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The transition to electric vehicles in the private fleet (GREENPARK)

Identification of the technical, societal and taxation framework for an efficient transition to greener fleets

FEDERAL PUBLIC SERVICE
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Dit rapport is eveneens beschikbaar in het Nederlands.

Table of contents

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List of tables and figures

Executive summary

Background and aims

The electric vehicle (EV) market in Europe continues its remarkable growth that was unforeseen five years ago by most forecasters. Also in Belgium, the market for EVs is taking off. Policy makers have made radical decisions in ending the sale of fossil fuel vehicles within 10 to 15 years to tackle the climate emergency. OEMs are following the trend and are committed to moving from internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). Private buyers are seeing the momentum, too, but not all are convinced as the purchase price is still a bottleneck.

This study aims to provide an overview of the current situation and foreseen actions in Belgium and other countries. Secondly, buying intentions, attitudes, barriers and incentives to make the switch to EVs in Belgian private drivers are studied. Then, we aim to forecast the deployment of BEVs and the related charging infrastructure. All of this has an impact on the environment and society – but what are the main points of attention? Finally, the findings are translated into recommendations for policy actions.

State-of-the-art in Belgium

In 2022, about 1% of the passenger car fleet in Belgium was a BEV, corresponding to ~81,000 vehicles, and approximately 4% had some form of electrification (BEV and plug-in hybrid, PHEV). Despite this small share, there has been strong growth in the sales of BEVs in recent years. But especially the private market for BEVs is still small: in 2022, 87.1% of newly registered BEVs were company-owned cars. For private buyers, there are currently no direct subsidies when buying an EV. There are some tax benefits but the tax difference between EVs and non-EVs is relatively small for the most popular vehicle models.

In Flanders, the desire was expressed that all new cars should be zero-emission from 2029. This is however legally difficult to enforce (no regional competence), but could be indirectly enforced by, for example, sharply increasing the registration tax for ICEVs. The Brussels regional government will ban diesel vehicles from 2030 and petrol/LPG vehicles from 2035 from their streets through the Low Emission Zone (prohibition to drive). Wallonia will follow EU regulations that prohibit the sales of fossil fuel cars from 2035 – for the moment, more ambitious targets were not set – facing the same legal constraints as mentioned above for Flanders.

EVs need to be charged. The number of charging points has developed rapidly since 2013, and especially since 2019. In 2021, there were >12,000 public charging points (AC recharging) and >800 fast chargers (DC recharging). In total there were almost 100,000 charging points installed in Belgium in 2022, including private charging infrastructure. There are now on average 5.5 public charging points per 100 km in Belgium. An EU-appointed commission states that countries should aim for a maximum of 10 EVs per public charging point – currently we are around 13 EVs per public charger.

The total cost of ownership (TCO) refers to the total sum of the costs of a vehicle over the lifetime of the vehicle, minus its residual value. The TCO is dominated by the purchase cost. Taxes make up a very small part of the TCO in Belgium. In 2022, averaged over all car segments and with an assumed lifetime of 9 years and 135,000 km, BEVs are the cheapest option when compared to similar petrol or diesel cars. BEVs are not the cheapest option when considering the purchase price, but they are when considering the TCO. Mainly for more expensive cars in terms of their purchase price, the TCO is at the advantage of BEVs. For smaller cars in segments B (Opel Corsa, Peugeot 208) or C (VW Golf), the difference between fuels is small, however, for now, ICEVs are still cheaper over their lifetime. When the mileage of BEVs would be increased from the assumed 135,000 km to 150,000 km (but not the lifetime, so a higher mileage per year), BEVs are expected to have an even lower TCO because of the low recurrent costs compared to ICEVs. When the lifetime of cars would be increased from 9 years to 15 years (but not the total mileage, so fewer kilometres per year), it is observed that BEVs are no longer the cheapest option: petrol cars now have the lowest TCO. When the electricity price would increase by more than 16%, the TCO of a petrol-fuelled car would be the lowest (without changes in the prices of diesel or petrol). Changes in the charging mix have a much smaller impact (e.g. more charging at home).

The carbon footprint of each phase in the lifetime of a vehicle is assessed for BEVs compared to ICEVs. BEVs have higher materials CO_2 emissions (cradle-to-grave, mainly because of the production of the battery), but lower energy CO_2 emissions (well-to-wheel) compared to fossil fuel vehicles. In total, BEVs on the Belgian market always have lower life cycle CO_2 emissions compared to fossil fuel cars because of no CO_2 exhaust emissions and the favourable energy mix. Roughly one-third of the CO_2 emissions from a BEV is from vehicle production, one-third from battery production, and one-third from the use (i.e. electricity for charging). Emissions from battery production can be halved by moving the battery production to Europe. A larger share of renewable energy can reduce emissions from charging a BEV by up to 75%. Recycling gives rise to a 49% reduction in vehicle manufacturing emissions and a 10-12% reduction in battery manufacturing emissions (following current European practices).

State-of-the-art in other European countries

Norway is identified as a frontrunner in the electrification of the fleet, with >88% of new car sales being electric compared to 26.5% in Belgium. Norway reached this point by offering a diverse set of incentives, both financial and non-financial. All countries studied have some incentives in place to stimulate the sales of EVs. The measures are diverse and include purchase subsidies, but also taxes that impact the use with a differentiation for EVs and ICEVs. Most incentives have time and volume limits, and several countries are planning to cut back or phase out current incentives.

Country reports in attachment 2 of this report provide more details by country (the Netherlands, United Kingdom, Norway, Sweden, France, and Germany).

Consumer profiles: a survey

There is no systematic survey of drivers in Belgium about electric driving. As a result, there is little knowledge on the determinants of a transition to fully electric driving, and on the general attitude towards the technology and the transition towards electric fleets. Barriers and facilitators that work for private drivers in Belgium are unknown. Therefore, an online survey was performed in May 2022 in >2000 representative drivers to identify consumer profiles.

- The attitude towards EVs is a decisive factor in consumers' car purchase intentions: EV enthusiasts are 10 times more likely to purchase a BEV than those who are hesitant.
- Whereas innovators are motivated by the technological side of the EV, the majority will probably be motivated to drive electric in a different way (lower purchase price, no noise or vibration, no shifting).
- (Purchase) price is important: The purchase price is by far the most important cost factor (in TCO) for consumers. Consumers with higher budgets are more likely to buy an EV. The still-to-develop second-hand market for EVs is important for those in the price segment below €20,000 and willing to buy an EV.
- Financial incentives are the most encouraging, in addition to having access to a (public) charger which is also considered important. The lack of charging infrastructure may become a barrier to the broader adoption of electromobility as the number of EVs is growing.
- There is a lack of knowledge about EV technology, prices and charging options. We identified a gender and age gap (women and older people are less inclined to buy an EV), differences according to the level of education (highly educated drivers are more interested in buying an EV), and regional differences (people in Wallonia are more hesitant).

Deployment scenarios

A modelling approach was developed to forecast the future car population by the powertrain. Different scenarios evaluate the stock turnover, ranging from a baseline scenario to a 100% BEV sales scenario. Projected increases in the demand for mobility (in the form of higher car ownership) are taken into account. It is important to note that vehicle fleets turn over at a slow rate. Even with 100% of car sales that are zero-emission, it does not mean that the next year all cars on the road will be zero-emission. By 2030, the share of BEVs in the whole fleet ranges from 26% in the Norway scenario (realistic market penetration of EVs mimicking growth rates in Norway) to 74% in the 100% BEV scenario. The latter figure is the result of the most optimistic scenario with all electric car sales from 2024 onwards.

Compared to earlier studies, our predictions are rather optimistic concerning the transition to a zero-emission car fleet. With the recent announcements of a sales ban for fossil fuel cars in Europe and the introduction of zero-emission zones (for example in Brussels), there are reasons to believe that the transition will be and should be accelerated. We did not account for possible new (zero-emission) motor technologies, e.g. hydrogen. Also, we did not consider factors that might impede the transition to BEVs, like a shortage of charging infrastructure, and delays in car deliveries (EV supply quotas that cannot meet the demand in Belgium).

In parallel with the increase in the electric fleet, the number of charging points needs to increase exponentially. A concise estimation of the growing need for charging infrastructure was performed for this study. We predict a total need for 1.7 million public and private charging points in 2030 in Belgium, from the almost 100,000 that are installed in 2022. This results in an increased roll-out of charging points from 1,750 per week in 2022 to 5,500 per week in 2030.

Impact assessment

A holistic overview of the environmental and societal impact of EVs is presented taking into account the expected evolution of EVs in the private fleet. The impacts studied are life cycle CO_2 emissions of cars; direct air pollution emissions from transport; noise from road transport; congestion; road and fire safety; fairness of the mobility system; and organization of the mobility system including mode choice.

- Emissions (CO_2 and other air pollutants) impact of ICEV phase-out: A largely positive impact of BEVs is to be expected. Non-exhaust emissions become more important and need to be regulated (Euro 7 limits).
- Noise: There is no motor noise in BEVs: it's mainly on roads with lower speed limits that BEVs reduce noise. At speeds above 50 km/h, rolling noise dominates and there is no significant noise reduction left from BEVs compared to ICEVs. In areas with lower speed limits, noise annoyance of local residents reduces.
- Congestion: Replacing ICEVs with BEVs has no direct impact on congestion. However, the predicted increase in car ownership and car use will likely worsen the congestion problem.
- Road safety: The impact on traffic safety needs to be monitored as evidence appears. The weight of BEVs, the lack of noise, and the aggressive acceleration are issues of concern.
- Fire safety: Fire from EVs / batteries needs to be handled differently by fire departments – guidelines and regulations are necessary. For now, there is no real evidence that fire risk is higher in EVs compared to ICEVs, but a follow-up is necessary as the number of EVs in the fleet rises.
- Fairness: A fair transition to an electric fleet should be strived for. A myriad of measures could be taken, ranging from financial and fiscal measures, to developing the second-hand market, the provision of sufficient (public) charging opportunities at a reasonable cost, but also education and awareness raising.
- Organization of the mobility system: Electrification of the fleet can be linked to the other emerging concepts of automation and shared mobility for enhanced benefits. Also, parking schemes need rethinking.
- To mitigate the negative impacts of motorized transport, the Avoid-Shift-Improve principle should be pursued.

Policy recommendations

The report concludes with policy recommendations based on the lessons learned from this study and further expert input.

General introduction

To achieve deep decarbonization of the transport sector to meet climate goals, the transportation sector must make deep cuts in its greenhouse gas emissions. Next to limiting the distance travelled with motorized modes, and stimulating a modal shift to active transport modes, the electrification of the fleet seems the only immediately viable path for doing this (including a concurrent decarbonization of the power grid).

This project aims to study different aspects related to the greening of private fleets in Belgium through electric vehicles (EVs)[1]. It addresses aspects related to societal, technological, economical and taxation elements in the current state, as well as the financial instruments that could be developed and/or promoted to encourage the greening of private fleets.

In addition, technical aspects, life cycle CO_2 emissions, the total cost of ownership, charging infrastructure and the second-hand market are considered. Several deployment scenarios are explored by applying a stock turnover model and considerations about vehicle sales and scrappage, and an analysis of the impact of the transition to an electric fleet is provided. Finally, policy recommendations are formulated on the basis of this study and based on expert input.

To achieve this aim, (a) the report brings together current numbers and knowledge about battery electric vehicles (BEVs), including an international benchmark, (b) it reports on a survey performed in May 2022 to gain insight into consumer preferences, and (c) it presents prospects for BEV deployment in the private fleet based on new calculations and estimates its impact.

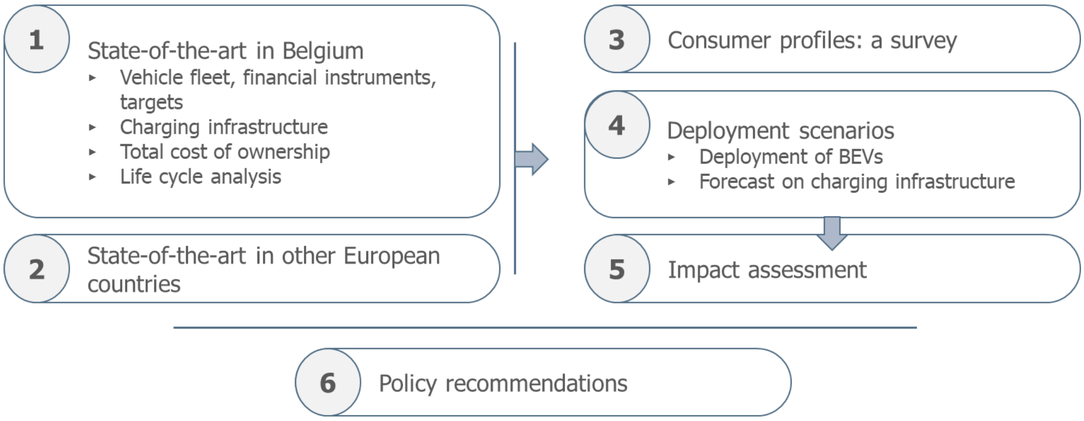

Figure 1 Overview of the six main sections of this report

[1] In this report, the term electric vehicles (EVs) refers to all vehicles with a plug. It consists of 100% battery electric vehicles (BEVs) and hybrid vehicles with a plug (PHEVs).

1 State-of-the-art in Belgium

1.1 Introduction

In this first chapter, aspects related to the current state of EVs in Belgium are explored.

First, we set the scene by presenting numbers of the **current car fleet** in Belgium (current fleet and new registrations), including the number of alternatively fueled and zero-emission vehicles. Also, the financial instruments currently in place in Belgium, and national and regional targets that will impact the deployment in the years to come are discussed.

With the recent growth in EVs, also the need for **charging infrastructure** has grown. The current supply of EV chargers in Belgium and the regions is explored. We do consider charging on the private domain, but we focus on public charging and fast charging.

A very important factor in the transition to electric fleets is the cost of an EV. The purchase price is an important element, however, the **total cost of ownership** (TCO) presents a more complete picture of the costs incurred during the lifetime of a vehicle. A comparison will be made between the current TCO of fossil fuel cars and EVs, accounting for the purchase price, regional taxation, current fuel and electricity costs, maintenance and insurance, residual value, etc. The TCO for private vehicles (not leasing) is based on assumptions so inherently uncertain, nevertheless, a best estimate is presented.

Finally, an answer is sought to the question whether indeed EVs bought and driven in Belgium are more environmentally friendly, considering **life cycle CO_2 emission**, than their fossil fuel counterparts. Environmental benefits are the number one reason for governments for transitioning to a fully electric fleet, but these benefits are also often contested. Therefore, the life cycle CO_2 emissions from vehicles from different car segments and different fuels are compared.

1.2 Current state in Belgium

1.2.1 Current fleet

As can be seen from the table below, in 2022 Belgium has a population of around 11.6 million. The number of registered passenger cars is around 5.9 million. A total of 170,821 (2.9%) cars are equipped with electronic drivetrains (BEV + PHEV). In 2022, 368,210 new vehicles were registered and in 2021 (most recent numbers) 702,004 second-hand vehicles, of which respectively 127,738 and 29,312 were alternatively fuelled (including gas-powered, BEV, PHEV, hybrid).

Table 1 Key statistics of the current car fleet in Belgium and by region (year 2021/2022)

	Belgium	Brussels	Flanders	Wallonia
Population [1]	11,584,008	1,222,637	6,698,876	3,662,495
Number of cars [1]	5,947,479	488,717	3,608,338	1,839,513
Number of BEV (fleet 2021) [2]	51,969	5281	38,872	7816
Number of PHEV (fleet 2021) [2]	118,852	15,754	88,517	14,581
Number of registrations of first-hand cars in 2022 [2]	368,210	46,026	235,575	86,609
Number of registrations of second-hand cars in 2021 [2]	702,004	63,341	375,224	263,439

Source: [1] statbel.fgov.be (2022), [2] ecoscore 2021. Attention, the numbers from EAFO, statbel.fgov.be and ecoscore may differ slightly.

In the last 10 years, the number of alternatively fuelled cars has developed rapidly. Only 10 years ago, the absolute number of registered vehicles with alternative drive systems was less than 500 (excluding LPG, Source: EAFO). Of the alternative drive systems in 2011 30% were natural gas vehicles (143), and 67% were BEV (323). PHEV (16) and H_2 (1) are underrepresented. By the end of 2022, the number of registered alternatively fuelled cars (excluding LPG) is 266,581, with more than 165,000 PHEVs (62%) and around 81,000 BEVs (31%). The figure below shows the growth of all EVs in Belgium.

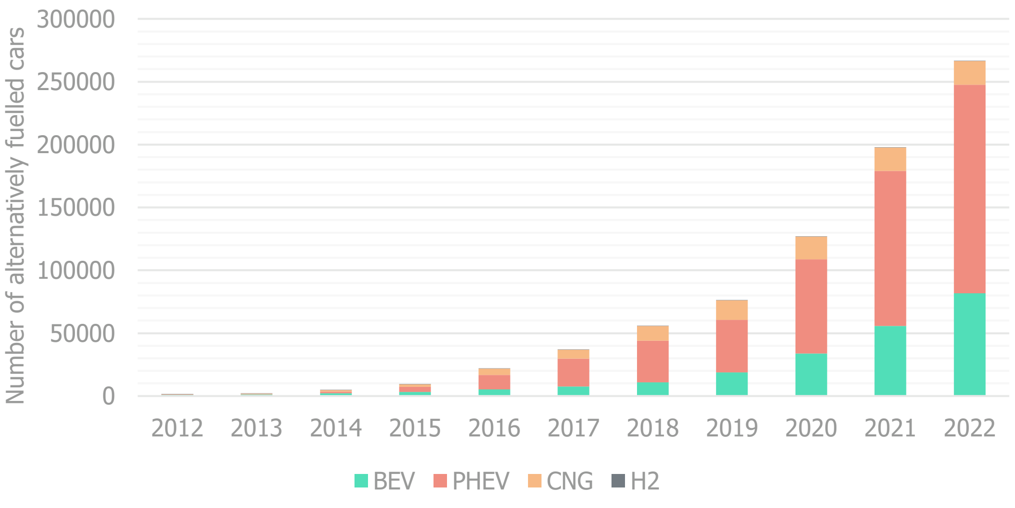

Figure 2 Evolution of alternatively fuelled cars in the whole Belgian fleet (LPG is excluded)
Source: EAFO, 2022 (https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/belgium/vehicles-and-fleet)

If we take a closer look at the last five years, we see an increase in BEV and PHEV. Table 2 shows the share of propulsion technologies of cars in Belgium by year (2018 to 2022). The share of passenger cars increased by 1.6% over the last five years, from 5.85 million vehicles to the current number of 5.95 million. In these five years, the share of petrol-powered vehicles has increased by 20%, while the share of diesel-powered vehicles has decreased by 24%. The share of gas-powered vehicles was stagnant. The largest increases could be seen in BEVs. In the last five years, these increased by almost a factor of 8. Hybrid vehicles increased by more than 300% (PHEV and regular hybrids). Nevertheless, the share of BEVs represents only 1.2% of passenger cars in Belgium. Hybrid drives have a market share of 6.3% (PHEV and regular hybrids). The number of residents per vehicle changed by 1% from a value of 1.94 in 2018 to 1.95 in 2022. On average, cars in Belgium are used for 9 years, 2 months, and 26 days before they are discarded (exported, recycled, etc.).

Table 2 Recent evolution of the car fleet in Belgium (2018-2022)

	2018	2019	2020	2021	2022
Passenger cars	5,853,782	5,889,210	5,888,589	5,927,912	5,947,479
• petrol-driven	2,518,942	2,709,604	2,843,903	2,951,770	3,021,102
• diesel-powered	3,193,658	3,005,928	2,815,755	2,623,556	2,424,932
• gas-powered	15,500	14,924	14,957	15,999	17,740
• electric motor	9,244	15,338	23,983	40,851	71,651
• hybrid	87,012	110,984	154,807	258,916	375,107
• not specified	29,426	32,432	35,184	36,820	36,947
Population per passenger car on 1 August	1.94	1.94	1.95	1.94	1.95

Source: https://statbel.fgov.be/nl/themas/mobiliteit/verkeer/voertuigenpark#figures (Target date August). Attention, the numbers from EAFO, statbel.fgov.be and ecoscore may differ slightly.

From November 2021 to October 2022, the peak number of new PHEVs registered was in March, with 5,851 being registered. The lowest number was 2,943 in December. Registrations of all-electric vehicles peaked in September, with 3,873 new registrations. The weakest month was November 2021, with 1,990 new BEVs registered. In total in 2022, there were 368,210 new registrations of cars (the lowest level since 1995), and clearly, EVs are still a minority (~26%). Peaks in registrations usually coincide with deliveries and shipping arrival dates.

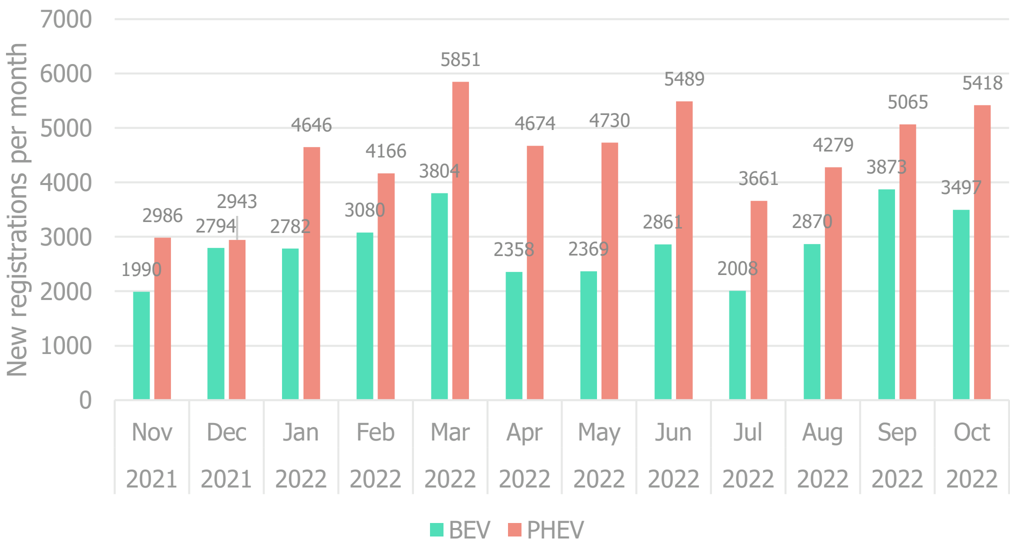

Figure 3 New registrations of EVs in Belgium per month in 2021-2022
Source: EAFO, 2022 (https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/belgium/vehicles-and-fleet)

Privately-owned cars account for around 82% of the vehicle fleet in Belgium (year 2021). In 2021, 4,755,541 cars were privately registered. Most of them were registered in Flanders (2,784,222), then Wallonia (1,666,263). In Brussels, there were 305,056 cars registered. In the last 10 years, there is a levelling in the number of privately-owned cars, in contrast, the number of non-private cars is still growing.

Table 3 Number of privately-owned cars by region and per year since 2013

Year	Belgium	Brussels	Flanders	Wallonia
2013	4,622,444	326,886	2,732,894	1,562,664
2014	4,669,887	326,000	2,762,907	1,580,980
2015	4,729,530	327,236	2,798,754	1,603,540
2016	4,750,652	325,866	2,804,146	1,620,640
2017	4,772,843	324,297	2,813,129	1,635,417
2018	4,776,249	317,599	2,811,648	1,647,002
2019	4,756,514	308,470	2,799,177	1,648,867
2020	4,758,551	307,851	2,792,601	1,658,099
2021	4,755,541	305,056	2,784,222	1,666,263
Source: Ecoscore, 2021				

The share of private vehicles in the three regions differs but is comparable to the vehicle structure of all passenger vehicles (see above). At present, alternative drives play a subordinate role. Deducting leasing and company cars results in the following numbers of private cars by type of drive. In 2021, there were 128,849 (3%) alternatively fuelled vehicles (including LPG, CNG, EV), 2,702,110 (57%) petrol vehicles and 1,924,582 (40%) diesel vehicles in the Belgian fleet. The number of vehicles by type has changed over the years. According to Ecoscore, in 2013, there were 37,701 (1%) alternatively fuelled vehicles, 1,893,026 (41%) petrol vehicles and 2,691,717 (58%) diesel vehicles in Belgium. Since 2013, the three types of engines have developed differently. Alternative propulsion has tripled, and the share of petrol vehicles has also grown strongly, but diesel vehicles have become fewer.

Alternatively fuelled private vehicles in Belgium have increased overall. The BEV, CNG and PHEV drive technologies all saw strong growth.

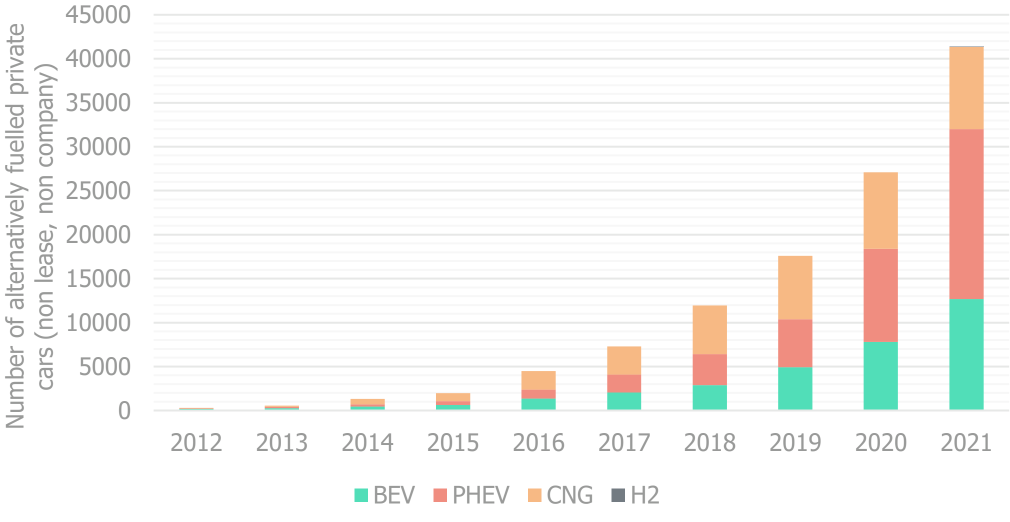

Figure 4 Evolution of alternatively fuelled private cars in the Belgian fleet (LPG is excluded)
Source: Ecoscore, 2021 (https://ecoscore.be/fiches)

New registrations in 2022 show that the trend of increasing popularity of alternatively fuelled cars continues. BEVs and PHEVs make up 26.5% of the newly registered cars in 2022 compared to 18.4% in 2021 and 10.8% in 2020. The market share of EVs is thus increasing.

Table 4 New registrations of cars in the Belgian fleet in 2022 compared to registrations in 2021
Source: FEBIAC, 2023 (https://www.febiac.be/public/pressreleases.aspx?ID=1448)

Engine type	2022	2021	Evolution 2022 vs 2021
Petrol	48.9%	52%	-3.1%
Diesel	16.4%	23.7%	-7.3%
PHEV	16.2%	12.5%	+3.7%
HEV	7.5%	5.1%	+1.8%
BEV	10.3%	5.9%	+4.4%
LPG	0.7%	0.5%	+0.2%
CNG	0.1%	0.3%	-0.2%

The stark differences in engine type of privately owned cars vs company cars continue in 2022 as well. Of the 37,619 newly registered BEVs in 2022, 87.1% are company-owned cars. Similarly, of the 59,281 newly registered PHEVs, 91.4% are company owned. More non-rechargeable HEVs are privately owned with a share of 54.6%.

Table 5 Engine type of the newly registered privately owned and company-owned cars in the first semester of 2022
Source: FEBIAC, 2022 (https://www.febiac.be/public/pressreleases.aspx?ID=1426)

Engine type	Privately owned	Company-owned	Total
Petrol	53.9%	46.1%	96,977
Diesel	21.8%	78.2%	35,108
PHEV	9.2%	90.8%	30,049
HEV	56.6%	43.4%	14,466
BEV	14.4%	85.6%	17,187
LPG	88.6%	11.4%	1,318
CNG	14.1%	85.9%	284
H_2	5.6%	94.4%	18

In Belgium, a total of 641,428 private second-hand cars were registered in 2021. In 2013, this was 540,970. In Flanders, the most vehicles are registered, with 335,180, followed by Wallonia with 250,963 and Brussels with 55,285. Of the registered second-hand cars, EVs play a minor role: 2765 BEVs were registered in 2021 (up from 917 the year before), and 5085 PHEVs (up from 2464 the year before). Although this is a very small percentage of the total fleet, their amount is increasing every year. In 2020 there was a temporary shrinkage in the second-hand car market due to the COVID crisis.

Table 6 Registrations of private second-hand cars by region and per year since 2013

Year	Belgium	Brussels	Flanders	Wallonia	Yearly growth rate	Hereof alternatively fuelled vehicles[1]	Share in percent
2013	540,970	49,441	300,236	191,293	-	3630	0.67%
2014	547,136	48,975	303,323	194,838	+1.1	4131	0.76%
2015	568,640	49,613	316,152	202,875	+3.9	4260	0.75%
2016	556,097	50,253	299,075	206,769	-2.2	5070	0.91%

2017	577,888	51,283	313,380	213,225	+3.9	6161	1.07%
2018	588,322	53,492	316,021	218,809	+1.8	7563	1.29%
2019	637,525	55,046	346,619	235,860	+8.4	9671	1.52%
2020	604,341	52,753	327,154	224,434	-5.2	11,517	1.91%
2021	641,428	55,285	335,180	250,963	+6.1	18,502	2.88%

[1] Including BEV, PHEV, regular hybrids, LPG, CNG, H_2
Source: Ecoscore, 2021 (https://ecoscore.be/fiches).

As discussed above, EV sales are still a minority in Belgium, but sales are increasing. There are two main reasons for the increase in the total number of cars with electric drives: First the European legislation towards OEMs and federal states (to meet Paris goals) are leading to federal, regional, and local policies and to OEM targets. And second the technological developments and the related decreasing battery prices. These two reasons are coupled with further effects: On the one hand, there are new and old OEMs that now offer BEVs for sale. By now, there are over 200 different BEV or PHEV vehicle models. In addition, production runs with a higher volume of vehicles. Technological development is also advancing rapidly. The average range of a BEV is usually over 300 real kilometres and there is an expected price drop in the future. Furthermore, the expansion of the charging infrastructure has started, and the rollout is being carried out nationwide by various actors. While a few years ago it was mainly pioneers who bought EVs, they are no longer a niche product. The top five BEVs sold in Belgium in 2022 (company cars and privately-owned) are the Tesla Model Y, the BMW iX3, the Audi Q4 e-tron, the Audi e-tron, and the Polestar 2. Car manufacturers have recognized the electromobility market and are introducing new products. Volkswagen launched an affordable e-variant on the market with the ID 3, and Renault is also trying to set new standards with the ZOE, which has been a best-selling EV for years. Currently though, the electric vehicle market is dominated by limousines and SUVs, while family cars (minivan, station wagon) are lagging behind.

1.2.2 Financial instruments

1.2.2.1 Financial incentives to purchase EV

In Belgium, there is no direct financing or subsidies for the purchase of an EV by private persons as in other European countries. In Flanders, there was a purchase subsidy available since January 2016, but this ended in 2020. However, there are taxation advantages (see further).

State financing models are strong incentive systems for the consumer, as the price is still the most important factor when buying a car. The reduction of various taxes or bonus payments on the purchase of EVs increases the interest in buying. This can be seen in various European countries such as the Netherlands, Germany, and Norway.

- **Flanders**

In Flanders, up until the end of 2019, the purchase of a BEV could benefit from a premium of up to €4000. For a motorbike, the amount of the benefit was €1500, and €750 for a class B moped (in each case, with a maximum of 25% of the list price). However, the subsidy scheme was scrapped in 2020 and there are currently no premiums offered at all. The premium was only available for 100% EVs (no hybrid vehicles) or fuel cell vehicles (on hydrogen). Cars with a small additional motor running on fossil fuels (range extender) were not eligible (e.g. BMW i3 with range extender).

Some local governments in Flanders have purchase subsidies for zero-emission taxis/shared cars.

- **Brussels**

There is no direct financing or incentives for the purchase of an e-car by private persons. In the Brussels Capital Region micro and small companies who need to replace a diesel van due to the Brussels' LEZ, may receive a purchase subsidy for a non-diesel van for 20% of the purchase price (max €3000). This does not apply to private owners.

- **Wallonia**

There is no direct financing or incentives for the purchase of an EV by private persons.

1.2.2.2 Financial incentives and deterrents to drive the shift from combustion engines

Several cities introduced a driving ban for vehicles with certain emission classes through a LEZ. Conditions for entering a LEZ differ by city, and they become stricter over time. Cities with an active LEZ are Brussels, Antwerp, and Ghent. More cities are considering installing LEZs.

Brussels has introduced an air bonus, called *Brussels Air Premium*. This incentive encourages motorists in Brussels to abandon their cars in favour of more environmentally friendly modes of transport such as public transport, cycling, walking and car sharing. All residents of the Brussels-Capital Region who have their number plates removed and, if necessary, their vehicle destroyed, can receive a Brussels' Air bonus with a maximum of €3000 per replaced vehicle. The Brussels air bonus refers to a mobility package, the content of which varies depending on the option chosen.

1.2.2.3 Taxation model for cars (private fleet)

Vehicle taxes in Belgium are based on a complex system. The decisive factors are the type of car engine, size, power, number of cylinders, and valves. The range of charges for the use of a car goes from a minimum of €24.24 to €4957.87 per year. In practice, for the most popular vehicle models, the tax difference between EVs and non-EVs is relatively small and not significant to obtain an acceptable payback time.

The table below gives an overview of all tax measures in place in Belgium and the regions.

Table 7 General overview of all tax measures

Category	Description
Registration Tax Benefits	In Flanders, zero-emission vehicles are exempted from vehicle registration taxes; natural gas and plug-in hybrid vehicles were exempted until 2020. In Wallonia and the Brussels Capital Region, there is a minimum BIV (vehicle registration tax) of €61.50 for EVs. See further for more details per region.
Ownership Tax Benefits (annual circulation taxes)	In Flanders, zero-emission vehicles are exempted from annual circulation taxes; natural gas and plug-in hybrid vehicles were exempted until 2020. In Wallonia and the Brussels Capital Region, for 100 % electric vehicles, the "circulation tax" is €83.56 (minimum tariff). See further for more details per region.
Company Tax Benefits	BEVs were 120% deductible from company taxes until the end of 2019. From 2020 onwards they are 100% deductible. Depreciation write-offs are now differentiated by CO_2 emissions; with the largest differentiation of all European countries in Belgium. This applies only to companies and self-employed persons.
Benefit-in-kind taxation	The calculation is based on list price, CO_2 emissions, fuel type, and vehicle age.
Income tax reduction for charging infrastructure	A federal tax reduction for the installation of charging infrastructure for private individuals up to €1500: Anyone who chooses to purchase and install a home charging station as a private individual between 1 September 2021 and 31 August 2024 can count on a tax reduction of up to 45% on the investment. The reduction will be systematically phased out over time.
VAT	When you buy a car in Belgium, you have to pay the multi-plant tax. This is 21%. There is no specific reduced tariff for EV cars. If a used car is bought in a shop or from a car dealer, 21% VAT is also added to the sales price. When buying a car from a private individual, no taxes are due.

Source: EAFO (2022), https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/belgium/incentives-legislations, Transport & Environment (2022), The good tax guide: A comparison of car taxation in Europe., and own summary

Since 1 January 2013, the granting of environmental incentives has, in principle, no longer been exercised at the federal level. From that date onwards, the regions had to decide to grant incentives for low-emissions cars. However, some federal incentives exceptionally remain effective until 2024 but without annual indexation of the amounts (ACEA tax guide 2021) – this is the Personal Income Tax (PIT) reduction of 15% (with a maximum of €3,140) on the purchase price of a purely electric-powered four-wheeler (no M1 vehicles: passenger cars) purchased by a private person.

- **Flanders**

Annual circulation tax: EVs are permanently exempt from paying annual road tax. PHEVs were exempt until the end of 2020.

Registration tax (BIV): EVs are permanently exempt from registration tax. PHEVs were exempt until the end of 2020.

- **Brussels**

Annual circulation tax: EVs have the lowest rate of annual ownership (circulation) tax, which is €85.27. Depending on the power and engine displacement of the vehicle, the annual road tax can grow to €4,964.78 (dd. 1/07/2022).

Registration tax (BIV): In the Brussels Capital Region, there is a minimum registration tax of €61.50 for EVs.

Brussels is preparing "Smart Move", a smart kilometre charge. In the future, this will replace the road tax and registration tax, and combine them into one.

- **Wallonia**

Annual circulation tax: EVs have the lowest rate of annual ownership (circulation) tax, which is €83.56. From September 2023, a new taxation scheme is planned to be introduced. Depending on the size, the weight and the power of the vehicle, the annual road tax for ICEVs can grow to €3000. EVs will get a reduced rate (-74% for BEVs and -20% for hybrid vehicles). There will be a gradual shift towards the new taxation scheme – the full scheme will only be implemented from 1st March 2026.

Registration tax (BIV): In Wallonia, there is a minimum registration tax of €61.50 for EVs. Part of the registration tax uses an eco-malus system, with the tariff depending on the CO_2-emission of a vehicle (up to €3500). This should work as an additional incentive for the purchase of a car with lower emissions. Large families benefit from a deduction of one category for three dependent children under 25, and two categories for four or more dependent children (for vehicles emitting less than 226 gCO_2/km). Also for the registration tax, a new taxation scheme is foreseen from September 2023 onwards. The maximum fee will be €9000

The proposed scheme is not approved yet and still under discussion.

1.2.3 National and regional targets

Several plans and targets support the transition to electric fleets in Belgium. Primarily, the EU has decided to phase-out ICEVs (cars and vans) in 2035. Flanders and Brussels are more ambitious and proposed earlier target dates.

- **Belgium (national)**

The National Energy and Climate Plan for Belgium intends to achieve the European energy and climate goals by 2030:

  - Reduction of greenhouse gas emissions by at least 40% compared to 1990.
  - Increasing the volume of renewable energy to the minimum threshold of 27%.
  - Energy efficiency improvement by at least 27%.

From 1 January 2026, purchased, leased or rented company cars with CO_2 emissions higher than zero will no longer be tax deductible for the employer. On top of that, the CO_2 tax ("Solidarity tax") will be much more stringent for fossil-fuelled company cars. This has been laid down in a legislative draft of 14 September 2021 ("Fiscale en sociale vergroening van de mobiliteit") and was accepted in parliament beginning of December 2021.

- **Flanders**

Flanders intends to make all new cars sold zero-emission from 2029. ICEVs cannot be sold anymore, including hybrid vehicles. This also holds for vans. Heavy trucks are still excluded. The shift to zero-emission cars in 2029 is conditional on certain conditions to be met. Also, it is unclear whether Flanders has the legal competence to take this decision.

- **Brussels**

The Brussels regional government will ban diesel vehicles from 2030 and petrol/LPG vehicles from 2035 from their streets. It will be achieved by gradually extending the criteria for the Brussels' LEZ.

- **Wallonia**

Currently, Wallonia will follow EU regulations and prohibit the sales of fossil fuel cars from 2035.

From 1 January 2023, it was planned to have a LEZ in the whole Walloon region. However, the introduction is postponed until at least 2025. The system would be progressive. The most polluting diesel and petrol cars would be affected first, i.e. cannot be driven on Walloon roads anymore (with some exceptions). EVs and hybrid vehicles with a maximum CO_2 emission of 50 grams per kilometre will not be affected.

While the Walloon municipalities have been able to establish one or more LEZs on their territory permanently or temporarily since 1 January 2020, none have yet confirmed schemes.

1.3 Charging infrastructure

1.3.1 Current state

1.3.1.1 National level

There are currently 13,598 public charging points in Belgium (publicly accessible points), and 842 of these are fast chargers (Figure 5). In Belgium there are on average 5.5 public charging points per 100 km (European Automobile Manufacturers' Association ACEA, 2020, https://www.acea.auto/press-release/electric-cars-10-eu-countries-do-not-have-a-single-charging-point-per-100km-of-road/). At EU level, The Netherlands leads the way with 47.5, followed by Luxembourg with 34.5 and Germany with 19.4. Belgium is at a comparable level to Austria (6.1), Italy (5.1), Sweden (5.0), and Denmark (4.4). In 2021, there were 0.08 public charging points per EV in Belgium (https://www.iea.org/data-and-statistics/charts/ratio-of-public-chargers-per-ev-stock-by-country-2020). An overview map of charging points in Belgium and Europe can be found at https://oplaadpalen.nl/.

The number of charging points has developed rapidly since 2013. At that time, there were 331 public charging points and 47 fast-charging points (12.43%). Fast-charging means a DC recharging point (charging power generally over 22 kW). Already in 2015, the number of charging points quadrupled (1,335), and fast chargers were 77. By 2018, the value of charging points had doubled again. A first jump is observed between the years 2017 and 2018, from 1,493 to 2,716. Fast charging points have also grown, to 242 in 2018. In the following years, the number of charging points grew by leaps and bounds, eventually crossing the 10,000 mark in 2021. In 2021, there were 12,756 charging points and 842 fast chargers. The increase since 2015 can be explained by the "Vlaamse Proeftuin Elektrische Voertuigen" programme. Since 2018, the Fluvius network expansion has been in operation, providing 750 new charging points every year, which explains the increase in charging points in the following years. Please note that the EAFO data differs in part from other data sources, as these are counted at the beginning of the year.

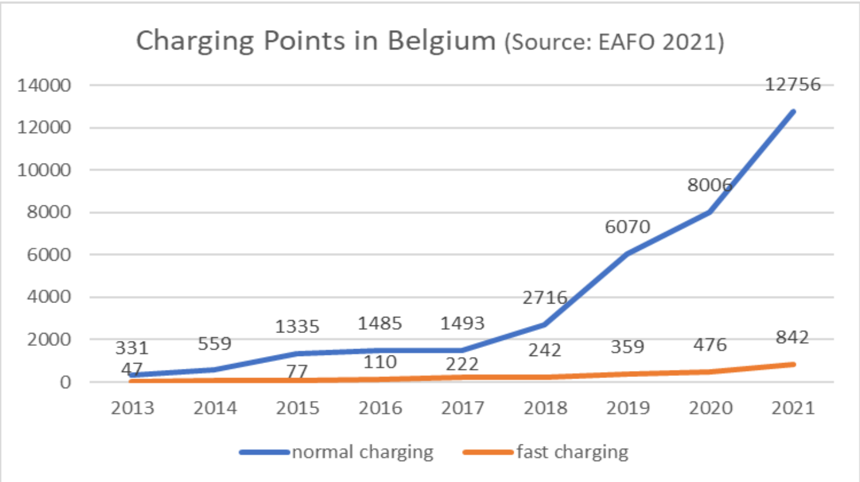

Figure 5 Public charging points in Belgium per year since 2013 (normal = AC charging; fast = DC charging) Source: European Alternative Fuels Observatory, 2021. https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/belgium/infrastructure

Charging points are currently not registered nationwide and uniformly, and are only collected retroactively on the portal of the European Union. These are then unfortunately distorted in time. While the regions of Flanders and Brussels make their data available on various platforms, the availability of data on Wallonia is poor. Although there are portals that provide nationwide figures, some of these are a year old. The Netherlands is a pioneer here, publishing up-to-date figures on charging infrastructure every month.

Additionally, following the EU regulation, all regions introduced new obligations to apply to the installation of charging stations for electric vehicles in the parking lots of new construction and renovation of buildings. The builder or permit holder is responsible for compliance with these requirements.

1.3.1.2 Regional level

- **Flanders**

By the end of 2021, there were 5798 public charging points for EVs in the Flemish Region. That is 13 times more than in 2016. At that time, there were 430 public charging points. 203 of the 5798 are fast-charging (>23 kW) stations. This corresponds to 3.5% of the number of public charging points. The Flemish Region has many more public charging points for EVs than the other regions. More than 8 out of 10 of Belgium's public charging points were located in the Flemish Region by the end of 2021.

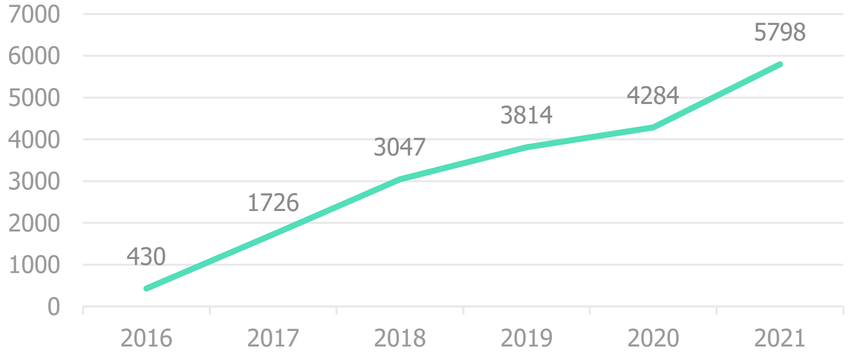

Figure 6 Public charging points in Flanders per year since 2016
Source: https://www.vlaanderen.be/statistiek-vlaanderen/mobiliteit/publieke-laadpunten-voor-elektrische-wagens

In the larger cities, there are more charging points than in the smaller municipalities. By the end of 2021, Ghent was the leader with 478 public charging points for EVs. Antwerp, Mechelen, Bruges, Leuven, Kortrijk, Hasselt, Aalst and Zaventem also had more than 100 public charging points on their territory at that time. All municipalities have at least one public charging point.

Flanders plans to roll out up to 30,000 charging points by 2025. 30 million euros have been earmarked for this. The goal is to have at least one fast charging point within 25 kilometres. A combination of normal and (ultra) fast chargers will be used. Fast chargers will be rolled out at attractive locations along major traffic axes and in strategic locations near or in the cities, preferably close to the medium-voltage network. This can be found in the Concept note: "Approach to the roll-out of charging infrastructure 2021-2025".

Flanders's strategy of expanding electromobility is supported by a fundamental decision to expand the charging infrastructure for EVs. This aims to create opportunities for the future expansion of the charging infrastructure for EVs and to develop the necessary information about this charging infrastructure (decision from 2021/09/24). In addition, the government has issued a call for projects for the introduction of ultra-fast charging stations in parking lots along highways and regional roads. Here, such charging infrastructure is to be provided within a radius of 25km (decision from 2021/09/07). The charging infrastructure in the Flanders region was organized by system operator Fluvius until 2020. From 2021, this is taken over by the Flemish Government (Departement Mobiliteit en Openbare Werken). This can be found in a government decision of 13/09/2021, which specifies the possibilities for the future expansion of the charging infrastructure for EVs and develops the necessary information on the charging infrastructure for this purpose.

In Flanders, new obligations apply to the installation of charging stations for EVs in the parking lots of new constructions and renovations of buildings. The builder or permit holder is responsible for compliance with these requirements.

Table 8 Overview of obligations for charging points at parking lots in Flanders

	New construction (environmental permit from March 11, 2021)	Structural renovation (environmental permit from March 11, 2021)	Existing buildings from 2025
Residential buildings	Parking lot with 2 or more parking spaces: charging infrastructure required for each parking space	Parking lot with more than 10 parking spaces: charging infrastructure mandatory for each parking space	No obligations
Non-residential buildings	Parking lot with more than 10 parking spaces: - at least 2 charging points - and charging infrastructure for 1 out of 4 parking spaces		Parking area with more than 20 parking spaces: at least 2 charging points

Source: www.energiesparen.be/verplichtingen-laadpunten (11/2021).

- **Brussels**

Compared to other European capitals and metropolises, the number of charging points in Brussels is limited. Currently, there are 1,192 (semi-public) charging stations across the capital region, 994 with a loading capacity of 22 kW, 198 with 38,6 kW and 20 with over 50 kW (Delivery Plan Brussels, 2022). Now the Brussels' regional government has implemented new measures to facilitate its plan to install an additional 250 charging stations, the equivalent of 500 charging points, for EVs across the city. Overall, the Brussels regional government is aiming for a total of 8000 charging points by 2025, and 11,000 charging points by 2035.

