Affordability of battery-electric vehicles in the EU

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A cost comparison between new and used electric vehicles and their combustion equivalents for car owners and European governments

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Authors: Mark Bunse, Matti Defillet, Marle de Jong, Carlo Hamelinck, Loes Knotter, Lisa Mulder, Eric van den Heuvel

For: Fuels Europe

Address: Cruquiusweg 111-A
1019 AG Amsterdam
the Netherlands
+31-20-2117205
info@studiogearup.com
www.studiogearup.com

Executive summary

The transport sector is responsible for nearly a quarter of Europe's greenhouse gas emissions.[1] Therefore, the EU mobility strategy and other legislation aims to strongly reduce climate emissions from mobility, through the introduction of zero-emission vehicles and renewable and low carbon fuels and other measures. Current EU ambitions aim for 30 million zero emission vehicles,[2] and 27-29% renewable energy in transport.[3] Some Member States aim for an even higher share of zero emission vehicles, and are heavily subsidizing this development.

The European Commission has repeatedly stated that the energy transition and future mobility should be just and inclusive. In this context, car affordability of battery-electric vehicles (BEVs) is seen as an important aspect. A Total Cost of Ownership evaluation allows to compare the affordability of battery electric vehicles to the affordability of internal combustion engine vehicles for car owners and it at the same time gives clear insights in the costs and foregone incomes for Member States. Three main conclusions can be drawn:

1. **New BEVs are becoming competitive to new ICEVs** in all Member States where subsidies are applied. Specifically, in the Netherlands, Germany, and Romania, the analysed BEVs are already cheaper than their ICEV counterparts. In eight other Member States, subsidy schemes bring the total cost of ownership of BEVs within the range of ICEVs. This is the case in Croatia, Greece, Hungary, France, Italy, Finland, Slovenia and Spain. Under certain conditions, new BEVs may become competitive to new ICEVs, even if subsidies and tax exemptions were discontinued. In five countries (the Netherlands, Spain, Greece, Finland and France) BEVs remain roughly on par with ICEVs if subsidies are removed.
2. **New BEVs compete with second-hand ICEVs since new ICEVs become more expensive and the market for second hand BEVs is small:** The majority of the European population cannot afford a new vehicle, and thus relies on the second-hand car market. However, the penetration of BEVs in the second-hand car market is currently limited. For quick adoption, new BEVs need to compete with used ICEVs. In Member States with high subsidy schemes, new BEVs can already compete with four-year-old second hand ICEVs, such as in Germany. In countries without support schemes, such as Poland, the premium for owning a new BEV over a used ICEV may amount to about 11,000 € over a 5-year ownership period. The differences in affordability across Europe may negatively impact the inclusiveness of the transition to a zero-emission transport sector.
3. **The costs and the loss of tax revenues for European governments due to the support of BEVs over ICEVs are considerable**, translating to around 2,000 – 8,000 € per car over its first 5-year ownership. If subsidies were discontinued, BEVs still can only generate a similar revenue to the government if their purchase prices remain higher than those of ICEVs, because their current main contribution to government income is the purchase value added tax (VAT) for new vehicles. Governments earn less on the energy consumed in electric vehicles compared to fuels in ICEVs due to the lower energy consumption and the significantly lower taxation. **When used cars are compared, the government revenues from a second-hand BEV is roughly half of the government revenues from an equivalent ICEV**. These observations imply that the introduction of BEVs is costly for the society. This could restrict the durability of current benefit schemes for BEVs.

Among the 16 analysed Member States of the European Union, the countries with the highest subsidy schemes for electric vehicles were the Netherlands, Romania and Germany. Czech Republic, Hungary and Poland offer the lowest level of subsidies.

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[1] EEA 2021, Indicator assessment - Greenhouse gas emissions from transport in Europe.
[2] EC 2020, COM(2020) 789 final: Sustainable and Smart Mobility Strategy –putting European transport on track for the future.
[3] EC 2021, SWD(2021) 621 final: Impact Assessment Report accompanying the proposal for a directive of the European Parliament and the Council (amending the Renewable Energy Directive) in the Fit-for-55 package.

Considering the investigated car models (Volkswagen Golf, Volkswagen ID.3, Renault Clio, Renault Zoe), it can be concluded that the VW ID.3 is more competitively priced than the Renault Zoe in comparison to their respective ICEV counterpart. The business case of the Zoe still largely depends on subsidies, while in a few cases the ID.3 can reach total cost parity with the Golf even without purchase subsidies, namely where cheaper energy costs for the EV more than compensates the higher purchase and depreciation costs (Netherlands, Spain).

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1 Introduction

When a consumer decides on the purchase of a (next) car, both the purchase price and the total cost (per kilometre or per time-unit) matter. The catalogue prices of battery-electric vehicles (BEVs) still largely exceed those of their internal-combustion-engine vehicles (ICEVs) counterparts. Sales are currently supported by subsidies and discounts, but this is costly to the government and subsidy allocations are often capped in size or limited in time. The total cost of ownership is the most important indicator to judge affordability. It is necessary to understand how the total cost of ownership (TCO) of BEVs performs in comparison to the TCO of ICEVs and which parameters impact these TCOs. Furthermore, it is necessary to analyse the impact of the support schemes to the state income, which also has consequences for the citizens (increasing taxes or cuttings in other services). Understanding these relations is particularly crucial since financial support is slowly phased out in many European Union (EU) Member States. Finally, the obligation to car manufacturers to sell electric vehicles and in some countries to give additional discounts, is compensated by higher prices for ICEVs. Effectively, the purchase of (any) new car is increasingly costly and this will impact the mobility of the lower income segment.

To gain insight into these matters, studio Gear Up developed a TCO model with a bottom-up approach. Several TCO calculators are available on the Internet and in the literature,[4] though they differ in underlying assumptions and methods which highly influence the results. Moreover, the presented results are often limited to a few cost elements. The studio Gear Up TCO model allows for an in-depth analysis of the cost composition of car ownership and the related incomes and expenses to the government. In this way, it allows to understand the differences in cost composition between ICEVs and BEVs (whether bought new or used) and the implications that a battery-electric fleet has on the tax revenue of governments.

This report presents the results and their implications of the TCO comparison between ICEVs and BEVs. For selected countries, the differences between ICEV and BEV cost compositions are discussed. The TCO ranges of ICEVs and BEVs in 16 Member States of the EU are compared, as well as the impact on government income in these 16 countries. To compare potential differences in rural and urban areas, the effect of various shares of public charging on the TCO of BEVs is analysed. Unlike other TCO models, the effects of second-hand ICEV and BEV car purchases are also investigated. After that, the underlying methodology is explained. Detailed descriptions of assumptions and methods can be found in Annex 7.4. Finally, conclusions and recommendations are provided.

[4] Such as, amongst others, ANWB, Autoweek, ADAC and ICCT. A comparison between these tools and studio Gear Up's TCO model is provided in the methodology section of this report.

2 Subsidies put electric vehicles on par with combustion engine vehicles today

Across the European Union, support schemes for battery electric vehicles are implemented to stimulate the sales of zero-emission vehicles in line with government ambitions. These benefit schemes reduce the purchase costs of BEVs through purchase subsidies, tax benefits, and obligatory manufacturer discounts, influencing the cost competitiveness of BEVs. The total cost of ownership of BEVs is further reduced by the lower energy costs per kilometer, specifically in case of (cheap) home and office charging.

This is visible for Italy (Figure 1), the VW ID.3 is almost already on par with the VW Golf if purchase subsidies are not considered. Due to the attractive subsidy scheme in Italy (4,000 € by the government and a further obligatory 1,000 € by the dealer), the 5-year ownership of a new ID.3 is de facto 4,000 € cheaper than its respective ICEV counterpart. The dealer bonus is categorised as a manufacturer subsidy in Figure 1.

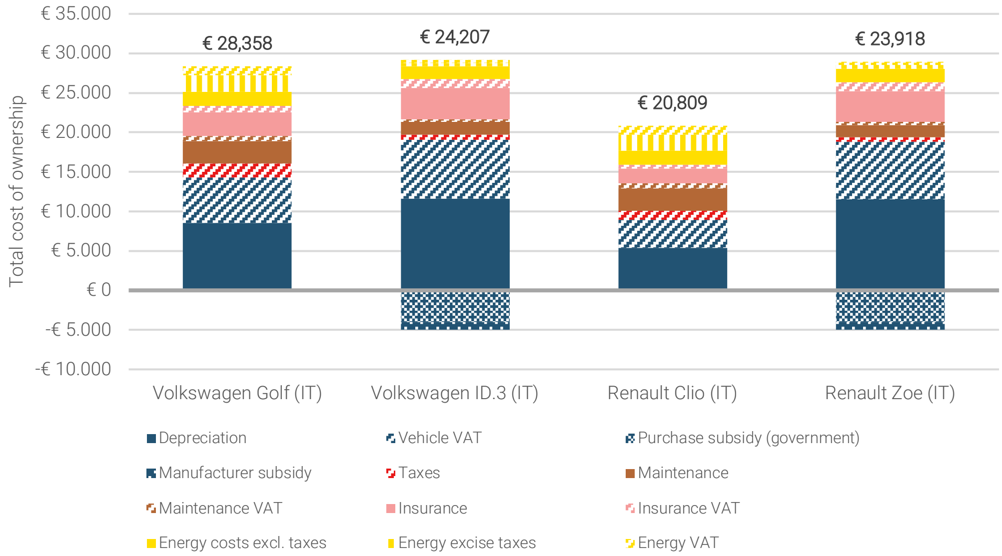


Figure 1 – The total cost of ownership of new cars in Italy over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

The most notable differences in the cost composition are higher depreciation and vehicle VAT costs for BEV, higher insurance costs, but significantly lower energy and maintenance costs. An ownership tax exemption for BEVs is also implemented in Italy's tax regime, making the registration tax the only tax expenses for BEV owners.

For Renault, Italy's subsidy scheme does not transform the BEV from an unfavourable to a favourable customer choice over its ICEV counterpart. Over the course of a 5-year ownership, the car owner spends about 3,000 € more when choosing a Renault Zoe over a Renault Clio. The Renault Clio is the overall cheapest option for the car owner among these four car models.

The Renault Zoe and VW ID.3 are almost on par for a 5-year ownership period. Nevertheless, the performance of the VW ID.3 is higher than the performance of the Renault Zoe. The engine power of the VW ID.3 is 110 kW, compared to 80 kW for the Renault Zoe. Also, the range for the VW ID.3 is higher (349 kilometres versus 316 kilometres for the Renault Zoe). The VW ID.3 is thus priced more competitively, as the higher-performing vehicle only costs 300 € more over a 5-year ownership.

While these results specifically present the local context of Italy, similar findings were generated for other European countries. A more general comparison across countries can be seen in Figure 2 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a. The TCO includes purchase subsidies and tax benefits for electric vehicles applicable in 2021 in the study countries. ICEVs (brown diamonds) are represented by the VW Golf and the Renault Clio, whereas BEVs (blue crosses) are represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from highest to lowest BEV affordability in comparison to the ICEVs, i.e. by the average gap between both types of cars.. The crosses in Figure 2 represent the BEVs and the diamonds their ICEV counterparts. The dark blue cross represents the VW ID.3 and the dark brown diamond the VW Golf. The light blue cross represents the Renault Zoe and the light brown diamond the Renault Clio.

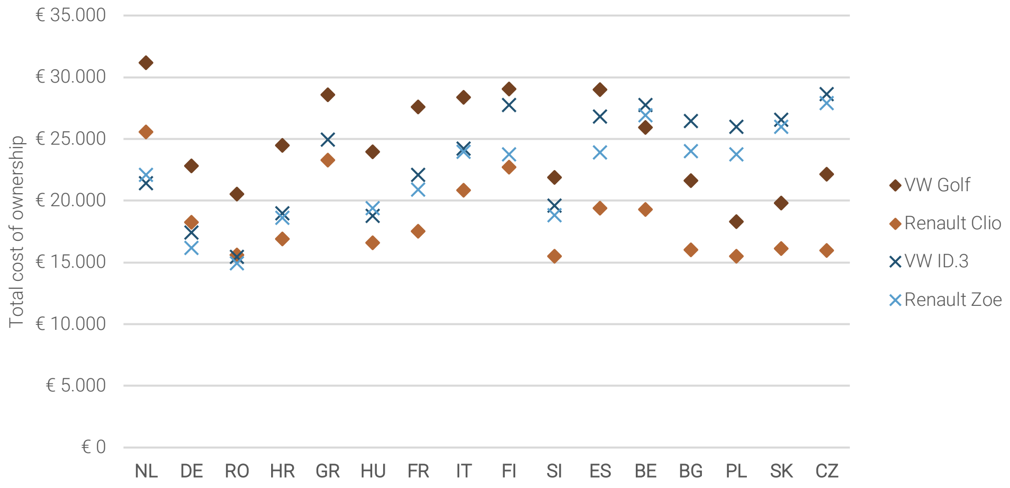


Figure 2 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a. The TCO includes purchase subsidies and tax benefits for electric vehicles applicable in 2021 in the study countries. ICEVs (brown diamonds) are represented by the VW Golf and the Renault Clio, whereas BEVs (blue crosses) are represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from highest to lowest BEV affordability in comparison to the ICEVs, i.e. by the average gap between both types of cars.

Large differences in cost competitiveness of BEVs can be seen among the sixteen countries (see Figure 2 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a. The TCO includes purchase subsidies and tax benefits for electric vehicles applicable in 2021 in the study countries. ICEVs (brown diamonds) are represented by the VW Golf and the Renault Clio, whereas BEVs (blue crosses) are represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from highest to lowest BEV affordability in comparison to the ICEVs, i.e. by the average gap between both types of cars.). The left side of the graph shows countries, where the BEVs are cost competitive with their ICEV counterpart. In Netherlands, Germany, and Romania, the analysed BEVs are already cheaper than their ICEV counterparts.

From Croatia to Spain, eight countries have the TCO of BEVs situated within the ICEV range, thereby making them an attractive choice to the consumer. The Renault Clio is the most affordable choice in these countries and the VW Golf the least affordable choice.

From Belgium to Czech Republic, for five countries the BEVs are more expensive than their ICEV counterparts. In Belgium this difference is relatively small. However, the difference increases up to a difference of 5,000 € between BEVs and ICEVs in Czech Republic. This is primarily caused by the lack of attractive support schemes in these countries.

Unfortunately, a definite answer cannot be provided for Spain because the base Golf configuration (Golf 8 1.0 TSI 66kW) is not sold there anymore. Instead, the Golf 8 1.5 TSI had to be implemented into the database, but due to its 50% higher cylinder volume and more horsepower, its catalogue price is higher, resulting in a larger overall ICEV range for Spain. With this in mind, BEVs appear to be rather on the higher end of the ICEV range, and therefore a slightly expensive choice in Spain but still within reasonable customer expectations for new car prices of this segment.

Furthermore, Greece does not produce Volkswagen or Renault vehicles, but relies on the import of these cars. Currently, Renault does not provide an official catalogue price for the Zoe in Greece, suggesting that this car cannot be obtained by official Renault car dealers in Greece yet. Figure 2 shows the total cost of ownership in Greece for the two ICEVs and the VW ID.3.

Figure 3 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a, if support schemes and tax benefits (at purchase and first registration) for BEVs are discontinued. shows the difference in the costs of ownership, when subsidies and tax exemptions are excluded. The assumption was made that BEVs would need to pay the same amount of tax as their ICEV counterpart, regardless of technical specifications and CO_2 performance. In Figure 3 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a, if support schemes and tax benefits (at purchase and first registration) for BEVs are discontinued. , five countries (the Netherlands, Spain, Greece, Finland and France) show that the BEV is roughly on par with their ICEV counterpart excluding benefits. In these countries, incentives seem unnecessary to reach cost parity for the car owner.

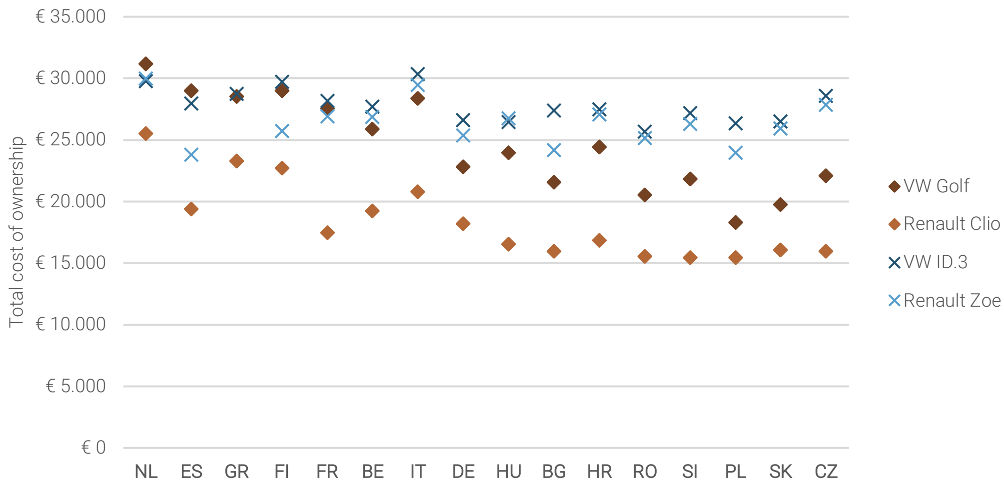


Figure 3 – Comparison of the total cost of ownership of new cars in 16 member states of the European Union over a period of 5 years when driven 12,000 km/a, if support schemes and tax benefits (at purchase and first registration) for BEVs are discontinued. ICEVs (brown diamonds) are represented by the VW Golf and the Renault Clio, whereas BEVs (blue crosses) are represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from highest to lowest BEV affordability in comparison to the ICEVs, i.e. by the average gap between both types of cars.

The difference in subsidy schemes cause large differences in BEV affordability between Member States. Bulgaria, Poland, Slovakia and Czech Republic, where the BEV is not cost competitive, do not provide any purchase subsidy, but only small tax benefits for BEVs. The country's economy and their income dependency on fuel excise may impact their ability and readiness to provide subsidy schemes for BEVs, leading to differences in the costs of owning a BEV across Europe.

3 Affordability of BEVs differs across Europe

The country's economy may influence the ability to provide subsidy schemes for BEVs and the affordability of BEVs for its citizens. This means that some countries have limited means to incentivise the purchase of electric vehicles, and most of the citizens are dependent on the second-hand market for their next car.

Annex A.3 shows vehicle purchase budgets per income quintile of a country. The graph also shows the purchase price of the four car models (VW Golf, VW ID.3, Renault Clio and Renault Zoe) including purchase subsidies. In the previous chapter it was shown that new BEVs are on par or cheaper than ICEVs over the first 5 years after purchase for several countries. However, this is not directly linked to the affordability of BEVs. In Western European countries, such as France, Germany, and the Netherlands citizens in the two or three highest income quintiles are able to afford a new car (representing 40 – 60% of the population). Looking at Central European countries, such as Hungary or Romania, citizens within the highest income quintile can afford a new car (representing less than 20% of the population), but new cars are much less affordable to the rest of the population. This means that a large part of the population in all the study countries drives second-hand vehicles.

3.1 Second-hand car market: New electric vehicles can only compete with used cars when subsidies are in place

The used car analysis depends on forecasts that are uncertain due to still low market penetration and brief experience with BEVs (further discussed in the methodology section). Therefore, the following results are to be interpreted as indicative.

When looking at the example of Poland in Figure 4, a used Renault Zoe is on par with a used Renault Clio, making a used BEV cost competitive with a used ICEV. For a used Renault Clio, the customer will pay more maintenance costs and energy costs over a five-year ownership, but pays less vehicle costs compared to its BEV counterpart. Nevertheless, the availability of BEVs in the second-hand market is currently limited. Therefore, new BEVs will have to compete with used ICEVs to be attractive to the masses. In Poland, a new Zoe is *de facto* 10,000 € more expensive over the first five years after purchase, than its respective second-hand ICEV counterpart.

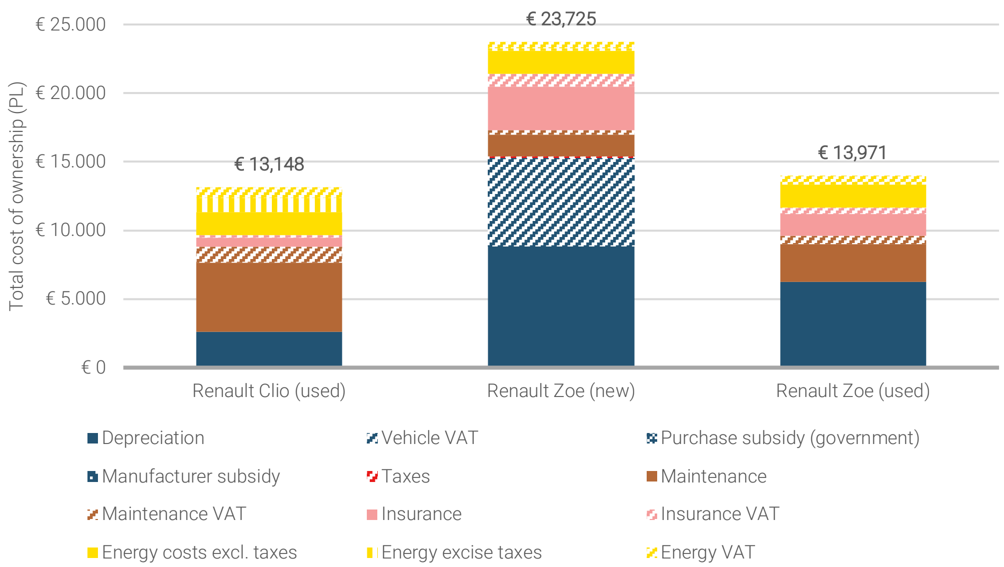


Figure 4 – Comparison of the total cost of ownership between a second-hand Renault Clio, newly bought Renault Zoe and a second-hand Renault Zoe in Poland. The second-hand cars are bought with a mileage of 60,000 km and an age of 4 years. The total cost of ownership is calculated for 5 years with a annual mileage of 12,000 km.

Countries that have a subsidy scheme in place bring the total cost of ownership of a new BEV closer to the total cost of ownership of a used BEV or used ICEV, for example the situation for Germany is shown in Figure 5. The relatively high vehicle costs of a new BEV are decreased by the purchase and manufacturer subsidy, leading to a 300 € difference over 5 years of ownership between a used ICEV and a new BEV. When excluding the subsidies, a similar difference between a used ICEV and a new BEV as for the example of Poland could be seen.

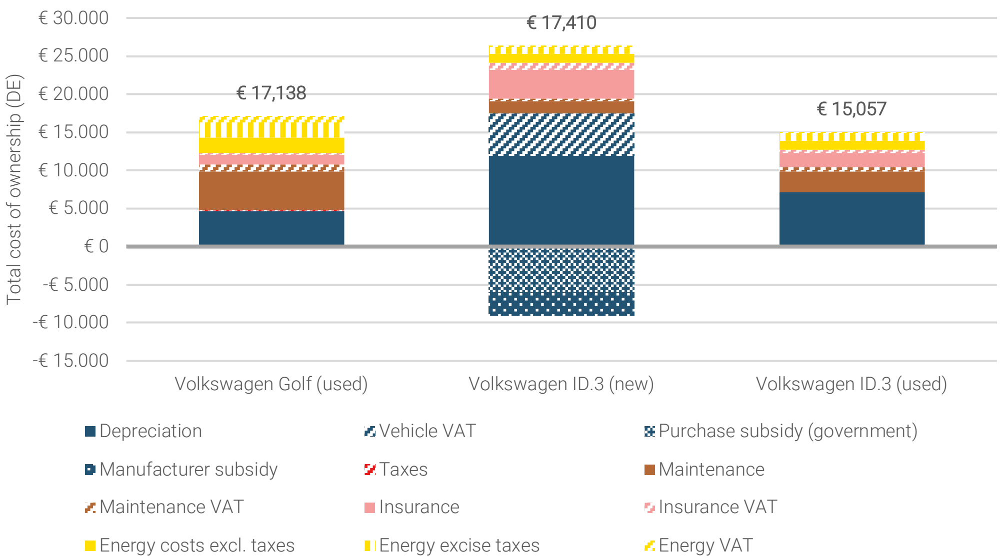


Figure 5 – Comparison of the total cost of ownership between a second-hand VW Golf, newly bought VW ID.3 and a second-hand VW ID.3 in Germany. The second-hand cars are bought with a mileage of 60,000 km and an age of 4 years. The total cost of ownership is calculated for 5 years with a annual mileage of 12,000 km.

It appears that residents of countries with lacking support for new BEVs have to wait until second-hand BEVs become widely available. However, without subsidy schemes in place to stimulate the sales of new BEVs the supply of used cars may be limited. A limited supply may influence the purchase costs of used BEVs. This problem may be partially resolved by the import of used vehicles of other countries.

3.2 The favourability of electric vehicles can depend on the consumers' ability to charge at home

The economies between European Member States differs, and their means to incentivize the purchase of BEVs, but there also differences within a country influencing the affordability of BEVs. By using the TCO model we have tried to examine the potential differences between rural and urban areas. To examine these potential differences in relation to car ownership, the effects of public charging and annual mileage were analysed. Two assumptions were made: (1) residents of urban areas are more likely to be bound to public charging due to the fact they are not owning their own electric parking lot and park their car larger distances away from their actual house or flat, and (2) residents of rural areas have a higher annual mileage due to living in remote areas.

When looking at the example of Belgium in Figure 6– The influence of the share of public charging on the total cost of ownership in Belgium. Subsidies and tax support measures are included. The blue lines represent the Volkswagen ID.3 for an annual mileage of 10,000 (solid) and 21,500 (dashed) kilometres. The brown lines represent the Volkswagen Golf for an annual mileage of 10,000 (solid) and 21,500 (dashed) kilometres. , the BEV may have a lower total cost of ownership depending on the share of public charging, although differences are rather small. When driving a Volkswagen for 10,000 kilometres a year, the ICEV is cheaper than the BEV no matter the share of public charging. The main difference between BEVs and ICEVs in operational costs are the energy costs, as the electricity price and excise are lower. If you drive 10,000 kilometres a year the lower operational costs of a BEV do not balance the higher purchase costs of a BEV compared to an ICEV.

While driving 21,500 kilometres a year the BEV is cheaper than the ICEV, until around a 45% share of public charging. After that the total cost of ownership of the BEV exceeds the total cost of ownership of the VW Golf ICEV. There is a smaller difference between the BEVs with different mileages than the ICEVs. Driving a Volkswagen Golf for 10,000 or 21,500 kilometres will lead to a 8,000 € difference, for the Volkswagen ID.3 this results in roughly a 5,500 € difference (50% home charging, 50% public charging). Again, this is caused by the difference in energy costs.

Under the aforementioned generalising assumptions, a BEV is more cost competitive for citizens living in rural areas than for urban areas, although the differences are rather small. This potential outcome is in contradiction to the environmental challenges that electric mobility is trying to solve, namely the particulate matter and NO_x emissions reduction that are particularly problematic in urban areas. Public charging costs in urban areas need to decrease, or even fall below household electricity prices in order to stimulate electric vehicles in urban areas.

Figure 6– The influence of the share of public charging on the total cost of ownership in Belgium. Subsidies and tax support measures are included. The blue lines represent the Volkswagen ID.3 for an annual mileage of 10,000 (solid) and 21,500 (dashed) kilometres. The brown lines represent the Volkswagen Golf for an annual mileage of 10,000 (solid) and 21,500 (dashed) kilometres.

As mentioned above, the lower energy costs make a BEV relatively cheaper when driving more kilometres per year. The difference between the price for household charging and public charging determines the difference in costs between rural and urban areas. Looking at Eurostat[5] data the household electricity prices differ between 10 and 30 cents per kWh across Europe. For public charging there is less of a variation, in most countries public charging costs around 40 cents/kWh. Figure 7 – The influence of the share of public charging on the total cost of ownership in Hungary, including subsidies and tax exemptions. The blue lines represent the VW ID.3 for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres. shows the example of Hungary, where there is a relatively big difference

[5] Eurostat, 2021, Electricity prices for household consumers - bi-annual data (from 2007 onwards), Dataset NRG_PC_204, retrieved July 2021.

between household electricity prices and public charging costs (0.42 €/kWh for public compared to 0.10 €/kWh for home charging). When the costs of household charging and public charging differ a lot, it will be more expensive to have a BEV in an urban area. Consequently, the BEV will become more expensive than its ICEV counterpart for a higher share of public charging.

Figure 7 – The influence of the share of public charging on the total cost of ownership in Hungary, including subsidies and tax exemptions. The blue lines represent the VW ID.3 for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres. shows the impact of the share of public charging in Hungary, while driving an annual mileage of 10,000 kilometres (solid line) or 30,000 kilometres (dashed line). The brown lines represent the Renault Clio and the blue lines represent the Renault Zoe. When driving a Renault Clio for 10,000 kilometres a year, this is cheaper than the Zoe no matter the share of public charging. Again, if you drive 10,000 kilometres a year the lower operational costs of a BEV do not balance the higher purchase costs of a BEV compared to an ICEV.

When driving 30,000 kilometres a year the Zoe is cheaper than the Clio, when the share of public charging is below roughly 30%. However, there is a great difference between the household electricity price and the public charging costs in Hungary compared to other European countries. In other European countries where the difference is smaller (e.g. the Netherlands, Germany or France), the BEV will be cheaper than its ICEV counterpart for a higher share of public charging.

As mentioned before, another potential difference between rural and urban areas is the number of kilometres driven by a car. When changing the annual mileage for BEVs and ICEVs, the difference in TCO between BEVs and ICEVs increase. This is caused by lower energy costs for electricity and higher excise duties on fuel. Meaning that BEVs are more affordable for people living in rural areas and/or drive a high annual mileage.

Current electrification strategies focus on urban areas, as these areas have more environmental problems with notably particulate matter and NO_x emission reduction than rural areas. The mismatch between the affordability of BEVs in rural areas and the more pressing environmental problems in urban areas should be addressed by policy. Public charging prices will have to decrease significantly or other regional incentives should be introduced.

