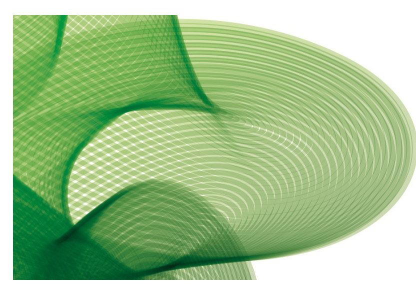
International Transport Forum

Understanding Consumer Vehicle Choice

A New Car Fleet Model for France



Decarbonising Transport

Decarbonising Transport Initiative

Understanding Consumer Vehicle Choice

A New Car Fleet Model for France

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The International Transport Forum

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Nicolas Wagner (Arafer, former ITF), supported by Elisabeth Windisch (ITF), managed the project, and designed the vehicle fleet model. The vehicle fleet model was made available to the MTES for further use.

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Executive summary

What we did

This report presents a model that helps to better understand how consumers in France choose vehicles. It presents the results for different scenarios for the future development of the French vehicle fleet and projections for related CO_2 emissions to 2050. The model distinguishes conventional, plug-in hybrid, battery-electric and fuel cell cars. It looks at both the private as well as company car fleets and considers non-monetary factors for vehicle choice. Among these are personal preferences, the availability of recharging infrastructure for electric vehicles, and policy incentives such as subsidies or preferential vehicle use rights. The methodology and the data used for this new passenger car fleet model are described in detail.

The study specifically sheds light on some of the uncertainties around the uptake of electric vehicles in the future. Electric vehicles made up a mere 2.5% of global passenger light-duty vehicles sales in 2018. How fast their share will grow is uncertain and forecasts differ widely.

Key model parameters are based on the findings of a stated preference survey among French vehicle buyers carried out in 2018.

What we found

The number of cars in France will increase by 18% between 2020 and 2050 from around 33 million to 39 million. The average number of cars per household in the model's baseline scenario increases from around 1.15 to 1.25.

The share of the electric vehicle types among all new cars entering service will reach around 55% by 2050. This includes plug-in hybrid, battery electric and fuel cell vehicles. Around 30% of the total French vehicle fleet will then be electric and the average CO_2 emissions per vehicle-kilometre will have fallen by more than two thirds, to c. 45 g CO_2/km from c. 140 g CO_2/km in 2018.

The share of electric vehicles in the company car fleet could be as high as 70% by 2050. This is because the high turnover rate of company cars results in fast adoption of new vehicle technologies. The high average annual usage of company cars also favours electric vehicles, as their running costs are typically lower than those of conventional vehicles.

Non-monetary factors play an important role for choosing vehicles. The time it takes to recharge an electric vehicle is important for consumers, for instance. Consumers in urban or peri-urban areas show stronger preferences for electric vehicles than those in rural areas.

Use patterns with high annual vehicle mileage and few long-distance trips favour the purchase of electric vehicles. Electric vehicles of all types will make up around 80% of vehicles with an annual mileage of 25 000 km by 2050. For vehicles with an annual mileage of around 3000 km, their share will be less than 25%. The purchase of plug-in hybrids becomes more appealing as the number of long-distance trips per year increases. That said, 50% of the vehicles with ten or more annual trips above 100 km will likely still be conventional cars in 2050.

Free parking for electric vehicles and free use of motorways are the two policy levers for boosting the uptake of electric vehicles, that have the biggest impact on consumers' vehicle choices, according to choice model estimates. Access to bus lanes for electric vehicles and the waiving of restrictions for car use in urban zones had a less strong positive effect.

What we recommend

Target the company car market to boost the uptake of electric vehicles

Around 25% of cars sold in France are company cars. Their typical use patterns and high replacement rate make them particularly suited for speeding up electrification of the French vehicle fleet. New vehicle technologies that find a sales market in the company car sector will quickly penetrate to the private household fleet. Policy makers should utilise this and strongly support companies in shifting their fleets towards alternative fuels.

Address non-monetary factors in vehicle purchase decisions

Non-monetary characteristics both of cars and in consumers are important factors for the choice of vehicles. The time it takes to refuel a vehicle or its environmental impact, the location of a buyer or their usage patterns influence the choice of technology. Any assessment of the market potential for new vehicle technologies should take such factors into account. Policies that target barriers to uptake rooted in non-monetary factors have great potential to help boost acceptance of electric vehicles.

Use stated preference surveys to improve understanding of consumer choices

Stated preference surveys, as used for this study, are useful to supplement national data sets such as household surveys. They help to incorporate additional socio-demographic parameters into choice models. They also allow exploration of the choices that consumers could make when faced with technologies or vehicle types they may not previously have encountered. In combination with revealed preference data, stated preference data can provide useful additional insights and improve assessment of the impact of new technologies.

Introduction: The role of electric vehicles in decarbonising transport

Decarbonising transport remains a major challenge for mitigating climate change in the decades ahead. Fuel combustion from transport is responsible for around one quarter of greenhouse gas (GHG) emissions globally. The ITF's current ambition scenario projects that the sector's CO_2 emissions, the main GHG in transport, will grow by 60% between 2015 and 2050. This is despite all present and currently foreseeable future mitigation efforts (ITF, 2019).

The CO_2 emissions of passenger vehicles remain one of the biggest concerns for decarbonising the sector. Passenger vehicles were responsible for around 27% of global oil demand in 2016 (IEA, 2017). Alternative-fuel vehicles can reduce, or even avoid, direct fuel burn of passenger cars and hence related CO_2 or other pollutant emissions. As such, consumers, policy makers and the media have turned their attention to plug-in hybrid electric vehicles, battery electric vehicles, or fuel cell electric vehicles.

Globally, the total electric light-duty vehicle stock was around 5 million vehicles in 2018. The sales of such electric vehicles amounted to around 2 million units in the same year. Only a few years earlier, respective sales numbers were still significantly lower (i.e. around 550 000 vehicles in 2015; 8 000 vehicles in 2010). The year-to-year growth of electric vehicle sales is currently in the range of around 60%. However, electric vehicles still only make up 2.5% of the global passenger light-duty vehicle sales (IEA, 2019).Their future uptake rates are subject to high uncertainty and respective forecasts vary widely (Kah, 2018).

It is still unclear for consumers at what point in time (if not already) the perceived benefits of electric vehicles outweigh their challenges. This will depend on factors such as consumer characteristics and preferences, vehicle-use patterns, the prevailing and expected future policy landscape, and also on the specific type of electric vehicle. Currently, benefits of electric vehicles can be faster acceleration, avoidance of noise and using gas stations, less environmental impact, potential government incentives and low running costs. Challenges are related to charging times and availability of charging infrastructure, range, battery life, high upfront costs) compared to conventional vehicles.

From a government perspective, there is uncertainty around the sustainability and impact of electric vehicles-supportive policies. The extent of the environmental benefits of electric vehicles is also uncertain. They will vary with factors such as the energy mix of a country, the sustainability of vehicle (and battery) manufacturing processes, availability of, and access to, resources, and (battery) recycling schemes that are put in place.

Further research is needed to shed light on these uncertainties and to define what role electric vehicles can potentially play in any climate change and CO_2 mitigation efforts. Findings may produce more robust outlooks on the future uptake of electric vehicles.

Study objectives: What motivates electric vehicle uptake?

This study tackles some uncertainties related to electric vehicle uptake. It assesses consumer preferences with regards to vehicle choice and evaluates how both monetary and non-monetary aspects, such as personal characteristics and preferences, or specific policy levers in favour of alternative-fuel vehicles, can impact consumer choices. Existing vehicle fleet forecasts often do not take such disaggregate, behavioural aspects into account, due to the significant amount of data required. In this study, a vehicle fleet model assesses the impacts of monetary or non-monetary factors on the overall vehicle stock and its average CO_2 emissions to 2050, considering various scenarios.

A specific objective of this study is to cover passenger cars in both the private and company car fleet market. A literature review focused on national-level car choice and/or car fleet models (see Annex 1) has shown that such a comprehensive scope, also encompassing company cars, is rare in the available literature. In addition, the vehicle fleet model should be easy to use to assess various (policy) scenarios and related questions for any potential future studies (in contrast to a model that may be more focused on answering very specific methodology-related questions, e.g. with regards to the usefulness of comparatively complex choice modelling approaches).

Study scope: What does the model account for?

The study scope can be defined by the geographic coverage of the vehicle fleet model, the types of vehicles it covers, and the time horizon it accounts for.

- *Geographic coverage:* consumer choices are, per definition, highly personal and depend on the characteristics of each decision maker, their circumstances, and surrounding conditions (such as the policy landscape or prevailing vehicle purchase or use costs). To be able to take such relevant, yet disaggregate characteristics into account, this project focuses on the specific study area of France.
- *Vehicle types:* four different passenger car types are considered; conventional vehicles, including conventional hybrids that cannot be recharged by an external electricity source; plug-in hybrid vehicles; battery electric vehicles and fuel-cell electric vehicles, regardless of whether they are purchased by private households or as company cars. Conventional hybrid vehicles are considered within the category of conventional vehicles, as their use does not differ significantly from fuel-powered vehicles (e.g. in terms of refueling modalities or infrastructure requirements). Rather, they are seen as necessary advances of conventional vehicles required to meet increasingly stringent vehicle emission standards as they are and will continue to be in place throughout Europe.
- The *time horizon* of the model is to 2050. This is to account for relevant future technology and cost developments in the sales market of the considered vehicle types, their impacts on consumer choice, and resulting average vehicle fleet emissions.

Building a fleet model to understand the future composition of the car stock in France

The vehicle fleet model allows to make projections of the size of the future vehicle fleet and the shares of the different vehicle types under various scenarios. This section sets out the methodology that was used to build the model.

The main *input* of the model is the vehicle fleet in the base year 2018, characterised by the age of the vehicles, their respective annual vehicle mileage and their vehicle type by energy source (i.e. either conventional, plug-in hybrid, battery electric vehicles and fuel-cell electric vehicles, in line with the scope of this study). The main *output* of the model is the vehicle fleet, characterised by the same parameters, for the subsequent year. Reiterating the same model steps allows obtaining the vehicle fleet and its characteristics of any year up to 2050 (see Figure 1).

