Federal Planning Bureau
Economic analyses and forecasts

WORKING PAPER 5-23

Total cost of ownership of car powertrains in Belgium

June 2023

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Abstract - We present a total cost of ownership (TCO) analysis per market segment and powertrain of new cars sold in Belgium. We differentiate our results between cars sold to private households and company cars. Even though the median TCO of electric cars is lower than the median TCO of conventional powertrains in several market segments, there is a significant overlap in the TCOs of different powertrains in each market segment. It is therefore important to consider the whole distribution of the TCO. In the case of company cars, electric cars benefit hugely from the preferential tax treatment given to company cars with low CO_2 emissions. Moreover, company cars are provided by companies to their employees as a benefit in kind. In a competitive labour market, part of this tax benefit for the employee will be compensated in the form of lower wages. If we take this additional element into account, then the relative position of plug-in hybrid vehicles (PHEV) also improves a lot compared to all powertrains.

Jel Classification – H22, H23, L62, L92, R48
Keywords - Total costs of ownership, company cars, alternative fuels, electric cars, plug-in hybrids

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Executive summary

According to the International Energy Agency (2021), the capital costs of electric vehicles remain a key barrier to their adoption. However, a rational purchaser would also consider the lower running costs of electric vehicles compared to conventional powertrains and take a Total Cost of Ownership (TCO) approach.

The TCO of different powertrains is not just relevant from a consumer's point of view. For policy makers, knowing how the TCO of different car powertrains (gasoline, diesel, electric, hybrid, plug-in hybrid) vary across different market segments (as defined by the body type and maximum engine power) and usage profiles (as defined by the annual distance driven) can contribute to the formulation of better focused policies to stimulate the uptake of electric cars.

Of course, besides the TCO, the consumer may care about non-monetary elements in the choice of specific car models. On top of "traditional" non-monetary elements (performance, comfort, safety, reliability), alternative powertrains are affected by barriers such as consumer scepticism, range anxiety, and high implicit discount rates. TCO calculations should thus never be the endpoint of the analysis, but they can provide useful insights for the design of discrete choice models that can capture non-monetary aspects.

In this paper, we present a framework for the calculation of the TCO of cars in Belgium. We present the results of our analyses separately per region and according to the legal status of the owners. Indeed, company cars enjoy specific tax advantages in Belgium compared to privately owned cars. Also, as a result of the Belgian federal system, the license tax and the annual road tax are calculated differently in Flanders than in Wallonia and the Brussels Capital Region.

There is a significant overlap in the TCOs of different powertrains for privately owned cars

Usage profiles are not entirely fixed for a given household. For instance, since electric cars have a lower variable cost than gasoline and diesel cars, it is likely that a household switching to an electric car will adjust its behaviour. An *ex ante* analysis that assumes the same usage profiles for all powertrains ignores the fact that *ex post* usage profiles will change. Instead of looking at TCOs for a fixed annual mileage, we therefore look at the range of TCOs for the distribution of annual kilometres driven by a sample of Belgian households.

We discuss here the results for privately owned cars in Wallonia – the results for privately owned cars in the Brussels Capital Region and in Flanders are very similar.

We calculate the TCO for each individual car model purchased in Belgium in 2021 and for each possible usage profile, where usage profiles are defined by the distances travelled annually. We then perform a comparison by market segment, where the market segments are defined by the body type and maximum engine power of each car.

Our analysis shows that there is no market segment where one powertrain clearly outperforms the others. In several market segments, electric cars have the lowest median TCO, but there is a large overlap in the distributions, especially in the lower power classes. There are also several market segments where no electric cars are on offer in Belgium.

We have also grouped our data in distance classes, where each distance class is defined by the quintiles of the annual kilometre travelled in Wallonia. For each car, we have recalculated the TCO for the average annual distance travelled in that distance class. Finally, for each distance class and market segment, we have identified the ten models with the lowest TCO.

In almost all cases, the group with the ten lowest models with the lowest TCO is dominated by gasoline and diesel cars. It is only for the highest distance class that there are also electric cars among the ten models with the lowest TCO, and only in 6 out of the 12 market segments. It is only in the highest power and distance class that there also gasoline plug-in hybrid cars (PHEVs) among the top ten.

We have repeated this exercise for the 50 models with the lowest TCO per market segment and distance class. The share of electric cars is much lower than if we focus on the 10 models with the lowest TCO: this confirm that, within each market segment, there is a limited number of different electric models on offer, and that those are mostly concentrated among the cheaper (from a TCO perspective) models.

Moreover, the cheaper electric models tend to have a lower driving range, which is a significant disadvantage compared to internal combustion engine vehicles. This illustrates the need to complement TCO analyses with discrete-choice models, which can indeed take such non-monetary elements into account.

By considering the whole range of user profiles, we illustrate how the diversity in usage patterns affects the relative positions of different propulsion technologies. On the other hand, of course, a given household travels a given number of km per year, and so, from the user's point of view, the only sensible comparison *ex post* is one in which we assume a *given* mileage.

If we calculate the TCO for households driving 15,000 km a year, we find that little changes in the ranking of the median TCO, but that the distribution of the TCO becomes much more concentrated around the central values. In the 5 market segments where electric cars have the lowest median TCO, the advantage over the other powertrains is more pronounced.

Finally, for cars that travel 30 000 km per year, electric cars have the lowest TCO in all power classes in which they are offered, and the difference with the other powertrains is very pronounced.

The specific fiscal regime for company cars clearly benefits electric cars

Several clauses in the tax code benefit company cars with low CO_2emissions. First, the extent to which the cost of a company car is tax deductible from company profits depends on the car's CO_2 emissions. Electric cars and plug-in hybrids enjoy a larger deduction than other cars. Second, if the company car is made available to the employee as a benefit in kind, two more elements are added: (a) the treatment of the benefit in kind in income taxation depends among others on the CO_2 emissions (b) except for company cars for company managers and the self-employed, a special solidarity contribution has to be paid by the employer, and this also depends on the CO_2 emissions.

In everything that follows, we assume that company cars are made available as benefit in kind, and should thus be considered “salary cars”.

Our analysis shows that, in Flanders[1], the tax breaks for electric cars and PHEVs with very low CO_2 emissions have a significant impact on the TCO for salary cars.

We follow the same procedure as we did for privately owned cars and also identify the ten models with the lowest TCO per distance class and market segment. The pattern that emerges is completely different from what we found for privately owned cars, clearly benefiting electric cars. Fully electric cars dominate the highest distance class in three market segments.

However, if we extend the analysis to the 50 models with the lowest TCO, we again find that the share of electric cars diminishes substantially, confirming the low diversity of models on offer. Moreover, we observe some gasoline hybrids, gasoline PHEVs and diesel PHEVs among the models with the lower TCO in the higher power classes and/or distance classes.

Passing on the tax benefit linked to company in the form of lower wages benefits plug-in hybrids

A key benefit of company cars from an employer’s point of view is that they allow companies to give their employees a benefit in kind, which is taxed at a lower rate than wage income. However, part of this tax benefit will be passed on to the employee in the form of lower wages. We do not have data that allow us to calculate exactly how big the impact on wages will be, but we develop a method to calculate an upper bound.

We therefore propose an alternative calculation of the TCO of salary cars under the assumption that 50.0% of the net value of the benefit in kind is reflected in wage savings.

Even a partial pass-through leads to an important decrease in the TCO for all powertrains with low CO_2 emissions (at least according to the test cycles), which even approaches zero in some cases. This confirms that the tax treatment of salary cars provides a very large financial benefit to alternative powertrains, and that one should not only look at the direct effects, such as the treatment in corporate taxation.

In most mark segments, the set of 10 models with the lowest TCO is completely dominated by electric, gasoline hybrid and diesel and gasoline PHEVs cars.

However, when we consider the set of 50 models with lowest TCO, gasoline cars are again prominent among family cars and SUVs in the lower power classes, confirming the low diversity of alternative powertrains in this market segment.

[1] The results for the other two regions are similar.

Synthèse

Selon l'Agence internationale de l'énergie (IEA, 2021), le coût d'achat des véhicules électriques reste un obstacle majeur à leur diffusion. Toutefois, un acheteur rationnel prendrait également en compte les coûts d'exploitation moins élevés des véhicules électriques par rapport aux motorisations conventionnelles, et se laisserait guider par le coût total de possession (en anglais, Total Cost of Ownership ou TCO).

Le coût total de possession des différents types de motorisation n'est pas seulement pertinent du point de vue du consommateur. Pour les décideurs politiques, savoir comment le TCO des différents types de motorisation (essence, diesel, hybride, hybride rechargeable, électrique) varie selon les segments de marché (déterminés par le type de carrosserie et la puissance maximale de la voiture) et les profils d'utilisation (déterminés par le kilométrage annuel parcouru) peut aider à formuler des politiques plus ciblées pour encourager l'adoption des voitures électriques.

Au-delà du coût total de possession, les consommateurs peuvent évidemment attacher de l'importance à des éléments non monétaires lorsqu'ils choisissent des modèles de voitures spécifiques, comme la performance, le confort, la sécurité, la fiabilité. Les motorisations alternatives restent aussi entravées par des obstacles tels que le scepticisme des consommateurs, la peur de la "batterie vide" et des taux d'actualisation implicites élevés. Le calcul du coût total de possession ne doit donc jamais être le point final de l'analyse, mais il peut fournir des indications utiles pour la conception de modèles de choix discrets capables de saisir les aspects non monétaires.

Dans cette étude, nous présentons un cadre pour le calcul du TCO des voitures particulières en Belgique. Nous présentons les résultats de notre analyse par région et en fonction du statut juridique des propriétaires. En effet, les voitures de société bénéficient d'avantages fiscaux spécifiques en Belgique par rapport aux voitures appartenant à des particuliers. De plus, la taxe de mise en circulation et la taxe de circulation annuelle sont calculées différemment en Flandre qu'en Wallonie et dans la région de Bruxelles-Capitale.

Pour les voitures particulières, les TCOs des différents types de motorisation se chevauchent considérablement

Les profils d'utilisation des voitures ne sont pas entièrement fixes pour un ménage donné. Par exemple, comme les voitures électriques ont un coût variable inférieur à celui des voitures à essence et diesel, il est probable qu'un ménage qui passe à une voiture électrique ajuste son comportement. Une analyse *ex ante* qui suppose les mêmes profils d'utilisation pour tous les types de motorisation ne tient pas compte du fait que les profils d'utilisation *ex post* changent. Au lieu d'examiner les coûts totaux de possession pour un kilométrage annuel fixe, nous étudions dès lors la fourchette des coûts totaux de possession pour la distribution complète du kilométrage annuel d'un échantillon de ménages belges.

Nous résumons ici les résultats pour les voitures particulières en Wallonie, les résultats pour ces voitures en Région de Bruxelles-Capitale et en Flandre étant très similaires.

Nous calculons le TCO pour chaque modèle de voiture acheté en Belgique en 2021 et pour chaque profil d'utilisation possible, les profils d'utilisation correspondent aux distances parcourues sur une année. Nous effectuons ensuite une comparaison par segment de marché, les segments de marché étant définis par le type de carrosserie et la puissance maximale du moteur de chaque voiture.

On observe dans notre analyse que, dans aucun segment de marché, un type de motorisation surpasse clairement les autres ou est surpassé par les alternatives. Dans plusieurs segments du marché, les voitures électriques ont le TCO médian le plus bas, mais il y a un chevauchement considérable entre les différentes distributions, en particulier pour les voitures des classes de puissance peu élevées. Il ressort aussi qu'aucune voiture électrique n'est disponible dans plusieurs segments du marché belge.

Nous avons également regroupé nos données en classes de distance, chaque classe de distance étant définie par les quintiles de kilomètres annuels parcourus en Wallonie. Pour chaque voiture, nous avons recalculé le TCO pour la distance annuelle moyenne parcourue dans cette classe de distance. Enfin, nous avons identifié les 10 modèles ayant le TCO le plus bas pour chaque classe de distance et chaque segment de marché.

Dans presque tous les cas, le groupe des dix modèles ayant le TCO le plus bas est dominé par les voitures à essence et diesel. Ce n'est que dans la catégorie de distance la plus élevée que l'on trouve également des voitures électriques parmi les dix modèles ayant le TCO le plus bas, et seulement dans six des douze segments de marché. Ce n'est que dans la classe de puissance et de distance la plus élevée que les véhicules électriques hybrides rechargeables à essence figurent également parmi les dix premiers.

Nous avons répété cet exercice pour les 50 modèles ayant le TCO le plus bas par segment de marché et par classe de distance. La part des voitures électriques est beaucoup plus faible que lorsque nous nous concentrons sur les 10 modèles ayant le TCO le plus bas : ce résultat confirme qu'il existe un nombre limité de modèles électriques dans chaque segment de marché, et que ceux-ci se concentrent principalement parmi les modèles les moins chers (du point de vue du TCO).

En outre, les modèles électriques les moins chers ont tendance à avoir une autonomie plus limitée, ce qui constitue un désavantage important par rapport aux voitures à moteur à combustion interne. Cela montre à quel point il est important de compléter une analyse du coût total de possession par des modèles de choix discrets, qui peuvent effectivement prendre en compte de tels éléments.

En considérant l'ensemble des profils d'utilisateurs, nous illustrons comment la diversité des modes d'utilisation affecte les positions relatives des différentes technologies de propulsion. D'autre part, un ménage donné parcourt un nombre donné de kilomètres par an, et la seule comparaison valable, du point de vue *ex post* de l'utilisateur, est donc celle où l'on suppose un nombre donné de kilomètres.

Si nous calculons le TCO pour des ménages parcourant 15 000 km par an, nous constatons que le classement du TCO médian ne change guère, mais la distribution des TCOs est beaucoup plus concentrée autour de ses valeurs centrales.

Dans les cinq segments de marché où les voitures électriques ont le TCO médian le plus bas, l'avantage par rapport aux autres groupes de motorisation est plus marqué. Dans la mesure où les distributions se chevauchent, la correspondance est moindre que lorsque tous les profils d'utilisation sont considérés dans leur ensemble.

Enfin, pour les voitures parcourant 30 000 km par an, les voitures électriques ont le TCO le plus bas dans toutes les classes de puissance dans lesquelles elles sont proposées, et la différence avec les autres groupes de motorisation est très prononcée.

Le régime fiscal spécifique pour les voitures de société favorise les voitures électriques

Plusieurs dispositions de la législation fiscale favorisent les voitures de société à faibles émissions de CO_2. Tout d'abord, le taux de déductibilité d'une voiture de société des bénéfices de l'entreprise dépend des émissions de CO_2 de la voiture. Les voitures électriques et les véhicules hybrides rechargeables bénéficient d'une déduction plus importante que les autres voitures. Deuxièmement, si la voiture de société est mise à la disposition du salarié en tant qu'avantage en nature, deux éléments s'ajoutent : (a) le traitement de l'avantage en nature dans l'impôt sur le revenu dépend entre autres des émissions de CO_2 (b) à l'exception des voitures de société des dirigeants d'entreprise et des indépendants, une contribution spéciale de solidarité doit être payée par l'employeur, et celle-ci dépend également des émissions de CO_2.

Dans tout ce qui suit, nous supposons que les voitures de société sont fournies en tant qu'avantage en nature et doivent donc être considérées comme des "voitures-salaires".

Notre analyse montre qu'en Flandre[2], les avantages fiscaux accordés aux voitures électriques et aux véhicules hybrides à très faibles émissions de CO_2 ont un impact considérable sur le coût total de possession des voitures-salaires.

Nous suivons la même procédure que pour les voitures particulières et identifions également les 10 modèles ayant le TCO le plus bas par classe de distance et par segment de marché.

Le schéma qui se dégage est complètement différent de celui que nous avons trouvé pour les voitures particulières, en faveur des voitures électriques. Les voitures entièrement électriques dominent dans la classe de distance la plus élevée, et ce dans trois segments de marché.

Toutefois, si nous étendons le graphique aux 50 modèles ayant le TCO le plus bas, nous constatons à nouveau que la part des voitures électriques diminue considérablement, ce qui confirme la faible diversité de l'offre. En outre, plusieurs modèles hybrides essence, et essence et diesel hybrides rechargeables figurent parmi les modèles ayant le TCO le plus bas dans les catégories de puissance et/ou de distance les plus élevées.

2 Les résultats pour les autres régions sont similaires.

La répercussion de l'avantage fiscal des voitures-salaires sous la forme d'une réduction de salaire profite particulièrement aux voitures hybrides rechargeables

Un avantage important des voitures de société du point de vue de l'employeur est qu'elles permettent aux entreprises de donner à leurs employés un avantage en nature, qui est imposé à un taux inférieur à celui du revenu salarial. Toutefois, une partie de cet avantage fiscal est répercutée sur le salarié sous la forme d'une baisse de salaire. Nous ne disposons pas de données permettant de calculer précisément l'effet sur les salaires, mais nous proposons une méthode pour calculer un plafond pour cet effet. Nous calculons donc à nouveau le TCO des voitures-salaires en partant de l'hypothèse que 50% de la valeur nette de l'avantage en nature est répercutée sous la forme d'une baisse de salaire.

Même une répercussion partielle entraîne une diminution importante du TCO pour tous les véhicules à faibles émissions de CO_2 (du moins selon les cycles d'essai), qui s'approche même de zéro dans certains cas. Cela confirme que le traitement fiscal des voitures-salaires procure un avantage financier très important aux groupes de motorisation alternatifs et qu'il ne faut pas se contenter d'examiner les effets directs, tels que le traitement de l'impôt des sociétés.

Dans la plupart des segments de marché, la gamme des 10 modèles ayant le TCO le plus bas est entièrement dominée par les voitures électriques, les voitures hybrides à essence, les voitures diesel hybrides rechargeables et les voitures hybrides rechargeables à essence.

Toutefois, si l'on considère le groupe des 50 modèles ayant le TCO le plus bas, les voitures à essence dominent parmi les voitures familiales et les SUV dans les tranches de puissance les moins élevées, ce qui confirme la faible diversité des motorisations alternatives dans ce segment de marché.

1. Introduction

According to the International Energy Agency (2021), the capital costs of electric vehicles remain a key barrier to their adoption. However, a rational purchaser would also consider the lower running costs of electric vehicles compared to conventional powertrains and take a Total Cost of Ownership (TCO) approach.

The TCO of different powertrains is not just relevant from a consumer's point of view. For policy makers, knowing how the TCO of different car powertrains vary across different market segments and usage profiles can contribute to the formulation of better focused policies to stimulate the uptake of electric cars.

Of course, besides the TCO, the consumer may care about non-monetary elements in the choice of specific car models. On top of "traditional" non-monetary elements (performance, comfort, safety, reliability), alternative powertrains are affected by barriers such as consumer scepticism, range anxiety, and high implicit discount rates. TCO calculations should thus never be the endpoint of the analysis, but they can provide useful insights for the design of discrete choice models that can capture non-monetary aspects.

In this paper, we present a framework for the calculation of the TCO of cars in Belgium.

We can summarise the contribution of this paper as follows.

First, in the literature, researchers usually impose the same annual mileage and economic lifetime on all cars to calculate TCOs. Within the population, however, there is a huge diversity in usage profiles.

These usage profiles are not entirely fixed for a given household, and moreover are also partly endogenous. For instance, since electric cars have a lower variable cost than gasoline and diesel cars, it is likely that a household switching to an electric car will adjust its behaviour. An *ex ante* analysis that assumes the same usage profiles for all powertrains ignores the fact that *ex post* usage profiles will change.

Instead of looking at TCOs for a fixed annual mileage, we therefore look at the range of TCOs for the distribution of annual mileage for a sample of Belgian households.

The advantage of considering the whole range of user profiles is that it allows us to illustrate how the diversity in usage patterns affects the relative positions of different powertrains.

Second, TCOs are usually calculated for privately owned cars. However, company cars enjoy specific tax advantages in Belgium. As the share of company cars in new car sales continues to grow, it is important to highlight how TCOs differ according to the tax advantages enjoyed by different types of owners.

A key benefit of company cars from an employer's point of view is that they allow companies to give their employees a benefit in kind, which is taxed at a lower rate than wage income. However, part of this tax benefit is passed on to the employee in the form of lower wages. We propose a method to take this additional element into account when calculating the TCO.

Third, as a result of the Belgian federal system, we also need to take into account that the license tax and the annual road tax are calculated differently in Flanders than in Wallonia and the Brussels Capital Region. Indeed, in Wallonia and Brussels, these taxes are determined by fiscal horsepower. Flemish taxes also take into account the car's CO_2 emissions and its Euro class. Our work illustrates the net impact of these differences.

Fourth, in this paper we use a different market segmentation than in previous analysis. Whereas in Franckx (2019) we presented the results by COPERT class, we now group the cars according to their body type and maximum power. While the COPERT class is important for emissions modelling, the new segmentation is more relevant from a consumer point of view.

2. Literature review

In a recent review of the literature, Franzò et al. (2022) conclude that most "of the identified contributions evaluating TCO of different powertrains are quite recent, as more than half have been published in the last three years". However, 19 out of the 40 reviewed papers referred to 2018 or even before.

Given the speed at which the costs of electric cars have decreased over the last decade, most quantitative findings in those papers are probably no longer representative. However, they can be still highly interesting from a methodological point of view. In this section, we look at the issues that are the most relevant for the current paper.

First, as Santos and Rembalski (2021) point out, if the objective of the study is to develop an understanding of the level of public support that would be needed to achieve cost parity between conventional and alternative powertrains given the resource costs involved in producing cars, the relevant metric is the TCO before taxes and subsidies. Cox et al. (2020) also exclude taxes or subsidies on vehicle purchase and insurance costs as these are not affected by the physical performance of the vehicle.

If, on the other hand, the objective is to understand the cost gap in the current policy context, than the TCO after taxes and subsidies is appropriate.

In this paper, we report the TCO after taxes and subsidies. This reflects our interest differences in the fiscal treatment between the three Belgian Regions, and between privately owned cars and company cars. Note that 37 out of 40 papers surveyed by Franzò et al. (2022) cover only privately owned cars. Our separate discussion of company cars thus adds to a small literature that merits more attention.

Second, a few authors include monetary indicators of barriers to the adoption of alternative powertrains that are not included in the direct costs of a car. For instance, Hao et al. (2020) approximate the cost of range anxiety by the cost of finding alternative transportation for trips that exceed an electric car's range. Note that, by doing so, they depart from a strict TCO approach: their value of the TCO depends on assumptions on how the car's owner would behave in specific, hypothetical circumstances. In a discrete choice model, this proxy to the cost of range anxiety would probably be included as a separate independent variable.