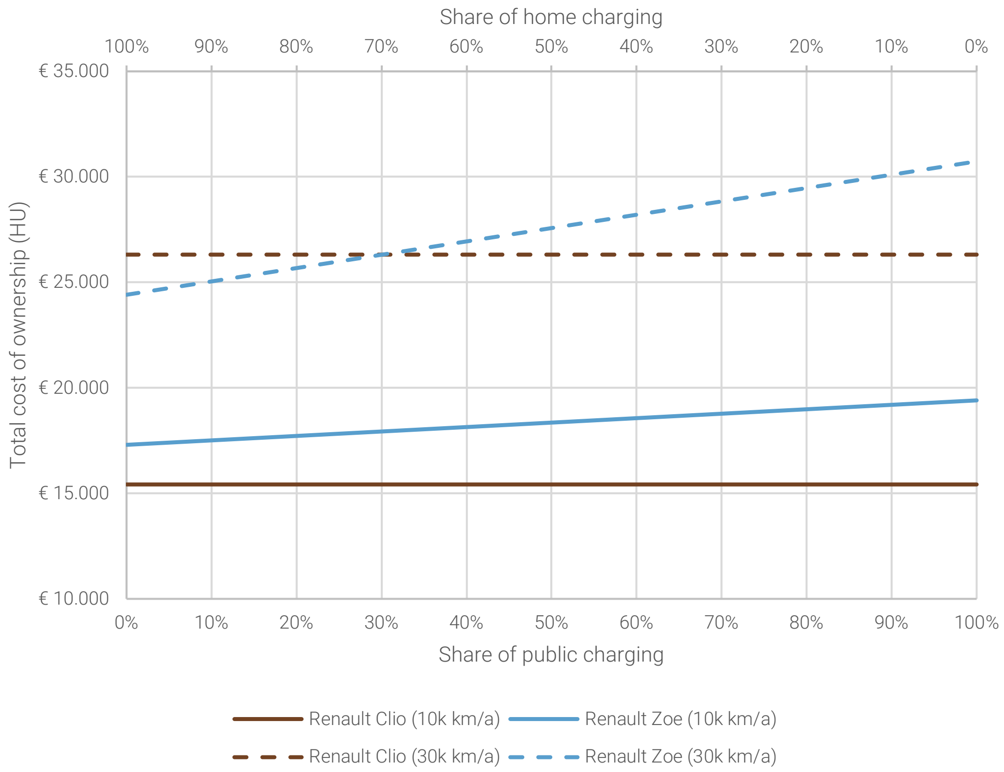


Figure 7 – The influence of the share of public charging on the total cost of ownership in Hungary, including subsidies and tax exemptions. The blue lines represent the VW ID.3 for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 10,000 (solid) and 30,000 (dashed) kilometres.

The extensiveness of subsidy schemes is causing differences in the affordability of BEVs across Europe. Citizens of Western European countries in the top income quintile are able to afford a new BEV. For some countries subsidy schemes are not even needed to bring a new BEV on par with a new ICEV (Italy, Spain, the Netherlands and Germany). However, only those countries are making new BEVs affordable for the top income quantile. In other countries most citizens are not able to afford a new BEV or ICEV and are dependent on the second-hand market.

For citizens driving a high annual mileage and/or living in rural areas the BEV will be more affordable. There are, however, remaining questions to be answered. For example, it remains unclear whether average citizens in Central Europe have sufficient access to capital for the higher upfront investment of BEVs, and if the charging infrastructure facilitates owning a BEV in rural areas.

The findings in this chapter underlined that BEVs have significantly lower operational costs than ICEVs due to their higher energy efficiency and lower energy prices per megajoule. Nevertheless, a mass adoption of BEVs would render large investments in infrastructure necessary.

With an increased electrification of the European car fleet, this will likely result in a boost of national consumption in electricity. As mentioned before, investments are therefore needed to increase the grid capacity to balance the electricity demand and supply. A study of McKinsey concluded that in general, electric vehicles are unlikely to create a power-demand crisis but could reshape the load curve.[6]

It is expected that there will be significant increases in local peak loads, leading to challenges when local transformers are pushed beyond their capacity. Not only spatial differences are

[6] McKinsey (2018). The potential impact of electric vehicles on global energy systems.

occurring, but also extensive charging during certain time periods (e.g. peak hours after work when returning at home) will lead to peak loads and possible problems.[7]

Concerned about the aspect of grid capacity and peak loads, Dutch local grid operator Alliander warned already that in certain regions in Amsterdam, peak loads will be 2.5 to 6 times higher in the future than actual available capacity. The current power grid in Amsterdam can handle up to 750 megawatts nowadays, but this needs to be increased to 2900 megawatts (normal loads) or even up to 4500 megawatts (peak loads) in 2050. They mention that it could happen that residents of a certain neighbourhoods who want to have a charging station for BEVs cannot be connected to the grid, which shows that local grid capacity could be a serious threat for the adoption of BEVs in certain areas.[8]

The affordability of BEVs is sensitive to future electricity prices, similarly to how the affordability of ICEVs is sensitive to oil prices. The expansion of grid capacity, high- and medium voltage distribution, public charging spaces, renewable electricity sources and energy storage solutions are all contributing factors to potential increases in future electricity prices. Estimating the upcoming costs of these investments were out of the scope of this research, however the implications of BEVs and ICEVs to the generated income of the government were further analysed.

[7] ELaad (2020). Charge Management of Electric vehicles at home
[8] Parool (2019). Netwerkbedrijf Alliander: 'Stad is hard op weg naar een stroominfarct'

4 BEVs negatively impact government income

Section 2 explains that the affordability of BEVs is mostly attributed to the subsidies, the absence of ownership taxes and fuel cost savings. While reducing costs to the car owner, these elements also cause substantial decreases in the generated revenue to the government. Figure 8 presents the generated government revenue from new ICEVs and their BEV counterparts in Italy in analogy to Figure 1 presented above. Over 5 years, a new VW ID.3 merely generates about 6,440 € of tax revenues in Italy after subtracting the purchase subsidy, whereas a new VW Golf generates about 12,220 €. Similarly, a new Renault Zoe generates 6,240 € of tax revenues in Italy, while a new Renault Clio generates 8,990 €.

If the subsidy scheme were to be discontinued, the VW ID.3 would still generate 2,000 € less tax income to the government due to its competitive pricing (resulting in low vehicle purchase VAT) and the low excise and VAT income from electricity. The Renault Zoe, on the other hand, appears to be able to generate more income to the government than the Renault Clio. Most of this stems from the fact that the catalogue price of the Zoe is more than twice as high (34,450 €) as the catalogue price of the Clio (16,400 €) in Italy, thereby resulting in higher VAT but drastically reducing public accessibility if unsubsidised.

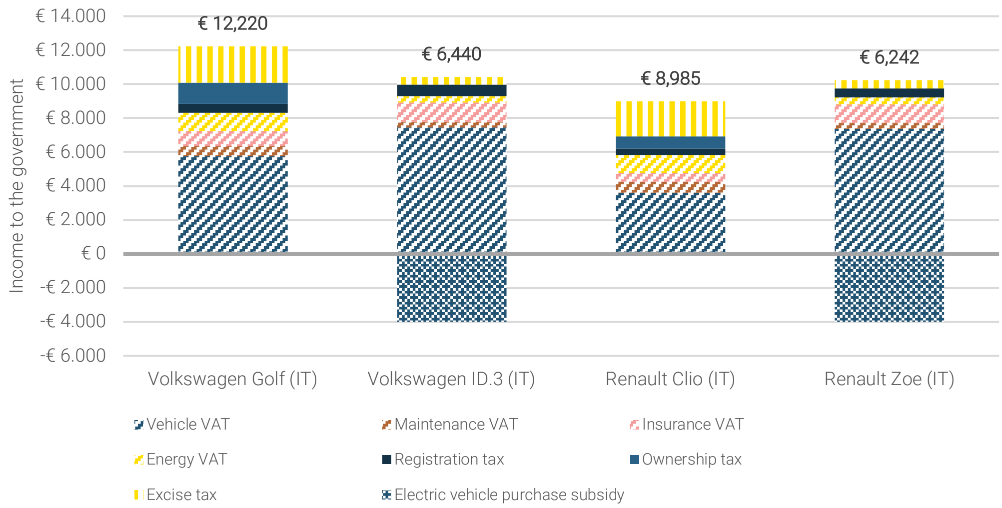


Figure 8 – Revenues for the government per car during an ownership period of 5 years with mileage of 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bold labels present the result of tax revenues minus purchase subsidies.

The effect of the price competitiveness of new BEVs on the government income was analysed for the 16 selected European countries (see Figure 9 – Revenues to the government from new cars over the first five years. All cars are assumed to drive 12,000 km/a. The ICEV (brown diamonds) is represented by the VW Golf and the Renault Clio, whereas the BEV (blue crosses) is represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from the highest loss to the highest increase in income from BEVs compared to ICEVs.). A distinct relation between BEV attractiveness to the consumer (shown in Section 2) and government income loss can be seen. Of all the analysed European countries, only Slovakia, Czech Republic and Poland do not lose income by BEVs compared to ICEVs due to their lack of policy support. This, however, also makes BEVs unattractive to the customer in these three countries. In the case of Poland, the ID.3 catalogue price is twice as high as the Golf catalogue price. The Renault Zoe's catalogue price is almost 2.5 times more expensive than the Clio's. Therefore, a considerable surplus on VAT is generated from buying more expensive cars without subsidies.

Apart from Spain, Belgium and Bulgaria, all the other countries lose significant amounts of government income with their current subsidy and tax exemption schemes. In the Netherlands, each VW ID.3 that is bought instead of a VW Golf generates about 10,500 € less government revenues over the first 5 years of ownership. Similarly, each Renault Zoe that is bought instead of a Renault Clio generates about 8,000 € less revenues to the Dutch government. Due to exceptionally high BEV subsidies, Romania even loses part of their governmental budget per sold electric vehicle. However, it should be noted that the Romanian subsidy scheme is capped at 82 million € in total[9]. Furthermore, the share of new-bought cars in Romania is considerably lower than the European average. Germany and France lose on average about 5,500 € of governmental income per sold electric vehicle compared to a sold ICEV.

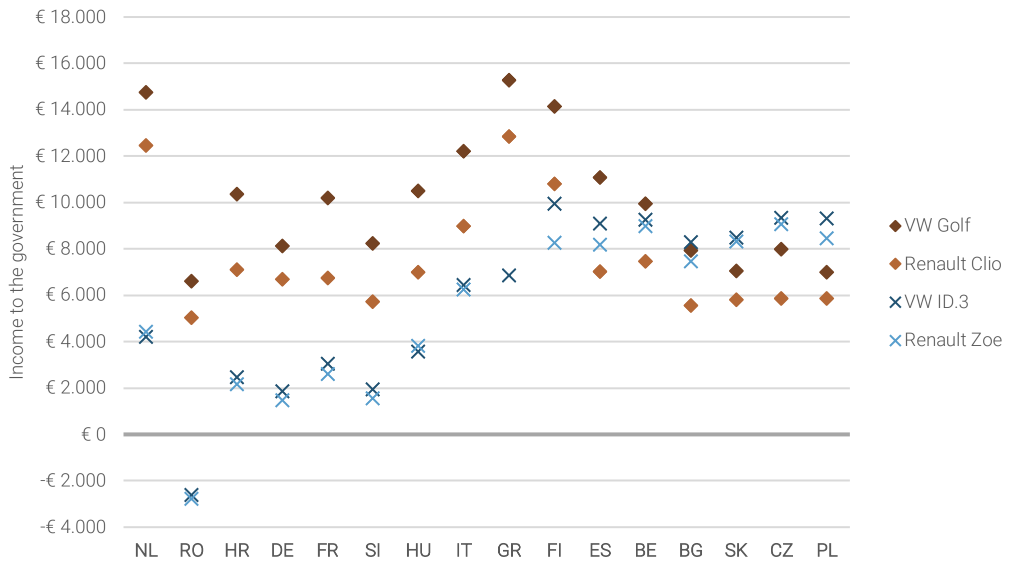


Figure 9 – Revenues to the government from new cars over the first five years. All cars are assumed to drive 12,000 km/a. The ICEV (brown diamonds) is represented by the VW Golf and the Renault Clio, whereas the BEV (blue crosses) is represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from the highest loss to the highest increase in income from BEVs compared to ICEVs.

From these results, it follows that current subsidy schemes cannot be sustained for longer periods of time. Therefore, this analysis was replicated without the influence of subsidies or tax exemptions. The figures can be found in the Annex A.1. It can be seen that BEVs are either on the more expensive side of the ICEV range or more expensive than ICEVs in almost all analysed countries. In this case, i.e. if the extra costs of BEVs are entirely paid by the consumer, tax income of BEVs and ICEVs can be in comparable ranges. This is mostly due to the higher VAT generated by selling considerably more expensive cars. The income generated by BEVs during their operation is rather low. It is therefore expected that over the lifecycle of the cars, BEVs generate less income to the government. To further study this effect, the influence of used ("second-hand") BEVs on the government income in comparison to used ICEVs are presented in the following.

Figure 10 presents the generated government income from used cars over a (second) ownership of 5 years, if tax exemptions were discontinued. Therefore, it presents the most optimistic case for government income generation, since neither purchase subsidies nor ownership tax exemptions are granted to BEV owners. The cars are 4 years old and drove 60,000 km prior to their acquisition, which roughly represents a car leaving a typical business lease contract. In all countries, BEVs generate significantly lower income to the government than their ICEV counterpart. For almost all countries (except Greece), about half of the expected income of an ICEV is lost when its BEV counterpart is chosen instead. For France and Finland, the losses are particularly high, accounting for 60% of the expected income of an ICEV. In combination with Figure 9 above, this shows that most of the government income from BEVs relies on the initial car purchase and thereby its VAT, which would be further reduced if (non-subsidised) BEV catalogue prices reached price parity with ICEVs.

[9] https://www.electrive.com/2021/03/29/romania-doubles-2021-ev-subsidy-budget/

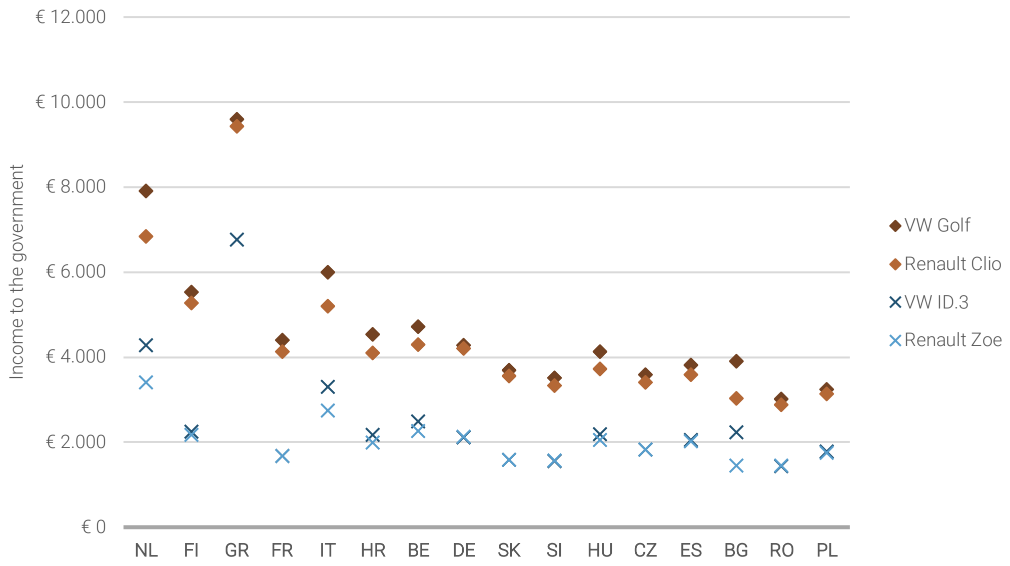


Figure 10 – Revenues to the government from second-hand cars over the first five years. These second-hand cars are bought at an age of 4 years and 60,000 driven km. All cars are assumed to drive 12,000 km/a. The ICEV (brown diamonds) is represented by the VW Golf and the Renault Clio, whereas the BEV (blue crosses) is represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from the highest loss to the highest increase in income from BEVs compared to ICEVs.

These results imply that the government will require additional sources of income from passenger cars in the future. One possible instrument could be to increase the (currently low) excise duties on electricity or to increase the annual car ownership tax. Another option would be to stimulate more new car sales and thereby generating more VAT. All these options, however, would negatively impact the affordability of BEVs or of passenger car transport as a whole, respectively. It should be noted that stimulating more new car sales equates to increased consumption which may entail negative environmental and social impacts (e.g., from the manufacturing process and the extraction of rare earth metals).

5 Methodology

This chapter summarises the underlying methods and assumptions of the developed TCO model. A detailed description of the methodology can be found in the Annex A.2. The TCO model includes 16 countries and four car models. The countries provide a mix in socio-economic development, geography (Western, Southern and Central Europe) and the presence or absence of a dominant car manufacturer industry. In collaboration with FuelsEurope, the following 16 countries were included: the Belgium (BE), Bulgaria (BG), Croatia (HR), Czech Republic (CZ), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Italy (IT), the Netherlands (NL), Poland (PL), Romania (RO), Slovenia (SI), Slovakia (SK), and Spain (ES).

By analysing the top five most sold ICEVs and BEVs in Europe for 2020,[10,11] there were two ICEV/BEV couples with comparable performance, and thus, four different car models are included in the TCO: Volkswagen Golf (ICEV), Volkswagen ID.3 (BEV), Renault Clio (ICEV) and Renault Zoe (BEV).

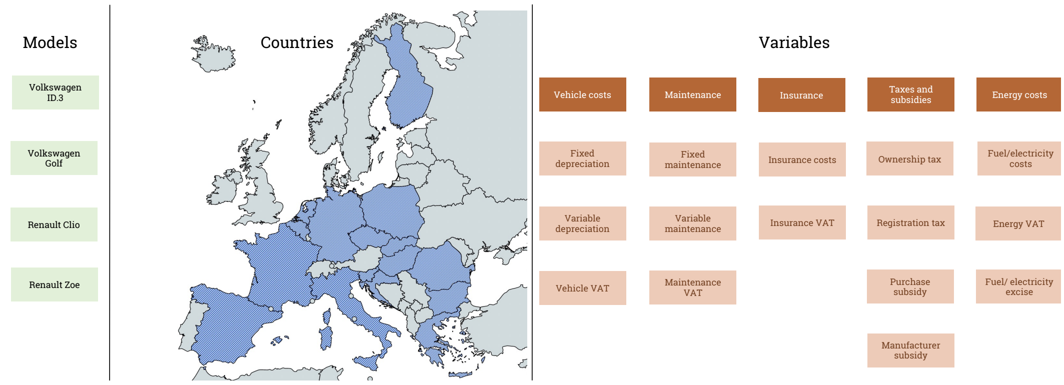


Figure 11 – The scope of the studio Gear Up TCO model for the present study. The TCO model includes 16 different countries and four different car models: comparable EVs and ICEVs from two brands.

The most relevant cost factors of car ownership were determined. In total, ten cost factors were analysed: fixed depreciation, variable depreciation, registration tax, ownership tax, fixed maintenance, variable maintenance, tyre costs, insurance, fuel/electricity costs, fuel/electricity excise, as well as all Value Added Taxes of these. These components can be roughly divided into five categories: depreciation, maintenance, insurance, taxes and subsidies, and energy costs.

5.1 Depreciation

An acquired car is an asset that requires initial investment but loses value over time. After the end of the ownership period, the car is sold to a new owner. The difference in purchase cost and resell value is called depreciation. While some TCO models (e.g. ICCT) incorporate the whole purchase price in their TCO model, this TCO model uses the depreciation instead to include the value loss of the car and thus the amount lost by the car owner. This provides a better indicator for the actual costs to the car owner, as part of the car price will be recovered upon reselling.

First, data concerning the purchase prices of the most basic models was collected for all the 16 countries. Most basic model could however differ between countries, with differences in production types in different countries, which resulted that for some of the countries not the most basic model was taken. Purchase prices were collected through the websites of manufacturers.

[10] Focus to Move, 2021, Europe 2020. Volkswagen Golf keeps the market crown but the Renault Clio is only 5k behind.
[11] Motor1, 2021, Europe became the world's biggest plug-in electric car market in 2020.

The approach focused on using available data of the ANWB TCO calculator[12] to define a formula for the depreciation rate depended on the number of kilometres driven (variable deprecation rate) and the ownership period in years (fixed depreciation rate). We acknowledge the possibility of more factors that influence the depreciation; however, we assumed that these two variables will have the most impact on the deprecation rate. The formulas for both depreciation rates were reversed engineered from the ANWB TCO calculator. The reverse engineering process was done for a Volkswagen Golf 8 1.0 TSI 66 kW.

The ANWB tool is based on Dutch data of cars in the Netherlands, and consequently, so are the derived formulas. The assumption was made that the depreciation rate across countries is similar. Comparing the depreciation rates with tools from other countries[13][14] did not show significant differences.

Furthermore, the assumption that a BEV would have a similar value loss over time and driven mileage was made. When testing this assumption by comparing the depreciation rate with other depreciation tools,[15] it shows that this differs with some models have a steeper or more gradual depreciation rate for BEVs. However, the development of the depreciation rate is currently unknown due to their limited and recent entrance into the passenger car market. Speculations on the depreciation of BEVs differ, with some parties claiming lower depreciation due to less mechanical complexity, and other parties claiming higher depreciation due to steep technology advances and battery wear. The assumption was made that any potential differences between ICEVs and BEVs will further decrease, and thus, the TCO model assumes a value loss for BEVs similar to ICEVs. This assumption can only be further verified once more data on electric vehicles becomes available. The depreciation formulas for both fixed and variable depreciation were designed to make a flexible model which could be easily expanded. If differences between ICEV and BEV depreciation prove to be significant in the future, the model can be adapted easily. A more elaborate explanation on the assumptions and methodology to determine the depreciation rates can be found in Annex A.2.

5.2 Maintenance and insurance

The maintenance costs were determined by the same approach as the depreciation costs, thus reverse engineering with data from ANWB to design a formula for the maintenance costs of cars depended on the number of kilometres driven and the ownership period of the car.

Data was collected for three different cars, two similar ICEVs (Volkswagen and Renault) and a BEV (Renault). ANWB provided five different variables related to maintenance costs: costs maintenance bodywork, repair and maintenance costs over whole ownership, tyre size, tyre price and lifespan tyres. Four of the five variables were similar among the three cars and only the repair and maintenance costs over the whole ownership differed between the models (dependent on the ownership period and mileage). For repair and maintenance costs, two formulas were defined based on the ownership period of the car and the kilometres driven. The formulas which were reversely engineered from the ANWB by the data of the ICEVs was not applicable for the Renault Zoe. Therefore, the TCO model includes two different maintenance formulas, one for ICEVs and one for BEVs. A more elaborate explanation on the assumptions and methodology to determine the maintenance costs can be found in Annex A.2.

There still is a lot of uncertainty concerning the maintenance costs of BEVs. Some TCO models assume lower maintenance costs for BEVs due to having fewer parts than an ICEV. However other TCO models assume higher maintenance costs, as the parts of BEVs are more

[12] The Dutch motoring club ANWB offers a TCO calculator that provides a great level of detail and transparency, and allows for adapting assumptions for cost calculation (https://www.anwb.nl/auto/autokosten). Therefore, it has been replicated/"reverse engineered" also by other parties, such as the International Council on Clean Transportation (ICCT) in their 2018 study "Using vehicle taxation policy to lower transport emissions: An overview for passenger cars in Europe".
[13] The money calculator, 2021, Car depreciation by make and model.
[14] Omnicalculator, 2021, Car depreciation calculator.
[15] Autoweek, 2021, Kostenberekening auto.

expensive and reparations are expected to take longer due to difficulty of the maintenance work. Our current formula assumes lower maintenance costs for BEVs, compared to ICEVs. This assumption can only be further verified once more data on electric vehicles becomes available.

The insurance costs needed to be estimated as there are great differences between regions and insurance companies within countries. Data was generated for a Volkswagen ICEV and a relation was found between the catalogue price and the insurance costs. Assuming a linear dependence of insurance costs to the catalogue price, a fixed percentage of 2.93% of the catalogue price was applied to all cars in the model. This assumption was later tested by comparing this with different TCO Models (ANWB, Autoweek and ADAC)[16], and this estimate was in sufficient agreement with these three TCO models.

5.3 Taxes and subsidies

Most countries apply taxes once when a vehicle is purchased or registered, and annually during the period of ownership. Three different types of tax categories were implemented in the TCO model: VAT, registration and ownership taxes. Registration and ownership taxes have different sub forms and can be dependent on various variables, such as cylinder volume, horsepower, weight, CO_2 emissions et cetera. All these different taxes were calculated separately and based on the 2021 ACEA tax guide[17] and the technical information found for the different models.

The VAT was applied on four different variables: maintenance costs, insurance costs, energy price, and vehicle purchase price. The VAT differs per country and is a percentage.

Countries apply different benefit schemes to stimulate BEV car sales, divided in tax benefits and subsidies. Countries may have a purchase subsidy and a manufacturer subsidy. The purchase subsidy is provided by the government and only applies for a new car purchase. The manufacturer subsidy is an obligatory cost reduction that the manufacturer has to provide for BEVs in some countries.

The tax benefits for BEVs can have different shapes and forms across countries and are not always present. For example, countries may include a discount on the registration tax when registering a BEV rather than an ICE. Table 1 in Annex A.3 shows the benefit scheme per country for BEVs, which is based on the 2021 ACEA tax guide, in order from highest discount of new BEVs to the lower, considering a five-year ownership period., several detailed assumptions (e.g. on car specifics or family background) were required. The assumptions were made to represent the EU population and the most basic car configuration to the best of our knowledge.

The TCO model is based on national policies, however there are also regional and municipal (qualitative) incentives to stimulate the sales of BEVs which are not taken into account and could impact the TCO. These are for example[18] lower zero emission zones, free parking benefits, electric driving lanes, charging incentives and municipality tax benefits.

5.4 Energy costs

The TCO includes the energy costs per energy carrier, where the total energy price consists of the fuel wholesale/electricity costs, fuel or electricity excise duty and VAT. Technical specifications provided by the manufacturer (according to the new WLTP standard) are used to determine the energy consumption for ICEVs and BEVs. For ICEVs, the fuel economy of the car was expressed in litres per 100 km. Furthermore, the fuel price based on the weekly oil bulletin of the European Commission[19] and excise differ per country. The fuel prices including and excluding taxes were compared to calculate the fuel excises for all different countries. The assumption was made that the difference between the fuel price including and excluding

[16] ADAC 2021, ADAC Autokosten-Rechner.
[17] ACEA 2021, ACEA tax guide.
[18] Wallbox 2021, EV and EV charger incentives in Europe: A complete guide for businesses and individuals.
[19] EC 2021, Weekly oil bulletin.

taxes minus the VAT would equal the fuel excise. This assumption was verified by researching the excise duty tables of the European Commission[20]. We did not include the excise duties directly into the TCO model, as the fuel prices taken from the weekly oil bulletin are more recent.

For BEVs, the fuel economy is expressed in kWh per 100 km. Two types of electricity prices were included in the TCO model: the electricity price for households based on data from Eurostat[21] and public charging based on various sources (sources can be found in Annex A.2). Differences can be found between these prices, including them both ensures a more realistic estimation of the costs.

Public charging suppliers often offer subscriptions for (fast) public charging. Including these subscription schemes in the TCO model would have required further assumptions concerning how effectively the BEV owner utilises them. In general, there is a lack of transparency concerning the public charging composition, which rendered the data acquisition challenging at times. It was therefore assumed that the excise duty does not differ between household kWh and public charging kWh. The difference in prices is thus a combination of increased supply / margin costs and the hence resulting increased VAT.

5.5 Comparison to other TCO models

To validate the results presented in this report, the developed TCO model developed was compared to four TCO calculators found online and in literature, which are:

- The "Autokosten berekenen" tool by the Dutch motoring club ANWB,
- The "Kostenberekening Auto" tool by the Dutch car magazine Autoweek,
- The "Autokostenrechner" by the German motoring club ADAC,
- The "Using vehicle taxation policy to lower transport emissions: An overview for passenger cars in Europe" (2018) study by the International Council on Clean Transportation (ICCT)

In some TCO calculations, the input parameters were limited to a selection or not aligned with the base parameters used in this study. In this case, the input parameters of studio Gear Up's model were adjusted to ensure comparability. Apart from inputs, no changes have been made to the model. The outputs of the other TCO models were often expressed as an averaged monthly cost or a cost per kilometre over the ownership period. These averages were back-calculated to the total (non-averaged) cost over the total ownership period to allow for better comparability with the results shown above.

Overall, it was found that the model developed by studio Gear Up is in good agreement with the TCO models listed above. For the case of ANWB, the agreement could be explained partially by the fact that the depreciation and maintenance calculations are based on ANWB data. Nevertheless, the Autoweek tool and the ADAC tool produce similar outcomes for the same input parameters when compared to the model by studio Gear Up.

[20] EC 2020, Excise duty tables – Part II energy products and electricity
[21] Eurostat 2021, Electricity prices for household consumers - bi-annual data (from 2007 onwards).