Currently, Brussels is developing a Delivery Plan for Charging Infrastructure for Electric Vehicles which is planned for the end of 2022. The Delivery Plan describes the current state of affairs of charging infrastructure in Brussels and the future needs for charging infrastructure, the different strategies for rolling out on-street and off-street normal/semi-fast/fast chargers and the concrete actions that stakeholders can take to realize the roll-out in collaboration with the region.

Since 10 March 2021, there are also new rules on charging infrastructure and charging points in Brussels for car parks (decree 25/02/2021). Each new car park with at least 10 spaces must at least be equipped with a charging point for EVs and provide the necessary conduits for the passage of electrical wiring to allow the future installation of a charging point for each parking space.

- **Wallonia**

Wallonia does not have a collected body or organization that manages or monitors charging infrastructure development. Therefore, figures on charging points are sometimes difficult to obtain. The last report, in 2020, indicated that there were about a thousand charging stations accessible to citizens. Wallonia's ambition is to have 12,000 charging points (5600 stations) by 2026. This ambition is currently in the planning stage.

Since March 2021, there are obligations on the installation of charging infrastructure for new constructions or important renovations.

- *residential:* a charging infrastructure must be included in the permit application for each parking space if there are at least 11 spaces
- *non-residential:* offices, shops, industrial buildings, boarding houses, etc. with at least 11 parking spaces that are newly built or undergoing major renovation must be equipped in Wallonia with at least one charging point and the infrastructure for connections on at least 1 out of 5 parking spaces to be able to install charging points afterwards.

1.3.1.3 European-wide actions

- **Cross-border projects**

IDRO - to encourage cross-border electric driving and charging, Belgium, the Netherlands and Luxembourg are setting up 2021 the joint service IDRO (Benelux ID Registration Organization). Through a website (www.benelux-idro.eu) IDRO will issue and manage unique ID codes for charging station operators and mobility service providers in the Benelux countries. Through these unique ID codes, operators and providers can determine which card was used and when for a certain charging operation so that the appropriate invoice can be sent to the correct customer. Charging is also expected to become easier for customers, who will be able to obtain meaningful information about location, availability, and cost. The goal is to make charging EVs as easy as refuelling.

BENEFIC - a cross-border project for the development of charging and refuelling infrastructure for alternatively fuelled vehicles (https://www.benefic.eu). It includes the following categories: charging infrastructure for EVs, electric taxis and buses, CNG and LNG infrastructure, hydrogen refuelling infrastructure, and shore-side electricity for inland navigation ('BrussEls NEtherlands Flanders Implementation of Clean power for transport').

- **Other actions**

Tesla implements superchargers in Belgium: 227 Superchargers on 16 locations across the country (11/2022). The peak power of the V2 Supercharger has been upgraded to 150 kW and On-Route Battery Warm Up has been introduced on cars to ensure they arrive with the optimal temperature for charging, reducing the average charging time by 25%. With the introduction of V3 Supercharging in Europe, charging speeds of up to 1600 km per hour are achieved.

Ionity EU is building, operating, and constantly growing a network of high-power charging infrastructure along highways in 24 European countries.

1.3.2 Energy prices

With the increase in the number of EVs, a look at the electricity/energy market and its costs is essential. The cost of energy is made up of three components:

- the price of the energy itself,
- the transmission and distribution costs,
- and the taxes and surcharges.

Table 9 Energy prices for cars

	Flanders	**Wallonia**	**Brussels**
Structure of the electricity price (2021)	- 41% energy - 19% grid/network costs - 23% surcharges - 17% VAT	- 39% energy - 24% grid/network costs - 20% surcharges - 17% VAT	- 45% energy - 21% grid/network costs - 17% surcharges - 17% VAT
Price per kWh 2020	27.46 c€/kWh	27.70 c€/kWh	23.25 c€/kWh
Price per kWh 2021	26.16 c€/kWh	26.41 c€/kWh	22.03 c€/kWh
Price per kWh 2022	49.34 c€/kWh	53.11 c€/kWh	48.21 c€/kWh
Cheapest offer (year contract, July 2022)	€829 per year	€844 per year	€938 per year
Most expensive offer (year contract, July 2022)	€1331 per year	€1347 per year	€1267 per year
Price per 1L Super 95 (E10) 2021	---------------------------------€1.5624---------------------------------		
Price per 1L Super 95 (E10) 2022 (until August)	---------------------------------€1.8888---------------------------------		
Price per 1L Diesel (B7) 2021	---------------------------------€1.5727---------------------------------		
Price per 1L Diesel (B7) 2022 (until August)	---------------------------------€1.9904---------------------------------		
Note: Since the second half of 2021 energy prices have increased significantly. Consult current prices for a more accurate comparison. Sources: CREG, statbel			

The price of an annual contract with an electricity supplier in the three regions differs. Recent information about the price of an annual contract can be accessed via the website of the CREG (https://www.creg.be/en/market-functioning-and-monitoring-suppliers-products-and-prices-on-electricity-and-natural-gas). In July 2022, the cheapest tariff could be concluded in Flanders at €829, followed by Wallonia (€844) and Brussels (€938). The most expensive contracts were in Wallonia (€1347) and Flanders (€1331), cheaper is Brussels with €1267 per year.

Over the last year, energy prices have risen significantly, and the Belgian electricity price is one of the most expensive in Europe. Especially the energy component costs are rising. In January 2020, the price for one kWh was around €0.25. In September 2021 this was already €0.30, and in July 2022 this was €0.47 (VREG, https://dashboard.vreg.be/report/DMR_Prijzen_elektriciteit.html). While transaction and network costs have remained the same, the share of the energy component costs has increased from €0.08 to €0.11, and to €0.31 in July 2022. In response to this steep increase, the VAT was temporarily lowered from March 2022 until and including December 2022 from 21% to 6%.

As an illustration, the price evolution of the electricity price in the residential sector in Flanders is shown below according to various categories.

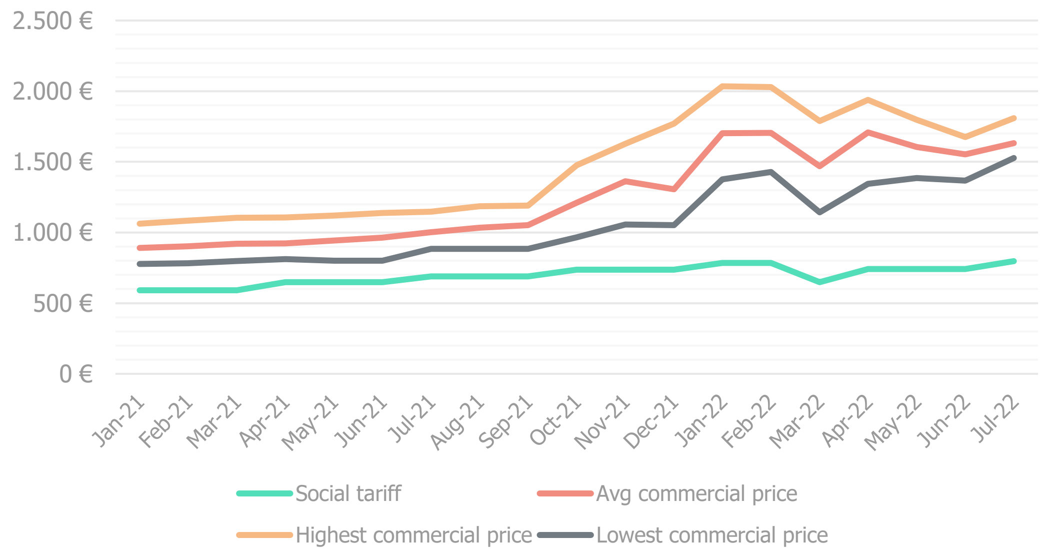

Figure 7 Monthly evolution of the annual electricity price for a household in Flanders
Source: VREG, 2022 (https://dashboard.vreg.be/report/DMR_Prijzen_elektriciteit.html)

1.4 Total cost of ownership

The total cost of ownership (TCO) refers to the total discounted sum of the costs of a vehicle over the lifetime of the vehicle, minus its residual value (Franckx, 2019a). It includes the acquisition cost, but also other costs such as fuel costs, insurance costs, taxes, etc. The TCO is an important number for fleet owners when buying new company cars or leasing cars. For private customers, the purchase price or upfront cost is often decisive. The TCO omits non-monetary factors such as the range of an EV, the availability of charging stations, or aesthetics that may be equally important when choosing a car.

In this chapter, the TCO is compared for several car models that are currently on sale in Belgium in diesel, petrol and battery electric versions.

1.4.1 Methods

Within the framework of the current project, a tool was developed to estimate the TCO of different cars in Belgium (developed by The New Drive, for Vias institute). We compare BEVs with diesel and petrol cars in different car segments. Real cost information from different popular car models was collected. Results are different by region as taxes differ by region. The tool comes in the form of an Excel spreadsheet.

Elements of the TCO included in the tool:

- The purchase price or acquisition cost: Net price, including VAT, options and 5% discounts. Prices are variable and unit prices from one moment in time are used in the tool (2022); for example Tesla announced a price drop for several models in January 2023.
- Residual value: This is the estimated revenue from a vehicle when sold at the end of its useful life. In the tool, this value depends on the fuel, the purchase price, the mileage, the age, and the range (for EVs). The minimum price assumed for a car wreck is €360. The formula used is based on work from the TU Eindhoven (TCO model for electric driving, prof. M. Steinbuch). The purchase price minus the residual value is the depreciation.
- Fuel cost (for ICEVs): Depends on the reported fuel use per km (WLTP) of the car model, annual mileage (ratio of total mileage and life years, assumed as 135,000 km and 9 years) and fuel price including VAT. Petrol and diesel prices are based on average prices from March to June 2022 from Energia.
- Electricity cost (for BEV): Depends on the reported electricity use per km (WLTP) of the car model, annual mileage (ratio of total mileage and life years, assumed as 135,000km and 9 years) and the electricity price. Electricity prices depend on the type of charger used: An EV is assumed to be charged at home for 50% of the distance (€0.45/kWh), 13% at work (€0.15/kWh excluding VAT), 29% at public chargers (€0.40/kWh), and 8% along the way at fast chargers (€0.75/kWh). The result is an average price of €0.42/kWh. The costs for the installation of a charger at home are not included, but for private customers, this means an extra initial investment of approximately €1000.
    - The charging mix, i.e. the share of charging at different locations, is based on numbers from a survey in the Netherlands in 2022 in 2547 EV drivers (Wolterman et al., 2022).
    - Prices are based on the average electricity price for families in the first half of 2022 (home charging); the average price to charge at work is based on estimates from The New Drive; the average price at public chargers is based on the standard price at Allego chargers and public chargers in Brussels in September 2022; for fast charging the average price of electricity at FastNed stations and Tesla Superchargers were assumed in September 2022. Prices are variable over time and space and are rounded to the nearest 5 Eurocent.
- Insurance cost: Over the lifetime, including VAT. This is the sum of different common insurances (depending on the purchase price of the vehicle; i.e. omnium for more expensive vehicles, third-party liability insurance for cheaper vehicles), breakdown assistance, and legal assistance.
- Maintenance cost: This cost consists of two parts: reparations and maintenance (€/km), and tyres (€/year). The first cost is multiplied by the total assumed mileage (135,000 km), and the second one by the assumed lifetime (9 years). Reparations and periodic maintenance are assumed to be 25% lower for EVs because of fewer moving parts in these vehicles; however, this cost also partly depends on the purchase price making reparations somewhat more expensive in EVs. At present, however, it is not known how the actual maintenance costs of a BEV will develop.
- Taxes (at entry): Assumes the regional taxes that are due at registration of the vehicle.
- Annual taxes: Assumes the regional taxes that are due annually.

- No discounting is performed at the moment: it is unclear whether private customers (as we target in this project) discount rationally when purchasing cars. Individual customers may even use irrationally high discount rates, giving high weight to the purchase price and less so to costs incurred during the use phase.
- Private lease could reduce the initial cost of EVs, but, although a growing market, we have not yet calculated their impact on the TCO.

1.4.2 Results & discussion

A comparison is made between the TCO of BEVs and ICEVs, of different car segments, and between regions.

In order to allow direct comparison, one or two reference cars per car segment[2] were selected from the TCO-tool. All the selected models are available as BEV, and in a diesel and petrol version (or a very similar model from the same manufacturer). These models are often not available as PHEV and therefore this group was excluded from our evaluation. It should be noted that the choice of car models may influence the results to a limited extent, but due to the careful selection of models, we believe the conclusions are robust, especially as the main analyses focus on differences between powertrains.

- Segment B (Small): Opel Corsa, Peugeot 208
- Segment C (Compact): Volkswagen Golf
- Segment D (Mid-size): Hyundai IONIQ / i30
- Segment SUV-B (Subcompact Crossover): Opel Mokka, Peugeot 2008
- Segment SUV-C (Compact Crossover): Jaguar I-Pace / E-Pace
- Segment SUV-D (Large Crossover): Mercedes EQC / GLC

Car segments E, F and SUV-EF are excluded because too few car models are sold in these segments. Segment A cars were not included because no model is currently available in an EV, a petrol and a diesel version, making a direct comparison impossible.

1.4.2.1 Differences in TCO between BEVs and ICEVs

The TCO is dominated by the purchase or acquisition cost. However, also the fuel or electricity cost is important, together with the insurance cost and the maintenance cost. The residual value negatively contributes to the TCO, as this amount can be compensated when the car is sold or scrapped. Figure 8 shows that taxes play only a minor role in the TCO.

Currently and averaged over all segments, BEVs are already the cheapest option, not when considering the purchase price, but they are when considering the TCO (Figure 8, Table 10). Petrol and diesel-fuelled cars are only slightly more expensive than BEVs when considering the TCO. BEVs have the lowest cost per kilometre driven (recurrent costs) and the highest residual value. In the exercise, we assumed a lifetime of a car of 9 years which corresponds to current averages in the Belgian fleet and a lifetime mileage of 135,000 kilometres.

The 2022 Car Cost Index from LeasePlan revealed similar numbers in 22 European countries: fuel costs represent 15% (18% from Table 10) of the TCO of a BEV, while this is 23% (27% from Table 10) and 28% (22% from Table 10) for petrol and diesel drivers. Earlier studies, for example from the Federal Planning Bureau in Belgium provide mixed results with mostly favourable TCOs for fossil fuel vehicles (Franckx, 2019a).

Table 10 Different components of the TCO, by fuel type

All segments combined	**BEV**	**Diesel**	**Petrol**
Purchase price	45,905 €	36,373 €	33,697 €
Residual value	-11,653 €	-4,920 €	-4,558 €
Fuel cost	0 €	15,740 €	19,337 €

[2] Following the segmentation from https://mow.vlaanderen.be/tco/

Electricity cost	12,665 €	0 €	0 €
Insurance cost	12,334 €	10,889 €	10,472 €
Maintenance cost	9,487 €	9,698 €	9,349 €
Taxes (at entry) [1]	41 €	837 €	971 €
Annual taxes [1]	512 €	2,929 €	2,093 €
Sum	**69,290 €**	**71,547 €**	**71,361 €**

[1] Average over all three regions

Figure 8 Different parts of the TCO, by fuel type

For customers, **there is certainty about the purchase price** (=upfront cost)**, but there is uncertainty about the factors that make a BEV cheaper** like the lifetime and mileage (recurrent costs), the electricity price, or the residual value.

Given the absence of data on the second-hand market, our initial assumption considered the cost of ownership over a car's entire lifetime, not just for its first owner (Franckx, 2019a). To test how variable the TCO is to **changes in the lifetime and mileage**, sensitivity analyses are carried out. The first one assumes a lifetime of 15 years with an annual mileage of 10,000 km (reasoned assumption of (Franckx, 2019a)). This coincides with the trend of increasing mileage seen all over the world. To assess the importance of changes in lifetime or mileage, further sensitivity analyses assume a lifetime of 15 years and a total mileage of 135,000 km, and a lifetime of 9 years and a total mileage of 150,000 km.

- When the mileage of BEVs would be increased to 150,000 km (but not the lifetime), BEVs are expected to have an even lower TCO because of the low recurrent costs compared to ICEVs (Franckx, 2019a). This can be observed from our simulation (Table 11).
- When the lifetime of cars would be increased to 15 years (but not the total mileage, so fewer kilometres per year), it is observed that BEVs are no longer the cheapest option: petrol cars now have the lowest TCO (Table 11).
- When both the lifetime and the mileage would be extended to 15 years and 150,000 km, all fuels have similar TCOs, with the petrol car being slightly cheaper (Table 11).

Since 2021, **electricity and fuel prices** have been increasingly variable. Fluctuations in the electricity price can negate the small advantage of BEVs compared to ICEVs in the TCO. To test the sensitivity of our conclusions to increases or decreases in electricity prices, we perform several simulations. Firstly, we double and half the prices to charge a vehicle[3]. Diesel and petrol prices will likely follow roughly similar paths as the electricity price, however, we decided not to change the fuel prices in the current exercise. Secondly, we test a change in the charging mix to try to approximate the charging mix of privately owned cars even better. Therefore we apply the charging mix revealed by the Dutch Charging Survey in 2022 for private cars bought by private drivers (no company cars, no leasing) (Wolterman et al., 2022)[4]. This scenario increases the share of charging at home from 50% to 61%.

- In Table 12 it can be observed that in the baseline scenario, the electricity cost accounts for approximately 18% of the TCO. When the electricity price doubles, the share increases to 31% and BEVs are no longer the cheapest option (*ceteris paribus*, meaning that we assume no change in price in the petrol or diesel prices, or a change in usage of a vehicle).
- When the electricity price would increase with more than 16%, the TCO of a petrol car would be the lowest (*ceteris paribus*).
- When the electricity prices would be lower again to half of the current level, electricity would represent only 10% of the total TCO and the TCO would be lowered by more than €6000.
- Changes in the charging mix have a much smaller impact. Given our assumptions and with more home charging, the total cost of charging will increase modestly. This is because, with current household energy contracts, it seems somewhat cheaper to charge at work or on a public charger than to charge at home (this effect is expected to be temporary).

The **residual value** is an important contributor to the lower TCO of BEVs, but given the recency of the second-hand market, there is uncertainty about this factor. The developing second-hand EV market currently mainly consists of expensive cars (Tesla, etc.) and first-generation smaller EVs with a shorter range (Nissan Leaf, Renault Zoe, etc.). In general, for different EV models, the second-hand value of EVs seems proportionally higher compared to similar diesel or petrol variants – at least this is what was estimated by our model. This could be confirmed by Mobia (*personal communication* Mobia, September 2022). The price of second-hand EVs is currently high because the demand for EVs is high, and the supply of new and second-hand cars is low, among others because of delays in the delivery of new vehicles. Long delivery times currently also increase the prices of second-hand ICEVs, especially petrol SUVs and small cars, but also older ICEVs (*personal communication* Traxio, October 2022). It is unsure how this will develop in the future. But with LEZs getting stricter, it is expected that ICEVs will get a lower second-hand value in the near future compared to EVs.

[3] Scenario doubling of electricity price: Home (€0.90/kWh), work (€0.30/kWh excluding VAT), public chargers (€0.80/kWh), and along the way at fast chargers (€1.5/kWh). Scenario halving of electricity price: Home (€0.225/kWh), work (€0.075/kWh excluding VAT), public chargers (€0.20/kWh), and along the way at fast chargers (€0.375/kWh).

[4] Scenario change of charging mix: 61% home, 26% public, 6% work, 7% fast charging. In the baseline scenario, the charging mix used was 50% home, 29% public, 13% work, 8% fast charging.

Table 11 Sensitivity analysis of the TCO with varying lifetimes and mileages

All segments combined	Baseline (9y; 135,000 km)			Sensitivity (15y; 150,000 km)			Sensitivity (15y; 135,000 km)			Sensitivity (9y; 150,000 km)		
	BEV	**Diesel**	**Petrol**	**BEV**	**Diesel**	**Petrol**	**BEV**	**Diesel**	**Petrol**	**BEV**	**Diesel**	**Petrol**
Purchase price	45,905 €	36,373 €	33,697 €	45,905 €	36,373 €	33,697 €	45,905 €	36,373 €	33,697 €	45,905 €	36,373 €	33,697 €
Residual value	-11,653 €	-4,920 €	-4,558 €	-5,827 €	-2,315 €	-2,144 €	-6,193 €	-2,615 €	-2,422 €	-10,964 €	-4,355 €	-4,035 €
Fuel cost	0 €	15,740 €	19,337 €	0 €	17,489 €	21,485 €	0 €	15,740 €	19,337 €	0 €	17,489 €	21,485 €
Electricity cost	12,665 €	0 €	0 €	14,072 €	0 €	0 €	12,665 €	0 €	0 €	14,072 €	0 €	0 €
Insurance cost	12,334 €	10,889 €	10,472 €	20,557 €	18,149 €	17,454 €	20,557 €	18,149 €	17,454 €	12,334 €	10,889 €	10,472 €
Maintenance cost	9,487 €	9,698 €	9,349 €	13,365 €	13,256 €	12,773 €	12,876 €	12,674 €	12,211 €	9,976 €	10,279 €	9,910 €
Taxes (at entry)	41 €	837 €	971 €	41 €	837 €	971 €	41 €	837 €	971 €	41 €	837 €	971 €
Annual taxes	512 €	2,929 €	2,093 €	853 €	4,882 €	3,488 €	853 €	4,882 €	3,488 €	512 €	2,929 €	2,093 €
Sum	**69,290 €**	**71,547 €**	**71,361 €**	**88,965 €**	**88,672 €**	**87,724 €**	**86,703 €**	**86,041 €**	**84,736 €**	**71,876 €**	**74,442 €**	**74,594 €**

Table 12 Sensitivity analysis of the TCO with varying electricity prices and charging mixes

All segments combined	**BEV (baseline)**	**BEV (electricity price x2)**	**BEV (electricity price /2)**	**BEV (different charging mix) [1]**	**Diesel**	**Petrol**
Purchase price	45,905 €	45,905 €	45,905 €	45,905 €	36,373 €	33,697 €
Residual value	-11,653 €	-11,653 €	-11,653 €	-11,653 €	-4,920 €	-4,558 €
Fuel cost	0 €	0 €	0 €	0 €	15,740 €	19,337 €
Electricity cost	12,665 €	25,330 €	6,332 €	13,181 €	0 €	0 €
Insurance cost	12,334 €	12,334 €	12,334 €	12,334 €	10,889 €	10,472 €
Maintenance cost	9,487 €	9,487 €	9,487 €	9,487 €	9,698 €	9,349 €
Taxes (at entry)	41 €	41 €	41 €	41 €	837 €	971 €
Annual taxes	512 €	512 €	512 €	512 €	2,929 €	2,093 €
Sum	**69,290 €**	**81,955 €**	**62,958 €**	**69,806 €**	**71,547 €**	**71,361 €**

[1] Charging mix based on the National Charging Survey in the Netherlands in 2022, specifically the mix for private cars bought by private drivers (no company cars, no leasing).

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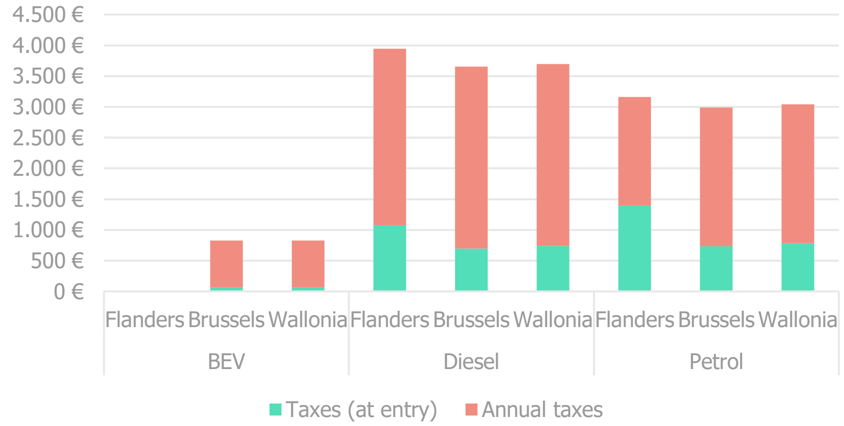
1.4.2.2 Impact of regional policy on TCO

Taxes differ by region, but appear to be only a small factor in the total cost of owning a car (Figure 9). Taxes are lowest for BEVs and highest for our selection of diesel cars.



Fuel	Region	Total TCO
BEV	Flanders	€ 68,737
	Brussels	€ 69,566
	Wallonia	€ 69,566
Diesel	Flanders	€ 71,727
	Brussels	€ 71,436
	Wallonia	€ 71,477
Petrol	Flanders	€ 71,458
	Brussels	€ 71,288
	Wallonia	€ 71,337

Figure 9 Taxes over the lifetime of cars with different fuels, by region (left), and total TCO by fuel and region (right)

1.4.2.3 TCO of different vehicle segments

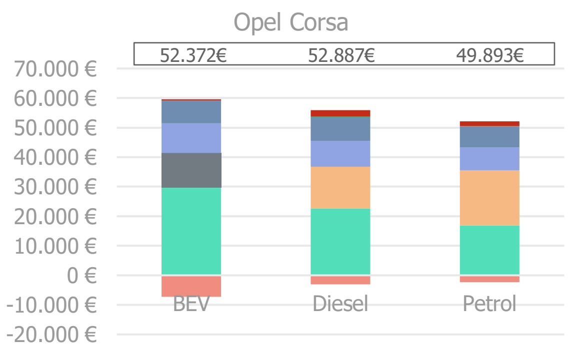
In our simulation with reference cars per segment, it appeared that for almost all SUVs the TCO for BEVs is already lower than the TCO for ICEVs, despite the higher purchase price (Table 13). More in general terms, mainly for more expensive cars in terms of their purchase price, the TCO is in the advantage of BEVs. For smaller cars in segments B or C, the difference between fuels is small, however, for now, ICEVs are still cheaper over their assumed lifetime.

Table 13 Different parts of the TCO (y-axis), by fuel type for cars from different segments

Legend

Purchase price · Residual value · Fuel cost · Electricity cost
Insurance cost · Maintenance cost · Taxes (at entry) · Annual taxes

Segment B (Small)



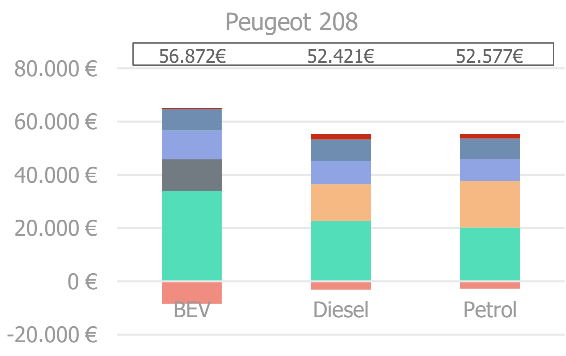
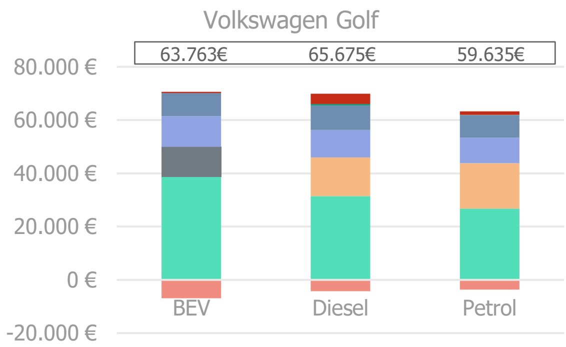
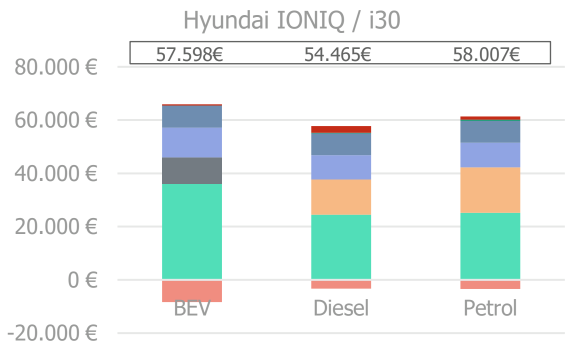


Table 13 Continued from the previous page

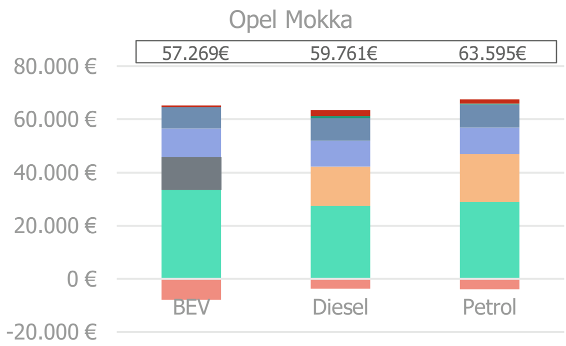
Segment C (Compact)

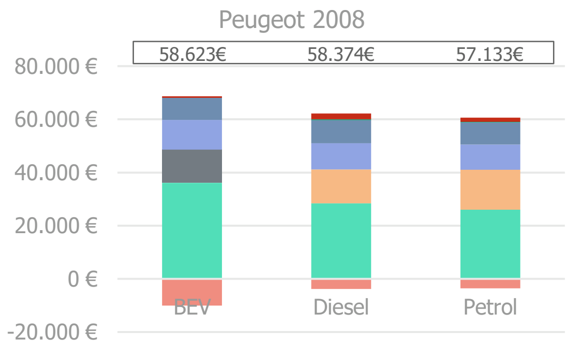


Segment D (Mid-size)

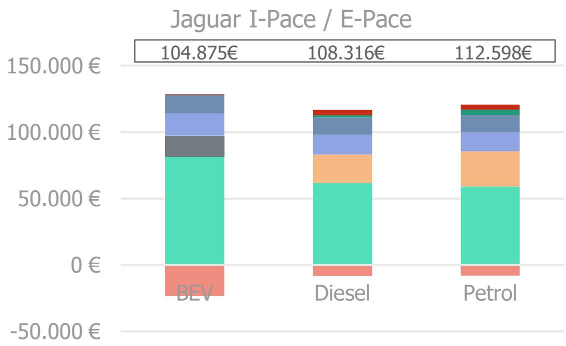


Segment SUV-B (Subcompact Crossover)

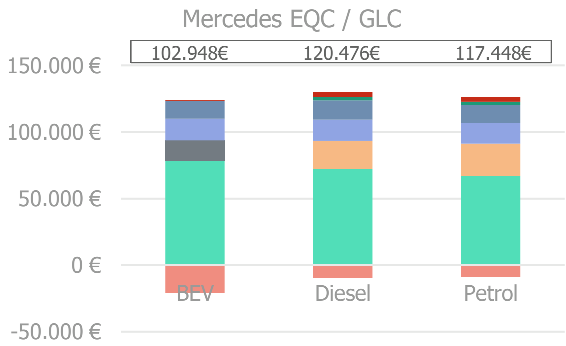




Segment SUV-C (Compact Crossover)



Segment SUV-D (Large Crossover)



As shown above, the cheapest powertrain depends also on the lifetime mileage of a car. A simulation was done by car segment to select the cheapest powertrain until a certain amount of kilometres during the 9-year lifetime of a vehicle (Figure 10). It is shown that with high mileages, a BEV is always the best option. Especially for smaller cars, fossil fuel cars are more economical when lifetime mileages are lower. The results are somewhat dependent on the vehicle models selected.

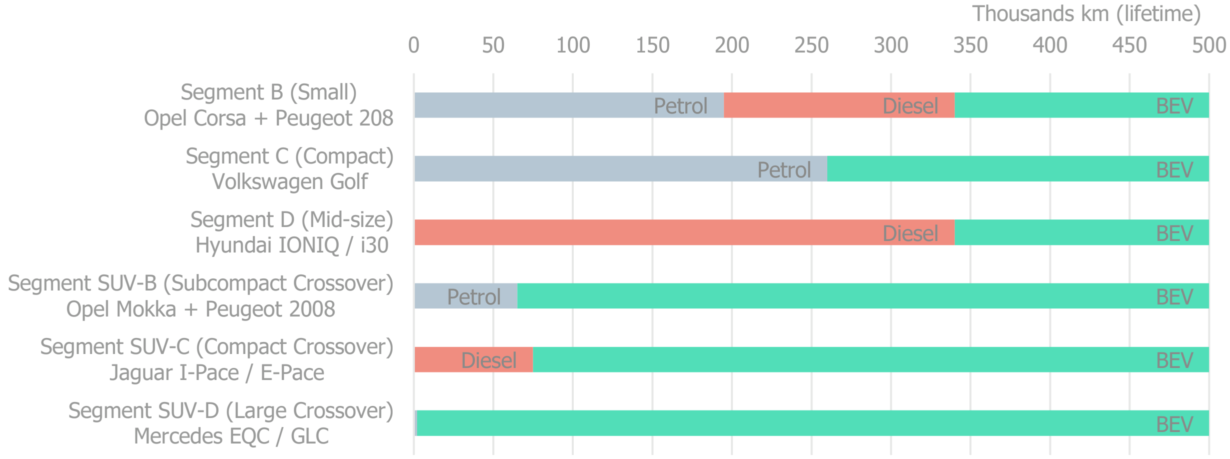


Figure 10 The cheapest powertrain by car segment depending on the lifetime kilometres over a lifetime of 9 years (for selected car models)

1.5 Life cycle analysis of a BEV

Reducing passenger car CO_2 emissions is a fundamental part of achieving the EU's climate ambitions, including reaching net zero by 2050. PHEVs and BEVs have gained much interest over the past decades concerning this aim because they are seen as cleaner alternatives to traditional internal combustion engines. It is quite easy to understand that PHEVs and BEVs emit less or no greenhouse gases (GHG) at the tailpipe because less or no fossil fuels are used to propel the vehicle. However, the electricity used by the electric powertrain still has to be produced and can also be a source of GHG emissions. Also, other pollutants are still emitted by PHEVs and BEVs, for example from tyres and brakes (discussed in section 5.2.2).

EVs have mostly been criticized for the environmental impact of their production phase and in particular the production of the battery. The production of the battery requires raw material mining and processes which are heavy carbon emitting (Tintelecan et al., 2020). The question was raised as to whether these types of vehicles really have a less negative impact on the environment compared to traditional ICEVs.

To assess the environmental impact of EVs, it is therefore essential to consider all phases of the vehicle life cycle. Many scientific studies use the standardized Life Cycle Assessment (LCA) method prescribed by the ISO 14044 standard which allows the calculation of different environmental impact categories including the GHG impact. In this chapter the life cycle GHG emissions of BEVs and ICEV counterparts in Belgium are investigated across vehicles of different segments.

A comprehensive recent study by Bieker (Bieker, 2021) investigated the GHG emissions of current and future passenger cars in China, Europe, India, and the United States; he looked at ICEVs and hybrid, plug-in, fully electric, and fuel-cell electric vehicles. Bieker concluded that deep decarbonization can be achieved only with battery and fuel-cell electric vehicles, as their expected lifetime emissions are as much as two-thirds lower than those of petrol cars. As the power grid continues to decarbonize, these figures would get even better. It will be checked whether this holds for Belgium using the most recent numbers.

1.5.1 Goal & scope

The assessment in this study follows the steps as presented in the ISO 14044 standard for life cycle assessment. Firstly, the goal and scope are defined. The goal of this part of the study is multi-faceted. The first goal consists of comparing the current environmental impact of each phase of the life cycle of different categories of BEVs to their ICEV counterparts. Secondarily, the future impact will be assessed based on different scenarios, projections and influencing factors, such as the evolution of the electricity mix in Belgium and Europe, possible battery replacement and the location of the battery manufacturing. We limit the discussion to BEVs, leaving PHEVs out of the scope. For the quantitative analysis, the figures used are adapted to the situation in Belgium wherever possible.

To have a good overview and to make a comparison on an equal basis, seven vehicle segments will be analyzed and the vehicle models have been selected among the best-selling ones. These segments are part of the vehicle classification which is commonly used in the European automotive industry as well as in the TCO tool developed for this project. For each segment, a BEV and two ICEVs, one petrol and one diesel, are chosen out of the options available in an online tool from Flanders with details on different vehicles (https://mow.vlaanderen.be/tco/). The data on the vehicles are collected from the technical specifications provided by the manufacturer and can be found in Attachment 1: Life cycle analysis of a BEV: Selected vehicles per car segment and their technical specifications.

1.5.2 Life cycle inventory and impact assessment

The next two steps are grouped in this section. The life cycle inventory step consists of listing all phases and components of the life cycle that may contribute to the total GHG emissions. For each component, several different scenarios and influencing factors that will be investigated are identified. In the following step, the impact of each listed phase is assessed and made concrete by computing the GHG emissions in CO_2 equivalents.

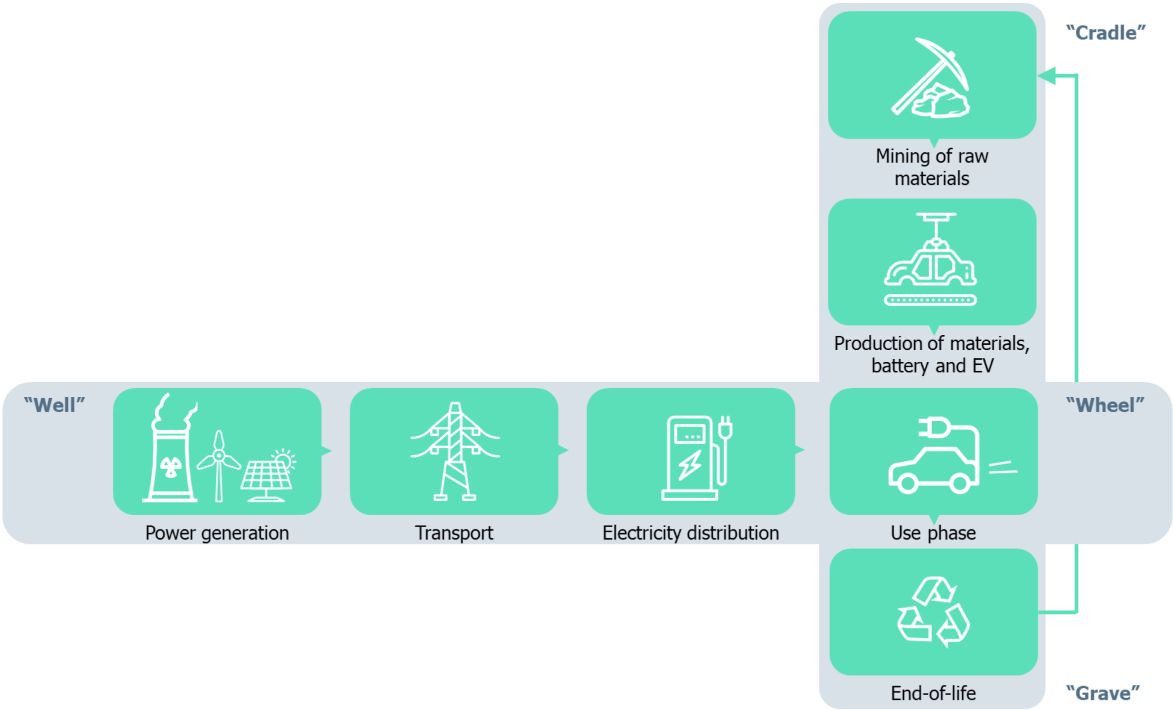


Figure 11 Phases of the life cycle analysis of electric vehicles (adapted from (Verbeek et al., 2015))

1.5.2.1 Car and battery manufacturing

In this section, the GHG emissions originating from manufacturing a BEV are considered. A distinction is made between the empty vehicle, i.e. the car without the battery, and the battery itself.

The study of Ellingsen (Ellingsen et al., 2016) studied values for CO_2 emissions per kg of **vehicle** produced in Europe and found values ranging from 3.9 to 5.7 kg of CO_2 per kg of vehicle. The average 4.8 kg CO_2 per kg of a vehicle is used to calculate the CO_2 emitted by the production of the range of vehicles. These vehicle manufacturing emissions decrease linearly as a function of the reduction in the carbon intensity of the electricity mix, thus resulting in projected emissions of 2.9 kg CO_2 per kg of vehicle manufactured in Europe in 2030. To obtain a value in g CO_2/km, the former values are divided by the lifetime mileages of the vehicles, which are assumed to be constant at 135,000 km for all car segments. This estimate is based on historical data which shows an increasing trend in vehicle lifetime – up to 9 years now – and a decreasing trend in the annual mileage – down to 15,000 km per year.

The **battery** manufacturing process consists of two distinct phases, each with its GHG emissions (Hoekstra, 2019). Firstly, the raw materials must be extracted and refined. In this step, a distinction is made between different production locations and types of battery chemistry. The most commonly used battery type in BEVs is lithium-ion Nickel Manganese Cobalt (NMC, but lithium-ion iron and phosphorous or LFP is growing quickly) which has emissions of 37-58 kg CO_2 per kWh of battery produced in the US, and up to 105-111 kg CO_2/kWh in China. These emissions are location-dependent since the cathode material production relies on the local electricity mix.

The second phase of the battery manufacturing process consists of manufacturing the cells and assembling them in packs. A literature review performed by (Hao et al., 2017) shows that while the emissions of this phase were initially estimated at 50-110 kg CO_2/kWh, more recent studies that take into account high-volume manufacturing find much lower estimates of only 2-5 kg CO_2/kWh. A global weighted average over the different battery chemistries and production locations yields emissions of 65 kg CO_2/kWh (Transport & Environment, 2020), which is the number used in the scenario "World" later on. The conservative 115 kg CO_2/kWh is used in the scenario "China".

In a white paper (Bieker, 2021) by the International Council on Clean Transportation (ICCT) production emissions are estimated at 54 kg CO_2/kWh for the latest state-of-the-art NMC battery in Europe in 2021. This further decrease is due to the trend of increasing specific energy of batteries, i.e. higher storages of kWh per kg of battery, thus requiring fewer materials for the same battery capacity. This number is in line with the low estimates in (Transport & Environment, 2020, 2022) of 59 kg CO_2/kWh and 56 kg CO_2/kWh in 2020 and 2030 respectively assuming the low carbon electricity of Sweden is used in the manufacturing process. These slightly more conservative numbers are used in the scenarios "Europe 2020" and "Europe 2030" later on.

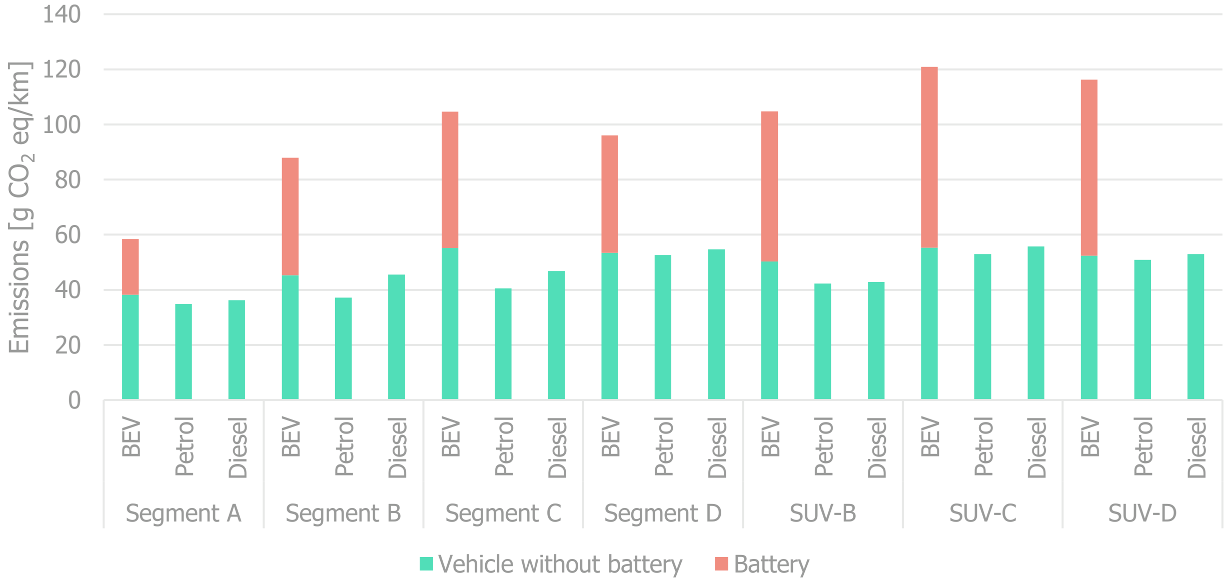


Figure 12 Manufacturing emissions of the range of vehicles, assuming vehicle and battery manufacturing takes place in Europe and China respectively

The manufacturing emissions of the range of vehicles are shown in Figure 12. Vehicle production is assumed to take place in Europe, while the batteries of the BEVs are currently mainly manufactured in China. The latter assumption is grounded in the fact that China is the global leader with 77% of lithium-ion battery manufacturing capacity in 2021 (S&P Global Market Intelligence, 2021). Additionally, as predicted by the European Battery Alliance, Europe is set to meet 69% and 89% of its battery demand in 2025 and 2030 respectively (European Commission, 2022).

The transport of the batteries from China to Europe by ship gives rise to emissions of 25-73 kg CO_2 eq per battery, which, once averaged over the lifetime, is only 0.2-0.5 g CO_2 eq per battery-km. This amount is negligible compared to manufacturing emissions and is thus omitted from the analysis.

Since the battery manufacturing process is carbon intense, the manufacturing emissions of BEVs are 61-158% higher than their ICEV counterparts. SUVs and cars with large batteries are situated on the higher end of this range whereas smaller BEVs tend to be on the lower end. Secondarily, it can be observed that the contribution of the battery remains fairly constant across the range of vehicles at 43-66 g CO_2 eq/km, except for Segment A with only 20 g CO_2 eq/km due to the comparatively small battery capacity of 23.8 kWh of the Fiat 500 Berlina. Because of the increasing trend in the battery capacity and vehicle mass as the vehicle gets larger, the total emissions show an overall increasing trend as well.

Figure 13 shows the sensitivity of the battery manufacturing emissions to the location of manufacturing. The battery manufacturing process uses local electricity. The constitution and carbon intensities of different electricity mixes are discussed in detail in section 1.5.2.4. Due to the coal-rich electricity mix in China, the battery manufacturing emissions are almost twice as high as those in Europe when production takes place in China instead. The 5-13% decrease in emissions in the future projections is exclusively due to projected improved battery cell density. The further decarbonisation of the electricity mix used in the production process is not considered here, but it can be expected to continue decreasing as time goes on.

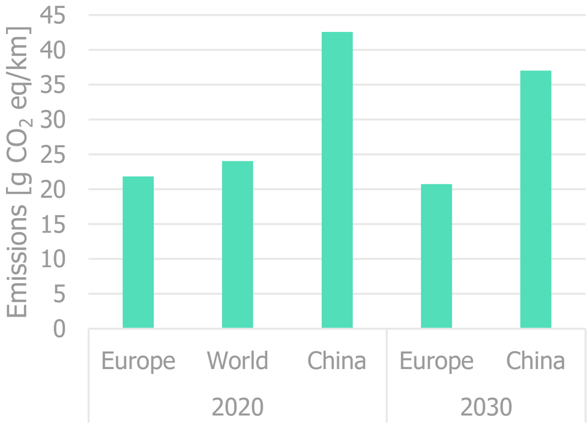


Figure 13 Battery manufacturing emissions of a 50 kWh battery in Europe, the world and China in 2020 and projections for 2030

The battery of a current BEV is estimated to last at least between 1500 and 3000 charging cycles before losing 20% of its capacity (Few et al., 2018). With a range of 400 km, this translates to a battery lifetime of 400k to 1200k km, far larger than the high-end estimate of 300k given to the motor of diesel cars before motor maintenance becomes too expensive and the car is scrapped. However, an electric motor has fewer moving parts so may not break down as easily. Either way, the battery may not be the bottleneck determining a BEV's lifetime, especially considering that batteries are expected to last between 5000 and 10000 charging cycles in 2030 (Few et al., 2018) due to fundamental chemistry changes. In conclusion, one battery may very well suffice for a BEV and therefore a battery replacement, with additional manufacturing emissions, seems unnecessary.