Third, a TCO can be calculated either from the perspective of the first owner or from the entire lifetime until scrapped.

The calculation of the TCO from the perspective of the first owner requires an estimate of the number of years during which the first owner will hold its car, and of the value on the second-hand market.

Given that the resale value of the car is the most important part of the TCO (Lévay et al. 2017), the key question is then whether reliable estimates exist of a car's depreciation during the period of first ownership.

While estimates of the depreciation of conventional powertrains can fall back on decades of observed transactions, the situation for alternative fuels is more contentious. Several authors have argued that electric cars depreciate faster than conventional cars, as the quality of new batteries improves so fast that the offer on the second-hand market has a hard time competing with new models (Brückmann et al. 2021, Lévay et al. 2017, Schloter 2022, Scorrano et al. 2019). However, at some point in the future, the market for electric cars is likely to get more mature, and then this assumption could be reversed (Danielis et al. 2018). Hoekstra et al. (2017) argued that resale values for electric cars are low because people are unfamiliar with and untrusting of the new technology.

Given that it is only recently that electric cars have achieved non-negligible market shares, the body of evidence for the depreciation of electric cars is much less solid than for conventional powertrains (Brückmann et al. 2021).

In a recent empirical analysis of publicly available data of 24,000 used vehicle sales, Schloter (2022) finds that electric vehicles have a substantially higher depreciation of 13.9% per annum compared to gasoline vehicles with 10.4% per annum.

However, based on three experiments in Switzerland, Brückmann et al. (2021) find the opposite of resale anxiety: a higher expected resale value of BEVs compared to conventional cars. Also, in a survey in Sweden, it was found that only 8% of the respondents included depreciation and interest cost in their cost computation (Hagman et al. 2017). In other words, there appears to be a large discrepancy between the objective cost of depreciation and the attention paid to it by potential buyers.

In summary, we are still far from a consensus on how to deal with the resale value from the perspective of the first owner.

One way to deal with this uncertainty is to apply a Monte Carlo simulation to the future resale price (as Danielis et al. 2018). Alternatively, several authors have opted for a lifetime perspective, assuming a zero (or very small) salvage value (Cox et al. 2020, Rusich and Danielis 2015, Santos and Rembalski 2021) at the end of a vehicle's economic lifetime. In those cases, expected lifetimes range from 10 (Rusich and Danielis 2015) to 16 (Cox et al. 2020) years. Franzò et al. (2022) consider 4 different values: 6, 8, 10 or 11 years.

In this paper, we will adopt such a lifetime perspective, except for company cars.

Fourth, the high level of uncertainty regarding key parameters (such as the future evolution of fuel and electricity prices, the energy storage density of batteries or the battery's lifetime) is widely acknowledged in the literature. Several authors (Cox et al. 2020, Danielis et al. 2018, Hao et al. 2020, Wu et al. 2015) have used Monte Carlo analysis to deal with these uncertainties.

Fifth, the vast majority of analyses compares the TCO of a limited number of cars that are similar according to most characteristics except for their powertrain, or that are considered "representative" for a market segment (where "representative" is usually defined as "the model with the highest sales"). According to Franzò et al. (2022), most analyses only consider a limited number of segments.

An alternative to working with "real" cars is to work with a bottom-up technical approach such as in Cox et al. (2020), who start from a common platform to all powertrain types (the "glider") and who define only the most basic design parameters for a vehicle as independent input parameters. In this approach, vehicle energy consumption, for instance, "is not defined as an input parameter, but is rather calculated based on input values such as the vehicle mass, driving patterns, aerodynamic characteristics, and rolling resistance".

A key contribution of our paper is that, even though we perform the comparison at the level of market segments, we consider the whole range of cars that have been sold on the Belgian market in 2021.

Sixth, most analyses do not take into consideration the heterogeneity of use profiles. One obvious source of heterogeneity is that households vary in their mobility needs and thus also in annual kilometres travelled. This is an element that is taken into account by, for instance, Bubeck et al. (2016), Danielis et al. (2018), Scorrano et al. (2020) and Franzò et al. (2022).

We use the Monitor survey to obtain a distribution of use profiles that is based on a representative sample of the Belgian population (see below).

3. Data sources

As mentioned above, the TCO depends not only on the technical characteristics of a car, but also on the mobility behaviour of households.

We therefore do not limit ourselves to calculating the TCO for an average household: we take a sample from the Monitor survey conducted by the FPS Mobility and Transport. For each household in the sample, we calculate the TCO of each car sold in Belgium in 2021, for the average number of kilometres this household travels on an annual basis. Since we know the Region where the household is domiciled, and whether the car in question is a company car or not, we can take these elements into account in calculating the TCO.[3].

We obtained under license from a commercial data provider (S&P Global Mobility) a database (henceforth the "S&P dataset"[4]) containing the list prices and main technical characteristics of all new cars purchased in Belgium from 2020 to 2022. We combined this data with data from the European Environmental Agency to estimate fuel consumption and CO_2 emissions according to the WLTP test cycle. This information allowed us to calculate all taxes on passenger cars in Belgium, including all taxes specific to company cars.

We also used the fuel consumption according to the test cycle to calculate the cost of fuel consumption - in other words, we do not calculate the TCO in real world driving conditions, but the TCO that would be estimated by a consumer who uses the car's certificate of conformity as a source of information.

A second important data source was the Belgian Mobility Survey Monitor, which combines socio-demographic data with data on household travel behaviour and cars used by the household (including non-household owned cars such as company cars).

Thirdly, we used a database on maintenance costs from the German car club ADAC to construct a predictive model of annual maintenance costs for each car model in our database (see Annex 2 for the details).

3.1. Annual kilometres travelled per power train and age class

We calculated, for each car from the S&P dataset, the TCO for each household from the Monitor survey. One of the parameters used here (besides the Region in which the household lives) is the number of kilometres the household travels on an annual basis with the car in question.

3 We do not know, however, whether the company car is a leased car. We therefore assume that the company cars are subject to the license tax and annual road tax in force in the Region in which the household is domiciled.

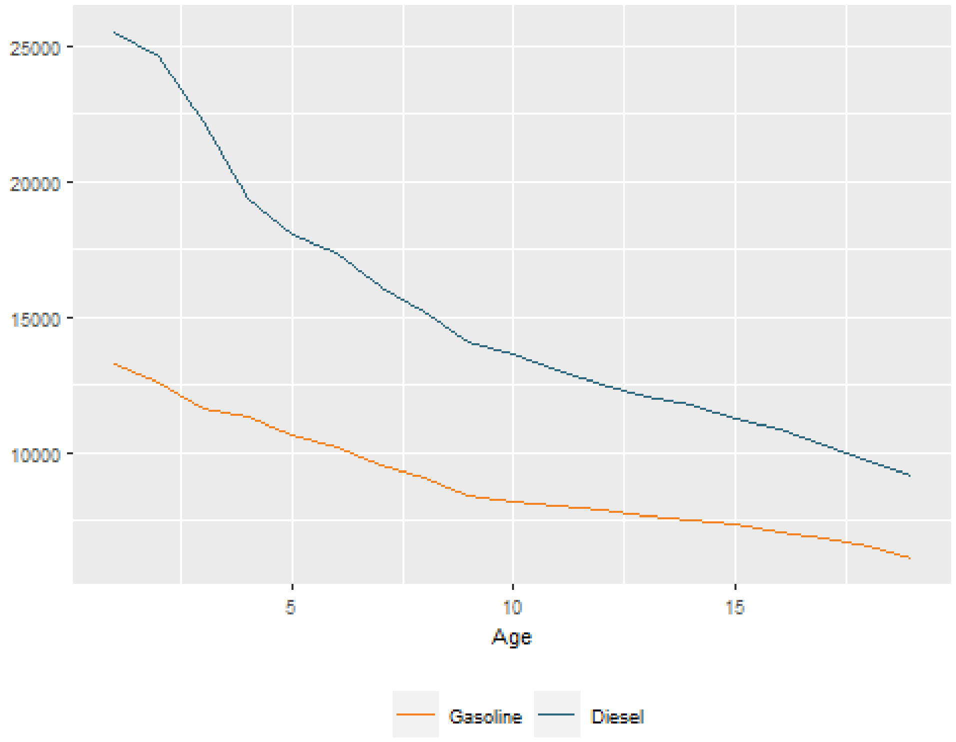
4 Includes content supplied by S&P Global Mobility; Copyright © New Vehicle Registration database, December 2022. All rights reserved; S&P Global is a global market leader of independent industry information. The permission to use S&P Global copyrighted reports, data and information does not constitute an endorsement by S&P Global of the manner, format, context, content, conclusion, opinion or viewpoint in which S&P Global reports, data and information or its derivations are used or referenced herein.

In other words, in each case we compare the TCO of different car models for a given mobility need. Inevitably, the TCO of a given car model will vary as a function of these mobility needs. It also follows that the choice of a given model will partly depend on these needs: a household that travels a lot of kilometres on an annual basis will, for example, rather choose a car with lower variable costs.

This is illustrated with Graph 1 which gives the annual distance travelled by diesel and gasoline cars in the Belgian car fleet in 2017, the last year for which we have complete data by propulsion technology and age class. We find (as expected) that diesel cars cover more kilometres on an annual basis than gasoline cars. It is also clear that the number of kilometres driven is a decreasing function of car age.

For the other powertrains, a clear pattern is not really discernible, if only because observations are not always available for all age categories. They have therefore been omitted from the graph.

Graph 1 Annual distance travelled as a function of age
Km per year



Source: Own calculations based on data from the FOD Mobility and Transport

3.2. The expected lifetime of a car

While the Monitor survey contains data on the annual distance travelled by cars for each household, it does not include data on the intended lifetime of cars.

Table 1 gives the median and mean ages at which privately owned gasoline and diesel cars were withdrawn from circulation between 2002 and 2019. In general, diesel cars are withdrawn from circulation faster than gasoline cars.

In what follows, we calculate the TCO under the assumption that the expected lifetime at new purchase is 10 years for all car models – this is between the average lifetime of diesel and gasoline cars.

Table 1 Age at retirement from Belgian car stock.

Cartype	Mean	Median	Standard deviation
Gasoline	11.3	12	4.6
Diesel	9.1	9	4.5

4. The components of the TCO

The Total Cost of Ownership consists, on the one hand, of the fixed costs when purchasing a car and, on the other hand, of the net present value of the annual costs:

$$TCO = (1 + VAT_{car})\ p_x + BIV - \frac{RV}{(1+i)^n} + \frac{1-(1+i)^{-n}}{i}\left(\left[1 + VAT_{fuel}\right] p_y\ y + AnnFixCosts\right)$$

where p_x is the the purchase price of the car, VAT_{car} is the VAT on the purchase price, BIV is the license tax, n is the economic lifetime of the car, RV is the residual value, i is the discount rate, VAT_{fuel} is the VAT on fuel, p_y is the price of fuel/electricity (excises and other duties included), y is the annual fuel/electricity consumption and $AnnFixCosts$ are the annual fixed costs. This formulation of the TCO assumes that the annual costs remain constant through time.

The annual fixed costs are broken down into the following components:

– the annual road tax;

– insurance costs;

– periodic control costs

– maintenance costs, VAT included.

Annex 1 discusses the different components of the annual costs in more detail. For the sake of conciseness, we shall from now on use “fuel cost” to refer to both the cost of fuel consumption and the cost of electricity consumption.

Both the BIV and the annual road tax are regional competences. In Wallonia and the Brussels-Capital Region, they are mainly determined by the fiscal horsepower of the car. In Flanders, the Euro class and the CO_2 emissions also play an important role in the calculation of these taxes. We discuss these elements in more detail in Annex 5.

To calculate the TCO, we proceeded as follows:

– For each household-car combination in the Monitor survey, we know: (a) the region of the household (b) whether the car is owned by the household or the business (c) the annual mileage.

– For each individual car in the S&P Global Mobility database, we calculated the TCO for each household in a subsample of the Monitor, taking into account: (a) the region where the household lives, which (in combination with the car’s CO_2 emissions, Euro class and fiscal horsepower) determines the license tax and annual road tax (b) whether the car is a company car - in which case we take into account that the cost of the cars is (partially) deductible from corporation tax and (partially) exempt from VAT (c) the number of kilometres driven by that household per year, which determines the fuel and/or electricity costs.

As discussed in the literature review, in this paper, we calculate the TCO for the entire economic lifetime of the car, rather than from the perspective of the first user. In the absence of data on the scrap value of cars, we set $RV = 0$. We thus assume implicitly that new car prices reflect buyers' expectations of future resale prices.

For company cars, we make specific assumptions regarding life cycle and value on the second-hand market. These are discussed in more detail in Chapter 0.

5. TCO for privately owned cars

We now proceed to compare the TCO of new cars purchased by individuals in 2021.

We use an annual interest rate of 3.5% - this corresponds to the interest rates we found on www.beste-autolening.be, a website specifically dedicated to comparing car loans on the Belgian market.

When comparing the TCO of different powertrains, it is important to compare only models that are potential substitutes for each other: it makes little sense to compare the TCO of a small city car with the TCO of an SUV with a different powertrain. We therefore partition the cars on offer in market segments according to two criteria: (a) the body type of the car (b) the maximum power of the engine.

Since people do not choose an "average" car, we compare the distribution of TCO for all passenger car models offered on the Belgian market in 2021. This is an important difference from the approach commonly used in TCO calculations, which usually compares a limited number of cars that the researcher considers to be "close substitutes" and "representative" for a whole market segment.

For the body types, we relied on the classification used in the S&P database. As the S&P classification is very detailed, we have grouped different body types - see Table 2. Note that in this paper, the term "van car" refers to vehicles that are (from a tax point of view) passenger cars but have a "van like" appearance, such as for instance a Citroën Berlingo with passenger seats in the back. Light duty vehicles are not part of the subject of this analysis.

Since camper vans and minibuses cannot really be considered to be passenger cars, we omit them from further analysis.

Because of their low market share and atypical profile, we are also not going to retain convertibles and sports cars in the presentation of the results.[5].

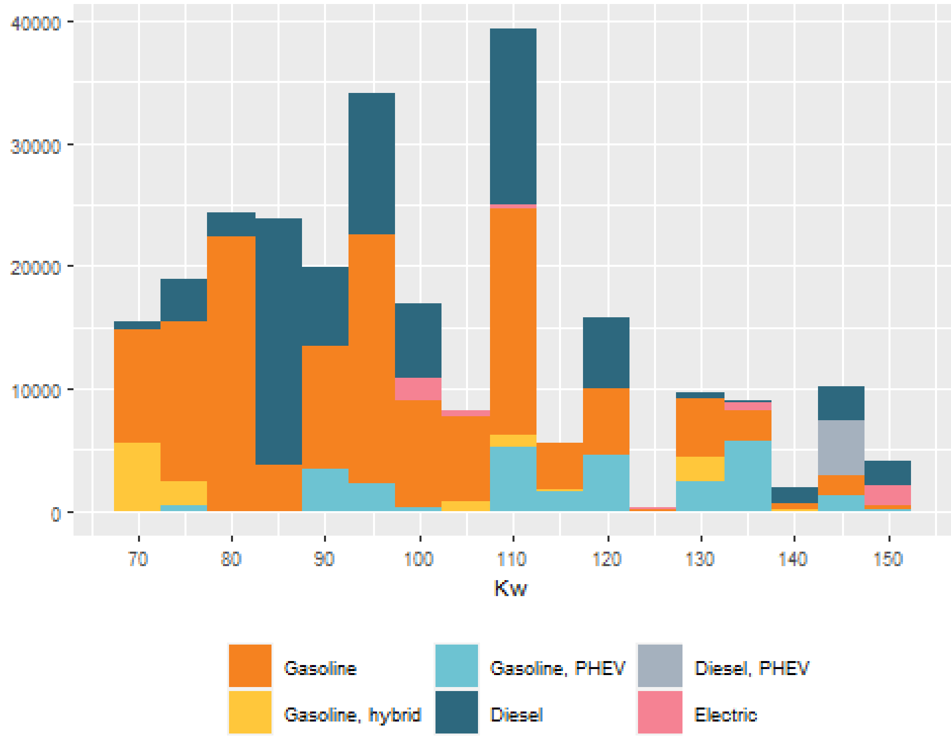
Table 2 Simplified body types

Body type in S&P database	Simplified bodytype	Market shares (%)
Convertible, Retractable Hardtop , Targa/T-Roof	Convertible	0.80
Coupe, Roadster	Sportscar	1.82
LCV Combi Van, Estate High Volume	Van car	3.00
Hatchback , Sedan, Monospace, Wagon	Family car	41.68
SUV Closed , SUV Open, Pickup Double Cab, SUV Pickup	SUV	52.53
LDV Recreational Van , LCV Recreational Van	Camper	0.00
LCV Van Bus	Minibus	0.17

We define 4 powerclasses based on maximum power: 70 to 89 kW, 90 to 109 kW, 110 to 129 kW and 130 to 150 kW. Cars with very small or very large maximum power are thus not included in the presentation of the results.

[5] The comparison for these body types is available on request

Graph 2 **Distribution of maximum engine power**
Cars sold per powertrain.



Source: Own calculations based on S&P data

5.1. Regional differences in TCO

As mentioned above, the license tax (BIV) and the annual road tax are a regional competence, and are calculated differently in Flanders than in Wallonia and the Brussels Capital Region.

For all car models that are sold in the three regions in 2021, we have calculated the difference (in percentages) between the TCO in Wallonia on the one hand, and the TCO in Flanders on the other hand. Table 3 represents the average difference. To keep the results clear, we have limited ourselves to the most common powertrains and have not broken down the segments further by body type. "NA" means that the market segment in question is not available in at least one of the regions.

This shows that the TCO for all powertrains and power classes is higher in Wallonia than in Flanders. Comparisons between Brussels and Flanders reveal similar patterns.

Note that we have to be careful when interpreting this result.

Firstly, in Table 3, we consider only the models offered in the two Regions. In contrast, if we take the average TCO by region and market segment for all cars sold in at least one region, the difference between these averages is less pronounced. For example, there are models sold in Flanders but not in Wallonia, and their TCO is on average 9.3% higher than that of models sold in the three Regions. However, the TCO of models sold only in Wallonia are on average only -0.5% higher than those of models sold in the three Regions.

Second, these averages hide important differences at the level of individual models: for some models, the TCO is higher in Flanders than in the other Regions.

Third, our calculations refer to new cars sold in 2021: they say nothing about the prices and license taxes paid for second-hand purchases or about the annual road taxes levied on the cars in the fleet. In other words, if the car fleet in Wallonia has a higher proportion of used cars than the Flemish car fleet, the effective purchase prices and the license and road taxes paid by residents of those regions may be lower. Even with these caveats in mind, it is clear that we need to differentiate our detailed results according to the region where a car is sold.

Table 3 Difference in average TCO between Wallonia and Flanders (cars sold in all regions)

Cartype	70-89 kW	90-109 kW	110-129 kW	130-150 kW
Diesel	20.5	17.8	15.8	14.2
Diesel, PHEV	NA	NA	NA	8.1
Electric	NA	12.0	10.3	11.5
Gasoline	24.2	22.0	19.4	17.3
Gasoline, hybrid	18.7	16.7	15.0	13.4
Gasoline, PHEV	13.7	13.6	14.2	14.0

5.2. The distribution of the TCO for all usage profiles (Wallonia)

In this section, we first look at the distribution of TCO across all usage profiles in the Monitor survey. In other words, the distribution reflects both the differences in technical-financial characteristics of the cars and the diversity of the usage profiles (in particular, differences in annual distance travelled per car). If it turns out that the lowest deciles of the TCO for a given powertrain are systematically higher than the highest deciles for all the other powertrains, we can conclude that this powertrain has a higher TCO than the alternatives for (almost) any value of the annual distance travelled by Belgian households. This will allow us to identify powertrains that are “dominated” in a given market segment.

This analysis will be complemented in Sections 5.3 and 5.4 by an analysis from the perspective of households with a predetermined annual travel demand.

For the sake of clarity, we limit our discussion here to the results for Wallonia - except for the different distribution of usage profiles, the same findings apply to the Brussels Capital Region. In Annex 3, we present the results for Flanders, which are also very similar, despite the differences in the fiscal regime.

Graph 2 shows the boxplots of TCO by market segment. Each boxplot is bounded at the bottom by the first quartile of the distribution of TCO, and at the top by the third quartile. The thick horizontal line is the median of the distribution. The thick dots below and above the boxplot itself represent the outliers.