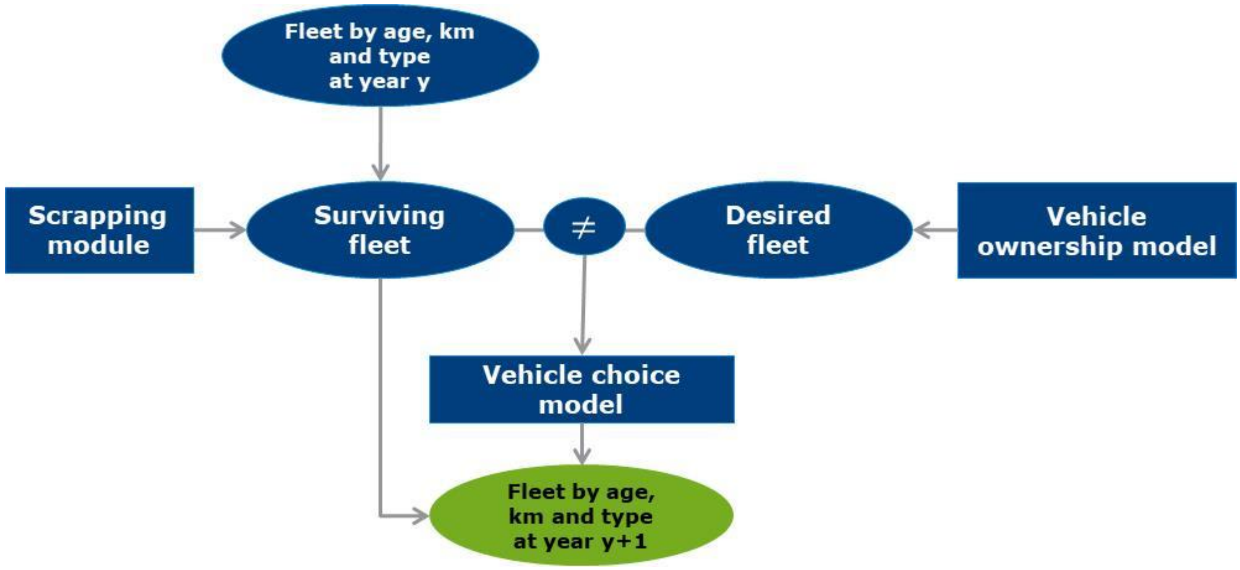
The main components of the vehicle fleet model are:

- the **vehicle ownership** model that defines the vehicle demand of households (or companies) in a given year – it defines the *desired* car fleet
- the **vehicle scrapping** module that defines how many, and which, vehicles leave the vehicle fleet each year because they are scrapped – it defines the *surviving* car fleet
- the **vehicle choice** model that defines which type of new cars (either conventional, plug-in hybrid, battery electric vehicles or fuel-cell electric vehicles) enter the fleet.

The number of new cars that enter the fleet each year is defined by the difference between the desired and the surviving vehicle stock numbers to ensure that the total car demand is met each year.

The main components of the model are discussed in more detail in the following sections. First, the methodology for private cars will be described, followed by a discussion regarding the cars of legal entities (company cars). In general, the methodology applied for legal entities is a simplified approach compared to the one applied for private households.

Figure 1. Overview of the vehicle fleet model



The vehicle ownership model

The vehicle ownership model defines the vehicle demand of households (or companies) in a given year. It defines the *desired* car fleet in the future.

Future vehicle ownership for households is estimated using regression analysis. More specifically, a multinomial logit model is estimated that provides the probability of distinct choice alternatives. Three choice alternatives (*k*) were defined for the households: do not own a car; own one car; own two or more cars. The choice alternative of owning one car was used as the reference choice alternative; its utility value is therefore set to zero. All parameter estimates for the other two choice alternatives have to be interpreted in reference to the 'one car' choice alternative. The below formula provides the specification of the logit model. It shows how to derive the probability *P* for a household *i* choosing choice alternative *k* (comprised in choice set *C*) on the basis of the households' specific utility values *U* for each choice alternative.

$$P_k(i)=\frac{\exp(U_k(i))}{\sum_{k\in C}\exp(U_k(i))}$$

The household-specific utility values for each choice alternative *k* are estimated using the following utility function:

$$U_k(i)=\beta_0^k+\beta_1^k Income_i+\beta_2^k NbActives_i+\beta_3^k Rural_i+\beta_4^k LargeUrban_i+\beta_5^k SmallUrban_i+\beta_6^k Periurban_i+\beta_7^k PKO_{km2_i}$$

The utility of a choice alternative is a function of

- a set of household characteristics: household income, number of active persons (employed or self-employed) in the household, and location of the household (rural, large urban, small urban or suburban area)
- a variable that indicates the quality of the public transport system in the area where the household is located; i.e. the offered person-kilometres of public transport by square kilometre

- a constant specific to each choice alternative (β_0).

The parameters defining the weights of the household characteristics ($\beta_{1\text{-}6}$), of the public transport variable (β_7), as well as of the alternative-specific constants (β_0), are estimated by using the data set of the French household survey *Enquête nationale transports et déplacements* (Department of Demographic and Social Statistics, 2008).

Table 1 shows the parameter estimates resulting from the regression analysis. All estimates are significant at the 99% confidence level. The parameter signs are as expected. For example, on average, a higher household income means that households are more likely to own two or more cars (rather than one car), but less likely to not own a car at all (rather than one car). Households with more active persons in the household have a tendency to own two or more cars rather than one car or no car at all, compared to households with fewer active persons. Households in rural and peri-urban areas are more likely to own two or more cars, rather than one car or no car. An increase in the quality of public transport increases the likelihood of households not owning a car, and decreases the likelihood of owning two or more cars.

Table 1. Parameter estimates for the car ownership model

Choice options	Constant	Household income	Active household members	Rural areas	Large urban areas	Small urban areas	Peri-urban areas	Quality of public transport
Two or more cars	-2.785	0.0001	1.077	0.378	-0.010	-0.017	0.823	-0.0001
No car	0.996	-0.0001	-0.824	-0.596	-0.240	-0.298	-0.722	0.0001
Rho square: 0.2								

The vehicle ownership model is applied to a household population that is based on data from the French National Institute of Statistics and Economic Studies (INSEE, 2017) in the base year 2018.

Applying the vehicle ownership model: assessing vehicle ownership scenarios

Assumptions on the development of model input parameters allow developing establish vehicle ownership scenarios. For a baseline scenario, urbanisation developments are assumed to be in line with Commissariat général au développement durable (CGDD, 2013a). Notably, an increase of 1% per year in the share of peri-urban households is assumed. Household income increases by 1.2% per year. Public transport supply improves by 1.2% per year (and 1.7% in Paris), and population growth is based on projections of INSEE’s *omphale model* “scenario central” (INSEE, 2017).

Figures 2 and 3 show the results for the baseline scenario, and three alternatives. For the alternative scenarios, some input parameters progress at a different pace compared to the baseline scenario. Specifically, the growth of peri-urban areas, household revenues, or public transport supply (PKO) is doubled. Figure 2 shows that the vehicle ownership rate (the average number of cars per household) is expected to increase from around 1.15 to 1.25 by 2050 in the baseline scenario. If household revenues were to increase at twice the assumed rate, then the vehicle ownership would be expected to increase to around 1.35 in the same time frame. If public transport supply were improved by twice the rate assumed for the baseline scenario, the vehicle ownership rate would only increase to 1.22 by 2050.

Figure 2. Vehicle ownership rates – scenarios to 2050

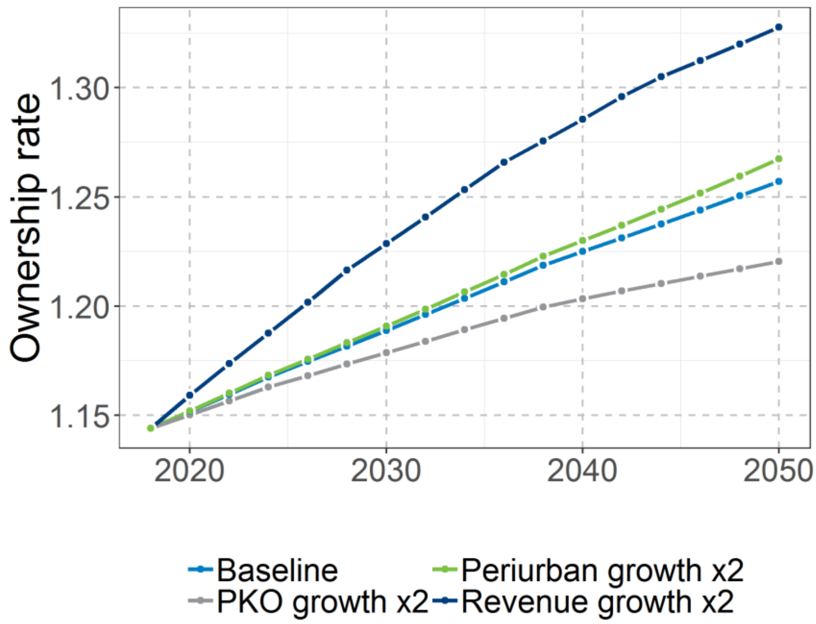
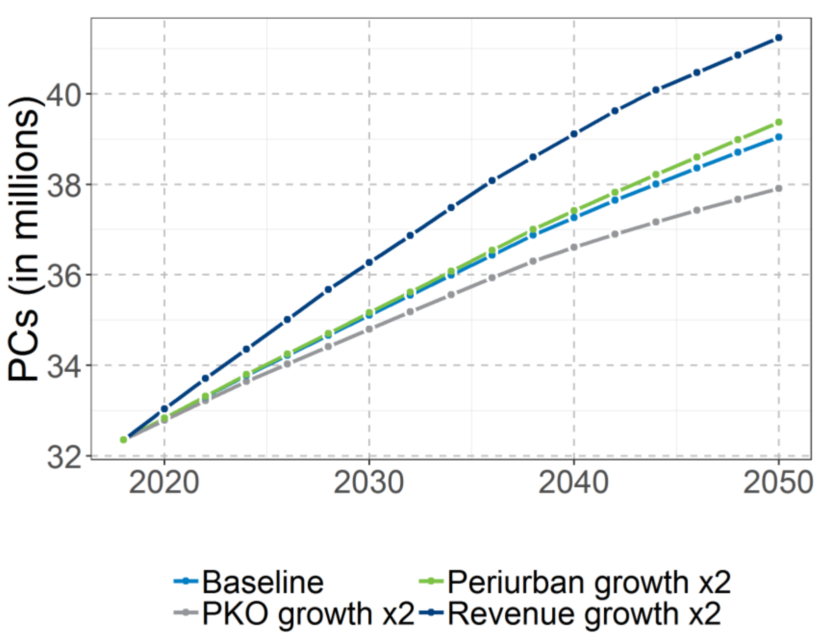


Figure 3 shows what these future ownership rates would mean for the total passenger car (PC) fleet in France. In the baseline scenario, the car stock would increase from around 33 million in 2020 to around 39 million in 2050. In the increased revenue growth scenario, this number would increase to 41 million. In the improved public transport supply scenario, this number would drop to around 38 million. The accelerated peri-urban growth scenario, would only slightly increase the total car stock compared to the baseline scenario.