1.5.2.2 Infrastructure

The infrastructure required to use BEVs can be split up into two categories: general infrastructure and specific infrastructure. The general infrastructure includes the different kinds of roads BEVs are driven on. Due to their higher weight, the roads can be hypothesized to deteriorate quicker, although this effect is likely small. Charging stations are infrastructure specific to the use of BEVs. To our knowledge no details regarding the construction and maintenance of charging stations are readily available, their impact is expected to be relatively small and will not be assessed here. Similarly, the construction of petrol stations for fossil fuel vehicles is also excluded.

1.5.2.3 Vehicle and battery end-of-life

When the battery of a BEV reaches its automotive end-of-life – typically assumed to be when it has lost 20% of its original capacity – there are multiple retirement options to consider. The various options outlined by Zhu et al. are shown in Figure 14 (Zhu et al., 2021). At the top of the waste management hierarchy stands "reduction", which is not a retirement option but aims at reducing hazardous waste by modifying industrial production. The five options below it are all options in which the end of automotive service of the battery also means the end of the entire battery life, except for the "reuse" option, where the battery is given a second life as a refurbished or repurposed pack for less-demanding vehicles or other applications. Restoring refers to disassembling the battery and restoring the cathode materials so that they can be reused. Recycling consists of extracting and processing valuable raw materials. Finally, incineration refers to using some battery materials as fuel for other processes while disposal turns to create landfills of batteries.

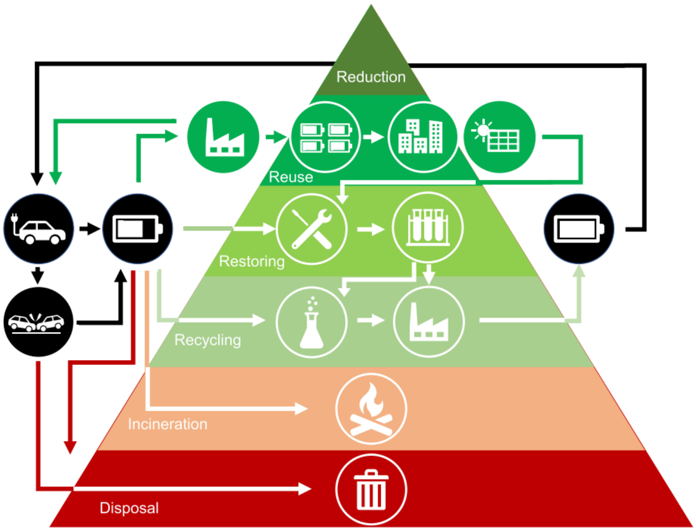


Figure 14 Retirement options for BEV batteries
Source: (Zhu et al., 2021)

To minimize the environmental impact of BEVs, reusing the batteries is preferable so that their lifetime can be extended. However, in practice, a pyrometallurgical process is commonly used in Europe to recycle vehicle batteries (Mathieux et al., 2017). The metal alloy and slag produced during this process are further refined in a hydrometallurgical process which then allows for the recovery of the metal sulphates such as aluminium, lithium and manganese. In this way, they can be reused to produce the cathodes of new lithium-ion batteries. The amount of greenhouse gases emitted during this recycling process is proportional to the mass of the battery, specifically 1.06 kg CO_2 per kg of battery (Pipitone et al., 2021). However, the recycled materials can be reduced so the battery's carbon footprint is actually diminished. Values of the recycling savings are then estimated at -1 to -2.5 kg CO_2 per kg of battery (Hall & Lutsey, 2018). The average -1.75 kg CO_2 per kg of battery of this range is used in the calculations below.

The end-of-life treatment of the empty BEV is the same as that of an ICEV. The vehicle is scrapped and its materials are recycled. In this way, the vehicles' carbon footprint is also diminished, since the recycled materials can be reused to a great extent. Values of the recycling emissions in the literature vary from -2.33 to -3.52 kg CO_2 per kg of vehicle (Buberger et al., 2022). As a conservative estimate, -2.33 kg CO_2 eq/kg is used in the calculations.

In Figure 15 the manufacturing emissions of the Segment A and SUV-C cars with and without recycling are shown. Recycling gives rise to a 49% reduction in vehicle manufacturing emissions and a 10-12% reduction in battery manufacturing emissions. Since the savings obtained through recycling are per kg of vehicle and per kg of battery, the largest environmental impact comes from recycling larger vehicles. This can be seen from the figure, where 21 g CO_2 eq/km or 2.8 tons of CO_2 eq is saved for the Segment A car while 33 g CO_2 eq/km or 4.5 ton CO_2 eq is saved for the Segment C car.

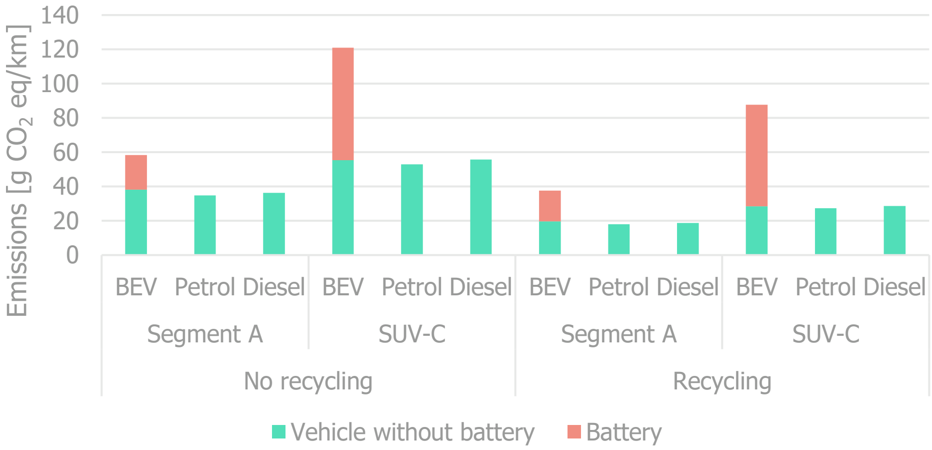


Figure 15 Manufacturing emissions with and without recycling

1.5.2.4 Fuel & electricity

The fuel component concerns the GHG emissions in the part of the energy chain which is commonly referred to as "Well-to-Wheel". This part can be further subdivided into "Well-to-Tank" and "Tank-to-Wheel". For a BEV, the GHG emissions in the Well-to-Tank phase depend on:

- the electricity consumption of the vehicle;
- the electricity mix and the CO_2 emissions associated with the production and distribution of each source of electricity.

For ICEVs, the GHG emissions in the Well-to-Tank factor are obtained by summing the emissions from mining, processing and delivery of fossil fuels.

Regarding the electricity mix, different scenarios are considered since its composition varies greatly from country to country. Hence the 2020 electricity mixes of Belgium, Poland (coal-rich), Sweden (renewable-rich) and China are considered and shown in Table 14. China is included in the discussion because a large share of batteries is manufactured there. In the future, the batteries for EVs will be produced in Europe (European Commission, 2022), so best-case and worst-case European electricity mixes are taken into account to allow for a comparison.

Table 14 The electricity mix in 2020 in Belgium, Sweden, Poland, China, and worldwide and their associated emissions Source: (IEA, 2022a)

Electricity mix	Belgium	Sweden	Poland	China	World
Oil	0.1%	2.1%	1.2%	0.1%	2.8%
Natural gas	29.8%	0.07%	10.7%	2.8%	23.5%
Coal	2.1%	1.1%	69.4%	64.1%	36.7%
Nuclear power	38.7%	30.0%	0%	4.7%	10.3%
Biomass and other	7.7%	6.8%	5.6%	1.6%	2.4%
Renewables	21.6%	61.7%	13.2%	26.6%	24.2%
Emissions [g CO_2 eq/kWh]	198	49	645	551	448

Another factor that influences the composition of the electricity mix, besides the location, is time. The share of fossil fuels in the electricity mix is projected to decrease while the share of renewable energy sources will increase. In Table 15 the average electricity mix in Europe is shown, based on IEA's data for 2019 and projections for 2030 and 2040 as in ENTSO-E's ten-year network development plan. It should be noted that these projections only describe possible future scenarios and should not be interpreted as forecasts. The scenario "Belgium 2030 Full Nuclear Exit" is a projection based on the National Energy and Climate Plans approved in 2019, which are summarised in (Ember, 2020). This projection assumes that all seven nuclear reactors in Belgium will be shut down well before 2030 and that nuclear energy will predominantly be replaced by gas energy. The scenario “Belgium 2030 Partial Nuclear Exit” is adapted to take into account the recent developments regarding the nuclear reactors in Belgium. The two largest reactors will be kept open until 2035 (De Tijd, 2022).

Table 15 The average electricity in Europe in 2019 and future projections for Belgium and Europe
Sources: (IEA, 2022b), (Entsog & Entso-e, 2020), (Ember, 2020) and own calculations

Electricity mix	**Belgium 2030 Partial Nuclear Exit**	**Belgium 2030 Full Nuclear Exit**	**Europe 2019**	**Europe 2030**	**Europe 2040**
Oil	0.05%	0.05%	1.3%	0.05%	0.01%
Natural gas	42.0%	55.7%	21.0%	14.8%	11.8%
Coal	2.0%	2.0%	17.7%	5.2%	0.7%
Nuclear power	13.7%	0.0%	22.7%	19.5%	12.0%
Biomass and other	1.2%	1.2%	5.6%	2.3%	0.7%
Renewables	41.0%	41.0%	31.6%	58.2%	74.7%
Emissions [g CO_2 eq/kWh]	189	239	284	135	82

The Tank-to-Wheel emissions refer to the emissions coming from the specific use of the fuel to propel the vehicle forward. In the case of a BEV, there are no Tank-to-Wheel emissions. For ICEVs the Tank-to-Wheel emissions come from burning fossil fuels and can be expressed in g CO_2 per litre of fuel consumed or more commonly per km driven. The Tank-to-Wheel emissions and consumption characteristics across the range of vehicles under consideration are summarised in Table 16. The details of the vehicles can be found in Attachment 1. The consumption characteristics are important to determine the Well-to-Tank emissions.

Table 16 The Tank-to-Wheel emissions and consumption characteristics across the range of vehicles (for the selected vehicle models)

	WLTP emissions [g CO_2 eq/km]	WLTP consumption [kWh/100km or l/100 km]
BEV	0	12.7 - 18.2
ICEV (Petrol)	105 - 153	4.6 - 6.8
ICEV (Diesel)	89 - 126	3.4 - 4.8

With these parameters, the Well-to-Wheel emissions across the range of vehicles are shown in Figure 16. The following assumptions are made:

- The Well-to-Tank emissions for petrol and diesel cars are 26 and 28% of the Tank-to-Wheel emissions respectively (Knobloch et al., 2020).
- The Well-to-Tank emissions of BEVs and the Tank-to-Wheel emissions of petrol and diesel cars as specified by the Worldwide Harmonised Light Vehicle Test procedure (WLTP) are increased by 25% in the calculations since real-world fuel use of vehicles is widely recognised to exceed manufacturer ratings.

From the figure, it can be observed that the Well-to-Tank emissions of BEVs, concerning the production of electricity, are about the same or slightly lower than their ICEV counterparts at 31-45 g CO_2 eq/km. The main reason why BEVs have lower emissions is that they emit no greenhouse gases by using electricity, whereas the burning of the fuel is the primary source of GHG emissions of ICEVs with values of 111-191 g CO_2 eq/km. It can be observed that petrol cars emit 2-29% more CO_2 per km than diesel cars, but it is well-known that diesel cars perform worse when it comes to particulate matter emissions, a metric not considered here. In general larger, heavier cars have higher emissions, with some exceptions and variations inherent to the choice of representatives of the different car segments. In total the Well-to-Wheel emissions of BEVs, with values of 31-45 g CO_2 eq/km are only 17-25% of the Well-to-Wheel emissions of the ICEVs which have values of 142-241 g CO_2 eq/km.

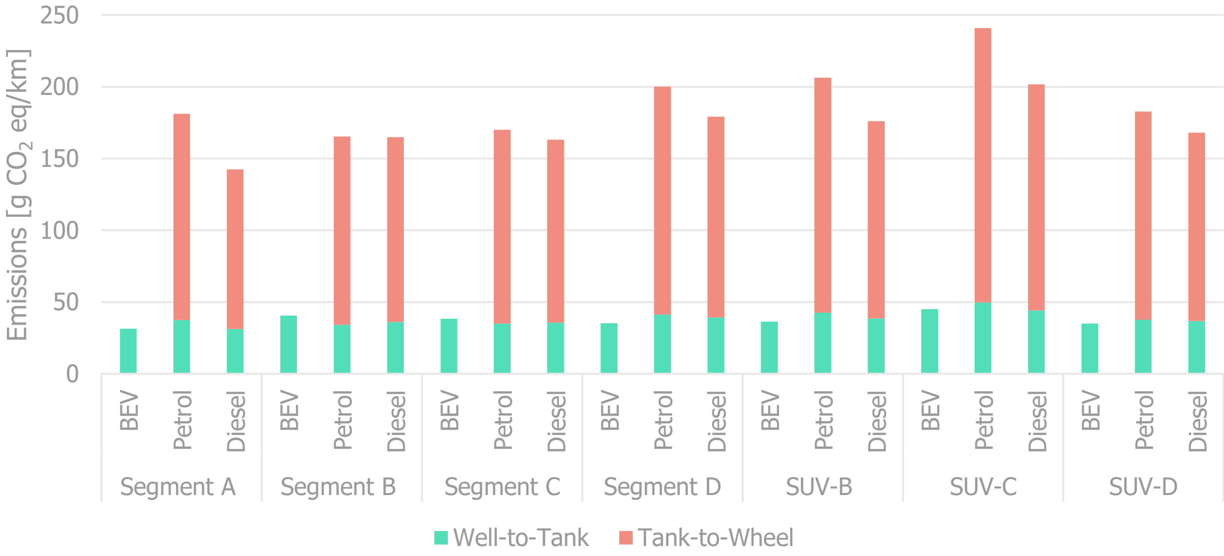


Figure 16 The Well-to-Wheel emissions across the range of vehicles. BEVs use the 2020 Belgian electricity mix

The impact of different electricity mixes on the emissions of the highest-consuming EV category SUV-C is shown in Figure 17. Driving a BEV right now on electricity generated in Poland is more than three times as polluting as driving the same BEV on electricity generated in Belgium, with emissions of 117 g CO_2 eq/km compared to 36 g CO_2 eq/km, but still only half as polluting as driving the petrol counterpart. With the current electricity mix of Sweden, a BEV does 4 times better than a BEV in Belgium with emissions of 9 g CO_2 eq/km and emits only 60% of the projected average European emissions in 2040 due to the high share of renewable energy sources. In conclusion, despite already doing better than their ICEV counterparts, there is still a lot of room for improvement in Europe. The most obvious course of action is to put extra effort into the further "greening" or decarbonisation of the electricity mix on which BEVs rely.

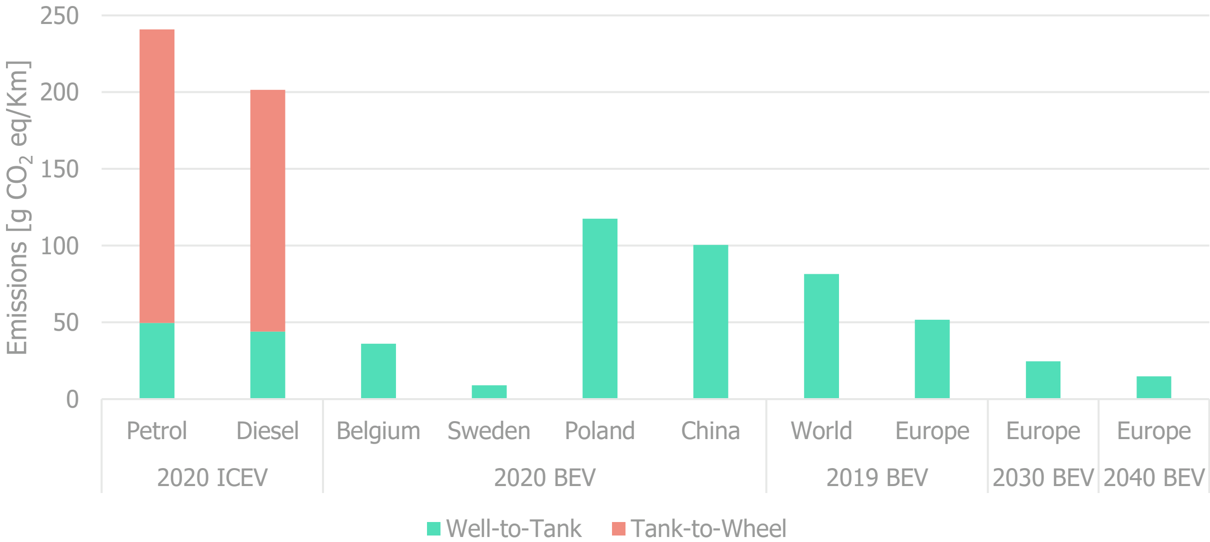


Figure 17 Well-to-Wheel emissions of the SUV-C category for different electricity mixes compared to the ICEV emissions

Finally, it is worth noting that the composition of the electricity mix also varies on an hour-to-hour basis. Therefore, charging during off-peak hours, when "greener" electricity is available can significantly reduce GHG emissions with reductions of up to 360 kg of CO_2 per vehicle per year or 24 g CO_2 per vehicle-km according to (Energy Monitor, 2022).

1.5.3 Interpretation

To interpret the results, the total carbon impact of BEVs and ICEVs and the relative importance of each contributing factor are discussed in this section.

By summing the contributions of the previous sections the total carbon impact is obtained in Figure 18. In this calculation the following assumptions are made:

- The batteries are assumed to be produced in China with an environmental impact of 115 kg CO_2/kWh.
- The vehicles are produced with an environmental impact of 4.8 kg CO_2/kg of vehicle.
- The BEVs use the Belgian electricity mix for charging which has a carbon intensity of 198 g CO_2/kWh.
- One reference vehicle was chosen in every segment and propulsion (see appendix 1).

It is immediately clear that under these circumstances BEVs outperform ICEVs from an environmental viewpoint. The BEVs have life cycle emissions of 90-166 g CO_2 eq/km, 41 to 68% of their ICEV counterparts, which have life cycle emissions of 179-294 g CO_2 eq/km. There is an overall increasing trend in emissions as the vehicle size increases, due to increasing vehicle mass, battery size and Well-to-Wheel emissions. It is also clear that BEVs have lower life cycle GHG emissions thanks to having no Tank-to-Wheel emissions. Without considering these tailpipe emissions, BEVs have higher life cycle GHG emissions than ICEVs due to the environmentally unfriendly battery manufacturing process.

For BEVs the life cycle GHG emissions are split into three roughly equal parts:

- The battery manufacturing emissions amount to 32-42% of the life cycle GHG emissions, except for the Segment A car where they only account for 23% since the chosen representative Fiat 500 Berlina has a small battery.
- The production of the electricity used to charge the vehicle over its lifetime contributes 23-34% of the life cycle GHG emissions.
- Vehicle manufacturing emissions account for 33-42% of the life cycle GHG emissions.

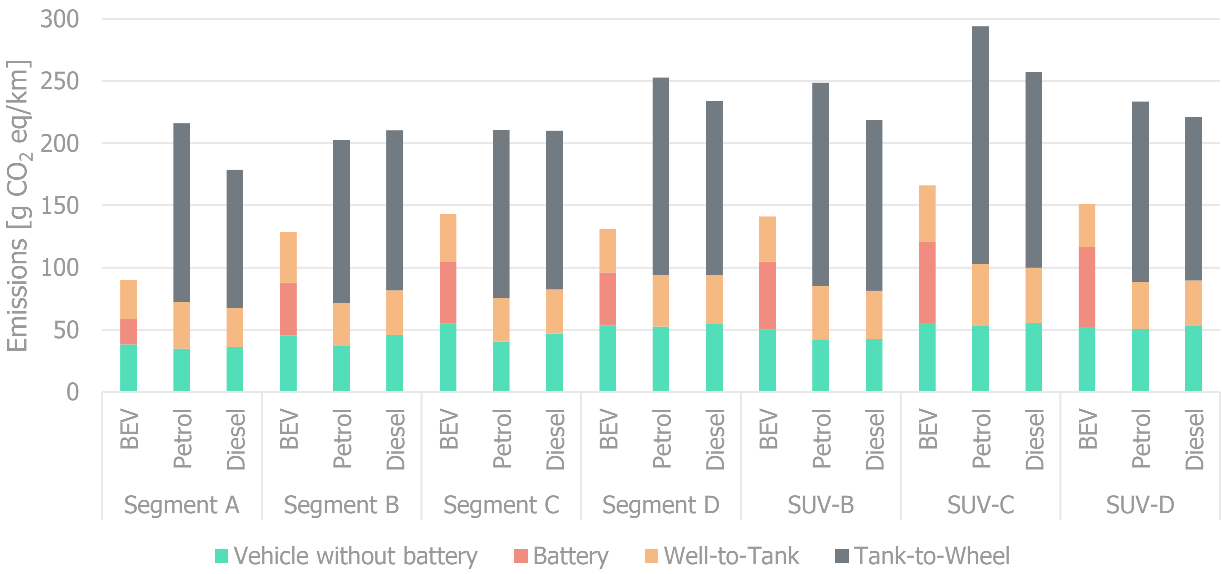


Figure 18 Life cycle GHG emissions of BEVs and their ICEV counterparts, assuming the batteries are manufactured in China and the BEVs use the Belgian electricity mix for charging

As an example, Figure 19 shows the life cycle GHG emissions of the SUV-C BEV using the average European electricity mix in 2020 and 2030 compared to the life cycle GHG emissions of the SUV-C ICEVs in 2020. The assumptions made in the calculations are summarised in the following table:

	Vehicle manufacturing environmental impact [kg CO_2/kg of vehicle]	Battery manufacturing environmental impact [kg CO_2/kWh]	Electricity mix carbon intensity [kg CO_2/kWh]
2020	4.8	59	0.284
2030	2.9	56	0.135

These projected reductions due to technological advances and the greening of the electricity mix result in 40% reduced vehicle manufacturing emissions, 13% decreased battery manufacturing emissions and a 45% decrease in Well-to-Tank emissions. In total a BEV manufactured and operated in 2030 has 31% lower life cycle GHG emissions than an identical BEV in 2020, from 165 down to 115 g CO_2 eq/km.

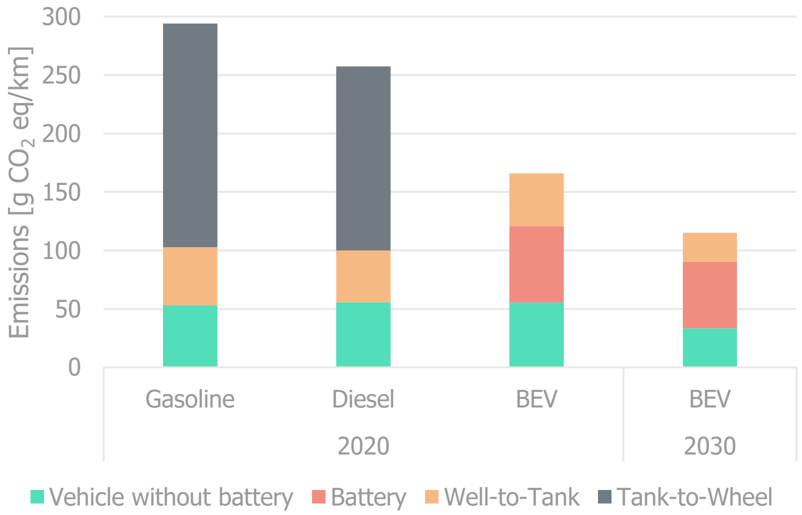


Figure 19 Life cycle GHG emissions of the SUV-C BEV using the average European electricity mix in 2020 and 2030 compared to the SUV-C ICEVs in 2020

Figure 20 shows the life cycle GHG emissions of the vehicles in the SUV-C category in several different future scenarios – specifically applied to Belgium – with varying locations of battery manufacturing and varying electricity mixes as described previously:

- Worst case
  - the battery of the BEV is produced in China with an environmental impact of 115 kg CO_2/kWh
  - the BEV uses the worst-case Belgian electricity mix, namely the one provided in the scenario "Belgium 2030 Full Nuclear Exit", which has a carbon intensity of 239 g CO_2/kWh.
- Base case – Battery Production in China
  - the battery of the BEV is produced in China with an environmental impact of 115 kg CO_2/kWh
  - the BEV uses the most realistic future electricity mix, namely the one provided in the scenario "Belgium 2030 Partial Nuclear Exit", which has a carbon intensity of 189 g CO_2/kWh.
- Base case – Battery Production in Europe
  - the battery of the BEV is produced in Europe with an environmental impact of 59 kg CO_2/kWh
  - the BEV uses the most realistic future electricity mix, namely the one provided in the scenario "Belgium 2030 Partial Nuclear Exit", which has a carbon intensity of 189 g CO_2/kWh.
- Best case
  - the battery of the BEV is produced in Europe with an environmental impact of 59 kg CO_2/kWh
  - the BEV uses a very optimistic future electricity mix with a large share of renewable energy, comparable to the current Swedish electricity mix which has a carbon intensity of 49 g CO_2/kWh.

Vehicle production is always assumed to take place in Europe. In all scenarios, the BEVs perform better from an environmental standpoint than their ICEV counterparts. The life cycle GHG emissions in the worst case scenario at 143 g CO_2 eq/km are still 48% and 39% lower than those of a petrol and diesel car respectively, while those in the best case scenario at 76 g CO_2 eq/km are 72% and 68% lower respectively.

The base case scenario with battery production taking place in China has total life cycle GHG emissions of 133 g CO_2 eq/km, only 6% lower than in the worst case scenario due to the less carbon-intense electricity mix in the partial nuclear exit scenario compared to the full nuclear exit. Producing the batteries in Europe instead in turn gives rise to a 24% reduction in emissions due to the less carbon-intense battery manufacturing process. Finally, using an electricity mix based on almost exclusively renewable energy reduces the total emissions by another 25%, down to only 76 g CO_2 eq/km in the best-case scenario.

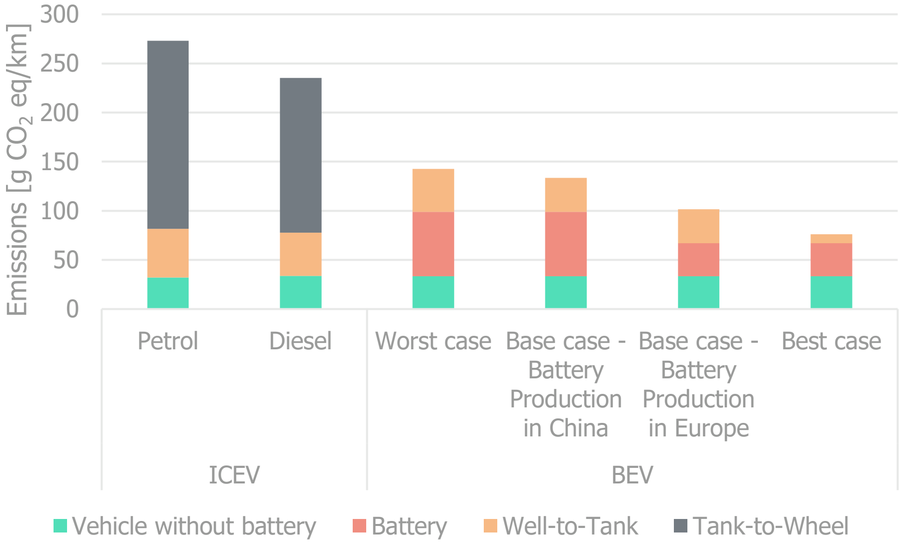


Figure 20 Life cycle GHG emissions of the SUV-C vehicles in different scenarios

In conclusion, BEVs outperform ICEVs from an environmental standpoint, when it comes to greenhouse gas emissions. On average, across the different car segments, a BEV using the current Belgian electricity mix has life cycle GHG emissions of 136 g CO_2 eq/km while petrol and diesel cars have emissions of 237 and 219 g CO_2 eq/km respectively. For a BEV, roughly one-third of the life cycle emissions originate from the carbon-intense battery manufacturing process. In the future, these emissions can be cut in half by producing the batteries in Europe, using less carbon-intense European electricity mixes in the manufacturing process, rather than in China. Another third of the life cycle emissions come from the production of the electricity used to charge the BEVs. Using an electricity mix with a larger share of renewable energy can reduce these emissions by up to 75%.

Our findings are comparable to the results of the LCA in (Puig-Samper Naranjo et al., 2021), where they found 135 g CO_2 eq/km for a BEV using the electricity mix of Spain with a vehicle lifetime of 150,000 km and life cycle emissions of 261 and 241 g CO_2 eq/km for petrol and diesel cars respectively. Similar results were also found in a new analysis for Europe revealing that the average European BEV is more than three times cleaner than equivalent petrol cars bought in 2022 (-69% CO_2 emissions) (Transport & Environment, 2022). This study also included PHEVs: despite their green credentials, PHEVs' lifecycle emissions are much closer to polluting conventional petrol cars than to BEVs.

2 State-of-the-art in European countries

2.1 Introduction

This chapter provides an overview of the current situation and foreseen developments and policy measures in neighbouring, comparable and leading countries.

- The evolution of the electric vehicles market and the link with influencing variables like EV deployment strategies, charging infrastructure, taxation and financial incentives.
- Tools to monitor the progress of policy strategies on electric vehicle adoption (data gathering method, data openness, monitoring tools …).
- Countries included: the Netherlands, United Kingdom, Norway, Sweden, France, and Germany.

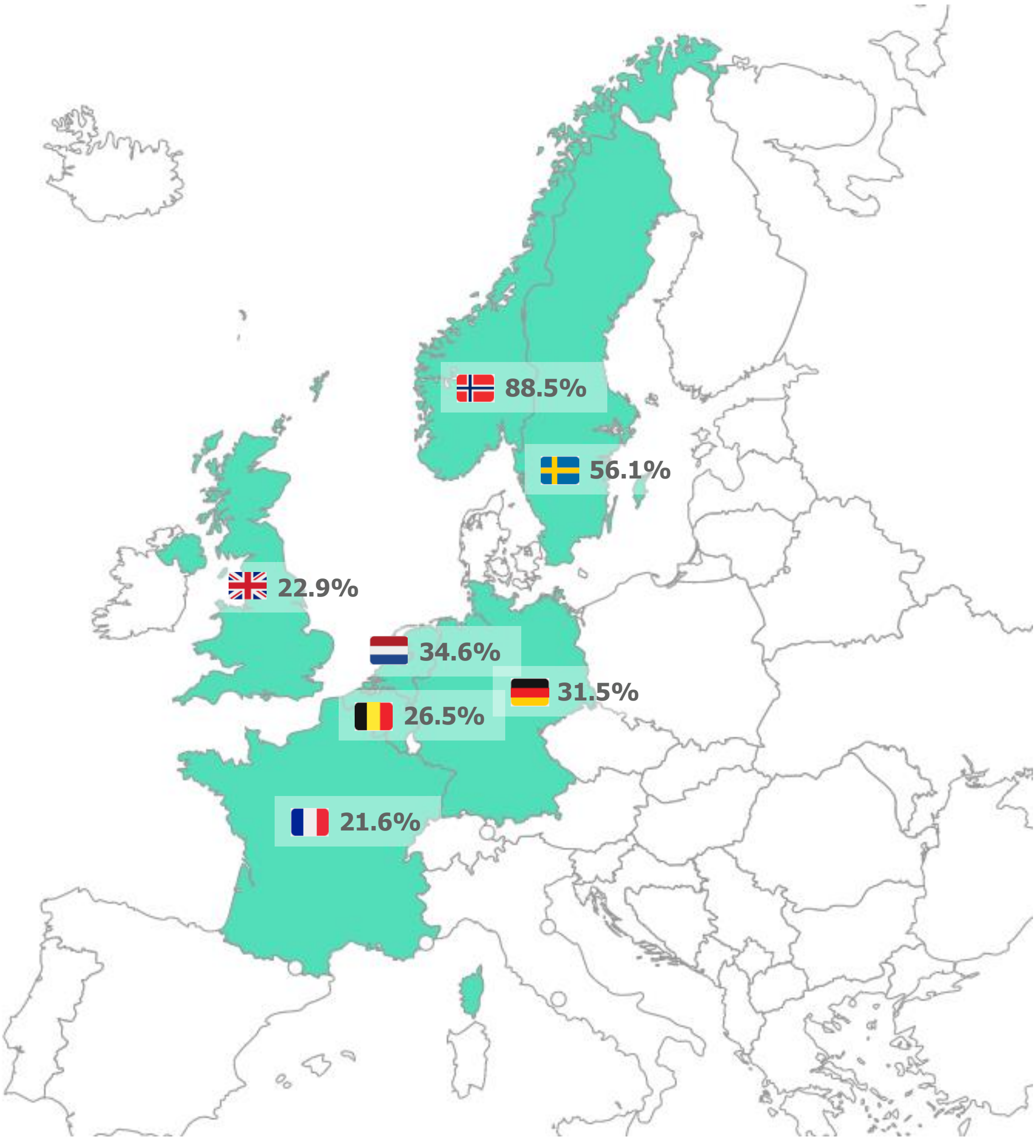


Figure 21 Countries included in the benchmark with the EV share in total sales (BEV + PHEV) for the year 2022

2.2 Summary

Table 17 shows the main numbers of 2022 **sales of BEVs and PHEVs** in the selected countries, and in comparison to Belgium. Norway has by far the highest share of EVs, with 79.3% being BEVs and 9.2% PHEVs. Belgium is lagging behind in the sales of BEVs, however, there was a 66% increase in sales compared to the year before, and the share of PHEVs is higher. In fact, Belgium is the only country where the share of PHEVs is larger than the share of BEVs. In the EU new sales of fossil fuel cars will be forbidden from 2035 onward. Some countries announced more ambitious goals, for example, Norway wants to stop the sale of ICEVs as early as 2025.

Table 17 Overview of the number of new registrations of BEVs and PHEVs in the selected countries for the year 2022, the share of BEVs and PHEVs in total sales, and the percent change with the year 2021

Year 2022							
BEV – total numbers	37,638	73,394	267,203	138,287	95,035	203,122	471,394
PHEV – total numbers	59,281	34,512	101,414	16,124	66,614	126,547	362,093
BEV – share in total sales [%]	10.3	23.5	16.6	79.3	33.0	13.3	17.8
PHEV – share in total sales [%]	16.2	11.1	6.3	9.2	23.1	8.3	13.7
BEV – % change with 2021	+66.0	+15.1	+40.1	+21.6	+65.4	+25.3	+32.3
PHEV – % change with 2021	+24.1	+11.4	-11.5	-57.8	-14.4	-10.3	+11.3

Source: ACEA,2022 (https://www.acea.auto/files/20230201_PRPC-fuel_Q4-2022_FINAL-1.pdf) and own calculations

Recent data shows a high number of **charging stations** per million inhabitants in the Netherlands, leading to only 4 EVs per public charger (Table 18). On the contrary, Norway also has a high number of chargers per million inhabitants, but because of the high number of EVs in the fleet, the number of EVs per charger is the highest of all 7 countries considered. In Belgium, the number of EVs per public charger is 13 which is somewhere in the middle compared to the other selected countries. An EU-appointed commission states that countries should aim for a maximum of 10 electric vehicles per public charging point. With the increasing numbers of EVs in Belgium, more EV charging infrastructure needs to be installed to stay within (or close to) the recommended limit.

Table 18 Overview of available charging infrastructure in the selected countries

							
Nr public charging points / 1M inhabitants [1]	1222	5245	643	4469	2337	1155	773
Nr public charging points / 100km of road infrastructure [2]	5.5	47.5	19.1	5.8	5.0	4.1	19.4
EVs per public charger [3]	13	4	13	24	18	9	13

Sources: [1] Eco-movement, 2022: https://www.eco-movement.com/statistics-infrastructure-ev/; [2] ACEA, 2020: https://www.acea.auto/press-release/electric-cars-10-eu-countries-do-not-have-a-single-charging-point-per-100km-of-road/; [3] EAFO, 2021: https://www.eafo.eu/sites/default/files/2021-03/EAFO%20Europe%20on%20the%20electrification%20path%20March%202021.pdf; own calculations

All countries have some **incentives** in place to stimulate the sales of EVs (Table 19). The measures are diverse and include pricing measures that tackle the purchase cost, but also taxes that impact the use or the ownership. Most incentives have time and volume limits. Measures are discussed in more detail in the country reports. Below is a summary of the most important lessons learned from the country benchmark:

- The bonus/malus or feebate system is used in several countries. This system imposes a fee on vehicles with high CO_2 emissions or fuel consumption (i.e., low fuel economy) and provides a rebate to vehicles with low CO_2 emissions or fuel consumption (i.e., high fuel economy). In France, the introduction of the malus-scheme had a good effect as France now has one of the cleanest new vehicle fleets with an average of 98.5 gCO_2/km while the EU average is 108.2 gCO_2/km in 2020. Sweden has struggled with inconsistent funding for incentives; the country's bonus-malus system adopted in 2018 was designed with reliability and transparency in mind, resulting in steadier EV sales and one of the highest EV market shares in Europe.
- Norway has shown that EV-friendly tax schemes (e.g. zero VAT on EV purchases, or higher VAT on polluting vehicles) can be an effective alternative to direct monetary grants when it comes to boosting EV purchases.
- Rather than introducing new fiscal or financial measures, several countries are cutting back existing subsidies or tax exemptions in the coming years. In Germany, the government will remove subsidies for PHEVs from 2023 as they are not always as environmentally friendly as initially thought. In France as well, a purchase subsidy will only be available for cars emitting less than 20 gCO_2/km, to boost BEV sales. As EVs are already quite mature in the company car market where the TCO is more important than the purchase price, the German government will also cut all purchase subsidies for company cars from 2023.
- Abruptly phasing out BEV subsidies or tax incentives creates a run before a certain financial advantage is removed, and a sudden drop in EV sales disrupts the market (e.g. in the Netherlands). In countries where the incentives are only changing a little by reducing gradually, there are fewer disturbances in the BEV sales figures (Weken et al., 2021).
- All countries took measures to support EV sales, however, at the same time countries are also still subsidizing fossil fuel cars, for example via tax reductions on petrol prices that peaked in the first half of 2022.
- No country has plans to increase BEV financial or fiscal incentives, only no changes or phasing out of incentives.
- Several national governments, regional and city authorities provide non-financial benefits to provide high-value benefits to end users at relatively low cost, for example, preferential parking and road access as in Norway.

Table 19 Incentives for electric vehicles in European countries (black = national measure, green = local measure)

							
Subsidy/bonus to purchase a new vehicle		x	x		x	x	x
Subsidy/bonus to purchase a second-hand vehicle		x				x	x
Subsidy for charging infrastructure	x [1]		x	x	x	x	x
Scrapping program for old vehicles						x & x	
Reduction from road tolls, parking and other charges		x	x	x	x	x	x
Exemption from VAT on purchase				x			
Exemption from annual road tax	x	x	x				x [2]
Reduction of annual road tax	x			x	x		x [2]
Exemption from registration tax	x	x	x	x		x	
Reduction of registration tax	x					x	
Personal income tax reduction (benefit-in-kind)	x	x	x	x	x	x	x
Access to extra-infrastructure		x		x			

[1] Tax deductibility in Belgium.
[2] Temporary exemption; after 10 years or from 2030 annual taxes are to be paid.

2.3 Country reports

The detailed country reports are included in Attachment 2: State-of-the-art in European countries.

3 Consumer profiles – a survey

3.1 Introduction

There is no systematic annual survey of drivers in Belgium about electric driving. As a result, there is little knowledge on the determinants of a transition to fully electric driving, and on the general attitude towards the technology and the transition towards electric fleets. Barriers and facilitators that work for private drivers in Belgium are unknown. Therefore, a survey was developed to identify consumer profiles. We wanted to find out which drivers are forerunners in the transition towards electric driving, and who is currently left behind. Factors that convince people or hold them back are investigated.

The web-based survey was carried out in **May 2022** in a sample of **>2000 drivers** who possess a vehicle in their household. Respondents had to live in Belgium. We aimed for a **representative sample**, and where this was not possible weights were applied to correct for underrepresented groups. Current EV drivers were excluded and were presented with a longer questionnaire on their experiences (for results, see Chapter 5).

Several European countries already perform regular surveys on electric driving. In the Netherlands, there is an annual survey of EV drivers and one on charging infrastructure. In Nordic countries, there is the Nordic EV Barometer. In 2021 it is the fourth time the survey has been conducted among a representative sample of around 1000 adults in the countries Norway, Sweden, Denmark, Finland and Iceland. Additionally, Norway also conducts a large survey among EV drivers about their perception (approximately 15,000 drivers).

3.2 Description of the sample

A general description of the sample can be found in the table below (Table 20). These descriptive statistics are based on the unweighted sample. A weighting of the data is applied afterwards to obtain a representative sample within the population.

Table 20 Description of the sample

	Overall (N=2110)
Age group	
• 18-34	439 (20.8%)
• 35-54	822 (39.0%)
• 55 +	849 (40.2%)
Gender	
• Male	1018 (48.2%)
• Female	1092 (51.8%)
Region	
• Flanders	1377 (65.3%)
• Wallonia	608 (28.8%)
• Brussels	125 (5.9%)
Urbanisation	
• Urban	405 (19.2%)
• Suburban	518 (24.5%)
• Peripheral	703 (33.3%)
• Rural	484 (22.9%)
Education	
• Secondary education or lower	1189 (56.4%)
• Higher education	921 (43.6%)

	Overall (N=2110)
Job	
• Student	66 (3.1%)
• Young professional (<10 years experience)	283 (13.4%)
• Senior professional (>10 years experience)	847 (40.1%)
• Freelancer/independent	59 (2.8%)
• Job seeker	43 (2.0%)
• Other (not looking for a job, houseman or -wife, unable to work, …)	185 (8.8%)
• Retired	627 (29.7%)
Number of cars in household	
• 1	1242 (58.9%)
• 2	737 (34.9%)
• More	131 (6.2%)
Company car	
• Yes	279 (13.2%)
• No	1771 (83.9%)
• Missing	60 (2.8%)

Currently, in the sample, most households own a petrol car, followed by a diesel (those without a car were excluded). About 1% owned a BEV, however, note they were redirected from the current survey and entered into an extensive survey on driving experiences (see further). There are statistically significant differences in the type of car owned depending on the net household income as shown in Figure 22. About 50% of households with a net income of over €4000 per month own a petrol car while about 65% of those with an income lower than €4000 per month do ($p < 0.001$). The reverse trend is observed for diesel cars ($p < 0.001$). Finally, households having a net income of over €4000 per month are up to 3 times more likely to own a plug-in hybrid car (PHEV) compared to lower-income households ($p < 0.05$). These trends already suggest that **high EV car prices** may be a **bottleneck in the transition** to a greener vehicle fleet.

13.2% of the sample owned a company car. People who own a company car are 4 times more likely to own a PHEV: 6.1% vs 1.5% ($p < 0.001$).

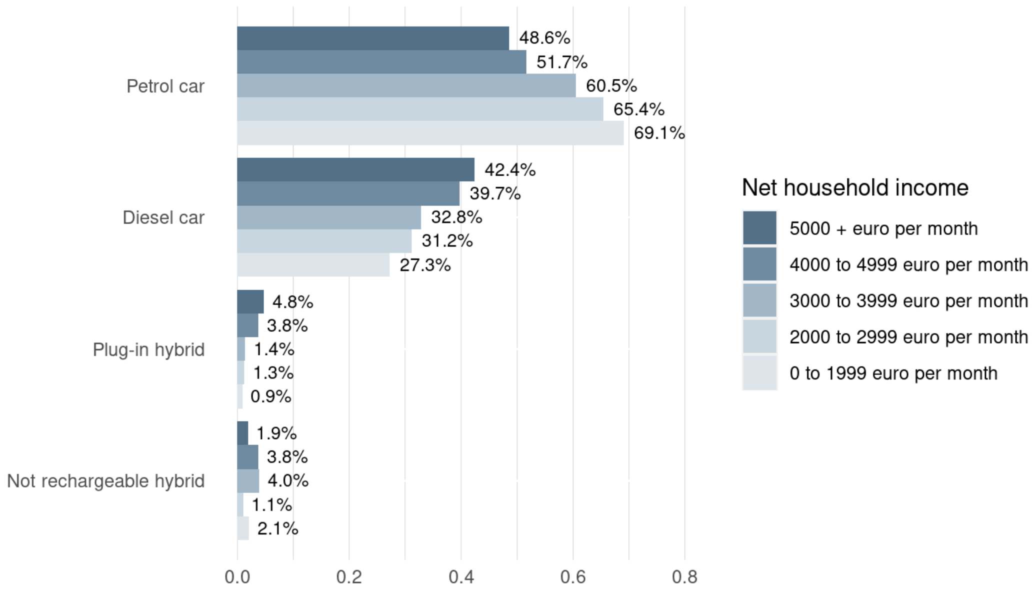


Figure 22 Type of car owned by net household income, n = 2110 (unweighted)

3.3 Current access to charging stations

Out of 2110 weighted respondents, **16%** indicate that they currently **have access to** – or will have access to – **an EV charging station**. The distribution of the type of charger that they have access to is shown in Figure 23.

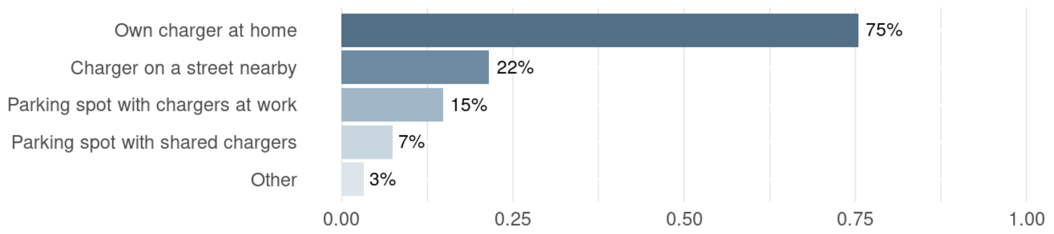


Figure 23 Type of EV charger that the respondents have access to, n = 334

People are **more likely to have access to an EV charger if they have a company car**: 34% vs 13% ($p < 0.001$). This can be explained by the fact that companies who offer company cars are likely to have EV chargers available at work, or they (partly) refund the installation of a car charger at home.

People living in **Wallonia** are **less likely to have access to an EV charger**: 13% vs 17% and 18% in Flanders and Brussels respectively ($p < 0.01$). This observation indicates that **Wallonia** may be **lagging behind in the transition to a greener vehicle fleet**.

Somewhat surprisingly, there were **no statistically significant differences in access to EV chargers by degree of urbanisation**: 14.4% of people living in rural areas have access to an EV charger while 16.2% and 16.6% in urban and suburban areas respectively do. However, there are significant differences in the **type of charger** people have access to **depending on the degree of urbanisation** as shown in Figure 24. 81% of drivers living outside the city have access to their own charger at home, while that is the case for only 56% of people living inside the city ($p < 0.001$). Conversely, more people in the city have access to a charger on a street nearby and parking spots with shared chargers than people outside the city ($p < 0.001$). Because urbanisation is not correlated with access to EV chargers, it can be concluded that **different types of chargers cover the needs in each case**.

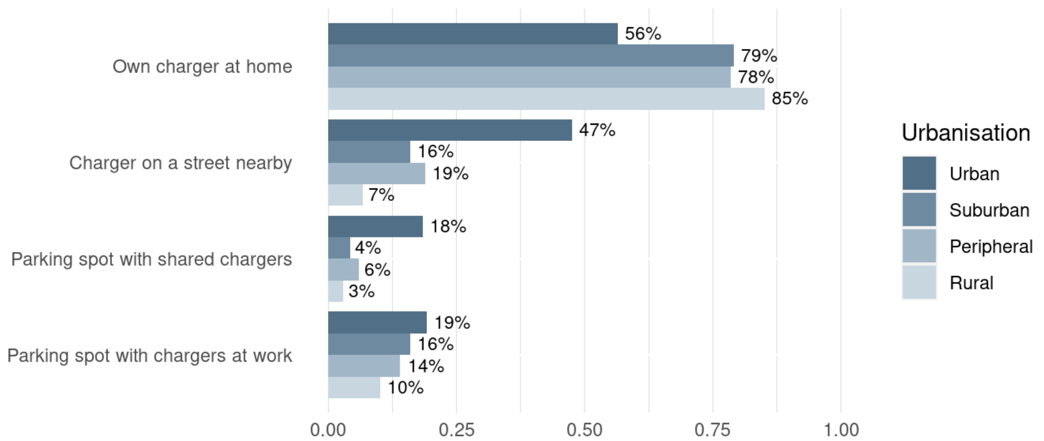


Figure 24 Type of EV charger by urbanization among respondents who have access to an EV charger, n = 334

3.4 Driver profiles

In this section attitudes of the public towards EV technology are discussed based on the answers to some questions that tried the gauge the driver profile the respondents fit into.

