 4 000. By 2026, the subsidy will be omitted

Figure 4-1 and Figure 4-2 show the impact of purchase subsidies for electric passenger cars and charging infrastructure on the TCO. A first observation is that without purchase subsidies, BEVs are equally costly to own and operate than their corresponding fossil fuel cars. For a small car, the current TCO is € 20 904 (€ 0.28/km) in the baseline analysis. Without subsidies, the TCO increases to € 30 975 (€ 0.41/km), which is approximately equal to the TCO of the petrol car for which the TCO is € 30 754 (€ 0.41/km). For a medium-sized car, a similar finding holds. Even without purchase subsidies, the electric passenger car is cheaper than the comparable petrol car.

At the same time, the composition of the TCO changes significantly if purchase subsidies are discontinued. While the purchase subsidies resulted in a one-time cost for electric cars below those of petrol cars, the TCO results show that one-time costs become significantly higher without subsidies. For small cars the one-time costs of an EV exceed those of a petrol car by nearly € 6 000. For medium-sized cars the one-time cost difference is equal to € 4 812.

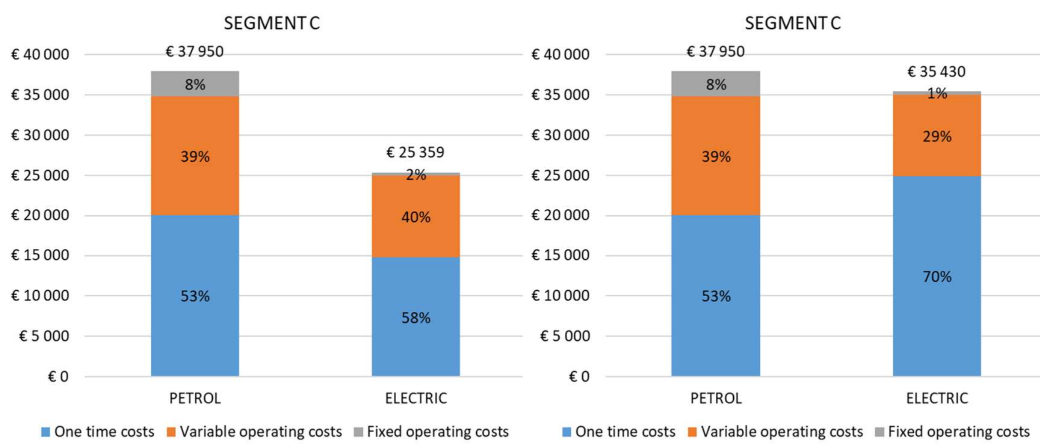
This means that we cannot conclude that purchase subsidies in Germany are no longer required. The high upfront cost to purchase a vehicle is an important constraint, especially for households in lower income classes. These are the consumers that will be most affected when purchase subsidies are cancelled. However, for vehicles in higher segments, we can make a case for abandoning the purchase subsidies. Consumers buying these vehicles are typically from a higher income class. In addition, a recent study for the German car market finds that purchase prices of these high segment passenger cars will be at par with fossil fuel cars soon, while this is not the case for small and mid-sized cars (Goetzel and Hasanuzzaman, 2022).

Figure 4-1 TCO segment B Germany with purchase subsidy (left), without purchase subsidy (right)



Source: own calculations

Figure 4-2 TCO segment C Germany with purchase subsidy (left), without purchase subsidy (right)

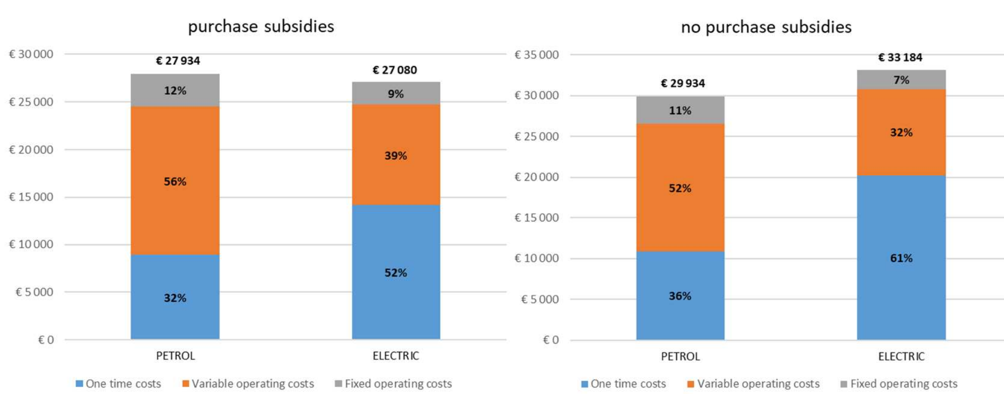


Source: own calculations

In Italy, a purchase subsidy applies both to BEVs as to low emission fossil fuel cars. Figure 4-3 and Figure 4-4 show the impact on TCO of respectively small and medium cars in a scenario where these purchase subsidies are abandoned. For both car sizes, a cancelation of the purchase subsidies leads to BEVs being more expensive than the comparable petrol car. In the baseline scenario, one-time costs for BEVs were already higher than those of ICEVs. With the elimination of purchase subsidies, this difference is even more pronounced.