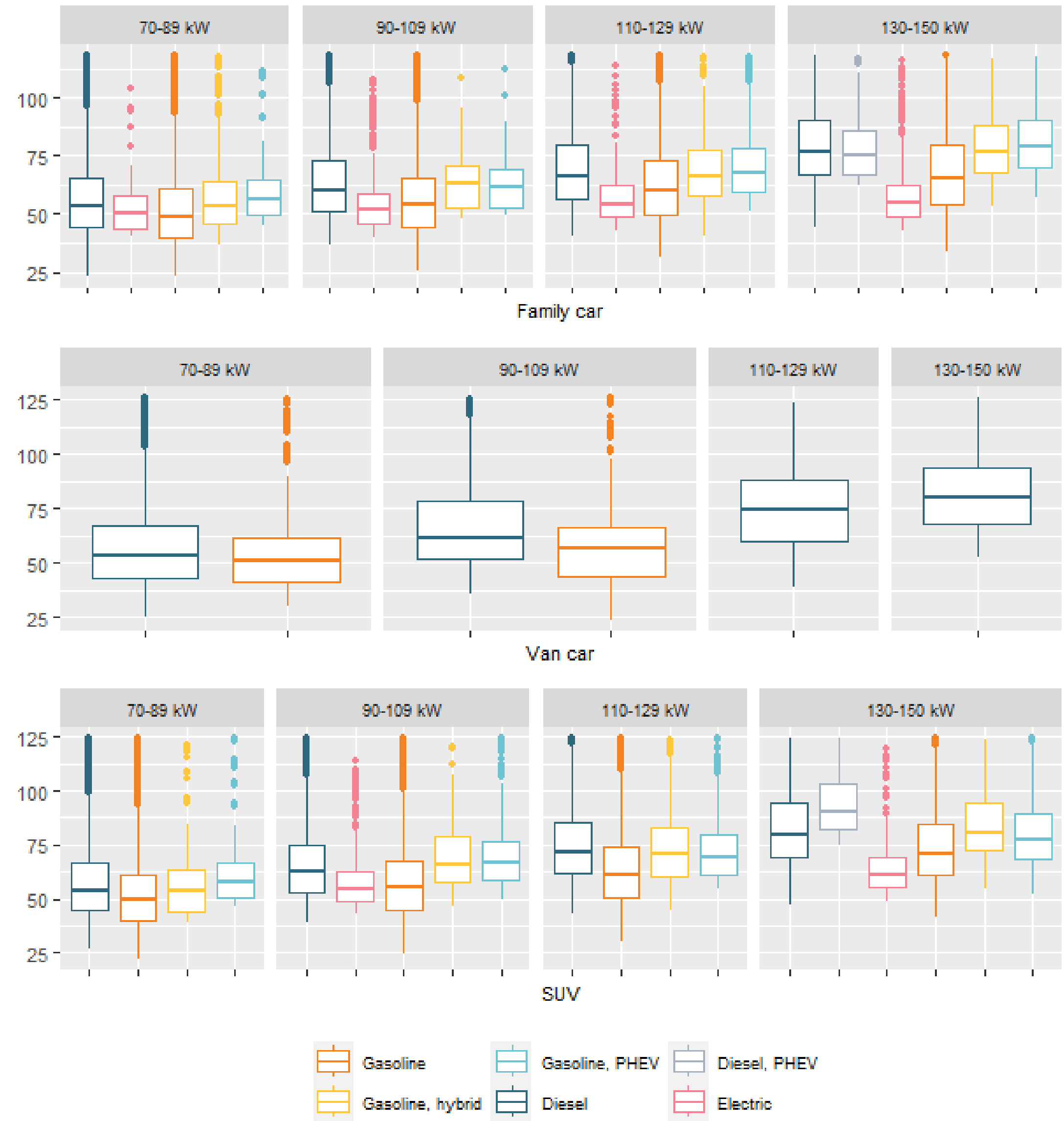
It is immediately clear from the graphs that there is no market segment where one powertrain clearly outperforms the others, or is outperformed by the alternatives:

– Among “family cars”, electric cars have the lowest median TCO, except for cars with maximum power between 70 and 89 kW, where gasoline cars score best. The median TCO for diesel cars, gasoline hybrids and gasoline plug-in hybrids (PHEVs) is significantly higher than for electric and gasoline cars, especially in the higher power classes. There is, however, a large overlap in the boxplots, especially in the lower power classes. The first quartile for gasoline cars is even below that of electric cars in the 90-109 kW power class. Diesel-PHEVs are only offered in the highest power class.

– Van cars are only available with gasoline or diesel engines, and gasoline cars are only offered in the lower power classes. Gasoline cars have the lowest median TCO in the market segments in which they are offered (the two lowest power classes), but the differences with diesel cars are not pronounced.

– In SUVs, electric cars score best for cars with maximum power between 130 and 150 kW, otherwise gasoline cars have the smallest median TCO. Electric cars are not sold in the first and third power classes. Except in the lowest power class, the median TCOs of diesel cars, gasoline hybrids and gasoline PHEVs are significantly higher than the TCOs of electric and gasoline cars.

Graph 3 Distribution of the TCO (Wallonia, privately owned cars)
Total cost of ownership (1000 EUR) per market segment and powertrain



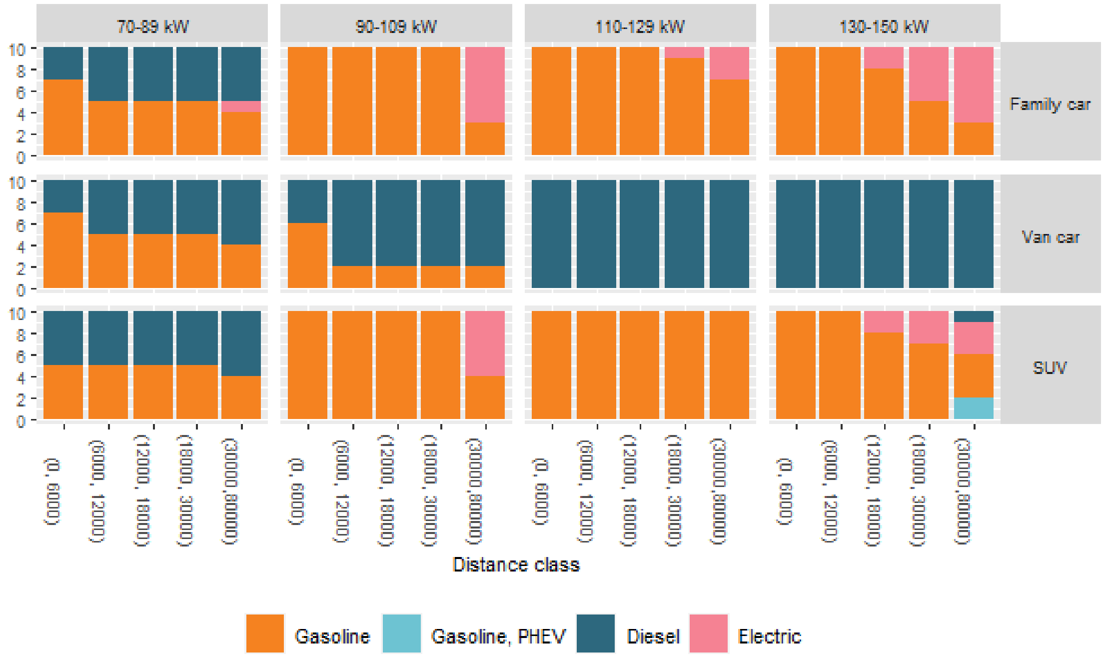
Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Another way to look at the results is represented in Graph 4. We have grouped our data in distance classes, where each distance class is defined by the quintiles of the annual kilometre travelled in Wallonia. For each car, we have recalculated the TCO for the average annual distance travelled in that distance class. Finally, for each distance class and market segment, we have identified the ten models with the lowest TCO. Graph 3 gives the count per powertrain for this group.

In almost all cases, the group with the ten lowest models with the lowest TCO is dominated by gasoline and diesel cars. It is only for the highest distance class that there are also electric cars among the ten models with the lowest TCO, and only in 6 out of the 12 market segments. It is only in the highest power and distance class that there also gasoline PHEVs among the top ten. This implies that the relatively low median value for the TCO of electric cars that we had observed in some market segments is mainly due to the use profiles with a high annual mileage.

Graph 4 10 models with lowest TCO per market segment and distance class (Wallonia, privately owned cars)

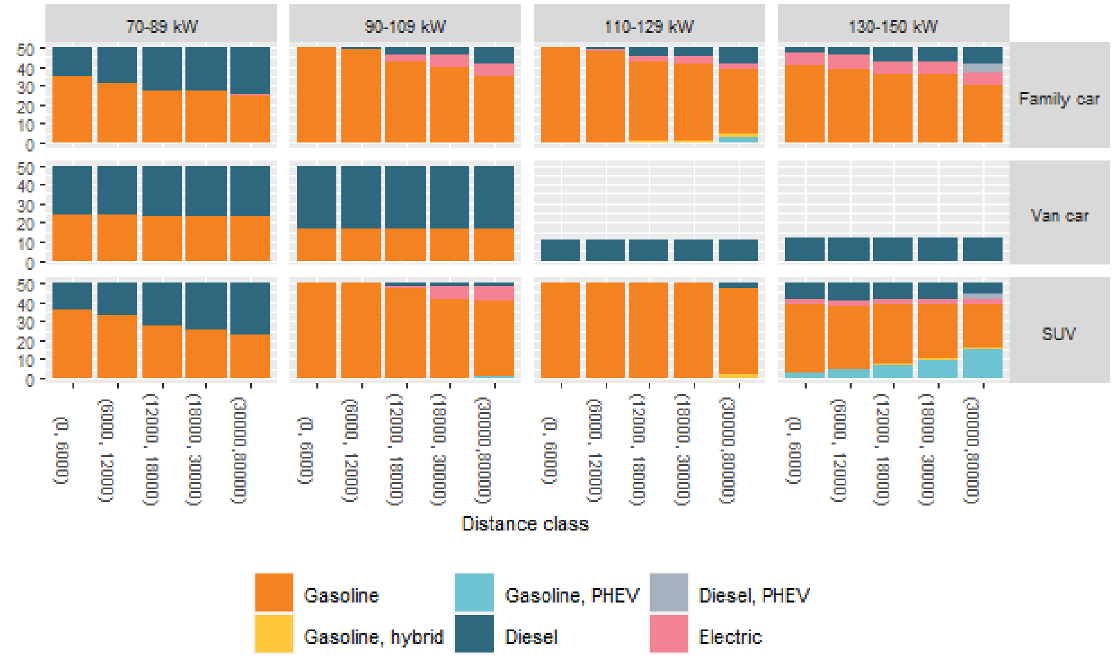
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

In Graph 5, we repeat this exercise for the 50 models with the lowest TCO per market segment and distance class. The share of electric cars is much lower than if we focus on the 10 models with the lowest TCO: this confirm that, within each market segment, there is a limited number of different electric models on offer, and that those are mostly concentrated among the cheaper (from a TCO perspective) models. There is also a limited number of gasoline hybrids, gasoline PHEVs and even diesel PHEVs among this "top 50". Note also that in some market segments (LDV with a maximum power above 100 kW), there are less than 50 models on offer on the market.

Graph 5 **50 models with lowest TCO per market segment and distance class (Wallonia, privately owned cars)**
Number of models per market segment and powertrain



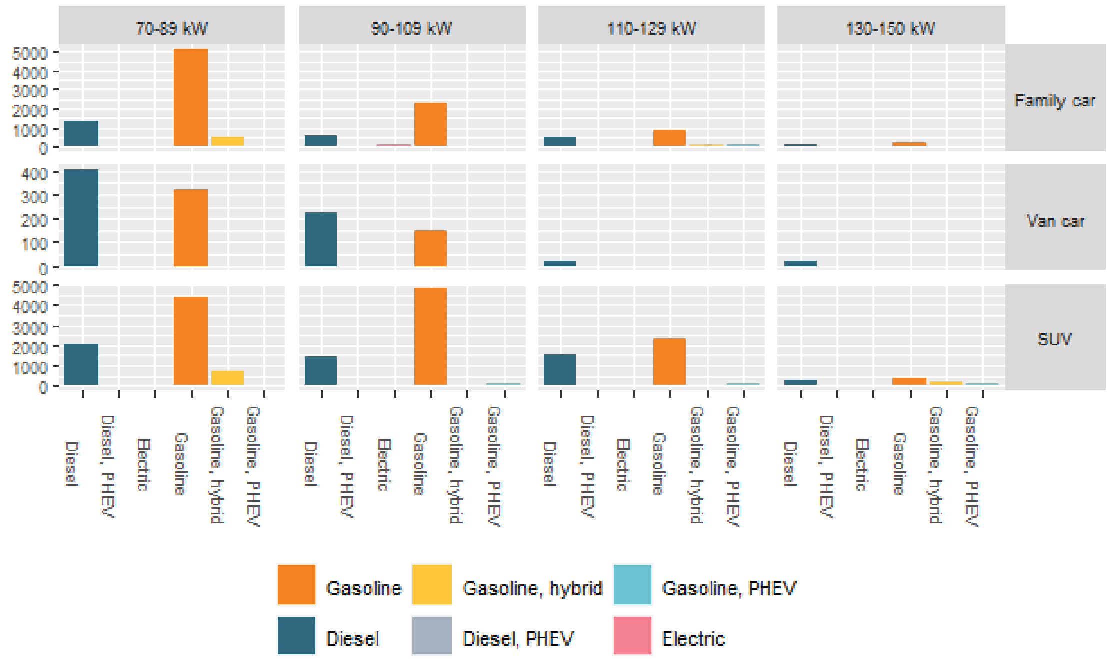
Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

However, it is important to bear in mind that the TCO is only one of the elements that plays a role in the purchase of a car, and that a low TCO does not necessarily imply that a car model will have a high market share.

This can be seen very clearly in Graph 6, where we present the total sales of passenger cars to households in Wallonia, broken down by market segment. This clearly shows that very few cars are sold in the power class above 131 kW, and this regardless of body type. Few cars are also sold in the 111 to 130 kW power class, except SUVs. Among family cars, almost all cars are bought in the lowest power class.

In addition, the very low sales of electric cars also stand out, even in market segments where they have the lowest median TCO.

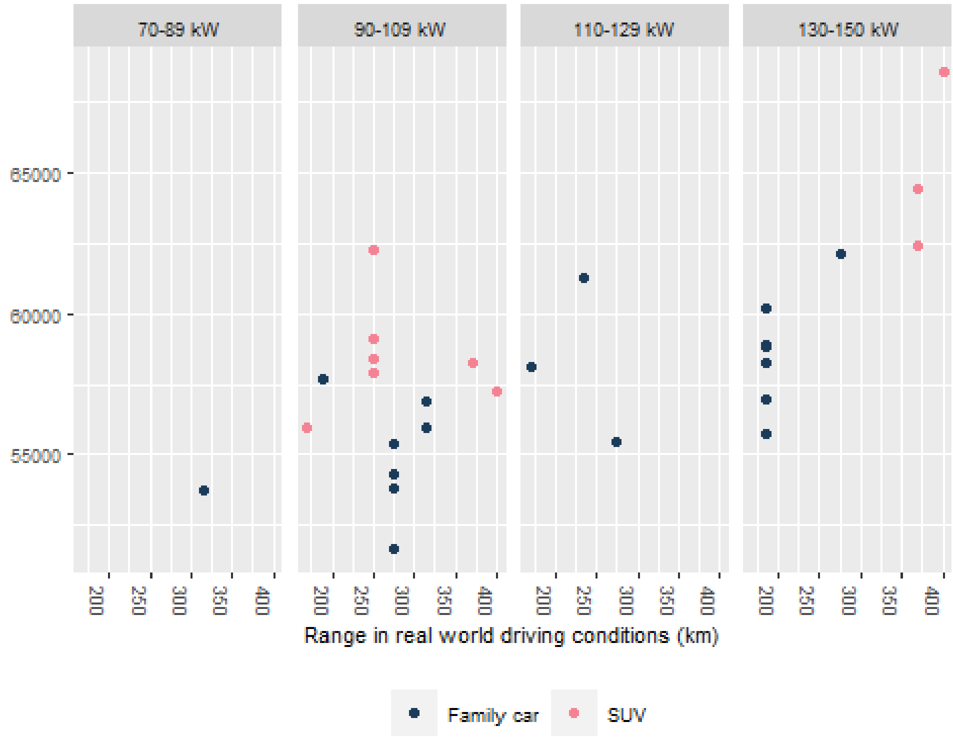
Graph 6 Sales per market segment and powertrain (Wallonia)
Cars sold



Source: Own calculations based on S&P data

This apparent paradox can be better understood by looking at Graph 7, where we present the relationship between the range of electric vehicles and their TCO. This clearly shows that the cheaper electric models tend to have a very low range, which is a significant disadvantage compared to internal combustion engine vehicles. This illustrates the need to complement TCO analyses with discrete-choice models, which can indeed take such non-monetary elements into account.

Graph 7 **Range electric cars versus TCO (Wallonia)**
Total cost of ownership (EUR)



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data. The ranges of individual electric vehicles have been gathered from various open access Internet sources.

In summary, differences in median values say very little. In each market segment, there is a significant overlap in the TCOs of different powertrains. This overlap results not only from differences in the technical characteristics of cars and their purchase price, but also from the diversity in use profiles. Because TCOs take nothing but monetary factors into account, they in themselves have very limited predictive power when it comes to the market shares of different powertrains.

5.3. The distribution of the TCO for an annual driving distance of 15 000 km (Wallonia)

As already pointed out above, by considering the whole range of user profiles, we illustrate how the diversity in usage patterns affects the relative positions of different propulsion technologies. That we have found no powertrain with the boxplot of TCOs that is almost entirely above or below the distribution for all other propulsion technologies, is in itself a relevant finding.

On the other hand, of course, a given household travels a given number of km per year, and so, from the user's point of view, the only sensible comparison is one in which we assume a *given* mileage.

Here we look at the distribution of the TCO for households driving 15,000 km a year - just a little more than a new gasoline car, but far below a new diesel car (see Graph 1). We summarise the results for cars owned by Walloon households, but the results for the other regions are similar.

Comparing Graph 8 with Graph 3, we notice that little changes in the ranking of the median TCO, but that the shape of the boxplots changes completely. Because we now consider only one usage profile, the distribution is much more concentrated around the central values.

In the 5 market segments where electric cars have the lowest median TCO, the advantage over the other powertrains is now very pronounced. To the extent that the boxplots overlap, it is much less so than when all use profiles are considered together.

This greater concentration is particularly striking in the case of electric cars, where the three first quartiles are very close together. This confirms that the total number of models on offer for electric and hybrid cars is much lower than for diesel and gasoline cars.

This confirms what we had already observed in Graph 5: there is a lower diversity of supply in electrified cars - this, on top of the limited autonomy of electric cars, is a disadvantage compared to combustion engine cars.

Graph 8 Distribution of the TCO for annual travel distance of 15 000 km (Wallonia, privately owned cars)
Total cost of ownership (1000 EUR) per market segment and powertrain

Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

5.4. The distribution of TCO for intensive users (Wallonia)

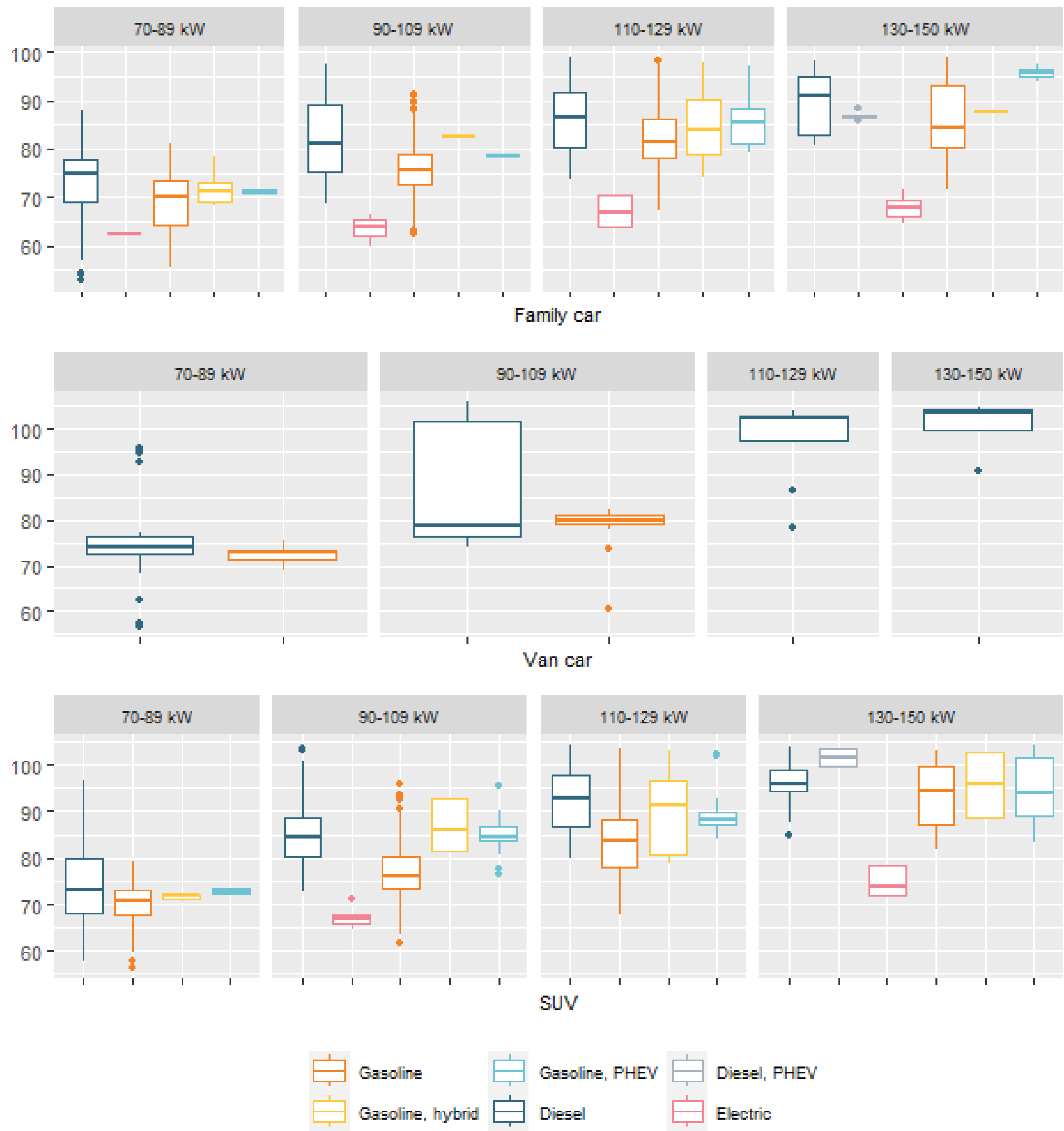
As electric and hybrid cars are characterised by high purchase costs and low running costs, it is interesting to also take a look at how their TCO compares with other powertrains for cars that are used exceptionally frequently. Here, we look at the distribution of TCOs for users travelling 30 000 km per year, which is above the average annual distance travelled by new diesel cars (Graph 1).

This exercise is also useful because future owners of electric cars are likely to use them more intensively than the cars with traditional powertrains that they currently use - we cannot assume that their current usage profile will remain unchanged.

Graph 9 shows that, with this annual distance travelled, electric cars have the lowest TCO in all power classes in which they are offered, and that the difference with the other powertrains is very pronounced. For SUVs, depending on the power class, electric or gasoline cars can all have the lowest median TCO.

If we compare Graph 9 with Graph 8, we find, as expected, that with a very high annual mileage, the advantage of electric cars becomes much more pronounced, at least in the market segments where they are offered. No other powertrain offers a clear advantage over the others.

Graph 9 Distribution of the TCO for annual travel distance of 30 000 km (Wallonia, privately owned cars)
Total cost of ownership (1000 EUR) per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

6. TCO for salary cars in Flanders

All the results we have discussed so far relate to cars purchased by private individuals.

However, the comparison will be different for company cars, as company cars are subject to a specific tax regime. The details of this are covered in detail in Annex 5.

Here we limit ourselves to the main points. First, the extent to which the cost of a company car is tax deductible from company profits depends on the car's CO_2 emissions. Electric cars and plug-in hybrids enjoy a larger deduction than other cars.

Second, company cars also enjoy a (partial) VAT deduction.