The attitude of people towards EV technology is shown in Table 21. **Only 8.1%** of the respondents are **currently convinced about the benefits of EVs** and willing to switch. According to the innovation adoption curve from Rogers, they can be split into 2.2% of innovators and 5.9% of early adopters. Note that these are not actual EV drivers, but drivers that are willing to switch soon.

On the other side of the spectrum, **27.5% of the respondents are not convinced** about the EV technology and they will use their ICEV for as long as they are available. These can be considered as laggards. Another 20.1% are sceptical and would only transition to EVs when the cost is more attractive or their favourite ICEV is no longer produced. We consider them as the late majority.

Finally, 44.3% of the respondents find themselves in the middle ('early majority') and would be willing to switch when the technology has matured and has clearly established benefits. These drivers could also be convinced by recommendations of current EV users.

In summary, whereas the innovators are motivated by the technological side of an EV, the majority will probably be motivated to drive electric in a different way. The results suggest an asymmetric adoption curve of Rogers with a skinny left tail (leaders) and a fat right tail (laggards).

Table 21 Attitude towards EV technology. Innovation adoption profiles are indicated in green

In which description do you recognise yourself the most?	Percent
I am not convinced about the EV technology - I will use my ICE car for as long as they are available. ~Laggards	27.5%
I am sceptical about new technologies, but I would consider the transition to EV if the overall cost is more attractive than ICE cars. ~Late majority	13.2%
I like stability and I would only buy an electric car when the current model I drive is no longer produced. ~Late majority	6.9%
I appreciate convenience. I would only buy an electric car when it has been on the market for a while and has clearly established advantages. ~Early majority	24.4%
I am pragmatic and I take the time to be convinced of the benefits of an electric car. My decision to use EV would be based on recommendations from users who already have the experience. ~Early majority	19.9%
I don't mind if there are still slight restrictions/limitations, I believe that the benefits of EV outweigh them and I am ready to switch. ~Early adopter	5.9%
I follow new technological developments and dare to take risks by being the first one to try new technologies (like electric cars). ~Innovator	2.2%

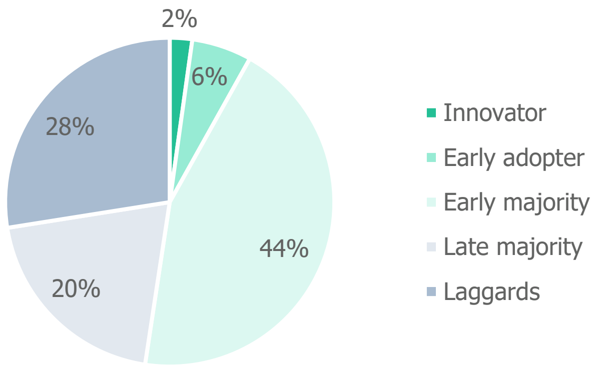


Figure 25 Driver profiles following the Innovation adoption curve of Rogers

The fact that a large proportion of people is sceptical about EV technology also shows in the number of people who have tried an EV: a large majority of **71% have never tried an EV**, while 16% have tried one as a passenger and the remaining 13% have driven an EV. Those who have tried an EV where clearly more convinced about EVs, especially those who tested an EV as a driver. However, we should be careful with the interpretation and we cannot conclude about causality. **43%** of people **know someone who owns or leases an EV.**

Despite the small percentage of people who have tried an EV, **57% admit to seeing EVs in their neighbourhood sometimes** and 19% see them often. The remaining 24% of people do not see EVs in their neighbourhood. It should be noted that this last percentage may very well be lower in reality, due to the quickly growing catalogue of EV models by different manufacturers. In **rural areas, EVs are seen the least often** ($p < 0.01$), with 35% of people not seeing EVs in their neighbourhood, while **in urban areas EVs are seen most often** ($p < 0.10$), with 25% of people often seeing EVs.

Next, the respondents were asked some climate-related questions. Of the 2110 respondents, **87%** self-report being at least **somewhat aware of the climate crisis**. Among higher educated people this percentage rises to 89% which is only slightly more, but statistically significant, than 86% among lower educated people ($p < 0.05$). A larger difference is seen in the percentage of people who indicate being very much aware of the climate crisis: 33% among higher educated vs 25% ($p < 0.001$). To the question "**how important**, in your opinion, is it that the **electricity used in an EV** comes from **renewable energy**?" **19%** think it is **vital**, and another **64%** of the respondents answered **(very) important**. 24% of the higher educated think it is vital compared to 15% among lower educated people ($p < 0.001$). It was shown in chapter 1.5 that it is important that the electricity used in an EV comes from renewable sources, but even with the worst electricity mixes in Europe EVs outperform ICEVs.

When asked about their general **attitude towards EVs**, **more men** than women indicate that they **are (very) enthusiastic** about EVs: 32% vs 22% ($p < 0.001$). This indicates an important gender gap. The same trend can be observed according to the highest level of education, with those having finished their **higher education** being **more enthusiastic**, 33% vs 22% ($p < 0.001$) and with a degree of **secondary education or lower** being **more hesitant**: 45% vs 37% ($p < 0.001$). More women are neutral ($p < 0.01$) as shown in Figure 26. It should be noted that in both cases the **largest proportion of people is (very) hesitant.** To look into where the hesitant people reside, the regional differences are shown in Figure 27. People in **Wallonia** are **more hesitant** ($p < 0.01$), demonstrating once again that Wallonia is **lagging behind** in the **transition to a greener vehicle fleet**. In **Brussels,** people are more **divided** ($p < 0.01$).

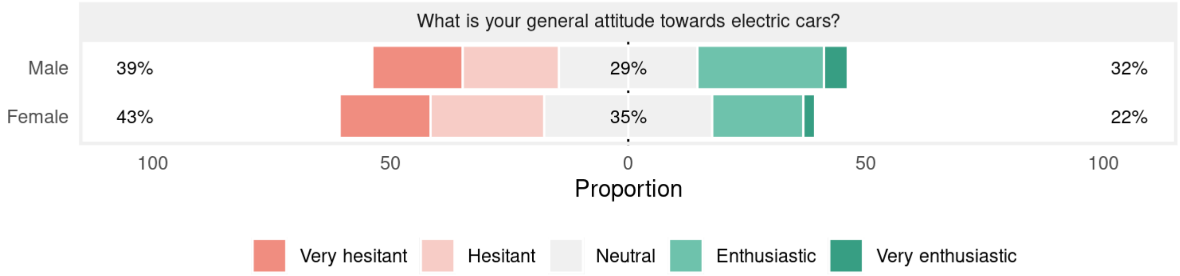


Figure 26 Attitude towards EVs according to gender

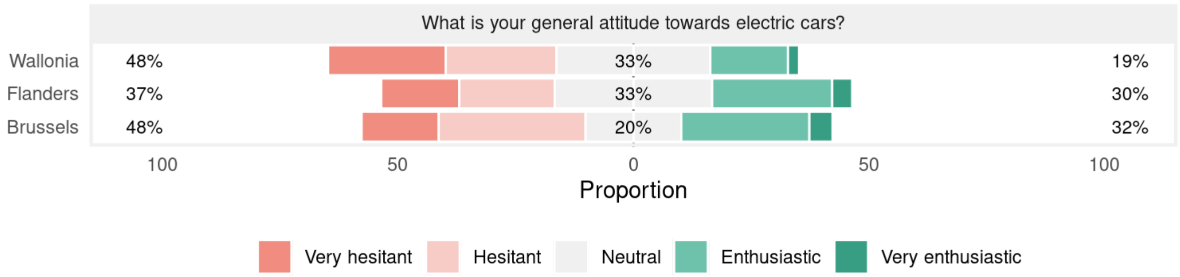


Figure 27 Attitude towards EVs according to region

Similarly, **almost twice as many men** indicate being **interested in the development of EV technology** ($p < 0.001$), while women are more neutral and uninterested ($p < 0.001$) as shown in Figure 28. Analogous to the attitude towards EVs, **higher educated people** tend to be **more interested**: 46% vs 33% ($p < 0.001$). Compared with the attitude towards EVs, overall **more people are interested** in the technology but are **not yet convinced**. This observation suggests that there is **room for improvement** in the **communication** and sharing of **information about EVs**.

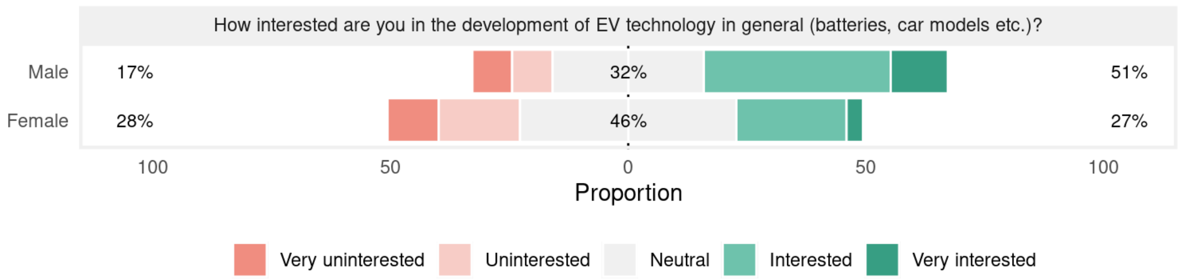


Figure 28 Interest in the development of EV technology according to gender

3.5 Barriers

To get an insight into what limits the transition to a greener vehicle fleet, some questions were asked regarding what barriers people face or experience. Firstly, **64%** of people experience some **difficulties finding** the **information about EVs** that they are looking for. **More men have trouble** finding all information: 69% vs 60% of women ($p < 0.001$), however keeping in mind that men are more interested in technology and more likely to buy an EV, they might look after information more often as well. No statistically significant differences were found according to age or level of education.

Subsequently, the respondents were presented with several items they have questions about and asked to indicate up to 3 options. The information people have the most trouble finding is about the **lifetime of an EV battery**, with 36% having indicated this option, followed by 26% and 25% having a hard time finding information about **public charging accommodations** and the **requirements for the installation of a charger at home**, respectively. Other information that people cannot find easily are accurate estimates of the range of EVs and their performance in cold weather, with 22% and 21% of people indicating these options respectively. Only 15% and 7% indicate experiencing difficulties finding information about requesting subsidies and the available models and characteristics.

It can be concluded that **making essential information** – such as information regarding public and private charging accommodations **– more readily available** to the general public may **seduce more people to transition to EVs,** especially certain subgroups of the population.

Next, respondents who did not indicate that they would purchase an EV as a next vehicle were given a list of eighteen possible reasons why one may not want to purchase an EV as their next vehicle and were asked to indicate up to 3 of them. The reasons, ordered by popularity are shown in Figure 29. The **price** is by far the most limiting factor, followed by a **lack of charging opportunities** and **insufficient range**. Noteworthy is that 17% of people falsely believe that EVs are not more environmentally friendly than ICEVs; and that 20% doubts the durability of the batteries while it is now recognised that batteries last much longer than the expected lifetime of a vehicle (up to 400k to 1200k km).

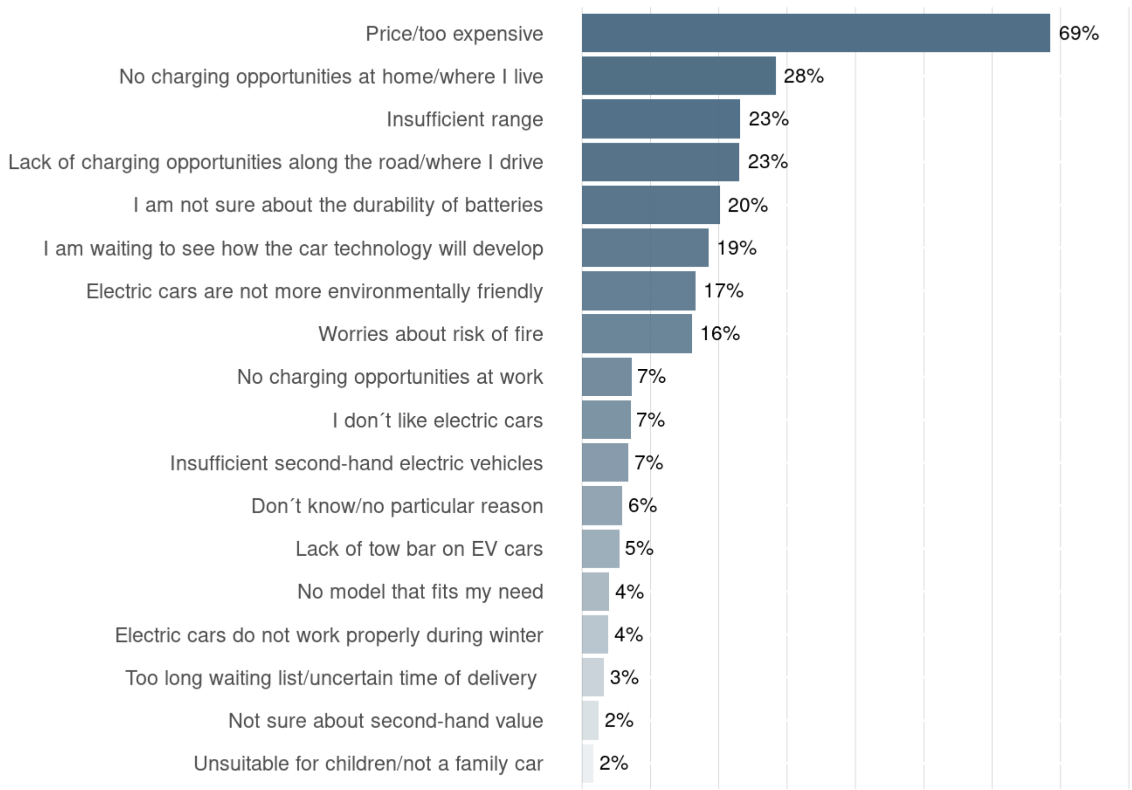


Figure 29 Possible reasons why one would not want to purchase an EV as their next vehicle, n =1864
'Insufficient range' is likely to be an underestimation due to an anomaly in the French translation (36% in the Dutch version, 4% in the French version).

Respondents that already tried an EV (as driver or passenger, n=491) gave similar answers as the complete sample. What did differ, is the bigger concern about the range in those who tried an EV (31%). The concerns about the risk of fire were smaller in those who tried (11%).

The same question on barriers was asked in the Nordic EV Barometer in 2021 in drivers that don't plan to buy a BEV. Price was also in the first place, followed by the insufficient range and lack of charging opportunities. The top-3 reasons are thus the same as in Belgium. What is surprisingly different, is the concern about fire safety that is much higher in Belgium. As the market is already further developed in Scandinavia, the availability of second-hand vehicles is also much less of a barrier. In the Netherlands, the 'ANWB Elektrisch Rijden Monitor 2020' asked for reasons not to drive an EV. Also in the Netherlands, price, range and charging opportunities were the top 3 barriers. Compared to 69% in Belgium, only 58% of drivers in the Netherlands point to the price (purchase price + annual costs) as the main barrier. Available purchase subsidies are probably responsible for this. Even though the Netherlands is the country with the highest density of public chargers in Europe, 27% still feel like there are too few public charging points and this is a barrier for them to buy an EV.

Some interesting **differences in the reasons not to purchase an EV between different subgroups** of the population are listed below:

- According to the region:
  - In Wallonia and Brussels, 24% of people believe that EVs are not more environmentally friendly, compared to 12% in Flanders ($p < 0.001$).
  - For people living in Brussels, the price is less of a concern: 58% vs 69% outside of Brussels ($p < 0.01$).
  - Almost twice as many people in Wallonia simply don't like EVs: 10% vs 6% in Flanders and Brussels ($p < 0.001$).
- According to education:
  - Lower educated people worry more about the possible fire hazard: 19% vs 12% ($p < 0.001$).
  - Lower educated people indicate that they simply do not like EVs: 8% vs 6% ($p < 0.05$).
  - For higher educated people, an insufficient range and a lack of charging opportunities are bigger pain points: in each case 27% vs 20% ($p < 0.001$). This might be because higher educated are more likely to consider purchasing an EV and are therefore more likely to run into practical concerns.
- According to degree of urbanization:
  - For people living in urban areas, no charging opportunities at home is one of the main reasons not to buy an EV with 35% vs 23% in rural areas ($p < 0.001$). On the other hand, for people living in rural areas, the price is a greater dealbreaker with 71% vs 64% in urban areas ($p < 0.05$).
  - At least 21% of people living in rural areas believe that EVs are not more environmentally friendly, which is significantly more than 15% of people living in or near cities ($p < 0.01$).
- According to age:
  - Price is less of a concern for younger people: 61% among people of the ages 18-34 vs 71% in older people ($p < 0.001$).
  - The elderly are waiting to see how EV technology develops: 25% among 55+'ers vs 15% in younger people ($p < 0.001$). Additionally, they are more worried about the possible fire hazard: 23% vs 12% ($p < 0.001$).

In conclusion, while the price is the main bottleneck, younger people are more willing to spend more money on an EV whereas the elderly are hesitant and are waiting to see how the technology develops. There is still a lot of misinformation about EVs, in particular about their environmental impact and possible fire hazard. The belief in this misinformation is the greatest in rural areas, in Brussels and Wallonia and among older people. Misinformation might be caused by a lack of (access to) information. There are also regional differences in the perception of the availability of charging stations, with no availability of chargers at home in urban areas holding a third of the people in cities back. Therefore developments in the production process that could **lower the purchase price**, **availability of public charging stations** and **more clear communication of information** about EVs are action points to **break down the barriers** that people are facing in the transition to EVs.

3.6 Incentives

Next, the respondents were asked about the factors that would encourage them to purchase an EV. The suggestions are ordered by the height of encouragement in Figure 30. The **most encouraging factors** are **road tax exemptions, discounted charging rates at home and easy access to public chargers**, all with more than 80% of people finding them at least somewhat encouraging. The least encouraging factors are the implications of COVID-19, the availability of a second (ICEV) car and the upcoming regulations restricting ICEV access. A purchase subsidy of €1000 encourages 61% of people while a subsidy of €3000 encourages significantly more people, namely 82% ($p < 0.001$).

The fast development of EV technology encourages 79% of men and 73% of women, while women are more likely to be encouraged by the positive opinions of other users and a clear view of recycling possibilities ($p < 0.01$).

In general, financial incentives are the most encouraging, except for having access to a (public) charger which is also considered important. **Young people** are **more easily seduced** and convinced than people of the age of 55 and above, in particular **by factors that have a financial aspect** ($p < 0.001$).

Similarly, people who already have EV purchase intentions are more easily convinced than those who do not yet think about purchasing an EV ($p < 0.001$).

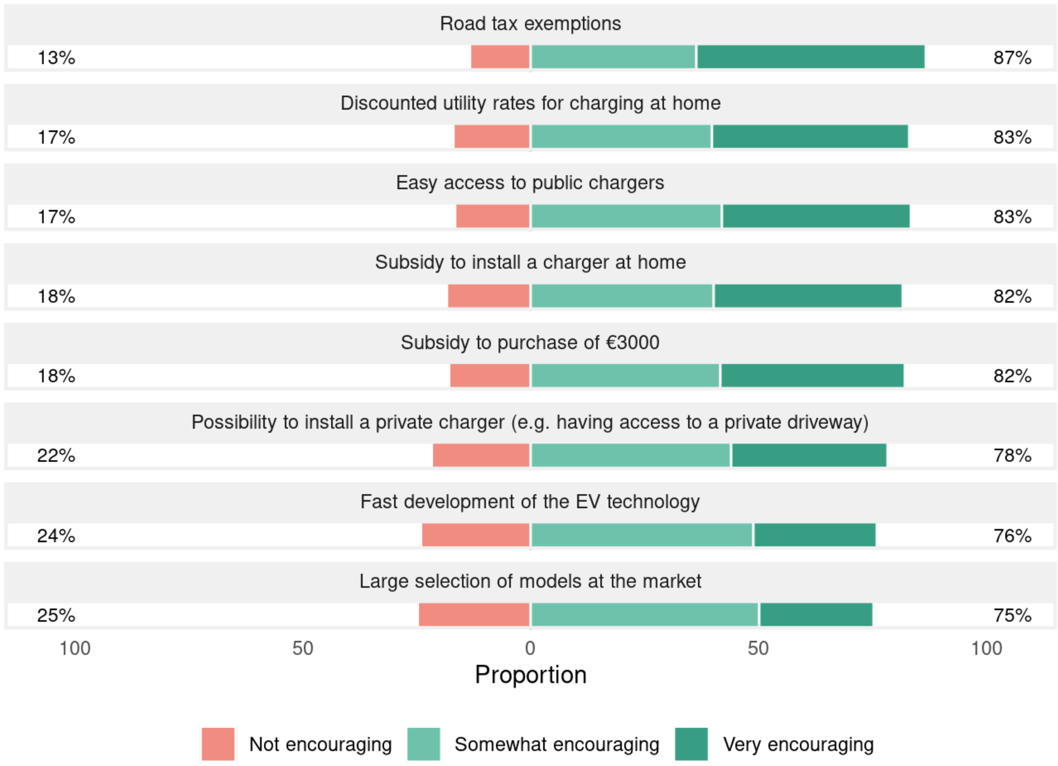


Figure 30 Factors that would encourage people to purchase an EV, n = 2110

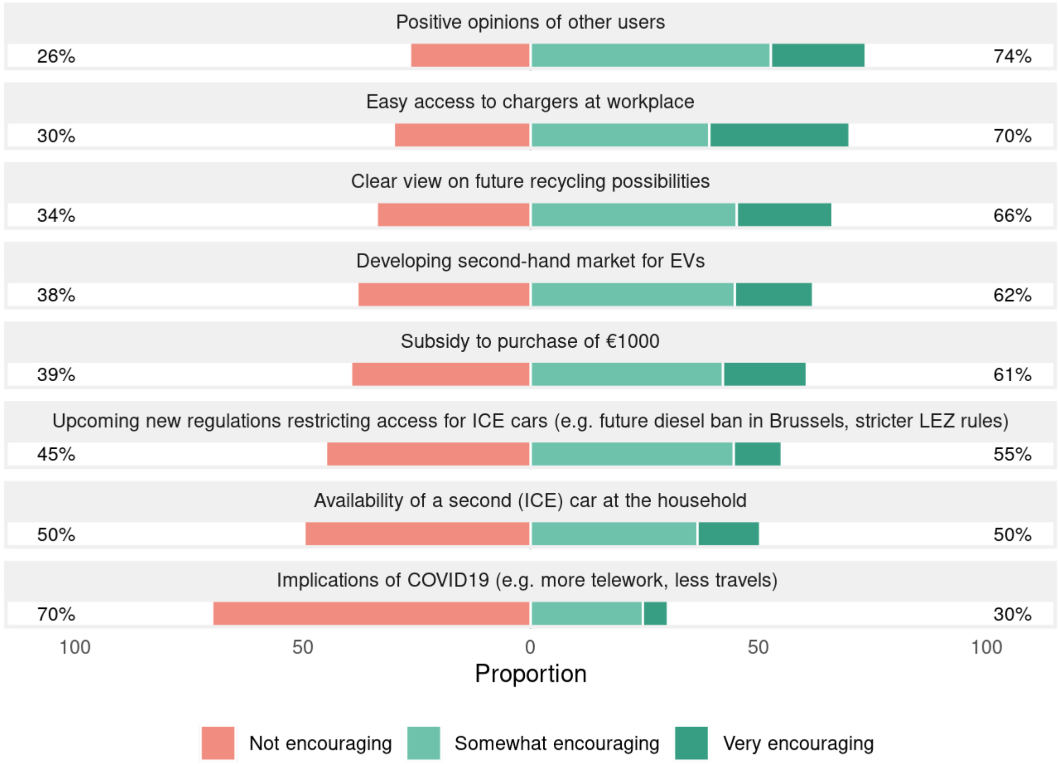


Figure 30 Continued from the previous page

Following the incentives, the respondents were presented with a few statements regarding their sense of personal obligation to purchase an EV and were asked about their opinion. The results are shown in Figure 31. Overall, the majority (strongly) disagrees or is neutral about the statements. Hence it can be concluded that **most people do not feel a strong personal obligation to purchase an EV** nor do the people around them expect them to.

Young people more often feel a strong personal obligation to purchase an EV: 21% vs 16% among people of the age of 35 and above ($p < 0.05$). Additionally, the people important to them more often have a positive attitude towards EVs: 25% vs 15% ($p < 0.001$). The same trends can be observed according to gender, with men feeling a stronger personal obligation than women ($p < 0.05$).

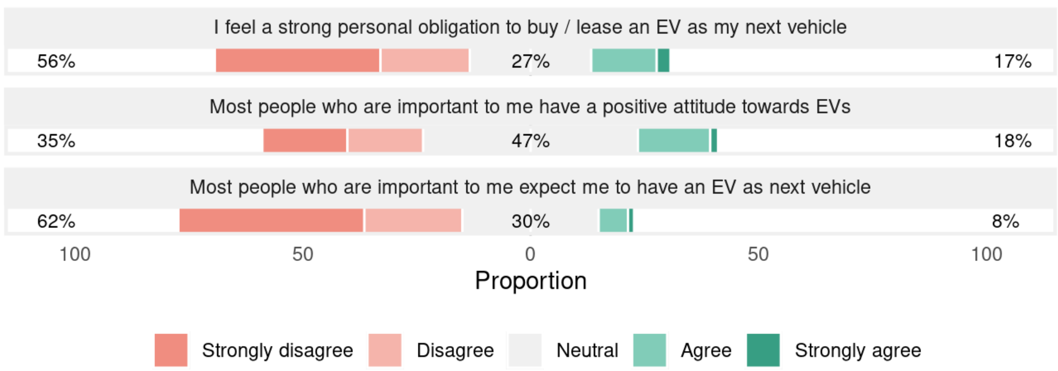


Figure 31 The respondents' opinions about certain statements on EVs, n = 2110

For the final part of this section, the respondents were asked if a “big lifestyle change” – such as relocation, change of household composition, a new job or promotion, the urgency of the climate crisis or a large increase in fuel prices – would encourage them to purchase or lease an EV. **For the majority (63%) no big lifestyle change would have an impact on their car purchase intentions.** However, for 19% of people, a large **increase in fuel prices** would make them more likely to transition to an EV. **The urgency of the climate crisis** could convince 11% of people to go electric. Finally, 8% of people could see themselves buying an EV if they got a promotion; this is in line with the answers to the open question if any other changes would encourage them, to which many answered "more financial means".

Of the people aged 18-34, 51% indicate that a big lifestyle change would encourage them to go electric, which is significantly more than 32% of people aged 35 and above ($p < 0.001$). In particular, the urgency of the climate crisis and a large increase in fuel prices are encouraging factors, with 16% and 25% indicating these options respectively. Similarly, 40% of men would be encouraged to purchase/lease an EV following a big lifestyle change, compared to 35% of women ($p < 0.05$).

These observations show that extra efforts should be undertaken to convince especially women and older people **to speed up the transition to a greener vehicle fleet. High fuel prices and the climate emergency** may be factors that support the transition to low-emission mobility.

3.7 Intentions for the next car purchase

In this section, the intentions of the respondents regarding their next car purchase, such as the type of car (e.g. diesel, petrol, EV, …), and the most important elements in this decision (e.g. purchase price, performance, comfort, …) are discussed.

3.7.1 Type of car

Firstly, when asked about their purchase intentions, 64% of people indicate they are looking to purchase a new car while the remaining **36%** are searching on the **second-hand** market.

The type of car the respondents intend to purchase next is shown in the table below (Table 22). The **most popular** choices are **petrol** cars (26%), followed by **plug-in hybrids** (20%) and **fully electric cars** (12%). The 20% for PHEVs is surprisingly high, given the high cost of ownership of PHEVs and at the same time the importance of the price criterium in the decision. Likely, future buyers are not yet very well informed about the purchase price and the TCO of PHEVs. Note also the large proportion of undecided people (30%).

Table 22 Car purchase intentions of the respondents with the differences between the new and second-hand market indicated, n = 2110

Type of car	Total [%]	New [%]	Second-hand [%]
Petrol car	25.5%	23%	**29.8%**
Diesel car	7.8%	5.8%	**11.1%**
PHEV	19.7%	**22.4%**	14.9%
Not rechargeable hybrid	5%	**5.9%**	3.4%
BEV	11.6%	**14.7%**	6.1%
Other (CNG, LPG, etc.)	0.9%	0.8%	1.1%
I don't know	29.6%	27.3%	**33.5%**

The purchase intentions thus differ according to whether one is looking to purchase a new car or a second-hand car. Significantly more people are looking at the **second-hand** market for **petrol and diesel** cars ($p < 0.001$) while all types of **hybrids and fully electric cars** are more often bought **new** ($p < 0.05$). Second-hand buyers are also more often undecided ($p < 0.01$).

There are statistically significant differences in the intentions for the next car purchase according to several different variables. Firstly, income plays a role in purchase intentions, as shown in Figure 32. People in households having a **net income over €5000** per month are **almost twice as likely to purchase a BEV** as their next vehicle: 20% vs 11% ($p < 0.001$). Similarly, a **net income of over €4000** per month gives rise to an **increased likelihood of looking towards a PHEV:** 25% vs 19% ($p < 0.01$). People in households with a **net income under €4000** are **more likely to purchase a petrol car**: 29% vs 18% ($p < 0.001$).

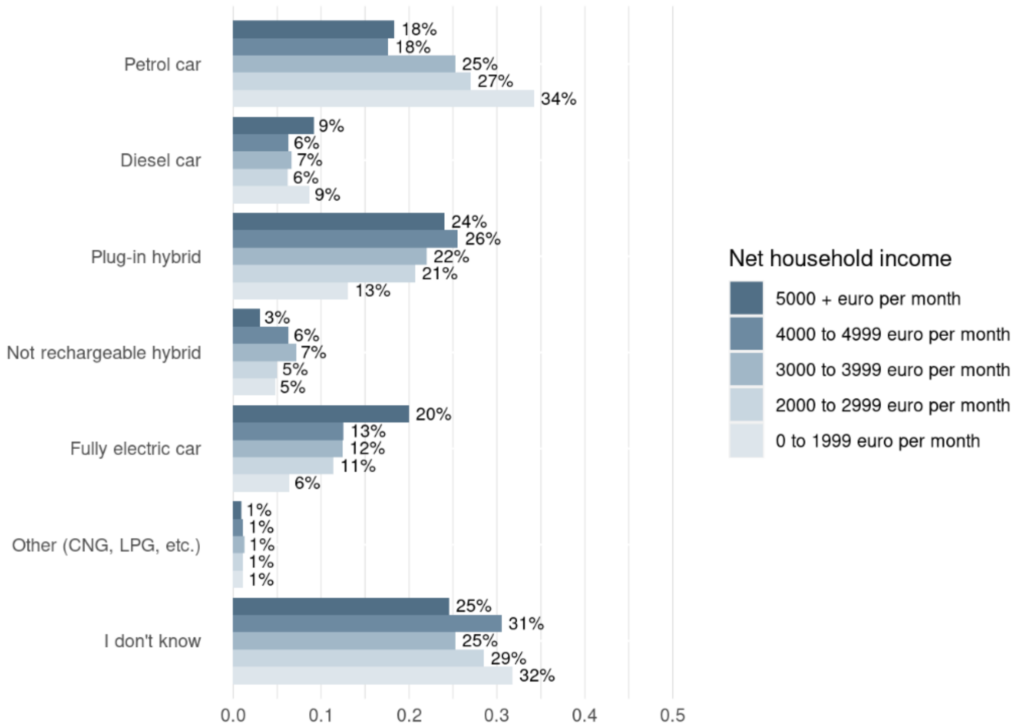


Figure 32 Intentions for the next car purchase according to net household income

It can also be observed in Figure 33 that **men** are **more likely to buy a PHEV** ($p < 0.01$) or a **BEV** ($p < 0.001$) than women while **women** are **more likely to buy a petrol car** ($p < 0.01$) and are overall **more undecided** ($p < 0.001$).

The same trends can be observed by the highest degree of education achieved ($p < 0.001$), with the **higher educated people choosing EVs more often**. This similarity can in part be explained by the fact that **men are 10% more likely to have achieved a degree from a university/graduate** school than women ($p < 0.05$). It is well-known that **higher educated people tend to have higher incomes** – which can also be observed in the data ($p < 0.001$) – and therefore the purchase intentions by education are similar to the purchase intentions by income. Combined, these observations explain the **observed correlations** for the purchase intentions by gender and income, which are both – at least in part – results of the **same underlying cause, namely income**.

Similarly, **people who own a company car are more likely to choose an EV** ($p < 0.001$). Once again, this correlation can be explained by the fact that people who own a company car **tend to have higher incomes** ($p < 0.001$). Of course, also the beneficial taxation of PHEV and BEV as company cars plays a major role and will become even more important by 2026 when only zero-emission company cars will be able to benefit from a tax deduction.

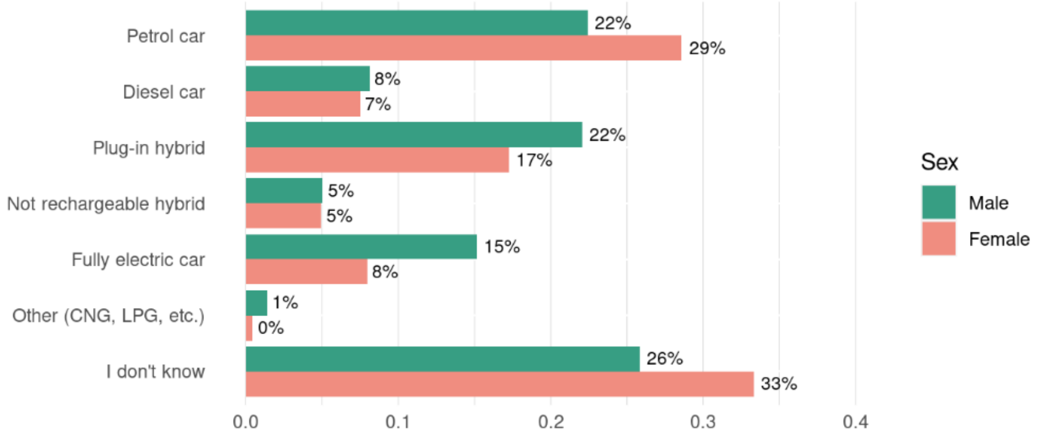


Figure 33 Intentions for the next car purchase according to gender

To test whether education itself makes people more likely to purchase an EV, purchase intentions according to their awareness of the climate crisis are shown in Figure 34. People **unaware of the climate crisis** are **more likely to purchase a petrol car** ($p < 0.001$) **or a diesel car** ($p < 0.10$) than those who are aware. The people who indicate being **at least somewhat aware** of the climate crisis are **twice as likely to purchase a PHEV**. These observations show that **raising awareness about the climate crisis** is of **utmost importance in the transition to a greener vehicle fleet**.

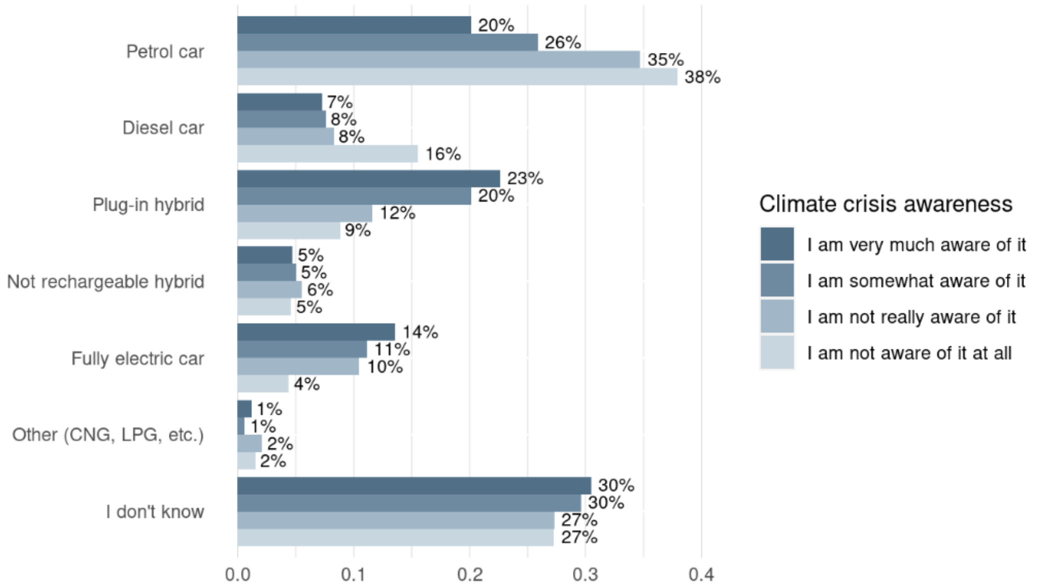


Figure 34 Intentions for the next car purchase according to climate crisis awareness

As shown in Figure 35, of the people who have access to an EV charging station, 37% indicate they intend to purchase a PHEV compared with 16% among those who do not have access to an EV charger and 34% indicate they intend to purchase a BEV compared with only 7% otherwise. **Having access to an EV charger** (public or private), a prerequisite to owning an EV, thus **increases the likelihood of purchasing a BEV by up to 400%** ($p < 0.001$). Conversely, **those who do not have access to an EV charger** are **more than three times more likely to purchase a petrol car** and are overall **more undecided** ($p < 0.001$). Note that having **access to an EV charger is positively correlated with having a higher income** ($p < 0.001$), hence the observed differences can once again be attributed in part to having more purchasing power.

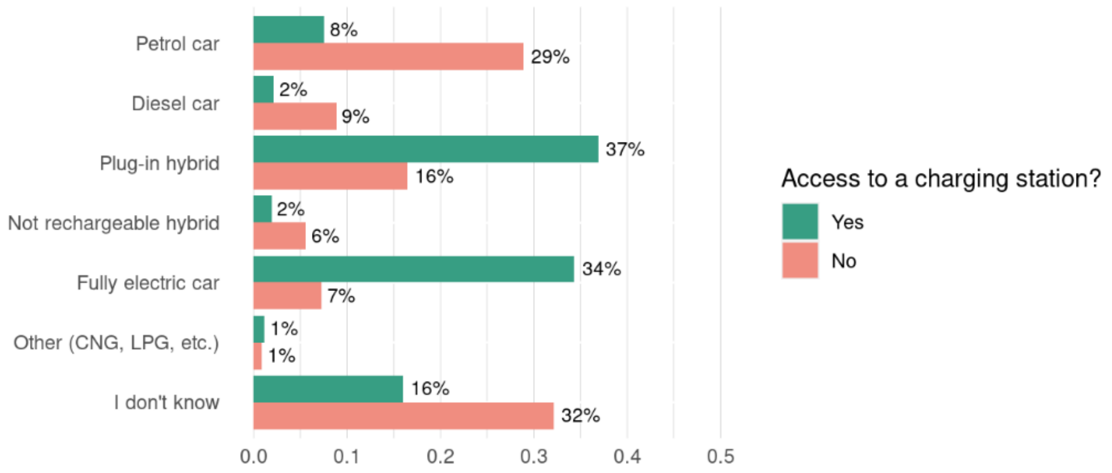


Figure 35 Intentions for the next car purchase according to EV charging station access

There are no statistically significant differences in car purchase intentions according to access to different types of parking spaces. Drivers without access to a private or shared parking space that have to park on public terrain have similar preferences for their next car as those who do have access to private or shared parking spaces. For example, they are just as likely to buy a BEV as their next vehicle.

Next, it can be observed that people in **Brussels** are **almost twice as likely to buy a PHEV** in the near future as in the other regions, while people in **Wallonia are only half as likely to buy a BEV and three times as likely to buy a diesel car** ($p < 0.001$) (Figure 36). It is unclear why people in Brussels are more likely to choose a PHEV compared to the other regions. Possibly this has to do with the upcoming zero-emission zone banning fossil fuel cars, the presence of car-sharing services in Brussels, or perhaps the people in Brussels with a higher income are more likely to buy PHEVs.

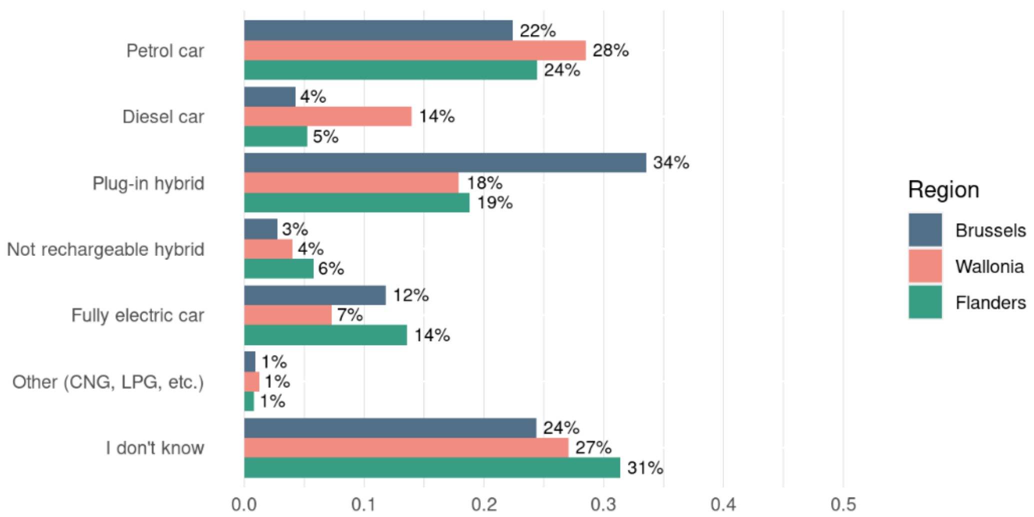


Figure 36 Intentions for the next car purchase according to region

People who drive **more than 20,000 km per year** are **more likely to buy a diesel car** than those who drive less: 20% vs 7% ($p < 0.01$). While it may be cheaper to use a diesel car for long distances compared to a petrol car, from an environmental standpoint it is this group of high mileage drivers who should be encouraged to go for an electric alternative. On the other side of the spectrum, people who drive **less than 20,000 km per year** are **more likely to buy a petrol car**, 28% vs 15% ($p < 0.001$), and are **more**

undecided: 31% vs 22% ($p < 0.01$). Therefore, due to this **high percentage of undecided people**, there is still **a lot to gain from incentivizing people to go electric**.

No statistically significant differences in car purchase intentions were found by degree of urbanisation or the number of people in the household.

Finally, the attitude of people towards EVs is a decisive factor in their car purchase intentions, as shown in Figure 37. **EV enthusiasts are 10 times more likely to purchase a BEV** than those who are hesitant and **3 times more likely to purchase a PHEV** ($p < 0.001$). Conversely, **EV sceptics are 6 times more likely to purchase a diesel car** than EV enthusiasts and **3 times more likely to purchase a petrol car**. This observation shows that **raising awareness about EV technology** and attracting a larger user base is **essential** to **accelerate the transition to a greener vehicle fleet**.

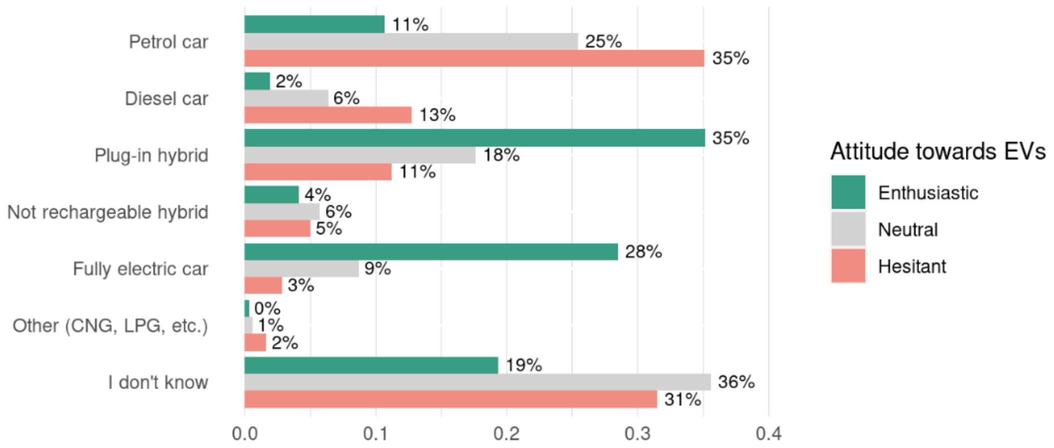


Figure 37 Intentions for the next car purchase according to attitude towards EVs

Of the people who are considering buying an EV, the action radius or range they consider according to their attitude towards EVs is shown in Figure 38. About **half of the respondents** are considering a **mid-range vehicle** with a range of 300 to 500 km. **EV enthusiasts** are **slightly more likely to consider a shorter EV range** than those who are hesitant towards EVs ($p < 0.10$). The difference is not as pronounced as in other literature, since the question was only asked to those who are already considering purchasing an EV, rather than to the general population. In the latter case, one can expect EV sceptics to choose longer-range EVs.

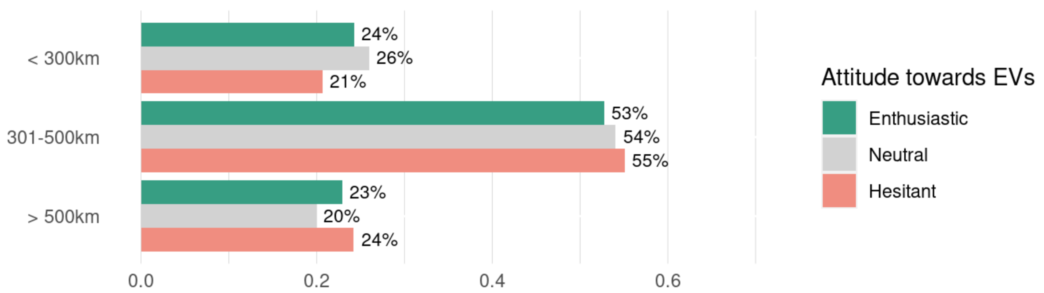


Figure 38 EV range considered by those who are looking to purchase an EV, according to their attitude towards EVs

3.7.2 Factors impacting the buying decision

Regarding their next car purchase, **the elements people find important** are ordered from most important to least important in Figure 39 and grouped by whether the respondent intends to buy an EV or not. Almost all the respondents find **purchase price** important, followed by **safety features** and **comfort**. At the other end are noise, delivery time and performance, which only about half of the people find important. Buyers of EVs find battery reliability, battery warranty and charging speed more important than buyers of non-EVs ($p < 0.001$). Noteworthy is the difference in the importance attributed to purchase price: while in both cases over 90% of respondents find purchase price important, the difference is statistically significant at the 0.01-level. There is a **small proportion of EV buyers** who find **purchase price unimportant**.