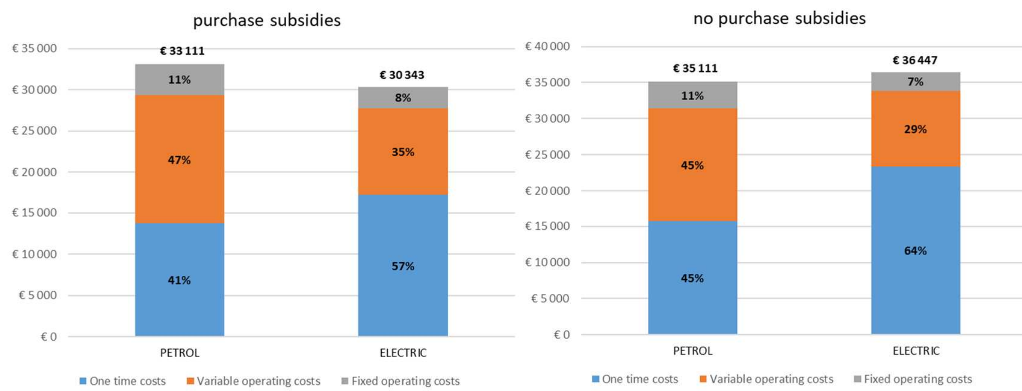
There is a consensus in the literature that purchase costs are one of the main vehicle attributes in a consumer's decision to by a vehicle (cfr. the meta-analysis by Liao et al. (2017)). Therefore, we can assume that the purchase cost gap between BEVs and ICEVs is one of the main constraints for BEV market penetration in Italy. The current purchase subsidies reduce the size of this cost gap. However, the subsidy for low emission fossil fuel cars may be a hindrance to the further growth of the BEV market because it supports the sale of new fossil fuel vehicles.

Figure 4-3 TCO segment B Italy with purchase subsidy (left), without purchase subsidy (right)



Source: own calculations

Figure 4-4 TCO segment C Italy with purchase subsidy (left), without purchase subsidy (right)



Source: own calculations

Many medium to lower-income household budgets do not allow for the purchase of a new car, even with compensating subsidies. With that lack of access to financing, the purchase cost remains a critical barrier for low-income households. Several studies criticize purchase rebates based on an equity argument. Many of the purchase rebates apply post purchase, so the buyer must first come up with the full purchase price of the car. Therefore, these rebates mainly benefit the wealthier households, who may have intended to buy an EV anyway (DeShazo, 2019; Wells, 2012).

To foster the affordability of EVs for medium and lower-income households, the development of a solid market for used cars with enough smaller models should be a priority for policy makers. **While many countries provide financial incentives to support the purchase of new cars, a much smaller number of countries have adopted similar incentives for the used car market.** Exceptions are the Netherlands, Germany, and France, where the government provides purchase subsidies for used BEVs. In the Netherlands, the subsidy only applies to small and compact BEVs. In France, a conversion bonus system is in place, that provides a higher amount for low-income households.

To conclude, **providing purchase incentives seems to be crucial to pace up the market penetration** of BEVs. This is especially the case in the used-car market, where the low-income consumer groups can be reached. To avoid that purchase grants benefit (only) the wealthier households and lead to costly government expenditures, purchase grants can be issued **exclusively to smaller cars and/or used cars**. In addition, **the amount of the purchase grant should be higher for lower-income households** (DeShazo et al., 2017).

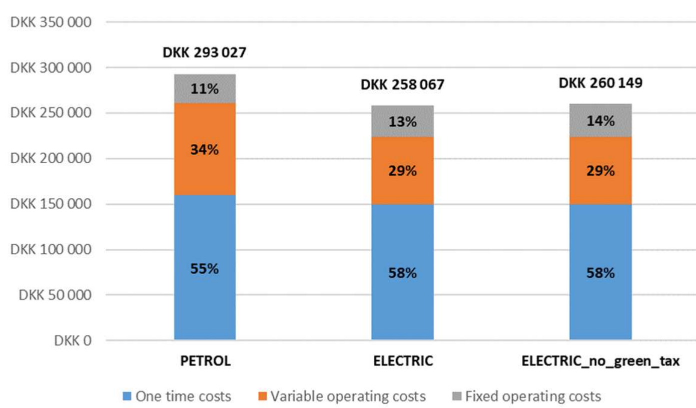
Recurrent tax incentives

Instead of providing support at the time of purchase, a government may decide to subsidize the use of BEVs by allowing for lower (semi)-annual taxes. Several EU countries have a vehicle tax system in place that is based on the CO_2-emissions of the vehicle. An example is the semi-annual Green Tax in Denmark, where zero-emission cars pay the lowest rate. In Germany, zero-emission cars that are registered before the end of 2025 are exempt from the annual motor vehicle tax for the first 10 years. In Italy, the exemption of the motor vehicle tax for BEVs lasts for five years after the first registration date.

Figure 4-5 and Figure 4-6 show the impact of the Green Tax in Denmark. The "no_tax_benefit" scenario assumes the same semi-annual Green Tax rate for BEV and petrol cars. The figures show that the impact on the total TCO is minimal. For the medium-sized car, the TCO of the electric vehicle increases from DKK 258 067 to DKK 260 149, which corresponds to an increase of 0.8%. For the SUV car, elimination of the Green Tax benefit increases the TCO from DKK 340 146 to DKK 349 282 (+2.7%). In both cases, the TCO of the electric passenger car remains well below the TCO of the comparable petrol car.

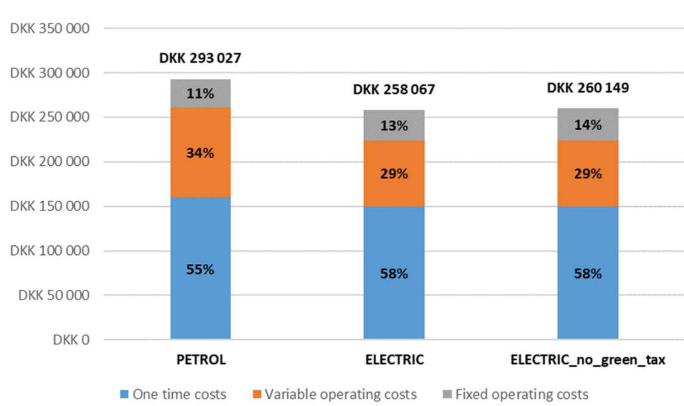
Given the **small impact on TCO**, one can expect that a tax relief for the recurrent vehicle taxes has a limited effect on the purchase choice of consumers. An argument in favour of an annual tax benefit is that it entails an equity advantage. While a purchase grant or subsidy only favours first owners, an annual tax reduction benefits all car owners. However, this is not always true. First, purchase subsidies may also apply to used cars, as is the case in Germany. Second, a tax relief scheme like the one in Italy, where the tax reduction is limited in time, only benefits the first owners which worsens equity issues.