Third, if the company car is made available to the employee as a benefit in kind, two more elements are added: (a) the treatment of the benefit in kind (VAA) in income taxation depends on the CO_2 emissions (b) except for company cars for company managers and the self-employed, a special solidarity contribution has to be paid by the employer, and this also depends on the CO_2 emissions.

Fourth, part of the benefit in kind is not deductible from corporate profits.

When comparing the TCO of different types of company cars, the differences in tax treatment should be taken into account. In everything that follows, we assume that company cars are made available as benefits in kind, and should thus be considered "salary cars".

In the case of salary cars, we should also take into account that part of the real value of the benefit in kind will be passed on in employees' wages (the employer will be able to offer a lower wage if he provides a salary car). We do not have data that allow us to calculate exactly how big the impact on wages will be, but we can estimate an upper bound - we refer to Annex 6 for the calculation method.

We will therefore calculate the TCO of salary cars in two different ways. First, we will only look at the direct costs associated with the purchase and use of salary cars. In a second step, we will also take into account the real value of the benefit in kind for the salary car user, under the assumption that 50.0% of this benefit is deducted from wages.

In what follows, we assume that salary cars are resold after three years at one-third of their original value (see Copenhagen Economics 2010).

As we did for privately owned cars, we take into account that the license and road taxes vary across regions and the sector of the owners: leasing companies and cars own by other companies in Wallonia and the Brussels Capital are subject to the same taxes[6] while different calculation methods apply in Flanders. We look here at the TCO for salary cars registered in Flanders by other companies than leasing companies, while Annex 4 covers the other fiscal regimes.

[6] Except that in Wallonia, a so-called ecomalus is added to the license tax for cars with very high CO_2 emissions.

Here as well, we look at the distribution of TCO across all use profiles for salary cars.

Graph 10 shows the boxplot of the TCO for all powertrains and market segments. Since some cars have an extremely high purchase price, we leave out the cars with the 5% highest TCO in the graphical representation.

It is immediately clear that the tax breaks for electric cars and PHEVs with very low CO_2 emissions have a significant impact on the TCO for salary cars.

First, among family cars, electric cars have the lowest median TCO across all power classes. The median TCO for diesel cars, gasoline hybrids and gasoline PHEVs are significantly higher than for electric cars.

Second, among van cars, it is always diesel or gasoline cars (according to power class) that have the lowest TCO.

Third, among SUVs, electric cars score best for cars with maximum power between 91 and 110 kW, and between 131 and 150 kW. In the other power classes, gasoline cars have the lowest median TCO.

Graph 10 Distribution of the TCO (Flanders, salary cars)

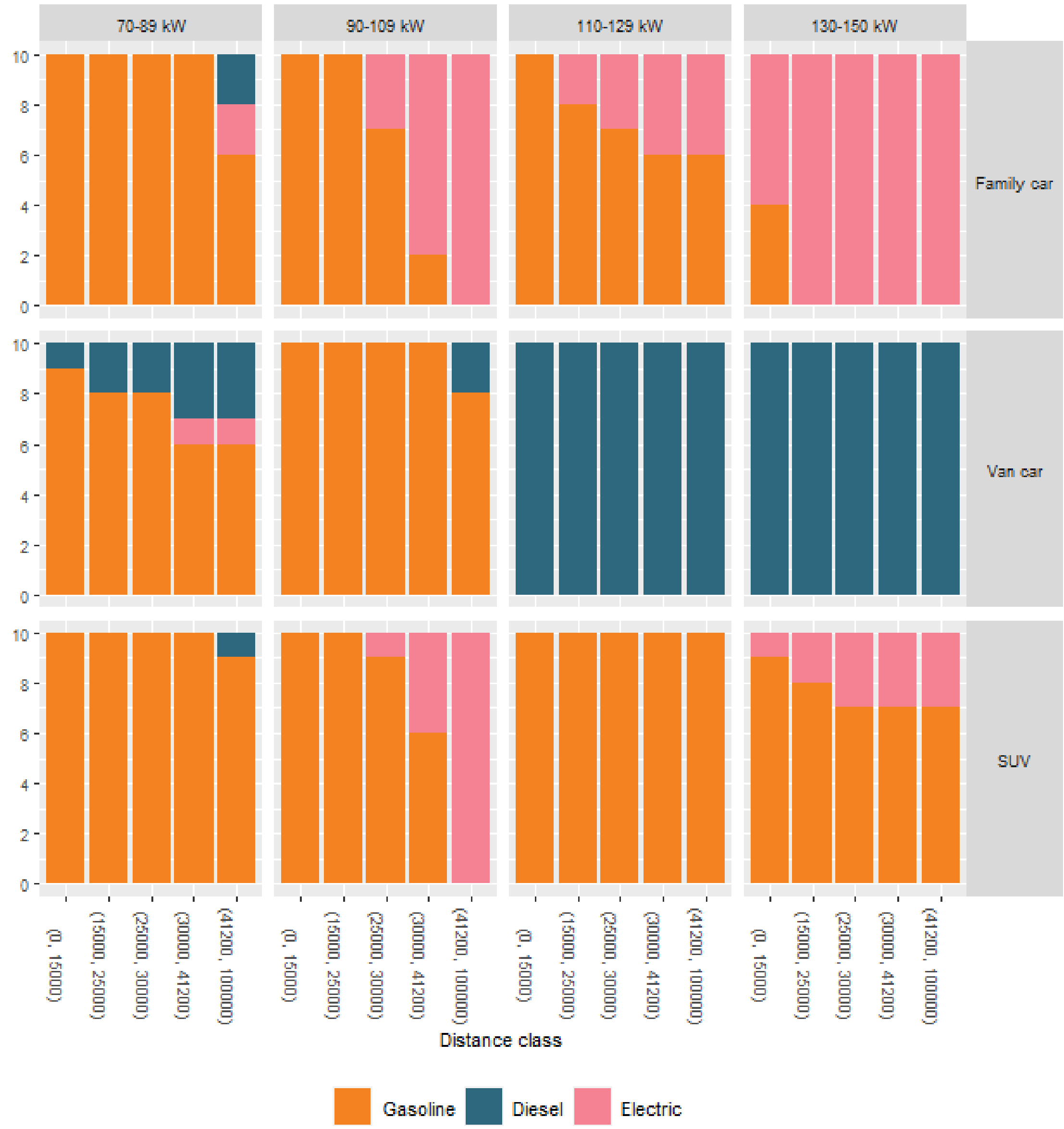
Total cost of ownership (1000 EUR) per market segment and powertrain

Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

We follow the same procedure as we did for privately owned cars and identify the ten models with the lowest TCO per distance class and market segment (Graph 11).

The pattern that emerges is completely different from what we found for privately owned cars. Fully electric cars dominate the highest distance class in three market segments. Among family cars, they score very well, except in the lowest distance classes and the lower power classes. Except in the van segment, diesel cars are almost completely absent from the set of salary cars with lowest TCO.

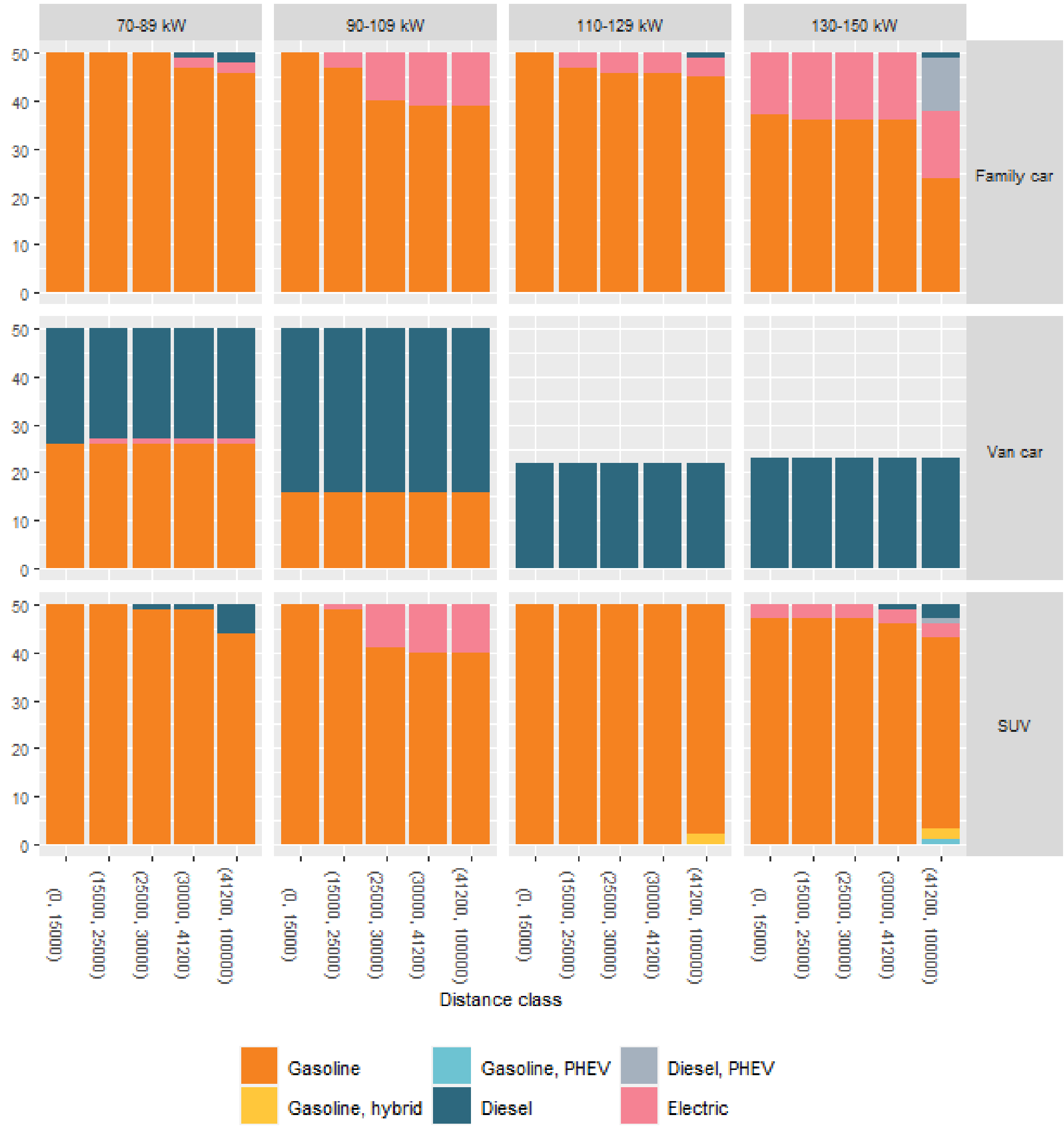
Graph 11 10 models with lowest TCO per market segment and distance class (Flanders, salary cars)
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

However, if we extend the graph to the 50 models with the lowest TCO (Graph 12), we again find that the share of electric cars diminishes substantially, confirming the low diversity of models on offer. Moreover, we observe some gasoline hybrids, gasoline PHEVs and diesel PHEVs among the models with the lower TCO in the higher power classes and/or distance classes.

Graph 12 50 models with lowest TCO per market segment and distance class (Flanders, salary cars)
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

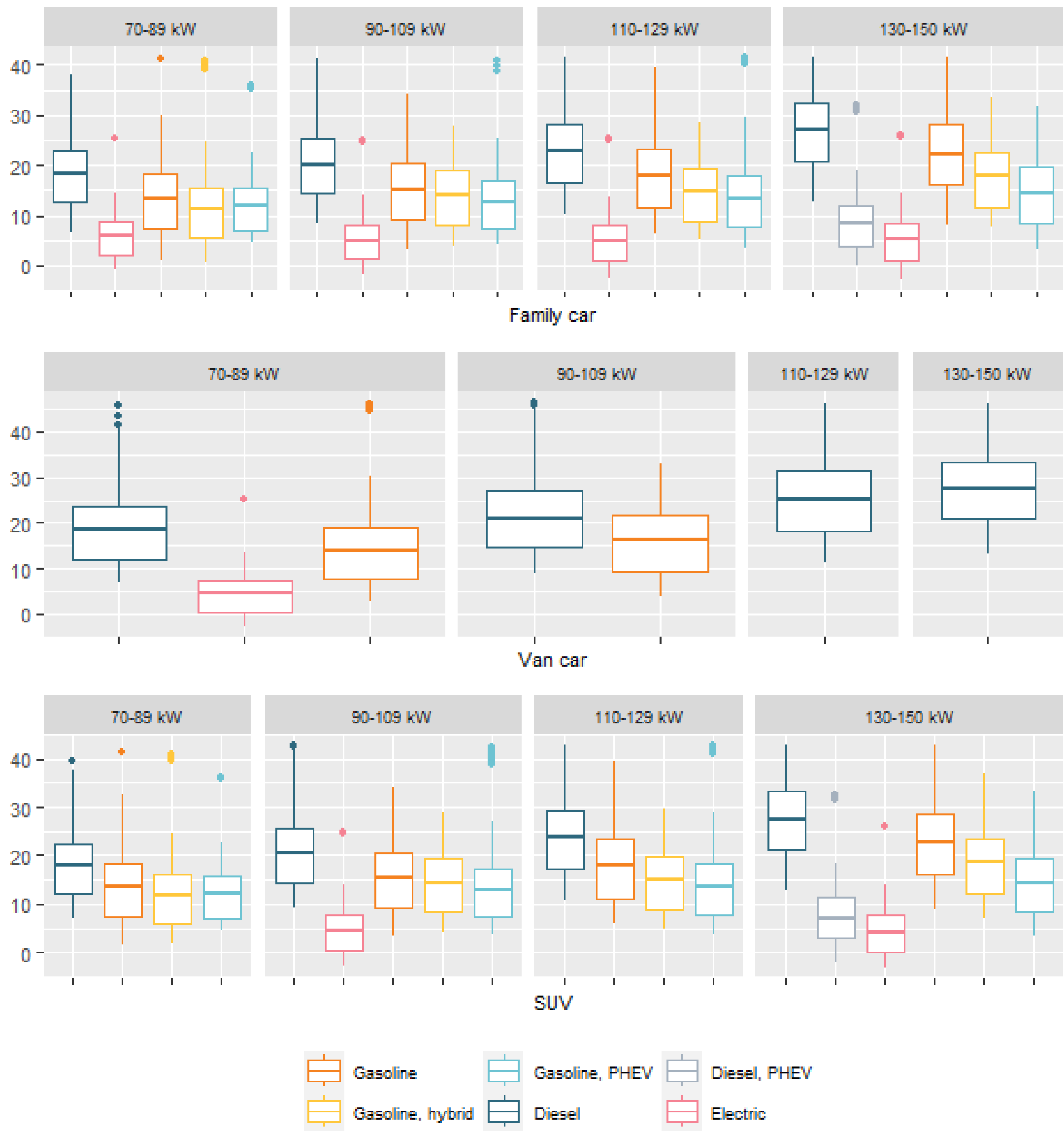
The full analysis with a fixed annual distance travelled is omitted here for the sake of conciseness. Instead, we elaborate on a topic that is specific to salary cars: the calculation of the TCO under the assumption that 50.0% of the net value of the benefit in kind (= real economic value of the benefit in kind to the user minus the tax levied on the benefit in kind) is reflected in wage savings.

Under this assumption, the relative position of diesel and gasoline PHEV changes completely, also compared to electric cars (Graph 13), and this applies both to family cars and to SUVs. The cost disadvantage for gasoline and certainly diesel cars is huge.

For van cars, the main change is that electric cars score best in the lowest power classes.

While in reality we cannot measure the rate of pass-through in wages, we see that even a partial pass-through leads to an important downward shift of the boxplot for all powertrains with low CO_2 emissions (at least according to the test cycles), which even approaches zero in some cases. This confirms that the tax treatment of salary cars provides a very large financial benefit to alternative powertrains, and that one should not only look at the direct effects, such as the treatment in corporate taxation.

Graph 13 Distribution of the TCOs (Flanders, salary cars - including partial pass-through of tax savings in wages
Total cost of ownership (1000 EUR) per market segment and powertrain

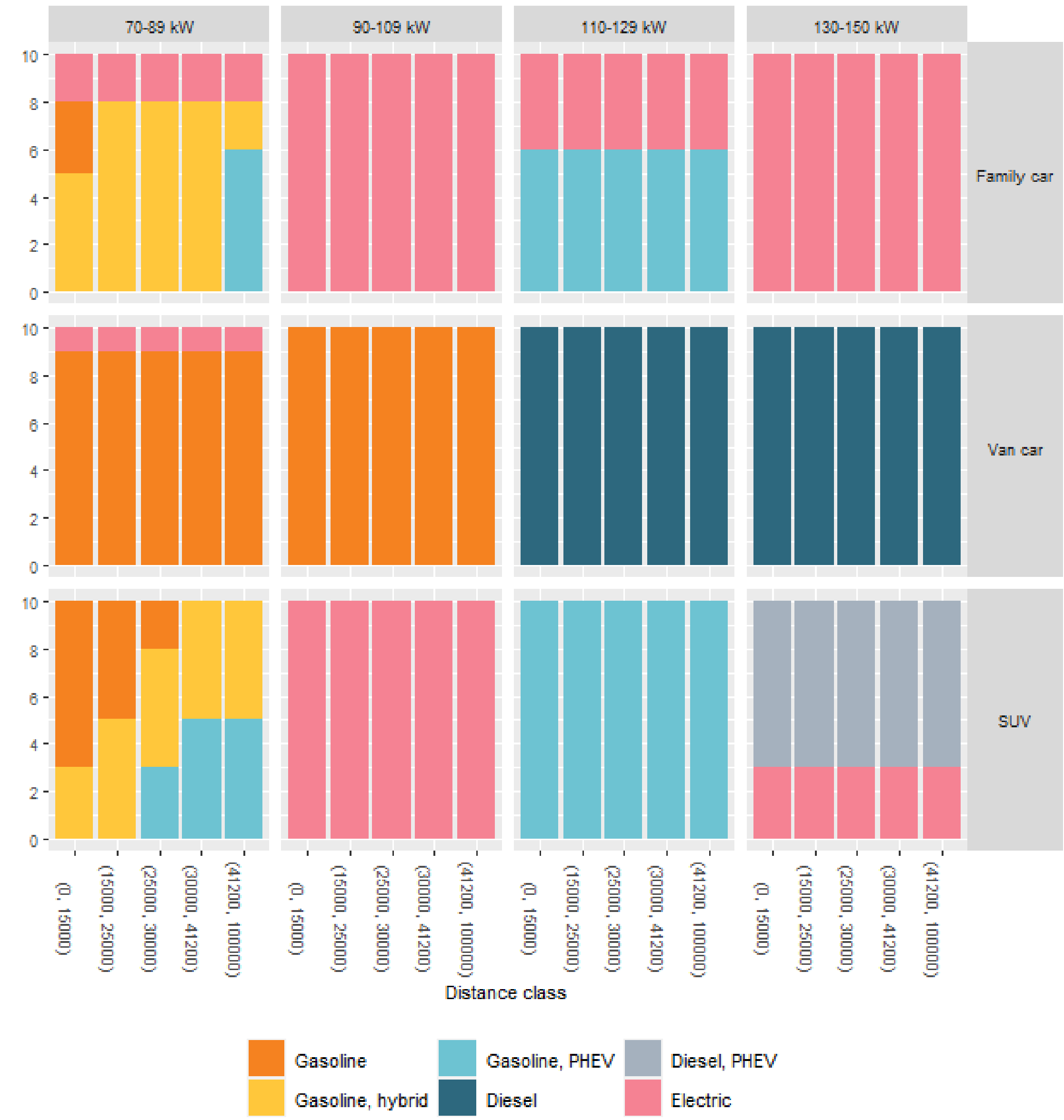


Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Graph 14 confirms that, except for car vans, the set of 10 models with the lowest TCO is completely dominated by electric, gasoline hybrid and diesel and gasoline PHEVs cars.

Graph 14 10 models with lowest TCO (potential wages savings included) per market segment and distance class (Flanders, salary cars)

Number of models per market segment and powertrain

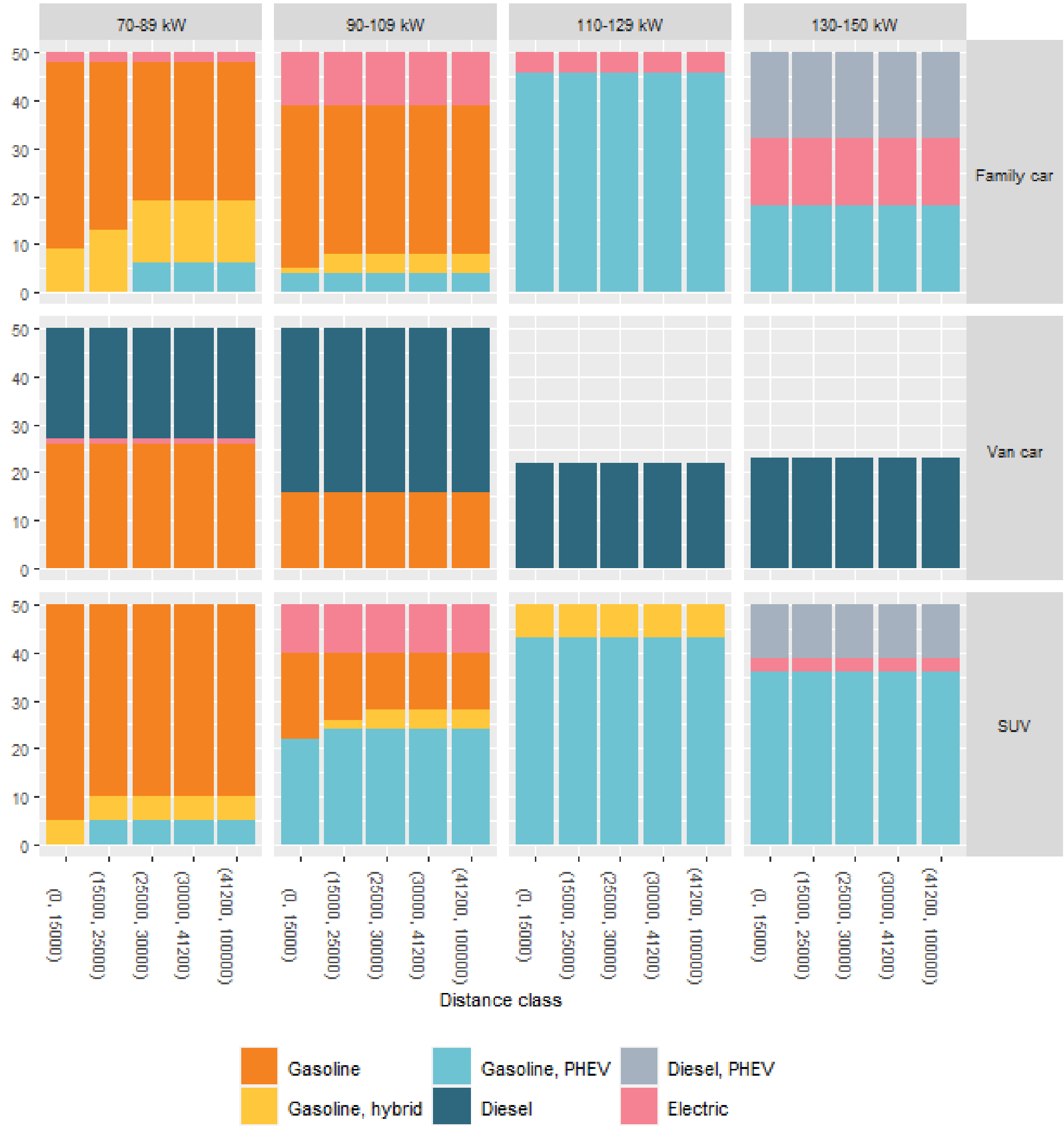


Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Graph 15 reveals that, when we consider the set of 50 models with lowest TCO, gasoline cars are again prominent among family cars and SUVs in the lower power classes, confirming the low diversity of alternative powertrains in this market segment.