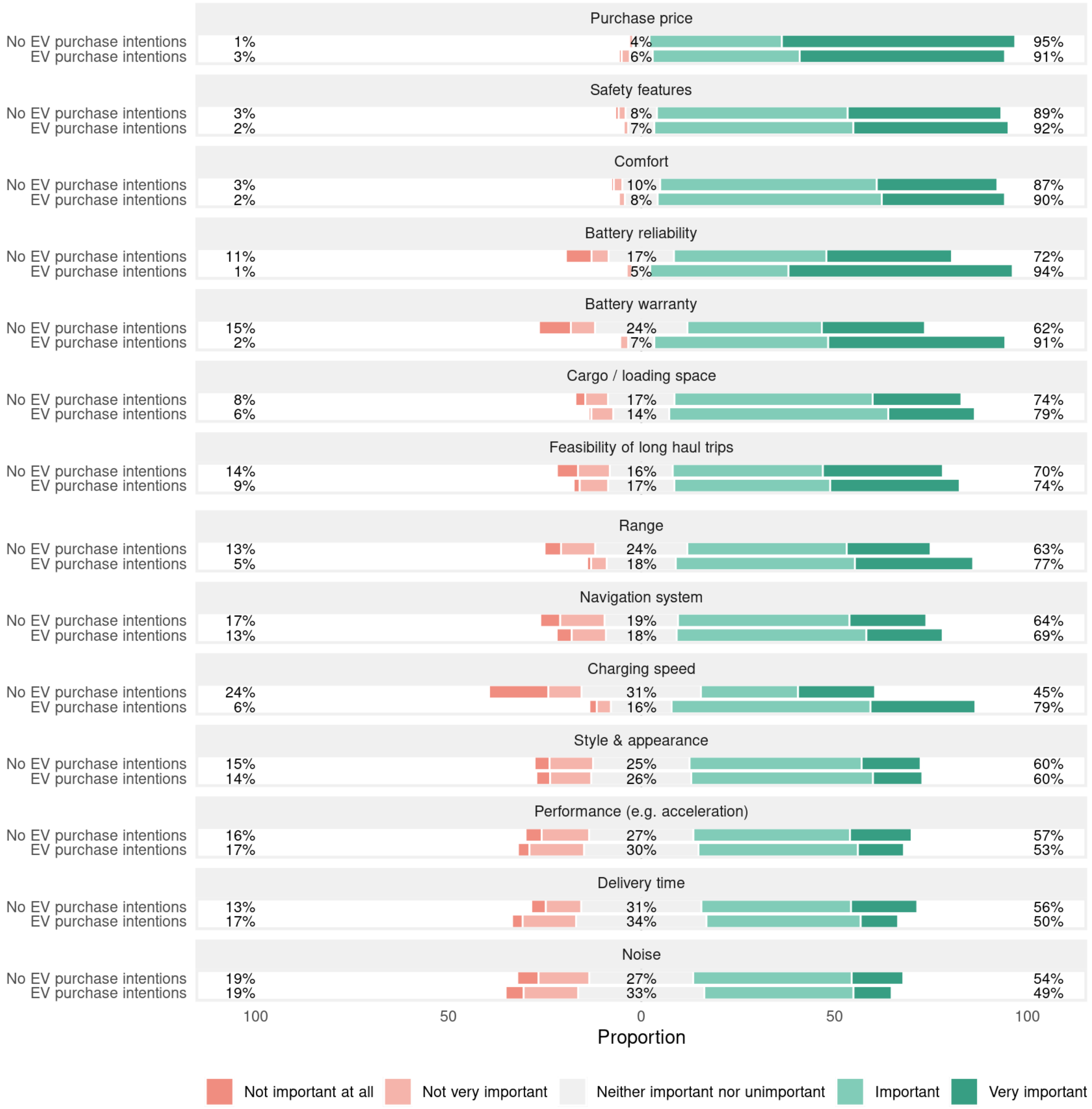


Figure 39 Important elements for the next car purchase according to the respondents' intentions

To delve deeper into the difference in the importance attributed to the purchase price, the price segment that people are considering for their next car purchase, according to their intentions, is shown in Figure 40. **EV buyers** are willing to **consider a higher price segment for their next car purchase** compared to non-EV buyers. Or EV prospects are just liberating a higher budget to be able to buy an EV. Conversely, one could derive that consumers with a lower price under consideration are realistic and do not intend to buy an EV. Nevertheless, for those willing to buy an EV but having a lower budget (<€20,000), developing the second-hand market for EVs is important.

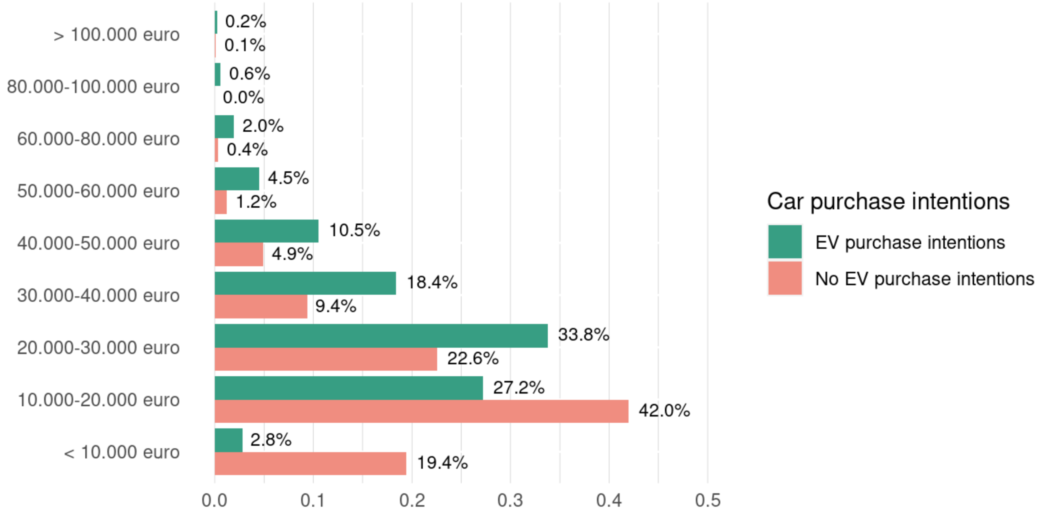


Figure 40 Price segment under consideration for the next car purchase according to purchase intentions

Concerning the **total cost of ownership**, the **purchase price** of the car is by far **the most important element** with 79% of people placing it in their top 3, while the **second-hand value** is viewed as **the least important** with only 15% placing it in their top 3, as shown in Figure 41. People who own a company car find the purchase price less important than those who do not own a company car ($p < 0.001$). People who intend to purchase an EV find fuel and electricity prices more important than those who do not have EV purchase intentions ($p < 0.05$).

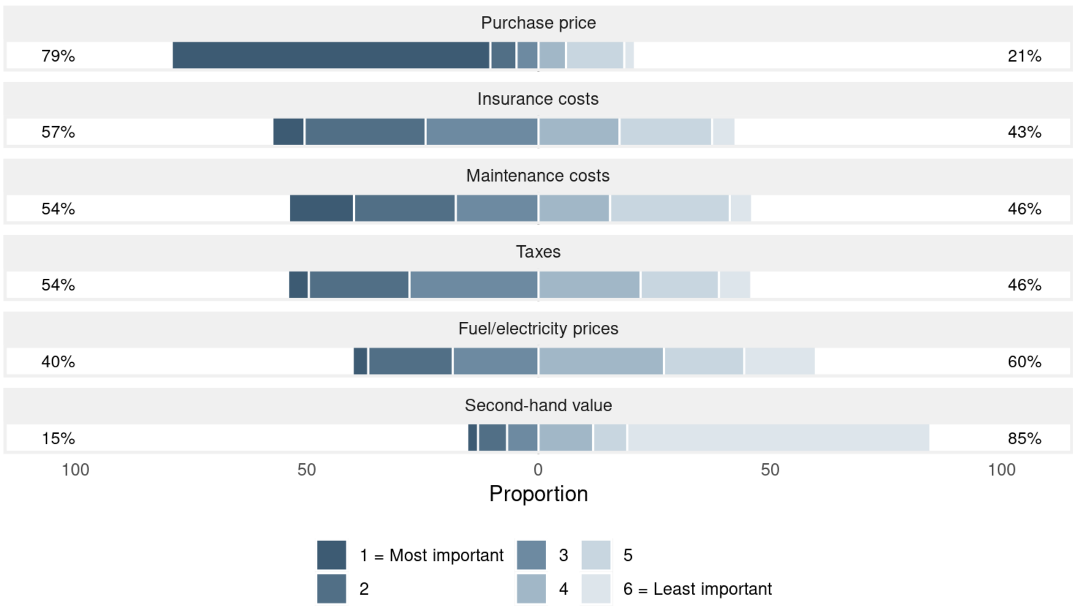


Figure 41 The elements of the total cost of ownership ordered by importance

4 Deployment of BEVs and charging infrastructure

4.1 Introduction

How will the BEV market develop in Belgium concerning timing and scale? And what about the charging infrastructure?

This chapter will first define a business-as-usual **scenario** with an **outlook up to 2040** to explore **the deployment and uptake of BEVs**. In this exercise, a stock turnover model is used in which projections are made about new car sales, but also about the lifetime and scrappage of the current car fleet, and future car ownership. Probable developments and regulations, e.g. the sales ban of ICEVs, are taken into account, as well as price parity predictions. Next, alternative scenarios are defined with variations in the main cost drivers (changes in the projected purchase price of BEVs and ICEVs), an all-BEV scenario in which all new cars will be zero-emission from 2024 onward, and a scenario with a modal shift from motorized to active modes that reduce car ownership.

Secondly, estimates will be produced on the needed **charging infrastructure** given the exponential increase in EVs in the next decade. The analysis will answer the question "How many charging points do we need in Belgium?". Private and public charging points are considered.

4.2 Deployment of BEVs

Electrification of the car fleet is much needed to reduce the climate impact of the transport sector. The transition to EVs started already in the past decade but has recently taken off at a higher pace and this evolution is likely to continue in the years to come.

To estimate the uptake of EVs in the fleet, we need to project into the future. Therefore, we need to make assumptions about how new vehicle sales will look like, how quickly cars are scrapped, and how car ownership will evolve. The time horizon for this exercise is the year 2040, aligned with the car ownership projections from the Federal Planning Bureau (Franckx, 2019b).

4.2.1 The stock turnover model

The **stock turnover model** makes the following assumptions:

- Total car ownership: Future (year 2040) total car ownership is modelled based on the established car stock model from the Federal Planning Bureau (Franckx, 2019b). The car stock model takes into account the Belgian population and GDP per capita, age and mileage of vehicles. The model projects 7.04 million cars by 2040, corresponding to 0.57 cars per capita, compared to 5.95 million cars in 2022.
- Vehicle scrappage: This parameter estimates how quickly cars are scrapped. In line with the assumption made in the TCO-tool, a lifetime of 9 years is used. So when vehicles in the car stock reach the age of 9 years, they are scrapped. In recent years, PHEVs were shown to have a shorter lifetime, largely explained by the high share of company cars that are typically replaced after 3 or 4 years. To account for this, we assumed a lifetime of 5 years for PHEVs. In the USA, recently the average lifetime of cars increased, so there used to be more 'younger' vehicles but now there are more 'older' vehicles (Leard & Greene, 2022).

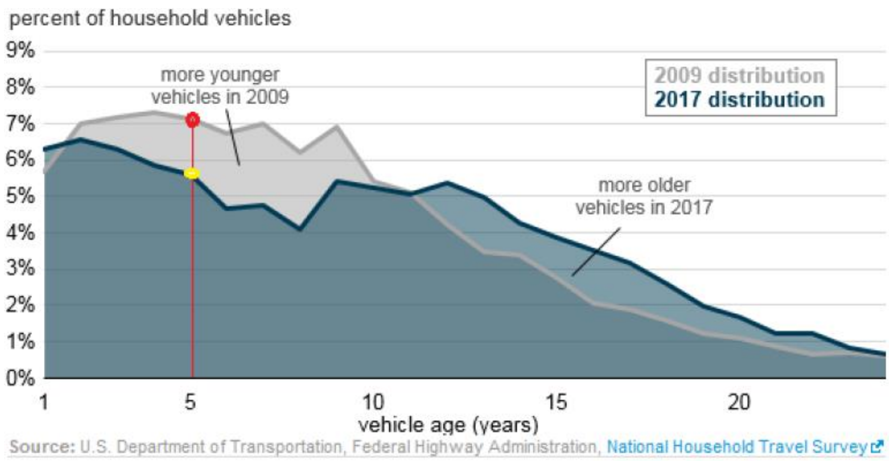


Figure 42 US household vehicle age distribution in 2009 and 2017
Source: Leard, B., & Greene, D. (2022, June 27). Reducing Vehicle Pollution: The Role of Stock Turnover. Presentation at the Health Effects Institute Annual Conference 2022.

- Vehicle sales: New car sales in year x are calculated as the difference between the estimated car ownership in year x, and total car ownership in year x-1 plus vehicle scrappage in year x. The sales volume of each powertrain depends on the scenario considered (see the next section on scenario definitions). This scenario is a simplification of real-world buying behaviour. For example, if the purchase price would be the only factor that influences a decision to buy a car with a certain fuel, we would all end up buying the same cars. Other factors play a role: the TCO of EVs and alternatively fuelled cars, availability of charging stations, consumer attitudes towards EVs, EV model availability, etc. (Brand et al., 2017). From the exploratory survey of 32 Belgian drivers in 2022, we learned that currently 75% and 84% report that easy access to public chargers and the possibility to install a private charger respectively were influential factors in their decision to go electric, while positive experiences of other EV drivers convinced two out of three drivers. However, in a couple of years, the TCO will likely become more important: the acquisition price will be lower for EVs compared to ICEVs, and range anxiety will reduce because of the mass availability of chargers.

- Vehicle sales are limited by legislation and a sales ban:
    - EU 2035 fossil fuel car ban: a ban on the sale of new petrol and diesel cars;
    - Federal phase-out of non-EV fiscal advantage by 2026 (company cars);
    - Brussels' implementation of the diesel/petrol ban by 2030/2035;
    - Walloon phase-out is still undecided, so for Wallonia, we follow the EU fossil fuel car ban by 2035.

In summary, each year, new vehicles are sold, used vehicles age by one year, and a fraction of used vehicles are removed from the stock via scrappage. With this method, the stock turnover model estimates the share of vehicles by fuel for each year up to 2040.

4.2.2 Scenario definition

4.2.2.1 Price parity scenarios

Achieving purchase price parity as soon as possible is critical to achieving a rapid transition to zero-emission powertrains. The purchase price is the most important factor when buying a new car for private customers, rather than the TCO, as was seen from our survey (see section 3.7.2). Likewise, a recent European survey found that consumers overwhelmingly choose BEVs over alternatives if upfront costs are similar (Element Energy, 2022).

The purchase price or acquisition price of BEVs is set to decline rapidly by 2030, mainly driven by declining battery prices and economies of scale due to higher production volumes. At the same time, ICEVs slightly increase in price. A Bloomberg study predicts that the BEV-to-ICEV price difference will get increasingly small over the next five-to-six years in all car segments (Figure 43) (BloombergNEF, 2021). BEVs reach the same price as equivalent ICEVs within a tight window between 2025 (for light vans) and 2027 (for B-segment) (Figure 43) (BloombergNEF, 2021). Based on these predictions, our business-as-usual scenario will assume price parity in 2026, with all consumers buying the vehicle with the lowest purchase price.

The Bloomberg study dates back to before the steep increase in energy prices in 2021 and 2022. It is expected that the impact on BEVs and ICEVs will be the same. However, because of the uncertain economic state, we will run alternative scenarios in which price parity will only be reached in 2028 or 2030. This might be reinforced by long delivery times and the decline in battery pack price (per kWh) that is compensated by an increase in total kWh to extend the range. Recent numbers from BloombergNEF show that battery prices actually went up in 2022 breaking the downward trend and contributing to an expected delayed date of price parity.

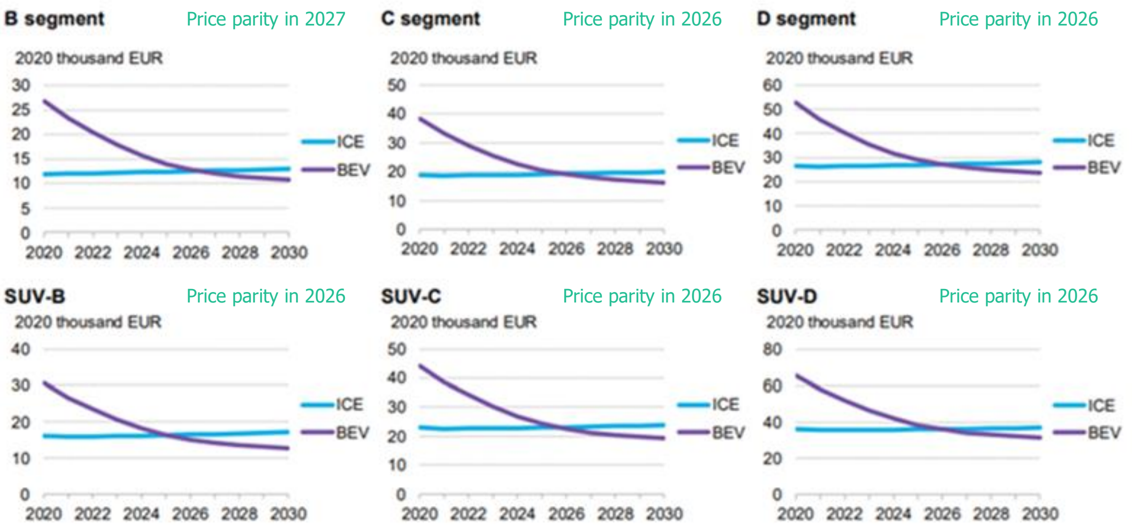


Figure 43 Estimated pre-tax retail prices for different car segments in Europe. Indicated in green is the year at which BEVs reach upfront cost price parity with equivalent ICEVs
Source: BloombergNEF, 2021

4.2.2.2 100% BEV scenario

Subsidies or incentives can have an impact on the price parity of BEVs and ICEVs. Currently, no subsidies, neither federal nor regional, are foreseen. However, we will evaluate a scenario in which from 2024 onwards BEVs are the cheapest and most attractive option and immediately achieve 100% of new car sales. This is a deliberately extreme scenario, but it will establish a lower-bound estimate for which we can then evaluate the penetration of BEVs in the total vehicle stock up to 2040, assuming that all vehicles remain in the fleet for the term of their useful life (Keith et al., 2019). In this scenario, we ignore current consumer preferences and the possible lack of charging infrastructure that could slow adoption.

4.2.2.3 Norway scenario

The frontrunner in the electrification of the fleet in Europe is Norway. In this scenario, the evolution of the share of different alternatively fuelled cars will be mimicked in Belgium (year 2014 in Norway = year 2023 in Belgium matching BEV shares, see the Norway country profile in the attachment). This steep increase in the share of EVs over the years does not result from one single measure or policy, but it is the result of early and continuous support for EVs, through financial and non-financial incentives. This scenario is aligned with the legislation and sales bans for fossil fuel cars that is desired in Flanders (year 2029) and foreseen in Europe (year 2035), and with the zero-emission zone in Brussels (year 2030).

4.2.2.4 Modal shift scenario

The modal shift scenario takes a different approach by challenging the future growth in cars and car usage that is often baked into EV projections. Changes in the organization of transport, and specifically an increase in shared mobility, will reduce car sales and the need for car ownership. Also, new urban planning paradigms, such as the 15-minute city can make a car unnecessary or unwanted, and support a behaviour change towards more use of active modes.

For an estimate of car ownership in 2040, we use a projection from the EIT Urban Mobility report on the sustainable urban mobility transition in Europe (https://www.eiturbanmobility.eu/costs-and-benefits-of-the-sustainable-urban-mobility-transition-in-europe/). This report models possible pathways to address the European Green Deal objectives for the transport sector. We consider a relatively conservative mix of promotion and regulatory measures that results in 455 cars per 1000 inhabitants, or 0.45 cars per capita, by 2040. We then relate this to predictions for the number of inhabitants in Belgium to estimate the total car stock under the modal shift scenario (12,277,333 inhabitants in Belgium in 2040; https://statbel.fgov.be/nl/themas/bevolking/bevolkingsvooruitzichten#figures, retrieved October 2022). This results in a total car fleet of 5,586,187 cars in 2040 under a sustainable transition scenario.

4.2.3 Model results

How quickly will the car fleet be replaced by BEVs? Given different scenarios, as defined above, the stock turnover is predicted. It is important to note that vehicle fleets turn over at a slow rate and very much depend on the average lifetime of a vehicle. Even with 100% of car sales that are zero-emission, it does not mean that the next year all cars on the road will be zero-emission. A slow turnover is a challenge for meeting the goals of reduction in greenhouse gas emissions.

4.2.3.1 Price parity scenarios

With price parity reached in 2026 for most car segments (and assuming a 100% uptake of vehicles with the lowest purchase price – this is unlikely in view of the survey responses), the share of BEVs in 2030 will be 67% (Figure 44). This corresponds to 4,319,569 BEVs on the roads in Belgium in 2030. By 2040, the share will increase to 90% or over 6 million BEVs.

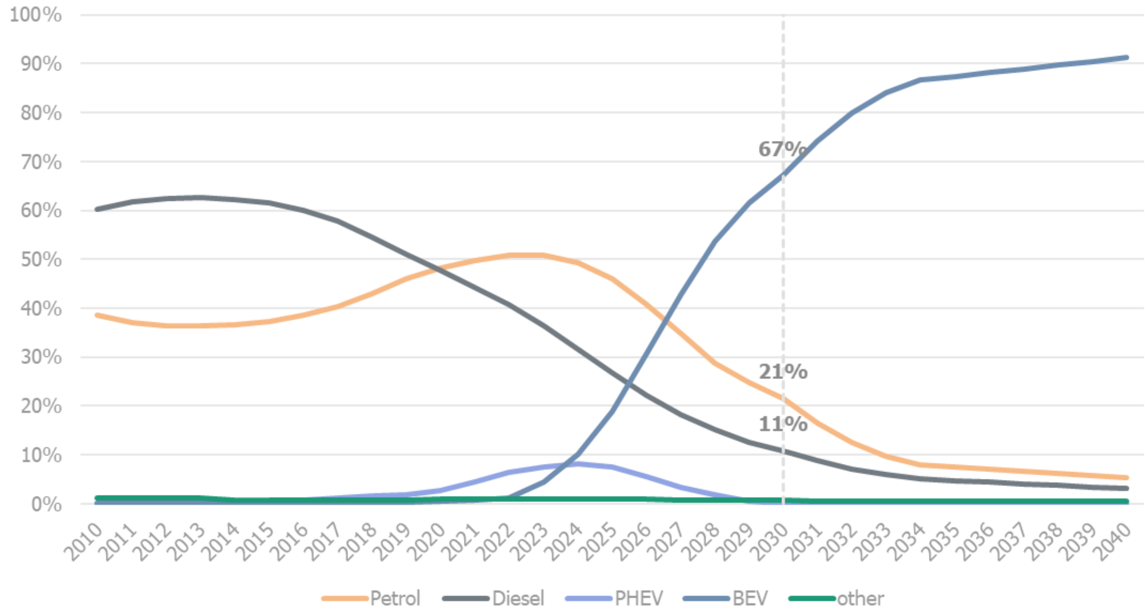


Figure 44 Vehicle stock until 2040 with price parity in 2026

When the Bloomberg assumptions would prove too optimistic, price parity will only be reached in 2028 or 2030, instead of in 2026. The BEV share in the year 2030 with price parity only in 2028 and 2030 will be 58% and 49% respectively (Figure 45, Figure 46). By 2040, the BEV share will be around 90% in both scenarios.

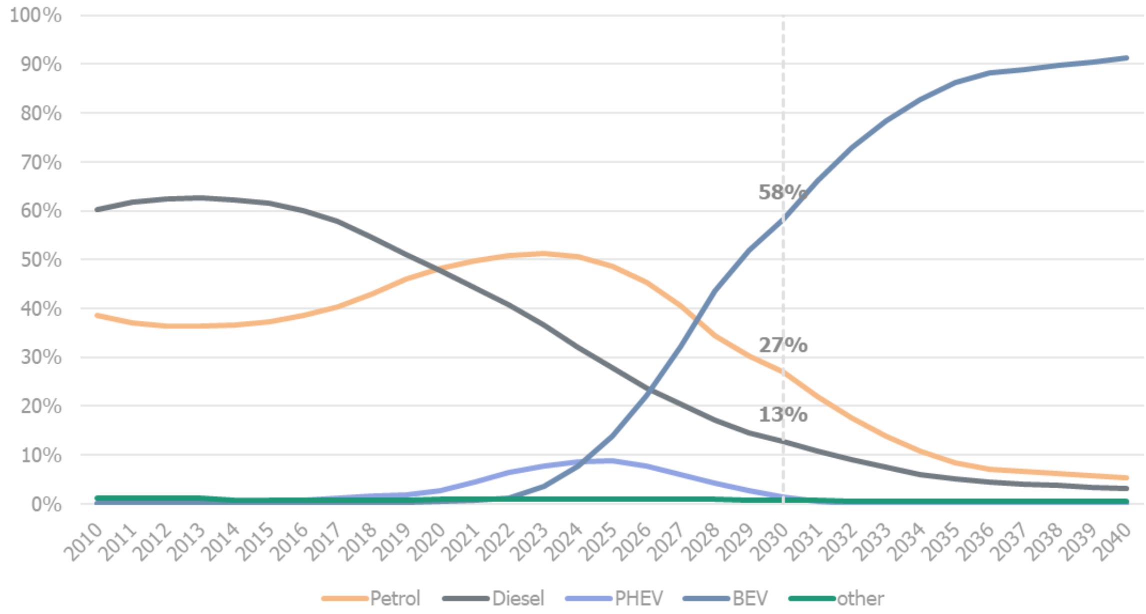


Figure 45 Vehicle stock until 2040 with price parity in 2028

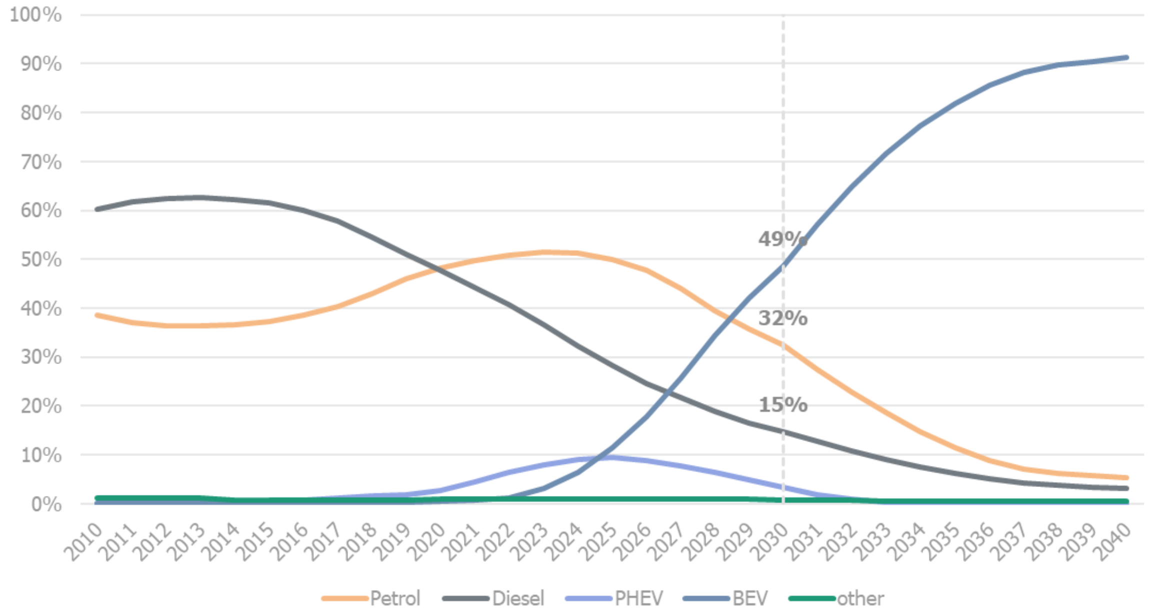


Figure 46 Vehicle stock until 2040 with price parity in 2030

4.2.3.2 100% BEV scenario

In the extreme scenario in which all new vehicles will be BEVs from 2024 onwards, three-quarters of the car fleet on Belgian roads will be fully electric by 2030 (Figure 47). Only 17% will be petrol powered by 2030, and 9% diesel. By 2040, around 90% of the car fleet will be fully electric.

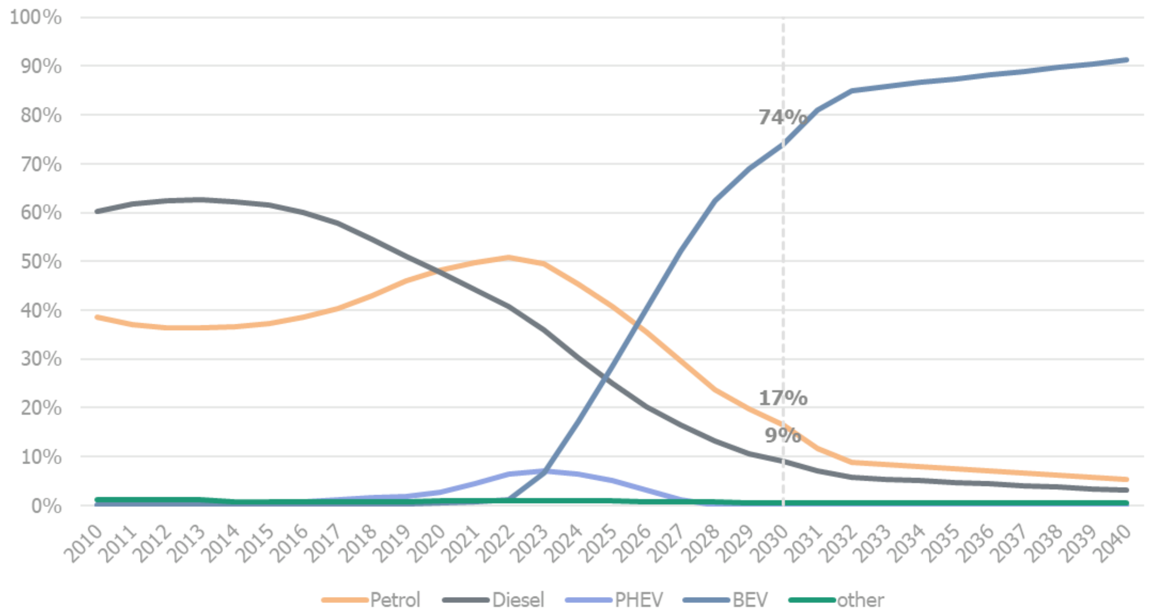


Figure 47 Vehicle stock until 2040 with 100% of BEV car sales from 2024

4.2.3.3 Norway scenario

Whereas the previous scenarios assume a radical change in car sales with 100% BEVs at some point in the near future, a possibly more realistic scenario models a more gradual transition where each year the share of BEVs in new car sales increases. A realistic transition path would be the evolution that was revealed in Norway.

This steady growth in EVs, both PHEVs and BEVs, results in a share of BEVs in the total fleet by 2030 of 26%, and a share of PHEVs of 15% (Figure 48). This deployment scenario results in a BEV-share of over 90% by 2040.

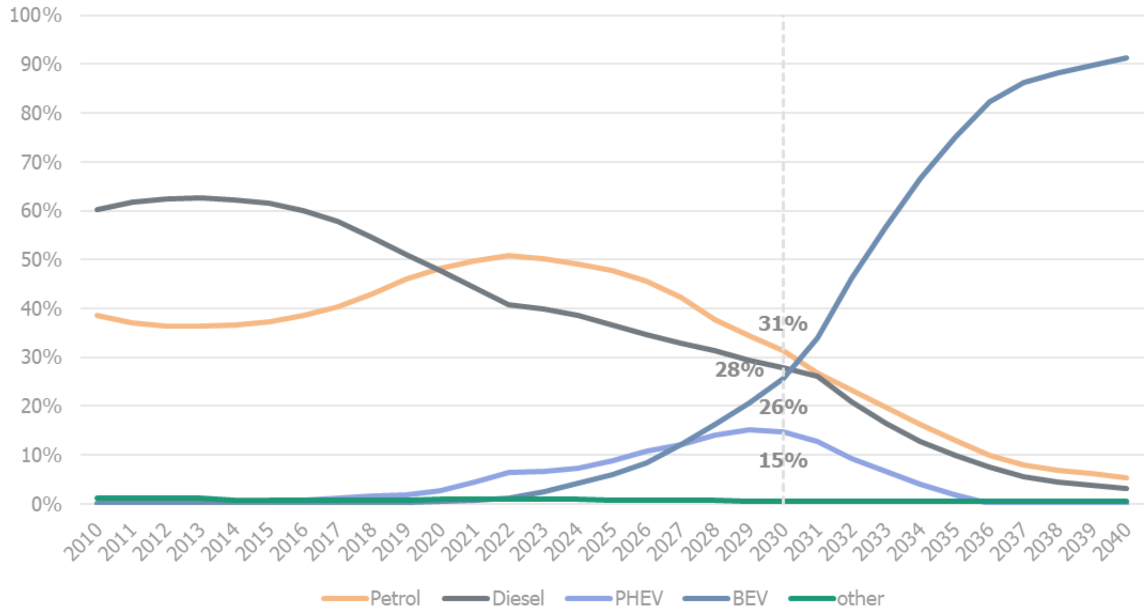


Figure 48 Vehicle stock until 2040 under the Norway scenario

4.2.3.4 Modal shift scenario

The modal shift scenario has a limited effect on the share of different engine types by 2030, but it results in fewer cars overall (Figure 49). Whereas in the price parity in 2026 scenario with a total fleet of 7.0 million by 2040 there will be 4.3 million BEVs by 2030, under the modal shift scenario (also with price parity in 2026) there will be only 3.8 million BEVs.

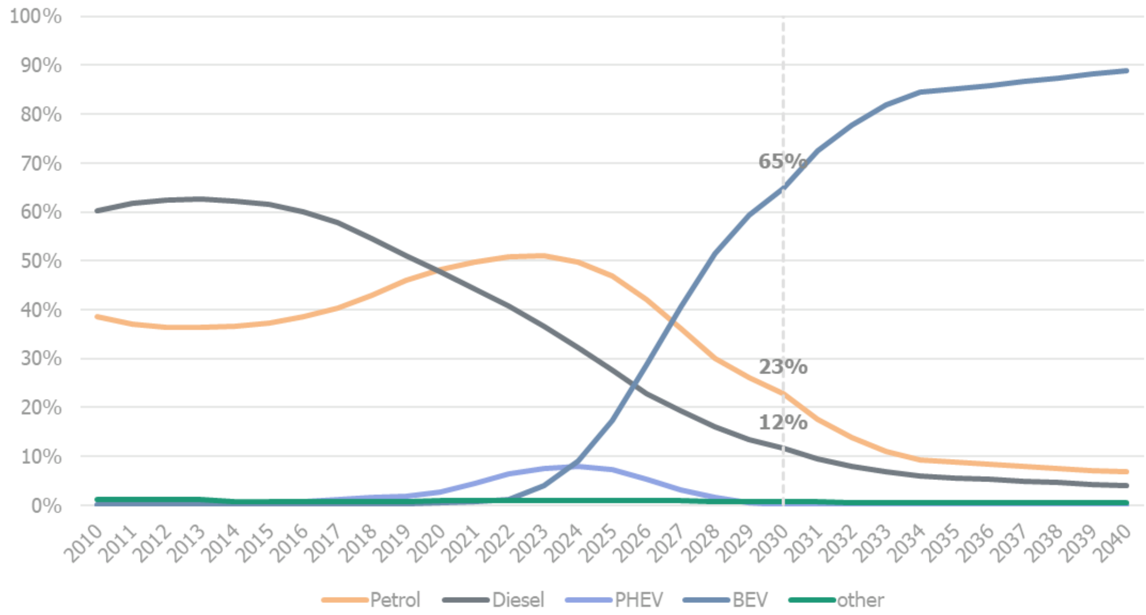


Figure 49 Vehicle stock until 2040 under the modal shift scenario

4.2.4 Discussion of the results

Several deployment simulations were performed resulting in different shares of BEVs in the total fleet over time. By 2030, the share of BEVs ranges from 26% in the Norway scenario to 74% in the 100% BEV scenario. The latter figure is the result of the most optimistic scenario with all electric car sales from 2024 onwards. Because of the assumptions made, all scenarios predict a zero-emission car share in the total car fleet of ~90% by 2040. Fossil fuel cars slowly phase out, and also PHEVs are expected to phase out because of their higher TCO and because of the planned sales bans and implementation of urban zero-emission zones.

Compared to earlier studies our predictions are rather optimistic concerning the transition to a zero-emission car fleet. With the recent announcements of a sales ban for fossil fuel cars in Europe and the introduction of zero-emission zones (for example in Brussels), there are reasons to believe that the transition will be and should be accelerated.

In a report published in April 2022, the Federal Planning Bureau in Belgium predicted that the fleet would consist of 43% EVs in 2040, versus 33% petrol-powered vehicles, and only 7% diesel (Federaal Planbureau, 2022). The Synergrid study from 2019 estimating the impact of EVs on the electricity net used the following estimates: 1.5 million EVs (cars and vans, BEVs and PHEVs) on Belgian roads by 2030, and 4 million EVs in 2040 (Synergrid, 2019). According to our more recent predictions following the latest trends, the threshold of 4 million will be reached much faster.

We did not account for possible new (zero-emission) motor technologies, e.g. hydrogen. Also, we did not consider factors that might impede the transition to BEVs, like a shortage of charging infrastructure, delays in car deliveries, or the EV supply quotas for Belgium (supply cannot meet the demand). On the other hand, concrete measures that might accelerate the transition were also not accounted for.

4.3 Forecast on charging infrastructure

In parallel with the increase in the electric fleet, the number of charging points will need to increase exponentially. Moreover, the unavailability of charging infrastructure was identified as one of the main barriers for drivers to adopt electric vehicles in our survey (see chapter 3). Therefore, the roll-out of private and public chargers should be closely monitored.

Based on a concise calculation with various assumptions (Attachment 3: Methodology of the charging infrastructure forecast), a 10-year forecast scenario of charging infrastructure is made.

This forecasting exercise focuses on:

- All charging infrastructure;
- for private fleets (both private and self-employed), company fleets and light commercial vehicles;
- in Belgium.

- **How many charging points do we need in Belgium?**

Calculations use fleet predictions, car use estimates, and predicted charging behaviour in the next decade. Modelling is done separately for home charging and for charging at shared and public chargers. The detailed methodology can be found in the attachment.

Figure 50 shows the prognosis for the number of charging points[5] for normal AC charging for the whole of Belgium. The strongest increase can be attributed to home charging, which has an expected total of 1.1 million home charging points by 2030, representing 64% of the AC charging market. Workplace charging is also on the rise with nearly 450.000 required charging points in 2030, although its share of the charging market is declining in favour of home charging. The relative share of public charging points remains stable over the years. Therefore the required number grows steadily to a total of 172.000 public charging points by 2030.

These numbers add up to a total need for **1.7 million charging points** in 2030 in Belgium, from the almost 100,000 that are installed in 2022. This results in an increased roll-out of charging points **from 1,750 per week** in 2022 to **5,500 per week** in 2030.

For fast charging and high-power fast charging, the total requirement by 2030, assuming 12 fast charging points per charging hub on average, is 772 fast charging hubs divided over highway locations, intercity locations and city locations. This amounts to approximately 9,200 fast charging points. The current supply of fast chargers can mainly be found at highway locations and intercity locations. In the future, a shift is expected in favour of city locations. These city locations are expected to play an important complementary role in the public AC charging infrastructure. There are clear indications that the supply of AC charging infrastructure will not be able to keep up with demand in urban areas, so fast charging sessions in or on the outskirts of the city should address this lack of regular AC charging infrastructure. In addition, the range of vehicles is also increasing towards the future, which means that the need for fast chargers along the highway will gradually stagnate.

[5] Most public charging stations exist of two slots or points. Private charging stations often have only one slot.

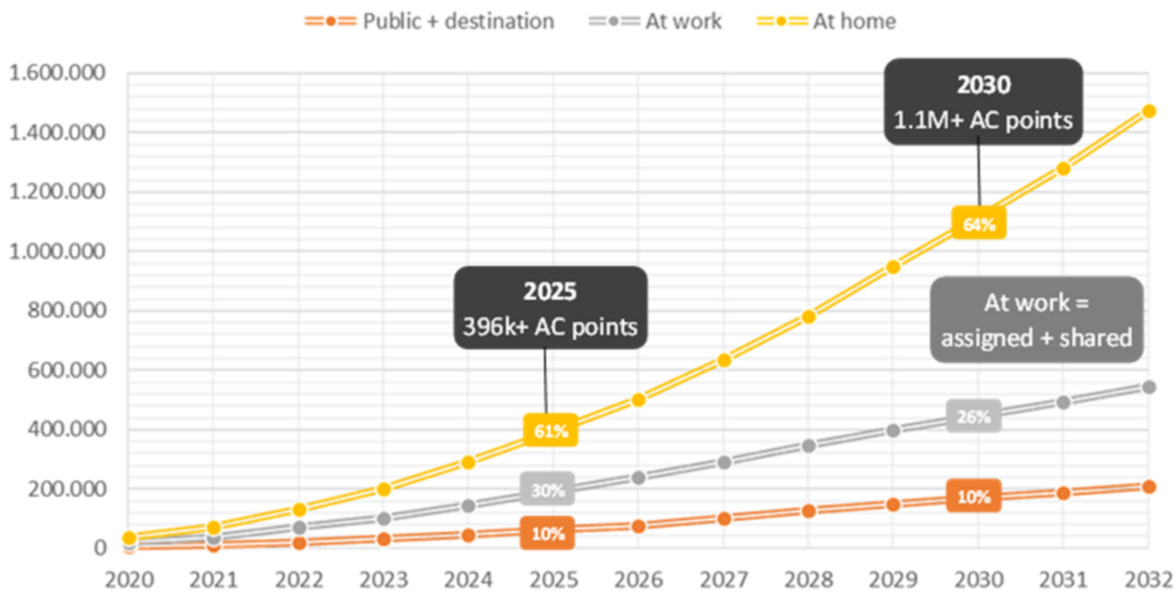


Figure 50 AC charging points needed (cumulative) for the car fleet in Belgium

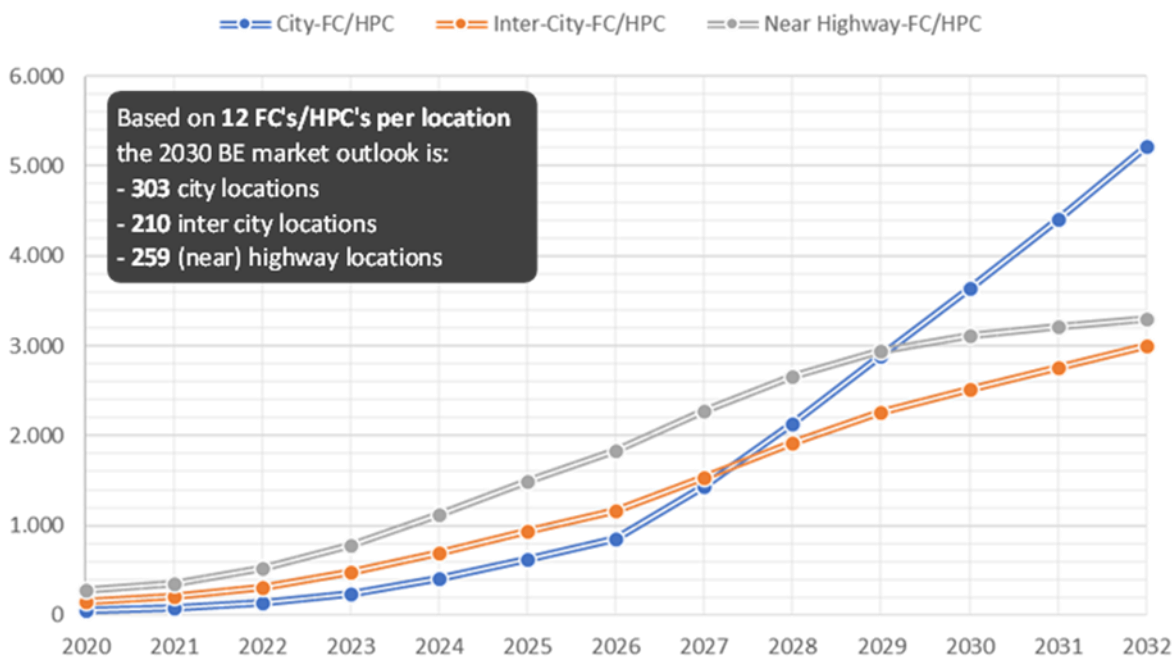


Figure 51 (High power) DC fast charging points needed (cumulative) for the car fleet in Belgium

Broken down by the needs of private vehicles only (excluding company cars and light commercial vehicles), the need for normal AC charging points amounts to about 850,000 charging points in 2032. The vast majority will be private charging points at home. Charging points at work comes in second place and strengthens their position over the years. The required number of public charging points remains rather limited, although this share will continue to increase after 2032 as even more private individuals without their own charging facilities will purchase a BEV.

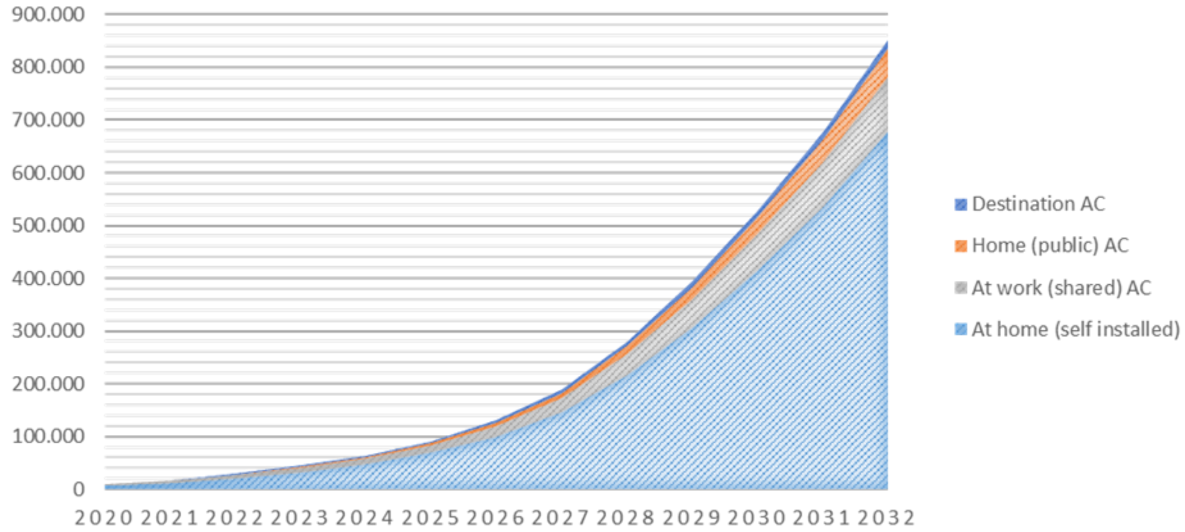


Figure 52 Charging points (cumulative) needed for the private vehicle fleet (excluding company cars and light commercial vehicles)

To conclude, the Belgian charging infrastructure deployment hasn't reached its full pace to meet demand, despite a significant backlog of reservations of BEVs. Especially when looking to the next decade, deployment has to accelerate by an order of magnitude to install up to 5,500 charging points per week in 2030.

5 Impact assessment

5.1 Introduction & scope

The transition of the car fleet to a higher share of EVs has an impact on our **environment** and our **society** as a whole. The aspects that are most likely to be significantly affected by the evolution of EVs on the market are discussed in this chapter. These factors are presented in Figure 53 and include: life cycle CO_2 emissions of cars; direct air pollution emissions from transport; noise from road transport; congestion; safety; fairness of the mobility system; and organization of the mobility system including mode choice.

We aim to present a holistic view of the environmental and societal impact of EVs taking into account the expected evolution of EVs in the private fleet up to 2040. We will not quantitatively weigh or compare different factors, or present a final assessment of the introduction of EVs in the Belgian car fleet. Rather we will discuss the key issues in the debate and this way present the strengths and weaknesses of EVs, knowledge gaps, and possible mitigating measures.