Figure 4-5 TCO segment C Denmark – impact Green Tax



Source: own calculations

Figure 4-6 TCO segment L Denmark – impact Green Tax



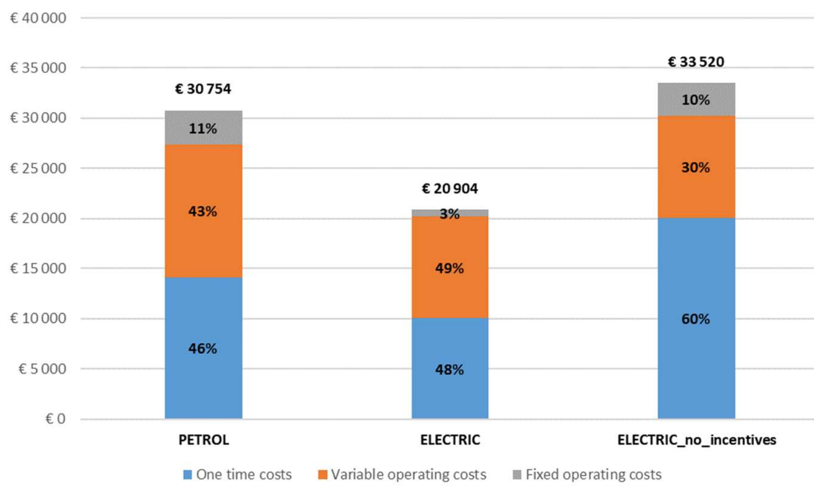
Source: own calculations

Impact of all financial incentives - Germany

We estimate the impact of an omission of all financial incentives for EV drivers. We do this analysis only for Germany, where financial incentives are currently the most generous across Europe. More specifically, we calculate the impact on TCO for the following scenario:

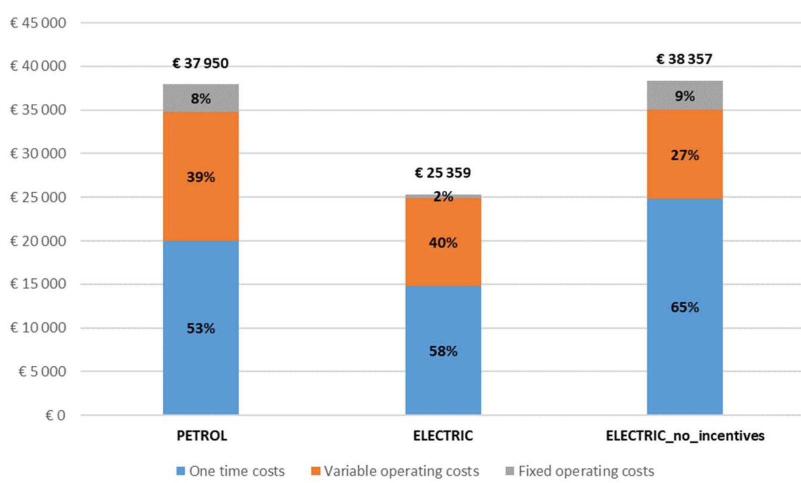
- purchase subsidies for EVs and charging infrastructure are omitted,
- there is no recurrent benefit from GHG quota,
- EV owners and ICEV owners pay similar annual motor vehicle taxes

Figure 4-7 Impact of financial incentives Germany - Segment B



Source: own calculations

Figure 4-8 Impact of financial incentives Germany - Segment C



Source: own calculations

Figure 4-7 and Figure 4-8 show that the German financial incentive package has a significant impact on the TCO of electric vehicles. If these incentives are abolished, the costs of small EVs increases from € 20 904 (€ 0.28/km) to € 35 520 (€ 0.45/km), which corresponds to a cost increase of no less than 60%. The EV also becomes more expensive than the ICEV, with a cost gap of 9%. For medium-sized vehicles, the same holds, although to a somewhat lesser extent. A cancellation of financial incentives increases the TCO of mid-sized EVs from € 25 359 (€ 0.34/km) to € 38 357 (€ 0.51/km), corresponding to a cost increase of 51%. In this scenario, the segment C EV is 1% more expensive than the comparable ICEV.

Access to finance

For lower income households, the relatively large upfront cost of a passenger car poses the main hurdle for car ownership. An alternative to provide purchase rebates, is the provision **of interest-free loans or financing plans that offer a long repayment period**. These alternative policies offer capital-constrained households access to the lower operating costs for electric vehicles while avoiding the high upfront costs (Caulfield et al., 2022). However, there may be **a risk for over-indebtedness**, to which these households are already very vulnerable.

Differential taxation: disincentives for ICEVs

Instead of providing subsidies and grants, the Danish government stimulates EV-ownership by charging very high registration taxes on ICEV cars and granting tax reductions for EVs. As a result, EVs are more affordable in Denmark than ICEV cars. However, this taxation strategy comes with equity concerns. The purchase of a passenger car remains very expensive in Denmark, irrespective of the fuel type. Car ownership is an affair of the wealthy, while lower income households cannot afford to own a car. Hence, the current taxation policy in Denmark might lead to a further deepening of the **wealth inequality** in the country. A study by the OECD shows that while income inequality in Denmark is low, the country has the third highest level of wealth inequality among the OECD countries (Balestra and Tonkin, 2018).

The concern about passenger car affordability in Denmark is also reflected in car ownership rates. Car ownership rates in Denmark are below EU-average rates. In 2020, car ownership in Denmark was equal to 0.47 cars per capita. In contrast, the EU-average ownership rate was equal to 0.56 cars per capita (ACEA, 2022). In 2019, 38.3% of Danish households did not own a car. This number is significantly higher than in other EU countries (ACEA, 2021). A point of attention for authorities is that high car taxation may result in **mobility poverty**.