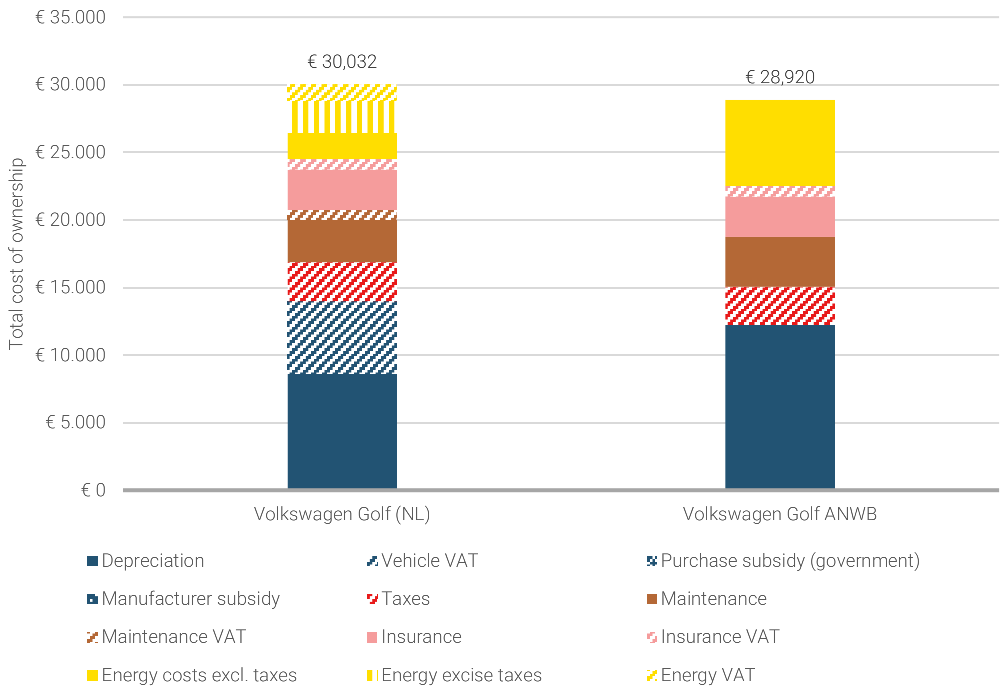


Figure 12 – Comparison of the total cost of ownership of a Volkswagen Golf calculated by studio Gear Up (left) to the results shown by the TCO calculator of the Dutch motoring club ANWB (right).

6 Conclusion and recommendations

This report investigated the affordability of electric passenger cars for citizens and the associated costs for the governments in 16 EU Member States.

It was found that new battery-electric vehicles are becoming increasingly competitive to new internal-combustion-engine vehicles for car owners. This total cost parity is partly achieved by high purchase subsidies and tax exemptions of electric vehicles. However, under certain conditions in four countries (the Netherlands, Spain, Greece and Finland), a new electric vehicle can have the same costs as a new conventional car, even if subsidies were discontinued. If battery prices continue to decrease and mass manufacturing of electric vehicles continues to increase, this cost parity can be expected to occur in more countries and under more conditions than currently seen.

Nevertheless, the majority of the European population cannot afford new vehicles and therefore depends on the second-hand car market. Due to their limited availability in the second-hand market, new electric vehicles currently have to compete with used conventional cars after subsidies. However, current differences in support schemes and socio-economic situations cause differences in affordability of BEVs across Europe. In three countries with high subsidies for electric vehicles (the Netherlands, Germany and Romania), it was found that new electric vehicles become favourable choices over e.g. four years old conventional cars. In countries without support schemes, the premium for a new electric car can be in the order of 11,000 € over a 5-year ownership period. For the time being, in most countries the subsidies are therefore required to make new electric vehicles accessible. Once used electric vehicles become available, their costs of ownership are expected to be on par with those of used conventional cars even without subsidies.

Interestingly, it was found that electric vehicles are more attractive for rural citizens in many countries since they rely less on expensive public charging. Furthermore, electricity costs in electric vehicles are significantly cheaper than fuel costs in conventional vehicles over the ownership period. Consequently, intensive car users save more money than occasional car users when choosing an electric vehicle over a conventional vehicle. Rural citizens tend to reach higher annual mileages than urban citizens, thereby profiting more. Nonetheless, from an environmental perspective, increasing the electric fleet in urban areas would be more desirable as the environmental challenges that electric vehicles address (most notably particulate matter and NO_x emission reduction) are more problematic in urban areas than in rural areas. It is expected that an increase of the electric fleet in urban areas requires a reduction in public charging prices to resolve this mismatch.

Finally, the impact of electric vehicles on government income was assessed. Due to their comparatively low operational expenses, it was found that electric vehicles generate most government income via their VAT upon their first purchase. With current subsidy schemes, governments lose significant amounts of income per electric vehicle in the order of 2,000 – 8,000 € per car over five years. When subsidies are excluded, government income may be on par with conventional cars due to their often twice-as-high catalogue price, therefore generating more VAT at the expense of accessibility. For used cars, the government loses about half of its income from conventional cars when choosing an electric car instead, even if tax exemptions were discontinued.

The affordability of electric cars for car owners comes at a cost for the government. It follows that governments will require additional measures to regenerate income in the case of an electrified fleet. These measures either influence the affordability of passenger cars directly (such as an increase in electricity excise or in ownership tax) or they may stimulate quicker fleet renewals at potential environmental costs. It remains, however, unclear how governments will address their losses in income implied by their electrification strategies, and how the cost will be distributed over society in the future.

A Annexes

A.1 Country-comparison of BEV attractiveness under the absence of subsidies and tax exemptions

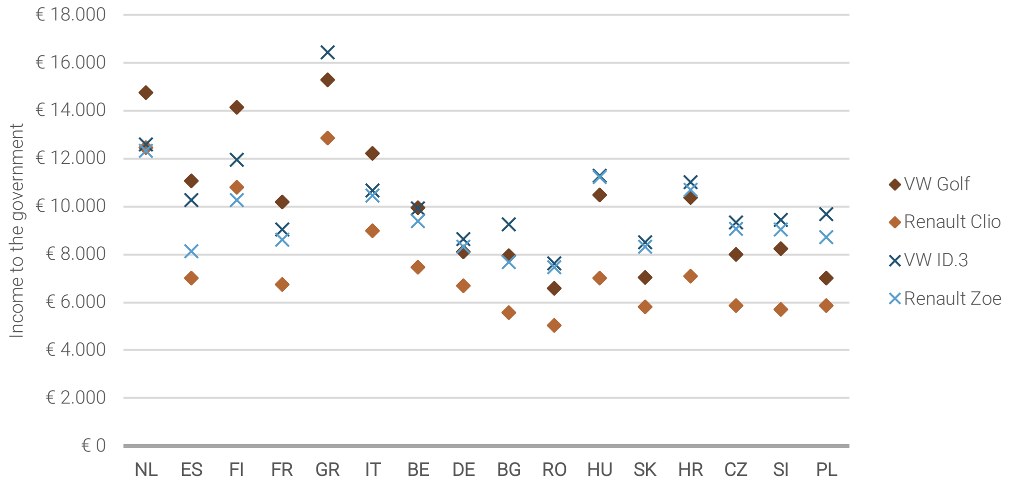


Figure 13 – Comparison of the total income to the government per new car in 16 Member States, if support schemes for BEVs were discontinued. All cars are assumed to drive 12,000 km/a. All cars are assumed to drive 12,000 km/a. The ICEV (brown diamonds) is represented by the VW Golf and the Renault Clio, whereas the BEV (blue crosses) is represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from the highest loss to the highest increase in income from BEVs compared to ICEVs.

A.2 Methodology

Depreciation

Two different data sources, Autoweek and ANWB, were analysed on usability for the model. Autoweek is based on data of 94,705 cars which have been sold in the Netherlands since 1980. The data found in Autoweek is based on data from an internal secondhand car dealer: CarBase. ANWB does not provide direct insights into their underlying data. Instead, only results depending on the input parameters are shown. During the reverse engineering process, we were unable to define a formula using the data of Autoweek and continued with the ANWB data.

Two sets of data were compiled, varying the annual driven mileage between 20,000 and 40,000. Per set of data was generated with a varying number of ownership years between 0-10. The mileage was set to zero. The specific Volkswagen Golf 1.0TSI 66 kW model was chosen, which was in line with the most basic model listed in Autoweek. In the third step no specific accessories were added, to keep the model the most basic.

The ANWB model generated two data points per ownership period. One datapoint listed the fixed depreciation in % and the second datapoint listed the variable depreciation in %.

The fixed and variable data approach a limit. Fixed depreciation approaches the 60%, and the variable depreciation the 40%. A separate formula was derived for the fixed and variable depreciation. Four different types of fits were analysed to approximate the data of ANWB: hyperbolic, exponential, logarithmic and polynomial fit. The parameters of the four different types of formulas were calculated such that they sufficiently describe the data points as well as reasonable tendencies beyond the investigated data.

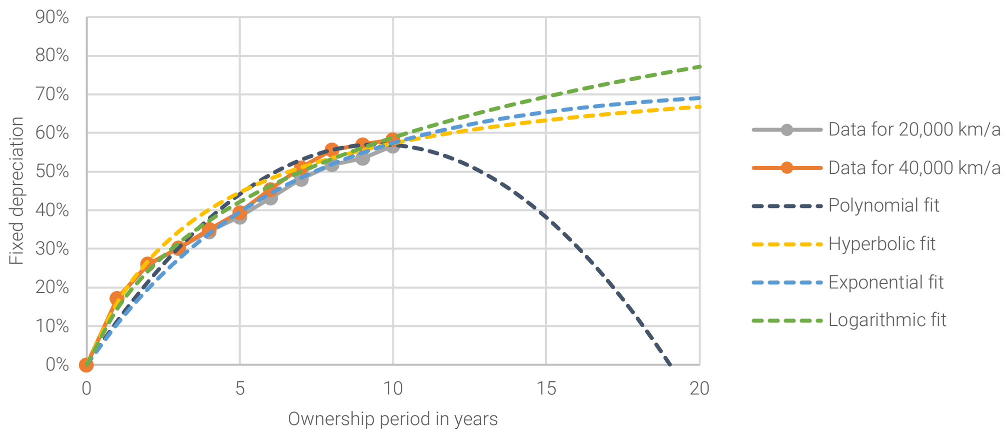


Figure 14 – Four different types of fits and the fixed depreciation data points of 20,000 km/a and 40,000 km/a.

All fits had suitable R^2 values, and all fitted the approximated the data well. The most efficient (needed the least amount of data points to approximate the data well) and the simplest fit (the least amount of parameters in the formula) was chosen. This was the hyperbolic fit, which needed just one datapoint to define the parameters.

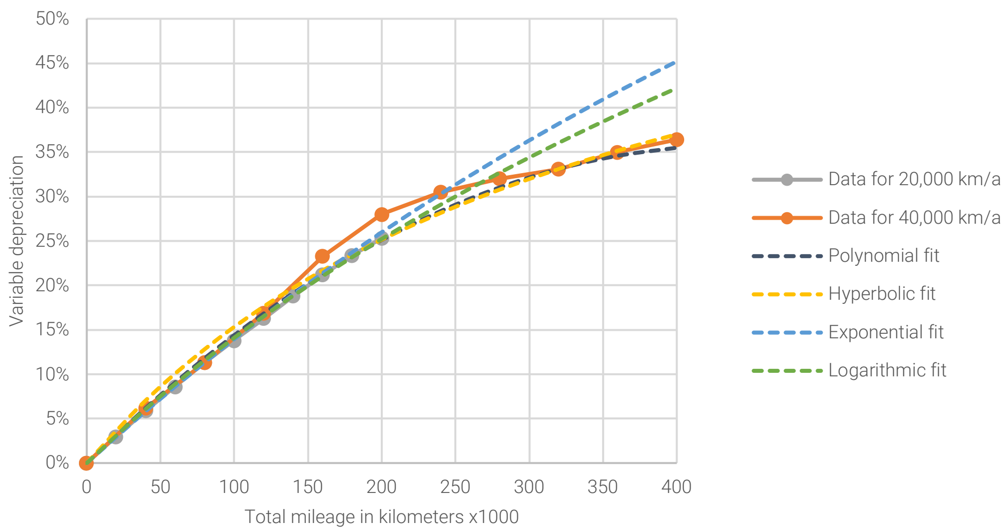


Figure 15 – Four different types of fits and the variable depreciation data points of 20,000 km/a and 40,000 km/a.

Again, the most efficient and simple formula was chosen, which was in the case of the variable depreciation also a hyperbolic fit. The total depreciation is the sum of fixed and variable depreciation. Nevertheless, as can be seen from the constants in the hyperbolic formulas, a depreciation of above 100% would be possible this way (for excessively high mileages and car ages). Therefore, a check function was implemented that limits the maximum depreciation to 95%, assuming that the remaining 5% are material value if the car was scraped.

As mentioned before, the assumption was made that a BEV would have a similar value loss over time. When testing this assumption by comparing the depreciation rate with other depreciation tools, it shows that some models have a steeper depreciation rate and others a more gradual depreciation rate for BEVs.

There are multiple potential explanations for the steeper depreciation rate for BEVs: (1) the relative newness of the technology and (2) the depreciation of the battery determines the depreciation.

The steep increase in technological performance of a car may impact the value loss of older models. New BEVs introduced on the market have an improved battery performance and range compared to BEVs introduced 5 years ago. The improvement in performance could cause a steeper depreciation rate for older models. However, we assume that the difference in technological performance is already decreasing and will decrease even more over time. Thus, the depreciation rate of a BEV will continue to grow more like the depreciation rate of an ICEV.

The second explanation was tested by analysing data of ANWB for a Renault Zoe with a leased battery and a bought battery. When comparing these two depreciation rates there was no evidence of the second explanation, as the depreciation rate was similar between a leased battery and bought battery. Consequently, the depreciation rate of BEVs by ANWB does not seem to be determined by the depreciation rate of the battery.

A more gradual depreciation rate for BEVs than ICEVs could be explained by the number of car components. The TCO model includes two formulas for maintenance costs, one for BEVs and one for ICEVs. The BEVs in general have lower maintenance costs than ICEVs. A potential explanation for the lower maintenance costs could be a fewer number of components in the BEVs. This could also positively impact the depreciation and cause a more gradual depreciation for BEVs.

It is currently unknown how the depreciation rate of BEVs will evolve. The assumption was made that the differences between ICEVs and BEVs will further decrease, and thus, the TCO model assumes a similar value loss for ICEV and BEV. This assumption can only be further verified once more data on electric vehicles is available.

Maintenance and insurance

Using the ANWB tool, four sets of data were created for each car model, varying the annual driven mileage between 5,000, 20,000, 40,000 and 100,000 km. Per set data was generated with a varying ownership period between 0-10[22] years. The mileage was set to zero.

In total, data was collected for three different cars, two similar ICE's and BEV. The following cars were chosen:

- the Volkswagen Golf 1.0TSI 66 kW
- the Renault Clio 1.0TCE 67KW Life
- Renault Zoe 52 kWh 80 kW Life.

For the Renault Zoe model, ANWB provided the option to lease or buy the battery. The data was generated for a battery owned Zoe, as Renault is one of the few manufacturers who offers to rent the battery. The assumption was made that this makes the data, and thus the formula more applicable to other BEV models.

Five variables were analysed: costs maintenance bodywork, repair and maintenance costs over whole ownership, tire size, tire price and lifespan tires. Four of the five variables were similar between the three cars. Costs maintenance bodywork is 250 €/a and tire price is 95 € for all three models. Lifespan tires and tire size differs between the models. The Volkswagen Golf has a tire size of 195/65R15H, with a lifespan of 40,000 km. Both the Renault models have a tire size of 185/65R15T, with a lifespan of 42,000 km. The maintenance costs concerning the replacement of tires and the bodywork costs were excluded, as they were quite similar between the ICE and BEV.

The assumption was made that the maintenance costs would have an annual (fixed) part (dependent on the ownership period) and a variable part (dependent on the number of kilometres driven).

[22] In the case of 100,000 km/a, the ownership period was reduced to 4 years for keeping the total mileage driven within reasonable bounds.

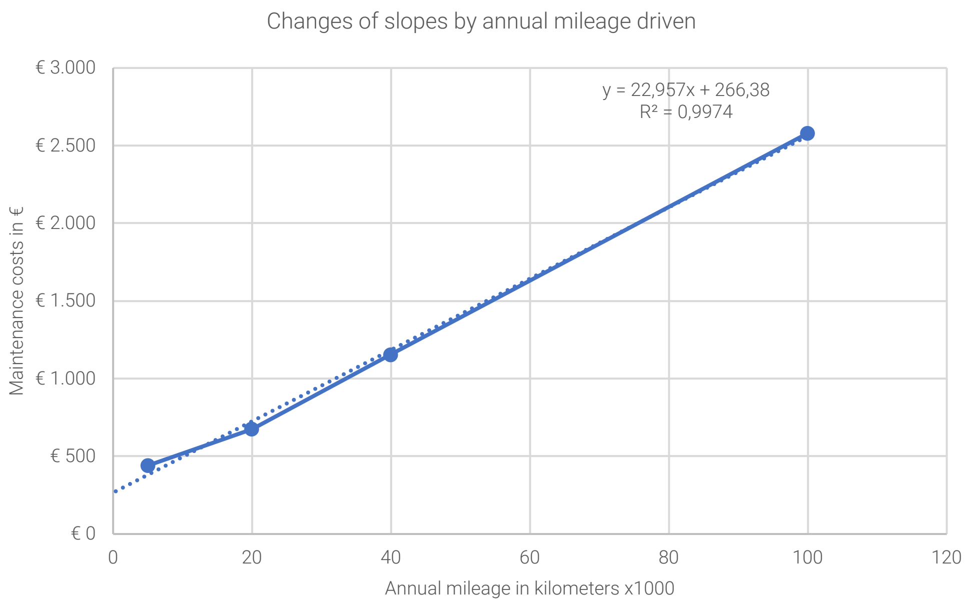


Figure 16 – Slopes of the maintenance curves for the Volkswagen Golf: The blue line represents the change in slope of the annual maintenance curve dependent on the annually driven kilometres (left y-axis).

A second graph was excluded in Figure 16, which would have been generated by the datapoints of the curves dependent on the number of kilometres driven. The blue line alone approximated the variable maintenance costs well.

The blue line represents the change in slope when having a different annual mileage. By extrapolating the trendline towards an annual mileage of 0 km, the fixed maintenance (that is independent of the use of the car) was derived. More precisely, the abscissa of the resulting trendline describes the fixed, annual maintenance costs. The slope represents the increase in maintenance costs dependent on the number of kilometres driven. The formula shown in in Figure 16 was normalised by the catalogue price of the Volkswagen Golf (to obtain a percentage) and the percentage was applied to all ICEs in the TCO model.

The formula shown in Figure 16 was not applicable for the Renault Zoe. When looking at the data of the three different models, there were only small differences between the Renault Clio and Volkswagen Golf. However, between the ICEs and the Renault Zoe there is almost a 50% difference after an ownership period of 10 years.

The process was repeated for the Renault Zoe. Figure 17 shows the outcome for the Renault Zoe, which was normalised by the catalogue price of the Renault Zoe (to obtain a percentage) and the percentage was applied to all BEVs in the TCO model.

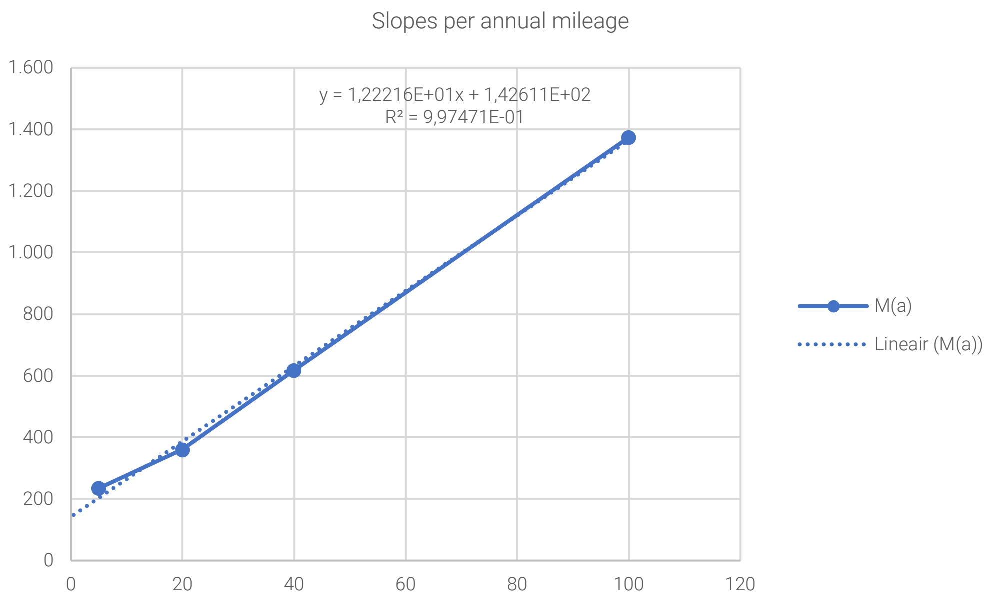


Figure 17 – Slopes of the maintenance curves for the Renault Zoe: The blue line represents the change in slope of the annual maintenance curve dependent on the annually driven kilometres (left y-axis).

TCO model comparison

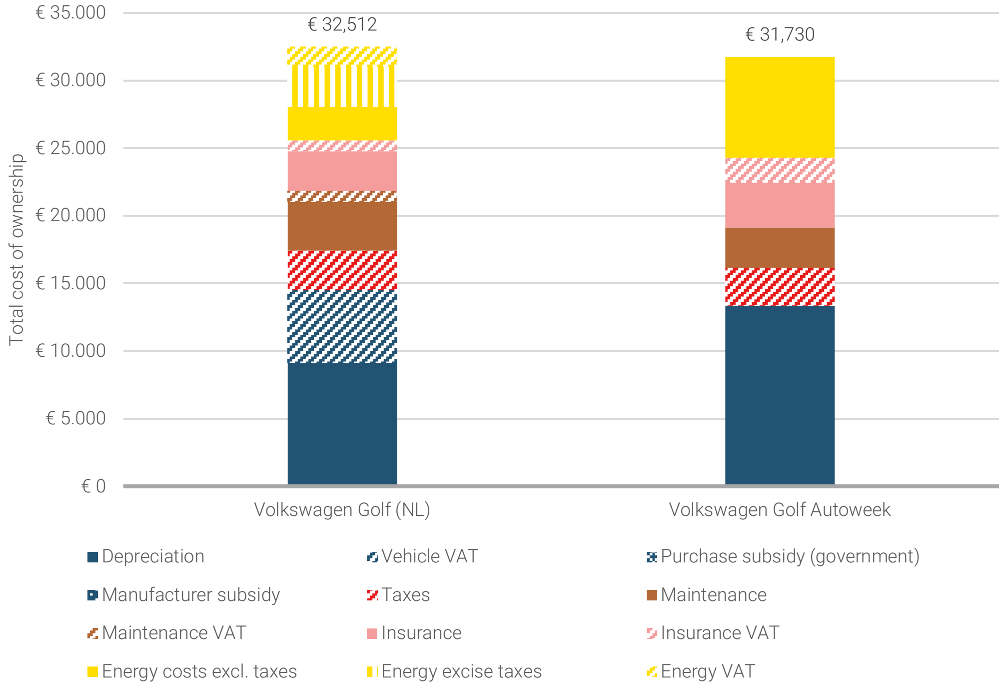


Figure 18 – Comparison of the total cost of ownership of a Volkswagen Golf calculated by studio Gear Up (left) to the TCO calculator offered by the Dutch car magazine Autoweek (right). Input parameters were adjusted to fit the model inputs and assumptions made by Autoweek.

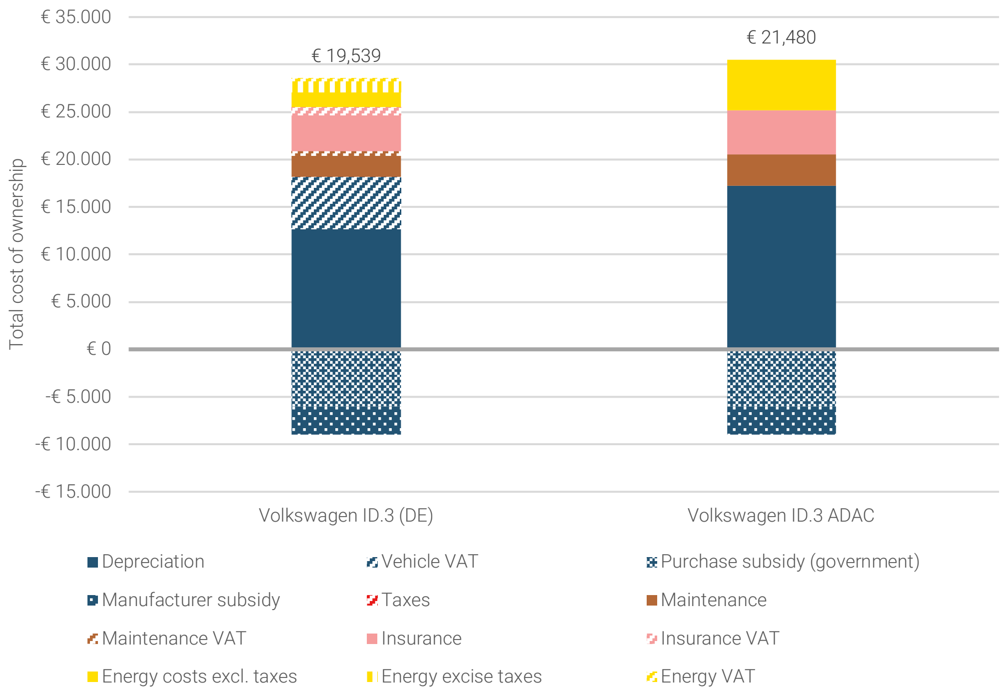


Figure 19 – Comparison of the total cost of ownership calculated by studio Gear Up (left) to the TCO calculator offered by the German motoring club ADAC (right). Input parameters were adjusted to fit the model inputs and assumptions made by ADAC.

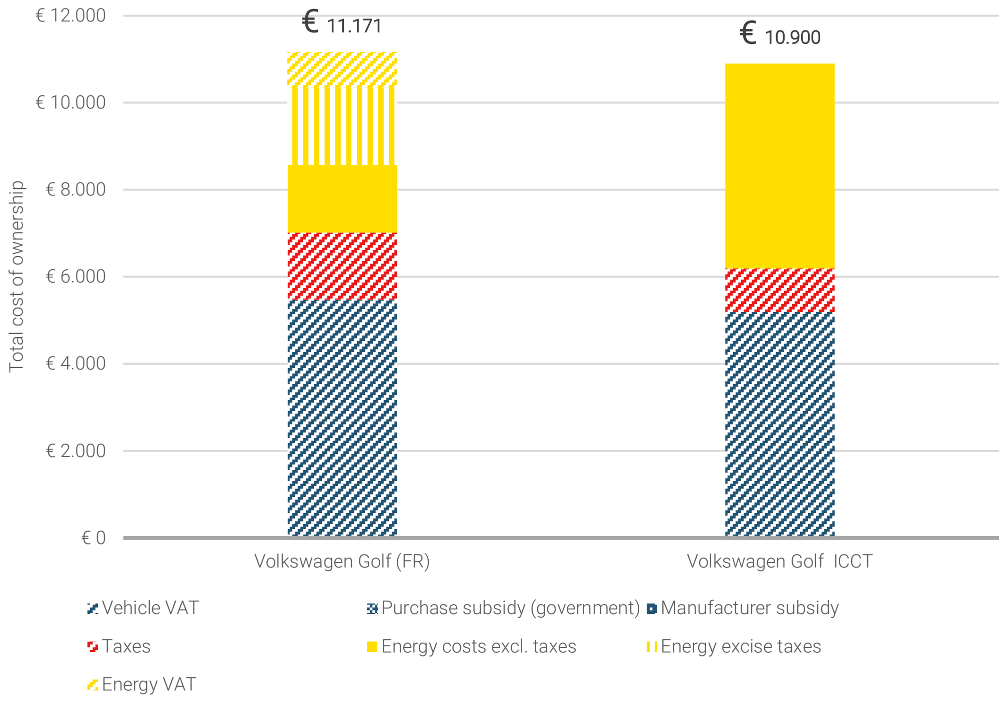


Figure 20 – Comparison of the total cost of ownership calculated by studio Gear Up (left) to the TCO study by the International Council on Clean Transportation (right). Input parameters were adjusted to fit the model inputs and assumptions made by ICCT. The ICCT model provided purchase costs instead of depreciation, and lacked insights into maintenance. For the purpose of comparison, depreciation / purchase price and maintenance were omitted.

Energy costs

Data on public charging prices were difficult to find for some countries. Multiple sources were used to determine public charging costs across Europe.

- **Netherlands:** https://www.anwb.nl/auto/elektrisch-rijden/wat-kost-het-opladen-van-een-elektrische-auto
- **Germany:** https://www.flowcharging.com/tarieven-openbaar-laden/
- **France:** https://belib.paris/assets/pdf/belib_tariffs_fr_en.pdf
- **Italy:** https://europe.autonews.com/blogs/good-bad-and-pricey-driving-electric
- **Spain:** https://www.20minutos.es/motor/noticia/4229471/0/hablamos-en-euros-cuanto-cuesta-recargar-un-coche-electrico/
- **Romania:** https://www.enelx.com/ro/en/electric-mobility/products/privates/juicepass-app-rates
- **Poland:** https://www.statista.com/statistics/1086183/poland-electric-vehicle-charging-prices/
- **Hungary:** https://molplugee.hu/en/prices

A.3 Country profiles

The 16 Member States assessed in the present study vary greatly in the affordability of electric vehicles. Notable differences in catalogue prices, fuel and energy prices, extent of subsidies for electric vehicles and taxation were found. Therefore, a brief status summary of electric vehicle affordability is given below for each country.

Please note, however, that subsidy provisions and tax exemptions are changing rapidly across Europe, and that identifying changes in subsidy schemes can be challenging in some cases. The following sections describe existing subsidy schemes to the best of the authors' knowledge (summarised in Table 1 below), but the validity and recency of the information below cannot be guaranteed. Nonetheless, these schemes were verified with various public sources due to their high influence on the results presented above.

Table 1 – Overview of existing subsidy schemes and tax exemptions for electric vehicles in the 16 analysed member states of the European Union.