Figure 3. Total vehicle stock– scenarios to 2050



How will the company vehicle stock evolve?

The vehicle ownership model uses the level of GDP as an explanatory variable for legal entities. It is assumed that the demand for vehicles by legal entities is correlated to GDP with an elasticity of 0.5 (i.e. a 1% increase in GDP results in a 0.5% increase of the vehicle ownership rate of legal entities). The number of legal entities is assumed to be constant over time. The GDP of France is assumed to increase by around 1.5% annually to 2050, approximately in line with *Projection de la mobilité courte distance à l'horizon 2030* (CGDD, 2013b). The resulting vehicle demand of legal entities would increase from around 2.4 million vehicles in 2018 to 3.0 million vehicles in 2050. The spatial distribution of vehicle demand of legal entities is based on employment data from INSEE (2018).

The vehicle scrappage module

The vehicle scrappage module defines how many, and which, vehicles leave the vehicle fleet each year because they are scrapped. It defines the surviving car fleet. Cars in both the private household and company car fleets, are scrapped according to a survival law based on total vehicle mileage developed in Kohli (2011).

The total annual vehicle mileage of a vehicle is in line with one of five different vehicle use profiles (in kms per year) derived from the ENTD (2008). The probability of a household car following a specific profile depends on the household's location type (rural, urban etc.) and the number of long distance trips that a household carries out with that car in a year (also reported in the ENTD, 2008). On average, a private car has an annual mileage of around 12 400 km.

The annual vehicle mileage of a company car can take nine different values. These values and the distribution of vehicles across these different annual vehicle mileages are in line with CGDD (2019). The average annual vehicle mileage of a company car is 30 600 km. The annual vehicle mileage for both private and company cars is assumed to stay constant over a vehicle's lifetime and over time to 2050.

For the *household vehicle fleet*, the difference between the surviving car stock and the desired car stock (defined by the ownership model) in a given year is met by either second-hand company cars that are sold to households or new vehicles entering the fleet. In contrast, the difference between the surviving and desired car stock of *companies* is solely met by new vehicles. The vehicle choice model defines which types these new vehicles are.

The vehicle choice model

The vehicle choice model defines which type of new cars enter the fleet. It uses data collected from a stated preference survey to assess which vehicle type consumers are likely to choose among the alternatives explored. The choices are: plug-in hybrid, battery electric, fuel-cell electric or conventional vehicle. This study also explores the potential uptake of vehicle types with specifications that are not yet necessarily on the market. For example, while fuel cell electric vehicles may be available, they are currently available at prices that are much higher than the prices that may be expected in the future to 2050. To explore potential preferences for such vehicles with specifications that are not yet on the market, a so-called stated preference survey was designed and carried out specifically for this study. Any other type of data set that collects information on so-called revealed preferences (e.g. on actual purchases that lie in the long or recent past) cannot provide such insights and would have been less useful for this study.

Box 1 provides more information on stated preference methods and their advantages and challenges in comparison to revealed preference methods.

Box 1. Benefits and challenges of stated preference methods

Stated preference (SP) surveys provide respondents with a set of descriptions of choice alternatives. Participants are asked to express their preferences by either choosing a preferred alternative, sorting the alternatives in decreasing order of preference, or by giving a rating value for each. Respondents can also be offered combinations of a few alternatives (typically two to five) and are asked to express their preference by indicating the alternative they would choose.

SP methods can be particularly insightful in areas where revealed preference data (data that describes actually observed choices) comes with certain limitations. For example, it can be difficult to obtain sufficient variation in the revealed preference data to examine all variables of interest (i.e. those that are thought to have an impact on the person's choice). There are often strong correlations between explanatory variables that make it difficult to estimate model parameters that reflect proper trade-off ratios. Finally, revealed preference data cannot be used in a direct way to assess preferences for products/services that do not yet exist, or that do not yet exist under certain conditions.

It is against the backdrop of such problems that the use of SP methods becomes an attractive option in choice research. Broadly, these methods are easier to control. The researcher defines the conditions which are being evaluated by the respondents. This means they are more flexible (they can deal with a wider variety of variables), and they are cheaper to apply (as each respondent provides multiple observations for variations in the explanatory variables which are of interest).

However, there are also issues with SP methods that should be carefully dealt with by the researcher:

- Estimates of absolute demand levels derived through the use of SP data alone requires careful interpretation. Marketing research has shown that people tend to overstate their responses under experimental conditions. As long as applications are mainly used to estimate relative utility weights rather than absolute values, SP methods have proven to be particularly useful. Where estimates of absolute demand are required, the use of SP methods in conjunction with revealed preference data offers a solution. With this type of approach, SP methods are typically used to initially estimate the trade-off ratios in the utility function. Then, aggregate revealed preference data (e.g. shares) are used to scale the utility function and obtain a model which is consistent with revealed preference data.
- Experiment design and ease of comprehensibility. Researchers should carefully consider whether a respondent can adequately evaluate the alternative options that are being presented to them and whether they can adequately express their preferences on the measurement scale being used. Experiments should be as simple and easy to understand as possible, while still covering all relevant explanatory variables that are of interest for the study.

In general, SP experiments need to be carefully designed to ensure the data resulting from such surveys provides the desired insights into respondent choice, behaviour and preferences. Where this is possible, they can be very powerful in assessing how consumers value the trade-off between different characteristics of product/services. They can also provide a means for projecting absolute demand for products or services that are not yet necessarily on the market as such (where combined with revealed preference data).

Collecting data using a stated preference survey

This sub-section provides information on the *design of the stated preference survey* that was carried out among private vehicle owners and some *generic results*.

The stated preference survey that was carried out for this study targeted persons that had bought either i) a brand new car in the past five years, or ii) a second-hand car, which was not older than five years, in the past two years. This target group was defined to ensure that respondents are limited to those that have recently purchased a car. These people are likely to have a better awareness of their preferences regarding their car choice than people who have never bought a car or bought a car a very long time ago. Ideally, the survey would have been targeted at new vehicle buyers only; however, this would have required more resources for data collection than available for this study. The pool of potential respondents would have significantly reduced in that case.

First, respondents were asked about their socio-demographic background (age, income, etc.), their recent car purchase (type of car) and their car usage patterns (type of trips that are made with the car, availability of parking facilities etc.). The main element of the survey was the stated preference section where respondents were asked to choose their preferred type of car, out of four different alternatives, while being shown the main attributes of each car type. Table 2 shows how such so-called choice games looked in the survey. Each choice alternative (type of car) was described by six attributes that were judged to be of high relevance for consumers when choosing their car. These attributes cover cost items (upfront vehicle purchase costs and vehicle running costs per month), the range of the car, the time needed for recharging/refuelling the vehicle and the availability of this infrastructure, and preferential policies that may be in place for electric vehicles.

The values of the attributes varied by choice game and independently from each other. This way, respondents were confronted with different choice situations. The exact values that attributes could take were defined upfront and were in the range of what was judged to be realistic values for these types of vehicles from the time of the survey to 2050. The number of values that attributes could take were limited (depending on the attribute, three to five values per vehicle type) and carefully chosen. This was due to stated preference survey design requirements and the resources available for this study. To further limit complexity in the survey design, preferential policies were assumed to either apply to no vehicle type at all, or to all three alternative-fuel vehicles types (plug-in hybrid, battery electric, fuel-cell electric) at the same time. The preferential policies that were tested are: free parking, free access to public bus lanes, free motorway access, circulation restrictions in France’s five biggest agglomerations, of which the concerned vehicles would then be exempted. Each survey respondent was asked to respond to 15 choice games. The survey was carried out by a market research service provider from November to December 2018.

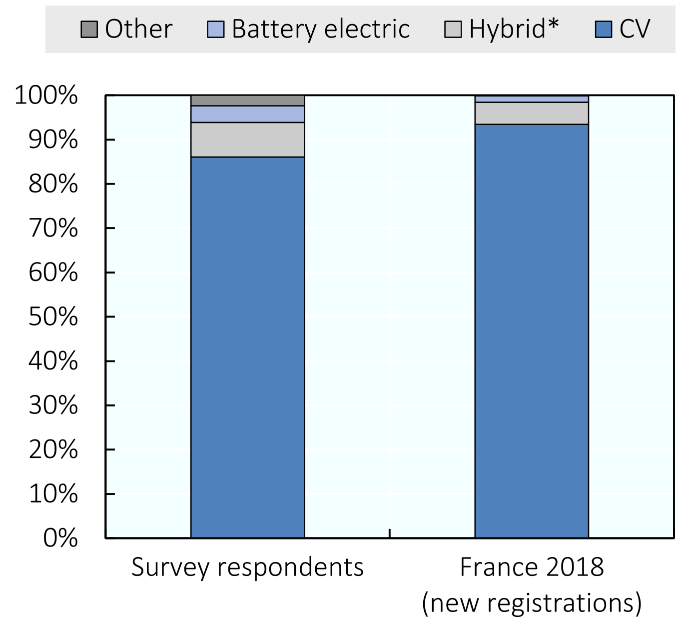
Table 2. Example choice game in the stated preference survey

Type of car	Conventional	Plug-in hybrid	Battery electric	Fuel-cell electric
Upfront purchase costs (EUR), including taxes and subsidies	17 000	22 600	26 600	32 000
Running costs per month (EUR) (for fuel/electricity, incl. taxes)	11	11	6	8
Range (km) (distance that can be driven without recharging/refueling)	630	650	270	600
Recharging/Refueling time (in min)	A few minutes	30	180	A few minutes
Availability of recharge infrastructure (in minutes of driving)	10 minutes	20 minutes	20 minutes	30 minutes
Preferential policy in place (if any)	None	Free parking		
Your preferred choice (please tick)	◯	◯	◯	◯

The survey yielded more than 1 000 responses. As a result, more than 15 000 responses for the choice games were obtained. The average annual income of the respondents is EUR 36 000; 80% of the respondents are employed (or self-employed), while 20% are unemployed, retired or in education; only 4% live in rural areas. The share of senior executives/managers ("cadres") among the survey respondents is higher than their share in the global population.