Graph 15 50 models with lowest TCO (potential wages savings included) per market segment and distance class (Flanders, salary cars)

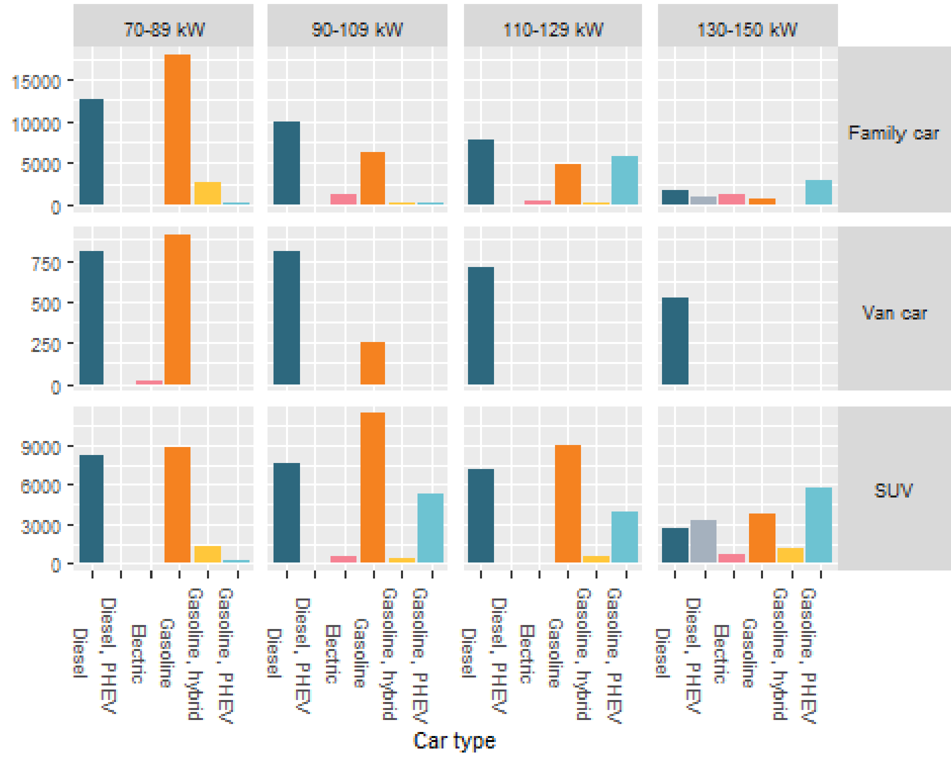
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Finally, contrary to what we found for privately owned cars, the sales for salary cars with a high maximum power is not negligible (Graph 16). We also note that the tax advantages for hybrid and PHEVs are reflected in much higher market shares than in the case of privately owned cars, while this is less pronounced for electric cars.

Graph 16 Sales per market segment (salary cars)
Number of cars sold



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

In summary, the analysis with salary cars has confirmed the need to look beyond the central values of the distribution of the TCOs.

On top of that, our analysis has shown that the tax benefits for electric cars and plug-in hybrid cars with very low CO_2 emissions have a huge impact on the TCO of salary cars, especially if one takes into account that at least part of these benefits will allow companies to save on wages. As a result of these tax benefits, electric cars and gasoline PHEVs are among the cheapest models on offer. However, the diversity of electric models with a low TCO on offer is low in most market segments when compared to the diversity of gasoline and diesel cars. Except in the lower power classes, gasoline PHEVs score much better in terms of diversity. Compared to family cars and SUVs, car vans continue to be dominated by diesel and gasoline cars.

7. Conclusion

In this paper, we have presented a total cost of ownership analysis of new cars that were sold in Belgium in 2021. We have presented results per market segment (defined as combinations of body type with classes of maximum engine power) and powertrain, distinguishing between cars owned by private households and salary cars.

We have compared the results both for all user profiles identified in a sample of the Belgian population, and for given user profiles.

In our calculation of the TCO for salary cars, we have also taken into account that part of the tax benefits of salary cars will be passed on to employees as lower wages.

The key conclusion of our study is that, in each market segment, there is a significant overlap in the TCOs of different powertrains. This overlap results not only from differences in the technical characteristics of cars and their purchase price, but also from the diversity in use profiles. It is therefore important to consider the whole distribution of the TCO.

For instance, in the case of privately owned cars, there are several market segments where electric cars have the lowest median TCO. However, if we look at the usage profiles with a TCO below that of the median for electric cars, there are many more use profiles with gasoline or diesel cars than electric cars. It is only in the highest distance classes that electric cars are among the ten models with the lowest TCO in some market segments. We also found that within each market segment, the diversity of electric car models on offer is much lower than for gasoline and diesel cars, and that the electric car models with the lowest TCO also tended to have the lowest range.

A more detailed look at the distribution of TCOs for an annual distance travelled of respectively 15 000 and 30 000 km confirmed that electric cars are more financially interesting for user profiles with high travel needs.

Our analysis of the company car market showed that electric cars benefit hugely from the tax treatment given to salary cars. If we take into account that part of the tax benefits may be passed on to employees in the form of lower wages, then the relative position of PHEVs also improves a lot compared to all powertrains.

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Annexes

Annex 1: Composition and distribution of variable costs

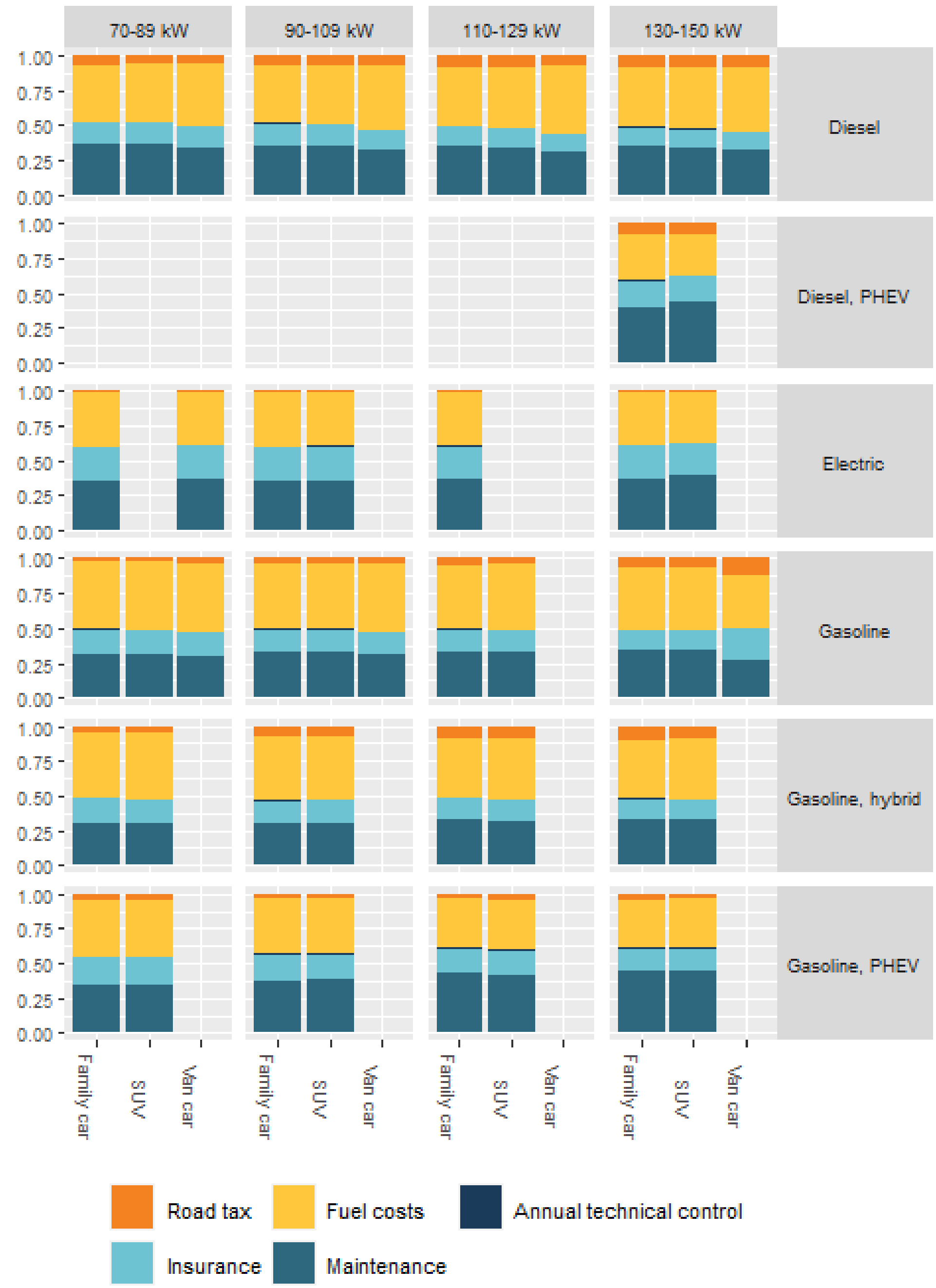
Graph 16 shows, by car body type and power class, the average share of each variable cost component in total variable costs. As discussed above, this considers both the variation across individual cars and the variation across households.

On average, fuel costs, insurance and maintenance costs have the largest share in total variable costs. Note that the share of fuel/electricity costs for electric cars does not differ dramatically from the share for conventional drive systems when controlling for market segment.

The share of annual control costs is very small, and we will not discuss it further.

The share of the annual road tax is also relatively limited, except for large cars.

Graph 17 Composition of the variable costs (Belgium)
Shares per powertrain and power class



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

As we have done when discussing the TCO, we will now show the full distribution of the variable costs.

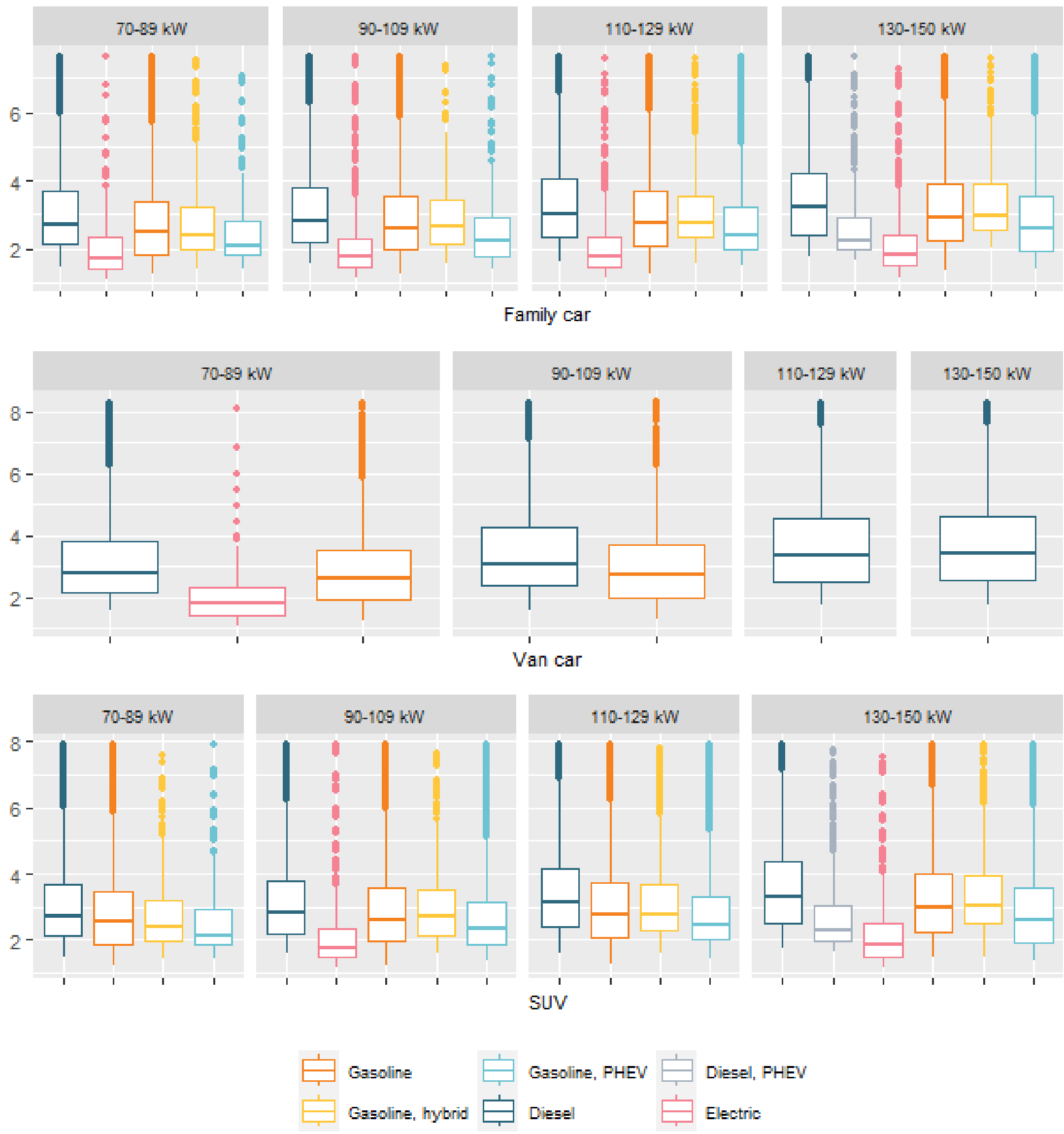
Graph 18 shows the distribution of total variable costs by market segment for privately owned cars.

A preliminary data analysis has shown that, especially for gasoline cars, there is a huge spread around the mean values, with extremely large outliers on the right-hand side of the distribution. We have therefore excluded from the graph the cars whose total variable costs are higher than the 9th decile.

In all market segments where they are offered, electric cars have the lowest median value for variable costs. The median variable cost is highest for diesel cars in all market segments, but the differences with gasoline cars are not pronounced.

Especially for gasoline and diesel cars, there is a very large spread around the median in all market segments. Remember that this spread is the combined effect of the spread in car characteristics.

Graph 18 Distribution of annual variable costs (Belgium)
Annual variable costs (1000 EUR) per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

It may also be useful to take a quick look at the distribution of the main components of variable costs.

a. The annual road tax

Let us first dwell for a moment on the annual road tax. In Wallonia and in the Brussels Capital Region, it is calculated on the basis of the car's fiscal HP, while in Flanders a double environmental correction is applied to the base rate. It follows from the high correlation between maximum power and engine capacity (which underpins the calculation of the tax HP) that, by market segment, the distribution of road tax is very much concentrated around the median. For the sake of clarity, we do not present these detailed results here.

We do compare average values viewed by power class and powertrain, noting: (a) in Flanders, the road tax is on average highest for diesel cars, and the lowest (zero) for electric cars (b) in Flanders, for cars in the lowest power class, the road tax is higher for gasoline PHEVs than for gasoline cars, but for higher power classes the opposite is true, and the difference increases with the power class (c) in Wallonia and the Brussels-Capital Region, the road tax is highest for gasoline hybrid cars and lowest for electric and gasoline cars (d) the road tax for gasoline cars is on average lower in Flanders in each power class, and the opposite is true for diesel cars.

Table 4 Median road tax per power class and powertrain (Wallonia)

KwGroup	Diesel	Diesel, PHEV	Electric	Gasoline	Gasoline, hybrid	Gasoline, PHEV
70-89 kW	220	NA	76	150	282	262
90-109 kW	306	NA	76	178	393	220
110-129 kW	393	NA	76	220	439	220
130-150 kW	393	393	76	393	574	328

Table 5 Median road tax per power class and powertrain (Flanders)

KwGroup	Diesel	Diesel, PHEV	Electric	Gasoline	Gasoline, hybrid	Gasoline, PHEV
70-89 kW	243	NA	0	112	201	133
90-109 kW	344	NA	0	146	331	113
110-129 kW	455	NA	0	189	343	114
130-150 kW	477	319	0	378	548	172

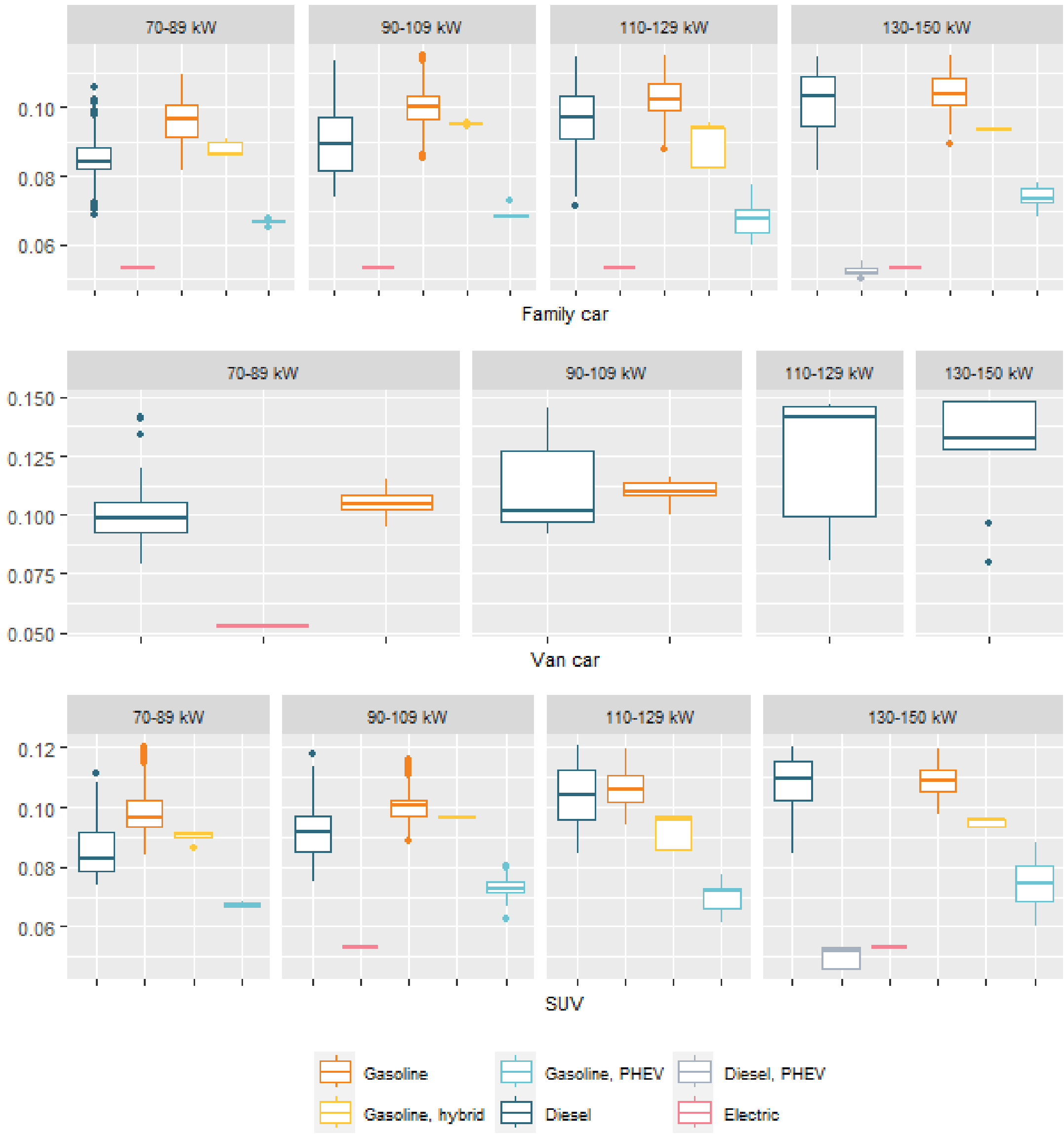
b. Fuel costs per kilometre

For fuel costs per kilometre, we observe a large spread around the median for gasoline and diesel cars in all market segments (Graph 19).

In the market segments where they are offered, the median fuel cost of electric cars is systematically the lowest, followed by gasoline PHEVs. However, it should be noted that these values are based on the test cycle, and the fuel cost of PHEVs in real driving conditions can be quite higher.

Across all market segments, median fuel costs are highest for gasoline cars. No clear line can be drawn in the differences between diesel cars and hybrid gasoline cars.

Graph 19 Distribution of the fuel costs (EUR)
Fuel costs (EUR per km) per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Annex 2: Annual maintenance costs

To estimate maintenance costs, we used data from the Allgemeine Deutsche Automobil-Club (ADAC). ADAC gives the costs over a five-year period for a car driving 15,000 km a year.

ADAC takes into account the following cost components:

– Oil changes
– Most common wear and tear repairs
– Tyre replacement
– Additional fixed repair costs

Workshop costs are based on German workshop hourly rates.

Since not all models from the S&P database are resumed in the ADAC list, we have constructed a predictive model of annual maintenance costs. The results are summarised in Table 6.

With an R2 of 0.89, the overall fit of the model is excellent.

This shows that maintenance costs are an increasing function of the price (*PurchPr*) and maximum power (*Kw*) of a car.