Country	Subsidy and tax benefits	Approximate discount new BEVs[23]
Belgium	BEVs are exempt from ownership tax BEVs only pay the minimum fee for registration taxes (30 €)	At purchase: 62 € Annually: 119 €/a
Bulgaria	BEVs are exempt from ownership tax	Annually: 191 €/a
Croatia	Purchase subsidy for BEVs: 9,200 €	At purchase: 9,200 €
Czech Republic	No incentives in place for BEVs	At purchase: -
Finland	Purchase subsidy for BEVs: 2,000 €	At purchase: 2,000 €
France	Purchase subsidy for BEVs: 6,000 €	At purchase: 6,000 €
Germany	BEVs are exempt from ownership tax Subsidy split manufacturer and state: By federal state: 6,000 € By manufacturer: 3,000 €	At purchase: 9,000 € Annually: 38 €/a
Greece	Purchase subsidy for BEVs: 3,850 € Exempt from registration tax Exempt from ownership taxes	At purchase: 4,772 € Annually: 959 €/a
Country	Subsidy and tax benefits (continued)	Approximate discount new BEVs
Hungary	BEVs are exempt from registration tax BEVs are exempt from ownership tax	At purchase: 327 € Annually: 161 €/a
Italy	Subsidy split manufacturer and state: By federal state: 4,000 € By car dealer: 1,000 € BEVs are exempt from ownership tax for the first five years	At purchase: 5,000 € Annually: 254 €/a
Netherlands	Purchase subsidy for BEVs: 4,000 € BEVs are exempted from ownership tax in 2021, this exemption will remain until 2024 BEVs only pay the flat fee for registration taxes (53 €)	At purchase: 5478 € Annually: 580 €/a
Poland	BEVs do not have to pay excise taxes, while registering the car	At purchase: 360 €
Romania	Purchase subsidy for BEVs (budget is 82 million for 2021): 10,000 € BEVs are exempt from ownership tax	At purchase: 10,000 € Annually: 8 €/a
Slovakia	BEVs pay the lowest fee for registration tax (33 €)	Annually: 17 €/a
Slovenia	Purchase subsidy for BEVs: 7,500 €	At purchase: 7,500 €
Spain	None they are still considering a purchase subsidy of 4,500 € for BEVs	At purchase: -

[23] Approximation of tax benefits by looking at the difference between the taxes of the Volkswagen ID.3 and Volkswagen Golf.

To assess the impact of public charging of BEVs against home charging, both the average household electricity price as well as indicative numbers for public charging electricity prices were researched for the 16 analysed member states of the European Union. The electricity prices are summarised in the table below.

Table 2 – Electricity prices per country for home-charging and for public charging. These prices include VAT and excise duty. Household electricity prices were extracted from Eurostat. Public charging prices were individually researched

Country	Household electricity price [€ cent/kWh]	Public charging electricity price [€ cent/kWh]
Belgium	28	35
Bulgaria	10	26
Croatia	13	35
Czech Republic	18	57
Finland	17	40
France	19	38
Country	Household electricity price [€-ct/kWh]	Public charging electricity price [€-ct/kWh]
Germany	30	32
Greece	17	48
Hungary	10	42
Italy	22	42
Netherlands	14	34
Poland	15	43
Romania	15	36
Slovakia	17	25
Slovenia	14	27
Spain	22	40

A.3.1 Belgium

According to public sources, electric vehicles received a subsidy of 4,000 € upon purchase in 2020. It seems this subsidy was discontinued in 2021. Nevertheless, tax exemptions for electric vehicles are still in place. In Wallonia and Brussels, for instance, only the minimum base registration tax of 61.50 € applies to new electric vehicles. Similarly, the annual ownership tax is reduced to its lowest, namely 83.56 €/a.

Since the discontinuation of subsidies, owning a VW ID.3 for 5 years is almost 2,000 € more expensive than owning a VW Golf. A Renault Zoe is roughly 7,600 € more expensive to own for 5 years than a Renault Clio.

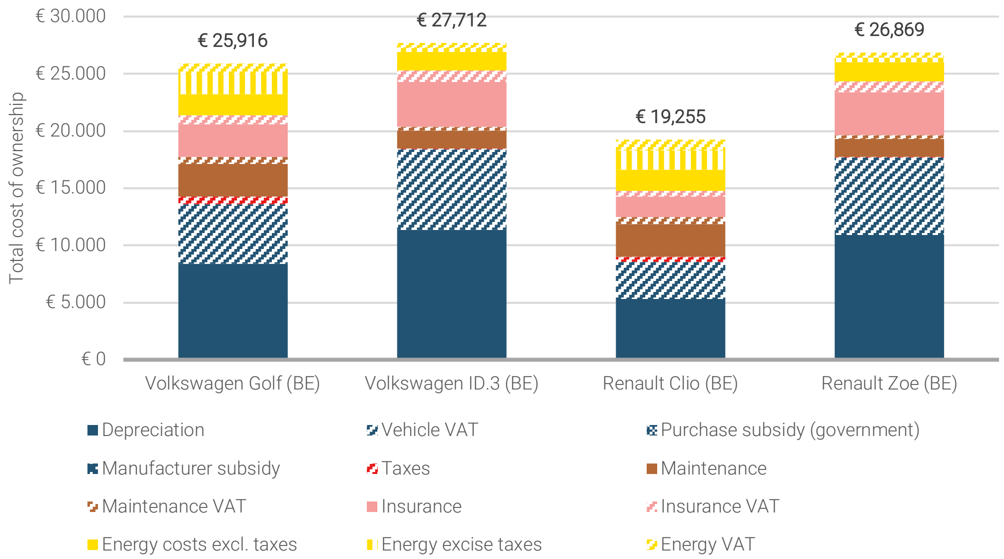


Figure 21 – The total cost of ownership of new cars in Belgium over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing an electric vehicle. Renault Zoe and VW ID.3 are only accessible by the highest quintile, and so is the VW Golf. Only the Clio is affordable for a lower quintile (here Q3).

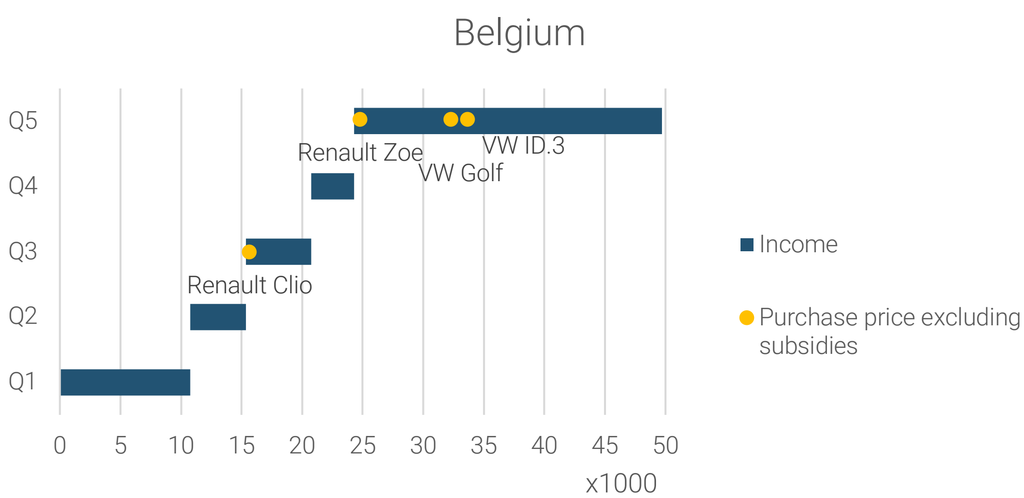


Figure 22 – Available budget ranges for new car purchases for all income quintiles in Belgium and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

Due to a relatively small price difference between public charging and household charging, variations in the share of public charging do not greatly influence the affordability of BEVs over ICEVs, neither for small annual mileages (8,000 km/a) nor high annual mileages (16,000 km/a).

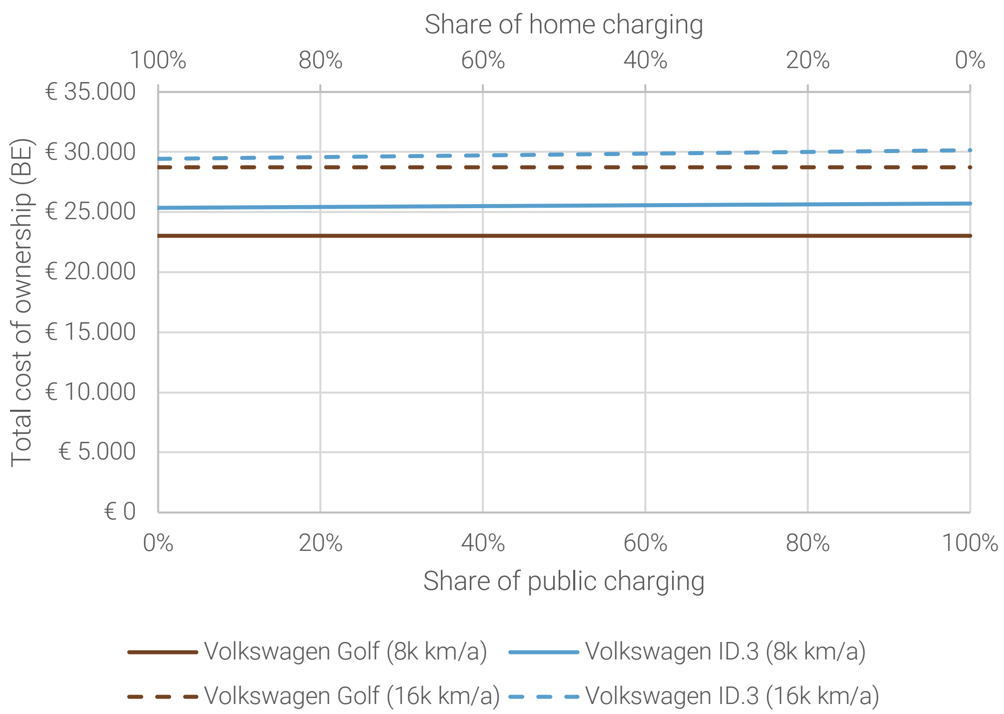


Figure 23 – Influence of the share of public charging on the total cost of ownership in Belgium. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

The same can be said about the impact on the economics of Renault cars.

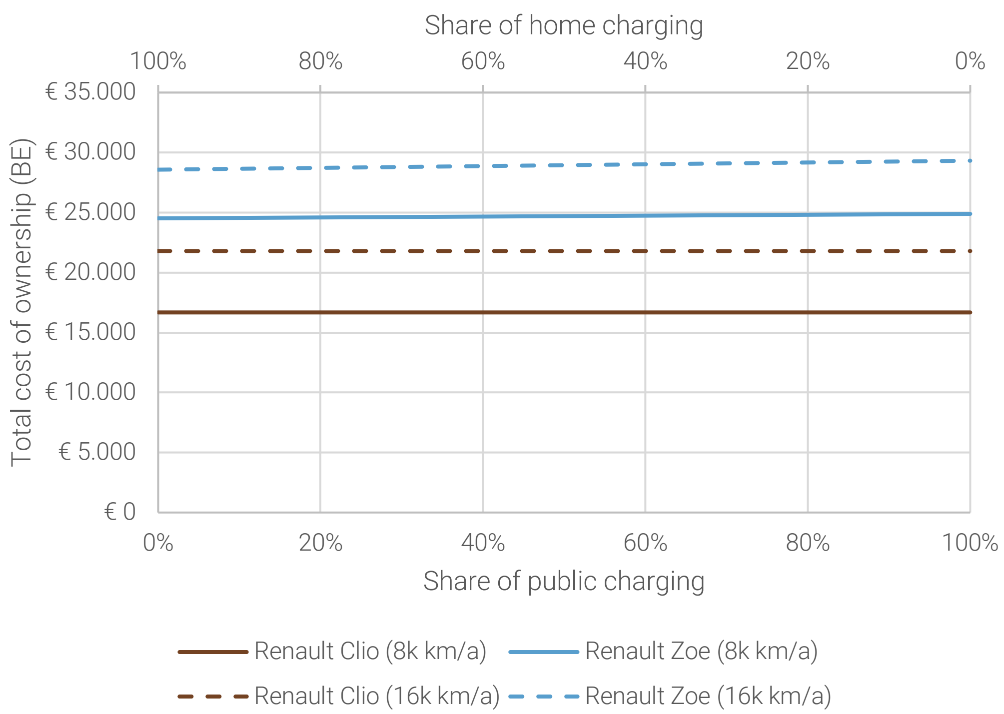


Figure 24 – Influence of the share of public charging on the total cost of ownership in Belgium. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.2 Bulgaria

In Bulgaria, electric vehicles are exempt from ownership tax. In 2018, a purchase subsidy of up to 10,000 € (via VAT reduction) was introduced. The subsidy was discontinued in 2020. This has implications on the affordability of BEVs in Bulgaria. Owning a VW ID.3 over 5 years costs about 5,000 € more than owning a VW Golf for 5 years. In the case of Renault, the difference is with 8,000 € considerably higher.

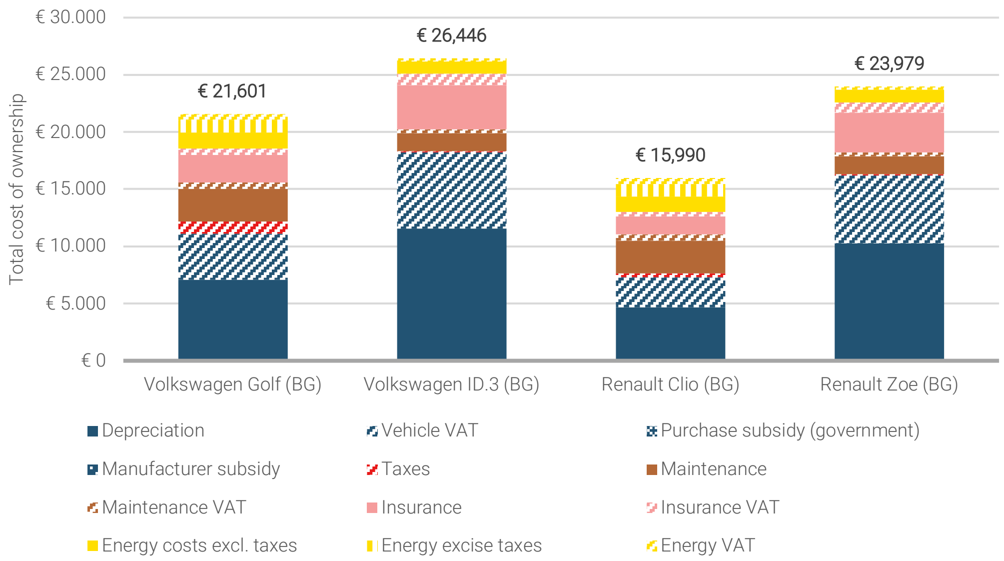


Figure 25 – The total cost of ownership of new cars in Bulgaria over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

It can be seen from the mobility budget distribution per income class and the car catalogue prices that Bulgarian citizens mostly depend on the second-hand car market to meet their mobility needs. All four car models reside in the higher range of the last income quintile.

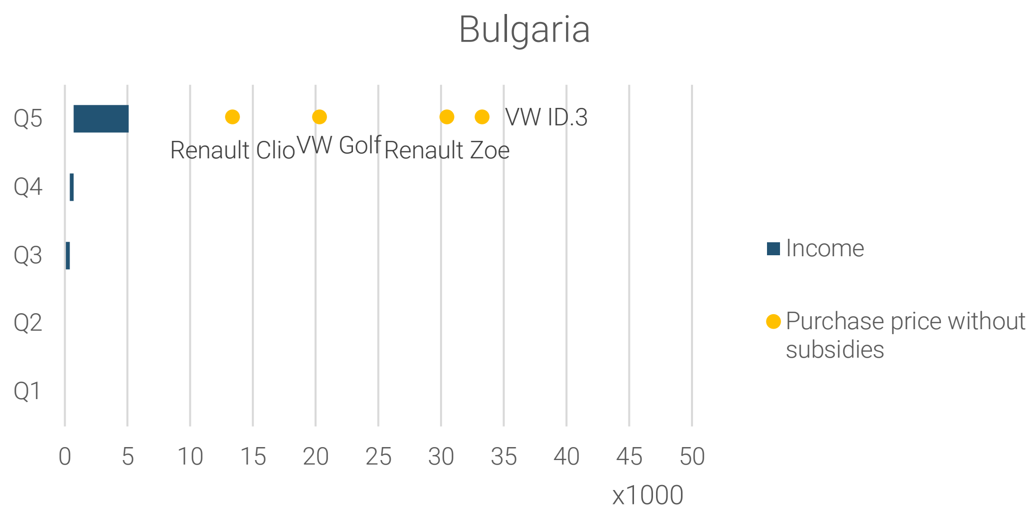
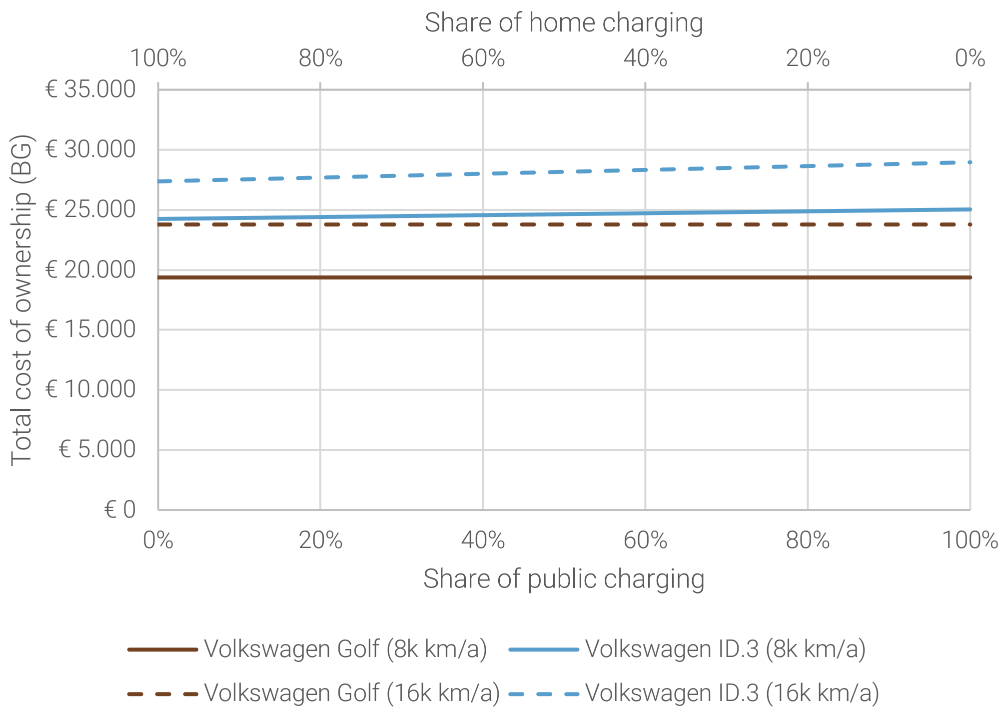


Figure 26 – Available budget ranges for new car purchases for all income quintiles in Bulgaria and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The price difference between public charging and home charging is lower than average in Bulgaria, which is why the share of public charging has a moderate impact on the overall economics. The electric vehicles remain more expensive than the ICEVs even by varying the annual mileage, both for 8,000 and for 16,000 km/a.



The same can be said about the impact on the economics of Renault cars, however the gap between the BEV and the ICEV becomes larger.

Figure 27 – Influence of the share of public charging on the total cost of ownership in Bulgaria. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

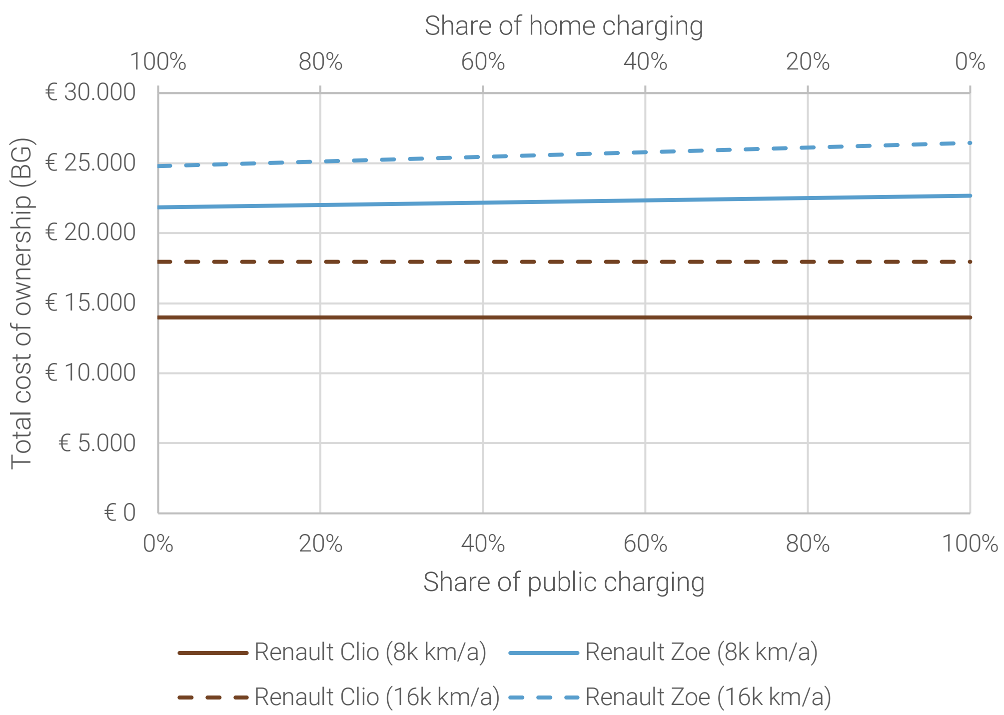


Figure 28 – Influence of the share of public charging on the total cost of ownership in Bulgaria. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.3 Croatia

Croatia provides, under the Fund for Environmental Protection and Energy Efficiency, a large subsidy for buyers of electric vehicles of 9,200 €. However, the fund is limited per year, and when it was increased by a further 5.8 million € in April 2021, this limit was reached within 2 minutes of publishing. For a general analysis of public accessibility, it may therefore be more suitable to refer to the business case without subsidies.

If the subsidies are obtained, electric vehicles show favourable affordability in Croatia. The VW ID.3 is more than 4,000 € cheaper over 5 years than the VW Golf. The Renault Zoe is about 1,700 € more expensive than the Renault Clio after subsidy. Without the subsidies, however, both electric vehicles are considerably more expensive than their ICEV counterpart.

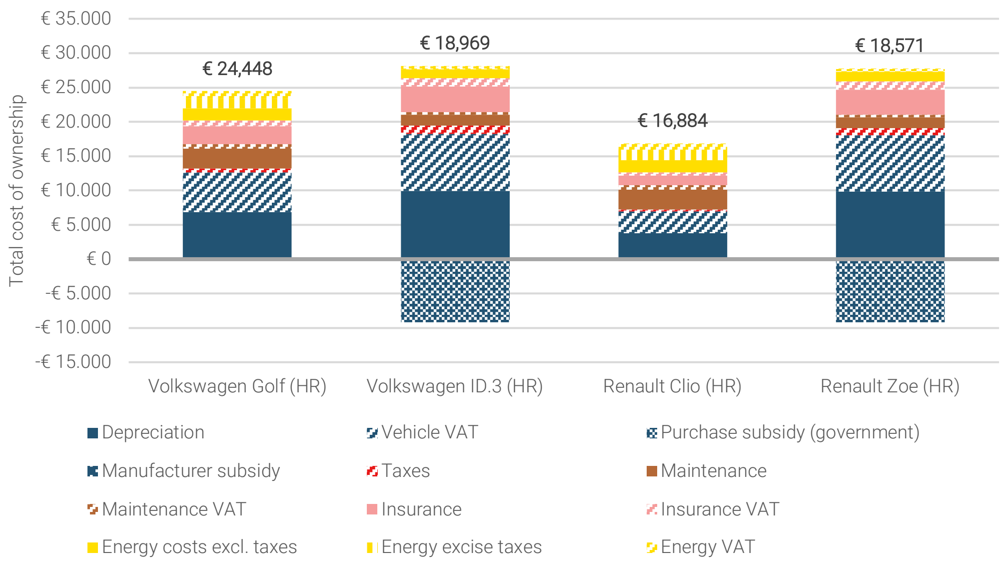


Figure 29 – The total cost of ownership of new cars in Croatia over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

When comparing the available budget ranges for new car purchases in Croatia, it can be seen that new cars are mostly reserved to the highest income quintile. The majority of the Croatian population therefore depends on the second-hand market for acquiring a vehicle.

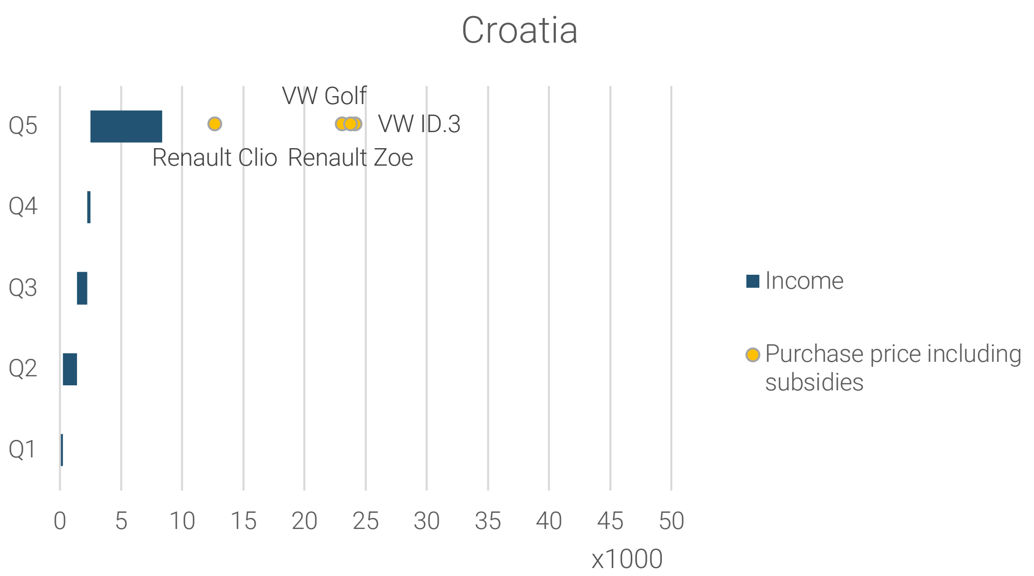


Figure 30 – Available budget ranges for new car purchases for all income quintiles in Croatia and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging is about average amongst the analysed countries. Due to the high purchase subsidies, neither the annual range nor the share of public charging make the ID.3 more affordable than the Golf.

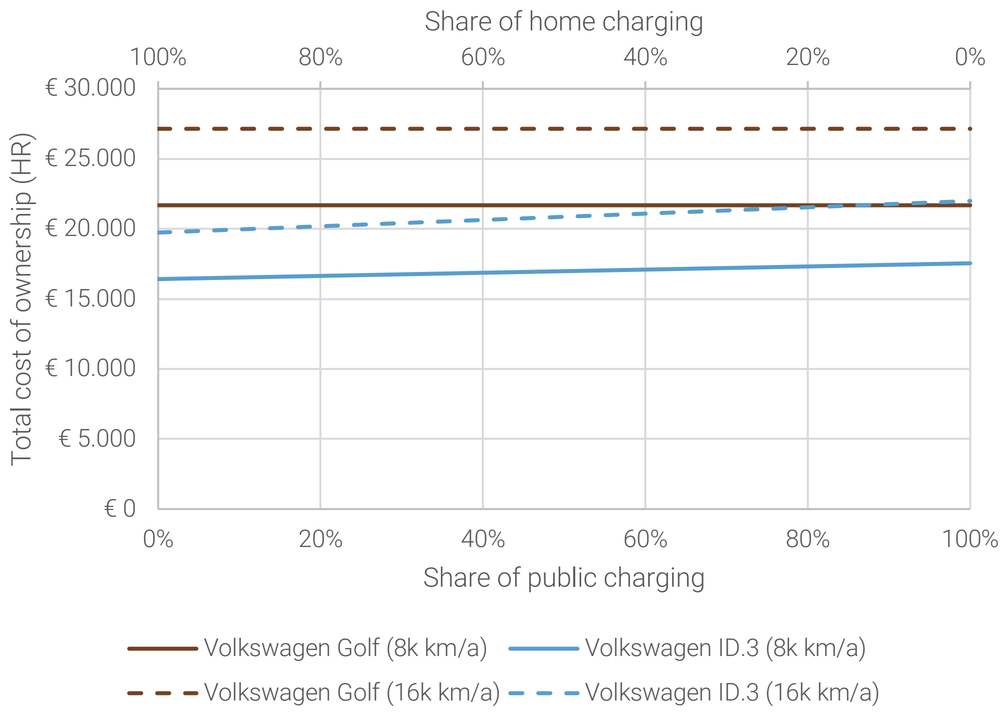


Figure 31 – Influence of the share of public charging on the total cost of ownership in Croatia. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

The Renault Zoe, however, becomes more affordable for higher annual mileages. In the case of 16,000 km/a, the Renault Zoe is on par with the Clio if charged exclusively at home.