86% of survey respondents indicated that their last car purchase was a conventional vehicle; 8% stated that they had bought a plug-in hybrid electric vehicle; 4% had bought a battery electric vehicle; and 2% had bought another type of vehicle. It is assumed that some respondents may have misunderstood the question based on the high share of people that indicated that they had bought a plug-in hybrid vehicle. They may have indicated their conventional hybrid vehicle purchase as plug-in hybrid vehicle purchase. Figure 4 provides a comparison between the survey respondents' previous car choice and the new passenger car registrations in France in 2018 for reference.

Figure 4. Choice comparison for vehicle type – survey respondents vs. 2018 registrations in France



Note: *Category includes conventional and plug-in hybrid vehicles in the French vehicle registration dataset. Survey respondents were asked to state plug-in hybrid vehicles only; however, this is likely to have been misunderstood. CV – conventional vehicle

Source: Survey carried out for this study and MTES (2019a).

The survey data set was calibrated against the characteristics of ENTD 2008 respondents and their respective weights in the ENTD. This was to mitigate the fact that the average socio-economic characteristics of the survey respondents did not perfectly fit the average characteristics of new vehicle buyers as identified in the ENTD 2008. This improves the quality of demand projections for different vehicle types by use of the vehicle choice model (as described in the following section).

Estimating model parameters to gain insights into consumer choice behaviour

This sub-section shows how a vehicle choice model is developed from the stated preference survey data and what insights can be obtained from parameter estimates.

Consumer preference between the different vehicle types can be obtained from the data collected in the stated preference survey. The impact of personal and vehicle characteristics (monetary and non-monetary) collected in the stated preference survey can also be evaluated. These insights were gained by estimating parameters of a multinomial logit model. The model specification is shown in the below formula. The probability *P* of a household *i* choosing vehicle type *k* is a function of the household-specific utility value *U* for each available vehicle type in the choice set *C*. The latter being comprised of conventional; plug-in hybrid; battery electric and fuel cell vehicles.

$$P_k(i)=\frac{\exp(U_k(i))}{\sum_{k\in C}\exp(U_k(i))}$$

The utility functions for the choice alternatives are all linear in parameters. The only variables that are not introduced in the standard form of (*parameter * variable*) are the cost variables. Rather, they are introduced as (*parameter * log(PurchaseCosts / 8 + AnnualUsageCosts)).* This is because the introduction of two different cost terms - to estimate weights (parameter values) for purchase costs and usage costs separately - did not yield significant results. Estimations further showed that a log-function and a division of purchase cost by eight yielded best outcomes. The log-function reflects that absolute cost increases are increasingly less relevant with higher vehicle costs. The fact that purchase costs are divided by eight can indicate that private vehicle purchasers look for an amortisation of the up-front vehicle purchase costs within eight years.

Table 3 gives more information on how the utility functions were defined. It shows which variables were introduced into the utility function of which choice alternative, and whether these variables were continuous or binary (dummy) variables (taking the value of either 0 or 1). It also provides the estimation results for all parameters and their level of significance. For example, the utility function for conventional cars includes the variables that define the car's costs, the car's autonomy and indicate whether the respective household is located in an urban area. The most comprehensive utility function is the one for battery electric vehicles. Here, variables that define the vehicle recharging/refuelling time, the availability of recharging infrastructure, and indicative policies that favour alternative-fuel vehicles are also relevant, and are thus included. Variables that indicate whether the questioned household has more than one car, how many long distance trips (>100km) are carried out by them, and the household revenue are also included here.

The model estimation yields the expected signs for all parameters. Cost increases reduce the utility of the respective choice alternative; an increase in vehicle autonomy (range) increases the utility etc. It is also interesting to note that multi-car households are more likely to purchase a battery electric vehicle (than households that only have one car); and that those households that more frequently carry out long-distance trips are less likely to purchase a battery electric vehicle. Households in urban areas get less use out of a conventional vehicle than households elsewhere. This may already reflect the impact of early policy levers in urban areas that support the uptake of alternative-fuel vehicles. The constants show that when accounting for all other variables, there is still some preference for conventional vehicles (for which the constant was set to 0) that remains unexplained by the model. The biggest disutility is related to fuel-cell cars. The unexplained factors may, for example, relate to the currently quite limited availability of fuel cell vehicles or little knowledge about this type of vehicle, their functioning or reliability. These factors may have unconsciously been taken account by some survey respondents (despite indications in the survey that such factors should not be considered when responding to the choice games).

Free parking and free motorways appear to have been the biggest impact on people's vehicle choices, out of the four policy levers tested. Notably, free parking has more than three times the impact of giving free access to bus lanes and almost seven times the impact of waving any urban access restrictions for alternative-fuel vehicles. A reason for the latter may be that respondents did not feel overly impacted by such restrictions, as they may live elsewhere and do not usually enter any of France's five biggest agglomerations with their private car. This policy lever could also be related to the urban area variable, which already shows a certain preference for alternative-fuel vehicles in urban areas. The effect of these two variables may be confounded in the model.

Table 3. Parameter estimates for the vehicle choice mode

Choice option Variable		CV	HY	EV	FC	Parameter estimates
Total costs (purchase plus usage)		x	x	x	x	-2.10e01 (**)
Autonomy (in km)		x	x	x	x	2.73e-005 ()
Vehicle recharge /refuel time (in min)			x	x		-6.32e-03 (**)
Recharge availability (in minutes of driving)				x		-4.80e-02 (**)
Policies favouring alternative fuel vehicles (dummy variables)	No urban restrictions in five biggest cities		x	x	x	1.23e-01 (*)
	Free motorways		x	x	x	7.83e-01 (*)
	Free parking		x	x	x	8.21e-01 (*)
	Access to bus lanes		x	x	x	2.50e-01 (*)
Multi-car household (dummy)				x		6.52e-02 (*)
Household income (in EUR)			x	x	x	3.86e-05 (***)
Number of long distance trips (>100km) per year				x		-2.44e-01 (**)
Urban area (dummy)		x				-1.12 (**)
Constants			x	x	x	-2.80 (***) -5.01 (***) -7.98 (***)

Notes: CV = conventional; HY = plug-in hybrid; EV = battery electric; FC = fuel-cell

* 80% confidence level; ** 95% confidence level; *** 99% confidence level

Defining model assumptions to make projections to 2050

Assumptions regarding the development of all input variables are required to apply the vehicle choice model and make projections of the market shares of different vehicle types.

For a baseline scenario, the assumptions regarding *household characteristics* (household income; household distribution across different urban/non-urban areas) are in line with the ones used for the car ownership model. The share of multi-car households and the use of household cars for long distance trips stay constant over time. Availability of *recharge infrastructure* doubles by 2050 (e.g. from 2040 onwards, only ten minutes of driving from home are required to reach recharge infrastructure for a battery electric vehicle instead of an assumed twenty minutes).

Table 4 summarises the main assumptions concerning the development of *vehicle characteristics*. The autonomy of battery electric vehicles is assumed to double between 2020 and 2050 (while battery costs per kWh experience a decrease – further below). The battery recharge time at public recharge infrastructure is assumed to halve over the same time period.

Table 4. Assumptions for the development of vehicle characteristics

Vehicle type	2020-30	2030-40	2040-50
Vehicle autonomy (range in kms)			
Conventional	630	700	770
Plug-in hybrid	650	715	780
Battery electric	270	405	540
Fuel cell	600	900	1200
Battery recharge time at public recharge infrastructure (mins)			
Plug-in hybrid	60	45	30
Battery electric	180	135	90

Table 5 shows the assumed *vehicle purchase costs* over time. Figure 5 shows the incremental vehicle costs of the different technologies compared to a 2018 conventional vehicle. The main source for the development of purchase costs is the National Research Council (2013) that provides such incremental vehicle cost estimates to 2050. The base year price of a conventional vehicle was updated to be in line with the average price of newly-registered conventional vehicles in France in 2017 (i.e. around EUR 28 000, as obtained from ICCT, 2018). Battery price assumptions are also updated to account for recent cost developments and to be more in line with a French cost-benefit assessment of electric vehicles (CGDD, 2017). More specifically, 2030 battery costs of around EUR 210 /kWh are revised downwards to EUR 135 /kWh; 2050 costs are adjusted from EUR 130 /kWh to EUR 100 /kWh. Cost decreases in between these years are assumed to be linear. Costs of fuel cell vehicles were updated to be more coherent with ICCT (2016).

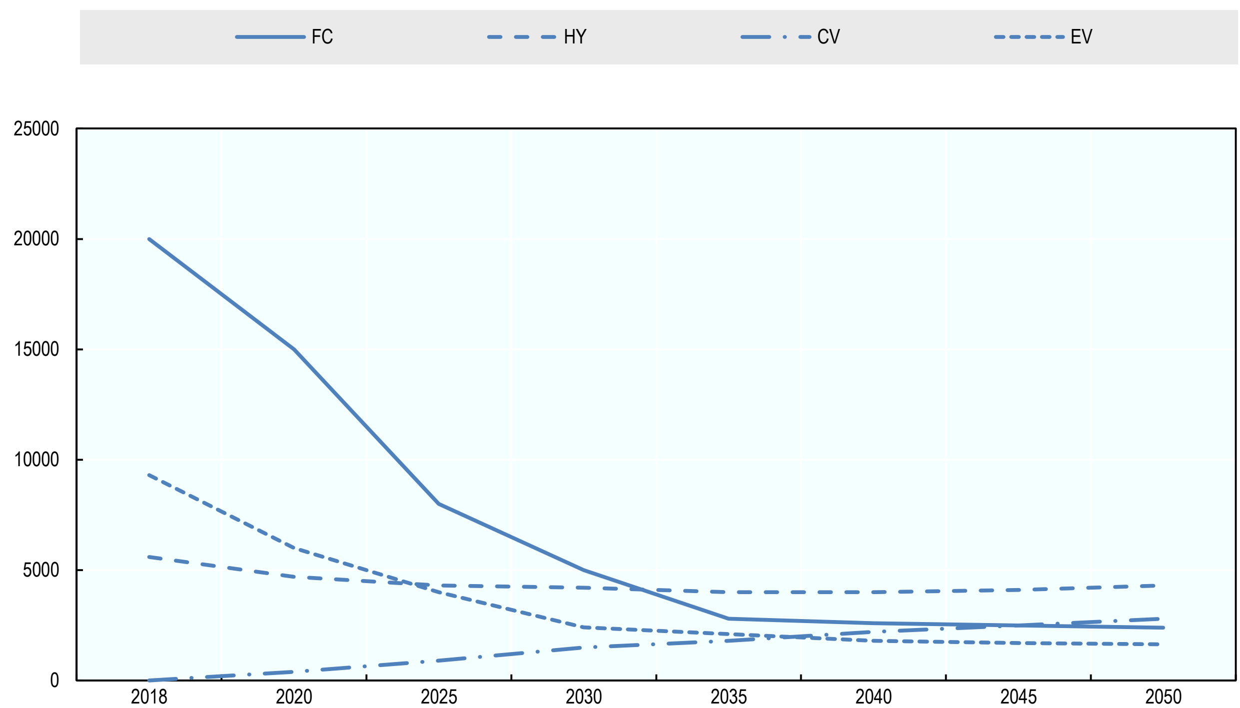
Overall, costs of conventional vehicles are assumed to increase over time due to vehicle efficiency improvements to meet increasingly stringent emission targets. On average, the assumed cost increases of conventional vehicles equate to a cost of around EUR 45 per gCO_2 saved (see below for assumed vehicle efficiency improvements of conventional powertrains to 2050). Costs of plug-in hybrid electric vehicles are assumed to stay relatively stable – price increases due to efficiency improvements in the conventional powertrain are balanced by cost decreases and performance improvements of the electric powertrain, i.e. the battery. The drivers of the cost decreases of battery electric vehicles are mainly battery cost decreases and respective performance improvements, similar to the savings that also apply to the battery systems in plug-in electric vehicles. Fuel cell technology is assumed to experience cost decreases thanks to strong efficiency increases of the fuel cells (that will allow smaller cells), and unit cost reductions in fuel cell stacks and on-board storage units.