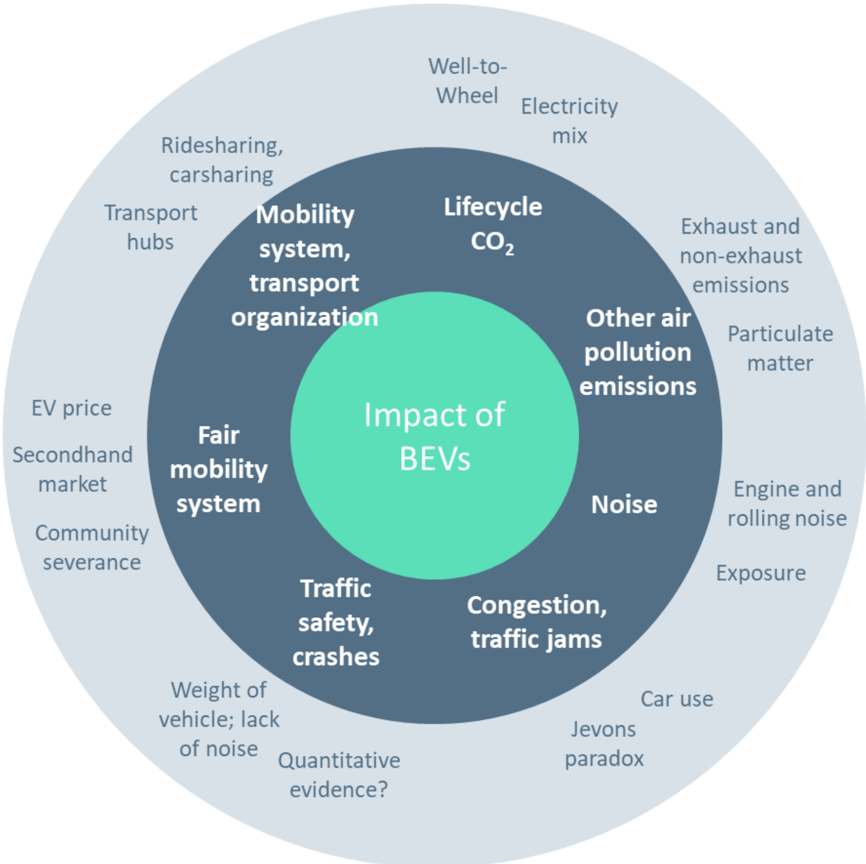


Figure 53 Impact of the deployment of BEVs on different aspects
The factors that are included in the chapter are presented in the dark blue circle, and the most important topics per factor are mentioned in the outer circle.

Subsequently, **the impact of different deployment scenarios** (Chapter 4.2) on each of the factors is evaluated, mostly in a qualitative way, except for the life cycle CO_2 emissions that we quantify. Specifically, we compare the current situation with future deployment scenarios and expected evolutions.

Impacts that are important, but are not studied in this chapter are:

- Impact on government revenues. The transition towards a fleet with high shares of EVs will lead to revenue loss for the government when current fiscal structures remain unchanged (revenue loss from the purchase tax, fuel sale; value added tax, see Figure 54 for the example of Norway). However, governments can adapt their policies once EVs become a success. This topic is complex and deeply interwoven with the actual uptake of EVs. A study of the Federal Planning Bureau tackles this aspect for Belgium.

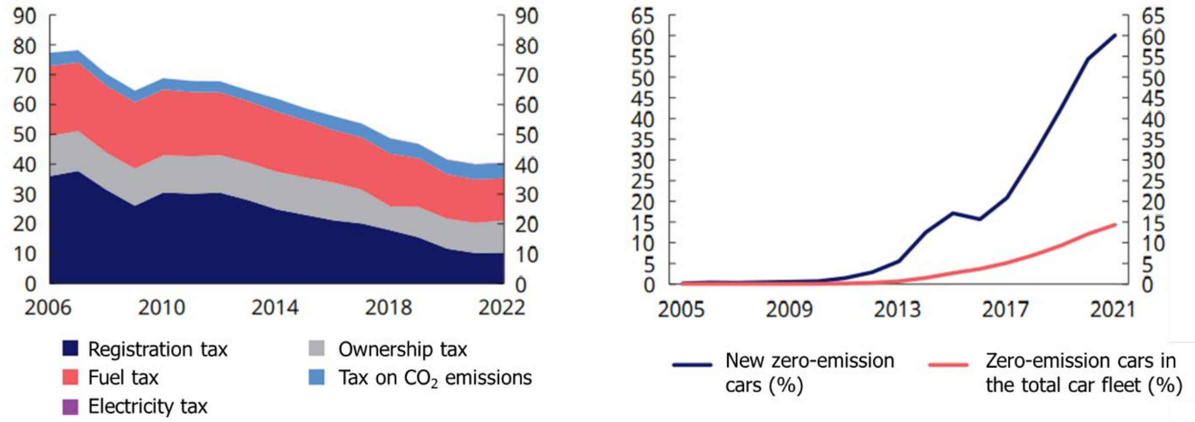


Figure 54 Example of Norway: Zero-emission cars and car-related tax revenues.
Left panel: Evolution of state revenues in billion-2022-Norwegian kroner (currency) since 2006. Right panel: Share of zero-emission cars
Source: Norway Ministry of Finance, Taxes, duties and customs 2022 (Page 171 in Pdf-file), https://www.regjeringen.no/no/dokumenter/prop.-1-ls-20212022/id2875345/

- Impact on the electricity net. A general concern in the energy transition is the question of whether our distribution nets are capable of powering millions of EVs. This topic has been extensively studied in the past, in Belgium and abroad, using what are now considered conservative EV deployment scenarios (Synergrid, 2019). Peaks in energy demand are expected in the evening when EV drivers return home and start charging their cars. To tackle this issue charging should be organized in a way that it can be spread as much as possible over time and at points on the grid with more capacity. Dynamic pricing can be used to rebalance the charging and shift to slow night charging, as was done in Norway. However, even with smart charging, a Belgian EV fleet of several million vehicles could be problematic according to recent estimates. Renewal of the electricity net is a long-term activity, and this huge challenge should be handled urgently or the electricity net could become a limiting factor in the deployment of EVs.

5.2 Impact of the deployment of BEVs

The expected **impact of the deployment of BEVs** is assessed. Both positive and negative environmental and societal consequences of the deployment scenarios, as presented above in Figure 53, are assessed using current statistics and evidence from the literature. Further, we also use numbers from an extensive but exploratory survey of 32 Belgian BEV drivers in which the drivers were asked about their experiences and satisfaction as well as any possible changes in driving behaviour since switching to a BEV. The impacts studied are life cycle CO_2 emissions of cars; direct air pollution emissions from transport; noise from road transport; congestion; safety; fairness of the mobility system; and organization of the mobility system including mode choice.

5.2.1 Impact on greenhouse gas emissions

Transport is the only sector where greenhouse gas emissions have increased in the past three decades in the EU, rising 33.5% between 1990 and 2019. Road transport accounts for about a fifth of EU emissions. Thereof 60.6% is from cars, 27.1% from heavy duty trucks, 11.0% from light duty trucks and 1.3% from motorcycles.

It is easy to understand that EVs emit less or no greenhouse gases at the tailpipe because fewer (for PHEVs) or no (for BEVs) fossil fuels are used to propel the vehicle. However, the electricity used by the electric powertrain and the electricity used during the production of the vehicle and the battery still has to be produced and can also be a source of GHG emissions.

In Chapter 1.5 the life cycle CO_2 emissions of BEVs and their fossil fuel counterparts were quantified and discussed. In Belgium and across vehicle segments, BEVs always have lower life cycle CO_2 emissions than ICEVs. It was quantified that BEVs have life cycle emissions of 90-166 g CO_2 eq/km, 41 to 68% of their ICEV counterparts, which have life cycle emissions of 179-294 g CO_2 eq/km. Higher segment vehicles emit more than lower segment vehicles: as the vehicle size increases, the vehicle mass increases, the battery size is usually bigger and Well-to-Wheel emissions are higher.

Scenarios

The yearly CO_2 emissions from cars in Belgium were quantified using the life cycle CO_2 emissions from Chapter 1.5 and the vehicle stock under different deployment scenarios from Chapter 4.2. In the scenarios, we assume that all vehicles have the same annual mileage, namely 15,000 km. As a result of this, in 2022 all cars registered in Belgium produced an estimated 20,052 kiloton CO_2 (life cycle emissions). This amount will decrease following the different EV deployment scenarios. Assuming constant lifecycle CO_2 emissions per vehicle kilometre per fuel in the next decade results in a 20% reduction in kiloton CO_2 from all cars in Belgium by 2030 (compared to 2022) in the scenario with price parity in 2026. This reduction is rather limited as the reduction in emissions per vehicle is counteracted by the increase in the total number of cars, and also considering that life cycle CO_2 emissions of BEVs do not equal zero. When a realistic deployment path is simulated, defined before as the Norway scenario, we see a reduction of only 4.6% in the CO_2 emissions from all cars in Belgium by 2030 as compared to 2022. The reduction in CO_2 emissions from all cars in Belgium amounts to 24% by 2040, compared to 2022.

When we account for the expected growth in renewable energy and thus a greening of the production and use of BEVs (as discussed in Chapter 1.5), there will be a reduction in kiloton CO_2 from cars in Belgium with 26% instead of the 20% presented before.

The modal shift scenario results in a bigger reduction in CO_2 emissions compared to all other scenarios. The composition of the fleet is similar but the total car fleet is smaller.

In conclusion, BEVs indeed emit less CO_2 over their lifetime than fossil fuel vehicles, generally speaking about half as much. However, if we aim to cut greenhouse gas emissions from transport by more than 50% replacing fossil fuel cars with BEVs will not be enough (even more so when the total car fleet grows and no electrification of heavy goods vehicles is pursued). Driving less, either through avoiding trips or shifting to cleaner modes of transport, will be essential to have a bigger impact on climate change (Avoid-Shift-Improve principle).

Table 23 Evolution of the CO_2 emissions per year by cars in Belgium (in kiloton CO_2)

Scenario	2022 (baseline)	2030	2040
Price parity in 2026	20,052	16,120 (-19.6%)	15,232 (-24.0%)
Price parity in 2028	20,052	16,877 (-15.8%)	15,232 (-24.0%)
Price parity in 2030	20,052	17,668 (-11.9%)	15,232 (-24.0%)
100% BEV (from 2024)	20,052	15,484 (-22.8%)	15,232 (-24.0%)
Norway	20,052	19,130 (-4.6%)	15,232 (-24.0%)
Modal shift	20,052	14,683 (-26.8%)	12,266 (-38.8%)

Table 24 Evolution of the average CO_2 emissions of the car fleet in Belgium (in g CO_2/vehicle km)

Scenario	2022	2030	2040
Price parity in 2026	225	167 (-25.7%)	144 (-35.8%)
Price parity in 2028	225	175 (-22.2%)	144 (-35.8%)
Price parity in 2030	225	183 (-18.5%)	144 (-35.8%)
100% BEV (from 2024)	225	160 (-28.6%)	144 (-35.8%)
Norway	225	198 (-11.8%)	144 (-35.8%)
Modal shift	225	169 (-24.7%)	146 (-34.9%)

5.2.2 Impact on air pollution emissions

Air quality is of large concern in Belgium and the world. The World Health Organization estimates that every year ambient (outdoor) air pollution causes 4.2 million premature deaths worldwide[6].

EVs lead to substantial air pollution health improvements due to the absence of direct, local exhaust emissions (Choma et al., 2020). While EVs do not produce exhaust emissions; there is interest in understanding how the non-exhaust emissions could affect the exposures and health of individuals living near major roads. Specifically, particulate matter is of concern given the demonstrated health impact. Non-exhaust particulate matter, including microplastics, also ends up on soil and road surfaces, and is then carried away with run-off rainwater. In this way, water laden with microparticles of rubber and metallic elements enters groundwater and wastewater, and may even run off into the oceans having an important environmental impact.

Non-exhaust emissions are produced by tyre wear, brake wear, road abrasion and resuspended road dust. A positive relationship exists between vehicle weight and non-exhaust emissions (Timmers & Achten, 2016). This means that EVs, which are heavier because of the battery, and larger vehicles (SUVs and larger cars) emit more non-exhaust emissions, specifically tyre wear and road wear, compared to ICE cars. EVs are on average between 11 and 25% heavier than petrol and diesel cars in the same classes, however batteries and vehicle bodies are expected to become lighter in the next decade (Høye, 2017; Timmers & Achten, 2016). Brake wear of EVs tends to be lower because of their regenerative brakes: when you brake, the motor turns in the opposite direction, this resistance slows down your car, the energy is then stored in the battery, and additional braking that wears the brake pads will thus be unnecessary. In practice, EVs combine regenerative and friction braking. There is no scientific consensus as to what the net effect is: "The net balance between reductions in brake wear emissions and potential increases in tyre and road wear emissions and resuspension for vehicles with regenerative braking remains unquantified" (Vanherle et al., 2021).

The composition of particulate matter in exhaust and non-exhaust emissions is very different: exhaust emissions (especially from diesel cars) contain the highly toxic black carbon (or soot), while non-exhaust emissions from brake and tyre wear contain elements such as copper, zinc, iron, and lead, among others (Timmers & Achten, 2016). Several toxicological and epidemiological studies have found links between particulate matter in general, and non-exhaust emissions specifically, and adverse health effects, such as lung inflammation and DNA damage, and mortality (Timmers & Achten, 2016). From a toxicological point of view, it is mainly the brake wear particles that are suspected to be the most harmful (Gerlofs-Nijland, 2020). Very recent research looks into the emission of microplastic particles from tyre wear into the environment (Vanherle et al., 2021).

There are still very high uncertainties in the amount of non-exhaust emissions from EVs, and further research would be necessary (Vanherle et al., 2021). However, in the meantime, several mitigation actions should be taken to reduce non-exhaust emissions from all vehicles, and more importantly from EVs. Policy so far has only focused on reducing particulate matter from exhaust emissions, but with Euro 7 limits on the EU table, it is proposed for the first time to set non-exhaust emission standards as well. In addition, there should be more efforts towards lightweight car bodies and regenerative brakes, or technological solutions such as removing copper from brake pads. Incentives should be provided to the automobile industry and to consumers to switch to less heavy vehicles.

Scenarios

Exhaust emissions (particulate matter and nitrogen oxides, among others) will decrease as BEVs do not directly emit air pollutants via their exhaust. So increasing the share of BEVs in the fleet in the coming years will be beneficial for those emissions. The relative importance of non-exhaust emissions on the total particulate matter will increase due to the higher share of BEVs in the vehicle fleet. Non-exhaust emissions are currently not regulated, but they are suspected to have an impact on health and the environment. Therefore the EU recently proposed the Euro 7 limits that also focus on non-exhaust emissions. Under a deployment scenario that assumes a growth in the total fleet, the absolute number of emitted non-exhaust particles will increase – close attention should be paid to that, and regulating those emissions should push car manufacturers to lower non-exhaust emissions in new cars.

[6] https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

5.2.3 Impact on noise

Research suggests that noise from traffic is associated with detrimental effects on sleep quality, mental health, and overall quality of life (Walker et al., 2016). The World Health Organization estimated that Europe sees around 1.7 million Disability Adjusted Life Years (DALYs) lost each year as a result of environmental noise – of which traffic is a key component (World Health Organization Regional Office for Europe, 2011).

Total noise from cars is a combination of engine noise and rolling noise. EVs do not emit engine noise. At speeds below 30-50 km/h, engine noise dominates for ICEVs; while above 30-50 km/h rolling noise (tire-road noise) is more important, depending among others on the road surface. It is thus mainly on roads with low speed limits that EVs reduce noise. At speeds above 50 km/h, there is no significant noise reduction left from EVs compared to ICEVs. Figure 55 shows the noise reduction, expressed in decibels (dB) for a BEV and HEV in comparison to an ICEV at different speeds (Verheijen & Jabben, 2010).

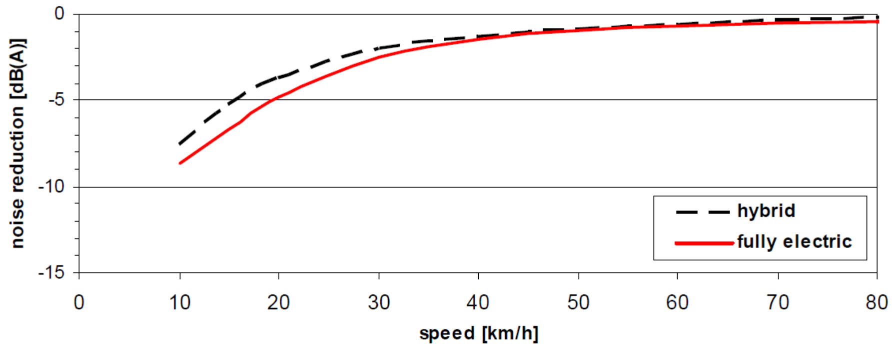


Figure 55 Noise reduction of HEVs and BEVs compared to conventional ICEVs
Source: Verheijen & Jabben, 2010

Lower noise is expected to also reduce noise annoyance. A Dutch study projected that a 100% electric fleet would reduce average urban noise levels by 3–4 dB and reduce annoyance effects by more than 30% (= number of people severely annoyed by traffic noise will be reduced by one-third) (Verheijen & Jabben, 2010). Near major roads, the noise reduction is lower because here average speed surpasses 50 km/h (Verheijen & Jabben, 2010). A simulation in France using 100% BEVs estimated an improvement for 10% of the citizens who would be under the limits fixed by legislation; the reduction would be 6% when EVs make an additional warning sound (Campello-Vicente et al., 2017). In a UK study, participants rated noise annoyance of fleets with different percentages of BEVs (0%, 20%, 40%, 60%, 80%, 100%) (Walker et al., 2016). Ratings of traffic noise were, overall, towards the negative end of the scale, but improved significantly when there were high proportions of BEVs in the traffic mix, particularly when there were 80% or 100% BEVs.

To achieve further reductions in noise, additional measures are necessary: more silent tyres, silent road pavement, or reductions in speed for example by increasing the number of 30 km/h speed zones in cities.

In our exploratory survey of Belgian BEV drivers, 59% of BEV drivers report that noise was an important factor in their decision to go electric. All 32 of the questioned EV drivers report being satisfied with the noise level of their car.

Scenarios

A shift towards a high proportion of BEVs is likely to improve the subjective experiences of people exposed to traffic noise from major roads, especially along roads with speeds below 50 km/h. We do require a large share of BEVs in the total fleet that drive at low speeds to really have an impact on health.

When accounting for mobility growth (all our simulated deployment scenarios assume growth in the total vehicle fleet, except for the modal shift scenario), it is likely that the noise reduction will be small, or there will be even a small increase in noise when considering the complete road network (Verheijen & Jabben, 2010).

5.2.4 Impact on congestion

The well-known Jevons paradox seems to apply to EVs: increasing energy efficiency (a BEV converts around 80% of the energy it uses to usable power, compared with around 20% for an ICEV) leads to higher demand and use, caused by lower prices. Next to the financial stimulus, the environmental impact of the EV also reduces, which might lead to drivers increasing the use of their vehicle "because it is not bad for the environment anymore", even for short car trips (European Environment Agency, 2016). In the long survey that we conducted among 32 BEV drivers, 9% reports driving more often due to the lower environmental impact. 28% of the questioned BEV drivers indicate that they take the car more often for short trips. A Norwegian study shows that the EV replaces 10 to 20% of the distances that a person would normally actively travel by public transport, by bicycle or on foot (Figenbaum et al., 2014). Local initiatives that offer free parking and charging points for EVs stimulate this behaviour (European Environment Agency, 2016).

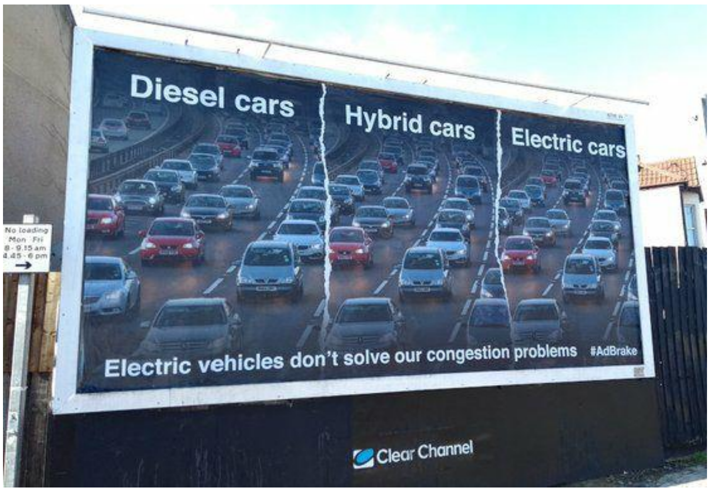


Figure 56 Advertisement in the UK, 2022 (used here for illustrative purposes)
Source: https://ecohustler.com/technology/guerilla-take-over-of-100-uk-billboards-in-anti-car-protest

Scenarios

The Federal Planning Bureau in Belgium assumes a constant level of road infrastructure by 2040 (Federaal Planbureau, 2022). An increase in road traffic will thus likely result in more congestion and will reduce the average speed on the road network.

The deployment of BEVs in the fleet will thus not solve congestion – on the contrary, BEVs may increase car ownership and use leading to growing congestion, and increased demand for road infrastructure and parking. To ease congestion our behaviour will need to change. This includes shifting towards more non-motorised active and/or public transport (Avoid-Shift-Improve principle).

5.2.5 Impact on safety

It is still early days to present definitive and evidence-based conclusions about the safety of EVs because the share of EVs in the total fleet is still small.

As such, there are no real indications why EVs would improve **traffic safety**: EVs have the same general characteristics as ICEVs (for example, the same in-vehicle safety systems); however, the EVs that are in the fleet now are newer vehicles compared to the current average fleet. Notably, car producers are continuously improving car safety systems.

A factor that is different between an ICEV and a BEV, is the **noise** level at low speeds (below 50 km/h). This may pose a risk to visually impaired people, or cyclists and pedestrians that rely on auditory cues to locate a vehicle out of eye range. Such risk situations may occur in shared streets, on parking lots and 30 km/h zones and also at crossings or exits (Pardo-Ferreira et al., 2020; Verheijen & Jabben, 2010). About 44% of the BEV drivers that we questioned report having been in a situation in which a vulnerable road user did not hear their BEV. To compensate, many drivers state that they are more alert while driving a BEV (Pardo-Ferreira et al., 2020). This is also confirmed by the survey results: 56% of BEV drivers indicate having changed their driving behaviour to compensate for the lack of noise. It has been proposed to specify minimum noise levels for vehicles, which would imply that EVs must produce an artificial sound whenever their engine is too silent. This will affect the potential reduction of noise annoyance presented before and thereby the reduction of adverse health effects that are caused by noise annoyance. The European Union (EU) has mandated all new EV models to be fitted with a new sound-emitting device, i.e. the acoustic vehicle alerting system (AVAS), as of 1 July 2021 (https://eur-lex.europa.eu/eli/reg_del/2017/1576/oj). The device will automatically generate a sound from the start of the car up to the speed of approximately 20 km/h, and during reversing. However, 20 km/h remains low and the driver can at any time deactivate the noise.

A second factor that may impact traffic safety differently in EVs compared to ICEVs, is the **weight** of the vehicle. EVs are on average heavier than ICEVs in the same classes because of the batteries. Based on the physical connection between the cars' weight and risk of injury, this indicates that EVs to a greater extent protect people inside the vehicle and increase the risk of injury for the other party (pedestrians and cyclists) in collisions than ICEVs. This could not be confirmed with a recent analysis of crash data in Belgium (see further, Table 25).

Next to the **aggressiveness** of the vehicle itself, i.e. the extent to which the car causes damage to other road users in the event of a collision, is also the driving style linked to EVs sometimes considered as 'aggressive'. EVs can take off faster because of the faster acceleration.

Currently, EVs in Belgium are mainly company cars that have a higher annual mileage than privately owned vehicles. But also, it appeared that more energy-efficient EVs may lead to a higher mileage because of the lower price and because of the lower assumed impact on the environment. When EVs drive further than ICEVs, they are likely to be involved in more crashes in total.

A recent analysis of crash data in Norway reveals some interesting **early patterns in EV crashes** (PHEV and BEV) (Liu et al., 2022). EVs are confirmed to be much more likely to collide with cyclists and pedestrians, probably due to their low-noise engines: 31.5% of EV crashes involve bikes/pedestrians, but this proportion is only 20.3% for ICEV ones (Liu et al., 2022). EV crashes are not statistically significantly more severe than ICEV crashes (Liu et al., 2022). Crashes with EVs are less likely to happen during the weekend; this confirms the higher use of EVs for commute traffic (Liu et al., 2022). As can be seen in Table 25, recent numbers for Belgium show that no increased risk of fatal/serious injury or increased risk of fatal injury in the event of a collision with an EV can be observed.

Table 25 Number of vulnerable road users in car crashes, by fuel type of the passenger car (sum over the period 2017-2020) (Vulnerable road users = pedestrians, cyclists, motorized two-wheelers)

	Fatalities (F)	Seriously injured (SI)	Light injuries	Not injured	Total	Injury severity (F + SI) / Total
Diesel	318	2420	22861	528	26127	10.5%
Petrol	126	1614	15070	372	17182	10.1%
BEV or hybrid	5	88	869	17	979	9.5%
Gas or hybrid with gas	2	22	203	3	230	10.4%
Unknown	72	498	6347	121	7038	8.1%
Total	523	4642	45350	1041	51556	10.0%

Source: Statbel (Algemene Directie Statistiek - Statistics Belgium)

Next to traffic safety, there might be concerns about **fire safety** with battery technology (Deloitte Insights, 2020; Høye, 2017). Firstly, there is a fire hazard (overheating, short circuit, overcharging). Secondly, there might be an increased risk after a crash has happened for the environment and first responders (electric shocks, hazardous chemicals and gases, fire). Difficulties with the post-crash rescue could impact crash outcomes. Lastly, the charging process might lead to increased risk: charging normally takes place without supervision while refuelling an ICEV is only possible when the driver is present. From the Deloitte Global Auto Consumer Study held in several countries worldwide (excluding Belgium), it appeared that in 2020 compared to 2018 concern over the safety of battery technology is still limited (around 10%), but it is growing (Deloitte Insights, 2020). However, it is important to stress that empirical studies that observe these risks are still lacking.

One measure that has been taken in some places to tackle the suspected risk of fire, is prohibiting parking in underground parking for EVs. Only one out of the 32 questioned Belgian BEV drivers reports having been in a situation where they were not allowed to park underground. Nevertheless, this might become an area for debate in the coming years. Currently, the fire department in Belgium is advocating for limitations for EVs in underground parking lots: fast chargers should be forbidden in underground parking, EVs cannot be parked lower than level -1, and smoke detectors and sprinklers must be provided.

Scenarios

Batteries, vehicle bodies & materials are likely to become lighter in the next decade – unless more efficient/lighter batteries are compensated by new batteries to extend the range. In France, road taxes depend among others on the weight of a car, making lighter vehicles more attractive for tax purposes. Possibly, this will also be introduced in Wallonia. Lighter vehicles are expected to be safer for other traffic participants, although at this point this could not be confirmed with Belgian crash data.

Several evolutions will impact crash risk, crash occurrence, and severity. Follow-up research and close monitoring of the number of crashes in Belgium and abroad as they become available, are needed to estimate the impact of the deployment of BEVs in the fleet.

5.2.6 Impact on the fairness of the mobility system

The introduction of EVs has disturbed the car market, but also society as a whole. The transition toward a fleet with more EVs, and over time the mass uptake, should happen in a fair and just way, strengthen equality in society, improve people's health and well-being, and tackle the climate crisis in Belgium and the world.

Inequalities in access to EVs happen in three areas: acquisition, charging, and use. Inequalities are not necessarily unfair, as they are often temporary (as many innovation processes), but they should be closely monitored, and timely action should be taken when necessary.

The **acquisition** or purchase cost of a (small) BEV is currently still higher than for an ICEV. This limits lower-income households in making a choice that is better for them in the long run (the TCO of several BEVs is already lower than for ICEVs), but also better for the environment. The right policy measures should give people access to make good choices (Frost et al., 2021). Projected price drops in BEVs, a second-hand market, or private leasing schemes, could lower the upfront cost of BEVs that now often is a bottleneck for lower-income households.

The **second-hand market** for EVs is still in its infancy. Lower-income households often rely on the second-hand market, and if the supply of EVs is too small, then these lower socioeconomic groups will be stuck using vehicles that are polluting and expensive to run for many years to come (for example, maintenance costs of EVs are estimated to be lower). However, the second-hand market is now quickly developing. The first generation of EVs had a relatively low second-hand value due to uncertainty over the durability of the battery; experience has shown that batteries last up to one million kilometres with little loss in battery performance increasing the value of a used car for the first owner but also the second-hand buyer. Access to the second-hand market could be improved by introducing a subsidy scheme for used cars; currently, only three countries in Europe have such a system in place: France, the Netherlands, and Germany. Current and past subsidy schemes have benefited early adopters of EVs most, while those early adopters have higher incomes already, are highly educated, and have more occupational prestige as was seen in the Netherlands (Duurkoop et al., 2022). With the very high shares of EVs as company cars in Belgium, supported by current policies, there is a risk for a growing mismatch between expensive upscale EVs being produced and sold to businesses, fleets and wealthy private buyers and the smaller, cheaper versions that will be needed in the second-hand market. On the other hand, with EVs entering the market via the corporate market 1) there is a faster turnover so the cars more quickly enter the second-hand market, and 2) companies pay the high upfront sticker price and then have middle income families benefit from the lower running costs of a second-hand EV. The lower number of new vehicles built and delivered to customers in 2020, 2021, and 2022 means fewer second-hand (electric) cars will enter the market in 2023 and 2024 further delaying the mass supply of EVs in the second-hand market, but creating a favourable supply-demand ratio for resellers.

A huge challenge in the mass adoption of EVs is the provision of **charging** points to all, also people without a place on their property. Publicly accessible chargers should be installed soon enough and in big amounts to provide drivers without a driveway the possibility to buy an EV. With the mass availability of chargers, it might be possible to reduce the size of the battery in a car, lower the acquisition cost of the expensive battery, and make smaller and cheaper EVs with a smaller battery a good option for lower-income households.

Maintenance costs are expected to be lower in EVs compared to ICEVs. However, the **use costs** of EVs are dominated by the cost of electricity. Lower-income households are likely to face significantly higher electricity costs for charging their vehicles because they are likely to rely more heavily on public charging points rather than charging at home (even though for now electricity prices at public chargers tend to be somewhat lower than private electricity fares – this is expected to be temporary). Policy should come up with actions to tackle the price differential faced by people who cannot charge their EVs at home. Moreover, increasingly stringent low emission zones in cities force car owners to either buy a (more expensive) clean vehicle or pay an annual fee to still be able to reach their homes with an older ICEV.

Inequality does not only happen through income. There is a **gender** gap in the adoption of new technologies; this also holds for the EV market. In Chapter 3, our survey found that men are significantly more likely to buy an EV than women. A recent survey in the UK revealed that almost 80% of women state they would suffer from range anxiety, and this is higher than in men (presentation by Prof. dr. Tim Schwanen, 2022[7]). Furthermore, there might emerge a **geographical** divide, with richer urban areas being a hotspot for the adoption of EVs with shorter distances and availability of public charging infrastructure, and poorer rural areas

[7] Francqui Chair for Tim Schwanen, Lecture 6: Electrification and automation, https://www.youtube.com/watch?v=nOSFuLXFuEA

with low levels of EVs. A positive side effect of this inequality is that lower-income households living near major roads with poor air quality will disproportionally benefit from the fast electrification of the fleet: Improvements to local air quality are expected because of the removal of direct exhaust emissions (Henderson, 2020).

Busy traffic has a negative effect on social interactions, well-being and health. **Community severance**, the phenomenon in which transport infrastructure and motorised traffic act as a physical or psychological barrier to the movement of pedestrians, will increase if the total car fleet increases, whether these are EVs or ICEVs is not important. Moreover, EVs will claim 'new' spaces: public charging infrastructure is often placed on sidewalks hindering pedestrians and taking space that could be used for green mobility such as cycle tracks, bus lanes, and compact, walkable spaces (Henderson, 2020). Cities worldwide have recently embraced the principle of the 15-minute city: citizens should be able to access their everyday needs within a 15-minute walk, cycle or public transport trip, without the need for a car. This is of utmost importance as the transition towards EVs is necessary, but decarbonization via EVs only will not be sufficient or fast enough to solve the climate emergency.

A fair mobility system does not stop at the country's borders. Mining of raw materials, production of batteries, and assembly of EVs mostly do not take place in Belgium. The harm caused by raw materials and during the production process (conditions for the local workforce, electricity generation, environmental harm, critical materials) should be accounted for when trying to achieve a zero-pollution mobility system, even if it does not take place in our own country.

Scenarios

In the deployment of BEVs in the Belgian fleet, a fair transition should be strived for. A myriad of measures could be taken, ranging from financial and fiscal measures (purchase subsidy, tax reduction), to developing the second-hand market, the provision of sufficient (public) charging opportunities at a reasonable cost, but also education and awareness raising. Some measures will be temporary, while others ask for continued efforts.

5.2.7 Impact on the mobility system & transport organization

Electrification of the fleet needs to be linked to the other emerging concepts of **automation** and **shared mobility** to get the full benefit (presentation by Prof. dr. Tim Schwanen, 2022[8]). Automated cars will likely travel longer distances; they will travel empty, for example, to return home after dropping a passenger at work; but they also enable maximal eco-driving as they require no intervention from a driver. Shared mobility will lead to fewer cars being owned, but also to fewer cars in the fleet as cars are used more efficiently, opening up space for other purposes. The high annual distance travelled by shared vehicles makes them more sensitive to TCO, resulting in a quicker uptake of EVs in this market. Moreover, a policy could force car-sharing companies to follow more strict emission standards, e.g. the state of California in the US requires rideshare operators such as Uber and Lyft to transition from petrol to EVs in their networks. When shared vehicles are electric, charging can be done more efficiently in transport hubs. Next to charging infrastructure, transport hubs can offer a myriad of functions to travellers. From our survey, 87% and 65% would like transport hubs to have the basic necessities such as toilets and the option to buy food and drinks respectively. There is also some interest in green, open space (29%) and non-food stores (13%).

In contrast to the wave towards a shared economy, are measures that stimulate private car ownership, be it an ICEV or an EV. As mentioned already before, private **leasing** of vehicles could be a means to avoid the direct acquisition cost that is currently higher for BEVs compared to ICEVs. The popularity of private leasing is growing; in some of our neighbouring countries, it is already quite common, for example in the UK the majority of cars are leased. A disadvantage of private leasing, compared to a loan, is that the driver will never own the vehicle, while the monthly amount is often comparable. The advantage of the system is that it takes away the burden of owning a car: only the fixed monthly fee has to be paid (no additional maintenance cost, insurance, taxes, etc.). Private leasing nevertheless likely leads to a higher TCO for private individuals, again disadvantaging less well-off groups. The green image of an EV could stimulate more people to **own** or drive cars more because it is not harmful to the environment anymore; this will change mode choice in favour of car driving. It will make it possible to keep pursuing car-centric spatial planning, with more urban sprawl and kilometres travelled, more parking space, and less green space or spaces for social interaction.

EVs require charging infrastructure, either private or shared, and either at home, work, or other locations. **Parking** and charging of EVs in the public domain create new issues not encountered before with ICEVs. About 55% of BEV drivers in our sample of 32 reports having had trouble finding an available charger, while 74% think that there should be more chargers, confirming what was mentioned before about the need to quickly install more chargers at more locations. Owners of EVs without the possibility to charge on their private terrain have to make use of shared chargers elsewhere, but some owners use an electrical cable from their home and divert this cable over the footpath to their car. For now, local regulations usually prohibit this, but in practice, drivers are not fined in most Belgian cities. Another phenomenon causing problems at public chargers is EVs that occupy a parking spot when their battery is fully loaded, or fossil fuel cars that occupy the parking spot. 74% of the questioned BEV drivers report having seen fully charged EVs or ICEVs occupying shared chargers. In some Belgian cities parking while charging is free of cost, even if the parking spot is located in a parking zone with paid parking. However, keeping the EV at the parking spot longer than necessary, can be an offence. For example in Brussels, an EV needs to be moved within 15 minutes when the vehicle is fully charged (during daytime hours); in 2021 359 fines were issued by *parking.brussels* for this offence. Today establishing these offences is rather difficult. In the future this should become easier: fossil fuel cars parked in a parking spot for charging could be automatically detected with data from the *DIV* database, and image recognition software would be able to detect whether a cable is connected from a vehicle to a charger.

Scenarios

A growing car fleet means more space is needed and facilitates car-centric spatial planning. Car sharing may reduce the total number of vehicles and also the space needed, and reduce emissions during production. Charging EVs in the public domain brings extra challenges that will need to be tackled. The transition to fully automated vehicles may be important in the further future: this trend possibly results in cars driving empty to pick up someone or something, resulting in more kilometres driven – with EVs these trips are somewhat cleaner, however, the additional miles may nullify the initial environmental gains.

[8] Francqui Chair for Tim Schwanen, Lecture 6: Electrification and automation, https://www.youtube.com/watch?v=nOSFuLXFuEA

6 Policy recommendations

6.1 Introduction

The most important policy conclusions, recommendations, and supporting measures are discussed in this section. They are based on the findings presented in the current report, combined with expert input and an analysis of the key measures already present in current policy plans. This is a non-exhaustive list; in transition processes, new issues may arise along the way.

6.2 Policy recommendations

6.2.1 Lessons from an international benchmark

- Norway is identified as a frontrunner in the electrification of the fleet. What can we learn from Norway and other leading countries (Sweden, the Netherlands)?
    - A combination of several measures was taken in these countries to support the electrification of the fleet: fiscal measures towards individual drivers and companies, but also the supply of sufficient public charging infrastructure, and offering other financial and non-financial benefits to EV drivers (e.g. free parking, free use of ferries, EVs can use bus lanes, no road toll).
    - A taxation radically in favour of BEVs: In Norway, taxes are based on emissions and vehicle weight (EVs are exempted from the weight-tax, and very beneficial for low-emission vehicles); BEVs do not pay value added tax (VAT). Both Norway and the Netherlands have a high tax differential between vehicles with respect to emissions.
    - The electricity price in Scandinavia is/was rather low (with their own gas and renewable energy), resulting in a TCO that is quickly lower for EVs than for fossil fuel cars.
    - Leading countries all have high GDPs – a population having a higher purchasing power facilitates the transition towards more expensive EVs (at least when considering the purchase price).
    - Leading countries historically invest large amounts in sustainable innovation. We see that this pays off when transitioning to new technologies.
- All countries studied currently have financial measures in place that support EV sales. Incentivizing the sale of EVs can happen in a budget-neutral way, e.g. through a feebate system or by cutting the tax reductions on petrol prices (making the TCO of fossil fuel cars less attractive).
- Subsidies or fiscal benefits for PHEVs or BEVs are being cut back in many countries, including Belgium. Abruptly phasing out BEV subsidies or tax incentives creates a run before a certain financial advantage is removed, and a sudden drop in EV sales disrupts the market (e.g. in the Netherlands) which is unwanted.
- Some countries, such as Belgium, rely more on the business fleet to drive change – which is promising because the lifetime of those vehicles is shorter and therefore the transition can be faster. After their first use, company cars are sold on the second-hand market providing more private buyers with the opportunity to buy a cheaper second-hand EV sooner. The Netherlands now provide a premium to individual customers to buy second-hand EVs – mainly to keep second-hand EVs in their own country rather than exporting those vehicles abroad. Countries such as Norway traditionally have a smaller business fleet and still are a frontrunner in electrification, having more financial incentives for the private fleet instead of financially supporting the already wealthier group with company cars.

6.2.2 Lessons from a survey of Belgian car drivers

- Lack of knowledge (TCO, energy management, charging infrastructure, open protocols, …) among private users, businesses (both supply and demand) and (local) governments. This could be mitigated by launching / supporting communication campaigns on the topic of e-mobility (private users), and through learning programmes with training courses (business and government users).

- Many drivers are in doubt about which car/powertrain to buy next. A long-term vision with clear policy plans would help customers to make the right choice for themselves and society. In this light, the decision of the European Union to phase-out of ICE cars in 2035 is crucial to provide certainty to investors, decision-makers and civil society.
- A high percentage of private customers intends to buy a PHEV as their next vehicle: this is contradictory to the high TCO of these vehicles. It is likely that customers are unaware of the total price and choose a PHEV for the wrong reasons.

- Awareness raising: in general, the government may play an important role to inform private consumers about e-mobility and charging infrastructure, based on their home/work situation (charging at home, in an apartment, public, ...) and region (Flanders, Wallonia, Brussels) or city.
  - The most important barriers to switching to BEVs are (purchase) price, uncertainty about the range, and availability of charging infrastructure. Communication will have the biggest impact when focusing on these topics.
- For the majority of drivers, financial measures lowering the purchase price are necessary to convince them to switch to EVs for their next vehicle.
  - For some buyers, their budget does not allow them to buy a BEV. The second-hand market currently does not match their needs.
- Organising a national annual survey of EV drivers to study trends and changes in attitudes. This type of survey is held in the Netherlands and also in Scandinavia. The federation EV Belgium[9] could be an entry point when aiming for such a survey.

6.2.3 Recommendations on charging

- Public charging:
  - The deployment of public (AC) normal chargers is very different per region:
    - In Brussels and Flanders, the public normal (AC) charging infrastructure has stabilized in the last year. The Flemish and Brussels regions and the cities of Antwerp and Ghent have now taken action to accelerate the deployment by launching concession assignments in their respective regions.
    - In Wallonia however, a clear policy plan with budgets and staffing has yet to be published. It's very important to have public infrastructure, especially in the bigger cities, to enable citizens without a driveway to drive with an EV.
  - The deployment of public (DC) fast chargers is very different per region:
    - On-street public fast (DC) charging infrastructure is being deployed, based on public tenders in Flanders.
    - The Brussels Capitol Region is currently validating a delivery plan for charging infrastructure, with multiple measures to deploy fast chargers. The measures are mainly focused on realizing fast chargers in the private domain.
    - Wallonia has been lagging behind. There are some public fast chargers in the private domain (gas stations, retail locations), but there is no public information that affirms the deployment of public fast chargers at highways or other key public locations.
- There is a risk of scarcity of charging infrastructure. This can be caused by a lack of local policy measures or a lack of materials or skilled staff. This should be monitored continuously. One possible avenue is to define minimum charging standards of the 'right to plug'. Specific education programs should be offered to train technical staff.

[9] EV Belgium is the representative federation dedicated to developing the zero emission mobility market in Belgium. The EV sector is represented, but also EV drivers.

- Consumer rights and lack of price transparency: due to the dual role of the e-mobility service provider and the charge point operator, differentiated pricing structures (energy tariff, rotation tariff, time tariff, …) and time-of-use incentives, it's difficult to provide transparency on charging costs for the end consumer. In theory, the service provider should inform the driver of the tariff per station. Therefore, there's a clear need of:
    - A framework that allows transparency on charging tariffs and defines the responsibilities of certain players in the market.
    - Clarity on payback mechanisms of charging sessions at home by the employer.
    - Monitoring of the correct price and pricing format by an independent watch dog/regulator.
- Lack of sufficient payment methods: Development of the European Alternative Fuels Infrastructure Regulation.
- Generic road signs of fast chargers at highway exits ("wegcode / code de la route").
- Trustees and associations of co-owners of apartment buildings play an important role in enabling the deployment of charging infrastructure in these apartment buildings and shared (business) parking spaces.
- Charging one or two EVs at a home location requires a higher power capacity. With the capacity tariff in Flanders in mind, it's important to guide citizens in smart charging their cars and supporting them with the necessary smart energy/building management systems, to lower the total electricity (distribution net) cost.

6.2.4 Lessons from the total cost of ownership calculations & the deployment scenarios

- The TCO of many cars is already lower for several car segments. However, a private buyer needs to be able to pay the upfront cost. A feebate system can support the private buyer in the short run (if the measure can be implemented quickly within 2 years), but later it will not be necessary anymore (the purchase price of BEV is as low or lower as for ICEV).
    - The TCO for BEVs is still higher for smaller cars. A measure that could support lower-income households and increase the share of smaller light-weight cars (beneficial for traffic safety, emissions, etc. but in contradiction with the current trend), is lowering the TCO for car segments A, B and C, for example through a subsidy or a feebate system.
    - Financial support for BEVs (possibly combined with making fossil fuel cars more expensive) should be a temporary measure that could accelerate the transition to an electric fleet.
- Differences in TCO between regions are small because taxes are only a minor part of the TCO, often in contrast to taxes in other countries.
- A first measure to support environmentally friendly behaviour is often to intervene on the price of a product: a choice that is beneficial for the environment will be cheaper, and the more polluting option gets more expensive. An alternative approach is not to focus on inflows such as new vehicle sales but to focus on outflows – in this case, vehicle retirements (Keith et al., 2019). Policies such as a car-scrapping bonus will encourage the replacement of the most polluting vehicles from the fleet.
- In the EV deployment scenarios (Chapter 4) we assumed an unlimited supply of EVs. However, quotas limit the supply of EVs to a country. Furthermore, the current delays in the delivery of EVs might hamper the transition to a fully electric fleet. Managing the supply of EVs to Belgium will be critical to be able to respond to the growing demand and stay on an ambitious path for the electrification of the car fleet.

6.2.5 Recommendations on the impacts of BEVs

- Life cycle CO_2 assessment:
  - An electricity mix with more renewable energy will lower the lifecycle CO_2 emissions of EVs.
  - Improving the lifecycle CO_2 emissions of the battery:
    - Production: Moving battery production to Europe will have a positive impact on the life cycle CO_2 emissions of EVs.
    - First-life: batteries last longer than first expected (more charging cycles, enabling up to 300,000 or even 500,000 kilometres per vehicle). These charging cycles can also be used for home applications or the storage of energy. There is a need, though, for more research and pilot projects in the field of Vehicle-to-grid and Vehicle-to-home technologies.
    - Second-life (after its life in a vehicle): reuse: energy storage in buildings.
    - End-of-life: recycling: companies are innovating to get as many raw and rare materials out of the battery again.
    - At the end-of-life of an EV, a battery should preferably be reused, instead of immediately recycled. Using it for other applications during its useful life improves the life cycle CO_2 emissions.
  - Measures to improve CO_2 emissions sometimes worsen the TCO – this should be avoided.
  - BEVs emit less CO_2 over their lifetime than ICEVs, generally speaking about half as much. However, if we aim to cut GHG emissions by more than 50% replacing ICEVs with BEVs will not be enough. Driving less will be essential to have a bigger impact on climate change.
  - To quickly reduce car emissions in attendance of the whole fleet to refresh, e-fuels might be a viable, but transitory, alternative. More research and investment is necessary, however, to further improve e-fuels and to monitor sustainability of this alternative in car fleets.
  - The Avoid-Shift-Improve principle should be pursued: avoiding trips, shifting to more sustainable modes, and improving fuel efficiency (e.g. shift from ICEV to BEV).
- Air pollution and noise: largely positive impact of BEVs expected. Non-exhaust emissions become more important and need to be regulated (Euro 7 limits).
- The impact on traffic safety needs to be watched as evidence appears. The weight of BEVs and the lack of noise are issues of concern.
- Fire safety: Currently each fire department zone has its policy concerning the fire safety of BEVs (after a crash, while charging, or in parking garages). This leads to uncertainty and a variety of rules that prevents a standardized large-scale roll-out. It's therefore recommended that a federal framework is determined and communicated that defines clear and generic safety regulations regarding charging BEVs, including:
  - A correct assessment of the risk of battery thermal runaway;
  - Guidelines/regulations regarding the floors in parking buildings on which EVs can be charged;
  - Guidelines/regulations regarding general safety measures in parking garages.
- Impact on congestion: need to check and make sure that ownership and/or use of BEVs will not increase otherwise this will worsen the congestion problem: needs to be monitored.
- Fairness and equality: need to make sure poorer people do not lose critical access to destinations; Monitor gender and geographical inequalities; the second-hand market will develop and play an important role in the just transition to a zero-emission fleet.
- Emerging trends in the mobility system: the emerging concepts 'automation' and 'shared mobility' should be tackled together with the electrification. For example, parking pressure in public spaces in densely populated cities can be mitigated by stimulating shared mobility, active and public transport.
  - A concrete measure could be to lower the TCO for shared vehicles, for example through a subsidy, lower taxes or other financial benefits.