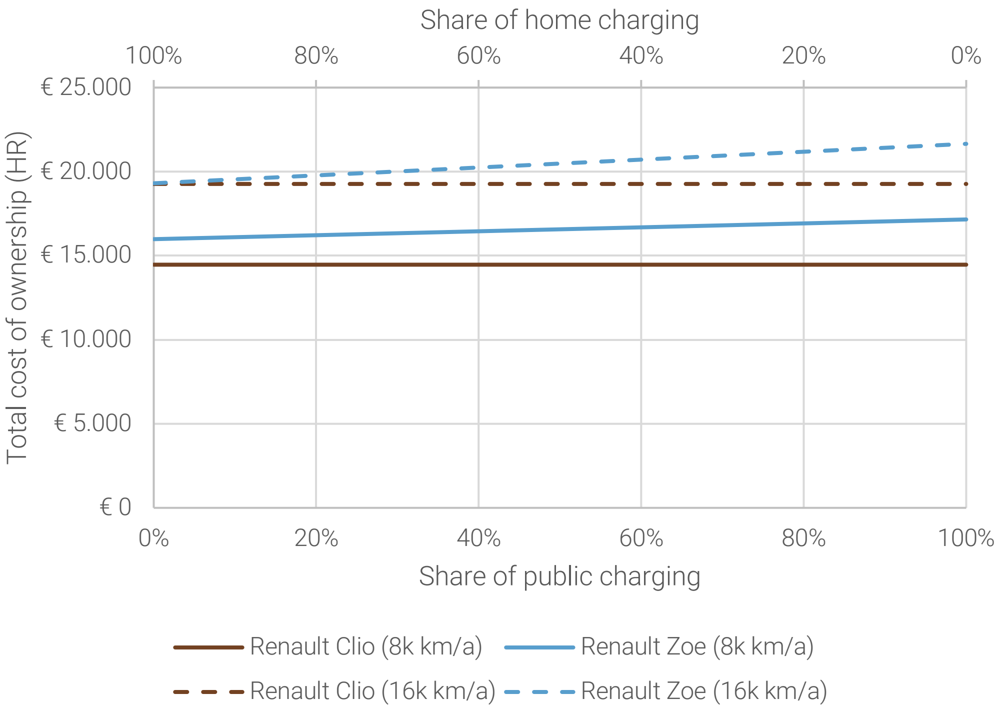


Figure 32 – Influence of the share of public charging on the total cost of ownership in Croatia. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.4 Czech Republic

Czech Republic appears to provide no purchase subsidies in 2021. However, electric vehicles are exempt from paying registration tax. Electric vehicles are more expensive than their ICEV counterpart in the Czech Republic.

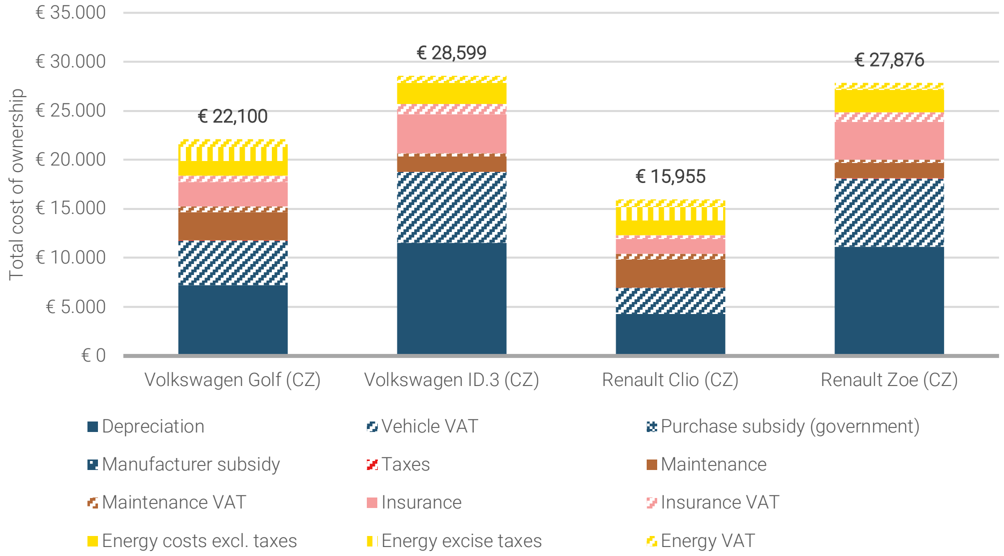


Figure 33 – The total cost of ownership of new cars in Czech Republic over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

In Czech Republic, the four analysed cars are only accessible to the highest income quintile. Therefore, large parts of the Czech population rely on the second-hand car market for purchasing a vehicle.

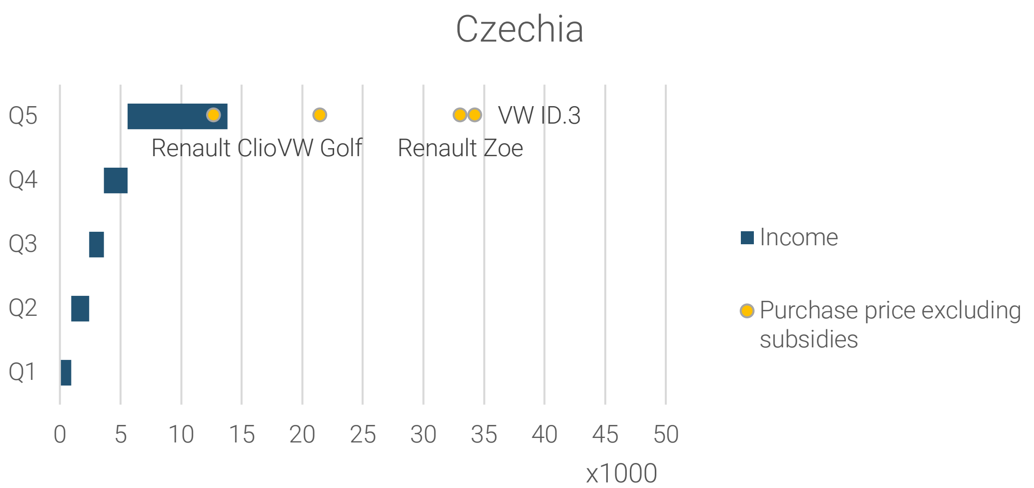


Figure 34 – Available budget ranges for new car purchases for all income quintiles in Czech Republic and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The price difference between public charging and home charging is above average in Croatia, which is why the share of public charging has a considerable impact on the overall economics. The electric vehicles are more expensive than the ICEVs and the gap increases by varying the share of public charging, both for 8,000 and for 16,000 km/a.

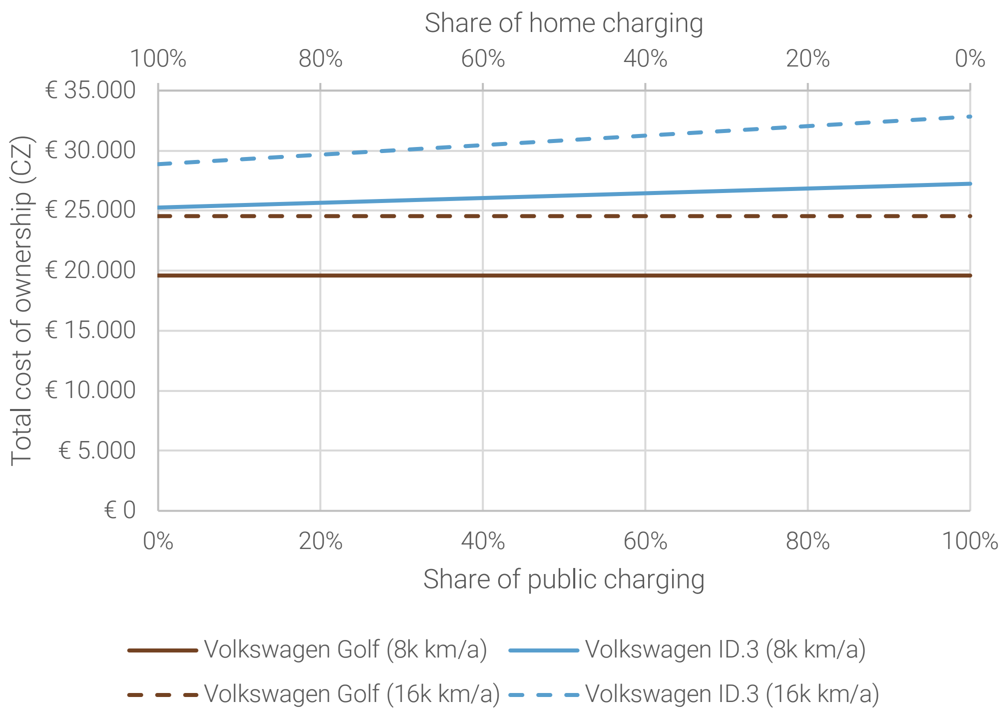


Figure 35 – Influence of the share of public charging on the total cost of ownership in Czech Republic. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

The same can be said about the impact on the economics of Renault cars, however the gap is larger between the two Renault models.

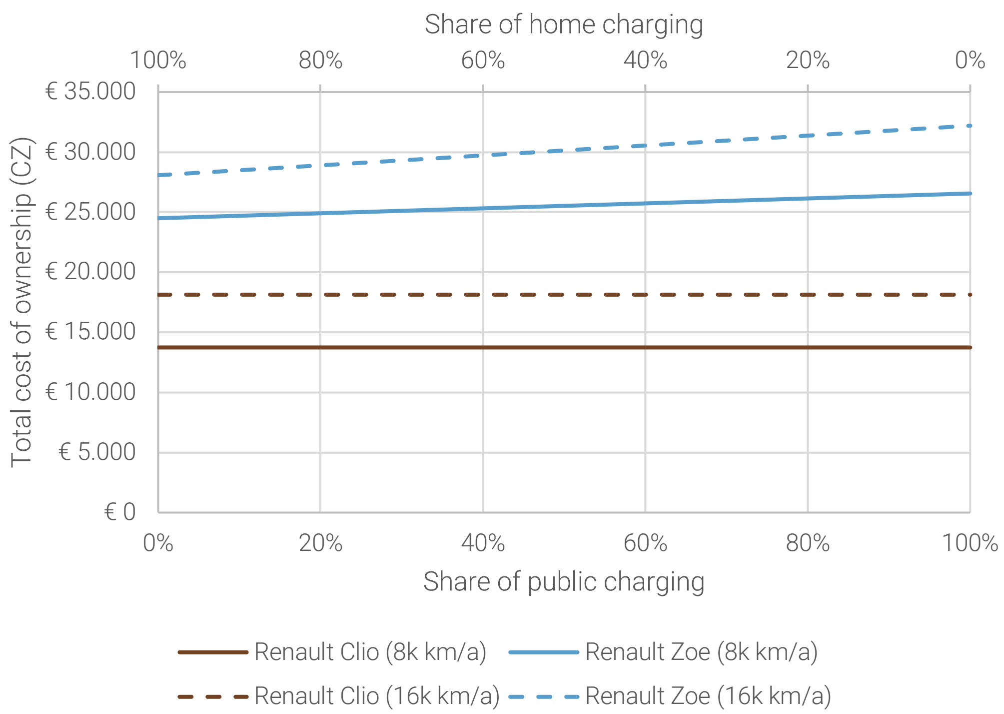


Figure 36 – Influence of the share of public charging on the total cost of ownership in Czech Republic. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.5 Finland

In Finland, electric vehicles are exempt from ownership tax. Finland provides a purchase subsidy of 2,000 €) for electric vehicles under 50,000 €. The subsidy may be discontinued after November 202. This has implications on the affordability of BEVs in Finland. The Renault Zoe is already more expensive than its ICEV counterpart. The Volkswagen ID.3 will become slightly more expensive, if no purchase subsidies are provided.

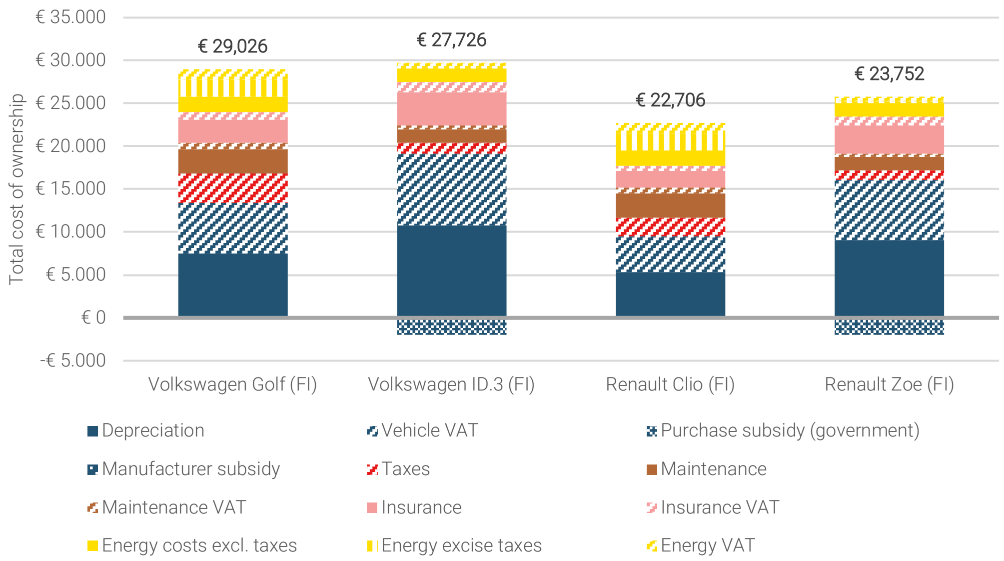


Figure 37 – The total cost of ownership of new cars in Finland over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing an electric vehicle. Renault Zoe and VW ID.3 are only accessible by Q4 and Q5, and so is the VW Golf. Only the Clio is affordable for a lower quintile (here Q2).

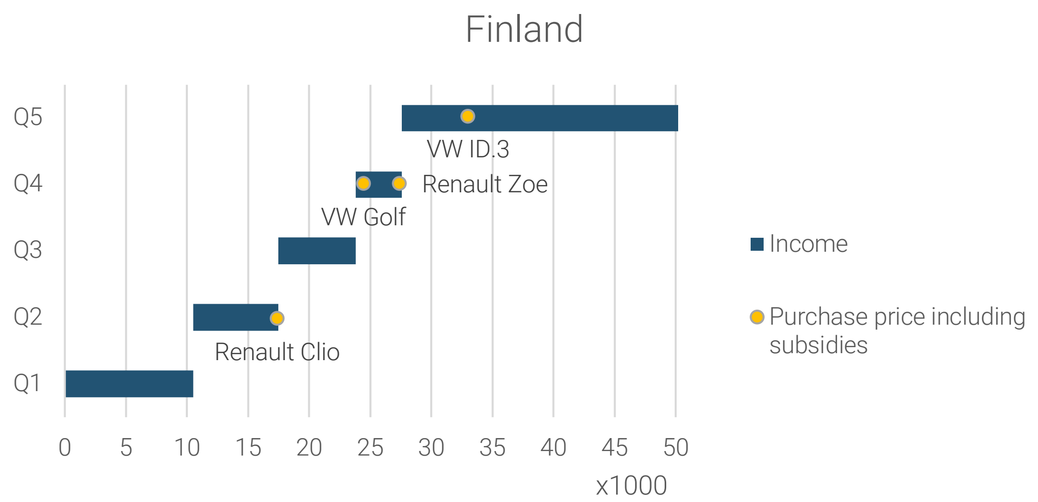


Figure 38 – Available budget ranges for new car purchases for all income quintiles in Finland and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The price difference between public charging and home charging is above average in Finland, which is why the share of public charging has a considerable impact on the overall economics. The electric vehicles can be less expensive than the ICEVs. With an annual mileage of 8,000 kilometres the VW ID.3 remains less expensive than the Golf until a share of 60% public charging. With an annual mileage of 16,000 kilometres

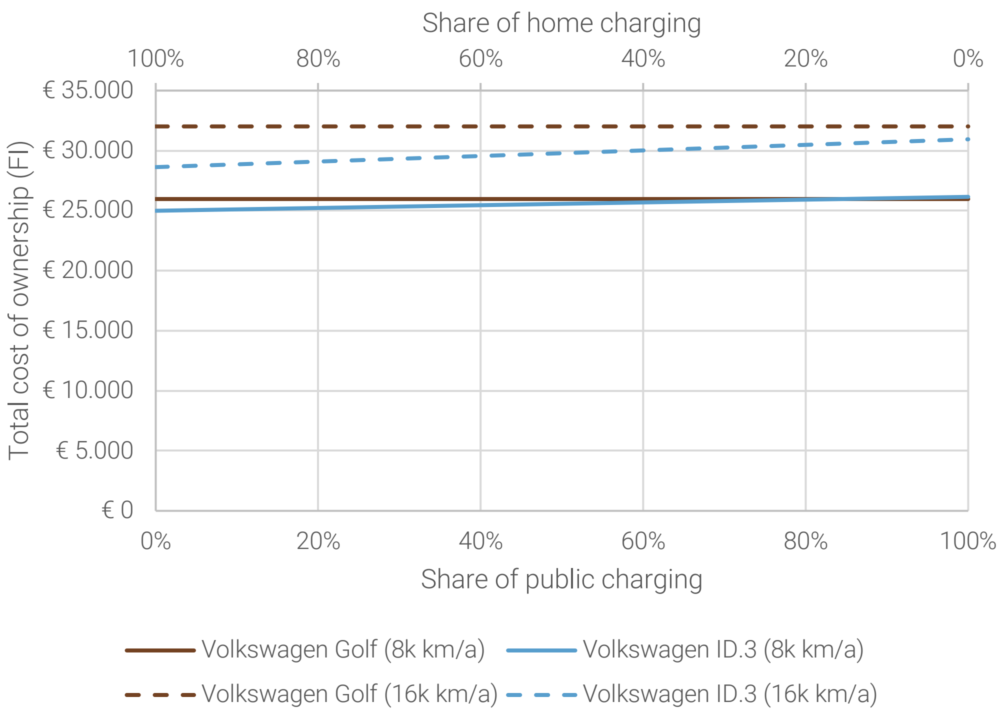


Figure 39 – Influence of the share of public charging on the total cost of ownership in Finland. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

The total cost of ownership of a Renault Zoe is always more than the Renault Clio, when driving an annual mileage of 8,000 km a year. For an annual mileage of 16,000 km the Renault Zoe is less expensive until a share of 40% public charging.

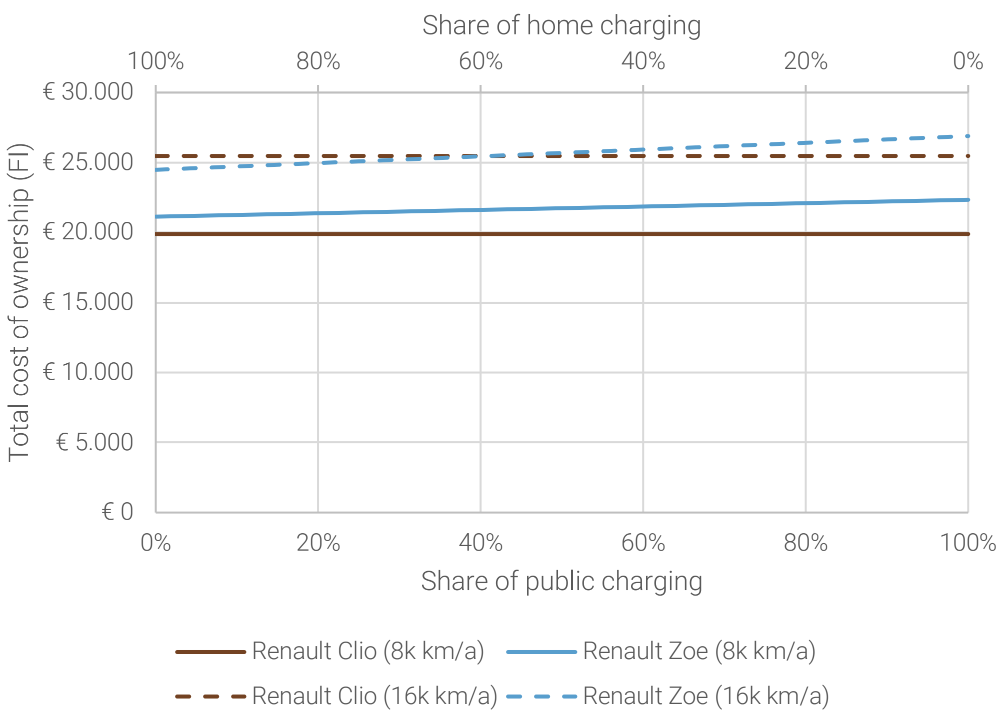


Figure 40 – Influence of the share of public charging on the total cost of ownership in Finland. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.6 France

It seems like France is phasing out their purchase subsidies for BEVs. From 2020 until May 2021 the purchase subsidy was 7,000 €, however between June until December in 2021 the subsidy was decreased to 6,000 €. Currently the purchase subsidy equals to 5,000 €. The TCO of ownership of an VW ID.3 is considerably lower than its ICEV counterpart. Even when excluding their incentives, the VW ID.3 is on par with the VW Golf. However, excluding the purchase subsidy would increase the gap between the Renault Zoe and its ICEV counterpart.

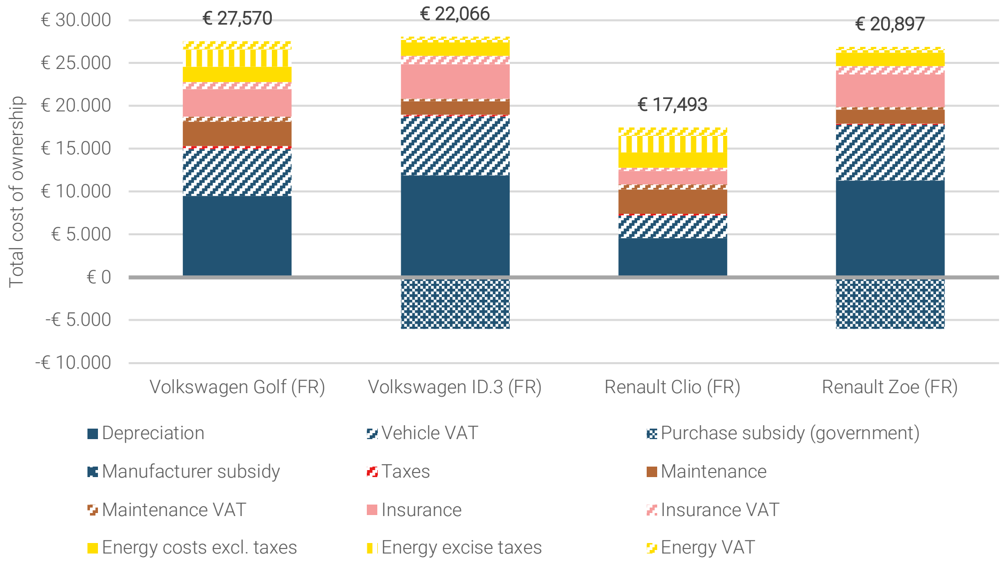


Figure 41 – The total cost of ownership of new cars in France over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing an electric vehicle even with the purchase subsidies in place. Renault Zoe, VW ID.3 and Golf are only accessible by the highest quantile. Only the Clio is affordable for a lower quintile (here Q2).

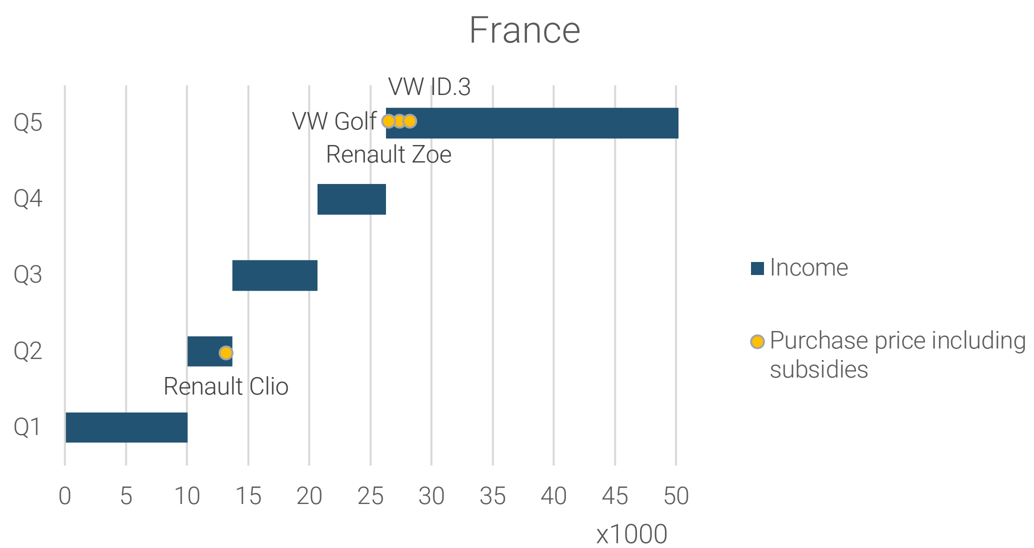


Figure 42 – Available budget ranges for new car purchases for all income quintiles in France and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in France is about average amongst the analysed countries. Neither the annual range nor the share of public charging can make the Golf more affordable than the ID.3.

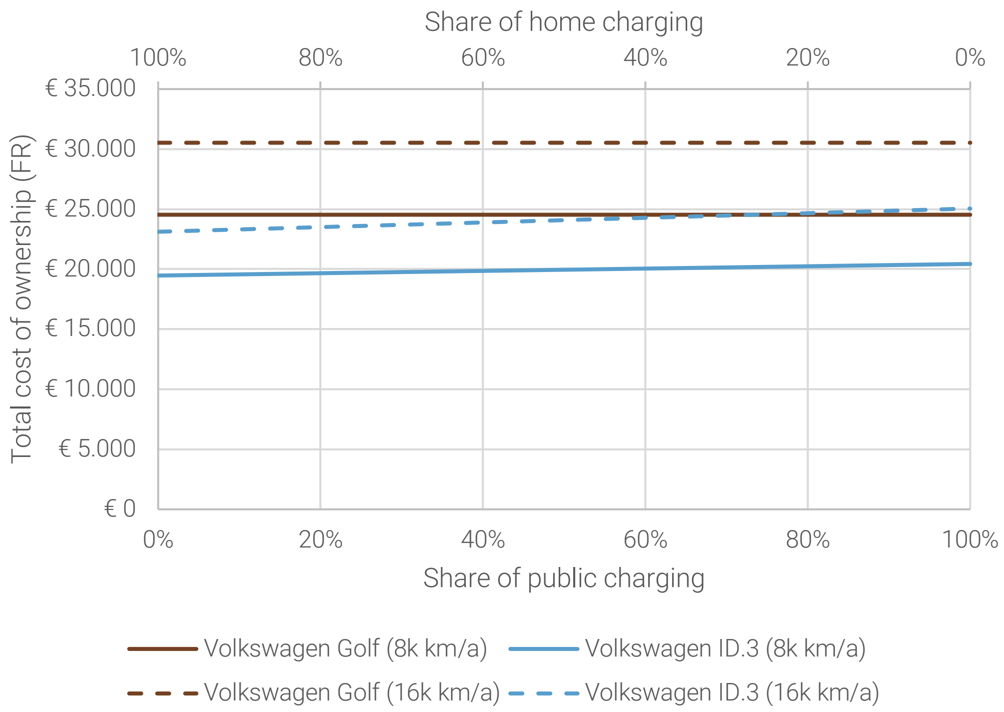


Figure 43 – Influence of the share of public charging on the total cost of ownership in France. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

The total cost of ownership of a Renault Zoe is always more than the Renault Clio, neither the annual range nor the share of public charging can make the Zoe more affordable.

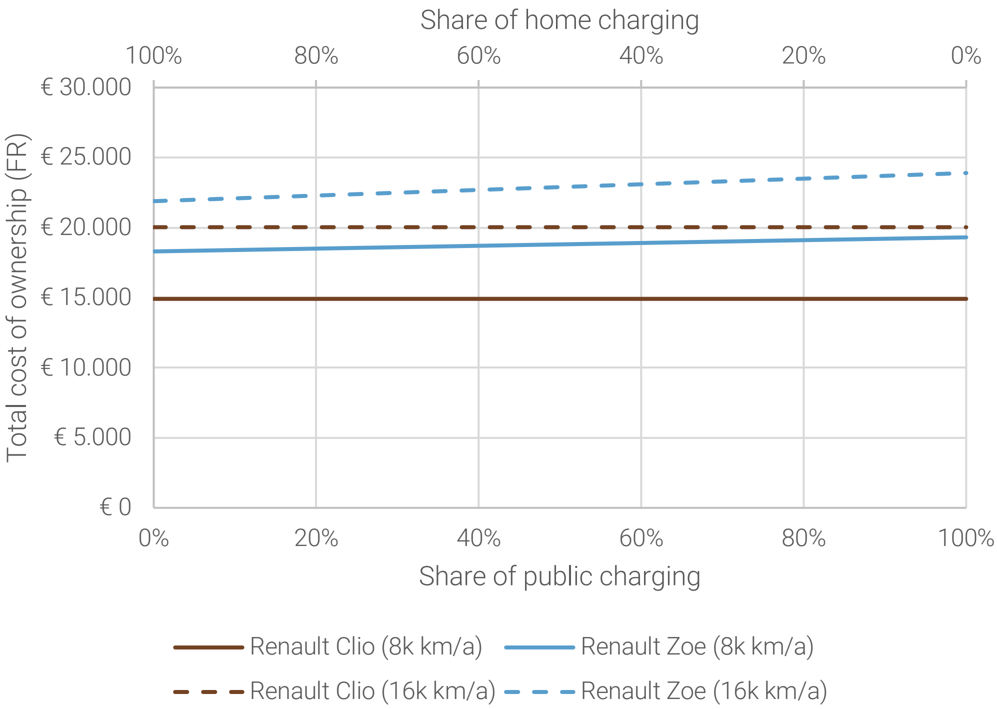


Figure 44 – Influence of the share of public charging on the total cost of ownership in France. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.7 Germany

Germany provides a purchase and manufacturing subsidy, which sums to 9,000 €. The total budget for BEVs incentives is 2.09 billion € for 2016-2025. There is also a tax exemption in place for BEVs. The total cost of ownership of the two electric models are considerably lower than their ICEV counterpart. However, when excluding the purchase and manufacturing subsidy the electric cars become more expensive than the fossil fuel cars.