Table 5. Vehicle purchase cost assumptions

Vehicle type	2020	2025	2030	2035	2040	2045	2050
Conventional	28 300	28 800	29 400	29 700	30 100	30 400	30 700
Plug-in hybrid	32 600	32 200	32 100	31 900	31 900	32 000	32 200
Battery electric	33 900	31 900	30 400	30 000	29 700	29 600	29 600
Fuel cell	42 900	35 900	32 900	30 700	30 500	30 400	30 300

Source: Adapted from National Research Council (2013).

Figure 5. Incremental vehicle costs of the different technologies compared to a 2018 Conventional Vehicle



Notes: FC = fuel-cell; HY = plug-in hybrid; CV = conventional; EV = battery electric;

Source: Adapted from National Research Council (2013).

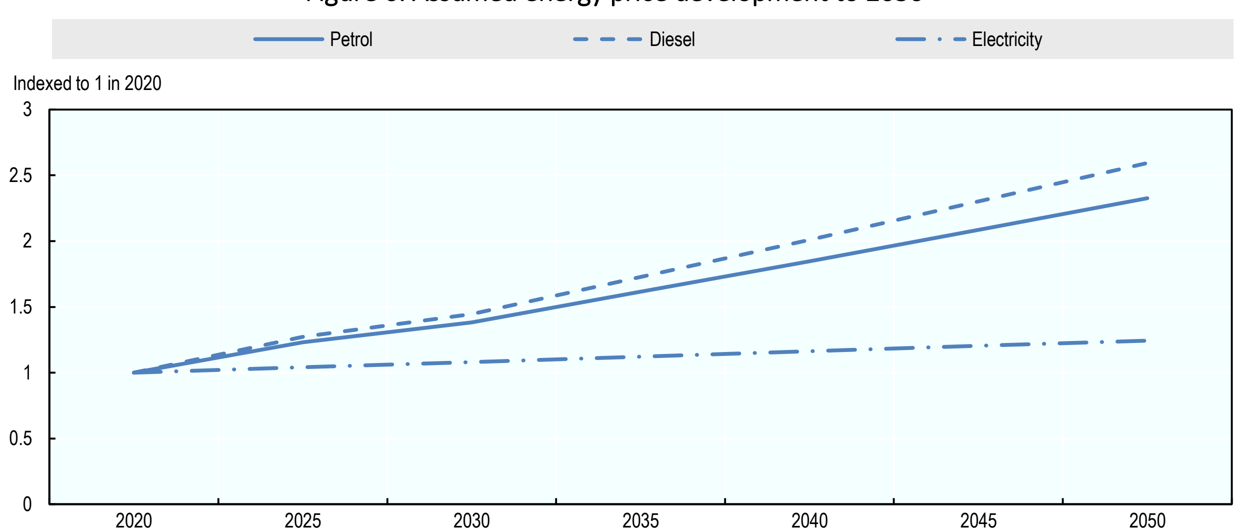
Vehicle use costs (see final assumed values in Table 6) depend on energy cost forecasts (including related taxes), expected vehicle efficiency improvements and assumed vehicle maintenance costs.

Table 6. Vehicle-use cost assumptions in EUR per 100 km

Vehicle type	2020	2025	2030	2035	2040	2045	2050
Conventional	12	12	12	13	14	14	14
Plug-in hybrid	11	11	11	12	12	13	13
Battery electric	7	7	7	7	7	7	7
Fuel cell	9	8	8	8	8	8	8

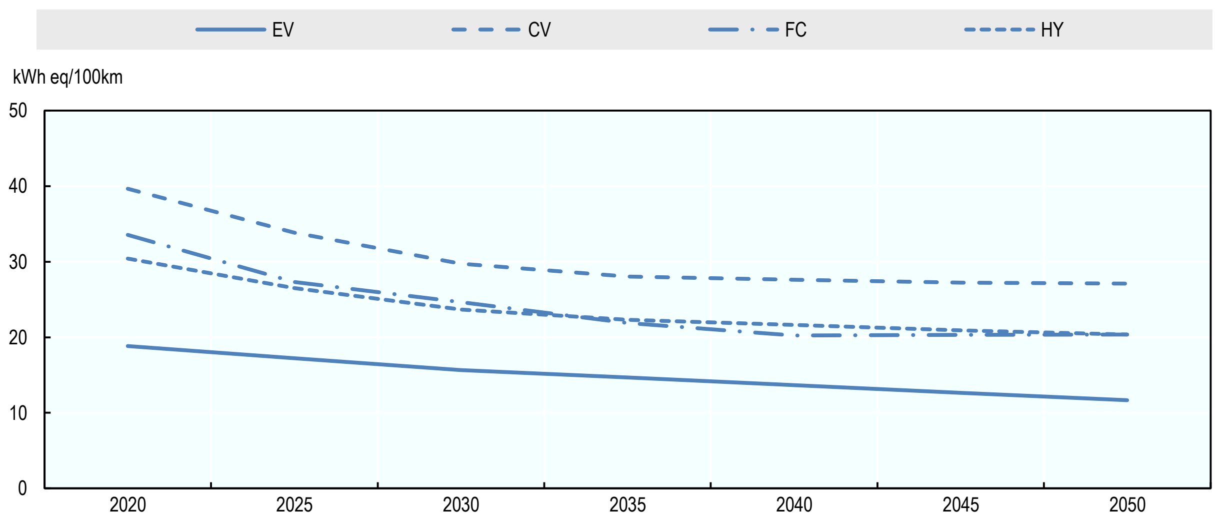
Costs for conventional fuel (before tax) are assumed to develop in line with oil price forecasts as used by the European Commission in its 2016 Reference Scenario (EC, 2016). This implies an annual increase of 2.3% in the period to 2030, and an annual increase of 0.7% in the period from 2030 to 2050. This results in a fuel price increase from around EUR 0.6 to EUR 0.9 per litre of fuel in the period from 2020 to 2050. The French energy tax (TICPE - La taxe intérieure de consommation sur les produits énergétiques) is assumed to remain constant at 2017 levels (around EUR 0.6 per litre petrol and EUR 0.5 per litre diesel). The carbon tax is assumed to increase from EUR 86/tCO_2 in 2020 to EUR 225/tCO_2 in 2030, EUR 400 in 2040 and EUR 500 in 2050; the VAT (applied to energy prices including taxes) is assumed to stay constant at 20%. It is assumed that electricity prices per kWh would increase from around EUR 0.12 to EUR 0.15 in the period from 2020 to 2050 (i.e. experiencing an increase of EUR 0.01 in each ten-year period). Figure 6 shows the assumed energy price development to 2050.

Figure 6. Assumed energy price development to 2050



The vehicle efficiency of conventional vehicles is assumed to improve by 50% in the period from 2015 to 2050. Values for 2015 were set to the average vehicle efficiency (or CO_2 emission) values of new conventional passenger vehicles (including conventional hybrids), as registered in France in 2015 and obtained from the vehicle CO_2 emissions monitoring datasets of the European Environment Agency (EEA, 2018). Test-cycle CO_2 emission values obtained from EEA (2018) were adjusted in line with ICCT (2015) to account for the difference of these values to vehicle emissions under real-life vehicle-use conditions. Values for intermediate years were obtained by applying a power function to reflect the expectation that more significant vehicle efficiency improvements will happen in the earlier years to 2050. The efficiency of battery electric vehicles is assumed to almost double in the period from 2015 to 2050, which is slightly more optimistic than forecasts in National Research Council (2013). The base value for 2015 is assumed to be 20.4kWh/100km in real world driving conditions (ICCT, 2016); plug-in hybrid vehicles are assumed to experience the same efficiency improvements as conventional and battery electric vehicles for their use in their conventional or electric mode respectively. It is assumed they run 50% of their annual mileage on electricity, and 50% on conventional fuel. The efficiency improvement of fuel cell vehicles is based on IEA (2016), resulting in vehicle efficiency improvements similar to battery electric vehicles. Values for 2015 for both plug-in hybrid and fuel cell vehicles are based on ICCT (2016). Figure 7 shows the assumed vehicle energy efficiency development to 2050 (in kWh eq. to allow a direct comparison between the different vehicle types).

Figure 7. Assumed vehicle efficiency development to 2050



Notes: EV = battery electric; CV = conventional; FC = fuel cell; HY = plug-in hybrid

Vehicle maintenance costs are based on CGDD (2017) and amount to EUR 5.25/100km for conventional vehicles, to EUR 4.73/100km for battery electric vehicles, and EUR 6.30/100km for plug-in hybrid electric vehicles. The maintenance costs of fuel-cell vehicles are assumed to be in line with battery electric vehicles.

In the baseline scenario, any of the *policy levers* that were tested in the stated preference survey do not apply to 2050. However, a purchase bonus is assumed to continue to apply to alternative-fuel vehicles. Table 7 shows how this purchase bonus is assumed to fade out by 2030. This purchase bonus is set at a level so that the total amount of the paid bonuses is within EUR 250 million (the budget envelope currently foreseen to be available). It is therefore a result of the vehicle fleet model.