To reduce the inequality impact of high car taxation and to prevent mobility poverty, public authorities can further invest in the **public transport network or other mobility solutions such as car sharing schemes** (see Section 4.2). Until today, these alternatives only exist in certain urban areas. Even there, car-sharing or pooling services are often limited in scope.

Low Emission Zones

As part of local policies to improve air quality and fight climate change, several European cities have implemented Low Emission Zones (LEZ) on (a part of) their territory. Although many studies show that the introduction of LEZs has a positive impact on air quality, empirical evidence shows that **the role of LEZs in electric vehicle uptake is quite limited**. Peters et al. (2021) show that the LEZ in Madrid caused a shift in vehicle registrations away from diesel towards alternative fuel types.

However, the new registrations were predominantly petrol cars, gas-powered vehicles, and PHEVs. There was not significant increase in the registration of BEVs. The authors argue that an LEZ may not be sufficient to accomplish an impact on BEV sales.

4.2 Cost-reducing strategies

Car-sharing schemes

Many studies show that one of the main hurdles for car ownership are the relatively large upfront costs. This finding is confirmed by the TCO-analysis presented in Chapter 3, which shows that electric passenger cars benefit from relatively low running costs. A **car-sharing scheme** may provide an elegant solution, because it avoids a large capital expense, while providing access to car use**. In addition to lowering the total costs for the users, car-sharing has the potential to reduce traffic congestion, lower parking needs and total emissions from passenger transport**. For a car-sharing scheme to work efficiently, a relatively high number of users should live nearby pickup and drop-off stations. Given these characteristics, car-sharing schemes can play an important role in **sustainable mobility in cities and urban areas**.

Although car-sharing schemes have the potential to offer a mobility solution to lower income households, there is ample evidence in the literature that currently **users of car-sharing services are typically wealthy households**. For example, a profiling study of car-sharing users shows that the typical user is young, well-educated, has a high income and resides in higher-density areas (Dias et al., 2017). People with lower income, racial or ethnic minorities, elderly people and people with disabilities are found to have significantly lower access to car-sharing schemes (Sanchez, 2018; Dill and McNeil, 2020). Therefore, the challenge for policymakers is to convince car-sharing operators to also offer their services in less affluent areas.

Electric car-sharing services require a change in people's behaviour and attitude in two dimensions. First, there needs to **be a shift from private ownership to shared ownership**. Second, there is a change in the **type of car from ICEV to EV**. Therefore, user acceptance for electric car-sharing schemes is even more challenging than for conventional car-sharing schemes. However, this also means that **electric car-sharing services may attract people who are interested in electric cars but cannot afford to buy one**.

Although currently car sharing schemes are predominantly used by wealthier households, we argue that these services can play an important role in the affordability of car use. Because studies show that the intention to make use of car sharing depends mostly on **social influence** (seeing your friends, colleagues or relatives using car services), a further uptake of these service is to be expected over time (Curtale et al, 2021). Currently, the offer of car-sharing and car-pooling services is limited in terms of location and time. Car sharing has not yet established itself as a true complement of public transportation. The service is limited to **highly populated areas** and requires a **mentality change** of car users.

Despite of the challenges and hurdles for a successful development of car sharing services, they can potentially play a role in providing mobility solutions for less affluent households. Hence, governments should further investigate the potential of car sharing schemes, especially in urban areas and areas where the quality of public transport services is insufficient.

4.3 Charging infrastructure

For the EV market to be successful, a dense and reliable public charging network needs to be deployed across Europe. Sierzchula et al. (2014) show **that the availability of a high-quality charging network is an important factor for increased EV market share**. However, many countries are lagging in this respect. Currently, charging of electric vehicles is predominantly done at home or at work (IEA, 2022). In Ireland, for example, public infrastructure development does not match the pace of the growing EV fleet. As a result, EV drivers should rely predominantly on home charging, which accounts for 80% of charging sessions (Caulfield et al., 2022).

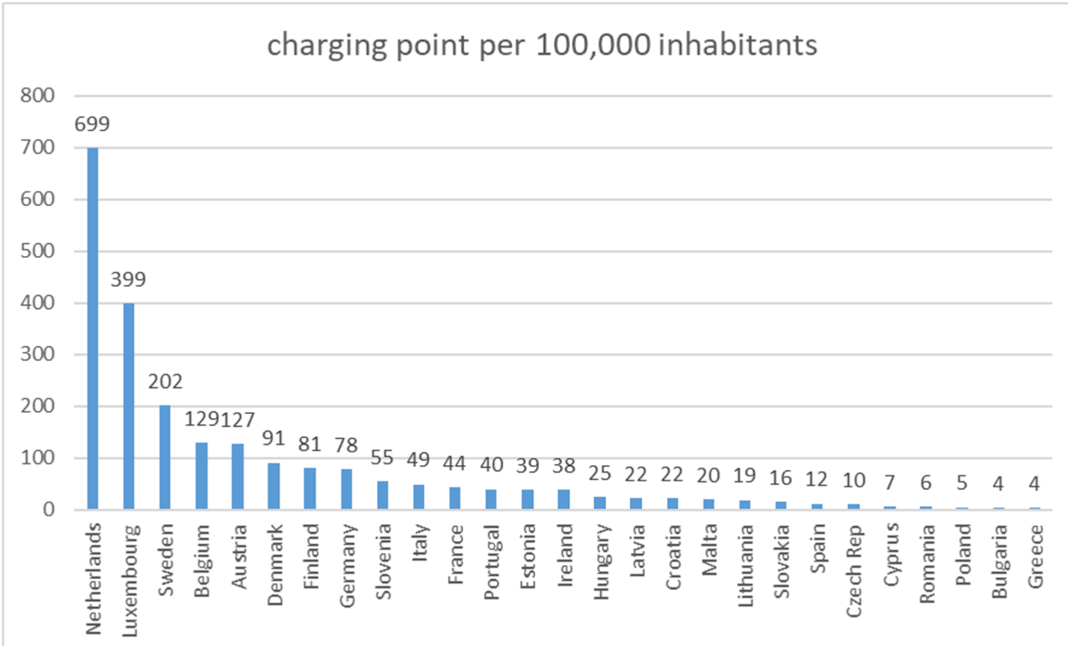
The importance of a charging network as precondition for EV uptake is further confirmed by Santos and Davies (2020). A survey among experts and stakeholders from five European countries shows that **the development of charging infrastructure is most important for a quick market penetration of electric cars**.