The size class of the engine[7]. plays a role: using the COPERT class "large" as a reference value, it turns out that (ceteris paribus) maintenance costs are lower for medium and small cars. However, the coefficient for the size class "small" (*sizesmall*) is not significant.

For the impact of fuel type, electric cars are taken as the reference class, and this shows that (ceteris paribus) all other propulsion technologies have higher maintenance costs, with the exception of gasoline plug-in hybrid (PHEVs) cars. The coefficient for CNG cars is not significant, though.

Finally, we created an interaction variable between the maximum power of the car and the powertrain. It is significant for all gasoline-based powertrains.

7 We calculate the size class of an engine using the COPERT methodology, which calculates emission factors for a number of classes determined by engine type and cylinder capacity. https://www.emisia.com/utilities/copert/ for more explanation

Graph 20 Linear model: maintenance costs

	Dependent variable:
	Maintenance costs
PurchPr	0.008*** (0.006, 0.010)
gas	184.970** (42.000, 327.940)
gashybr_phev	-222.997** (-405.647, -40.346)
gashybr_cs	293.721*** (128.054, 459.388)
dies	521.258*** (241.962, 800.554)
CNG	166.239 (-521.645, 854.123)
Kw	1.424*** (0.749, 2.098)
sizemedium	-56.032** (-103.552, -8.513)
sizesmall	-0.013 (-56.751, 56.725)
gas:Kw	1.222*** (0.589, 1.854)
gashybr_phev:Kw	4.556*** (3.436, 5.676)
gashybr_cs:Kw	-1.206** (-2.293, -0.118)
dies:Kw	-1.273 (-3.863, 1.318)
CNG:Kw	-0.354 (-7.881, 7.173)
Constant	228.344*** (70.137, 386.551)
Observations	603
R^2	0.872
Adjusted R^2	0.869
Residual Std. Error	141.133 (df = 588)
F Statistic	285.224*** (df = 14; 588)
Note:	*p<0.1; **p<0.05; ***p<0.01

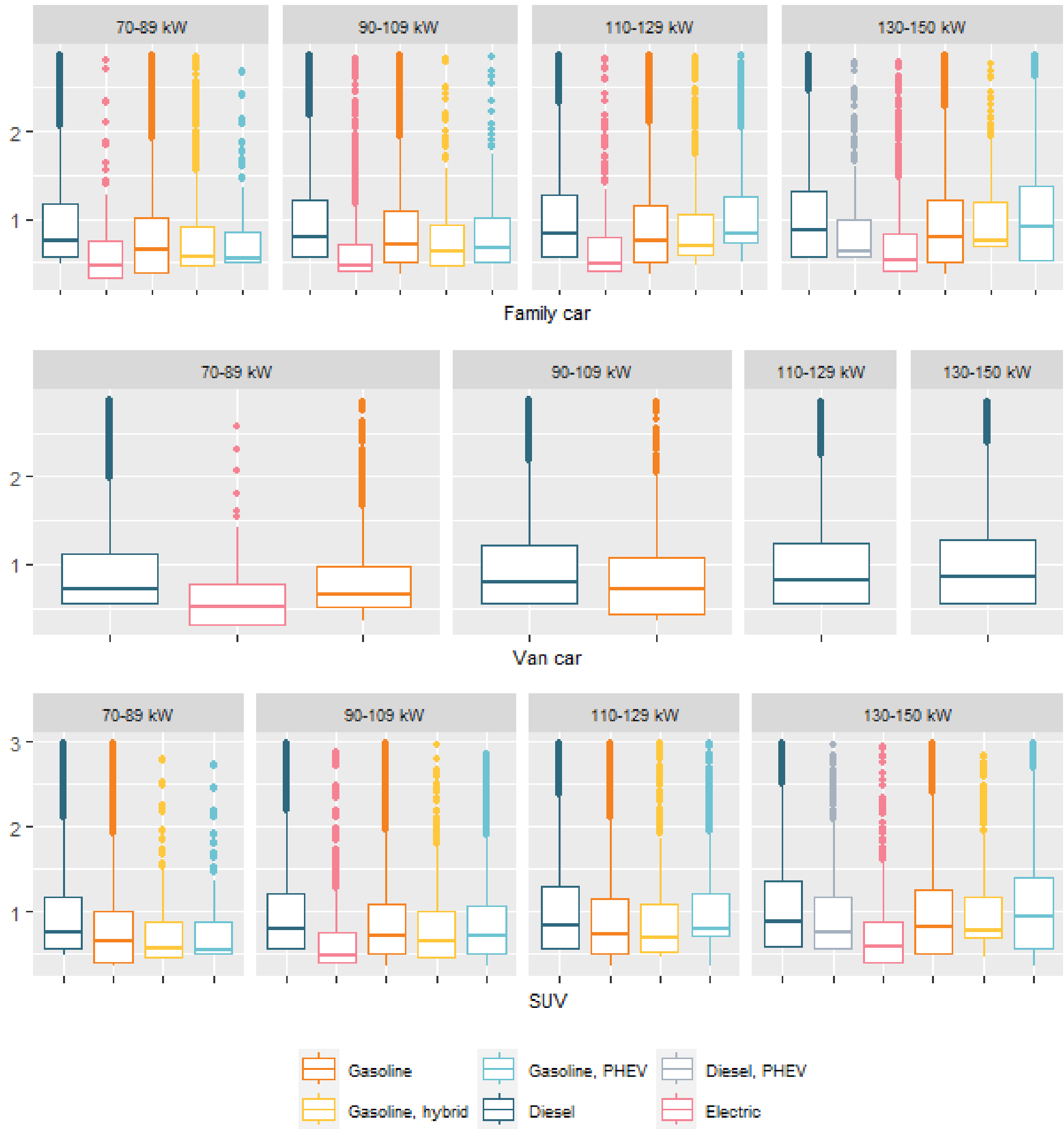
Source: Own calculations based on S&P and ADAC data

ADAC's estimates are for a fixed annual distance of 15 000 km. In our analysis, we assume that annual maintenance costs vary with the annual distance households travel. However, they do not increase strictly proportional to the number of kilometres: no matter how little one drives on an annual basis, minimal maintenance will always remain necessary. Therefore, we use Letmathe and Suares' (2017) estimate of annual maintenance costs for cars travelling less than 5,000 km annually as a lower bound. If the annual distance travelled exceeds 5000 km, we assume that maintenance costs do vary proportionally with annual mileage.

Graph 21 shows the distribution of annual maintenance costs, based on the methodology we elaborated above.

In all market segments in which they are offered, electric cars have the lowest median maintenance cost, and diesel cars or gasoline PHEVs have the highest median maintenance cost. Otherwise, no clear patterns can be identified. The differences in median values between gasoline and diesel cars are also not pronounced.

Graph 21 Distribution of maintenance costs (annual distance travelled according to Monitor)
Yearly maintenance costs (1000 EUR) per market segment and powertrain



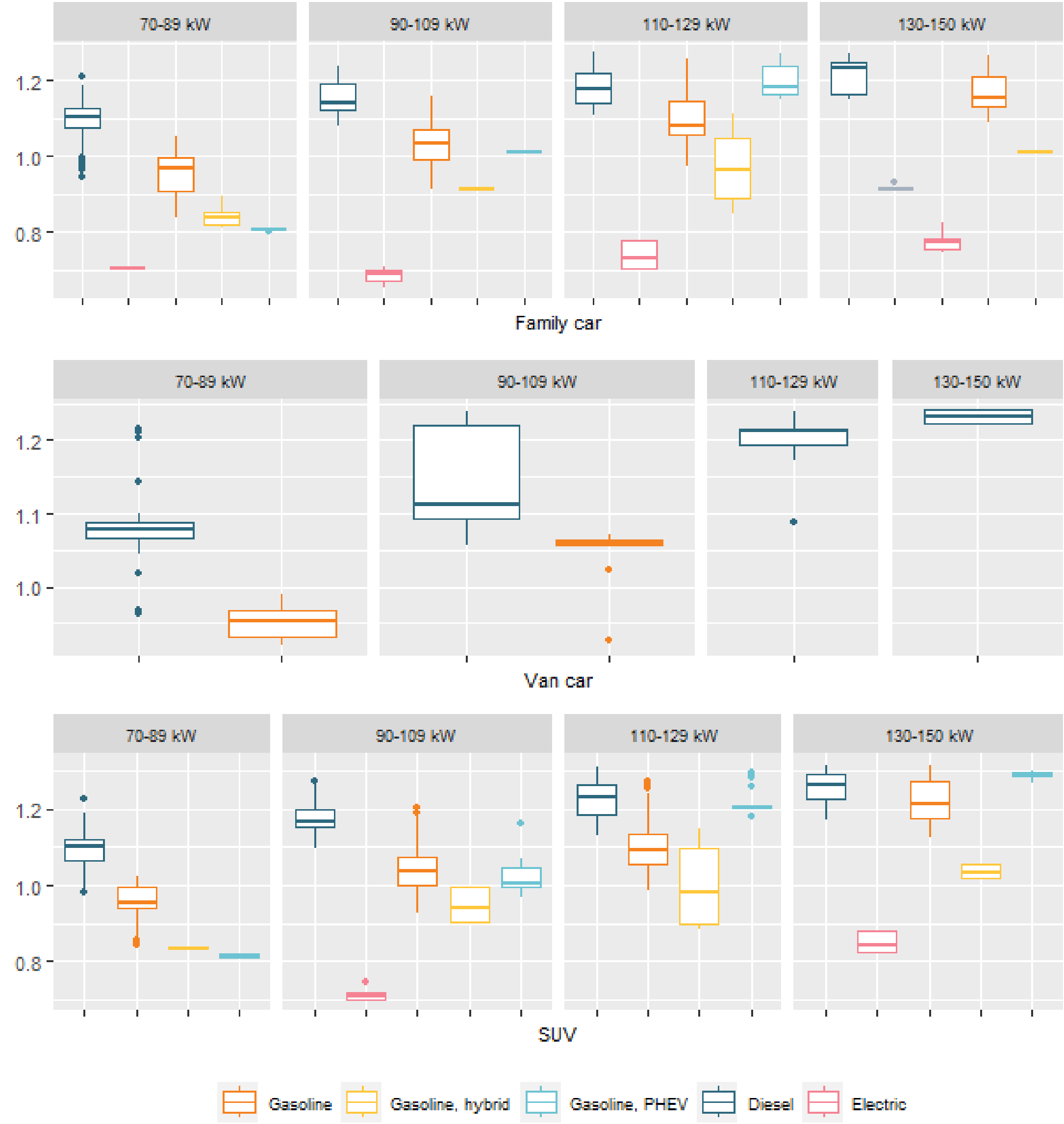
Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Even more than for the other cost components, there is a very large overlap in the distributions within each market segment. The asymmetry in the distributions above is largely due to the lack of an upper bound on annual maintenance costs, while there is a lower bound.

In Graph 22, we therefore also present the distribution assuming an annual distance travelled of 15 000 km (as in the ADAC publication). Under this assumption, the median maintenance cost is lowest for electric cars.

With a fixed annual mileage, the differences between diesel and gasoline cars are much more pronounced though, especially for vans and the less powerful family cars and SUVs.

Graph 22 Distribution of maintenance costs (Belgium, annual travel distance of 15 000 km)
Yearly maintenance costs (1000 EUR) per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

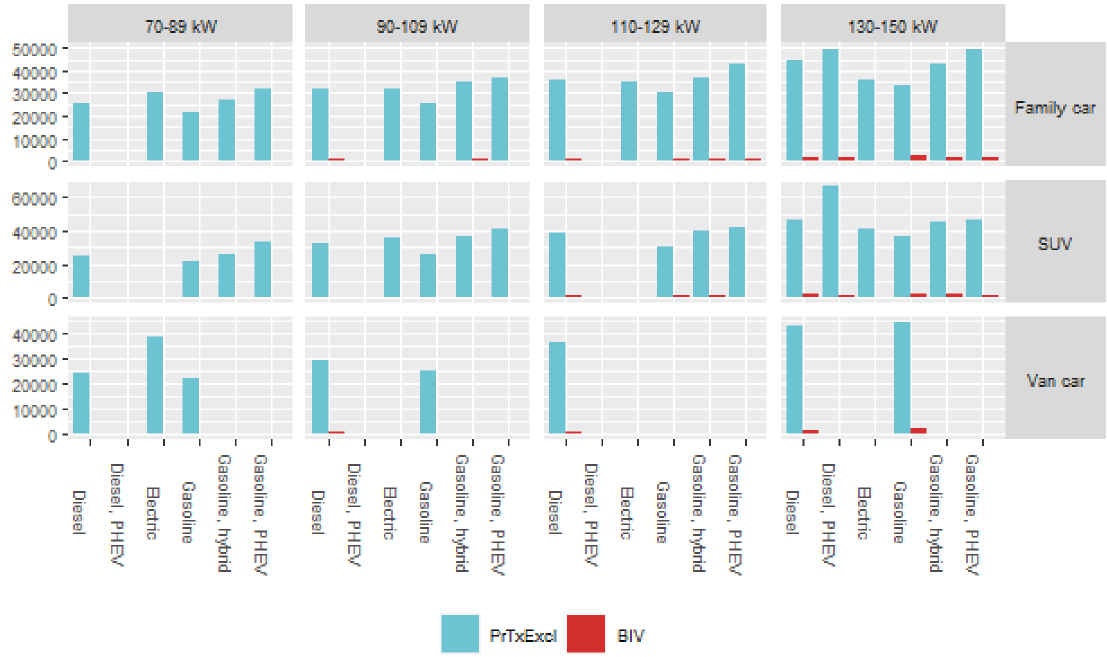
Annex 3: Distribution of the purchase price

Graph 23 gives (a) PrTxEcl, the average purchase price of a car by market segment (VAT included) (b) the average license tax.

In the case of electric cars, PrTxEcl also includes the purchase price of a private charging point (EUR 500 for an electric car) – we assume that plug-in hybrids are charged via a standard plug.

It is clear that the share of license tax in the total purchase cost is in fact very low, and we will therefore not discuss this cost component further.

Graph 23 Purchase cost and license tax per market segment
EUR per market segment and powertrain

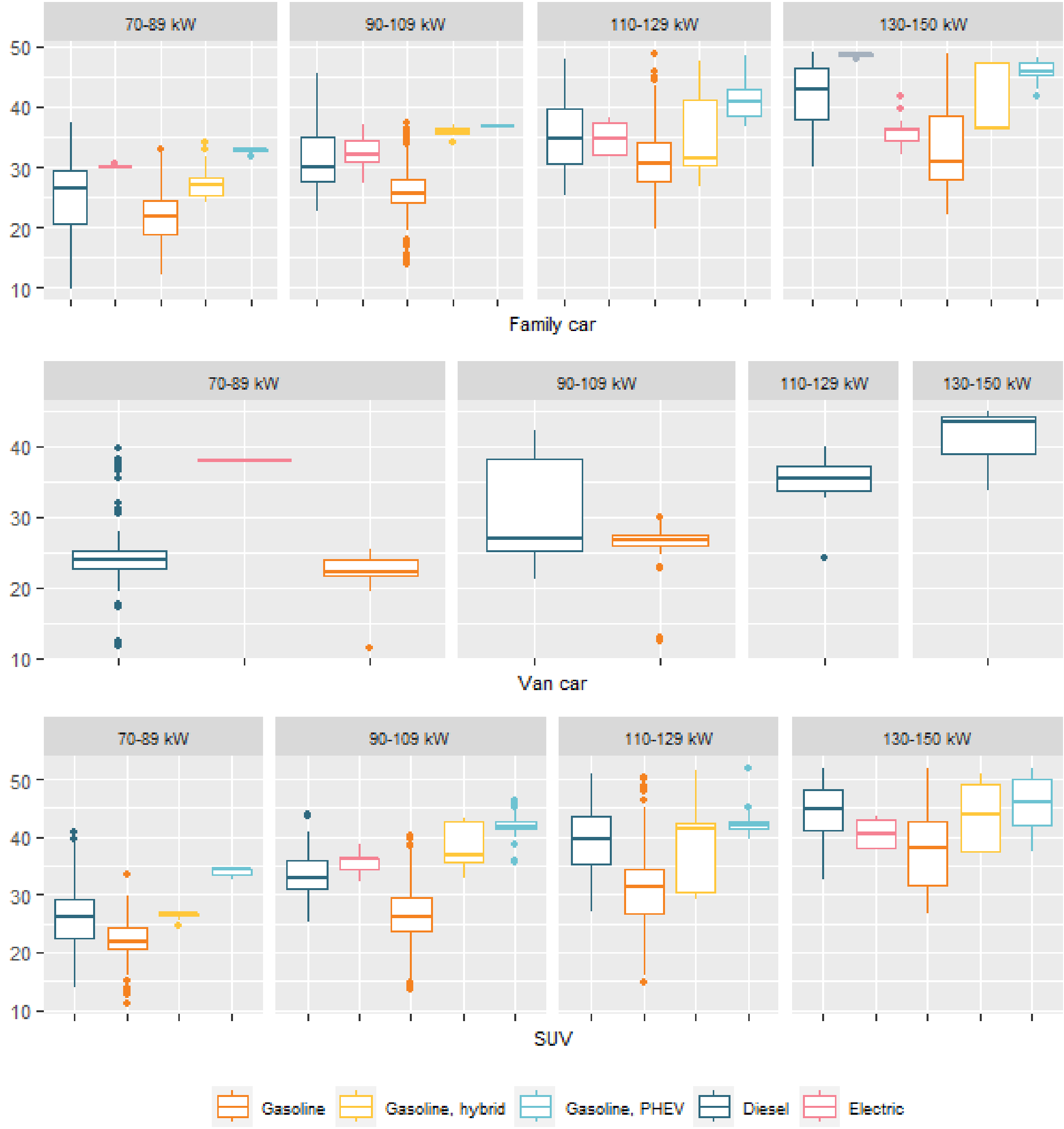


Source: Own calculations based on S&Pdata

When presenting the distribution of purchase costs (Graph 24), we excluded the cars whose purchase price falls in the highest percentile.

This confirms that the median purchase price of alternative powertrains tends to be (much) higher than for diesel and gasoline cars, at least for the lower power classes. For higher power classes, this is not the case: for both family cars and SUVs, the median purchase price of diesel cars is higher than that of electric cars. The median purchase price of gasoline PHEVs is always higher than that of electric cars.

Graph 24 Distribution of annualised purchase costs - 10 years
1000 EUR per market segment and powertrain



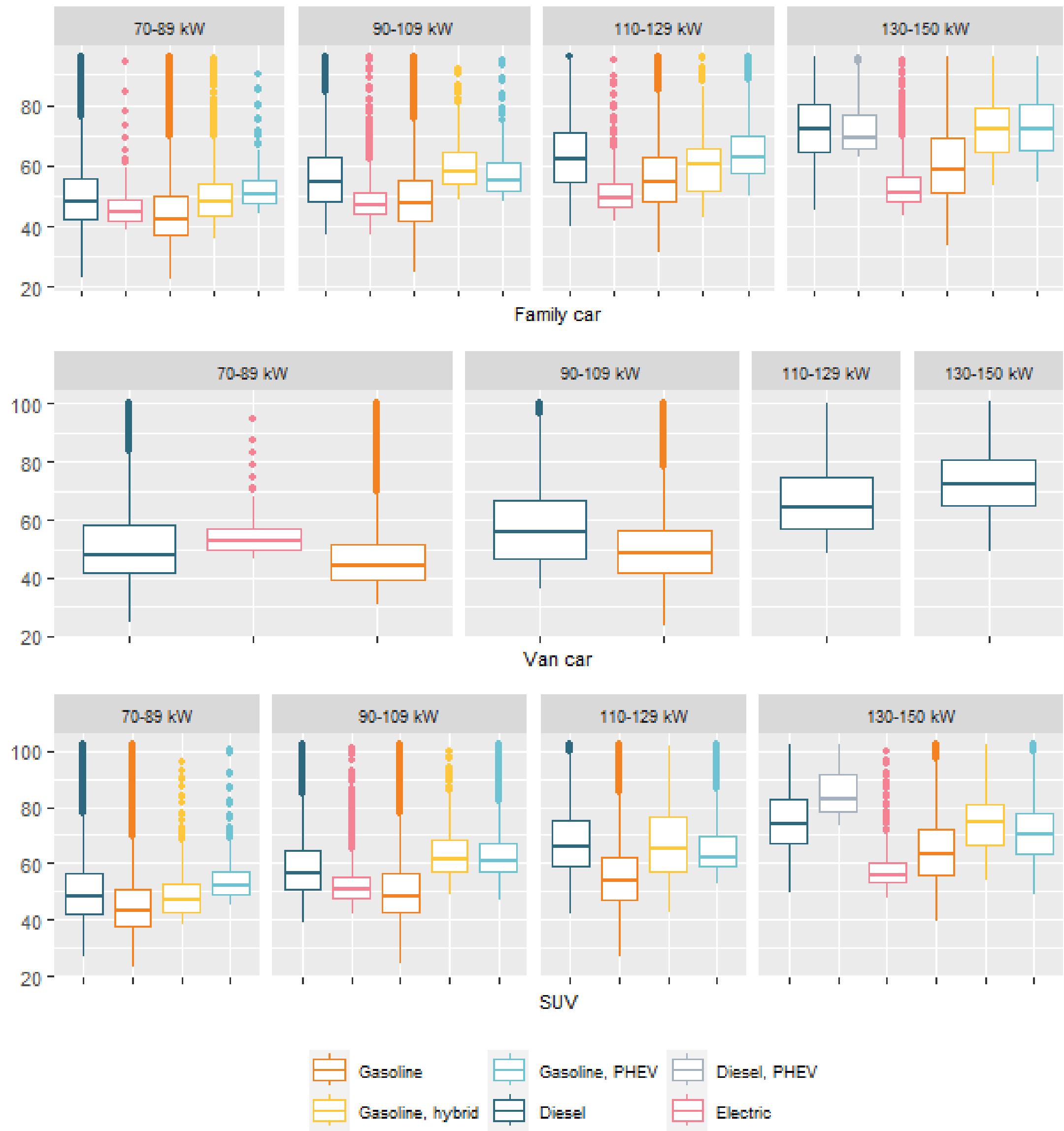
Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Annex 4: Distribution of the TCO for privately owned cars in Flanders

In this section, we summarize the findings for privately owned cars in Flanders.

The distribution of TCO for Flanders (Graph 25) per market segment reveals largely the same patterns as in Wallonia: the differences in car taxation and on the range of car models that are on offer in each region have an impact on the *size* of TCOs, less on the shape of the distribution.