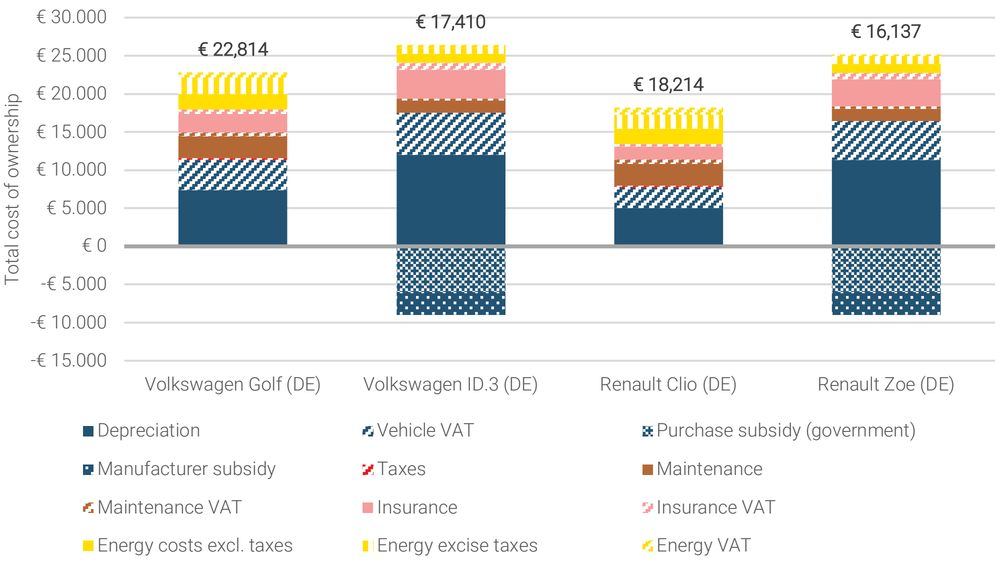


Figure 45 – The total cost of ownership of new cars in Germany over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing an electric vehicle even with the purchase subsidies in place. Renault Zoe, VW ID.3 and Golf are only accessible by Q4. Only the Clio is affordable for a lower quintile. Removing the purchase and manufacturing subsidy makes the purchase of a new electric vehicle less accessible.

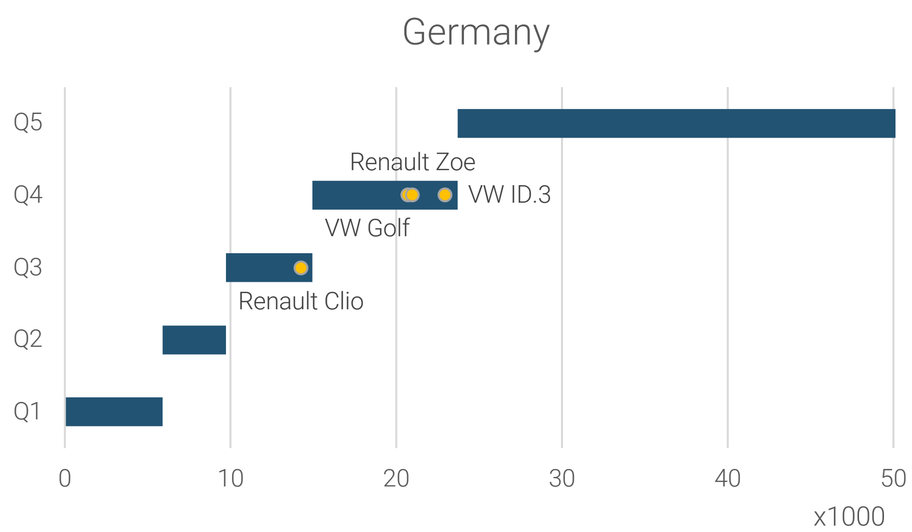


Figure 46 – Available budget ranges for new car purchases for all income quintiles in Germany and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in Germany is small compared to the analysed countries. Neither the annual range nor the share of public charging can make the Golf more affordable than the ID.3.

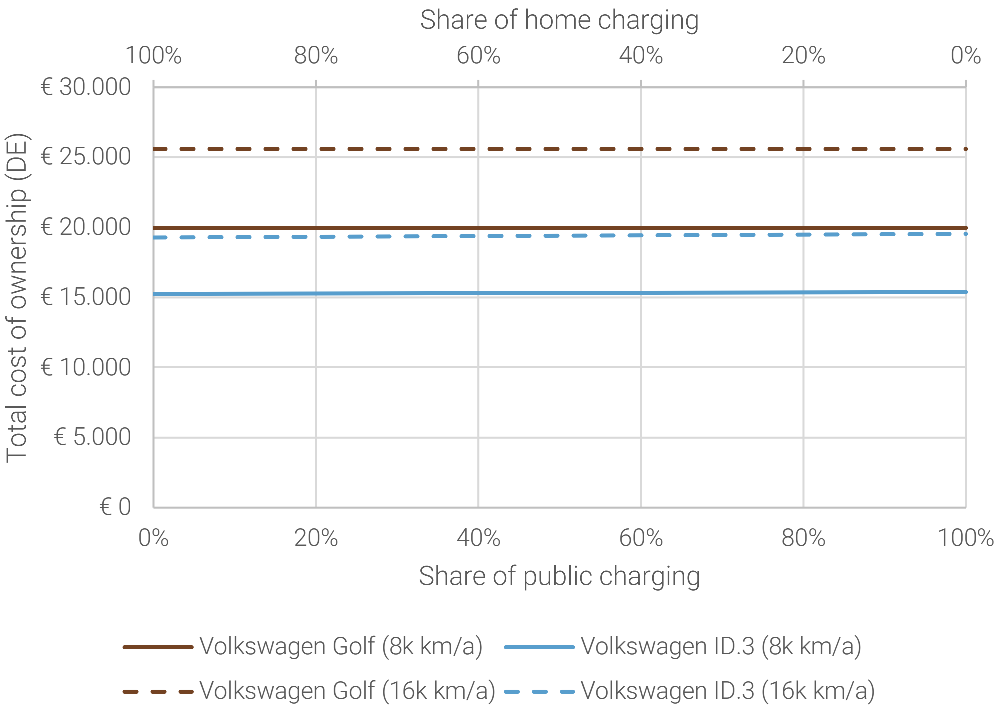


Figure 47 – Influence of the share of public charging on the total cost of ownership in Germany. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

This is also true for the Renault models, the electric models remain more affordable.

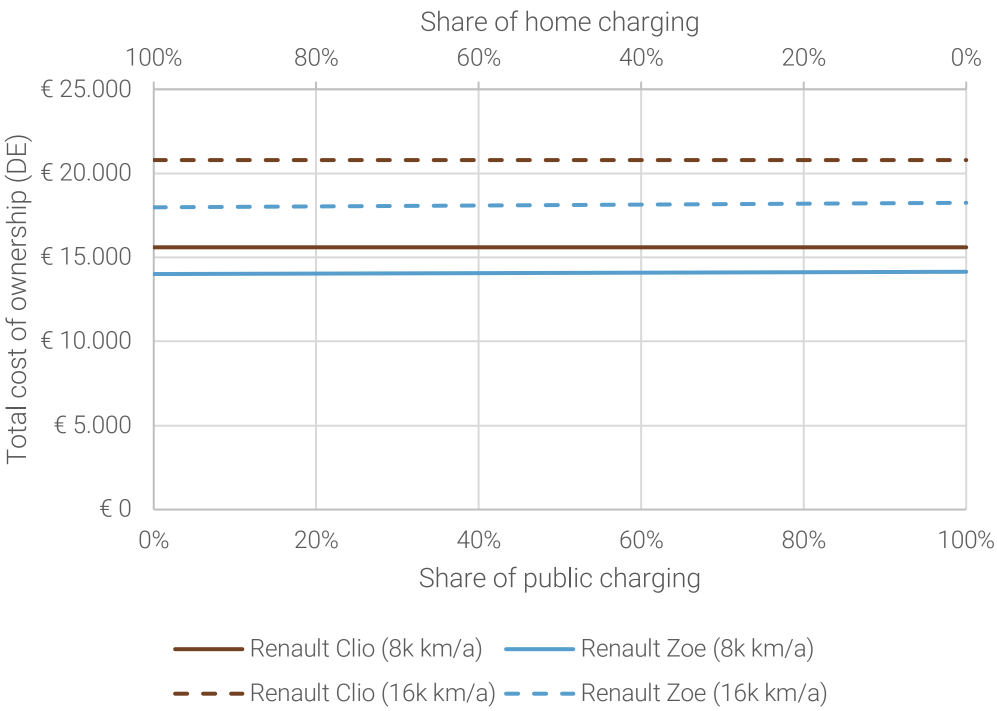


Figure 48 – Influence of the share of public charging on the total cost of ownership in Germany. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.8 Greece

Greece provides a purchase subsidy of 6,000 € and tax exemptions for electric vehicles. Greece does not produce their own cars and is currently not importing the Renault Zoe. With the current subsidies in place the VW ID.3 is more affordable than the VW Golf. If the benefits for BEVs are excluded the VW ID.3 becomes more expensive than the VW Golf.

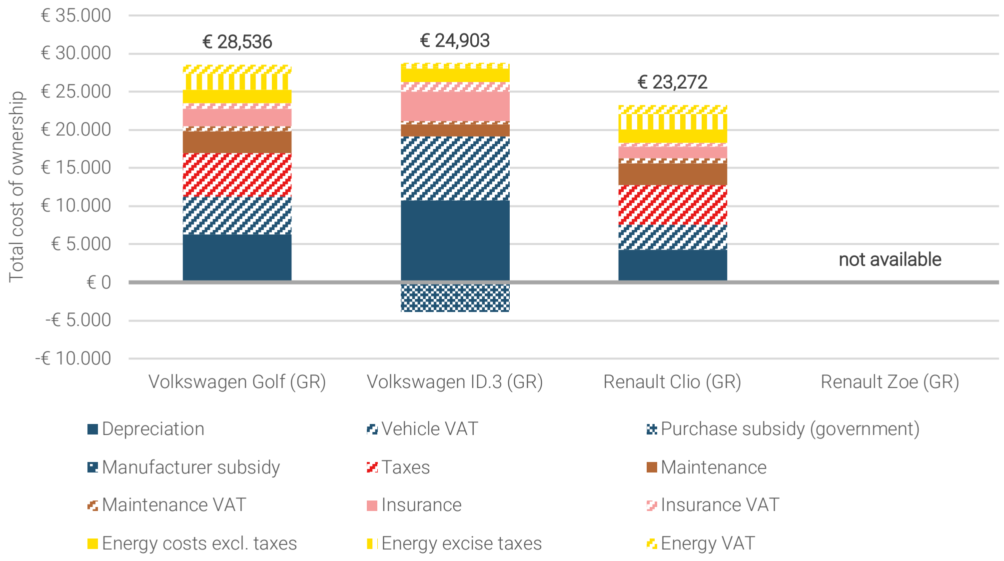


Figure 49 – The total cost of ownership of new cars in Greece over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing a fossil fuel or electric car even with the purchase subsidies in place. The two VW models only seem to be accessible for a small part of the population. In Greece most parts of the population are dependent on the second hand market.

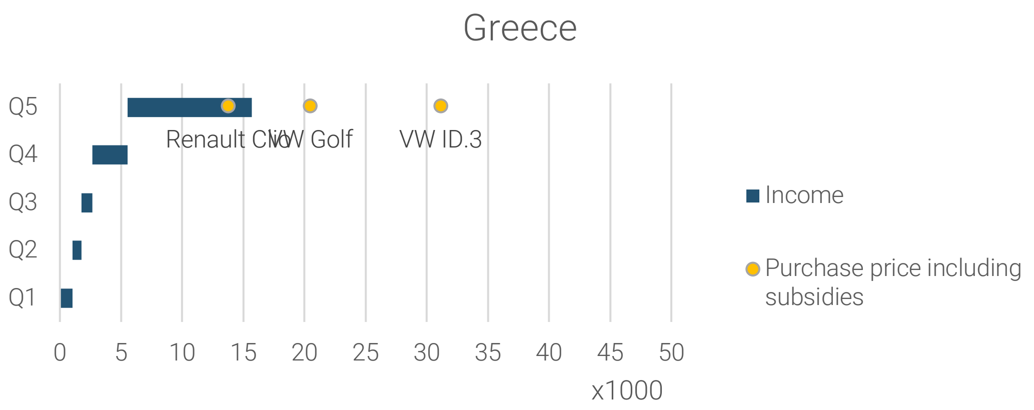


Figure 50 – Available budget ranges for new car purchases for all income quintiles in Greece and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in Greece is above average compared to the analysed countries. So, the share of public charging has a considerable impact on the economics of an VW ID.3 However, neither the annual range nor the share of public charging can make the Golf more affordable than the ID.3. No comparison could be made between the two Renault models, because the Renault Zoe is currently unavailable in Greece.

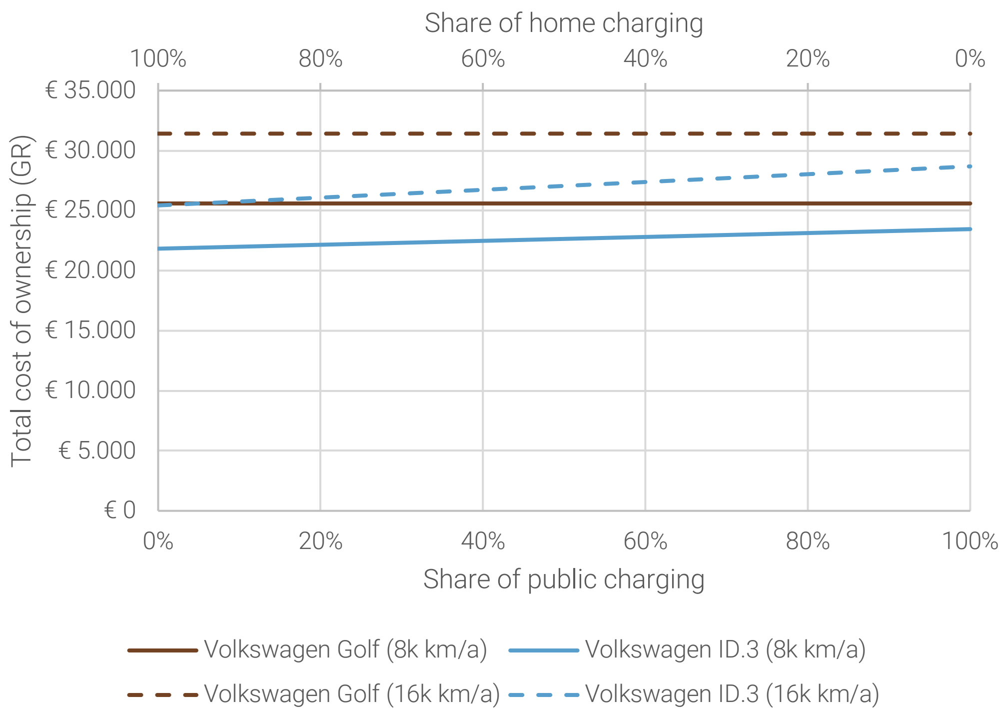


Figure 51 – Influence of the share of public charging on the total cost of ownership in Greece. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.9 Hungary

Hungary provides a purchase subsidy of around 6,950 €, if the car purchase price is below 30,500€. The budget for purchase subsidies reduced from 17 million € in 2020 to 8,5 million € in 2021. Electric vehicles are also exempted from ownership and registration tax in Hungary. Due to purchase subsidy for electric vehicles, the total cost of ownership of the VW ID.3 is less compared to the VW Golf. The Renault Zoe remains more expensive than the Renault Clio, even with the current subsidies in place.

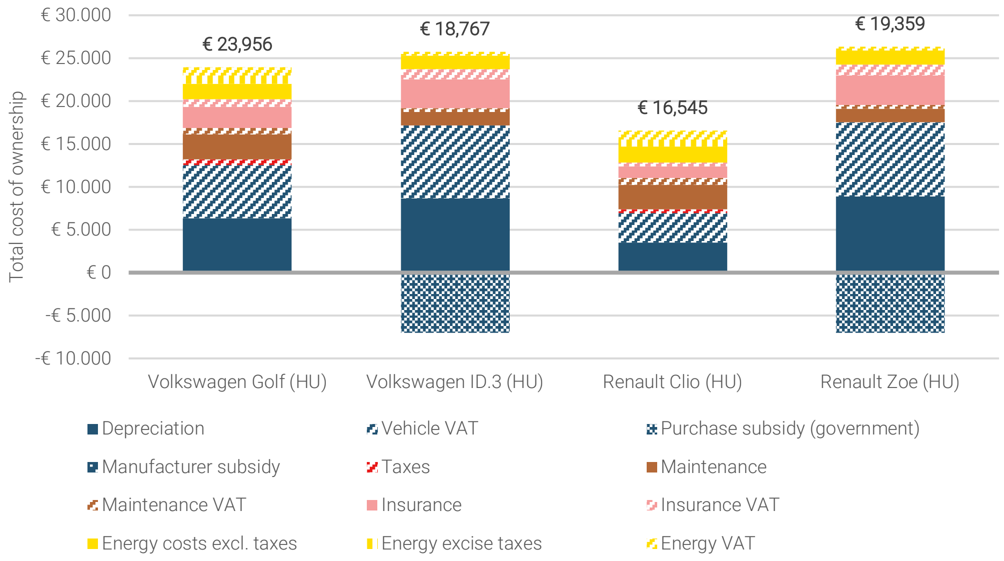


Figure 52 – The total cost of ownership of new cars in Hungary over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

However, most parts of the population cannot afford the upfront costs of purchasing a fossil fuel or electric car even with the purchase subsidies in place. In Hungary most parts of the population are dependent on the second hand market.

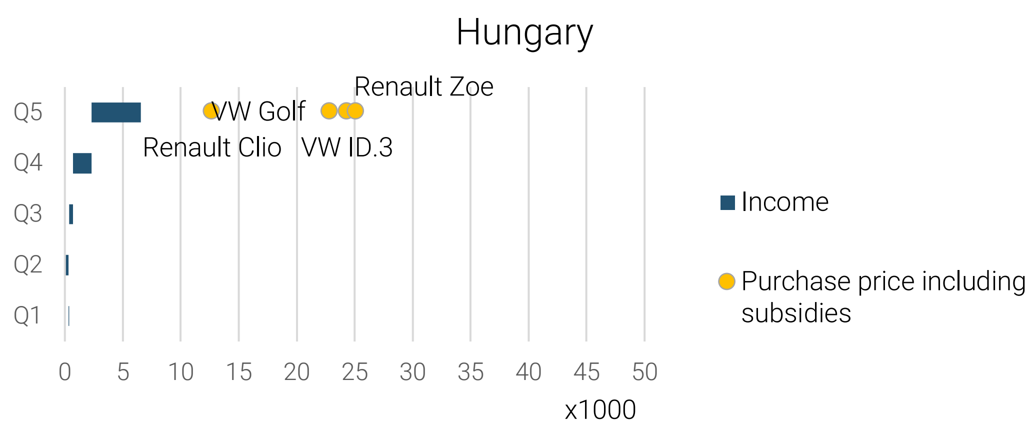


Figure 53 – Available budget ranges for new car purchases for all income quintiles in Hungary and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in Hungary is above average compared to the analysed countries. This is because the household electricity prices are relatively low. So, the share of public charging has a considerable impact on the economics of an VW ID.3 However, neither the annual range nor the share of public charging can make the Golf more affordable than the ID.3.

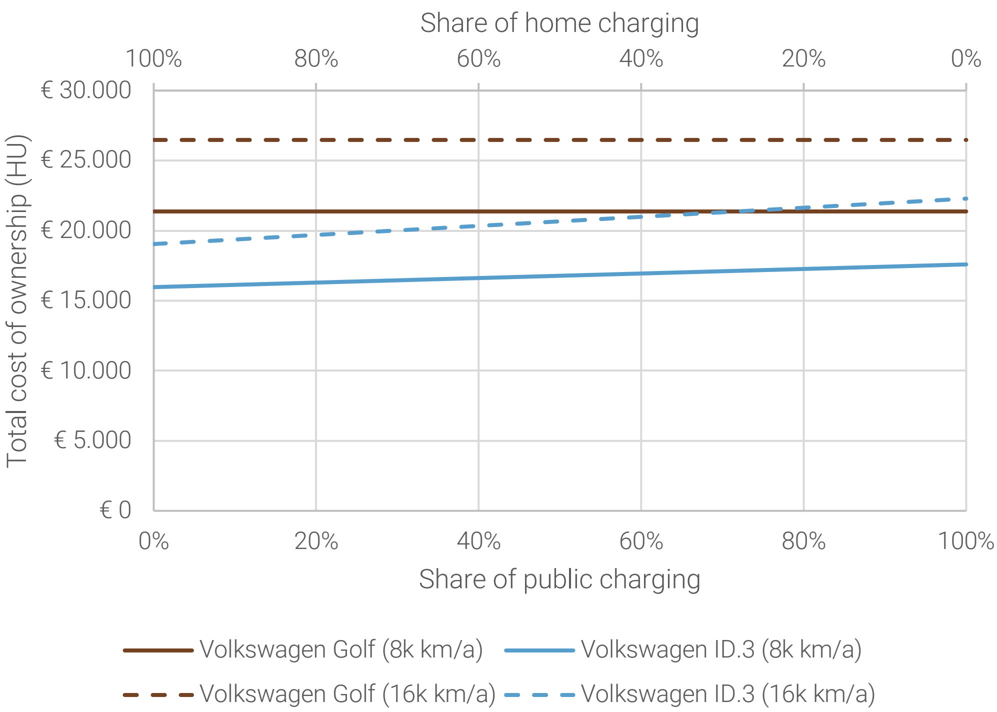


Figure 54 – Influence of the share of public charging on the total cost of ownership in Hungary. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

This is not the case for the Renault models, as neither the mileage or the share of public charging can make the Renault Zoe more affordable than the Renault Clio.

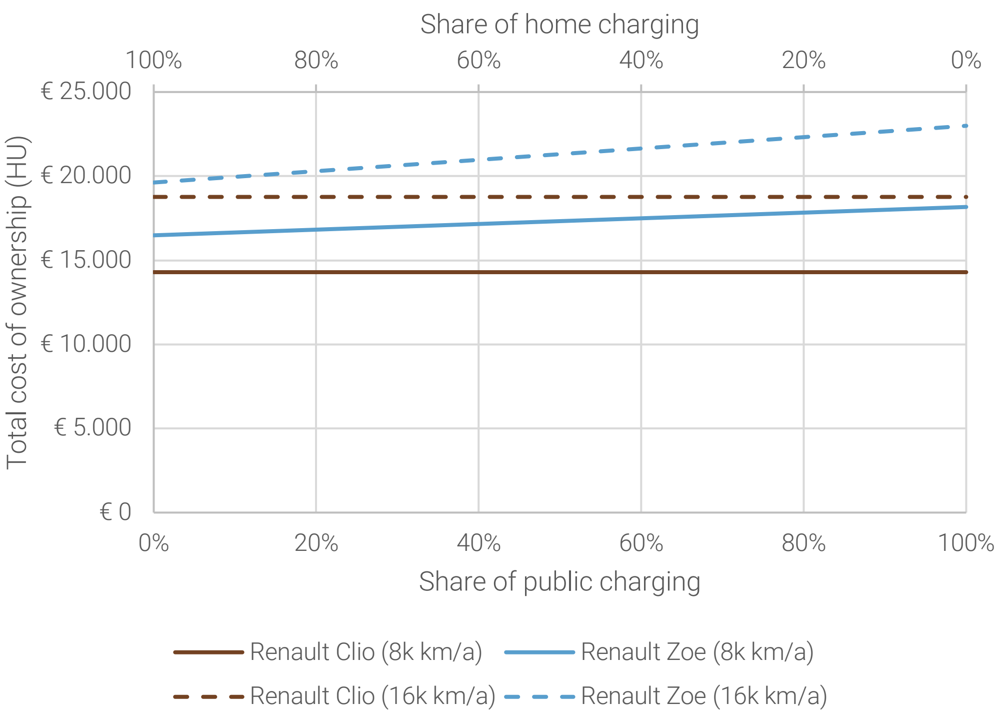


Figure 55 – Influence of the share of public charging on the total cost of ownership in Hungary. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.10 Italy

Italy provides a total budget of 312 million € in 2021 for electric vehicles incentives. For BEVs with a purchase price under 61,000 € they provide a subsidy of 5,000 €. However, there was a temporary increase between August and December 2020, where Italy provided a 6,000 € subsidy. Electric vehicles are also exempted from ownership taxes for a five-year period. The total cost of ownership of the ID.3 is 4,000 € cheaper than the VW Golf. Excluding the subsidies will make the VW ID.3 slightly more expensive than the VW Golf. The Renault Zoe remains more expensive than the Renault Clio, when including the subsidies the Renault Zoe remains 3,000 € more expensive.

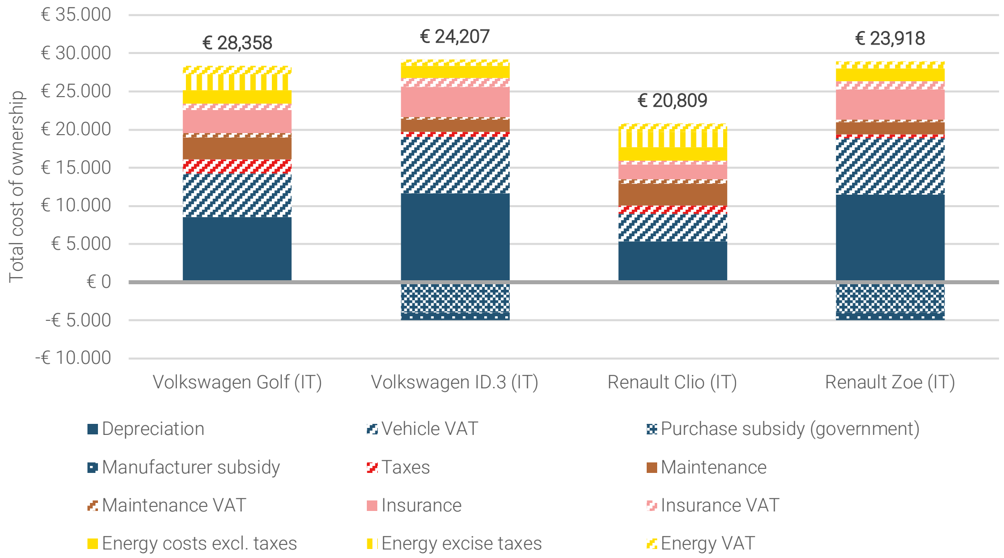


Figure 56 – The total cost of ownership of new cars in Italy over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

Most parts of the population cannot afford the upfront costs of purchasing a fossil fuel or electric car even with the purchase subsidies in place. Renault Zoe, VW ID.3 and Golf are only accessible by the top income quantile. The Renault Clio is affordable for Q4.

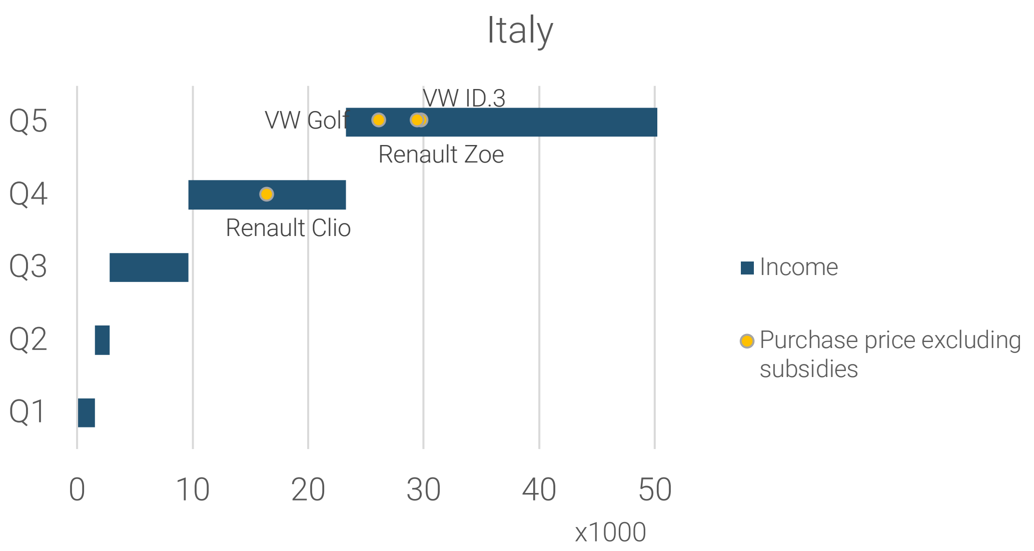


Figure 57 – Available budget ranges for new car purchases for all income quintiles in Italy and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in Italy is average compared to the analysed countries. Neither the difference in annual mileage or share of public charging can make the VW ID.3 more expensive than the VW Golf.

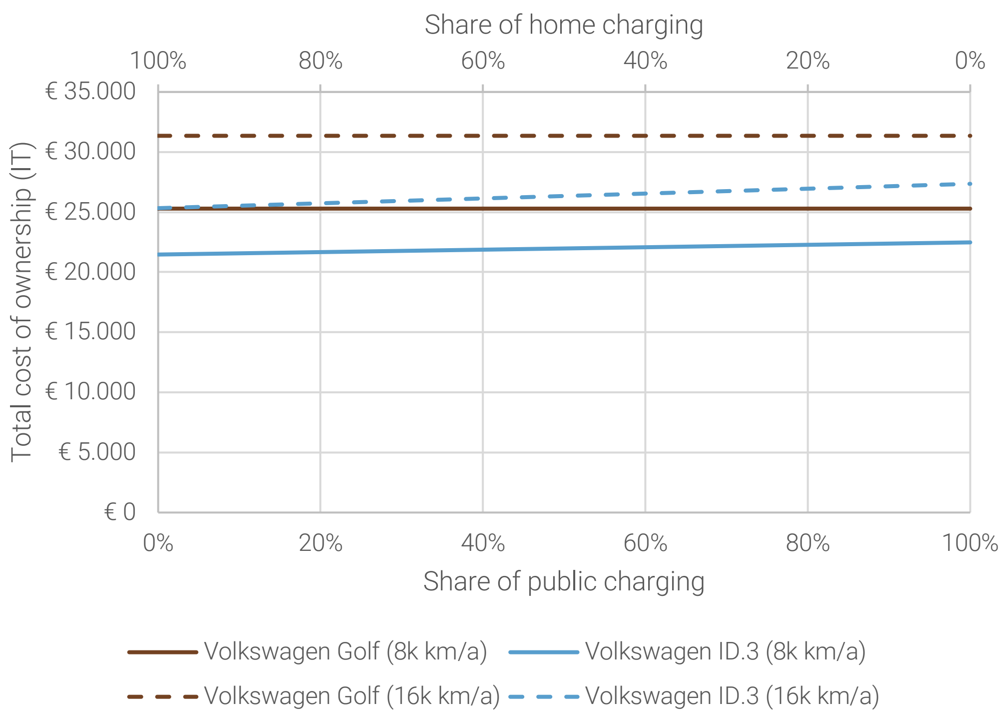


Figure 58 – Influence of the share of public charging on the total cost of ownership in Italy. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

This is not the case for the Renault models. Neither the difference in annual mileage or share of public charging can make the Renault Zoe less expensive than the Renault Clio.