In a multi-country analysis, Yao et al. (2020) evaluate a large set of financial and non-financial policy incentives on their capacity to boost electric vehicle uptake. They conclude that subsidies are only marginally important. Instead, governments should use their money to invest in a dense public charging network. **A high density of fast chargers has the most positive effect on EV uptake**.

A study by Transport & Environment computes the required number of charging points (weighted by the amount of energy they produce) across the EU (T&E, 2020). By 2025, 1.3 million public charging points need to be available. The number of required charging points increases to 3 million in 2030. By the end of 2021, about 330 000 public charging stations were accessible in the EU (ChargeUp, 2022). Hence, to meet the demand, large investments in additional charging points are needed.

There are significant differences between countries with respect to the quality of the public charging network. Figure 4-9 shows the number of accessible public charging points per 100 000 inhabitants in the EU-27. The Netherlands is leading convincingly with nearly 700 charging points per 100 000 inhabitants. In general, public charging stations are more frequent in Northern than in Southern countries. In addition to these country differences, Euronews (2022) reports that there are also large disparities within countries. Cities have a more extensive coverage than rural areas.

Figure 4-9 Installed public charging infrastructure per 100,00 inhabitants end of 2021



Source: ChargeUp (2022)

Access to public charging points

The results of the TCO model presented in Chapter 3 demonstrate that the use costs of an electric vehicle depend to a great extent on the charging mode of the user. Home charging is by far the cheapest alternative, although there is an upfront installation cost for the charging infrastructure. If the electricity grid at home is outdated, infrastructure installation costs can be high because adjustments to the electric installation are required. Nevertheless, having to rely on public charging points is more expensive than home charging.

Whether a household can charge at home depends on the type of building. In addition, if the household is renting instead of owning the property, the installation of charging infrastructure is up to the property owner.

Table 4-1 compares the housing conditions in several EU countries to the availability of public charging points in 2021. Per income group, the table shows the share of people that live in a detached house, semi-detached house or a flat.[26] This provides an indication of the opportunities to install a home charging system. In the group of households below the 60% medium equivalised income, the share of people living in an apartment is significantly higher than for households with an income above 60% of the median. The table also shows the number of public charging points per 100,000 inhabitants (ChargeUp, 2022). In general, countries that have the highest proportion of the population living in flats, also have a low number of accessible public charging points. Although charging infrastructure may be installed on private parking lots of these buildings, we may assume

[26] https://ec.europa.eu/eurostat/databrowser/view/ILC_LVHO01__custom_3467469/default/table?lang=en

that people in flats are in general more dependent on public charging infrastructure than people living in houses.

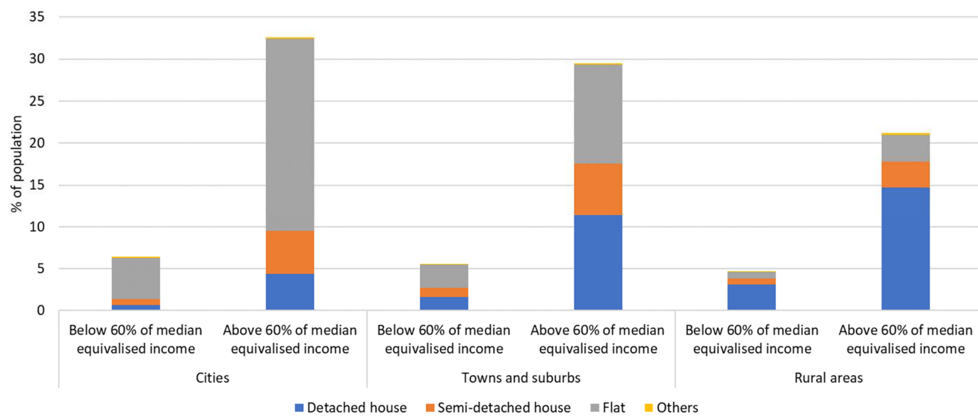
Table 4-1 Housing conditions and public charging availability in the EU-27 Member States at the end of 2021

Country	Above 60% of median eq. income			Below 60% of median eq. income			Charging points per 100 000 inhabitants
	Detached house	Semi-detached house	Flat	Detached house	Semi-detached house	Flat	
Austria	48	9	43	28	4	68	127
Belgium	38	43	19	22	33	45	129
Bulgaria	38	10	53	63	12	25	4
Croatia	67	10	23	77	9	14	22
Cyprus	46	28	25	40	31	29	7
Czechia	39	10	51	31	6	63	10
Denmark	56	13	31	31	8	62	91
Estonia	35	5	61	32	3	65	39
Finland	48	18	33	32	15	53	81
France	50	19	31	24	19	57	44
Germany	30	15	55	18	9	73	78
Greece	30	8	62	43	11	47	4
Hungary	68	5	27	72	5	23	25
Ireland	41	51	9	31	57	12	38
Italy	24	23	54	28	21	51	49
Latvia	31	3	66	34	3	63	22
Lithuania	35	5	60	36	5	59	19
Luxembourg	33	30	38	17	28	55	399
Malta	5	39	56	4	33	63	20
Netherlands	19	62	19	11	50	39	699
Poland	48	5	47	64	5	31	5
Portugal	35	16	48	43	19	38	40
Romania	57	1	42	90	1	9	6
Slovakia	50	2	48	59	4	37	16
Slovenia	68	6	26	58	5	37	55
Spain	14	20	66	14	21	65	12
Sweden	48	9	43	26	5	69	202