Graph 25 Distribution of the TCO (Flanders, privately owned cars)
Total cost of ownership (1000 EUR) per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

It can also be verified that the composition of the “top ten with the lowest TCO” is largely similar to what we found for Wallonia - the detailed results are available on request.

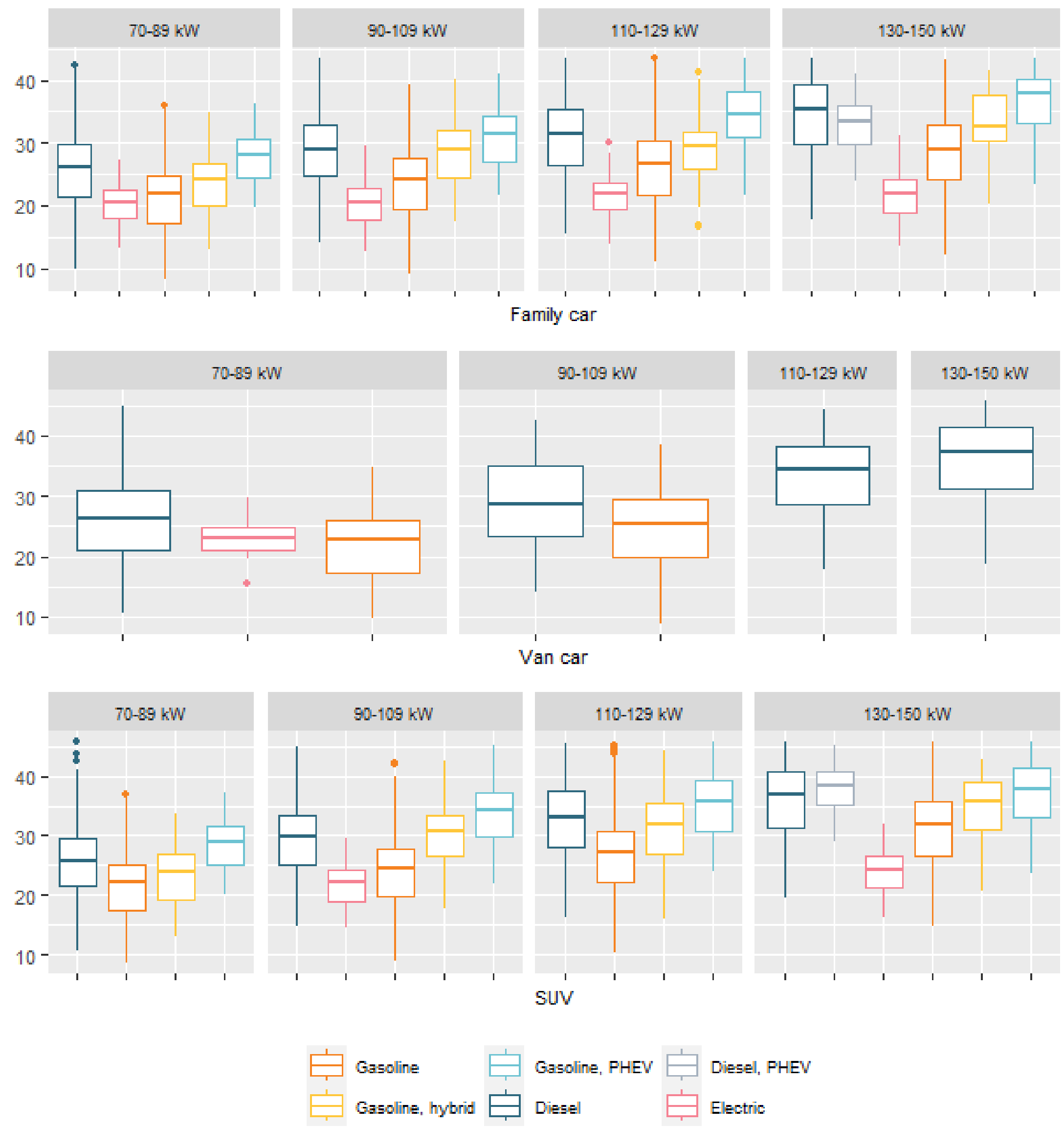
Annex 5: Distribution of the TCO for salary cars in Wallonia

The same license and annual road taxes apply to Wallonia, the Brussels Capital Region and leased cars.[8] We focus here on the TCO for salary cars registered in Wallonia by other companies than leasing companies.

In Graph 26, we represent the boxplots of the TCO for all powertrains and market segments. Since some cars have an extremely high purchase price, we exclude the cars with the 5% highest TCO.

Compared to the analysis in Section 6, the relative position of the different powertrains remains largely the same.

Graph 26 Verdeling van de TCO voor salariswagens in Wallonië (10 000 EUR)
Total cost of ownership (1000 EUR) per market segment and powertrain

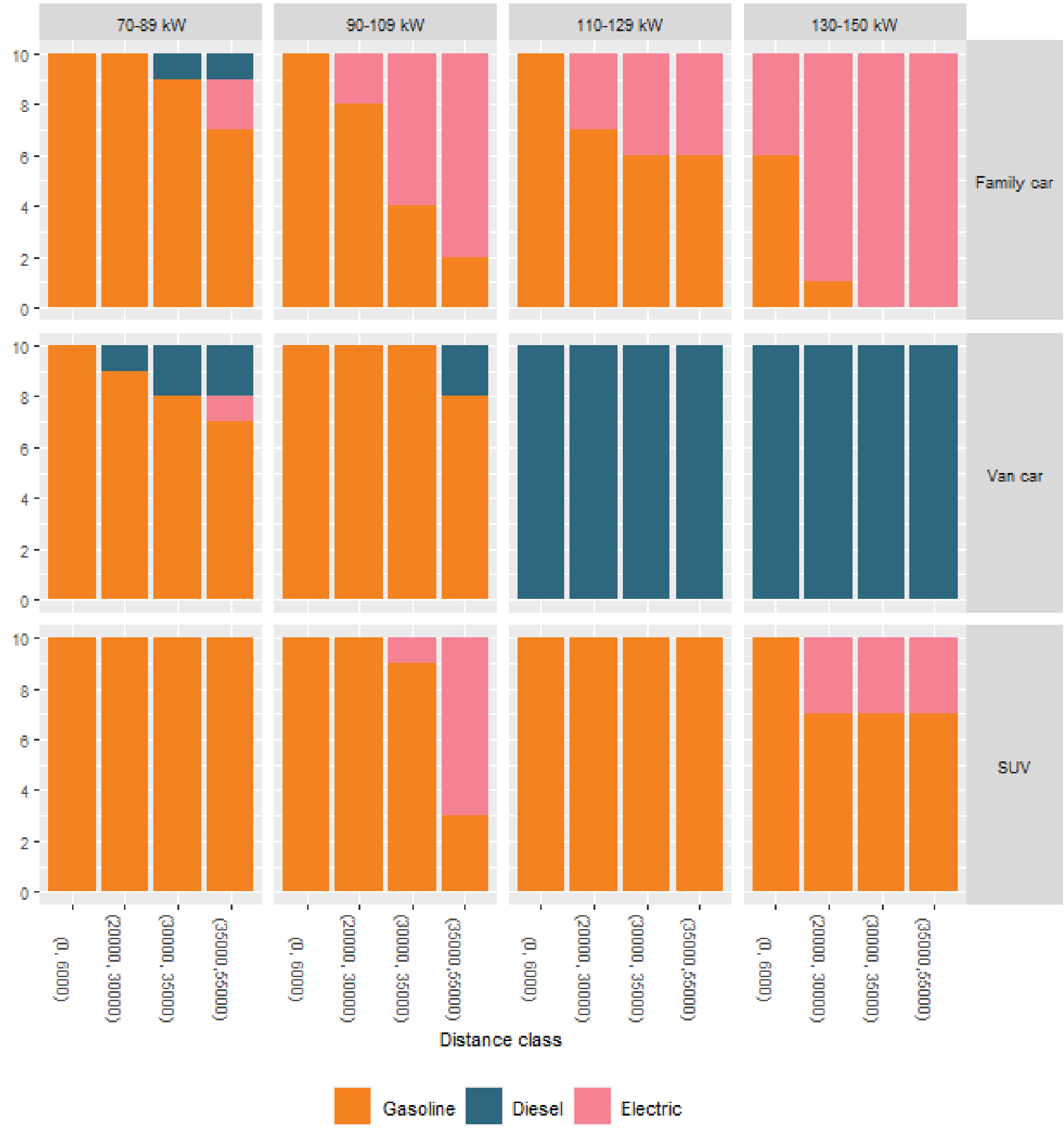


Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

[8] Except that cars with very high CO_2 emissions are also subject to an "ecomalus" in Wallonia.

The sets with then ten models with the lowest TCO per distance class and market segment (Graph 27) also reveal some changes compared to the situation in Flanders (except in the higher power classes): (a) a lower share of electric cars and gasoline PHEVs (b) a higher share of diesel cars.

Graph 27 10 models with lowest TCO per market segment and distance class (salary cars, Wallonia)
Number of models per market segment and powertrain

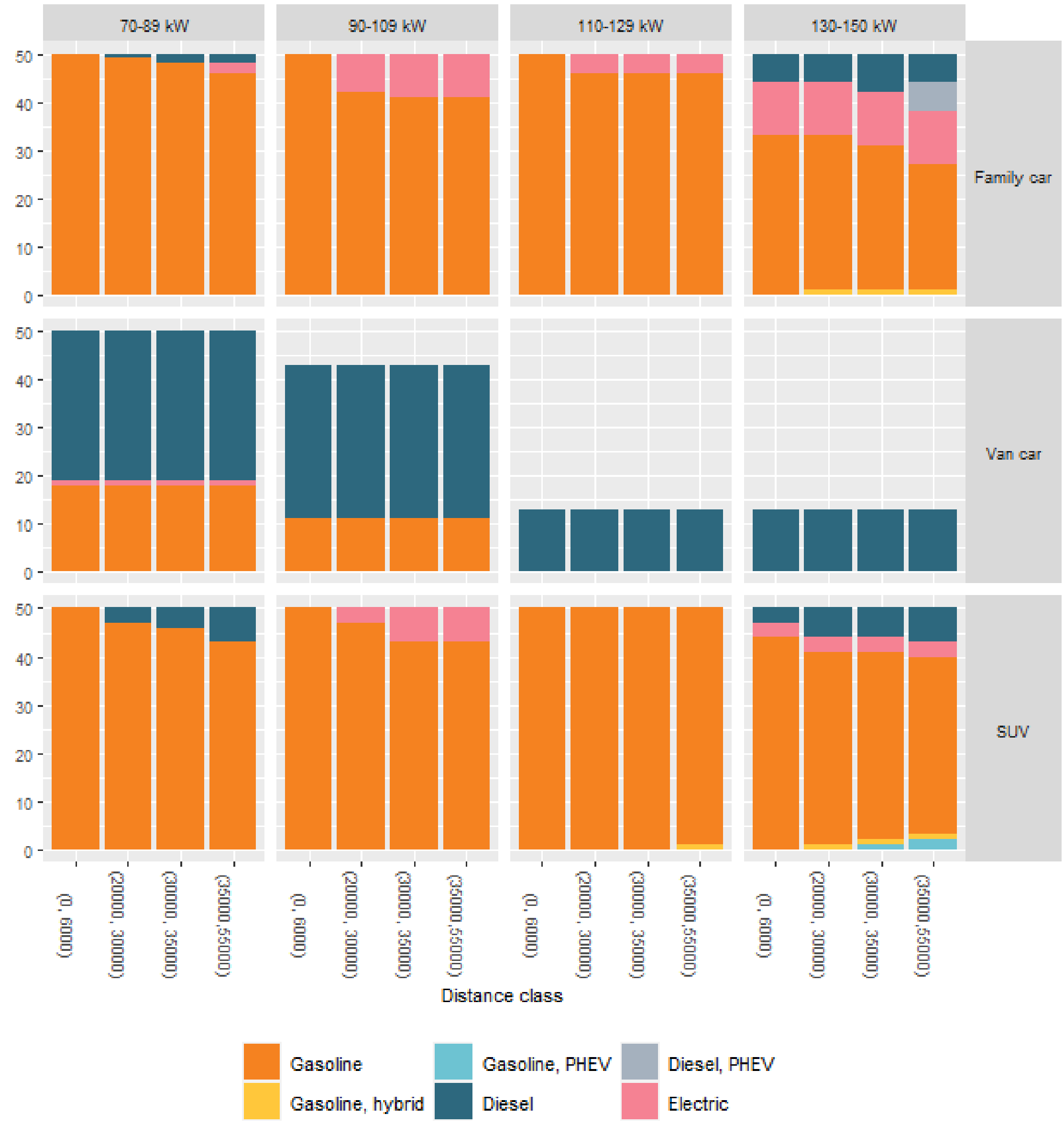


Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Compared to the set of 50 models with the lowest TCO in Flanders, the set in Wallonia (Graph 28) is even less diverse in the case of vans. For the other market segments, we find largely the same patterns as in Flanders.

Graph 28 50 models with lowest TCO per market segment and distance class (salary cars, Wallonia)

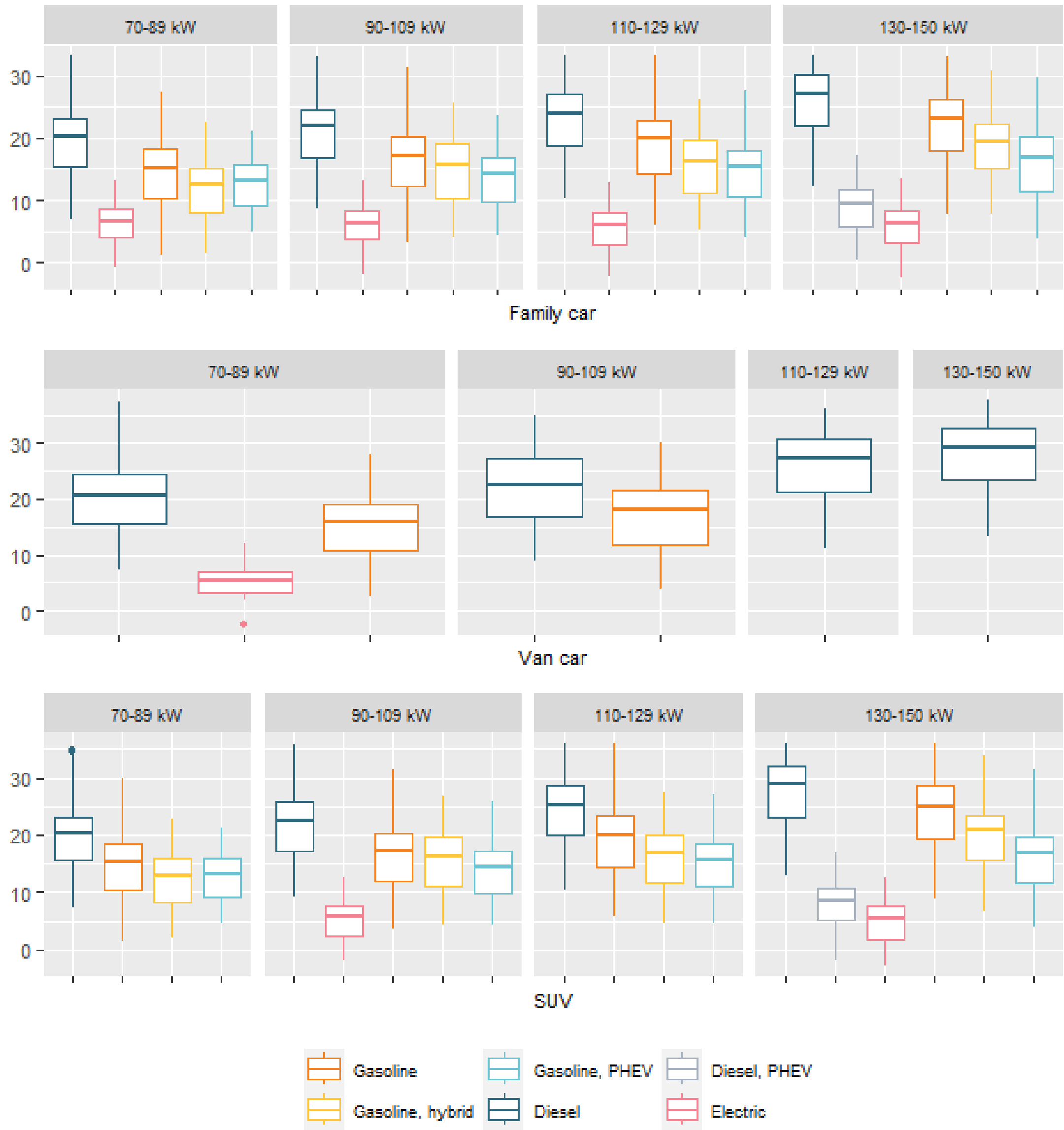
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Graph 29 reveals largely the same patterns as what we found in Section 6: even a partial pass-through leads to an important decrease in the TCO for all powertrains with low CO_2 emissions (at least according to the test cycles), which even approaches zero in some cases.

Graph 29 Distribution of the TCOs (Wallonia, salary cars - including partial pass-through of tax savings in wages
Total cost of ownership (1000 EUR) per market segment and powertrain

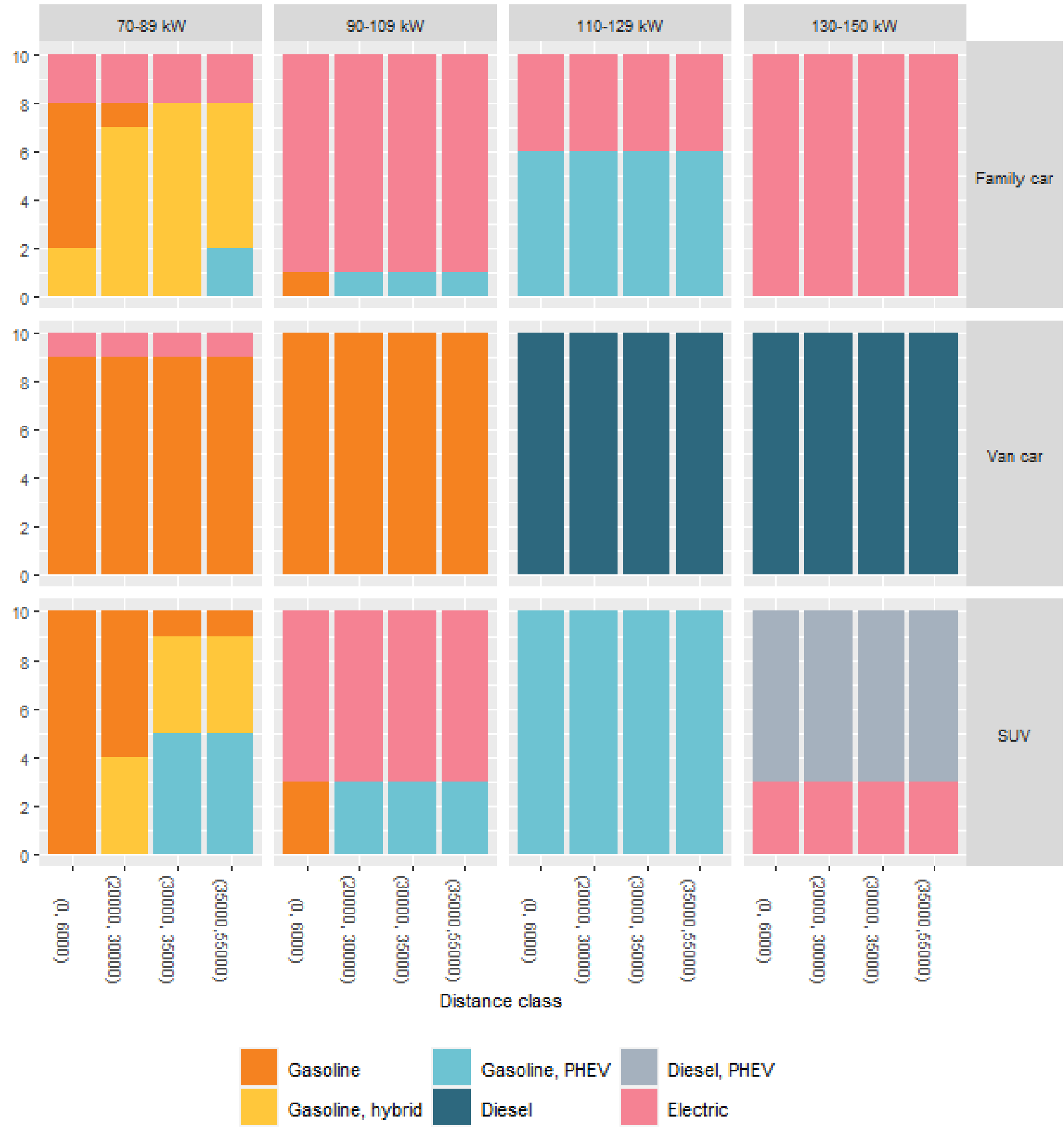


Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Finally, the composition of the set of the 10 (respectively 50) models with the lowest TCO in Graph 30 (respectively Graph 31) is also very close to what we found for salary cars in Flanders.