Table 7. Purchase bonuses in EUR applied to alternative-fuel vehicles: assumptions to 2030

Vehicle Type	2020	2025	2030
Plug-in hybrid	1 500	750	0
Battery electric	4 000	1 300	0
Fuel cell	4 000	1 300	0

How do companies chose which vehicle type to invest in?

The vehicle choice of companies is assumed to be more rational, i.e. more based on monetary factors, than those of households. As such, the vehicle choice model of legal entities is based on a generalised cost optimisation function that was randomised by applying a logit model to the cost functions (similar to the ones for households). The generalised costs *GC* for each vehicle type *k* are defined as:

$$GC(k)=\beta_0^k+\beta_1\ \left(\frac{purchaseCost_k}{7}+annualCost_k\right)+\beta_2\ \left(\frac{annualMileage}{autonomy}\right)\cdot(refuelTime+infraAvail)+\beta_3\ policyLever1\ \ldots$$

Where the constants were defined to be 0 for all choice alternatives other than for fuel cell vehicles (where the value is set to -3 to reflect a current disutility of this vehicle type that cannot be explained by generalised costs). The cost and time parameters (β_1 and β_2) are set to reflect an assumed value of time of EUR 30/h. This is the value of time used for business trips above 80km that are carried out by car, as defined by MTES (2019b). The impact of the different policy measures (parameters β_3 etc.) is assumed to be the same as for private households. Assumptions regarding vehicle characteristics (incl. costs) and recharging infrastructure availability are in line with the ones for private cars. The annual mileage distribution of company cars is in line with (CGDD, 2019).

Model calibration to 2018: Defining the share of private and company car sales for the base year

The overall fleet model is calibrated against approximate vehicle sales and fleet numbers in 2018. This is done by adjusting both the vehicle survival law and a probability function that defines how many vehicles transition as second-hand vehicles from the company car fleet to the household fleet each year. In 2018, vehicle sales amounted to around 1.5 million (75%) private and 0.5 million (25%) company vehicles (as estimated by the steering group of this project), resulting in a stock of 32.8 million (93%) private and 2.3 million (7%) company vehicles (CGDD, 2019).

The difference between the desired car stock (from the ownership model) and the surviving car stock (from the scrappage module), reduced by the cars that transition from the company fleet to the household fleet, is met by new cars. Each new car that enters the vehicle fleet is assigned a specific vehicle usage (as mentioned earlier in the description of the scrappage module). This mileage then defines (based on the survival law) when the vehicle will reach its end of life. The vehicle type of the new vehicle is defined by the vehicle choice model.

Results: Assessing the impact of policy measures on electric vehicle uptake

This section shows the development of the French car fleet to 2050 under various scenarios.

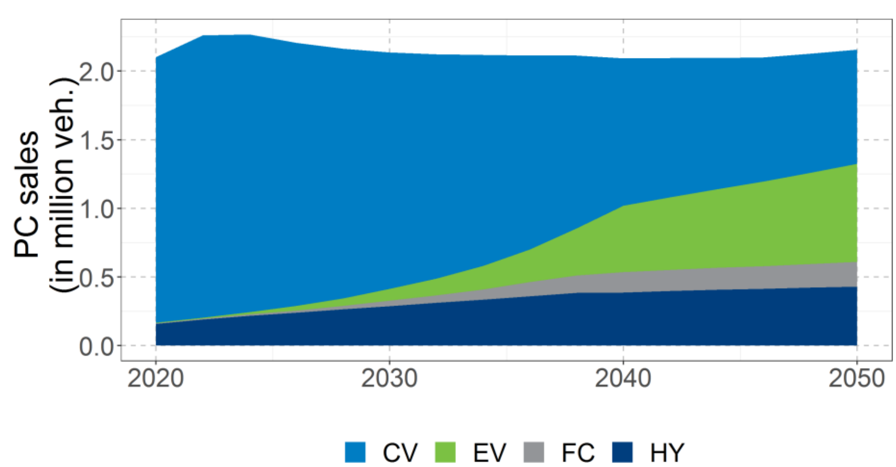
Results for the baseline scenario: Electric vehicles to attain 30% in the total fleet by 2050

Figure 8 shows passenger car sales of private and company cars for the baseline scenario. Despite a drop-off of the purchase bonus for alternative fuel vehicles (see Table 7) by 2030, the share of these vehicles is estimated to increase continuously. This is thanks to decreasing vehicle purchase and use costs, as well as the assumption of increasingly favourable vehicle recharging characteristics over time (faster recharging; higher availability of battery recharge infrastructure). The assumption that autonomy of battery electric vehicles will increase from 270km to 540km in the period from 2018 to 2040 is also relevant. From 2040 onwards, vehicle and battery recharge characteristics are assumed to be stable. However, due to further cost decreases of alternative-fuel vehicles, their sales share continues to increase to around 55% (plug-in hybrids, battery electric and fuel-cell vehicles combined) by 2050. The continuing relatively low share of fuel-cell vehicles is explained by their higher costs and their decreasing advantage over battery electric vehicles as the autonomy (range) of the latter ones is assumed to increase over time.

The share of electric vehicles in the total vehicle fleet amounts to around 30% as a result of these vehicle sales (or, more specifically, to 14% plug-in hybrids, 15% battery electric, and 4% fuel-cell vehicles).

Figure 8. Passenger car sales by energy type for the baseline scenario

private and company cars

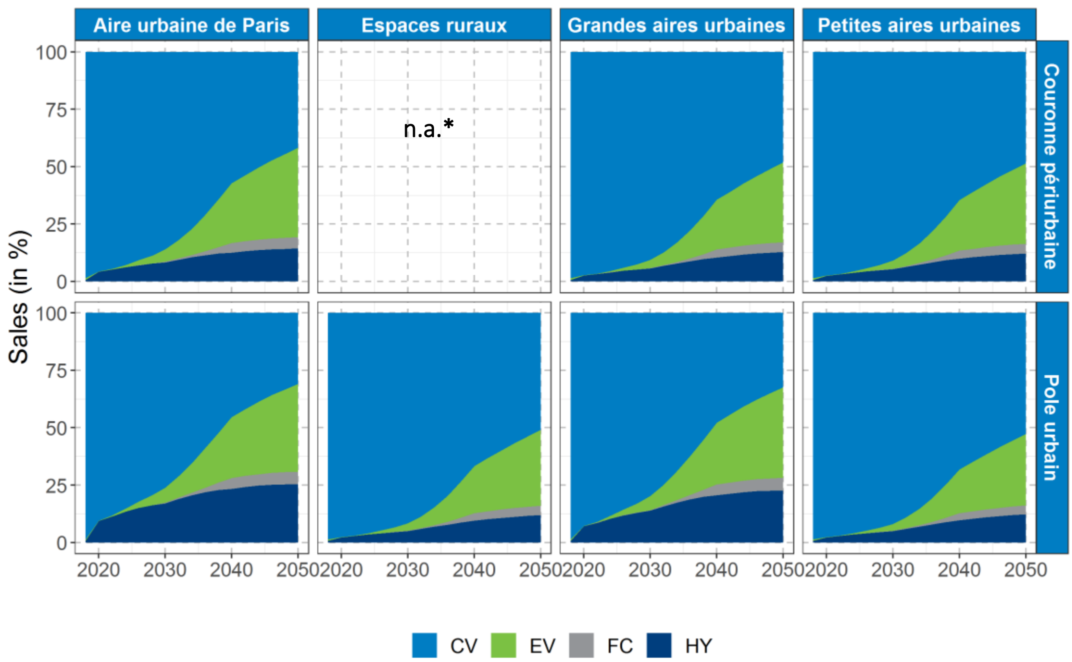


Notes: CV = conventional; EV = battery electric; FC = fuel cell; HY = plug-in hybrid

Sale shares of electric vehicles are expected to be higher in bigger urban areas (whether in Paris or elsewhere) than in rural or smaller urban areas (see Figure 9). This is likely to be related to the comparatively higher incomes of households located in these areas and a lower tendency to carry out frequent long-distance trips, which would not play in favour of battery-electric vehicles.

Figure 9. Passenger car sales by energy and geographic area for the baseline scenario

private and company cars



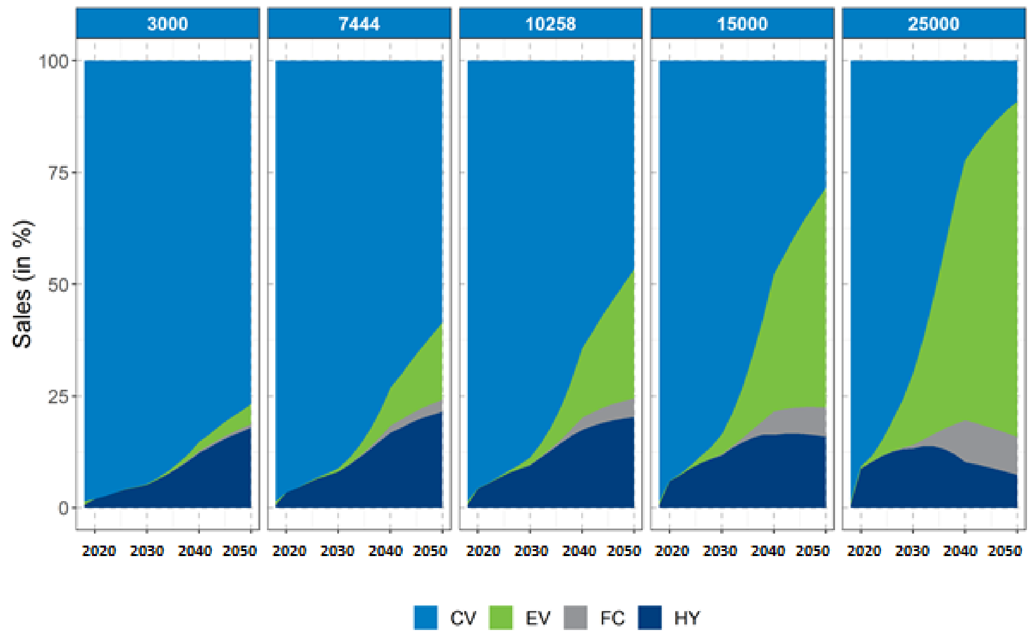
Notes: CV = conventional; EV = battery electric; FC = fuel cell; HY = plug-in hybrid

*By definition, there is no peri-urban ring ("couronne périurbaine") in rural areas ("espace ruraux"); this category is therefore left blank.