Source: Eurostat, ChargeUp

Figure 4-10 shows the housing conditions in EU-27 countries by income share and location (cities, towns and suburbs and rural areas). In cities most people live in flats. The share of the population living in flats is 76.6 % for people below the poverty line, and 70.2% for the others. In towns and suburbs, the share of houses is larger, for both income groups. However, 50 % of people below the poverty line live in flats, compared to 39.7 % for the others. In rural areas, most people live in (semi-) detached houses: 81% for the people below the poverty line and 84 % above. We can conclude from the figure that especially in cities, towns and suburbs, lower-income households are overrepresented among the group of consumers that do not have the possibility to install a charging network at home. Therefore, an inclusive EV uptake policy should make sure that sufficient high quality public charging stations are provided in these areas.

Figure 4-10 Housing conditions by income share and location, aggregated for EU-27 countries



Source: Eurostat

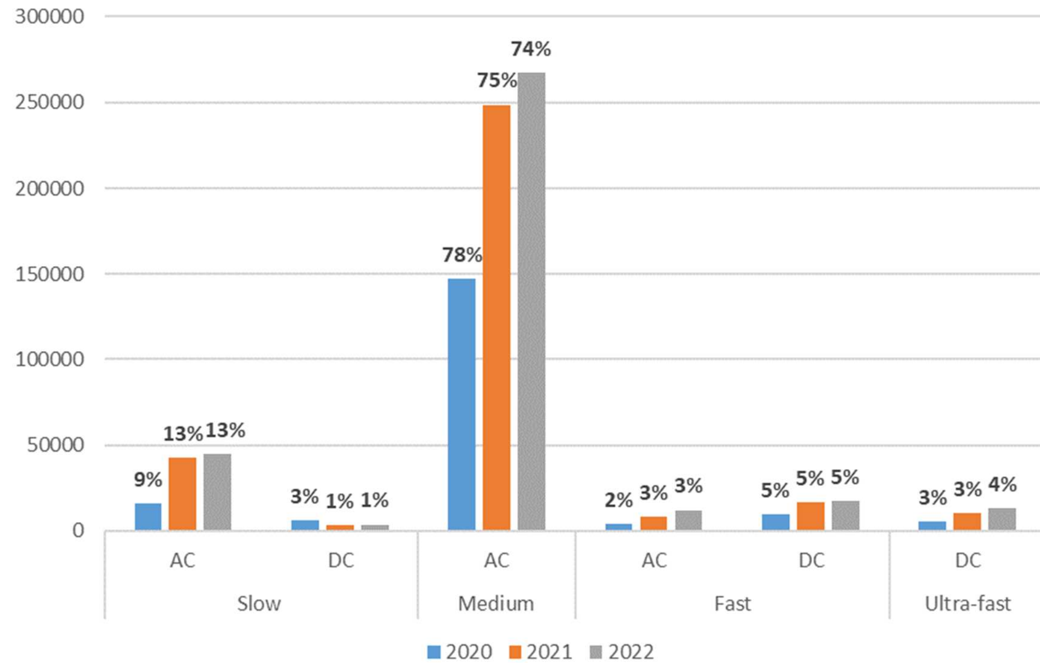
In cooperation with Leaseplan, Transport & Environment (2020) investigated the charging behaviour of EV users in Europe. They show in 2020, that the average EV driver charges 60% at home, 15% at work and 25% at a public charging station (6% fast and ultra-fast charging, vs 19% regular public charging). The figures of T&E are in line with other research on EV charging behaviour. Corchero et al. (2014) report that 71% of the charges are done at home or at work, 29% of the charges are carried out at public charging points. According to the model projections by T&E (2020), the share of home charging will decrease to 45% in 2030. Charging at work is expected to increase to 24% of all charging cycles. This means that **the share of public charging will increase from 25% to 31% by 2030, implying a need for additional public charging stations**.

Quality of the charging points

There are different types of charging points, depending on their power output, and charging speed. Electric vehicles are not always compatible with each charging type because the recharging connector and the vehicle inlet may vary among car models and across countries. Recharging is classified in AC-recharging (category 1) and DC-recharging (category 2). Within these categories, charging points are differentiated based on the speed of charging.

Figure 4-11 shows the number of different charging points installed in Europe. The data is obtained from the EAFO website. Most of the recharging points (74%) in Europe are medium-speed AC recharging points with a maximum power output between 7.4 and 22 kW. Fast and ultra-fast recharging represents only 8% and 4% of all charging points.

Figure 4-11 Number of charging points in Europe by type of charger



Source: European Alternative Fuels Observatory (https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/infrastructure)

Fast and **ultra-fast charging stations are currently underrepresented** in the European charging network. The availability of fast chargers is important because these types of chargers **enable longer journeys**. They can play a crucial role in accommodating drivers of EVs with a relatively short driving range, i.e., with **more affordable vehicles**. In addition, a high amount of publicly accessible fast chargers may convince those consumers, for which **range anxiety** is currently the reason why they are reluctant to switch to an EV.

Apart from the speed of charging, **the lack of standardization and harmonized payment systems** are also hindering a wide accessibility to public charging points. The EU's AFID directive prescribes that every charging point in the EU should be equipped with at least a standard AC and DC charging point. This should provide EV users with a more uniform access to different charging networks. However, a study by the European Court of Auditors shows that there is still a wide variety in payment systems and subscription types. Currently, there is no harmonised system that allows EV users to use all different charging network under a single contract agreement. Therefore, travelling across Europe may be compromised because EV users require multiple subscriptions and must use different payment methods (ECA, 2021). The AFID directive is currently being revised in a way that should overcome these issues. The adopted revision prescribes that there should be at least one electric charging pool for passengers every 60 km along main EU roads. The recharging stations should be accessible to all vehicle brands, payment should be easy and pricing should be transparent and affordable.[27]

Financial incentives for charging infrastructure

Several countries provide financial incentives and/or grants for the installation of private or public charging stations. Table 4-2 shows the national incentives that are currently in place to stimulate the installation of EV charging infrastructure.