Glossary

BEV	Battery Electric Vehicle
CO_2	Carbon dioxide
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse gases
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
LCA	Life Cycle Assessment
LEZ	Low Emission Zone
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
SUV	Sports Utility Vehicle
TCO	Total cost of ownership
WLTP	Worldwide Harmonized Light Vehicles Test Procedure

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Attachments

Attachment 1: Life cycle analysis of a BEV: Selected vehicles per car segment and their technical specifications

Segment A (city)	Fiat 500 Berlina	Fiat 500 1.2 Lounge	Fiat 500 1.3 Mjet
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	12.7	4.9	3.4
WLTP emission [g CO_2 eq/km]	0	115	89
Mass [kg]	1255	980	1020
Battery mass [kg]	182	/	/
Battery capacity [kWh]	23.8	/	/
Lifetime mileage [km]	135,000	135,000	135,000

Segment B (small)	Peugeot e-208	Volkswagen Polo 1.0 TSI	Volkswagen Polo 1.6 TDI
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	16.4	4.6	3.9
WLTP emission [g CO_2 eq/km]	0	105	103
Mass [kg]	1530	1045	1280
Battery mass [kg]	256	/	/
Battery capacity [kWh]	50	/	/
Lifetime mileage [km]	135,000	135,000	135,000

Segment C (compact)	Volkswagen ID.3 1ST	Volkswagen Golf VII 1.0 TSI	Volkswagen Golf VII 1.6 TDI
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	15.5	4.8	3.9
WLTP emission [g CO_2 eq/km]	0	108	102
Mass [kg]	1772	1141	1317
Battery mass [kg]	219	/	/
Battery capacity [kWh]	58	/	/
Lifetime mileage [km]	135,000	135,000	135,000

Segment D (mid-size)	Tesla Model 3 Standard Range Plus	Audi A4 Avant 2.0 TFSI	Audi A4 Avant 2.0 TDI
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	14.2	5.6	4.3
WLTP emission [g CO_2 eq/km]	0	127	112
Mass [kg]	1825	1480	1540
Battery mass [kg]	323	/	/
Battery capacity [kWh]	50	/	/
Lifetime mileage [km]	135,000	135,000	135,000

SUV-B (subcompact crossover)	Hyundai Kona Electric	Peugeot 2008 1.2 Puretech	Peugeot 2008 1.5 BlueHDi
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	14.7	5.7	4.2
WLTP emission [g CO_2 eq/km]	0	131	110
Mass [kg]	1760	1190	1205
Battery mass [kg]	346	/	/
Battery capacity [kWh]	64	/	/
Lifetime mileage [km]	135,000	135,000	135,000

SUV-C (compact crossover)	Volkswagen ID.4 1ST	Volkswagen Tiguan 1.4 TSI	Volkswagen Tiguan 2.0 TDI
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	18.2	6.8	4.8
WLTP emission [g CO_2 eq/km]	0	153	126
Mass [kg]	2049	1490	1568
Battery mass [kg]	493	/	/
Battery capacity [kWh]	77	/	/
Lifetime mileage [km]	135,000	135,000	135,000

SUV-D (large crossover)	Tesla Model Y	Peugeot 5008 1.2 PureTech	Peugeot 5008 1.5 BlueHDi
Vehicle type	BEV	ICEV	ICEV
Storage energy type	Lithium-ion	Petrol	Diesel
WLTP consumption [kWh/100km or l/100km]	14.1	5.1	4.0
WLTP emission [g CO_2 eq/km]	0	116	105
Mass [kg]	2003	1430	1490
Battery mass [kg]	530	/	/
Battery capacity [kWh]	75	/	/
Lifetime mileage [km]	135,000	135,000	135,000

Attachment 2: State-of-the-art in European countries

Detailed country report for:

1. The Netherlands
2. United Kingdom
3. Norway
4. Sweden
5. France
6. Germany

1 The Netherlands

1.1 State-of-the-art and evolution

1.1.1 Current fleet

In the Netherlands in 2021, 19.9% of the total car sales were BEVs, and another 9.6% were PHEVs. The figure below shows the monthly market share of EVs as a percentage of all new sales of passenger cars. There are large deviations between months in BEV sales with four noticeable peaks. These peaks are observed in the last month before an increase in the 'benefit in kind' taxation (company cars). Further, there is a higher number of BEV registrations in the last month of the quarter: this is due to the arrival dates of boats carrying new models. The effect of the purchase subsidies for consumers (from July 2020) is hard to distinguish from this graph.

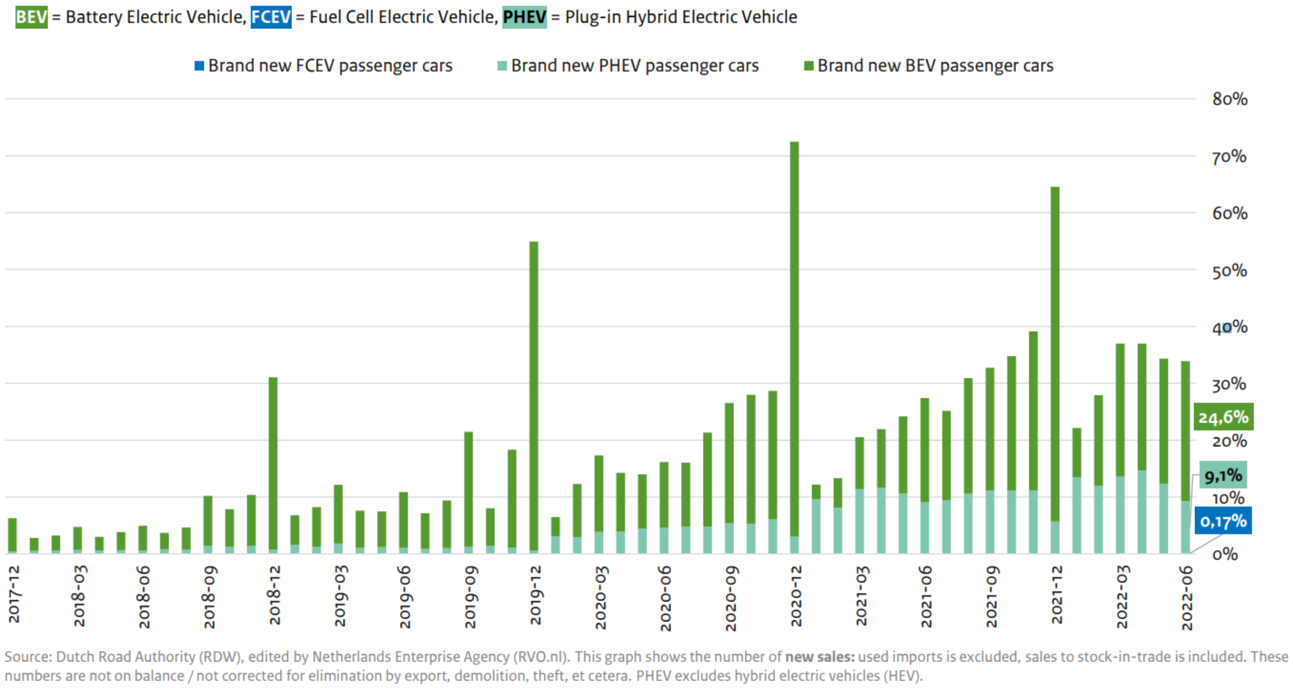


Figure 57 Evolution of EVs registrations per month
Source: RVO, June 2022 (https://www.rvo.nl/onderwerpen/elektrisch-rijden/cijfers)

1.1.2 Deployment strategies and targets

The Netherlands aims for 100% zero-emission car sales by 2030 (=~1.9 million private cars) and a 100% zero-emission fleet in 2050. Phasing out the tax incentive for zero-emission cars will be in line with this ambition. After all, a new car in the Netherlands has an average life of almost 18 years. And the preconditions have to be right: charging your electric car has to be as easy as charging your mobile phone. This also applies to hydrogen. For the existing vehicle fleet (including logistics), the government is committed to reducing emissions through innovative biofuels. To achieve this renewable energy target for transport, no more additional biofuels from food and feed crops will be used in the Netherlands than the 2020 level.

All measures are constantly evaluated to prevent over-subsidy of EVs ('hand aan de kraan' beleid): the incentive instruments are calibrated annually to keep the 'hand on the tap' and prevent over-stimulation (see here in the appendix p24-25 for detailed description). The size of the adjustment depends on the size of the deviation, which means that if there is a large overrun, there is a large adjustment and if the overrun is small, there is a small adjustment in the tariffs. This adjustment applies both upwards and downwards. In 2024-2025 there will be an integral evaluation of the climate policy and measures in the mobility domain may be adjusted to reach the 2030 goals. For none of the incentives in place, there is a plan for after 2025.

Climate goals (all sectors): 49% emission reduction (CO_2) by 2030; 95% by 2050 (base year 1990). Electric driving contributes to the Dutch climate goals. The advantage of electric driving will be even greater if green electricity becomes more available in the coming years.

In summary, the following goals for the transport sector were defined:

Ambition	
2020	10% of all new passenger cars sold will have an electric powertrain and a plug[1].
2025	50% of all new passenger cars sold will have an electric powertrain and a plug. At least 30% of these vehicles (15% of the total) will be zero emission (BEV or FCEV)[1].
2030	100% of all new passenger cars sold will be zero emission[2].

1.1.3 Charging infrastructure development, plans and strategies

The *Nationale Agenda Laadinfrastructuur* ('national charging infrastructure agenda') is a long-term policy agenda (up to 2030) with ambitions and actions that will ensure that we will soon be able to charge anywhere, anytime, easily and smartly. Many of the agreements and actions will be implemented locally and regionally. The market, the government and network management cooperate closely and support municipalities and regions in realizing a charging network and energy system that covers the entire country, is reliable and future-proof.

In 2014, The National Charging Infrastructure Knowledge Platform (NKL) was formed[10]. This independent, not-for-profit organization/alliance took up the development of the Open Charge Point Interface protocol (OCPI), and is dedicated to the rapid expansion of a cost-effective and futureproof charging network for EVs. The national charging infrastructure agenda, part of the Climate Agreement, is leading for many of the activities. NKL develops and leads research projects to make public charging more accessible.

Because of these early and coordinated actions, the Netherlands now has the highest density of public charging points in the world. The table below shows the total amount of charging points for electric vehicles.

Table 26 EV charging infrastructure in the Netherlands up to June 2022

Number of charging points at the end of	2017	2018	2019	2020	2021	june 2022
Regular public + semi-public	**32,875**	**35,861**	**49,520**	**63,586**	**82,876**	**96,473**
Regular public (24/7 publicly accessible)	15,288	20,228	27,773	39,968	51,423	60,354
Regular semi-public (limited publicly accessible)	17,587	15,633	21,747	23,618	31,453	36,119
Fast charging points, public + semi-public	**755**	**1,116**	**1,262**	**2,027**	**2,577**	**3,145**
- of which >100 kW			433	897	1,307	1,644
Fast charging locations	178	197	339	467	629	730
All regular + fast charging points	**33,630**	**36,977**	**50,772**	**65,613**	**85,453**	**99,618**
Number of plug-in passenger car (BEV + PHEV) per charging point	**3.5**	**3.7**	**3.9**	**4.2**	**4.5**	**4.5**
Private charging points[1]	~68,000	~80,000	~114,000	~158,000	~221,000	~259,000

Source: https://www.rvo.nl/onderwerpen/elektrisch-rijden/cijfers

A prognosis for the required charging infrastructure - calculated by APPM - shows that already from 2025 almost 550 charging points per working day will need to be installed. The assumption is that the increased charging volume will be divided between fast charge points and normal charge points according to a 15%-85% ratio. In 2030, a rate of over 1400 charge points per working day will even be needed to meet demand. For public charging stations (with two charging points per bollard) this means, for example, that approximately 217 public charging points per working day will have to be installed in 2030.

[10] IEA*, EV City Casebook and Policy Guide*, 2021 Edition

1.2 Financial instruments

1.2.1 Financial incentives to purchase EV

- In 2020, a purchase subsidy of €4000 for private citizens was announced.[11] The budget available for funding this subsidy turned out to be insufficient Funds originally earmarked for 2021 were used in 2020. This meant that only a bit more than 1 million of the originally 14.4 million was available in 2021. The subsidy budget for 2021 was emptied within four days. From 3rd January 2022 9:00 AM drivers can apply for a subsidy again (€3350 for a new EV; €2000 for a second-hand car). The subsidy program runs from July 1 2020 to July 1 2025. There was an intermediate evaluation of the SEPP (subsidy for private electric vehicles; the total amount of subsidy per year is capped, the available budget for 2020 and 2021 was quickly reached and no more subsidies were given in that year).[12]
- In the Netherlands, the business market is incentivized more than the private market. The 2020 introduced incentive would correct this difference, however, the available budget was very low (relatively and absolute).
- Company cars: subsidy of up to €5000 (or 10% of net purchase price). This subsidy program runs from March 15 2021 to December 31 2025. There is a total annual maximum for the government.
- Generally, governments in all countries aim to remove the benefits of BEVs over petrol cars when the market completely moved to zero-emission mobility, or when ICEVs are banned. Countries that are ahead in the BEV uptake, like Norway, can remove incentives for BEVs sooner than countries with lower uptake of BEVs. Despite having a policy of adjusting as we go, the Netherlands is particularly rapid in dialling back the incentives, e g in the case of BiK.

1.2.2 Financial incentives and deterrents to drive the shift from combustion engines

Several cities announced zero-emission zones (except for urban logistics). From 1 January 2025, at least 30 cities must have established a zero-emission zone, as agreed in the Climate Agreement. From that date onwards, all new lorries and vans entering a zero-emission zone must be emission-free. From 2030 onwards, all vehicles in the zero-emission zones must be completely emission-free. Currently, only older private cars on diesel cannot enter city centres with an environmental zone. Amsterdam has the ambition to ban all emitting cars/vehicles from the built-up area from 2030 onward (petrol, diesel, LPG).

1.2.3 Taxation model for cars (private fleet)

Registration Tax for passenger cars is fully based on CO_2 emissions and the type of motor fuel used. For passenger cars, the registration tax is progressive and varies between €356 and €458 per g/km exceeding the level of 1 g/km. Passenger cars using diesel are charged an additional €86.43 per g/km exceeding the level of 67 g/km. The registration tax for motorcycles and delivery vans is based on the value of the vehicle. Zero-emission vehicles are exempted from the registration tax.

Annual Motor Vehicle Tax is based on the dry weight and the fuel type used. A provincial surtax is applicable. The tax also varies according to emission norms - euro class (diesel category). Vehicles with a CO_2 emission of 0 are exempt. Low-emissions vehicles (CO_2 is not exceeding a level of 50 g/km) pay 50% of the taxes.

1.3 Measuring the effectiveness of the policy

- Website from the national government with recent statistics on EVs: a monthly overview of the number of EVs and charging points in the Netherlands.
- Report from the government (RVO Rijksdienst voor Ondernemend Nederland): Electric Driving on (the) road - Vehicles and charging stations - Overview up to 2020: with numbers on the total fleet (by fuel type), also speed pedelecs, buses, motorbikes, car sharing vehicles, etc. Numbers over time (from 2012). Including the most popular brands and models.

[11] FIER Automotive Mobility, *Dutch EV policy in an international perspective - executive summary,* June 2021

[12] Dutch Infrastructure Ministry, Tussentijdse evaluatie SEPP Subsidieregeling Elektrische Personenauto's Particulieren, 2021

- User information regulation for charging stations: As of 1 July 2021, charging station operators are required to share current information about, among other things, the location, occupancy status and the charging price of publicly accessible charging stations in the Netherlands with users via the National Access Point Web Portal. From 1 January 2022, additional information will be added about the power supplier, the power product supplied, the percentage of sustainably generated power and opening hours.
- Monitoring of charging infrastructure: definitions and methods (link), monthly numbers per province (link), type of chargers
- 2 annual national surveys on EVs: (supported by a.o. RVO)
    - 'National EV and driver survey 2021': 2600 current drivers of EVs, a survey by VER (Society for electric drivers), RVO and Rijksuniversiteit Groningen: Who exactly are these EV drivers? Why do they drive an electric car, what did they drive before they bought an EV and which political party do they vote for, for example? Annual survey (2020 was the first edition and serves as a baseline).
    - Charging EVs in the Netherlands: Experiences and opinions of EV drivers (survey from 2021) à annual survey (2021 was the second edition) asks about the charging behaviour of current EV drivers (~1500 drivers)
- Electric driving monitor: public opinion survey by ANWB (2017, 2018, 2019, 2020)
- www.nederlandelektrisch.nl: organized by communication departments from different companies that are in the Formule E-Team (FET). One output is a map of all public charging stations in the Netherlands, the number of registered EVs, etc. Website aimed at the general public.

For the collection of the data, two main bodies are responsible: (1) The Netherlands Government Service for Entrepreneurship (RVO) - an agency of the Dutch Ministry of Economic Affairs and Climate Change and the Ministry of Agriculture, Nature and Food Quality; (2) The Formule E-Team (FET) - a public-private partnership between industry, knowledge institutions and governments and has a wide variety of members.

The FET has been set up by the national government to: (1) advise the State Secretary of the Ministry of Infrastructure and Water Management on the implementation of policy on electric transport; (2) promote electric transport, including knowledge development, knowledge sharing, information provision, and promoting the roll-out of electric transport, vehicles, charging infrastructure and integration in the electricity grid; and (3) promote green growth and export of both products and services related to electric transport. FET members work to promote electric transport, including the agreements on electric transport made in the Climate Agreement.

2 United Kingdom

2.1 State-of-the-art and evolution

2.1.1 Current fleet

Until 2019, the UK had the second-largest European stock of light-duty plug-in vehicles in use after Norway. However, EV sales in the UK still represent a small proportion of new vehicle sales each month, but growth continues to accelerate. In August 2021, battery electric vehicles (BEVs) had a 10.9% share of the UK market, with plug-in hybrids at 7.4%, diesel at 7.5% (-65% compared to 2020) and petrol at 43.3%. Hybrid vehicles, including mild, plug-in and full hybrids, accounted for a combined 38.4% In the first eight months of 2021, fully-electric vehicles accounted for 8.4% of new sales (+106.7% compared to the same period of 2020).

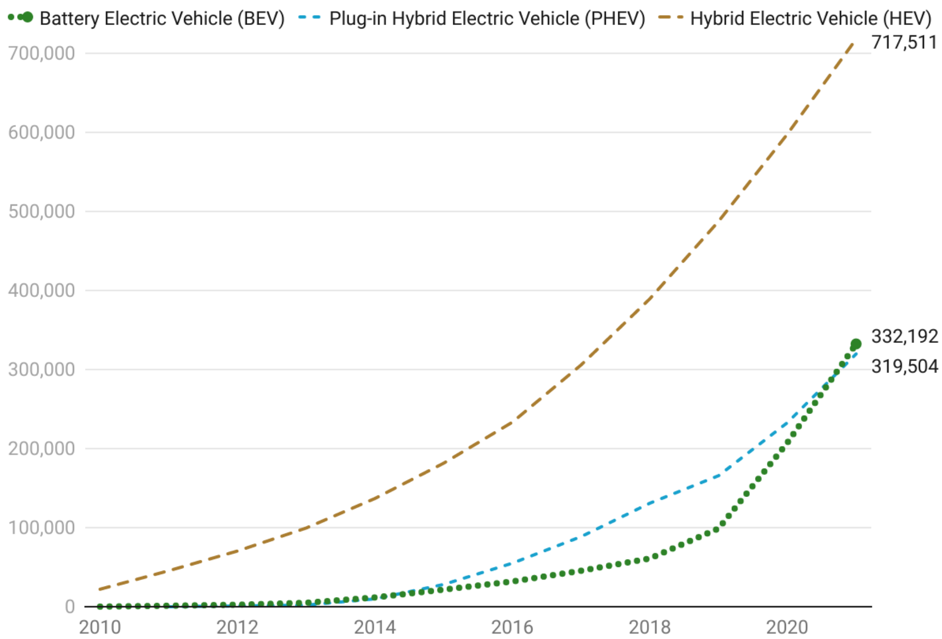


Figure 58 Total number of electric cars in the UK
Source: SMMT via RAC

The number of electric vehicles as a proportion of all new vehicles showed a significant increase in 2020. In 2015 just 1.1% of new vehicles registered had a plug compared to 3.2% in 2019; by the end of December, this figure had accelerated to 10.7%. In 2020 the average for the year was 6.6% BEV and 4.1% PHEV. These numbers reflect both the increase in demand for EVs and the decline in demand for traditional, particularly diesel, vehicles.

Currently, there are more than 330,000 BEVs on the UK's roads - with more than 125,000 registered so far in 2021 alone - along with 320,000 plug-in hybrids and over 700,000 conventional hybrids.

2.1.2 Deployment strategies and targets

The UK government has announced in November 2020 a ban on the sale of new diesel/petrol cars and vans by 2030, and to ban the sale of new hybrid vehicles by 2035. From then onwards, new cars and vans sold in the UK must be fully electric. Regarding hybrids, only those with significant emissions reduction can remain on the market although the exact values for that have not been defined yet. From 2040 heavy-duty trucks will be only electric.

2.1.3 Charging infrastructure development, plans and strategies

Recently we observed a dramatic increase in the number of public EV charging points in the UK. Between the end of 2016 and 2020, there was an increase of 220% in the number of public chargers. In January 2021, there were 20,775 public electric vehicle charging devices available in the UK. Of these, 3880 were rapid chargers. Rapid charging devices have grown quickly, increasing by 37% in the last year. The growth has been noticeable in slow chargers as well, as local authorities install on-street charging options to enable EV purchases for people without access to off-street parking. The Government's ambition is to ensure people are never more than 25 miles from an ultra-rapid charger on UK motorways and A-Roads.

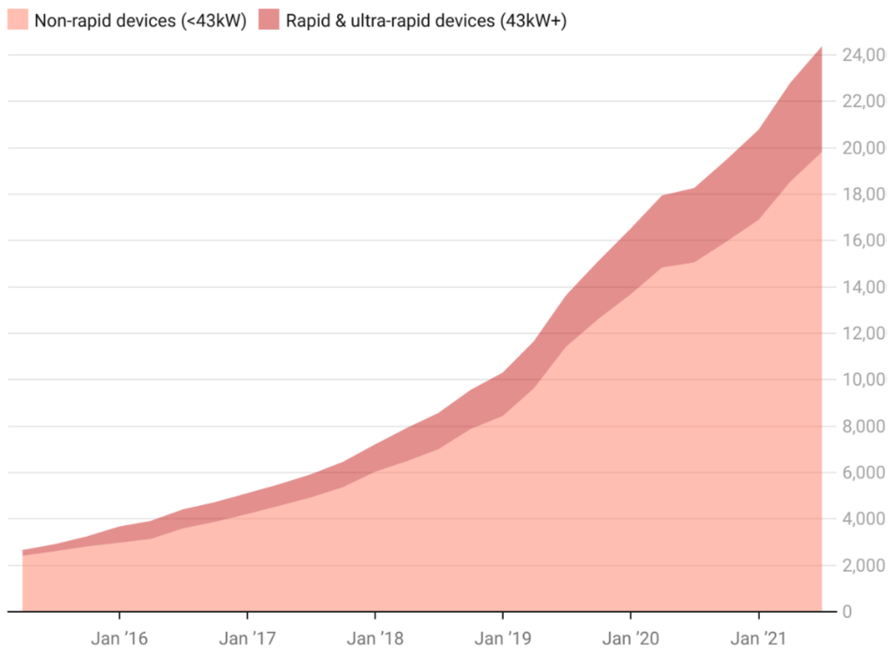


Figure 59 Number of public electric car charging devices
Source: RAC

England is investing also in new charging technologies. The National Innovation Agency has financed a trial of vehicle-to-grid chargers, or bi-directional chargers (they can send electricity two ways: to the car, or back to the grid). This will allow using the charger to charge the car when the electricity demand is low and then sell unused power back to the grid when demand is high.

HMT (*Her Majesty's Treasury*) launched the £400 million Charging Infrastructure Investment Fund (CIIF). The fund aims to catalyze and diversify investment in public charging infrastructure. It is subsidized by £200 million from the Government and this fund is to be match-funded by private investment. The first investment of £70 million is expected to result in a further 3000 new rapid charging points by 2024.

2.2 Financial instruments

2.2.1 Financial incentives to purchase EV

When announcing the proposed 2030 ban on internal combustion, the government said it will set aside £582 million for grants to help drivers switch to electric.

As of September 2021, a government grant of up to £2,500 is applied to the price of a new low-emission vehicle. More specifically, the grant will pay for 20% of the purchase price of the vehicle, up to a maximum of £2,500. This amount fell from £4,500 in early 2019. In March 2020 the available grant was reduced first to £3,500, then to £3,000. The discount is applied by the dealer, meaning the buyer should not do anything to secure the reduced price, and EVs are often advertised with the discount already in place. However, only cars with a list price under £35,000 and approved by the government are eligible for the grant, and to be considered for the full £2,500 they must be able to drive at least 70 miles on pure electric power (in previous years, the grant used to apply to cars costing under £50,000). Additionally, a grant of 20% up to a value of £1,500 is applied to electric motorcycles capable of travelling at least 31 miles on a charge, and to mopeds with a range of at least 19 miles. Small hybrid and electric vans capable of at least 60 miles of electric range, and which produce CO_2 emissions of less than 50g/km, receive a grant of 35% of the purchase price, max. £3,000. For taxis, the grant is up to £7,500 so long as they have a range of at least 70 miles and CO_2 emissions of less than 50g/km.

Currently, BEVs are exempt from Vehicle Excise Duty tax (VED) - '*Expensive car supplement*'. But from 2025 BEVs will no longer be exempt from vehicle excise duty.

EVs used to be fully exempt from company car tax. This increased to 1% in April 2021, and to 2% in April 2022. It is hoped this will encourage the use of EVs among company car fleets.

2.2.2 Financial incentives and deterrents to drive the shift from combustion engines

A purchase of a new diesel car that doesn't comply with RDE Act 2 (RDE2 / Euro 6d) requires paying a higher amount of car tax in the first year of ownership.[13] The extra taxes and surcharges for diesel vehicles include:

- Higher road tax and company car tax for diesel drivers
- Charges to drive in the centre of London
- Charges to drive in other city centres
- Parking surcharges for diesel cars
- Increased cost of parking permits for diesel owners
- Fines for driving on certain East London streets

CO2 emissions	First-year rate	First-year rate for diesel cars*	Standard rate** from second year onwards
0	£0	N/A	£0
1-50 g/km	£10	£25	£155
51-75 g/km	£25	£115	£155
76-90 g/km	£115	£140	£155
91-100 g/km	£140	£160	£155
101-110 g/km	£160	£180	£155
111-130 g/km	£180	£220	£155
131-150 g/km	£220	£555	£155
151-170 g/km	£555	£895	£155
171-190 g/km	£895	£1,345	£155
191-225 g/km	£1,345	£1,910	£155
226-255 g/km	£1,910	£2,245	£155
Over 255 g/km	£2,245	£2,245	£155

Figure 60 Vehicle tax rates for petrol and diesel cars, applicable from April 2021
source: https://www.gov.uk/browse/driving/vehicle-tax-mot-insurance

[13] RDE testing methodology from EU: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_18_3646

On the local level, in London, EVs and plug-in hybrids (PHEVs) are exempt from London's Congestion Charge scheme until 2025.

2.2.3 Taxation model for cars (private fleet)

Road tax, officially known as Vehicle Excise Duty (VED), is calculated based on the CO_2 tailpipe emissions of a vehicle, its list price and which year it was registered in. From VED exempted are pure BEVs. PHEVs pay reduced VED. Any vehicle (excluding BEVs) with a list price of £40,000 or above will incur an additional premium rate for 5 years (starting from the second time the vehicle is taxed). EVs will no longer be exempt from vehicle excise duty from 2025.

2.3 Measuring the effectiveness of the policy

The Office for Zero Emission Vehicles has been created as a part of Department for Transport and Department for Business, Energy & Industrial Strategy in order to facilitate the transition. However, at this moment, there is no initiative aiming at collecting the data related to the transition towards EV on the national level.

3 Norway

3.1 State-of-the-art and evolution

3.1.1 Current fleet

The Norwegian Automobile Federation reported that since 2021, vehicles without any type of electrification – battery electric vehicle, plug-in hybrid, hybrid – made up less than 10 percent of new car sales (4% petrol and 4% diesel). That's down from 17% from the previous year and ~50% compared to 2017.

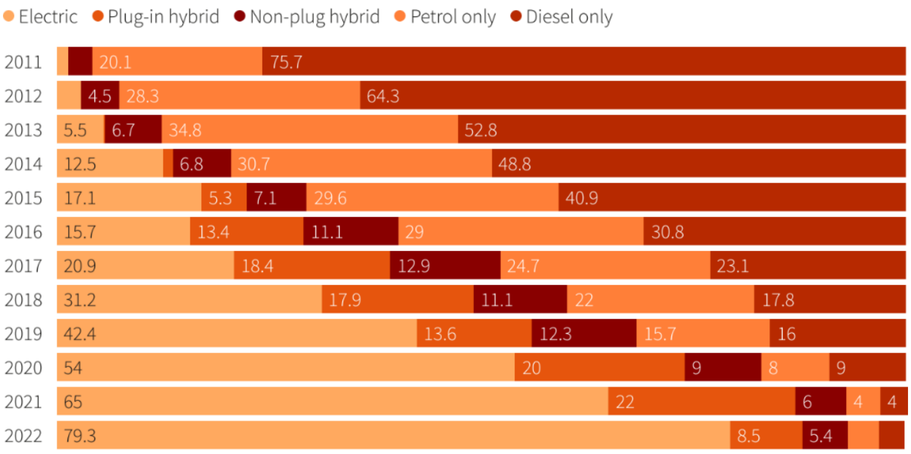


Figure 61 New car sales (market share per car type) in Norway per year (since 2011)
Source: Norwegian Road Federation (OFV)

Battery electric vehicles (BEVs) made up 54.3% of all new cars sold in Norway in 2020, a global record, up from 42.4% in 2019 and from a mere 1% of the overall market a decade ago, according to the Norwegian Road Federation (OFV). If we take into account also PHEVs, that number is 74%. In the first half of 2021, 57% of the newly purchased cars were BEVs. The numbers of conventional hybrids, as well as plug-in hybrids, are statistically small, with conventional hybrids accounting for less than 10% of new car sales. Until now, shares of 100% EVs continue to grow (79.3% in year 2022).

88% of cars in Norway are owned by households. Noteworthy, the majority of households that own electric cars also own conventional cars. Out of all households that owned EVs in 2018, just over one-third (37%) owned an electric car only, whereas 46% and 17% of households had also one or more conventional cars in addition to EV(s), respectively.[14]

3.1.2 Deployment strategies and targets

In 2012, there were fewer than 10,000 registered electric cars in Norway. Back then, the government set a goal to reach 50,000 zero-emission vehicles by 2018. This has been achieved within 3 years of the announcement (2015). In 2016, through its National Transport Plan 2018-2029 (NTP), the Norwegian Parliament decided on a national goal that all new cars sold by 2025 should be zero-emission (electric or hydrogen). However, an analysis from the Norwegian Automobile Federation shows that the last new petrol or diesel car sold in Norway will come earlier.

Additionally, by 2030, heavy-duty vans, 75% of new long-distance buses, and 50% of new trucks must be zero-emission vehicles, which has been announced in 2018 together with a requirement for all taxis set to be emission-free by 2023. A dedicated wireless charging system will help to support this goal.

[14] Camara et al., *Electric Vehicles, Tax incentives and Emissions: Evidence from Norway*, 2021

3.1.3 Charging infrastructure development, plans and strategies

Regulation on the requirements for EVSE (electric vehicle supply equipment) in new buildings and parking lots states that for all parking lots and parking areas of new buildings, a minimum amount of 6% has to be allocated to EVs (Norwegian Ministry of Transport, 2016).

Norway's first governmental support scheme for public charging infrastructure took place in 2009-2010. The support scheme was part of a fiscal stimulus package after the 2008 financial crisis and funded 100% of the installation cost for normal chargers (up to NOK 30 000 per charging point). The total support amounted to NOK 50 million and the scheme resulted in around 1800 so-called "*Schuko-points*" (household sockets). Many of these points can still be used, but several are also taken out of service due to high maintenance costs. The Schuko outlets have proven to be not ideally suited to long-term EV charging, and this is one of the inherent challenges when building out charging infrastructure before international standards are adopted.

In 2015 the state enterprise Enova introduced a support scheme to cover the Norwegian main roads with fast charging stations every 50 km (around 7500km road network). To reduce the risk of charging stations being out of order and reduce charging queues all locations must have at least two multi-standard fast chargers in addition to two 22 kW Type 2 points. The road network is split into several smaller segments, and operators were invited to compete for public funding. All the stations are owned and/or operated by private charging operators. The project was finished in 2017. Currently, some cities offer grant options for housing associations as a local incentive.

There are currently around 16,000 charging points in Norway, an increase from around 3,000 since 2011. This represents more than 9% of the total charging stations in Europe – all the more impressive given that Norway makes up only 0.7% of the total population of Europe.

On the consumer's side, Elbil (Norwegian Electric Cars Association) found that Norwegians are willing to pay a higher price for the service of fast charging - on average three times more than they pay for electricity at home. However, analysis of the number of BEVs per fast charger indicates that a high number of fast chargers per car is not a strong factor in explaining the differences in the BEV population between different regions of Norway.[15]

There are various charging schemes available for consumers. Different payment methods are offered, however, according to ELBIL, consumers complain about the complexity of the system. At the time when the network was developed, card payments were an expensive solution. The government has also not decided to use RFID payments as a default option. Few unified solutions have been proposed. Currently, energy company Fortum provides a *Charge and Drive* chip that allows charging at almost any charging station throughout the country. Members of ELBIL (approximately 100,000 EV drivers) have access to charging units all over the country at a reduced price. The nearest charging station can be found in their app or Electromaps EV charger map. The app can plan the journey in a way that accounts for the charging.

3.2 Financial instruments

3.2.1 Financial incentives to purchase EV

The incentives to purchase sustainable vehicles have been gradually introduced by different governments since the early 1990s. The current government has decided to keep the incentives for zero-emission cars until the end of 2021. After 2021 the incentives will be revised and adjusted in parallel with the market development. As indicated by ELBIL, the main objective of the Norwegian incentives scheme has been oriented on removing the price as a key barrier to purchasing EVs. An overview of current incentives and their evolution is provided below:

- **No purchase/import taxes** (1990-)
- **Exemption from 25% VAT on purchase** (2001-)
  The VAT exemption for zero-emission vehicles in Norway has been approved by the EFTA Surveillance Authority (ESA) until the end of 2022.
- **No annual road tax** (1996-2021).

[15] Lorentzen et al., *Charging infrastructure experiences in Norway - the worlds most advanced EV market*, 2017

Reduced road tax (2021-) the annual tax is levied as a tax on insurance with a fixed cost per day. Zero-emission vehicles were exempted up to 2020, but from 2021 a zero-emission vehicle owner will pay 30% less than ICEV owners.

- **40 % reduction of company car tax** (2018-).
  Between 2000 and 2018, the company car tax reduction was 50%. Depending on the production year, EV owners can now receive an additional discount on company car tax. Calculator of the company car's tax discount has been provided by authorities to estimate the amount of the discount. Additionally, in 2015 an exemption of 25% VAT on leasing has been granted.

3.2.2 Financial incentives and deterrents to drive the shift from combustion engines

Norway has a tax exemption on the purchase and usage of zero-emission cars, but also environmental taxes on polluting cars. This included a 25% VAT tax, a carbon tax close to 20%, and smaller amounts for weight tax, NOx tax, and a car scrapping fee. In 2018, financial compensation for the scrapping of a fossil van when converting to a zero-emission van was offered. Currently, there are no scrapping programs in place.

Other past and current incentives are:

- **No charges on toll roads, parking or ferries** (1997- 2017)
  Until 2017, EV owners were exempt from charges for toll roads and eligible for free parking. Since 2018, a maximum reduction of 50% of the total amount on ferry fares for EVs. 50% rule - which means that municipalities cannot charge more than 50% of the price for fossil fuel cars on ferries, public parking and toll roads. The height of the fee is now a municipal competence.
- **Access to bus lanes** (2005-)
  New rules were introduced in 2016 to allow local authorities to limit access to bus lanes only for EVs that carry one or more passengers.

3.2.3 Taxation model for cars (private fleet)

The purchase of a vehicle in Norway entails a one-off registration tax. You must also pay a registration transfer fee (for second-hand vehicles) or value-added tax (for new vehicles). If you buy a new vehicle from the dealer, the one-off registration tax, scrap deposit tax and VAT is included in the purchase price already.

The acquisition tax for all new cars is calculated by a combination of weight, CO_2 and NOx emissions. The tax is progressive, making big cars with high emissions very expensive. For the last few years, the purchase tax has been adjusted gradually to have more emphasis on emissions and less on weight.

Electricity-powered vehicles and fuel-cell cars are exempt from the registration tax. PHEVs benefit from a rebate from registration tax: 23% of the total weight is not included in the tax base. From 1 July 2018, the weight deduction is differentiated by electric range. To achieve full reduction, the electrical range must be at least 50km, vehicles with a shorter electrical range than 50km are entitled to a lower reduction (the type approved range divided by 50). "Flexifuel" vehicles (fuel with at least 85% ethanol) benefit from a rebate of NOK 10,000 per vehicle.

Until June 2013, PHEVs were not eligible for any tax reductions. In fact, due to the tax system that determines the level of the tax on the weight of the vehicle, PHEVs were more expensive than similar conventional cars due to the extra weight of the battery pack and its additional electric components.

The annual motor vehicle tax has been replaced in 2018 by a road traffic insurance tax collected by the insurance companies. If the vehicle has a permitted gross weight of 7500 kilos or more, the annual weight-based motor vehicle tax has to be paid additionally to the traffic insurance tax. This traffic insurance tax is paid daily. The rate for 2020 was as follows (NOK / day):

- Car under 7500 kg - 8.12
- Car under 7500 kg, diesel without factory-fitted particulate filter - 9.47
- Motorcycle - 5.65
- Vintage car, moped, tractor, taxi - 1.31

3.3 Measuring the effectiveness of the policy

The Electric Car Association (ELBIL) and Opinion carry out a large Nordic population survey "Electric car barometer". In 2021 it is the fourth time the survey has been conducted among a representative sample of the adult population of around 1000 people in each of the countries Norway, Sweden, Denmark, Finland and Iceland. Additionally, ELBIL is also conducting a large survey among EV drivers about their perception (approximately 15,000 drivers).

Cooperation between the governmental entity Enova and ELBIL resulted also in the development of an open, publicly owned database of charging stations that allows everyone to build services using standardized data free of charge. This has been instrumental in providing BEV users with up to date information about the charging infrastructure, and the data is being used by several in-car navigations systems in addition to charging maps and apps. It's been assessed that especially in an early market, this information is crucial for BEV owners.

4 Sweden

4.1 State-of-the-art and evolution

4.1.1 Current fleet

At the end of 2020, 122,977 PHEV and 55,734 BEV were on the road in Sweden. In 2020, EVs represented a 32.3% (see graph below) market share of new car sales which made Sweden the country with the highest car registration share among EU-27 member states. This increased popularity of EVs is expected to continue increasing over the next years.[16]

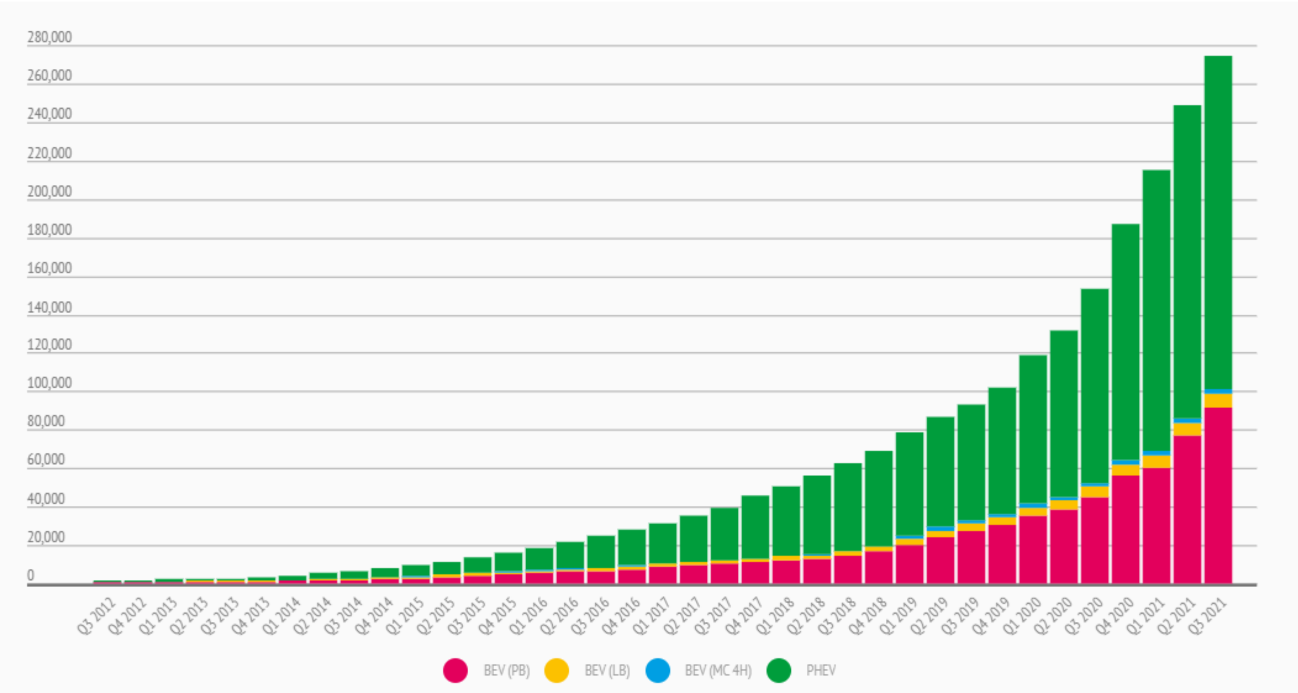


Figure 62 Number of registration of new vehicles in Sweden per type of engine propulsion
Source : Elbilsstatistik, Electric Vehicles market evolution in Sweden from 2012-2021

PHEVs is the segment that has seen the greatest gain in market share. This is mainly due to the phase-in of the 2021 EU target of 95 gCO_2/km and the policies implemented by the Swedish government. In March 2021, PHEVs share was 31.5% and BEV only 5.5% due to imminent policy changes that made the last chance for buyers to benefit from the strong incentive for PHEVs. In August 2021, for the first time, the share of BEVs is slightly ahead of PHEVs due to recent incentive adjustments.

4.1.2 Deployment strategies and targets

In 2018, the Swedish government has set a target of becoming carbon-neutral by 2045. Regarding the transport sector, it has to reduce its greenhouse gas emissions by 70% by 2030, compared to 2010. To achieve this, Sweden sets the target for phasing out all new sales of ICEV passenger cars in 2030 (only BEV and FCEV will be allowed). Furthermore, Sweden is a participant in the EV30@30 campaign that sets a collective goal for several countries to reach a 30% sales share of EVs by 2030. To do so, they introduced a bonus-malus scheme, created environmental zones for municipalities, and initiated a public fund for charging infrastructure deployment (both private and public).

[16] Swedish Transport Analysis, 2020 - Fordon i län och kommuner 2019

The government is aware that it will be difficult to replace all vehicles with electric ones thus they support also the development of bio-based fuels and invest in research and development of new technologies. To meet the climate reduction target, the Swedish government estimated that around 2.5 million EVs and PHEVs have to be on the roads by the end of the next decade. This would mean that one vehicle out of two will be electric.

4.1.3 Charging infrastructure development, plans and strategies

In October 2021, 14,051 public charging points were available in Sweden, of which 1529 are considered fast chargers. According to Elbilsstatistik, Sweden is rolling out charging infrastructure at an impressive pace. Annual growth of 36.5% was observed between October 2017 and October 2021. However, it is not comparable to the average annual growth of 62.1% of EVs. Private chargers are not included.

An appropriate metric for evaluating the number of charging points is the number of EVs per charging point. In October 2021, Sweden has 19.85 EVs per charging point which is higher than the recommended ratio of 10, while in 2015 this ratio was 8.3. The deployment of the charging infrastructure didn't follow the great EV uptake but it is important to note that in Sweden, 65% of EV owners have a home charger or a charging station at their workplace. Certain areas and major public roads still lack fast-charging stations. The government, therefore, appointed 15 million EUR for 2020-2022 to complete a nationwide fast-charging infrastructure network.

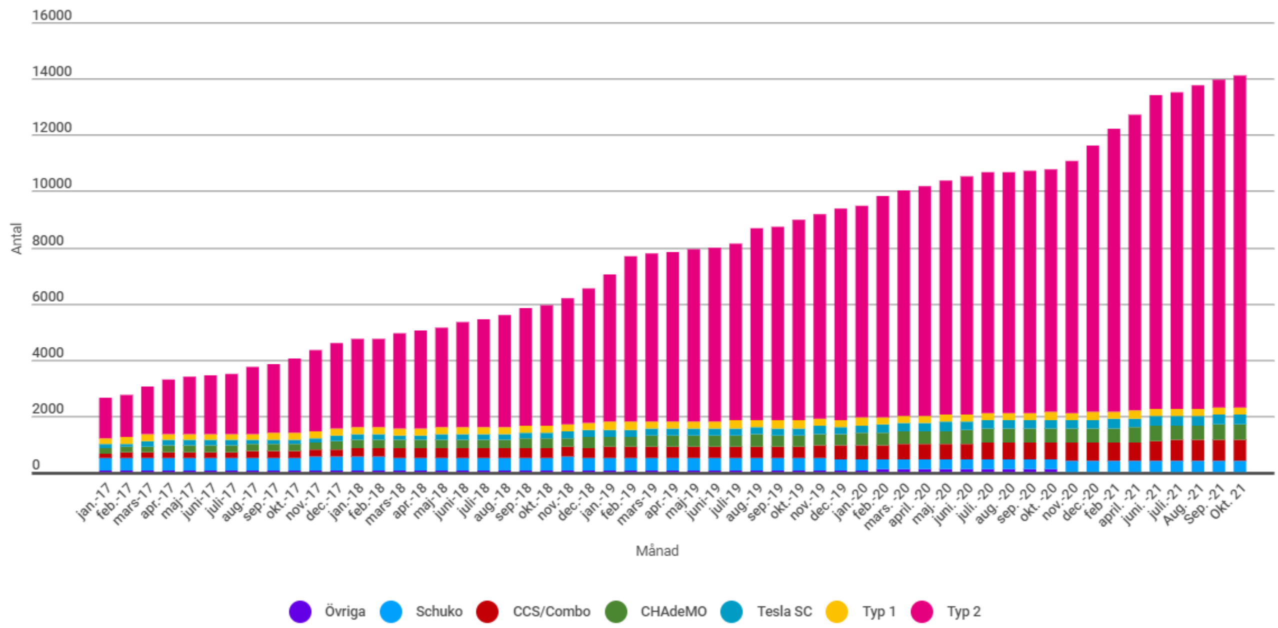


Figure 63 Public charging point evolution in Sweden from 2017 to 2021
Source: Elbilsstatistik

Sweden is a member of the EU-project GREAT (Green Regions with alternative fuel for transport) which aimed to facilitate long-distance trips by BEVs within Northern Europe. To this end, a corridor of new fast chargers has been installed allowing the connection between North Germany, Denmark and Sweden.

In Sweden, the first electrified road which allows driving and charging at the same time has been implemented. Their goal is to expand this electric road system (ERS) on major Swedish roads by deploying 2,000km of ERS on public roads by 2030.

4.2 Financial instruments

4.2.1 Financial incentives to purchase EV

Before July 2018, vehicles with zero emissions were exempted from vehicle tax for 5 years and were granted a 'super-green car rebate'. This has been replaced by a 'bonus-malus system' (feebate). The bonus is for low-emission vehicles (klimatbonusbilar) and the malus is for vehicles that emit relatively large amounts of CO_2 which will be penalized with higher vehicle tax for the first three years.