Concerning the impact of vehicle use patterns, Figures 10 and 11 show how a high annual vehicle mileage, and a low number of long-distance trips, favours the purchase of electric vehicles. High vehicle mileage favours battery electric vehicles specifically (Figure 10). Notably, the sales of the assessed electric vehicle types are estimated to sum to around 80% for vehicles with an annual mileage of 25 000 km by 2050 (compared to less than 25% for vehicles with an annual mileage of around 3000 km). An increasing number of long-distance trips per year makes the purchase of plug-in hybrids more appealing (Figure 11). Vehicles that carry out ten or more long-distance trips (above 100km) per year are likely to remain 50% conventional vehicles to 2050. Around half of the estimated electric vehicle share will go to plug-in hybrid vehicles, for which the range is expected to continue to be higher than for battery electric vehicles.

Figure 10. Passenger car sales by energy type and vehicle use (by annual mileage category) for the baseline scenario

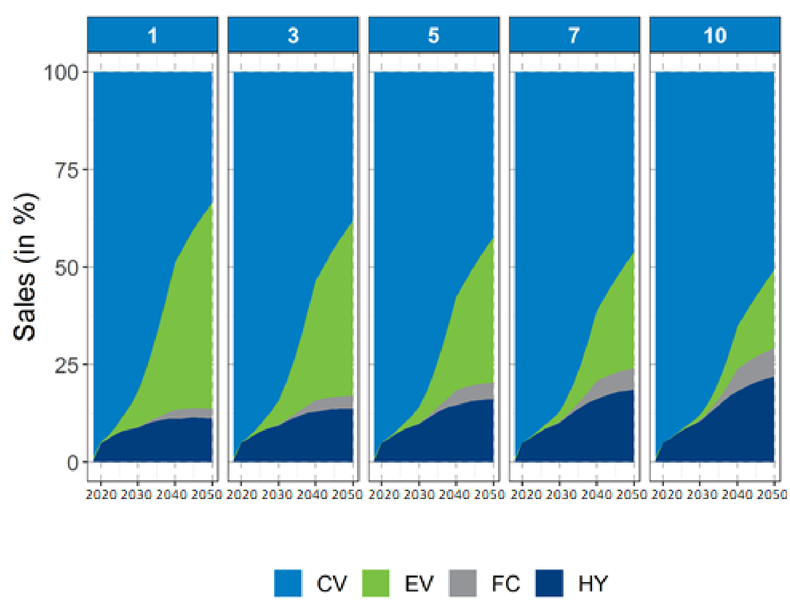
private and company cars



Notes: CV = conventional; EV = battery electric; FC = fuel cell; HY = plug-in hybrid

Figure 11. Passenger car sales by energy type and vehicle use (by number of long-distance trips) for the baseline scenario

private and company cars

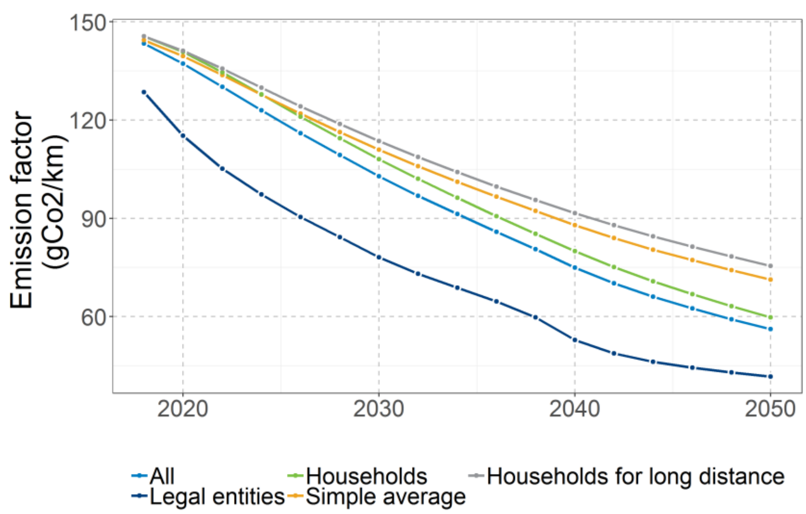


Notes: CV = conventional; EV = battery electric; FC = fuel-cell; HY = plug-in hybrid

By 2050, the combined share of electric vehicles (battery electric, plug-in hybrid and fuel cell) is estimated to be 30% for the private fleet, but as high as 70% for the company fleet. Current vehicle usage patterns explain these different uptake rates of electric vehicles in the private and company fleets. The high vehicle turnover rate in company fleets (where vehicles are assumed to be held for only four-five years before they transition to the private market or before they are scrapped) plays an important role as well. It allows the new technologies to penetrate the total vehicle fleet much faster than what would be the case for the private vehicle fleet market alone.

Figure 12 shows how average vehicle CO_2 emissions develop as a result of the estimated uptake of electric vehicles and their respective annual vehicle mileage profiles. In line with the findings presented above, average emissions of the company car fleet (the cars of legal entities; in dark blue) are consistently lower than those of private households (in green). New vehicle technologies penetrate faster and at a higher rate into the company car fleet than into the private household fleet. The orange line also shows how a simple average of the vehicles' CO_2 emissions (not accounting for vehicle mileage) differs from (i.e. is higher than) the average where the vehicle mileage is taken into account. This is because vehicles that are used more intensely are, on average, more likely to be electric vehicles in the future. Overall, the average vehicle-kilometre is estimated to cause less than 45 gCO_2/km in 2050, compared to around 140 gCO_2/km in 2018 (see the light blue line).

Figure 12. Average fleet CO_2 emission factors to 2050 for the baseline scenario

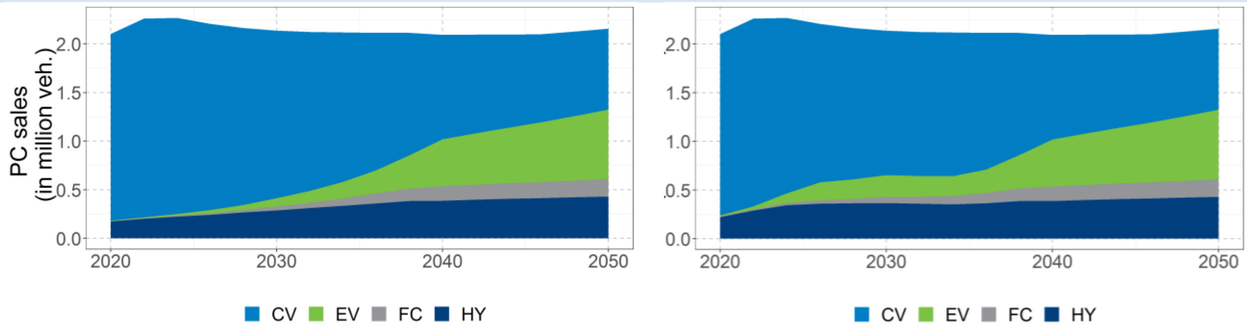


Results for alternative scenarios: Which policies will drive electric vehicle uptake?

A selection of alternative policy scenarios was tested in agreement with the French Ministry for an Ecological and Solidary Transition (MTES). Figure 13 shows the result for a policy scenario where the purchase bonus for electric cars is increased and extended up to 2030 (compared to the baseline). At the same time, a malus applies to conventional vehicles to restrain the overall costs of the bonus scheme to the overall budget envelope of EUR 250 million. Results indicate that an increased bonus also increases the sales share of electric vehicles in the respective years. The impact is, however, somewhat limited.

Figure 13. Passenger car sales for a strong bonus/malus scenario

Baseline scenario	Strong bonus/malus scenario



Key scenario input assumptions (EUR)

Bonus for electric vehicles is set so that the total amount of the paid bonuses is within a EUR 250 million envelope; i.e.

	2020	2025	2030	2035
Conventional	0	0	0	0
Plug-in hybrid	1 500	750	0	0
Battery electric	4 000	1 300	0	0
Fuel cell	4 000	1 300	0	0

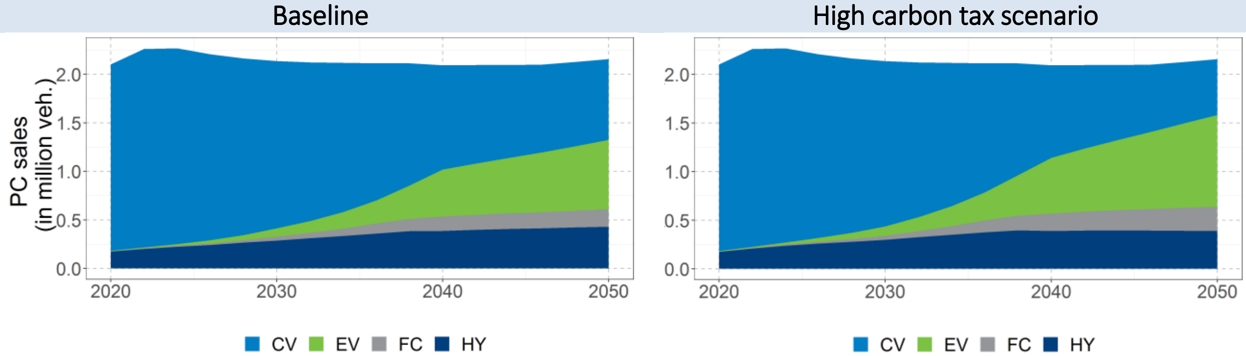
Malus on cars is introduced so that the bonus for electric vehicles can be kept till 2035; i.e.

	2020	2025	2030	2035
Conventional	-400	-900	-500	0
Plug-in hybrid	2 000	2 000	1 000	0
Battery electric	6 000	6 000	3 000	0
Fuel cell	6 000	6 000	3 000	0

A second policy scenario (Figure 14) assesses the impact of the carbon tax. The carbon tax is increased to reach a level of 775 EUR/tCO_2 in 2050, in line with Quinet (2019). The increased carbon tax helps to increase the sales share of electric vehicles (battery electric, plug-in hybrid and fuel cell) to around 75% (compared to around 55% in the baseline). The increased carbon tax especially benefits battery electric and fuel-cell vehicles that do not use any conventional fuels as their energy source.