Table 4-2 Financial incentives for EV charging infrastructure in Europe as of April 2022

	Private charging	**Public charging**
Austria	grant of € 600 for single use grant of € single-use installation grant of € 1 800 for a multi-use installation	subsidy between €300 and € 15 000 900 multi-unit dwellings,
Belgium	2022: 45% tax deduction up to € 1500 2023: 30% tax deduction up to € 1500	2021-2022: 200% tax deduction 2023-2024: 150% tax deduction
Denmark		tax deduction DKK 1/kWh
Finland	35% refund up to € 90 000	35% refund 50% for stations >= 11 kW
France		50% refund up to € 2 700
Germany	€ 900 grant for station at home several regional incentives	subsidy up to € 45 000
Greece	€ 500 grant for station at home	
Ireland	€ 600 grant for station at home	grant up to € 5 000
Italy	refund up to € 2,000	tax return up to € 3 000
Luxembourg	grant ranging from € 750 to € 1 650 depending on the type of charging station	
the Netherlands		36% refund tax return up to 75%
Spain	grant up to 70% for municipalities > 5 000 inhabitants grant up to 50% for municipalities <= 5 000 inhabitants	30% subsidy for installation <= 50 kW 35% to 55% subsidy for installation > 50 kW depending on company size
Sweden	50% grant up to SEK 15 000	50% grant purchase and installation costs
Poland	grant up to 25%	grant up to 25%
UK	grant covering 75% of costs up to £ 350	voucher-based scheme covering up to 75% tax benefit

Source: EVBOX (2022)[28]

[27] https://www.europarl.europa.eu/news/en/press-room/20221014IPR43206/car-recharging-stations-should-be-available-every-60-km-say-meps

[28] https://blog.evbox.com/ev-charging-infrastructure-incentives-eu

Research demonstrates that there is a good rationale for granting financial incentives for charging infrastructure instead of (or in addition to) financial incentives for EV purchases. Li et al. (2017) investigate the relative effectiveness of purchase subsidies for EVs and subsidies for the development of charging infrastructure on electric vehicle uptake. They find that **the deployment of public charging stations is much more effective in supporting EV sales than purchase subsidies**. The reason for this is that when a market is in an early stage of development, it is dominated by early adopters who a relatively price-insensitive. An important reason why people are reluctant to buy EVs is range anxiety. A dense network of public charging stations can **eliminate range anxiety** for potential EV adopters and thus boost EV sales. The authors show that **subsidizing charging infrastructure is much more cost effective than subsidizing EV purchases**.

5 Conclusion

This study investigates the implications of the proposed Fit for 55 policy measures on the affordability of future car use in the EU. The more stringent CO_2 emission standards and the future ban of the sale of new fossil fuel passenger cars in Europe implies that, over time, the European passenger car fleet should electrify. Because electric vehicles have currently still higher purchase prices than comparable fossil fuel cars, this raises a concern about the future affordability of passenger car ownership and use. Especially in the context of the current energy crisis, this concern has become even more topical.

To assess the future affordability of passenger cars in Europe, we calculate the total costs of ownership (TCO) for different car models available in three countries, Denmark, Germany, and Italy. The selection of countries is motivated based on their different fiscal treatment of EVs and ICEVs. We find that under the current conditions, the total costs of ownership (TCO) of electric passenger cars are cheaper than the TCO of comparable ICEVs. However, if the financial incentives for EVs that are currently in place would be abolished, this would no longer be the case and the affordability of passenger cars would worsen considerably. We investigate the impact of different scenarios on the TCO and assess the impact of assumptions on individual cost items in several sensitivity analyses.

Finally, we provide an in-depth discussion on the flanking measures that can be considered to help consumers making the transition to electric vehicles. We find that the development of a dense and high-quality public charging network is most important with this respect. Financial incentives also help to support consumers, but they should be designed and implemented in a way that they benefit those who need them most. Measures to support the second-hand market are currently insufficiently in place, while their importance to lower-income households is strong.

Annex 1: Car taxation in Germany, Italy and Denmark

Germany

Purchase subsidies

In Germany, the purchase of an EV is awarded with an environmental bonus of € 9 000 for vehicles with a list price below € 40 000 and a bonus of € 7500 for vehicles with a net list price above € 40 000. However, as of January 2023, this environmental bonus will be reduced to € 4 000 and in 2024 and 2025 the subsidy will be only € 3 000.

Used BEV purchasers receive a bonus of € 5 000 in 2022, while used plugin EVs receive a purchase subsidy of € 3 750.[29]

In addition, households can apply for a € 900 subsidy at the KfW Bank for the installation of charging infrastructure at home.[30]

Car registration costs

Car registration costs in Germany include the following three costs items:[31]

- Car registration at a local car registration office (Kraftfahrzeug Zulassungsstelle):[32] € 30.20
- Emission sticker: € 9.90
- License plates: € 37.90

There is no car registration tax in Germany apart from the registration costs discussed above.

Carbon tax

In Germany, the price for petrol includes a carbon price that is currently equal to € 30 per tonne CO_2, which corresponds to about 7 eurocents per litre petrol. This carbon tax is expected to increase gradually to € 55 per tonne in 2025 (approximately €0.13/litre petrol). As of 2026, the carbon price will be determined by the market. We assume a carbon price of € 55 per tonne CO_2 after 2025 in the base case.

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[29] The purchase subsidy for fully electric vehicles will be gradually reduced as of 2023. Plug-in electric cars will no longer be subsidized as of 2023.