Since 1 July 2018, vehicles having CO_2 emissions of 70 gCO_2/km (WLTP) maximum receive a bonus that depends on CO_2 emissions and that can be up to SEK 60,000. In April 2021, this bonus rose to SEK 70,000. This climate bonus is up to 25% of the price charged for the new car when it was first introduced on the Swedish market.

Sweden has introduced the 'Climate Leap' program that provides an investment incentive for a charging installation. For individuals willing to purchase home chargers, there is the 'Charge at Home' program. Through this program, individuals can receive up to 50% or SEK 10 000 (€1000) for hardware and installation costs of home chargers. For both public and private charging stations, companies, municipalities, councils and foundations can beneficiate from a grant that covers up to 50% of the investment.

4.2.2 Financial incentives and deterrents to drive the shift from combustion engines

Vehicles concerned by the malus for the three first years are the following:

- Petrol and diesel vehicles registered for the first time on or after 1 July 2018,
- PHEV registered for the first time between 1 July 2018 and 31 March 2021 that emits 95 gCO_2/km or more during mixed driving,
- PHEV registered for the first time on or after 1 April 2021 that emits 90 gCO_2/km or more during mixed driving.

On the local level, in some public spaces, EV owners get free parking as well as free access to drive in bus lanes. In Stockholm, when you subscribe to a parking space, the charging is free, you only pay for the parking fee.

4.2.3 Taxation model for cars (private fleet)

Newly registered vehicles in Sweden are subject to an exhaust emission inspection – with a payable fee of SEK 40. Additionally, a road traffic register fee of SEK 65 has to be paid as a form of registration tax.

The annual vehicle tax is divided into four components and the fee changes after 3 years of circulation. BEVs are exempted from the annual vehicle taxes.

Four components of the annual vehicle tax	
Basic charge	SEK 360/year
Carbon dioxide charge	For vehicles registered between 1.07.2018 and 31.03.2021: - SEK 82 * gCO_2/km (for vehicles emitting between 95-140 gCO_2/km) - SEK 107 * gCO_2/km (for vehicles emitting more than 140 gCO_2/km)
	For vehicles registered after 1.04.2021: - SEK 107 * gCO_2/km (for vehicles emitting between 95-130 gCO_2/km) - SEK 132 * gCO_2/km (for vehicles emitting more than 130 gCO_2/km)
Additional environmental charge for diesel vehicles	SEK 250/year
Additional fuel charge for diesel vehicles	SEK 13.52 * gCO_2/km

After three years of circulation, the annual vehicle tax changes:

- *For petrol vehicles*:
  SEK 360 + SEK 22*gCO_2/km (for every gram above 111g)
- *For diesel vehicles*:
  SEK 360 + SEK 22 for each gCO_2 above 111g + 13.52 × the CO_2 value of the vehicle + SEK 250
- *For vehicles registered before 1 July 2018:*
  Petrol-vehicle annual fee: SEK 360+ SEK 22*gCO_2/km (for every g above 111g)
  Diesel-vehicle annual fee: 2.37 × (SEK 360 + SEK 22*gCO_2/km (for every g above 111g)) + SEK 250

From January 2021, the fuel tax (excluding VAT) was increased by SEK 0.05/l on petrol and by SEK 0.03/l on diesel. Including VAT, the tax on petrol was increased by SEK 0.06/l and on diesel by SEK 0.04/l.

4.3 Measuring the effectiveness of the policy

In 2015, the Swedish government appointed the Swedish Energy Agency to coordinate the public charging infrastructure deployment efforts. In 2020, the government launched a major initiative to electrify the transport sector to fulfil Sweden's climate objective by creating the Government's Electrification Commission. It is represented by the government and representatives of the transport industry, academia, and local and regional public authorities. This initiative is relatively recent thus no official report or press paper has been released. It is composed of different working groups that collect data about charging infrastructure deployment and EV uptake. Two other known research institutes are the Swedish National Road and Transport Research Institute (VTI) and the Swedish Electromobility Centre (SEC).

- Elbilsstatistik is a Swedish source gathering all data related to EVs and infrastructure deployment on a monthly basis.
- Statistikdatabasen provides data on new registrations per region, and per motorization on a monthly basis.
- Swedish Transport Analysis is a government agency charged with providing decision-makers in the sphere of transport policy with sound and relevant policy advice.

5 France

5.1 State-of-the-art and evolution

5.1.1 Current fleet

According to INSEE, the French EV market has undergone a significant rise over the last few years as EV car sales have almost doubled between 2019 and 2020, while all new car sales dropped by around 25%. The BEV share in total EV sales has always been greater than the PHEV share, but the latter segment is the one which has experienced the greatest growth in the last two years. It experienced a growth of +131% between 2019 and 2020.

For 2021, during the first eight months, overall sales of new passenger cars increased by 12.8% compared to the same period in 2020. This increase in sales is mainly due to the growing interest in EVs in general but most importantly for PHEVs. The sales of PHEVs rose from 124,000 in the first eight months of 2020 to 280,000 in the first eight months of 2021. Regarding BEV sales, for the same period, they rose from 60,000 to 90,000, according to Auto Moto. The share of EVs in new registrations in October 2021 has been 33% higher than in the same period in 2020.

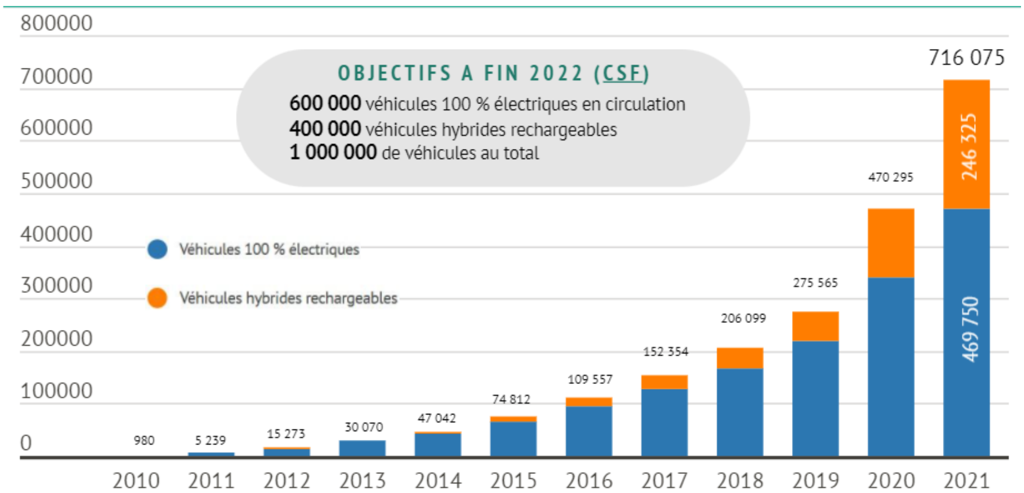


Figure 64 BEV and PHEV car sales per year since 2010
Source: Avere-France, Baromètre véhicule électrique en France, Octobre 2021

5.1.2 Deployment strategies and targets

According to the report "Stratégie de développement de la mobilité propre" released in 2015, the following development of BEVs and PHEVs is targeted: 2.5 million PHEVs and 1.9 million BEVs in 2030. In terms of share, this scenario achieves a 35% share of BEVs and 10% of PHEVs in new vehicle sales (Stratégie Nationale Bas-Carbone). The sale of cars using carbon-based fossil fuels will be banned from 2040[17].

The French government has been among the most generous in Europe in offering incentives for electric and hybrid vehicles, of which support measures worth 8 billion euros, that were put in place during the COVID-19 pandemic in May 2020.

In 2022, the French government wants to achieve 1,000,000 EV cars (400,000 PHEVs and 600,000 BEVs).

[17] In the meantime, the EU has decided to stop the sale of ICEVs from 2035.

5.1.3 Charging infrastructure development, plans and strategies

The national plan for the development of charging infrastructure is built in coherence with the "Strategy for the Development of Clean Mobility". This framework for action defines deployment targets for electric charging infrastructure but also for gas and hydrogen refuelling stations. In August 2015, the French law on Energy Transition for Green Growth set two objectives: (1) 50,000 charging spots by the end of 2020 and 100,000 charging points open to the public by 2022; (2) 7 million public and private charging points by 2030.

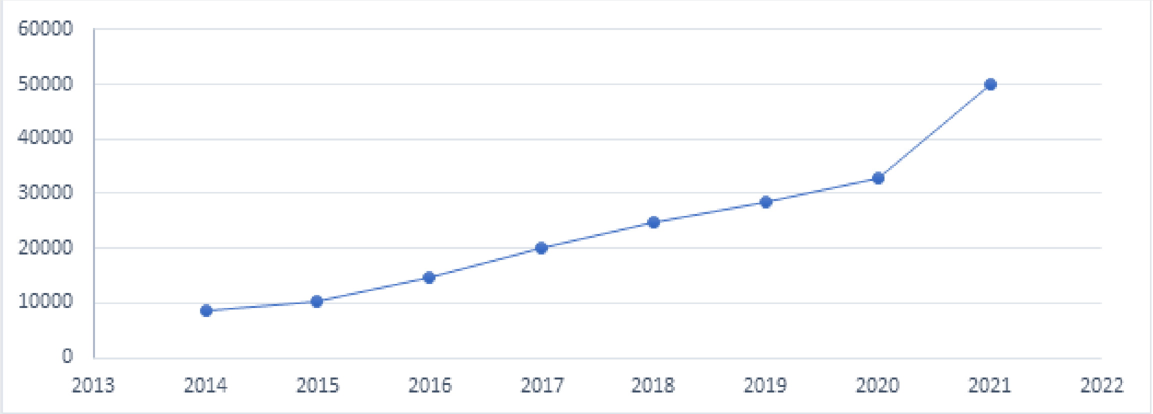


Figure 65 Number of public charging points in France from 2014 until October 2021
Source: Baromètre IRVE, Novembre 2021

In October 2021, more than 49,586 public charging points were installed in France of which 17,000 have been installed in 2021 and 6% are fast charging points. Among these, 40% are on public roads, 37% on car parks and the rest around shops and businesses. Therefore, France has failed to achieve two short-term targets but they seem to have accelerated the deployment since early 2021. By the end of June 2022, the number of public charging points increased to 64 546[18]. The next years will be crucial if they are to meet their initial targets. An analysis based on the EV market situation in 2020 states that to support the growth of EVs until 2030 and to power 8.5 million EVs, public chargers will need to grow to about 350,000 by 2030.[19] This implies an average annual growth of 28% from 2020. France is finally on the right track with a growth of 52% in 2021 (until the end of October).

Regarding the deployment along motorways, the French Ministry of Transport announced that by the end of 2022, all fuel stops near the motorway network will be equipped with charging stations. At the moment, 164 of 364 motorway stations are equipped with fast-charging stations and the French Government dedicated a budget of €100 million solely to this purpose.

5.2 Financial instruments

5.2.1 Financial incentives to purchase EV

Since 2007, France implemented a bonus-malus system.

There is a purchase grant (ecological bonus) depending on the CO_2 amount emitted by the vehicle which was set to decrease in January 2022. **New vehicles** with CO_2 emissions of 20 g/km or less (electric or hydrogen vehicles): (1) €6000 for private persons if the vehicle purchase cost is <€45,000 and the bonus amount is capped at 27% of the purchase cost. This amount will decrease to €5000 in July 2022; (2) €2000 if the vehicle purchase cost is between €45,000 and €60,000; (3) €2000 if the hydrogen vehicle costs more than €60,000. **Second-hand** vehicles with CO_2 emissions of 20 g/km or less and of weight <3,500 kg are entitled to a bonus

[18] Charging station barometer: https://www.avere-france.org/recharge-ouverte-au-public/
[19] ICCT, *Charging infrastructure to support the electric mobility transition* in France, 2021

of up to €1000. **Plug-in hybrid vehicles** emitting between 21 g – 50 gCO_2/km with a purchase cost <€50,000 are also granted a bonus of up to €1000 (this bonus is abolished in July 2022).

On the local level, La Métropole du Grand Paris (gathering of Paris and 130 municipalities) provides a conversion premium that can go up to €6000 for the purchase of a new or second-hand EV emitting less than 122 gCO_2/km or a hydrogen vehicle with [his own program](). This aid can be combined with the national conversion premium.

Since 2016, the Advenir programme finances the supply and installation of charging points for companies and collective housings. The ADVENIR programme has a budget of €100 million and aims to start the installation of 45,000 charging points by the end of 2023. This programme does not support the financing of charging station installations for individual houses but only for the following cases:

- individual or shared in collective residential buildings up to 50%. For the individual solution, the amount is capped at €600 or €960 if the charging station is equipped with an energy management system. For the shared solution, the amount is capped at €1300 or €1660 with the energy management system.
- private or publicly accessible company parking between 50% and 60%. €4000 until 50 parking spots then €75 per additional parking spot.

Additionally, since 1 January 2021, there is a tax credit of 75% of the cost, limited to €300 per charging point for individuals in private housing.

5.2.2 Financial incentives and deterrents to drive the shift from combustion engines

The malus is applied at the time of purchase of the vehicle when it is first registered in France and is calculated according to the CO_2 emission per kilometre of the vehicle. Before 2020, the revenue from this malus was used to finance grants for purchasing low-emission vehicles. Since 2021, the threshold of the malus is 133 gCO_2/km (WLTP standard), which corresponds to a tax of €50, and increases exponentially with a ceiling of €30,000 when CO_2 emissions exceed 218 gCO_2/km.

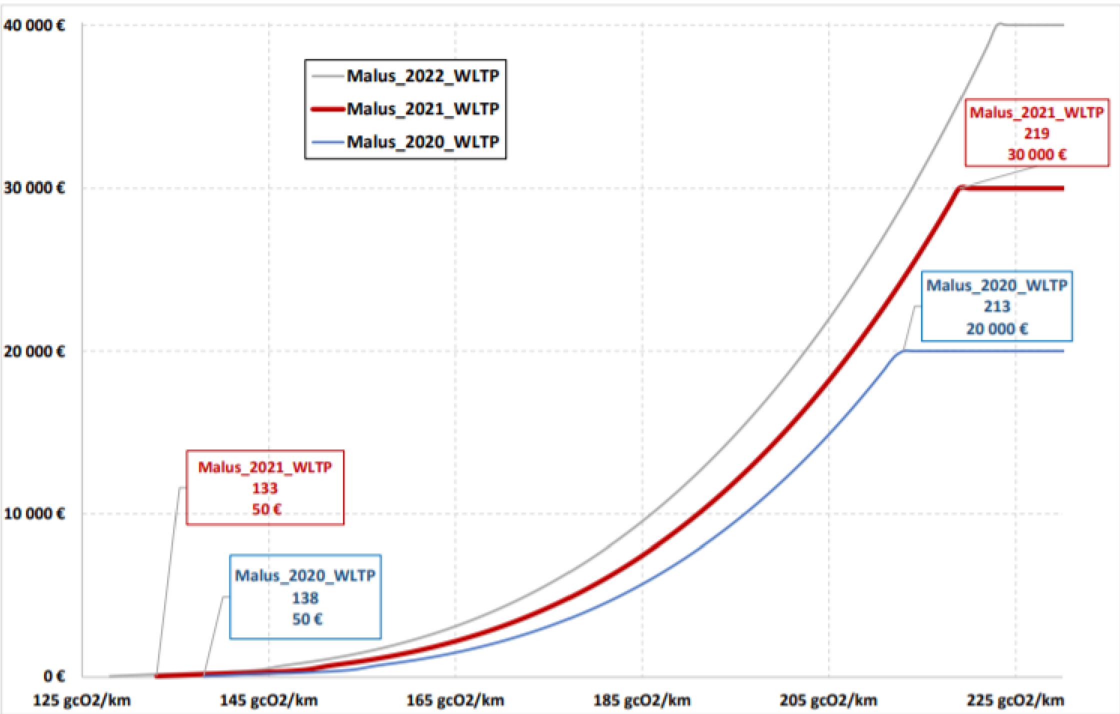


Figure 66 Malus applied in France at first registration of the vehicle, calculated according to CO_2 emissions per kilometre. Source: ACEA Tax Guide 2021

Disabled people are exempted from this malus and large families can benefit from a malus reduction. The reduction applies to families with at least three dependent children on the purchase of a vehicle with at least five seats and is limited to one vehicle per household. The CO_2 emission rate is reduced by 20 g/km per child starting from the third child.

From 2022, the CO_2 penalty will be capped at 50% of the price of the vehicle including VAT. As we can see in the figure above, the threshold will be at 128 gCO_2/km in 2022 and a maximum of €40,000; and 123 gCO_2/km in 2023 and a maximum of €50,000. Furthermore, an additional weight malus of €10 per kg will be adopted in 2022 for vehicles 1800 kg or more, BEVs and PHEVs excepted. The sum of mass-malus and CO_2-malus cannot exceed the CO_2 ceiling of the current year.

The malus for second-hand vehicles which depends on the fiscal horsepower of the vehicle has been abolished in 2021. Imported, second-hand vehicles are considered new and are therefore subject to malus with a discount of 10% per year according to the age of the vehicle.

Since 1 April 2015, a conversion premium (la prime à la conversion) aims to help all French people, whether private individuals or professionals, to buy a new or second-hand vehicle in exchange for scrapping a polluting vehicle and it can be combined with the ecological bonus. The polluting vehicle has to be registered before 2011 if it's a diesel vehicle and before 2006 if it's a petrol vehicle. The premium amount depends on factors such as CO_2 emissions, reference tax income (RTI) of the applicant, commuting distance and vehicle type. The applicant can't sell the purchased vehicle within 6 months nor until it has travelled at least 6000 km. If you live or work in a low-emission zone, you can receive a bonus of up to €1000.

The different types of vehicles, both new and used, that can qualify for the conversion premium (detailed description of the premium levels):

- Vehicles with CO_2 emissions less than 50 g/km: (1) €5000 if hybrid with min 50 km range & specific situation; (2) €2500 if hybrid with min 50 km range; (3) €1500 for other cases.
- Vehicles with CO_2 emissions of between 51 and 109 g/km (or between 51 and 137 g/km if approved on the WLTP norm): (1) €0 for an applicant with RTI>€13,849; (2) €3000 if RTI<€6300 or commuting distance >30 km or annual mileage>12,000 km; (3) €1500 for other cases.

5.2.3 Taxation model for cars (private fleet)

The registration tax depends on several tax components: purchase value, engine power, weight, the purpose of utilisation, age, CO_2 emissions, type of fuel, electric propulsion, and place of first registration. The regional tax varies between €27 and €51.20 per fiscal horsepower according to the region.

The écotaxe additionnel/malus for the first registration of the vehicle in France depends on the CO_2 emissions of the vehicle (WLTP standard). In 2021, the threshold of the malus is 133 gCO_2/km (WLTP standard), which corresponds to a tax of €50, and increases exponentially with a ceiling of €30,000 when CO_2 emissions exceed 218 gCO_2/km. The threshold decreases and the ceiling increases in the following years (see above).

For a second-hand vehicle, the malus ranges between €0 for those with a fiscal horsepower of less than 9 and €1000 for vehicles with a fiscal horsepower of more than 14. The tax is reduced by 10% per year from the date of a vehicle's initial registration. Imported, second-hand vehicles are considered new and are therefore subject to a malus with the discount rate according to the age of the vehicle.

In 2022, an additional tax of €10 per kg will be adopted for vehicles weighing 1800 kg or more, which will not apply to EVs.

Before 1 January 2021, an annual tax for polluting vehicles (>190 gCO_2/km) was applicable. It has been abolished in 2021 for private vehicles. Due to the recent hardening of additional ecotax/malus, the annual tax for polluting vehicles was overlapping the bonus-malus scheme.

5.3 Measuring the effectiveness of the policy

The Ministry of Ecological Transition and Avere France (National Association for the deployment of electric mobility) are collecting data on a monthly basis in the form of an electric mobility barometer. There is one barometer that gives an overview of the registration evolution of electric vehicles, the most sold vehicles and the other one is on the evolution of charging infrastructure. Additionally, Avere France manages the 'Programme ADVENIR', the main tool to develop charging infrastructure in France by monitoring the deployment and providing charging incentives.

France Stratégie is the entity that gives recommendations to the French government about the deployment strategy. In 2018, France Stratégie submitted a report of a study mission to the Minister of State, Minister of Ecological Transition and Solidarity and the Minister for Transport to help them establish a public policy for EVs. They recommended that the state is responsible for providing direct financial incentives and adapting the subsidies to the evolution of the price of EVs and that indirect incentives and public charging points should be monitored by cities.

6 Germany

6.1 State-of-the-art and evolution

6.1.1 Current fleet

The take-up of EVs has been rather slow in Germany compared to other European countries. However, recent government incentives facilitated a sharp increase in EVs in 2020 compared to 2019. BEV sales increased by 212% and by 342% for PHEV.[20]

The great BEV uptake continued in 2021 as 350,000 electric cars were newly registered in the first seven months of 2021. To put this number in the perspective, the same number of EV registrations occurred in the entire year 2020. In October 2021, 30.4% of newly registered cars were EVs which sets a new record in Germany. This can be explained by the slowed-down sales of ICEVs due to the semiconductor supply shortage. Car manufacturers decided to allocate the available semiconductors to EVs. This choice is motivated by a high rate of purchase from consumers because German subsidies for EV purchases are interesting (up to €9000). Mid-2022 the share of BEVs in new car registrations in Germany reached 14%. It is projected that almost 40% of car sales will be purely electric in 2025, and even 2 out of 3 in 2030.

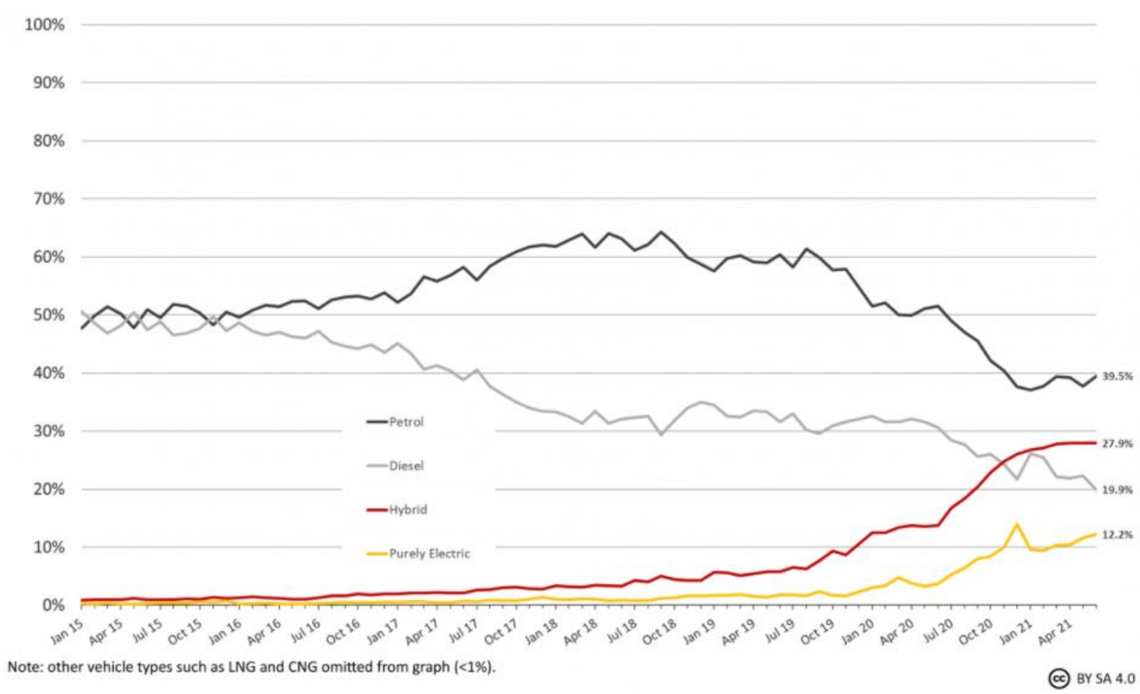


Figure 67 New monthly registrations per engine type
Source: Federal Motor Transport Authority KBA, 2021

6.1.2 Deployment strategies and targets

Despite a proposal from the European Union and contrary to many other European countries, Germany has not yet announced the phase-out of new diesel and petrol vehicles. Germany decided to leave the decision to ban fuel-based vehicles to individual cities and federal states. Berlin recently announced that it will ban non-electric cars from its city centre by 2030 and Heidelberg will also ban diesel and petrol vehicles by 2030. Recently, Germany has declared that they will follow the EU decision on the sales of zero-emission cars only by 2035.

[20] IEA, *Global EV Data Explorer*, 2021

In July 2021, Germany reached its initial target (National Electromobility Development Plan) of one million registered BEVs and PHEVs on German roads which was initially planned for the end of 2020. At that time, among all EVs, 54% were BEVs and 46% were PHEVs.

The government's long-term vision was initially to have between 7 million and 10 million electric vehicles by 2030. Due to the recent surge in EV sales, Germany announced the ambitious target of 14 million vehicles by 2030. To this end, they announced that they will prolong the buyer's programme for the purchase of new EVs until 2025 which will help Germany to achieve the climate targets by 2030. However, studies from independent companies mitigate this ambitious goal. According to GTAI research, 10 to 14 million EVs can be expected by 2030 and according to Mckinsey research, 7 to 10 million will be sufficient for Germany to reach its climate targets.

Great incentives for EV purchases combined with research funding and infrastructure expansion supports the EV uptake in Germany in the next decade. The German Federal Ministry of Environment (BMU) has a funding program "Renewably mobile" that supports several research projects on electric mobility. BMU developed ecological standards for EVs and supports projects on battery recycling. Furthermore, they provide financial aid for the purchase of EVs for social services. The Federal Government also launched innovation funding where €2.5 billion are allocated for research and development projects in the domain of electromobility and battery cell production and direct funding of €2bn for automotive manufacturers.

6.1.3 Charging infrastructure development, plans and strategies

As of 2021, public charging infrastructure is composed of 6500 DC charging points and 39,000 AC charging. Regarding private charging infrastructures, 740,000 wall boxes have already been installed. The Federal Government allocated €200 million for 1000 rapid charging stations for long-distance mobility so that the next fast-charging station should be accessible in just a few minutes by 2023. The government has allocated a budget of €500 million for the funding of 30,000 public charging points and €800 million for private charging facilities.

In November 2019, the Federal Cabinet agreed on "*The Federal Government's Charging Infrastructure Master Plan*" which intends to accelerate the charging infrastructure rollout to guarantee that the charging infrastructure will be adequate for 14 million EVs in 2030 or a total of one million public charging points. According to the German government, increasing the number of charging points is a key enabler for the electric transition. To this end, The German Federal Government has adapted its legal framework which limited the rapid development of the charging infrastructure over the past years. This master plan outlines legal measures for public and private charging points.

To meets its target of 1 million charging point by 2030, the Federal Ministry of Transport and Digital Infrastructure proposed schemes offering subsidies and tax benefits both on a national and a regional level. 300 million€ have been allocated for promoting public charger installation for SMEs (including municipal utilities and local authorities). The condition to beneficiate from this subsidy is to use renewable energy for charging and it covers 80% of the total installation cost. The national public subsidy structure is the following:

- Up to €4000 per AC/DC charger of 3,7 to 22 kW
- Up to €16,000 per DC fast chargers of 22 to 50 kW
- Up to €10,000 for low voltage and up to €100,000 for medium voltage grid connections.

Regarding national private subsidy, KfW-Bank (owned by the German state) launched in November 2020 an initiative that offers a €900 incentive to acquire and install a charging point for private use (max 22kW). 70% of the cost for a connection to the network or earthworks can also be financed. The maximum amount of funding per project is €45,000. A fund of €350,000 has been devoted to this initiative. To receive this fund, the electricity for the charging process must come from 100% renewable energy. This initiative has been so successful that the limit has been reached and it is not possible anymore to apply.

States, cities and energy companies proposed also their own EV charging incentives:

- Nordrhein-Westfalen (private): €500 grant if you produce your own sustainable electricity and €200 per kWh of storage capacity if an energy storage unit is installed.
- Munich (public): 40% of total costs (max €3000 for normal charging points and max €10,000 for fast charging points).

- Hannover (private): €500 incentive for a smart charging station.
- Limburg: €300 incentive per charging point.
- Baden-Wurtemberg: Up to 40% of the costs of acquisition, installation and network connection of AC and DC charging infrastructure in public and non-public areas are financed (max. €2500 per charging point).
- Bayern: Until 2023, there is a fund for public charging infrastructure. Charging points up to 22 kW are funded at 40% or a maximum of €2500. For charging points from 22 kW to 100 kW, the subsidy is also 40% or €10,000. If the power exceeds 100 kW, the subsidy is also 40% or €20,000. A grid connection is financed at 40% of the expenses or a maximum of €10,000.
- Berlin (WELMO financing program): up to 50% of the costs of purchasing or leasing AC and DC charging points in public and non-public areas (max. €2500 for AC and max. €30,000 for DC charging points) and their connection to the grid (max. €5500 for connection to the low-voltage grid and max. €55,000 for connection to the medium-voltage grid).
- Hamburg: The ELBE project covers 40-60% of the costs of procurement, installation, building electrical upgrades and commissioning of AC and DC charging stations in public and non-public areas.
- Mecklenburg-Vorpommern: Between 30% and 50% of the costs for charging infrastructure of municipalities and companies.
- Schleswig-Holstein: up to 50% of the eligible costs of public and non-public charging infrastructure are financed. For normal AC charging points, between €500 and €7500 are financed, and for (public) DC fast charging points (at least 150 kW) a maximum of €30,000 per charging point.
- Thuringen: Public charging infrastructure: up to €3000 for normal AC charging points (up to 22 kW), up to €12,000 for DC fast charging points (up to 100 kW), up to €30,000 for DC fast charging points (over 100 kW).

6.2 Financial instruments

6.2.1 Financial incentives to purchase EV

In mid-2016, to achieve the first 2020 target of 1 million EVs, the government decided to offer a buyer's premium (Umweltbonus) of €2000 for the acquisition of a BEV and €1500 for a PHEV with a CO_2 emission level below 50 gCO_2/km if the net price of the vehicle was less than €60,000. The vehicle manufacturer has to grant the buyer at least the same premium amount as a discount for the subsidy to be approved. This incentive program was supposed to end when the €6 million dedicated by the government was exhausted or by the end of 2019.

In November 2019, Angela Merkel announced that the environmental bonus would be increased and will be extended until 2025 or when the €2.09 bn government fund will be exhausted. The total bonus increased by 50% thus it rose from €4000 to €6000 for BEVs, and from €3000 to €4500 for PHEVs with a maximum net price of €40,000. For vehicles with a net list price between €40,000 and €65,000 the bonus for BEVs rose to €5000 and to €3750 for PHEVs. At that time, the bonus was still funded half by the government and half by the manufacturer.

Due to covid crisis, in June 2020, the government decided to double the share of the government as an *innovation bonus* until the end of 2021. In November 2020, the government decided to extend this innovation bonus until 31st December 2025.

It should be noted that the Umweltbonus can be combined with other subsidies and that the manufacturer's share is subject to 19%VAT. A condition to benefit from the Umweltbonus is that the purchased EV has to be registered in Germany and stay in Germany for at least 6 months. The following amounts of the Umweltbonus are the sum of the government and car manufacturers:

For vehicles with a net list price of up to €40,000, the net bonus:

- BEV: €9000 (€6000 and €3000)
- PHEV (<50 gCO_2/km): €6750 (€4500 and €2250€)

For vehicles with a net list price of up to €65,000, the net bonus:

- BEV: €7500 (€5000 and €2500)
- PHEV (<50 gCO_2/km): €5625 (€3750 and €1875)

For a PHEV to be eligible for the Umweltbonus there is also a minimum electrical range requirement of 40 km until the end of 2021, then it will be 60 km and from January 2025 it will be 80 km.

Second-hand vehicles are also eligible to receive this purchase subsidy, but there are several conditions to be met:

- The first registration is after 4/11/2019
- Received no environmental bonus (or any European subsidy)
- The first registration duration is less than 12 months
- Maximum mileage of 15,000 km

If the second registration of the vehicle was before 04/06/2020 then the vehicle doesn't receive the innovation bonus. Now, second-hand vehicles that meet the three criteria are eligible for the same purchase subsidy as new vehicles. Although it is a second-hand vehicle, the purchase subsidy is still provided by both manufacturers and the government.

In July 2022, Germany decided on a reduction in the subsidies for EVs. The incentives will expire once the allocated budget of €3.4 bn is spent. In the meantime, the government subsidy for vehicles below €40,000 will fall to €4500 in 2023, and to €3000 in 2024. For cars over €40,000 and below €65,000, the subsidy will drop to €3000 in 2023. There will be no subsidy for the purchase of cars priced over €65,000, and that will apply to vehicles priced at €45,000 and more from 2024. Subsidies for company cars will be eliminated, with only private customers benefiting from the scheme. The subsidies for PHEV will be cut completely from 2023. It is yet to be clarified what will happen to the subsidy-part from the car manufacturers.

You can benefit from a local incentive of up to €1500 for the purchase in addition to the Umweltbonus, depending on your region.

BEVs (or fuel cell vehicles) benefit additionally from an annual CO_2 bonus of €30 for 5 years. There is also a total tax exemption for 10 years until the end of 2030 for BEVs initially registered between 1 January 2016 and 31 December 2025. After the 10-year exemption, the annual tax will depend on the weight of the vehicle and will amount to up to 50% of the ICEV weight tax thus: up to 2000 kg - tax €5.625 per 200 kg; from 2001 up to 3000 kg - tax €6.01 per 200 kg; from up to 3001 kg - tax €6.39 per 200 kg.

6.2.2 Financial incentives and deterrents to drive the shift from combustion engines

There is an additional annual tax (malus) for vehicles emitting more than 95 gCO_2/km and for vehicles registered before 1 July 2009. At the same time, drivers of petrol and diesel models are forced to pay an additional €0.07 to €0.08 at the pumps following the introduction of a CO_2 tax in January 2021. Between 95 and 116 gCO_2/km, the rate is €2 per gCO_2/km. Starting at 116 g CO_2/km, the rates will gradually increase up to €4 per gram CO_2/km for vehicles with CO_2 emissions above 195 g/km (see table).

gCO_2/km	Tax [€]
>115-135	2
>135-155	2.2
>155-175	2.5
>175-195	2.9
>195	4

6.2.3 Taxation model for cars (private fleet)

Vehicle ownership tax is paid annually. As of 1st January 2021, PHEV and fuel-propelled vehicles are under the obligation of a two-component tax: cylinder displacement/capacity component, also known as base tax, and a CO_2 component. The base tax that depends on cylinder displacement: €2 per 100 cc (petrol) and €9.50 per 100 cc (diesel). If the car has been registered for the first time between June 2020 and the end of 2024, an annual bonus of €30 for vehicles emitting less than 95 gCO_2/km during 5 years applies.

For vehicles with high CO_2 emissions (>95 gCO_2/km), an additional malus applies (see above).

For vehicles registered between 1 July 2009 and 31 December 2020, the CO_2 component imposes a €2 tax rate per gCO_2/km from a threshold depending on the first year of registration: 120 gCO_2/km from July 2009, 110 gCO_2/km from 2012, 95 gCO_2/km from 2014. The cylinder capacity component is the same as for the vehicle registered in 2021.

For vehicles registered before 1 July 2009 with a Wankel-motor, it depends on the weight of the vehicle: up to 2000 kg - tax €11.25 per 200 kg; from 2001 up to 3000 kg - tax €12.02 per 200 kg; from up to 3001 kg - tax €12.78 per 200 kg. For vehicles registered before 1st July 2009 with a petrol or diesel motor (cylindric shape), the annual tax rate depends on the EURO-norm, engine displacement and fuel type (see table).

Vehicle emission class	Petrol (per 100cc)	Diesel (per 100cc)
Euro-3 and higher	€ 6.75	€15.44
Euro-2	€7.36	€16.05
Euro-1	€15.13	€27.35
Euro-0 (before the driving ban for diesel-powered vehicles)	€21.07	€33.29
Euro-0 (other)	€25.36	€37.58

From 1 July to 31 December 2020 the VAT rate is reduced from 19% to 16% to offset the economic impact of the Covid-19 pandemic. As of 2021, regular VAT is applicable. The buyer pays the seller the VAT amount in addition to the price of the car, and the seller pays it back to the state as tax.

6.3 Measuring the effectiveness of the policy

BMVI (Federal Ministry of Transport and Digital Infrastructure) is the main responsible entity for monitoring the expansion of the charging infrastructure in Germany. With the "Charging Column Ordinance" ("Ladesäulenverordnung"), the BMVI regulates the central requirements for public charging infrastructure. On behalf of BMVI, the National Centre for Charging Infrastructure, under the umbrella of NOW GmbH, coordinates and manages the activities to expand the charging infrastructure at various levels (federal / state / local governments). It supports the planning, implementation and promotion of the charging infrastructure. In doing so, it always has the overall system of public and non-public charging infrastructure and the users in mind. Data are collected and evaluated from the charging points using TOOL application.

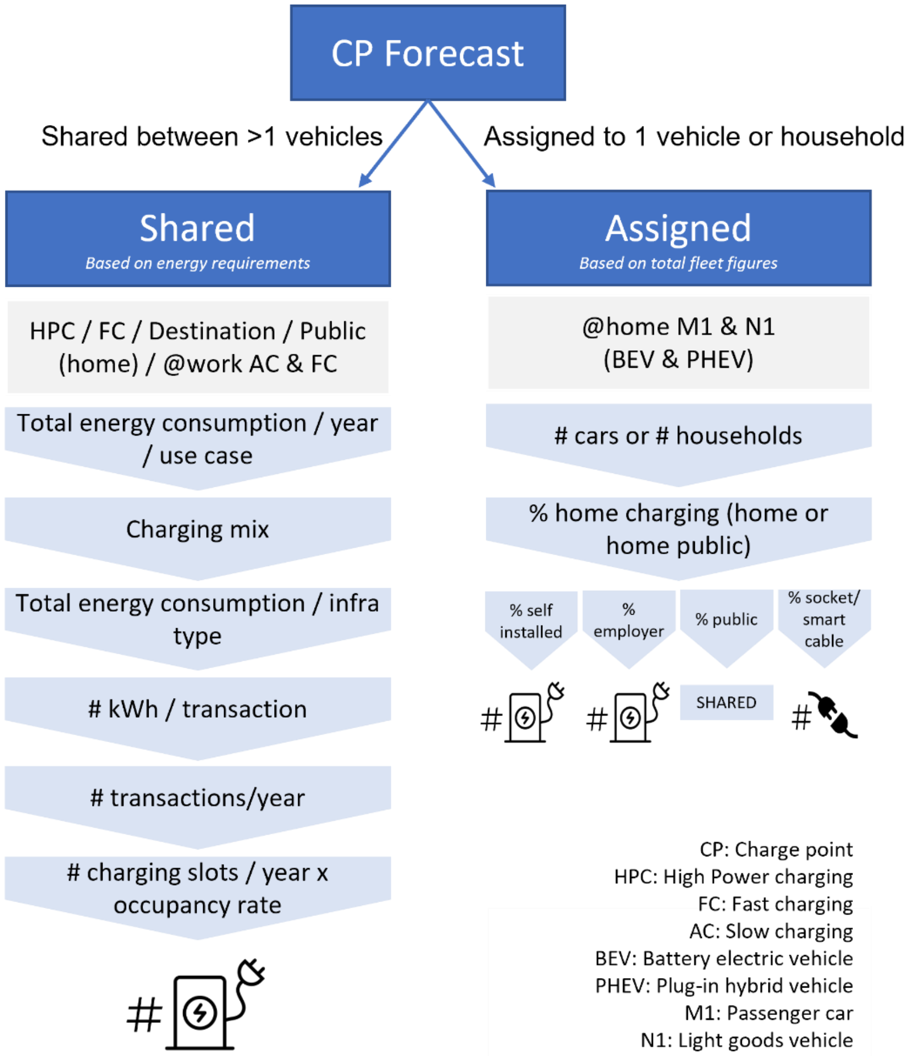
In Germany, all charging stations must be registered by the 'Stiftung EAR' (foundation for registration of electrical and old appliances). Both commercial and private charging stations for electromobility fall under this obligation and an explanation of the intended use of the station needs to be provided during the registration. This obligation falls within the implementation of the WEEE Directive of the Federal Environmental Agency of Germany.

In 2010, the Ministry has created a coordination office for the EV introduction: the Joint Agency for Electric Mobility of the Federal Government (GGEMO). GGEMO partnered with the German car industry leaders to form a German National Platform for Electric Mobility (NPE). The NPE's mission was to recommend certain measures to the federal government, monitor their effectiveness and adjust if necessary. Now, the German National Platform Future of Mobility is in charge of EV and charging infrastructure deployment in Germany (https://www.plattform-zukunft-mobilitaet.de/en/).

- On the website of the Federal Motor Transport Authority (KBA), it is possible to have a monthly or yearly overview of the registration of new EVs, brands, etc for the different regions - Link to data page
- For a yearly evolution of charging infrastructure in Germany - Link to data page

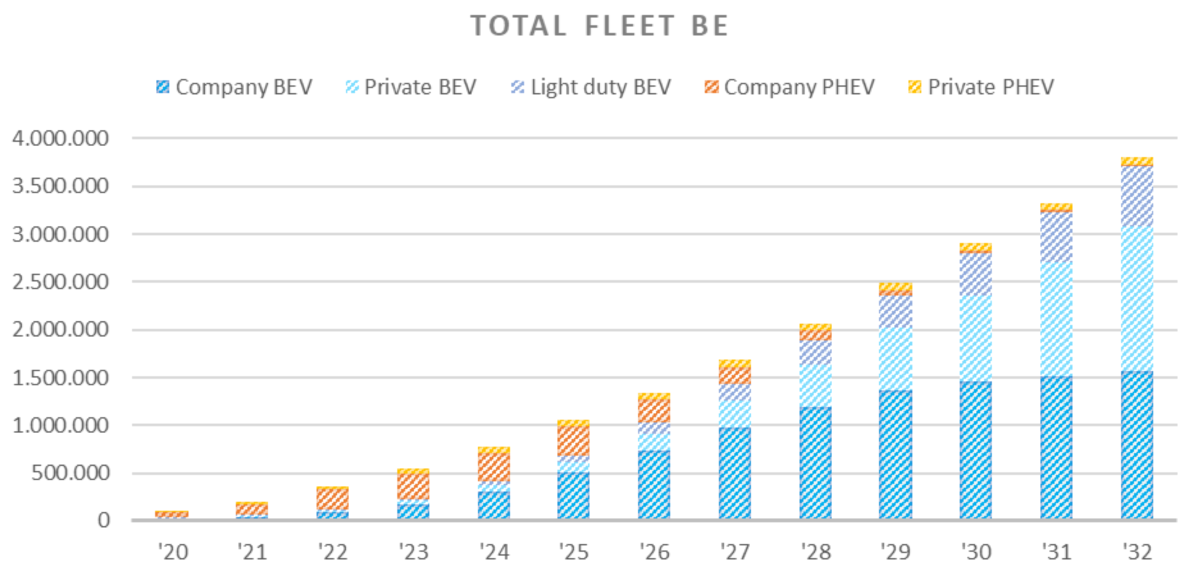
Attachment 3: Methodology of the charging infrastructure forecast

To forecast the total charging infrastructure needed, different methodologies can be used. A demand-based model seems the most logical choice. A market modelling approach was developed by *The New Drive* based on two types of charging infrastructure: shared charging infrastructure (High Power Chargers, Fast chargers, Destination chargers, Public (near home) chargers and normal/fast chargers at work) and assigned charging infrastructure (private chargers at home: self-installed/installed through employer and smart cables or standard sockets).



1 Shared methodology

The methodology for the shared charge point forecast is based on the energy requirements of the different types of vehicles. The uptake figures for BEVs and PHEVs are leading to the calculation of the energy requirements. The following figure, based on analysis of *The New Drive*, shows the total fleet forecast for Belgium until 2032, broken down by use case (type of vehicle and type of owner). This forecast is based on market insights into the drivers and enablers of the eMobility market, including international and national policies (Low emission zones, taxes, subsidies, …), price parity, TCO evolutions, demand vs. supply of charging infrastructure, historic fleet figures, etc. The uptake figures show an exponential increase in BEV, for both private and company-owned vehicles. The uptake of PHEVs is expected to increase until 2025-2027, after which the number of PHEVs begins to decline again, mainly due to regulatory and fiscal measures.



Based on these uptake figures of BEVs and PHEVs, replacement ratios and the increase in the total fleet the model calculates the total number of vehicles requiring charging infrastructure. This is then linked to a certain vehicle and driving behaviour (e.g. distance travelled per year, the evolution of the distance travelled and the average electricity consumption), based on scientific research. By multiplying these values, the model computes the total energy requirement per year, per use case.

In order to distribute the total energy demand over the different types of charging infrastructure, the charging mix must be determined. This charging mix shows the distribution of the charged amount of energy over the different types of charging infrastructure. The table below gives an example of the charging mix in 2020, based on our insights, Dutch charging research and Belgian figures regarding the dependence on public domain and private domain to park and eventually charge vehicles. Evolutions in charging behaviour towards the future are also taken into account. These are based on assumptions made by *The New Drive*, based on insights such as a higher range of vehicles (less HPC/FC), a higher relative share of the population that drives lower distances (less HPC/FC), fewer EV-owners with private driveway (more Home public AC), …

Use case name	Type	Fast charging			Destination charging	Home (public)	At work	Home (private)
		C-FC/ HPC	IC-FC/ HPC	H-FC/ HPC	AC	AC	AC	AC
M1 & N1	BEV	1,1%	3,9%	7,6%	3,2%	3,9%	17,8%	62,5%
M1	PHEV				5,0%	3,9%	33,1%	58,0%

By multiplying the charging mix with the total energy demand per use case, an annual energy demand per type of charging infrastructure can be derived. This can then be used to determine the number of charging sessions per year per type of charging infrastructure. It is done by first estimating the average energy demand per charging session and per type of charging infrastructure. For example, 23 kWh is charged at a fast charger/high power charger on average. For AC destination charging, an average of 16 kWh is charged. These figures are based on real-life data of charging sessions in Belgium and The Netherlands, collected based on inputs of several national and international charge point operators and thereafter analysed by *The New Drive*. To subsequently determine the total number of charging sessions, the total annual energy demand is divided by the energy demand per charging session.

The last step, to finally predict the number of charging points needed, is based on specific characteristics of the charging infrastructure. Depending on the average charging time and the total energy per charging session, a charging point can handle one or more charging sessions per day. Due to the high charging capacity of fast chargers, the number of charging slots for this type is high. At a regular public charging point (close to home), the number of charging slots is much lower, as these charging points are mainly limited to one charging session per night and possibly one or several shorter charging sessions (destination charging) throughout the day. By determining the number of charging slots per type of charging infrastructure per year and then dividing the annual number of charging sessions by this number, the number of charging points needed can be determined.

2 Assigned methodology

Unlike shared charging points, assigned charging points are only used by one vehicle or household, hence there is a direct relationship between the number of vehicles/households and the required number of assigned charging points. This category concerns home charging infrastructure and depot charging for light commercial vehicles.

For company cars, the total number of cars at home consists of the total number of company cars, functions cars and utility cars and light commercial vehicles that can be charged at home, but may not be used for private transportation. Within company cars, we distinguish indeed two different types: (i) salary cars (cars that are provided as an extra-legal salary instrument) and (ii) function cars (cars that allow the driver to perform his/her professional function).

It then is assumed that for every vehicle, a single charging solution must be present at home whether it is a self-installed charging point, a charging point installed through the employer, a smart cable/standard socket or a public charging point (forecast based on shared methodology).

The assigned charging infrastructure for private cars has a direct relationship with the total number of households, as it is expected that the majority of households won't install more than one private charging point. Therefore, the number of households with a minimum of one BEV or PHEV is derived by multiplying the average car possession of households in Belgium by the total number of BEVs and PHEVs. This is then broken down into privately purchased charge points, smart cables/standard sockets and public near-home charge points.

An example of the distribution for private and company cars is shown in the table below.

Use case name	Type	% self installed	% installed through employer	% public near home	% household socket / smart cable
Company car	BEV	3,4%	61,6%	33,0%	2,0%
Private car - household	BEV	43,9%	0,0%	43,0%	13,1%

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