Graph 30 10 models with lowest TCO (potential wages savings included) per market segment and distance class (salary cars, Wallonia)

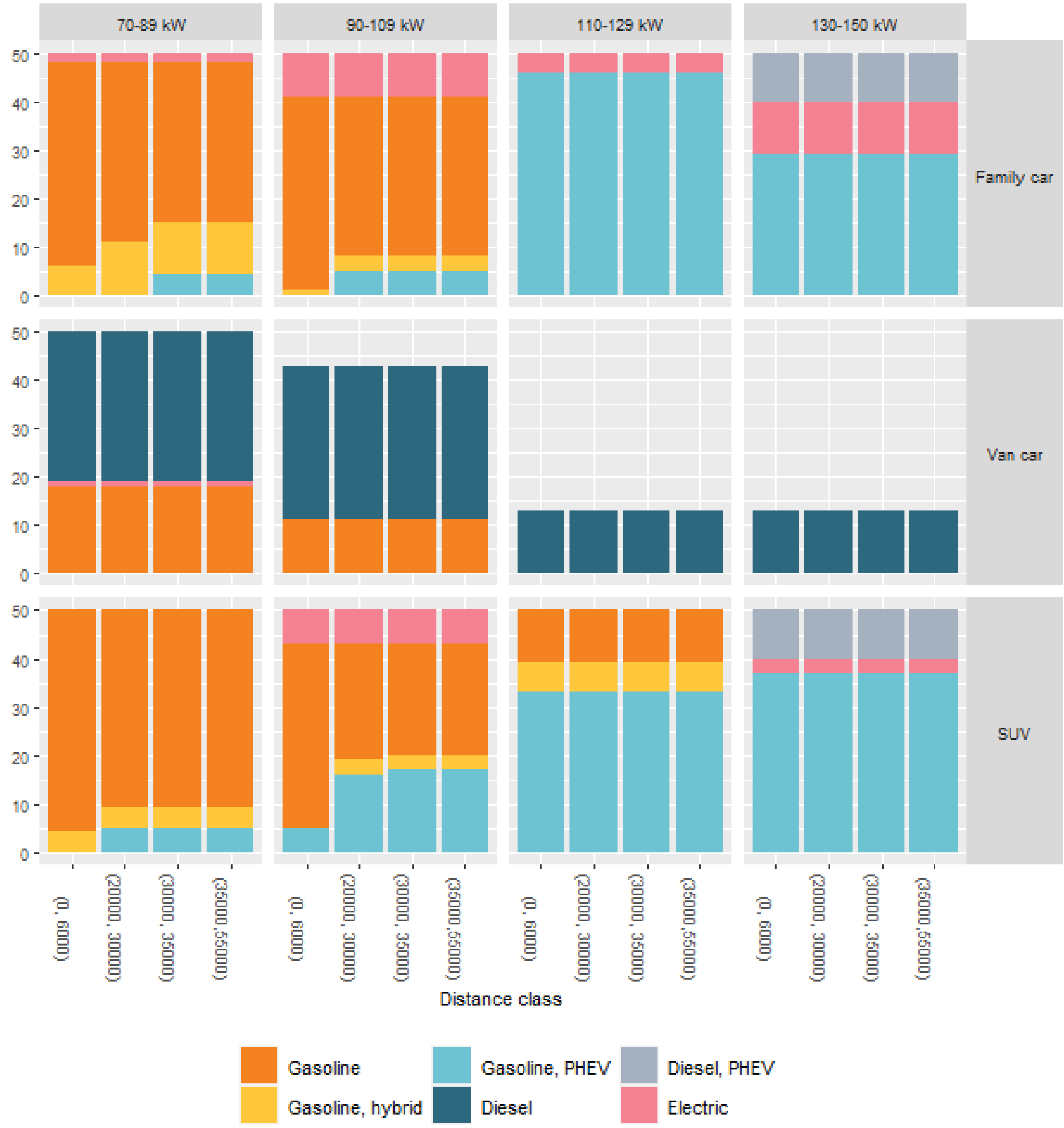
Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Graph 31 50 models with lowest TCO (potential wages savings included) per market segment and distance class (salary cars, Wallonia)

Number of models per market segment and powertrain



Source: Own calculations based on Monitor, S&P, EEA, ADAC and IEA data

Annex 6: Overview of taxes affecting cars in Belgium

In this chapter, we describe the existing taxes affecting the demand for company cars in Belgium. This overview is not intended to be exhaustive, and some complications have been abstracted from.

a. Annual traffic tax

The annual traffic tax is levied on all motor vehicles and their trailers. In this section, we focus on the regime for passenger cars that are not exempted because of their specific purpose (for instance, emergency vehicles).

In Belgium, setting the parameters of the annual traffic tax is a regional competence, except for leased cars, where the tax regime can only be modified with unanimity between the Regions.

Table 6 Annual traffic tax in het Brussels and Walloon Region in 2021/reference value in Flanders

PK	Annual traffic tax
4	76.32
5	95.52
6	138.12
7	180.36
8	223.06
9	265.80
10	307.92
11	399.60
12	491.28
13	582.72
14	674.40
15	766.08
16	1003.44
17	1240.92
18	1478.52
19	1715.40
20	1953.00

Historically, the tariffs were based on the taxable horsepower of the car, and the Brussels and Walloon Regions have maintained this system. In Flanders, the taxable horsepower also determines the reference value of the annual road tax before environmental correction.

However, a double environmental correction applies in Flanders.

First, there is a correction for the CO_2 emissions. A surcharge of 0.3% is applied to the base tariff for each gram of CO_2 emissions per km above 149 gram per km and below 500 gram per km. A discount of 0.3% is applied for each gram of CO_2 emissions per km below 149 gram per km but above 24 gram per km.

Second, there is a correction depending on the fuel, the EURO class and on whether the engine has a particle filter - see Table 7.

Table 7 Flanders: correction applied to the annual traffic tax according to fuel and Euro class

Euronorm	Diesel	Gasoline, LPG and CNG
Euro 0	+50%	+30%
Euro 1	+40%	+10%
Euro 2	+35%	+5%
Euro 3	+30%	+0%
Euro 3+ particle filter	+30%	Not applicable
Euro 4	+25%	-12.5%
Euro 4 + particle filter	+17.5%	Not applicable
Euro 5 or EEV	+17.5%	-15%
Euro 6	+15%	-15%

Also, in Flanders an (indexed) minimum tax of 31.72 EUR applies to all cars.

Since 2016, all electric and fuel cell cars are exempted from the traffic tax in Flanders.[9]

In the three regions, an additional tax is applied to cars that run on LPG.

Table 8 Surtax for LPG cars

Horsepower	SurTax
< 8 HP	89.16
8 to 13 HP	148.68
> 13 HP	208.20

In the three Regions, a 10% municipal tax is levied on top of the traffic tax.

b. License tax

The license tax is applied to passenger cars that are purchased in Belgium - including on the second hand market.

Here as well, since 2016, the Regions can determine the parameters of the tax, except for leased cars where the tax regime can only be modified with unanimity between the Regions.

In the Brussels and Walloon Regions, the tax is still determined by a car's fiscal horsepower and power expressed in kW. Table 9 represents the tariffs for newly purchased cars. When there is a conflict between the amount based on the HP and the amount based on the kW, the highest tariff applies. For cars that drive (even partially) on LPG, there is a deduction of 298 EUR.

Table 9 License tax in the Brussels and Walloon Region

HP	kW	2015
0-8	0-70	61.5
9-10	71-85	123.0
11	96-100	495.0
12-14	101-110	867.0
15	111-120	1239.0
16-17	121-155	2478.0
>17	>155	4957.0

The Walloon Region also applies a so-called "ecomalus", a surcharge that varies according to a car's CO_2 emissions. Cars that emit 145 gr CO_2 per km or less, are exempt from the ecomalus. For cars that

[9] The exemption for PHEV cars that emit at the most 50 grams of CO_2 per km no longer applies to cars purchased in 2021.

emit more, the Ecomalus gradually increases from 100 EUR to a maximum of 2500 EUR (for cars emitting 255 gr or more).

In Flanders, the system is more complex. In 2021, the following formula applied:

$$\text{BIV in euro} = \left((CO2 * f * q)/246\right)^{6} * 4500 + c) * LC$$

where:

- q is equal to 1.07 in 2021 and increases by 0,035 per year.
- f = 0.88 for LPG cars, 0.744 for dual fuel CNG-gasoline cars and 1 for all other cars;
- LC: correction for age - given that we consider only newly purchased cars in this analysis, LC = 100
- c: correction term for air quality, that depends on the fuel and Euro norm for the car - the values are given in Table 10.

Table 10 License tax correction term as from 2021

Euronorm	Diesel	Gasoline and other fuels
0	3106.80	1235.69
1	911.48	552.62
2	675.55	165.25
3	535.34	103.66
3 + particulate filter	506.81	Not applicable
4	506.81	24.88
4 + particulate filter	498.44	Not applicable
5	498.44	22.36
6	492.71	22.36

In Flanders. there is also a lower bound of 41.76 and an upper bound of 10439.45 EUR to the license tax (values for 2015. indexed annually). Electric cars are exempted from the tax.

c. Income taxes and corporate profit taxes

For company cars. the deduction in corporate tax depends on the nature of the expenses. For fuel costs. the deduction is set at 75%. For all other expenses. the corporate tax deduction depends on the CO_2 emissions of the car and on the fuel.

From assessment year 2021. the deductibility of car expenses is determined as a function of the following formula: 120% - (0.5% * coefficient * CO_2 emissions). The coefficient is '1' for vehicles with a diesel engine only; '0.95' for other vehicles; and is raised to '0.9' for vehicles equipped with a natural gas engine and a taxable power of less than 12 fiscal horsepower. The percentage of deductibility thus obtained is minimum 50% and maximum 100%. Notwithstanding this. the deductibility of vehicles with CO_2 emissions of 200 g/kilometre or more will be 40%.

If the employer makes the company car (partially or completely) freely available for private use by the employee ("salary car"). then part of the benefit in kind[10]. (BIK - see below) that results from personal

[10] A benefit in kind is a benefit that an employer or company grants to an employee or manager and that is considered professional income.

use is considered as Disallowed Expense[11] (VU) for corporate tax purposes. Car expenses are included in the Disallowed Expense at:

– 17% of the taxable amount of the benefit in kind if the employer does not reimburse fuel costs associated with the personal use of the vehicle;

– 40% of the taxable amount of the benefit in kind if the employer reimburses fuel costs associated with the personal use of the vehicle (even if only partially);

Due to lack of data on the proportion of personal use. we have always assumed 40%.

d. Income taxes

Since 2012. the benefit in kind (BIK) used for tax purposes is calculated by applying a CO_2 percentage to 6/7 of the catalogue value of the vehicle. namely:

$$\text{BIK} = \text{catalogue value} * \%(CO_2 \text{ coefficient}) * 6/7$$

The CO_2 base coefficient is 5.5% for a reference CO_2 emission that depends on the fuel type. If CO_2 emissions are higher than the reference CO_2 emissions. the base rate is increased by 0.1% per gram of CO_2. up to a maximum of 18%. If CO_2 -emissions are lower than the reference CO_2 emissions. the basic percentage is reduced by 0.1% per gram CO_2. up to a minimum of 4%. If the company car is powered exclusively by an electric motor. the applied CO_2 percentage is equal to the minimum. namely 4%.

Table 11 shows the reference values that were applicable in 2021.

Table 11 Reference CO_2-emissions for the calculation of the BIK

Cartype	RefCO_2
Diesel	88
Diesel. hybrid	88
Diesel. PHEV	88
Gasoline	107
Gasoline. hybrid	107
Gasoline. PHEV	107
LPG	107
CNG	107

There is also a minimum amount of 1.360 euros for the BIK.

e. Social security contributions

The employee is completely exempted from social security contributions on the use of a company car.

The employers' solidarity contribution is calculated as a monthly lump sum per vehicle that is made available to employees.

This monthly contribution. which may not be less than EUR 20.83. depends on the level of CO_2 emissions and the type of fuel and is fixed on a flat-rate basis as follows:

– for gasoline driven vehicles: [(Y x 9) - 768] : 12 = contribution (in EUR)

[11] This is defined as an expense that cannot be deducted for tax purposes.

- for diesel powered vehicles: [(Y x 9) - 600] : 12 = contribution (in EUR)
- for LPG. CNG or methane-fuelled vehicles: [(Y x 9) - 990] : 12 = contribution (in EUR)
- for electrically propelled vehicles: EUR 20.83

where Y is the CO_2 emission content in grams per kilometre.

f. VAT deduction

The deductible share of VAT is proportional to the professional use of the company car. unless that professional use is more than 50%. in which case the deductible share is 0.65.

Annex 7: Indicators of potential wage savings

By providing an employee with a company car free of charge at a favourable fiscal and parafiscal regime. a company can also save gross salary costs. In order to provide an estimate of these savings. we consider a company that maximises its profits and thereby offers its employees a company car and salary in which the employees are at least as well off as with a higher gross salary without a company car.

We proceed as follows. First. we determine all the elements that determine the company's profit when it offers a company car with fuel card to its employees. Next. we look at how employees' utility and budget constraints are affected by the offer of a company car as a benefit in kind. Based on this. we determine what wage an employer can offer that is acceptable to the employee if a company car is made available to the employee. We use this result to derive the maximum wages an employer can save by providing a salary car.

a. Profits with a company car

We consider the profit over the lifetime of the car (as a company car). Since this is short (three years according to Copenhagen Economics (2010)). we do not use annuities. but simply calculate the average over the years.
If the company car is a salary car. we assume that the benefit in kind consists of

- the provision of a car
- a variable cost (in concrete terms. the fuel paid with the bank card provided by the employer).

The purchase price of the car is p_x. The total loss of value over the lifetime of the car is then $p_x - RV$ where RV is the residual value at the end of the lifetime.

In what follows. we set the annual variable cost equal to the annual fuel consumption y. with market price p_y (including excise duties).

In the first step. we look at the part of the profit that is independent of the cost of providing the company car. This can be calculated as follows:

$$(1-\tau_\pi).\big(R - w\ (1+\tau_{ssr})\big).$$

where

- R is the part of the annual gross profit that does not depend on the cost of labour and the company car;
- w is the annual gross salary;
- τ_{ssr} the employer's statutory social security contribution rate;
- τ_π the (marginal) corporate tax rate.

We assume that the total number of working hours is exogenous - we normalise it to 1. We also abstract from the heterogeneity of the workforce and assume that everyone receives the same remuneration.

The second component of the profit is the cost associated with making the car available to the employee. abstracting from VAT.

We need to consider following parameters:

- θ_x and θ_y are the share of the (respectively fixed and variable) car costs that can be deducted from the corporate income tax (75% for the fuel costs and. for all other costs. a percentage depending on fuel and CO_2 emissions. see further for more details).
- BIV is the license tax. which can be deducted from the taxable profit.

So. over the lifetime. the net capital cost outside of VAT is $(1 - \tau_\pi \theta_x)\ (p_x - RV + BIV)$. while the annual cost of fuel consumption net of VAT is $\left(1 - \tau_\pi\ \theta_y\ \right)\ p_y\ y$.

The third component of profit is VAT. Φ. the deductible portion of VAT. is proportional to the professional use of the company car. unless that professional use is more than 50%. in which case $\varphi = 0.65$. Since we do not have data on the proportion of professional use. in CASMO we always assume $\varphi = 0.65$. We also assume that the VAT received on the sale of the car on the second-hand market is payable in full to the tax authorities.

Finally. there are two terms in the profit that are specific to salary cars:

- $H(p_x)$ represents the annual valuation of the benefit in kind by the tax administration if the car is made available free of charge for private use. This valuation depends on the CO_2 emission and on the purchase price p_x. In total. for salary cars. $\tau_\pi\ \nabla(y)\ H(p_x)$ should be deducted from profit after tax. where $\nabla(y)$ is the percentage of "rejected expenses" in the benefit in kind.
- T_{solr} is the annual solidarity contribution paid by employers for salary cars.

So the average annual profit after tax is (where n_{cc} is the expected life and we assume that the car is depreciated linearly):

$$\begin{aligned} \Pi \quad = \quad & (1 - \tau_\pi)[R - w_{cc}\ (1 + \tau_{ssr})] \\ & - \frac{1}{n_{cc}}(1 - \tau_\pi \theta_x)[(1 + (1 - \varphi)\ VAT)\ p_x + BIV - RV] \\ & - \left(1 - \tau_\pi \theta_y\right)[1 + (1 - \varphi)\ VAT]\ p_y\ y - \tau_\pi\ \nabla\ H(p_x) - (1 - \tau_\pi)\ \tau_{solr} \end{aligned}$$

b. The utility function for the employee

We assume that a potential employee is either working full-time or is unemployed. If he is unemployed. he receives the "reservation utility" $\bar{U}$. which is exogenously determined. As mentioned above. we normalise the number of hours worked to 1. A worker derives utility $U(x.y.c)$ from the consumption of both cars and other goods C. When the worker can use a company car with a fuel card for free. his budget constraint is:

$$C_{cc} = w_{cc}\ (1 - \tau_{sse})\ (1 - \tau_{inc}) - H(p_x)\ \tau_{inc}$$

w_{cc} is the annual gross salary for an employee with a salary car. τ_{inc} is the (marginal) income tax rate. τ_{sse} is the statutory employee contribution rate. and $H(p_x)$ is the valuation of the car by the tax administration (the benefit in kind).

If the employer does not offer a salary car. we consider the benefit of an employee who buys the same car and also pays the variable costs in full himself. For such employee the budget constraint is (where n_{pc} is the lifetime of a car purchased privately and w_{pc} is the annual gross salary for an employee without a salary car):

$$C_{pc} = w_{pc}\ (1-\tau_{sse})\ (1-\tau_{inc}) - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}} BIV$$

We are therefore abstracting from a possible tax deduction of commuting costs. Note also that a private person does not necessarily put a car on the second hand market as quickly as a firm. Therefore. we do not equate the lifetime of a car owned by a private person. n_{pc} . with n_{cc} a priori.

c. Gross salary for an employee with salary car

In what follows. we assume that the employer offers a single model as a salary car. In our formulation of the problem. we also assume that the number of kilometres travelled for private purposes. y. does not change when a salary car is made available by the employer. Clearly. this assumption underestimates both the benefits to the employee and the costs to the employer.

We also assume that the gross wage of an employee without a salary car and the price of the salary car are determined in a competitive market. and are a given for the employer. In that case. w_{cc} is the choice variable for the firm. w_{cc} will only be accepted if the utility for the employee is at least equal to the reservation utility and greater than the utility under an employment contract without salary car.

The employer is thus faced with a profit maximisation problem with two inequality constraints. The Lagrangian for the employer is then:

$$\mathcal{L} = \Pi + \mu\ \{U_{cc} - \overline{U}\} + \lambda\ \{U_{cc} - U_{pc}\}$$

Where U_{cc} is the utility with salary car. U_{pc} is the utility if the worker purchases the same car privately. $\overline{U}$ is the reservation utility for the worker. and μ and λ are the Lagrange multipliers.

The first order conditions for the gross wage with salary car are:

$$\frac{\partial \mathcal{L}}{\partial w_{cc}} = -(1-\tau_\pi)\ (1+\tau_{ssr}) + \mu\ \frac{\partial U}{\partial C}(1-\tau_{sse}).(1-\tau_{inc}) + \lambda\ \frac{\partial U}{\partial C}\ (1-\tau_{sse})\ (1-\tau_{inc}) = 0$$

$$\mu\ \frac{\partial \mathcal{L}}{\partial \mu} = 0; \frac{\partial \mathcal{L}}{\partial \mu} = U_{cc} - \overline{U} \geq 0; \mu \geq 0$$

$$\lambda\ \frac{\partial \mathcal{L}}{\partial \lambda} = 0; \frac{\partial \mathcal{L}}{\partial \lambda} = U_{cc} - U_{pc} \geq 0; \lambda \geq 0$$

Suppose that $U_{cc} > U_{pc}$. $\mu\ \frac{\partial \mathcal{L}}{\partial \mu} = 0$ then implies that $U_{cc} = 0$. If also $U_{cc} > U_{pc}$. then $\lambda\ \frac{\partial \mathcal{L}}{\partial \lambda} = 0$ also implies that $\lambda = 0$. But then the first-order condition $\frac{\partial \mathcal{L}}{\partial w_{cc}} = -(1-\tau_\pi).(1+\tau_{ssr}) = 0$ can never be satisfied. Thus. it is impossible to have a profit-maximising solution if both $U_{cc} > \overline{U}$ and $U_{cc} > U_{pc}$.

If $U_{cc} > U_{pc}$. then $\lambda = 0$. Then $\frac{\partial \mathcal{L}}{\partial w_{cc}} = 0$ is possible only if $\mu > 0$ and therefore $U_{cc} = \overline{U}$. However. this means that $\overline{U} > U_{pc}$ and therefore the reservation utility is not attainable if no company car is offered. Since we do not have any data that would allow us to calculate $\overline{U}$. we are not going to consider this possibility further.

Thus. the only remaining situation is where $\mu = 0$ and $U_{cc} = U_{pc}$. Then it follows from $\frac{\partial \mathcal{L}}{\partial w_{cc}} = 0$ that:

$$\lambda.\frac{\partial U}{\partial C} = \frac{(1-\tau_{\pi}).(1+\tau_{ssr})}{(1-\tau_{sse})(1-\tau_{inc})}$$

And from $U_{cc} = U_{pc}$ (assuming $p_x.\ p_y$ and y are the same for salary cars as for private cars):

$$w_{cc}\ (1-\tau_{sse})\ (1-\tau_{inc}) - H(p_x)\ \tau_{inc}$$
$$= w_{pc}.(1-\tau_{sse})(1-\tau_{inc}) - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}}\ BIV$$

And so we obtain the following expression for the difference in wages with and without salary cars:

$$w_{cc} = w_{pc} + \frac{H(p_x)\ \tau_{inc} - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}}\ BIV}{(1-\tau_{sse})\ (1-\tau_{inc})}$$

If $(1+VAT)\left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] + \frac{1}{n_{pc}}BIV > H(p_x)\ \tau_{inc}$. then $w_{cc} < w_{pc}$. Note that the left-hand side of the first inequality is the annual cost of the car purchased privately. while the second is the taxes that the employee must pay on his in-kind benefit if the car is provided by the employer. This formula makes sense: if the employee can save money by accepting a salary car. then the employer can also offer him a lower gross salary.

To simplify the notation. we set: $AC_{PC}(n_{pc}) = (1+VAT)\left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] + \frac{1}{n_{pc}}BIV$.

We then obtain the following indicator for the annual saving in net wages (that is. after deducting employees' social security contributions and income tax) made possible by the provision of a salary car:

$$\frac{H(p_x)\ \tau_{inc} - AC_{PC}(n_{pc})}{(1-\tau_{sse})\ (1-\tau_{inc})}$$

Note that the wage cost savings depend on the car's lifetime: every time the car is offered as a salary car. the employee saves the purchase cost once. but he has to pay tax on the benefit in kind every year. The longer the car is in use. the smaller the relative importance of the saved purchase price compared to the tax on the benefit in kind. and thus the smaller the benefit to the employee compared to buying a private car.

It should also be kept in mind that this indicator is not the *actual* value that will be subtracted from an employee's wages. First. the derivation of this formula is based on several strong assumptions. It is for instance unlikely that an employee will choose the same car when he has to pay for it than with it is offered to him by his company. Second. the actual pass-through of the tax benefit depends on the relative bargaining power of the employees and the employers. which is not directly observable. However. it seems reasonable to assume that this provides us with an upper bound to the potential wage savings.

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Responsible publisher: Baudouin Regout
Legal Deposit: D/2023/7433/14