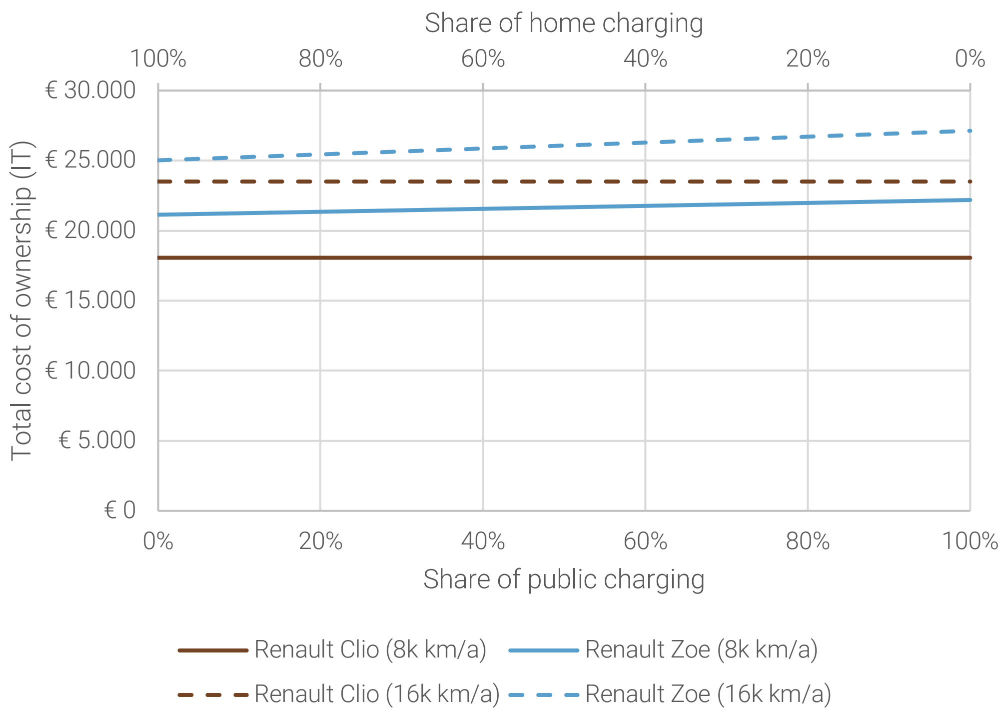


Figure 59 – Influence of the share of public charging on the total cost of ownership in Italy. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.11 Netherlands

For models up to 45,000 € catalogue price, the Netherlands gave BEV purchase subsidies of 4,000 €. However, the annual budget of 14.4 million € for 2021 was depleted within a day. De facto, if not ordered on the first day, the consumer therefore had no access to the purchase subsidy, unless they waited for next year's subsidy scheme. The 2020 budget was 10 million €. Furthermore, BEVs are exempt from ownership tax in the Netherlands.

If the subsidies can be received in time, owning a BEV is significantly cheaper than owning an ICEV. The VW ID.3 is 10,000 € cheaper to own over 5 years, while the Renault Zoe is 3,000 € cheaper to own.

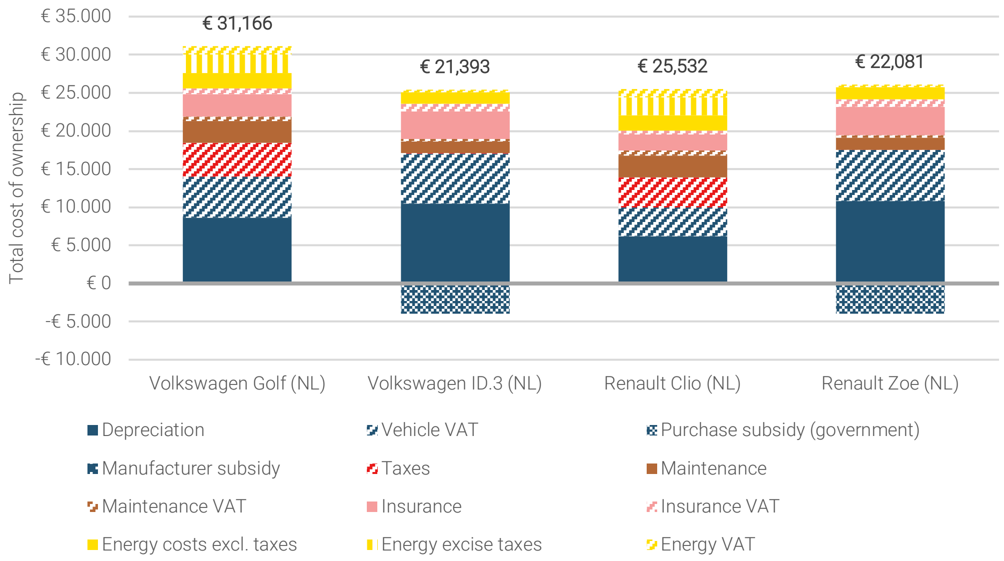


Figure 60 – The total cost of ownership of new cars in the Netherlands over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

The purchase of new vehicles remains only affordable for the top income quantiles. The Renault Clio for Q4 and the other three models for the top income quantile (Q5).

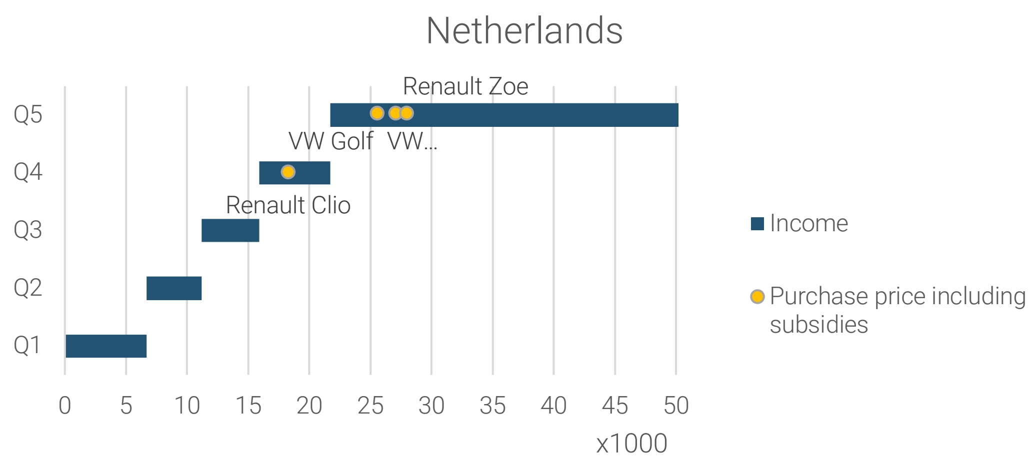


Figure 61 – Available budget ranges for new car purchases for all income quintiles in the Netherlands and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference in public charging prices and household charging in the Netherlands is average compared to the analysed countries. Neither the difference in annual mileage or share of public charging can make the VW ID.3 more expensive than the VW Golf.

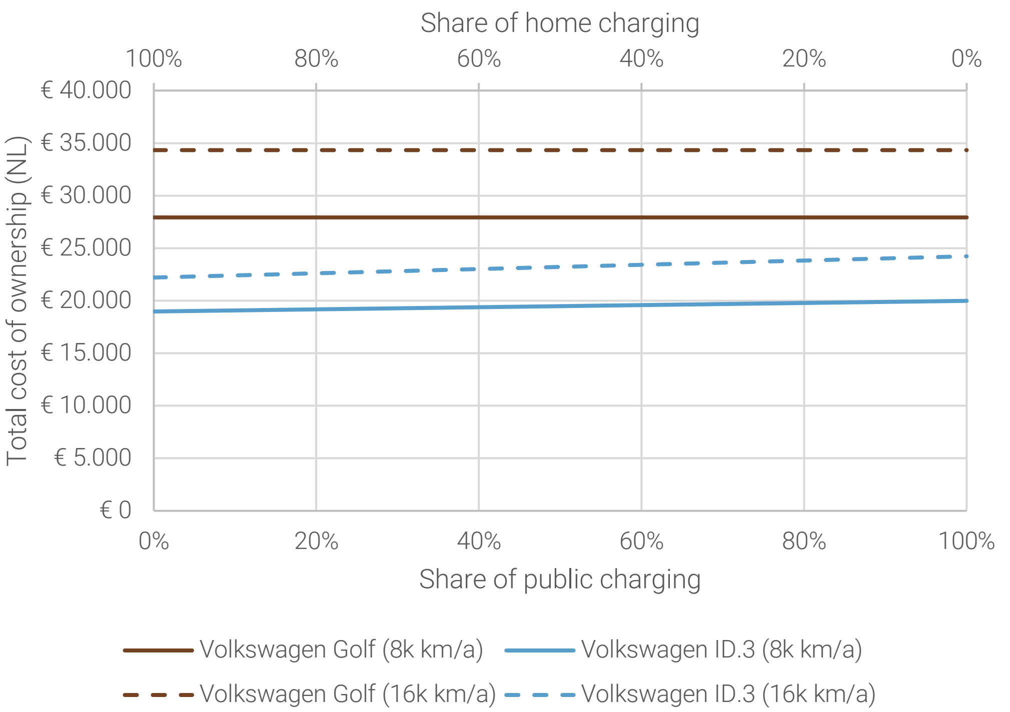


Figure 62 – Influence of the share of public charging on the total cost of ownership in the Netherlands. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

In the Netherlands the electric Renault is also cheaper than their ICEV counterpart. Neither the annual mileage or the share of public charging makes the Renault Zoe more expensive than the Renault Clio.

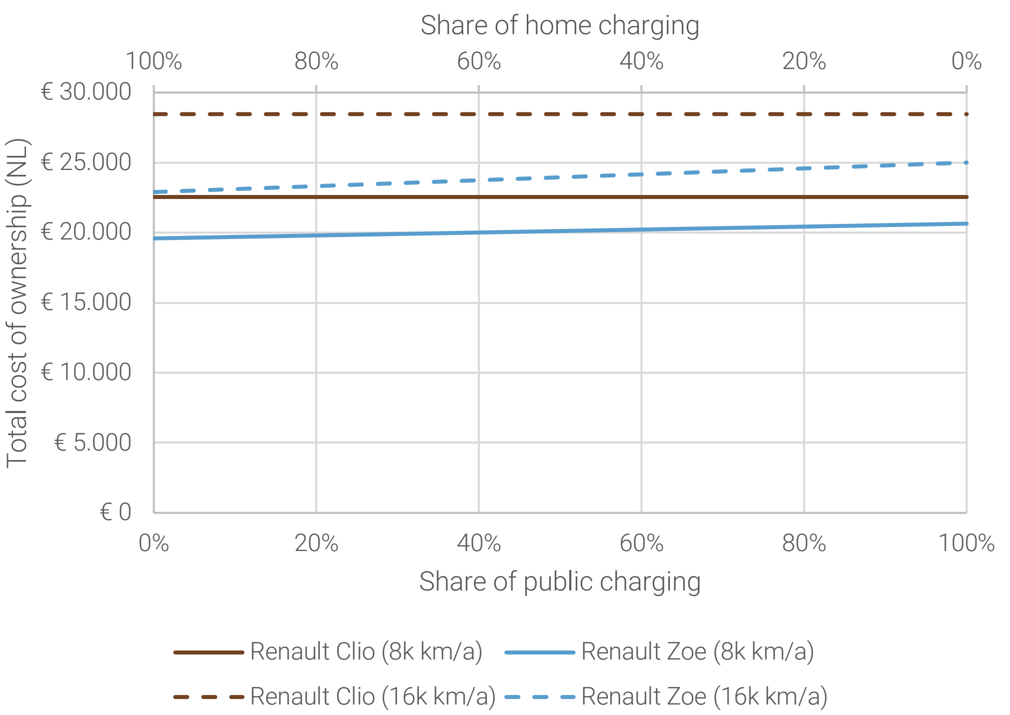


Figure 63 – Influence of the share of public charging on the total cost of ownership in the Netherlands. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.12 Poland

Older sources suggest that there was a subsidy on BEVs available in Poland of about 8,200 € per new vehicle. At the beginning of 2021, the subsidy scheme applied to up to 15% of the purchase price with a maximum subsidy of around 4,000 €. Only BEVs with a catalogue price of less than 27,500 € are eligible. The subsidy is limited to 2,000 BEVs in total and is valid until 2027. In addition, only a flat fee has to be paid when registering a BEV. Until 2021, BEVs were also exempt from purchasing tax.

Without purchase subsidies in place, it is particularly expensive to own a BEV in comparison to owning an ICEV. The cost difference is about 8,000 € over 5 years for the VWs and the Renaults.

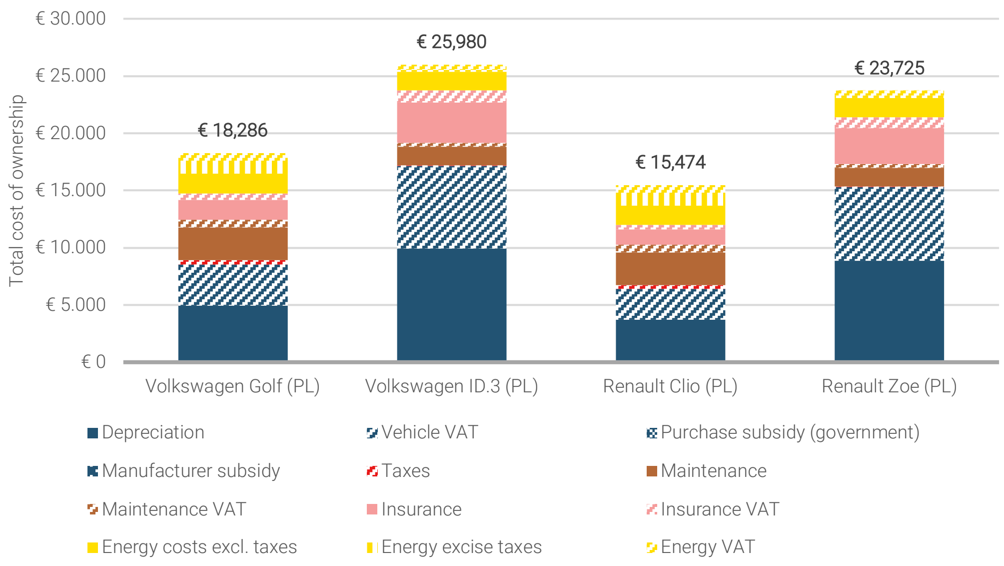


Figure 64 – The total cost of ownership of new cars in Poland over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

Similarly to the other countries, the new cars can only be afforded by the highest income quintile in Poland.

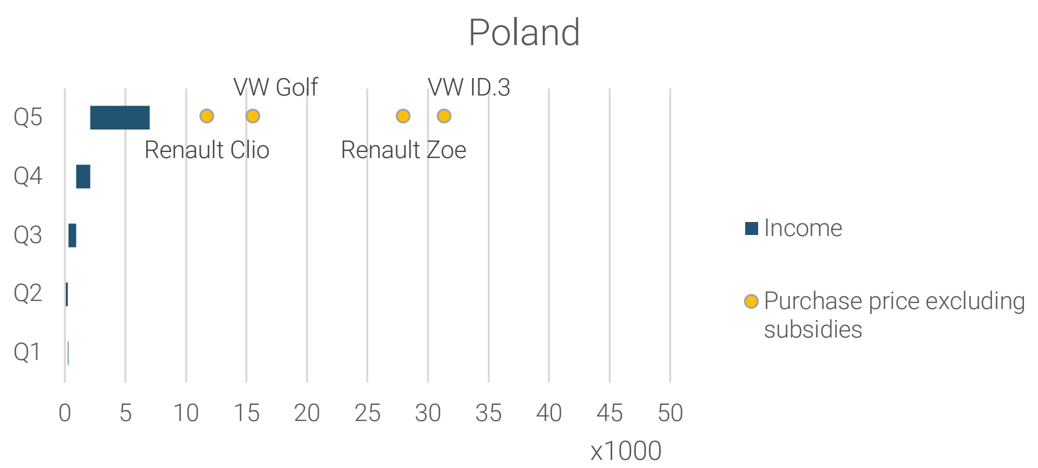


Figure 65 – Available budget ranges for new car purchases for all income quintiles in Poland and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

Since the gap between BEVs and ICEVs is with 8,000 € quite significant, changing the ratio of public charging to home charging has no impact on the results. In fact, it is even cheaper in Poland to own an ICEV that drives 16,000 km/a than to own a BEV that drives 8,000 km/a.

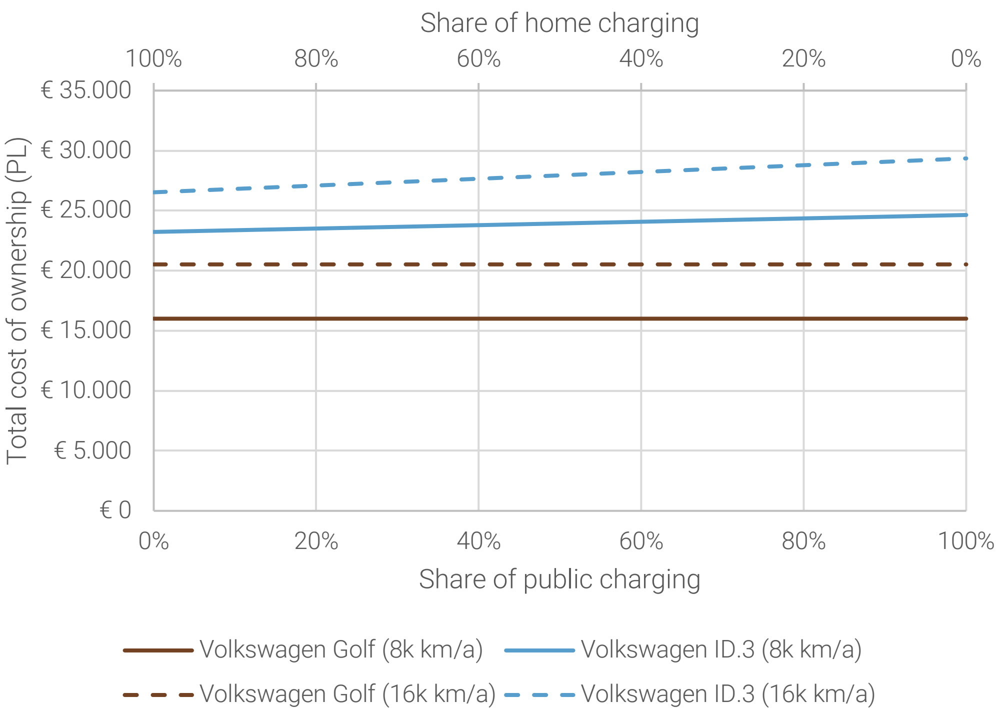


Figure 66 – Influence of the share of public charging on the total cost of ownership in Poland. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

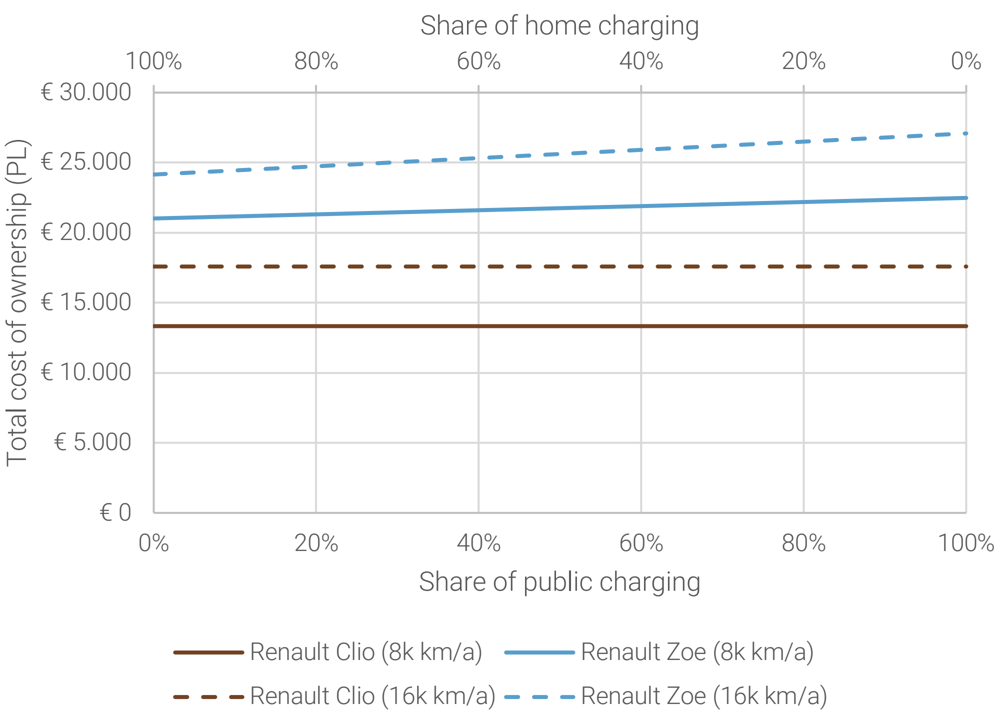


Figure 67 – Influence of the share of public charging on the total cost of ownership in Poland. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.13 Romania

Romania provides a high purchase subsidy for BEVs of 10,000 € with a total budget of 82 million €. This is enough to stimulate 8,200 BEVs in total (though it is unclear over how many years this total budget is spread). Moreover, BEVs are exempt from registration tax.

This high subsidy makes it particularly attractive to purchase a new BEV over a new ICEV. The ID.3 is 5,000 € cheaper to own over 5 years than the VW Golf. Even the Renault Zoe is cheaper to own over the Renault Clio in Romania.

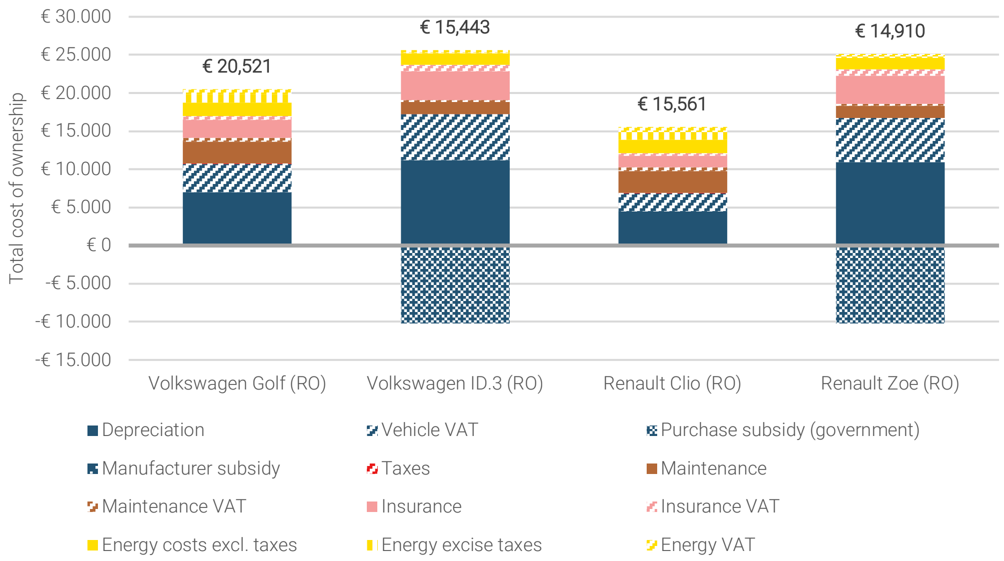


Figure 68 – The total cost of ownership of new cars in Romania over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

Nevertheless, only a small part of the Romanian population can afford new cars. The Romanian car market depends predominantly on second-hand cars. The high budget to support electric vehicles may not even be met by the demand of new cars in Romania.

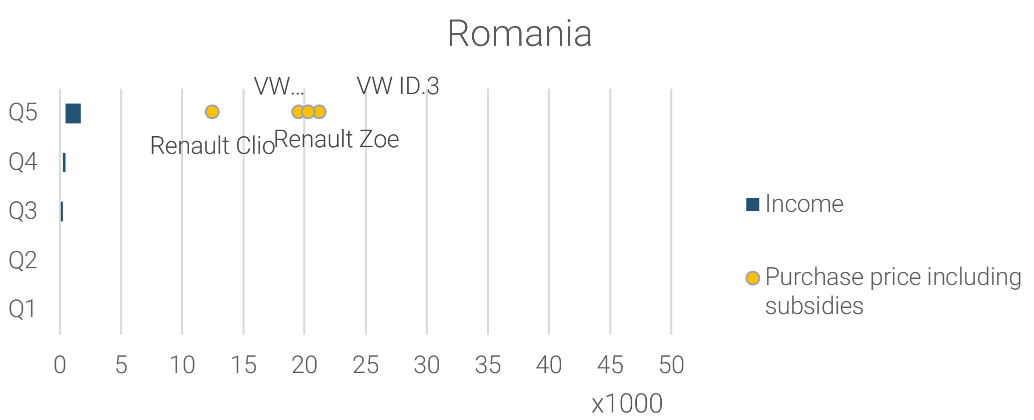


Figure 69 – Available budget ranges for new car purchases for all income quintiles in Romania and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference between public charging and household charging is with 22 ct/kWh slightly above the average of the analysed Member States. This makes it interesting for the Renault comparison, because for smaller and higher annual mileages, there is a break-even point where the Clio and the Zoe are on par. If exclusively charged in public, it may become slightly cheaper for car owners to choose the ICEV over the BEV.

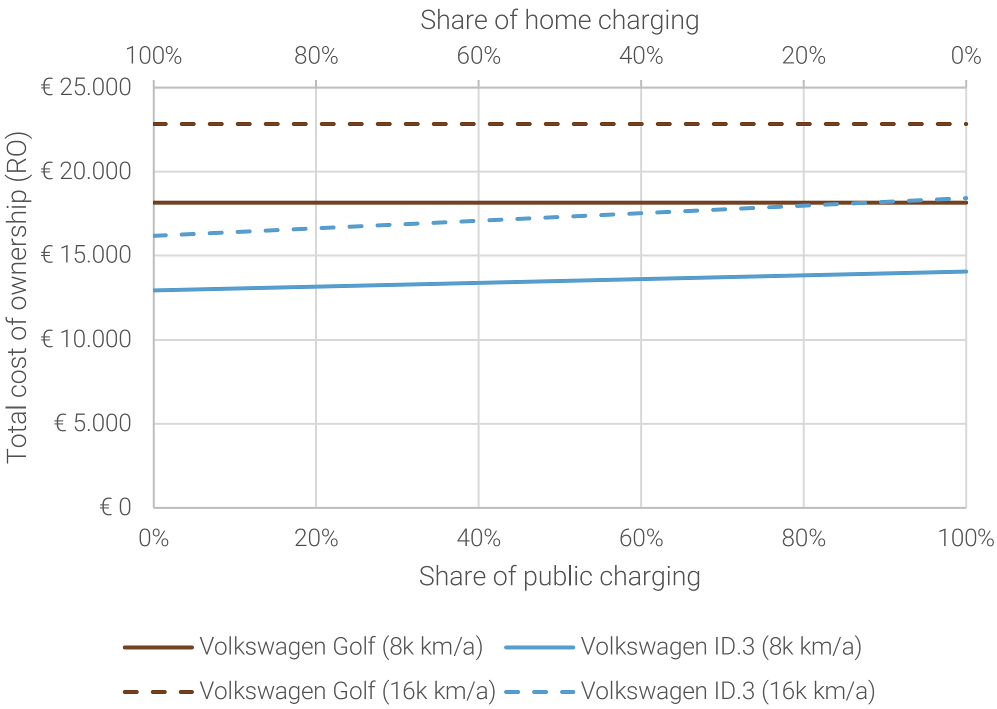


Figure 70 – Influence of the share of public charging on the total cost of ownership in Romania. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

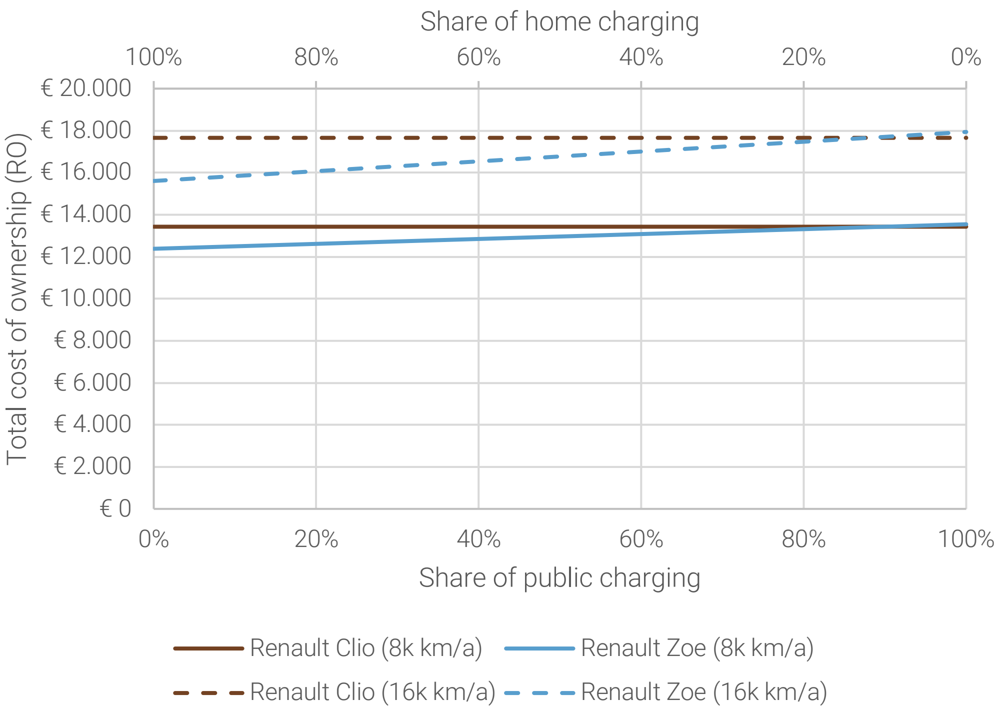


Figure 71 – Influence of the share of public charging on the total cost of ownership in Romania. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.14 Slovakia

Public sources gave evidence that there was a BEV purchase subsidy in place in Slovakia. In 2018, this subsidy amounted to about 5,000 € per BEV and 3,000 € per PHEV and had a total annual budget of 5.2 million €. Two years later, a second-round subsidy increased to 8,000 € for BEVs and 5,000 for PHEVs with an annual budget of 5 million €. This annual budget was enough to stimulate the purchase of up to 625 BEVs. Currently, there is not enough evidence to support that the subsidy has been continued, although there are plans to start a third round of support based on EU funds. BEVs owners do pay, however, the lowest possible amount of registration tax.