[30] https://www.kfw.de/inlandsfoerderung/Privatpersonen/Bestehende-Immobilie/F%C3%B6rderprodukte/Ladestationen-f%C3%BCr-Elektroautos-Wohngeb%C3%A4ude-(440)/

[31] https://www.simplegermany.com/how-to-register-a-car-in-germany/

[32] https://www.strassenverkehrsamt.de/kfz-zulassungsstelle

GHG Quota

Germany has implemented greenhouse gas reduction quota (GHG quota). As of 2022, owners of an electric vehicle can receive a premium of € 250 to € 480 per year from GHG quota dealers. For the year 2022, ADAC sets the premium at € 350.[33]

Vehicle ownership tax

The annual motor vehicle tax in Germany depends on the car's engine type, the engine capacity and the CO_2 emissions. Cars with a gasoline engine pay € 2 per 100 cm^3 engine capacity. For cars emitting up to 95 g CO_2/km (WLTP), owners pay no CO_2 surcharge. Between 96 and 115 gCO_2/km, the surcharge is equal to € 2 per gram. The surcharge for cars emitting more than 116 g CO_2/km increases gradually up to € 4 per gram for cars that emit more than 195 g/km.[34] The specific CO_2 surcharge is shown in the table below.

Table A 1 CO_2 component of the car tax in Germany

gCO_2 /km	**Tax (€ per gCO_2/km)**
96 – 115	€ 2.00
116 – 135	€ 2.20
135 – 155	€ 2.50
155 – 175	€ 2.90
175 – 195	€ 3.40
> 195	€ 4.00

Source: ACEA Tax Guide (2021).

Owners of a car emitting less than 95 gCO_2/km receive a tax credit of € 30 per year.

Between 2016 and 2020, owners of battery electric vehicles are exempt from the motor vehicle tax during a period of five years. After this period, they pay only 50% of the taxes. Note that the tax exemption does not apply to electric vehicles registered after 2020. The car tax for electric vehicles is based on the vehicle's weight. A tax rate per 200 kg permissible total weight applies as follows:[35]

- Up to 2 000 kg: € 5.625
- 2 001 to 3 000 kg: € 6.01
- 3 001 to 3 500 kg: € 6.30

[33] https://www.adac.de/services/e-angebote/thg-bonus/?utm_source=google&utm_medium=cpc&utm_campaign=thg_sea_generic&utm_term=thg_quote&utm_content=phrase

[34] https://theicct.org/germanys-vehicle-tax-system-small-steps-towards-future-proof-incentives-for-low-emission-vehicles/

[35] https://kfz-steuer.wiki/en/electric-vehicle-tax-germany/

Technical inspection

Periodical technical inspection is mandatory every 24 months after a car has been in use for three years. Costs for technical inspection depend on the weight of the vehicle, and range between € 100 and € 200. We assume an average cost for technical inspection of € 150 every two years.

Italy

Purchase subsidies

In Italy, an eco-bonus system is in place that entails a purchase subsidy for low and zero-emission vehicles. For the period 2022 to 2024, the subsidy amounts are the following:

Table A 2 Eco-bonus rates Italy 2022-2024

CO_2 emissions (g/km)	Bonus (€)
0-20	
With scrapping	5 000
Without scrapping	3 000
21-60	
With scrapping	4 000
Without scrapping	2 000
61-135	
With scrapping	2 000

In the basic TCO calculations, we assume that the purchase of a new vehicle replaces an older vehicle that is scrapped. Therefore, we apply the bonus with scrapping.

The bonus scheme for low and zero emission vehicles only applies to the first registration of the vehicle.

Italy also provides a refund of 50% under the form of a tax deduction for the expenses made for installing charging infrastructure (up to € 2 000).[36]

Car registration costs

In Italy, registration fees covering a stamp duty, registration fees and license plates are equal to approximately € 150 (ACEA, 2021).

A provincial registration tax is levied on the registration and transfer of passenger cars. The basis rate is € 150.81. For passenger cars with engine power exceeding 53 kW, the standard rate is determined at € 3.5119/kW for every KW above 53 (ACEA, 2021).

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36 https://www.agenziaentrate.gov.it/portale/documents/20143/2665720/Risposta+n.+412+del+25+settembre+2020.pdf/4acf3f94-a354-2c77-2714-b257bb35af7f

Annual vehicle tax

Electric passenger cars are exempted from annual vehicle taxes for five years after the first registration date. As of the sixth year, electric vehicle owners are charged the same amount as a corresponding petrol vehicle.

Road taxes and tolls

Italy collects tolls on motorways and for the passage of certain tunnels. We compute the average toll rate for passenger cars on a selection of motorways at € 0.08/km.[37] We assume that 20% of the vehicle kms are driven on the motorway.

Technical inspection

Technical inspection is required every two years after the car has been in use for four years. Expenses for technical inspection are equal to € 79.02.

Denmark

Registration costs

In Denmark, a registration tax is applied based on the sales price of the car (incl. VAT). The registration tax is substantial, ranging from 25% for cars with a purchase price below DKK 65 000 (€ 8 737) to 150% for cars with a purchase price above DKK 202 200 (€ 27 177) (ACEA, 2021). On top of this registration tax, a CO_2 surcharge is levied based on the CO_2 emission (WLTP) of the vehicle. For cars with CO_2 emissions below 50g/km, the registration tax is phased in gradually over the period from 2021 – 2035. A basic deduction in the registration tax is applied to all passenger cars. For zero- and low-emission cars, there is an additional tax deduction that declines yearly to a final level of DKK 137 000 (zero-emission) or DKK 35 000 (low-emission) in 2030.

In practice, the additional deduction for zero-emission cars in Denmark implies that most BEVs are exempt from registration taxes. This creates a substantial difference in purchase expenses for BEVs and ICVs.

Green tax

A semi-annual Green tax is charged based on the CO_2 emissions of the vehicle (ACEA, 2021). This tax is a fixed recurrent expense for the car owner because it is charged irrespective of the use of the vehicle.

Technical inspection

Technical inspection is required every two years after the car has been in use for four years. Expenses for technical inspection are equal to DKK 750 (€ 100.81).

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[37] https://www.tolls.eu/italy

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