Without these subsidies, BEVs are considerably more expensive than their ICEV counterpart. The VW ID.3 is about 7,000 € more expensive over the course of 5 years, while the Renault Zoe is about 10,000 € more expensive. Subsidies are therefore necessary to bridge the gap for the consumer.

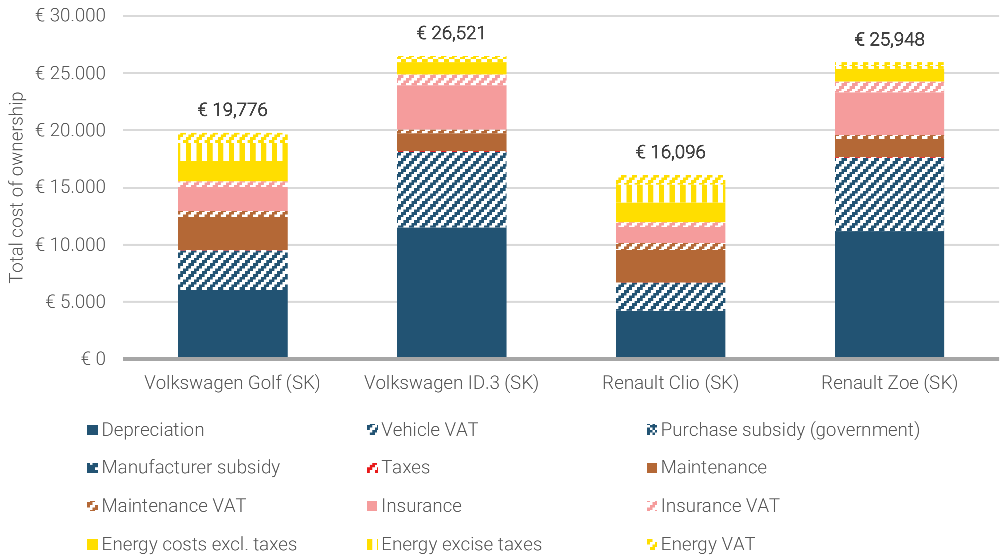


Figure 72 – The total cost of ownership of new cars in Slovakia over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

Slovakia primarily depends on the second-hand car market, as the majority of the population does not have the available mobility budget to be able to afford a new car.

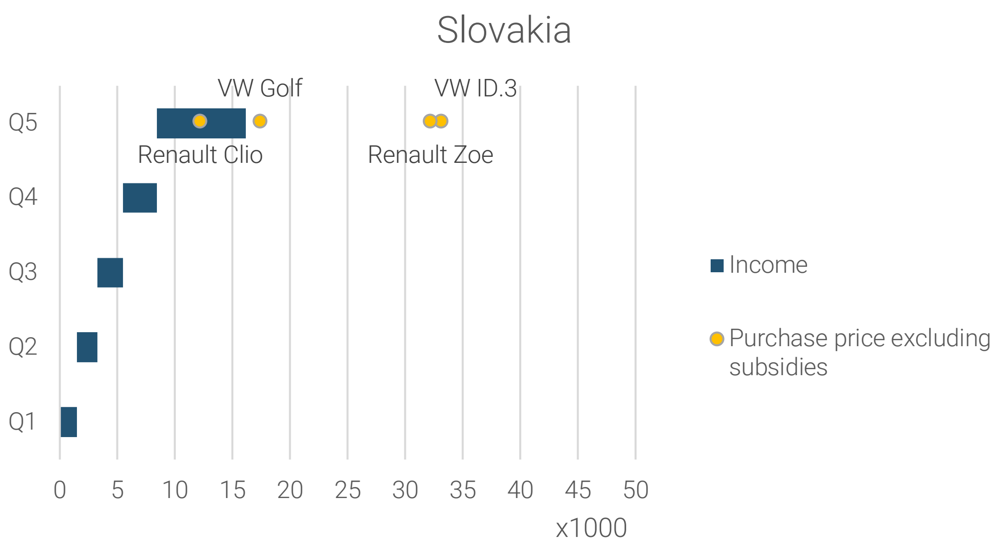


Figure 73 – Available budget ranges for new car purchases for all income quintiles in Slovakia and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

With only 8 ct/kWh, the difference between public charging and home charging plays barely any role in the affordability of an electric vehicle in Slovakia.

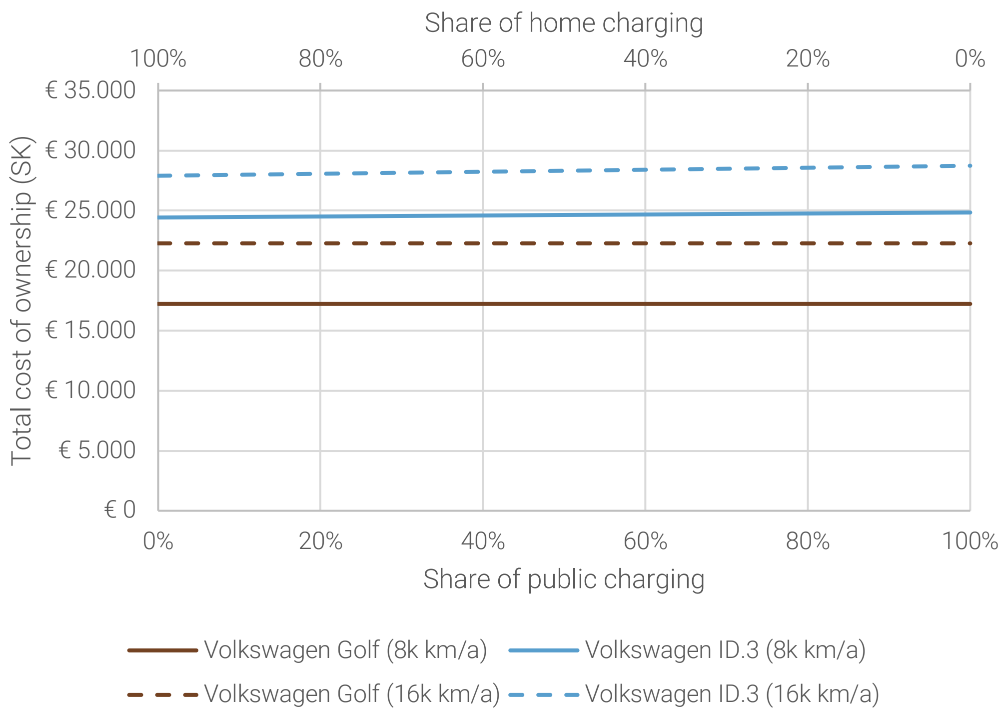


Figure 74 – Influence of the share of public charging on the total cost of ownership in Slovakia. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

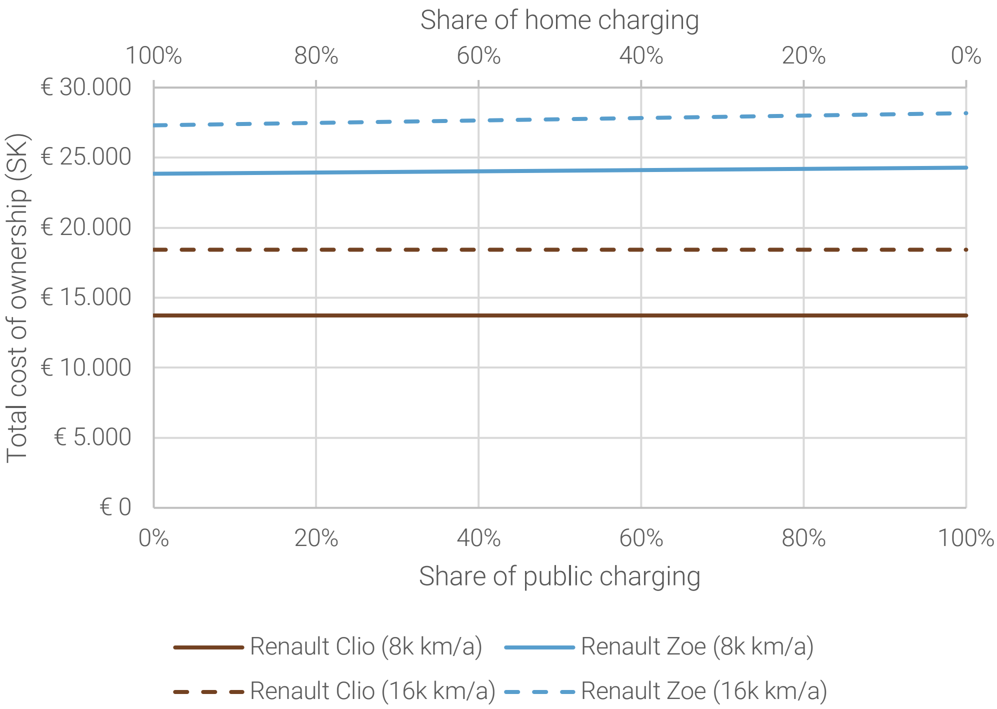


Figure 75 – Influence of the share of public charging on the total cost of ownership in Slovakia. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.15 Slovenia

Slovenia has a subsidy scheme of 7,500 € for the acquisition of a new zero-emission vehicle in place. Furthermore, BEVs have a road tax exemption and BEV owners pay the lowest rate of tax on motor vehicles. Nevertheless, taxation of vehicles is low in Slovenia by default.

The subsidies make owning a BEV attractive to the consumer. It is about 2,000 € cheaper to own a VW ID.3 over 5 years than to own a VW Golf. Owning a Renault Zoe, on the other hand, is still about 3,000 € more expensive than owning a Renault Clio. Without subsidies, both electric vehicles would be significantly more expensive than their ICEV counterpart.

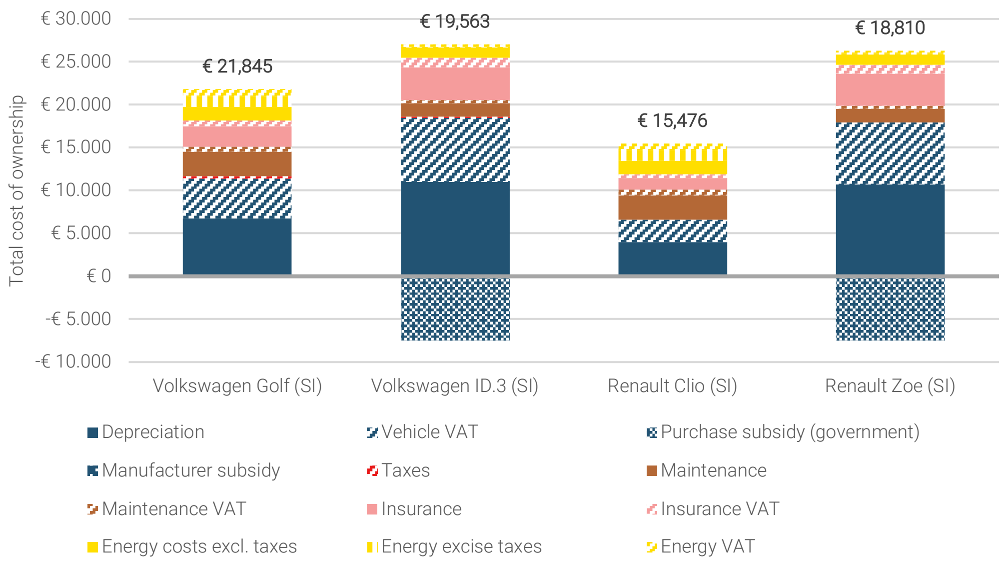


Figure 76 – The total cost of ownership of new cars in Slovenia over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

In Slovenia, owning a new car is mostly restricted to the highest income quintile. The Renault Clio, however, may already appeal to the upper part of the third income quintile.

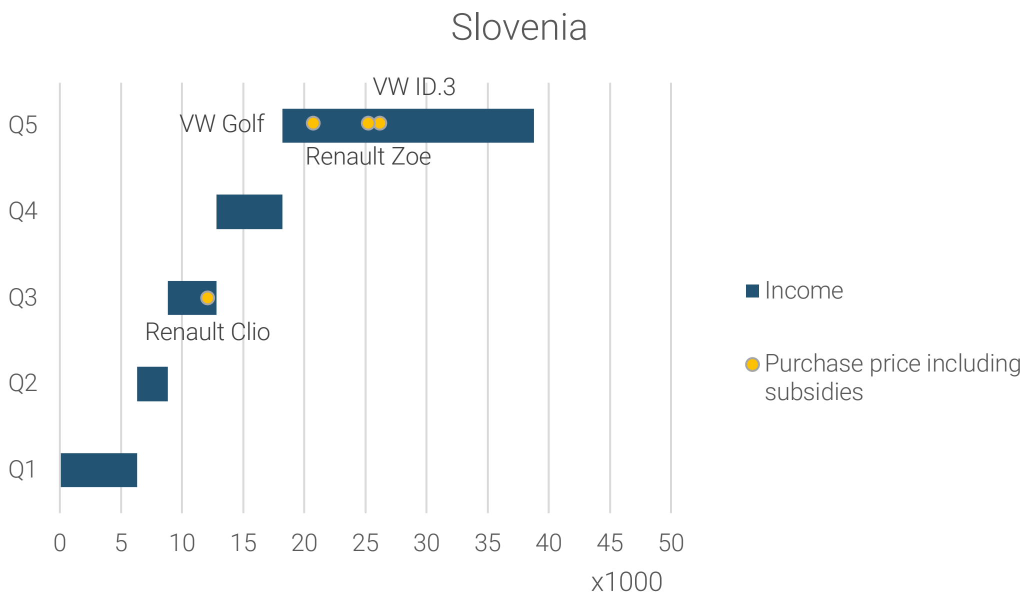


Figure 77 – Available budget ranges for new car purchases for all income quintiles in Slovenia and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The difference between public charging and home charging is with 13 ct/kWh quite low. The percentage of public charging therefore only plays a minor role in the affordability of BEVs in Slovenia.

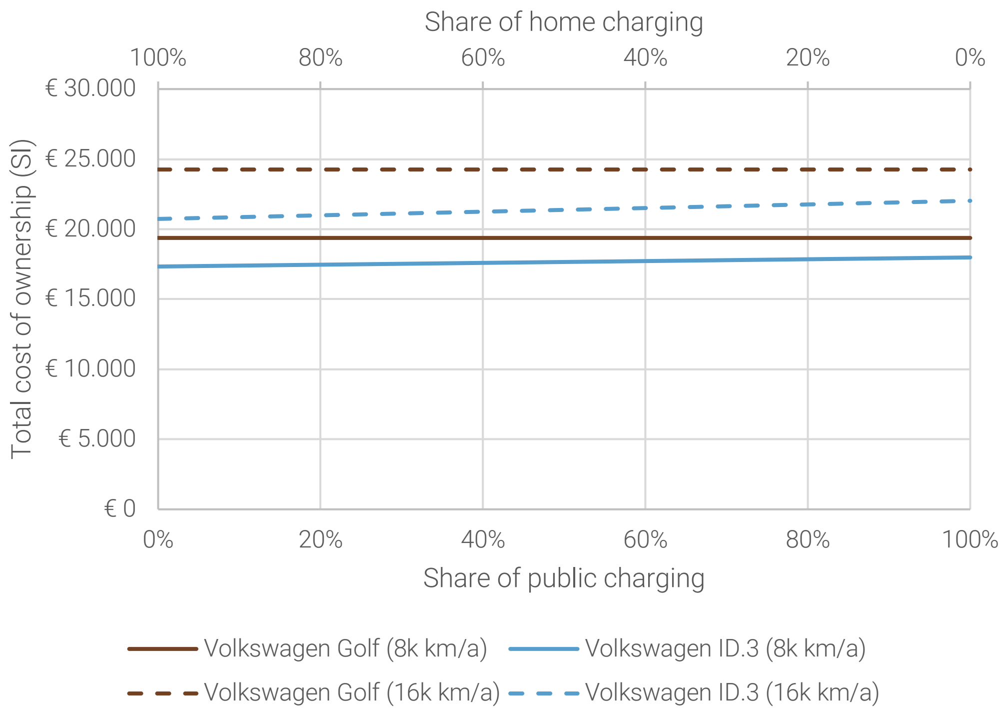


Figure 78 – Influence of the share of public charging on the total cost of ownership in Slovenia. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

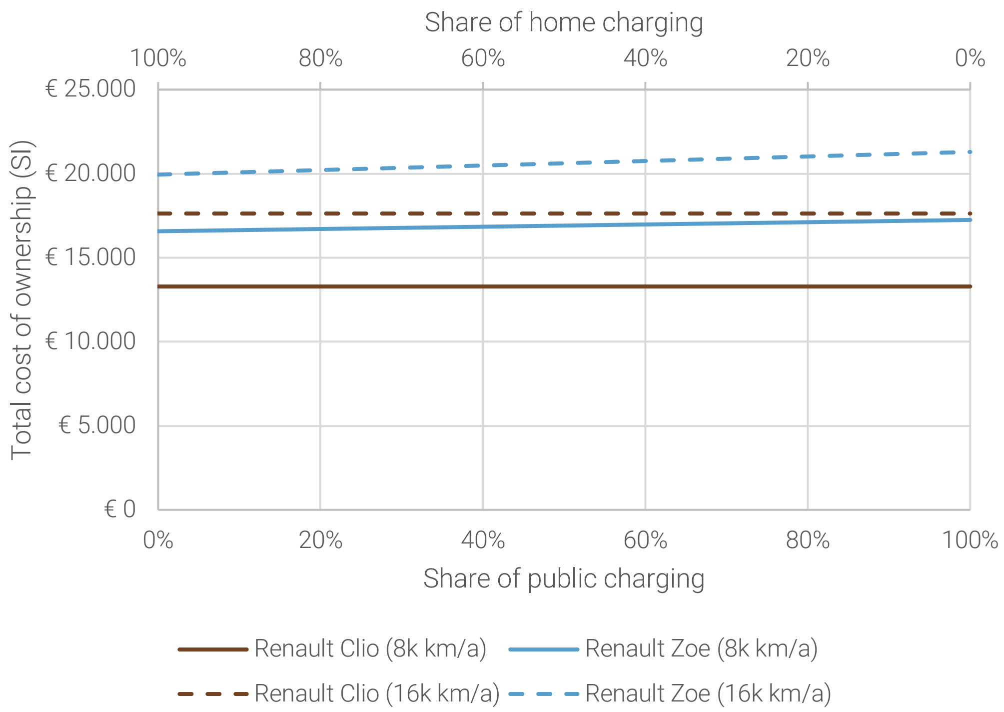


Figure 79 – Influence of the share of public charging on the total cost of ownership in Slovenia. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

A.3.16 Spain

While the Spanish government announced their ambitions to subsidise BEVs in the near future, public sources suggest that the subsidy scheme is still debated and refined and not accessible yet. Therefore, no subsidy was taken into account for Spain, although the situation may change in the future.

Without support, it is 2,000 € cheaper to own a Volkswagen ID.3 than to own a VW Golf. This can be partly explained by the fact that the cheapest available Golf in Spain is more performant than in other countries. It has a 1.5 L cylinder capacity (as opposed to 1.0 L in most other countries) and 110 HP instead of 90. This performance increase renders direct comparisons more difficult.

Similar to other countries, owning a Renault Zoe is considerably more expensive than owning a Renault Clio. The difference is about 4,500 € over of 5 years of ownership.

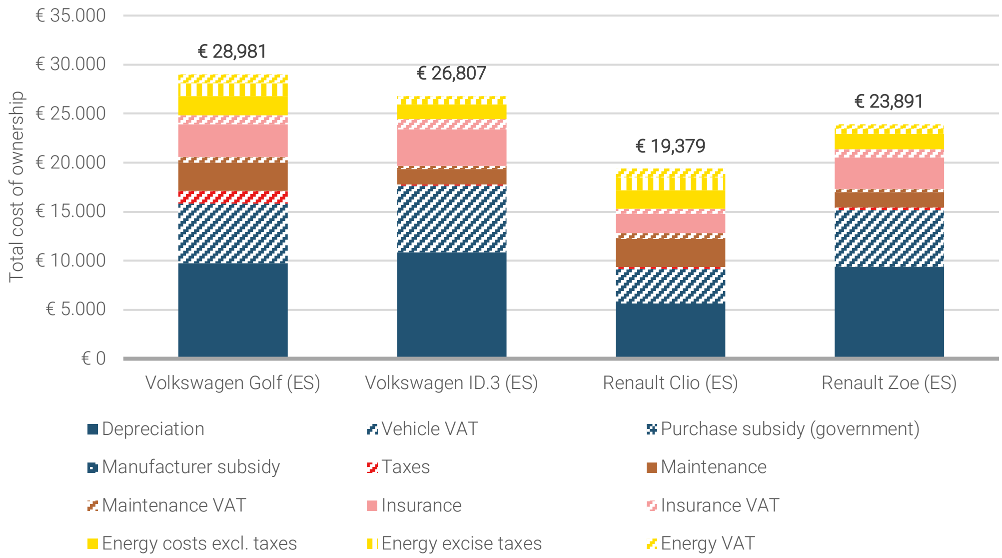


Figure 80 – The total cost of ownership of new cars in Spain over a period of 5 years when driven 12,000 km/a. For BEVs, the public charging ratio is assumed to be 50%. The bolded labels present the result of ownership costs minus purchase subsidies.

Spain's mobility budget distribution suggests that most of the analysed cars are only accessible to the highest income quintile. A new Renault Clio may also be affordable for the second highest income quintile.

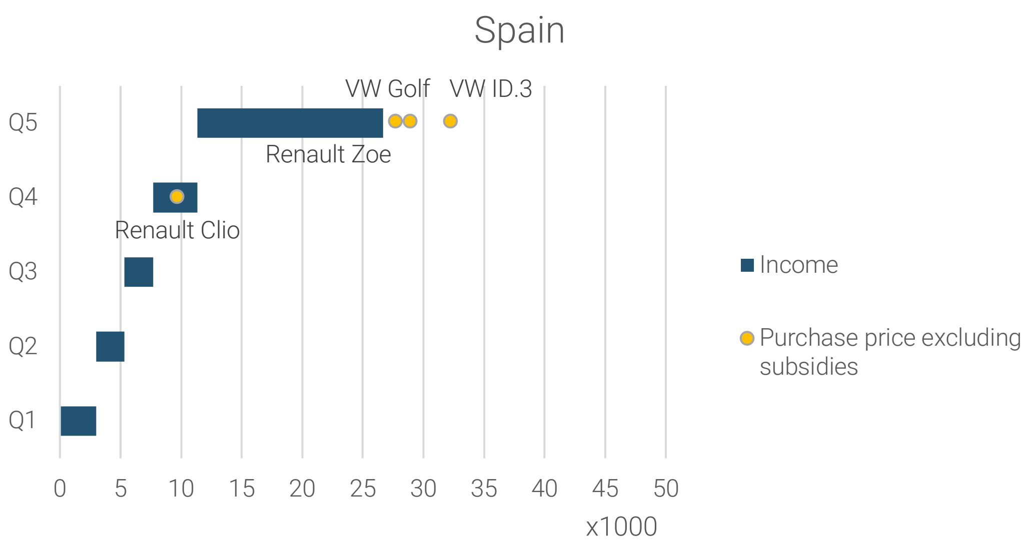


Figure 81 – Available budget ranges for new car purchases for all income quintiles in Spain and the catalogue prices of new ICEVs (blue) and new BEVs (yellow).

The price difference between public charging and home charging is with about 18 ct/kWh slightly below the average amongst the analysed countries. Therefore, varying public charging from 0 to 100% does not highly influence the results. For someone who uses the car occasionally (less than 8,000 km/a) and would have to rely primarily on public charging, the VW ID.3 and the VW Golf may be on par. Otherwise, the ID.3 is mostly the preferred option. The gap between the Renault Clio and Zoe is more significant, therefore the Clio is always the cheaper option.

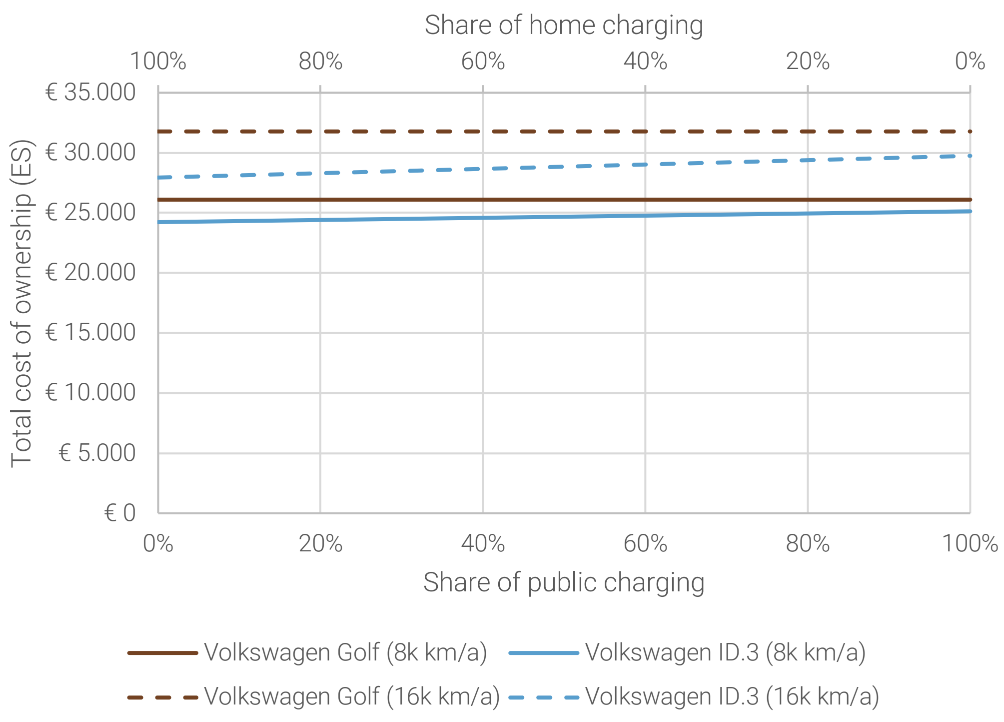


Figure 82 – Influence of the share of public charging on the total cost of ownership in Spain. The blue lines represent the VW ID.3 for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the VW Golf for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

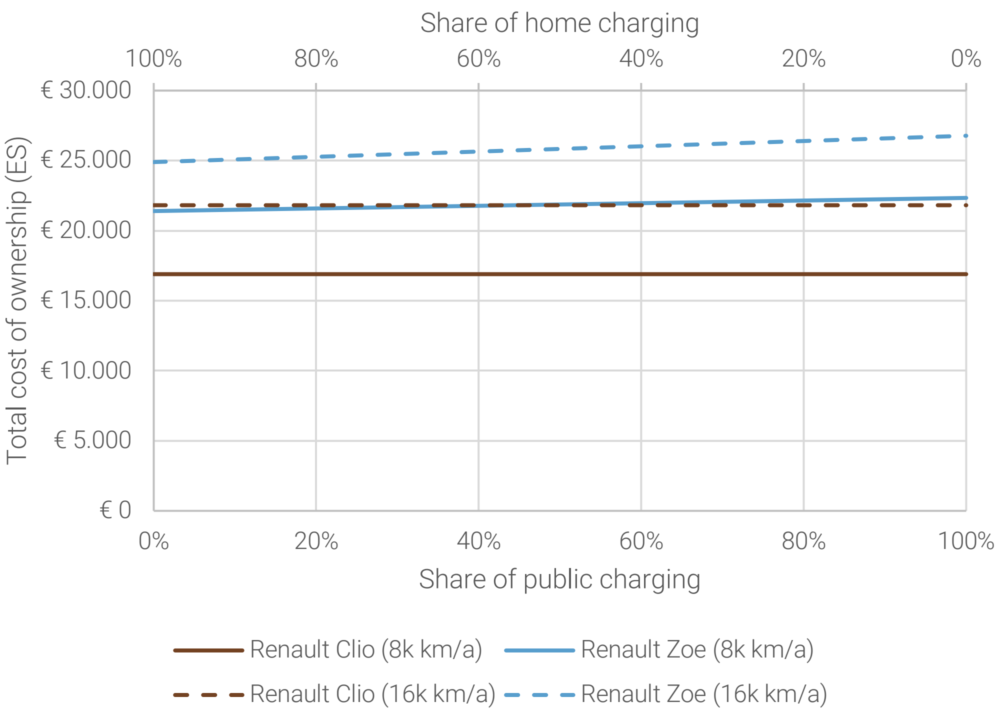


Figure 83 – Influence of the share of public charging on the total cost of ownership in Spain. The blue lines represent the Renault Zoe for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres. The brown lines represent the Renault Clio for an annual mileage of 8,000 (solid) and 16,000 (dashed) kilometres.

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