Figure 14. Passenger car sales for a high carbon tax scenario

Baseline	High carbon tax scenario



Key scenario input assumptions

Carbon tax in EUR per tCO_2:

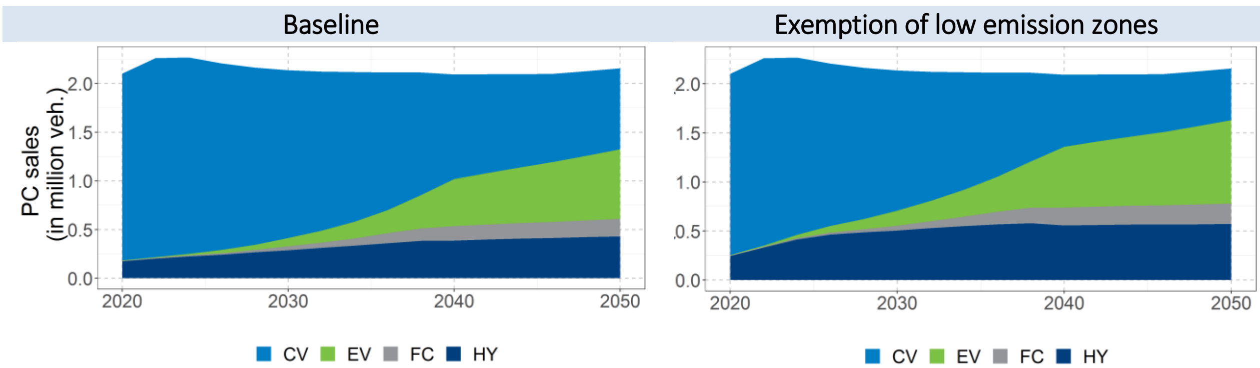
2020	2030	2040	2050
86	225	400	500

Carbon tax in EUR per tCO_2:

2020	2030	2040	2050
86	250	500	775

A third policy scenario (Figure 15) shows the impact of a preferential policy for electric vehicles. More specifically, the scenario assesses the impact of urban restriction zones placed upon conventional vehicles where all types of electric vehicles are allowed. Similar to the carbon tax scenario, results show that the sales share of electric vehicles can be increased to around 75% by 2050. In contrast to the carbon tax scenario, it is not only battery electric and fuel-cell vehicles that benefit from the measure; plug-in hybrid electric vehicles that are equally exempt from the emission zones can also increase their share in the vehicle sales market.

Figure 15. Passenger car sales for a preferential policy scenario



Key scenario input assumptions	
No preferential policies apply for any of the vehicle types.	Conventional vehicles are subject to circulation restrictions in France’s five biggest agglomerations from 2025 onwards. All types of electric vehicles (EV, FC, HY) are exempt from these restrictions.

References

Anable, J. (2013), *Modelling transport demand, behaviour and consumer choices*; Enhancing the state of transport modelling in IAMs IIASA, Vienna, 18th November, 2013.

Cambridge Economics (2008), Demand for Cars and their Attributes - A final report for the Department for Transport.

CEC (1996), CALCARS: The California Conventional and alternative fuel response simulator - A Nested Multinomial Logit Vehicle Demand and Choice Model, California Energy Commission, April 1996.

CGDD (2019), *Les flottes de véhicules des personnes morales - Caractéristiques et perspectives*, Commissariat général au développement durable, France (forthcoming).

CGDD (2017), *Analyse coûts bénéfices des véhicules électriques: Les voitures (Cost benefit analysis of electric vehicles: Cars),* Commissariat général au développement durable, https://www.ecologique-solidaire.gouv.fr/sites/default/files/Th%C3%A9ma%20-%20Analyse%20co%C3%BBts%20b%C3%A9n%C3%A9fices%20des%20v%C3%A9hicules%20%C3%A9lectriques.pdf

CGDD (2013a), *Projection de la mobilité courte distance à l'horizon 2030*, Commissariat Général au Développement Durable, http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0078/Temis-0078990/20843.pdf

CGDD (2013b), *Projections de la demande de transport sur le long terme*, Commissariat Général au Développement Durable, https://www.ecologique-solidaire.gouv.fr/sites/default/files/Th%C3%A9ma%20-%20Projections%20de%20la%20demande%20de%20transport%20sur%20le%20long%20terme.pdf

CTS (2014), *The Swedish Car Fleet Model - Evaluation of Recent Applications*, Centre for Transport Studies, Stockholm, Working Paper, 2014:18.

Department of Demographic and Social Statistics (2008), *Enquête nationale transports et déplacements (National Transport and Travel Survey 2008 (database),* https://www.statistiques.developpement-durable.gouv.fr/enquete-nationale-transports-et-deplacements-entd-2008

EEA (2018), *Monitoring of CO_2 emissions from passenger cars – Data 2018 – Provisional data* (database), European Environment Agency, https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-16#tab-news-and-articles

Element Energy (2013), *The Role of Biofuels Beyond 2020*; Commissioned by BP, September 2013.

EC (2016), *EU Reference Scenario 2016: Energy, transport and GHG emissions Trends to 2050,* European Commission, Luxembourg, https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf

ICCT (2018), "Fig. 5-24 Passenger cars: Vehicle price (incl. tax, unadjusted for inflation) by engine technology", in *European Vehicle Market Statistics Pocketbook*, http://eupocketbook.org/project/fig-5-24-pc-vehicle-price-by-engine-technology/

ICCT (2016), *Electric vehicles: Literature review of technology costs and carbon emissions,* The International Council on Clean Transportation, Washington DC, https://theicct.org/lit-review-ev-tech-costs-co2-emissions-2016

ICCT (2015), *Quantifying the impact of real-world driving on total CO_2 emissions from UK cars and vans,* The International Council on Clean Transportation, https://www.theccc.org.uk/wp-content/uploads/2015/09/Impact-of-real-world-driving-emissions-for-UK-cars-and-vans.pdf

IEA (2019), *Global EV Outlook 2019,* International Energy Agency, Paris, https://webstore.iea.org/global-ev-outlook-2019

IEA (2017), *World Energy Outlook 2017,* International Energy Agency, Paris, https://www.iea.org/weo2017/

IEA (2016), *Energy Technology Perspectives 2016,* International Energy Agency, Paris, https://webstore.iea.org/energy-technology-perspectives-2016

INSEE (2018), *Estimations d'emploi en 2016*, Institut national de la statistique et des études économiques, France, https://www.insee.fr/fr/statistiques/3202716

INSEE (2017), *Projections de population 2013-2050 pour les départements et les regions*, Institut national de la statistique et des études économiques, France, https://www.insee.fr/fr/statistiques/2859843

ITF (2019), ITF Transport Outlook 2019, OECD Publishing, Paris, https://doi.org/10.1787/transp_outlook-en-2019-en.

Kah, M (2018), *Electric Vehicles and Their Impact on Oil Demand: Why Forecasts Differ,* Columbia SIPA, New York, https://energypolicy.columbia.edu/sites/default/files/pictures/CGEP_Electric%20Vehicles%20and%20Their%20Impact%20on%20Oil%20Demand-Why%20Forecasts%20Differ.pdf

Kohli, Z (2011), *Car Longevity: A Biometric Approach*, Proceedings of YRS2011 - Seminar 2011, Denmark.

Maltha, Y. M. (2016), The changing influence of factors explaining household car ownership levels in the Netherlands; MSc Thesis, TU Delft.

MTES (2019a), *Données sur les immatriculations des véhicules (fichier 2.I.F.5);* https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-les-immatriculations-des-vehicules

MTES (2019b), *Valeurs de référence prescrites pour le calcul socio-économique* (Prescribed reference values for the socio-economic calculation) (database), https://www.ecologique-solidaire.gouv.fr/sites/default/files/V.2.pdf

MuConsult (2006), Dynamo: A new dynamic automobile market model for the Netherlands.

National Research Council (2013), *Transitions to Alternative Vehicles and Fuels,* Washington, DC: The National Academies Press, https://doi.org/10.17226/18264.

Quinet, A (2019), *La valeur de l'actionpour le climat (The value of action for the climate),* France Stratégie, https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2019-rapport-la-valeur-de-laction-pour-le-climat_0.pdf

RSG (2010), *Discrete Choice Models of the Preference for Alternative Fuel Vehicles*; Resource Systems Group, online presentation, http://slideplayer.com/slide/1619946/

UKERC (2010), *UK Transport Carbon Model - Reference Guide,* Working Paper, UK ENERGY RESEARCH CENTRE.

Annex: Operational vehicle fleet models

This section contains an overview of vehicle fleet models that have already been used on the national (or regional) level. More explicitly, it focuses on operational models that have been set up and used for policy making. The availability of literature on operational, national-level models in the public domain is somewhat limited. As a result, the level of detail provided below also varies across the different models reviewed. The first section provides information of the reviewed models that could be identified (covering the Netherlands, United Kingdom, Sweden and California in the United States). The following section then provides a comparison of the key characteristics of each reviewed model and a discussion on the main findings.

Who is doing what?

The dynamic automobile market model: The Netherlands

The Dynamic Automobile market (DYNAMO) model in the Netherlands has been developed for the Dutch Transport Research Centre and the Netherlands Environmental Assessment Agency (see MuConsult, 2006; Maltha, 2016). The most important car ownership prediction model in the Netherlands, its latest version (3.0) assesses the effects of general developments and government policy on the size, composition and use of the Dutch car fleet for the period up to 2050. Given the available literature, the following model description refers to DYNAMO 1.3.

The main feature of this model is an equilibrium module that relates vehicle demand and supply. Vehicle demand is defined by projections of i) demographic, socio-economic and societal parameters; ii) costs of car ownership and use; iii) technology developments. Vehicle supply is dependent on projections of vehicle imports and exports, vehicle scrapping, second-hand vehicles etc. The equilibrium module is then able to derive annual projections on:

- number and type of cars per household, i.e. their:
    - fuel type
    - weight class
    - age
    - consumption
    - type of owner (private versus lease/company cars)
- car use (in number of kilometres driven and by purpose)
- income effects on groups of households
- effects on government revenues

The car ownership per household is projected by household type, which is defined by i) its size (1, 2, persons or more); ii) the number of persons in employment (zero, one, or more); iii) the age of the oldest person (three age brackets); iv) the real disposable income of the household (low, medium, high), altogether resulting in 71 separate household types.

The resulting predicted car stock is categorised on the basis of four vehicle parameters: i) age (five categories); ii) fuel type (petrol, diesel, LPG); iii) weight (four categories); iv) car ownership type (private, lease/company car), resulting in 120 different car types. For each household type the number of cars of a specific type is predicted for a given year, resulting in a matrix with 8520 (=71 x 120) entries. The base year matrix (for the year 2003) was mainly established on the basis of data from the Dutch Centre for Vehicle Technology and Information.

The total number of household cars is defined on the basis of a nested choice model structure. The choice in the upper nest (of no car vs. car) is explained by the income group, household size, age group and the number of persons in employment of the household. The choice in the lower nest (of one car vs. more than one car) is explained by car prices, the number of kilometres driven per household (stemming from a different module) and the same household characteristics that are also used in the upper nest. Constants were added to the model in both nests for each household type to exactly predict the size of the car fleet in 2003 (the base year).

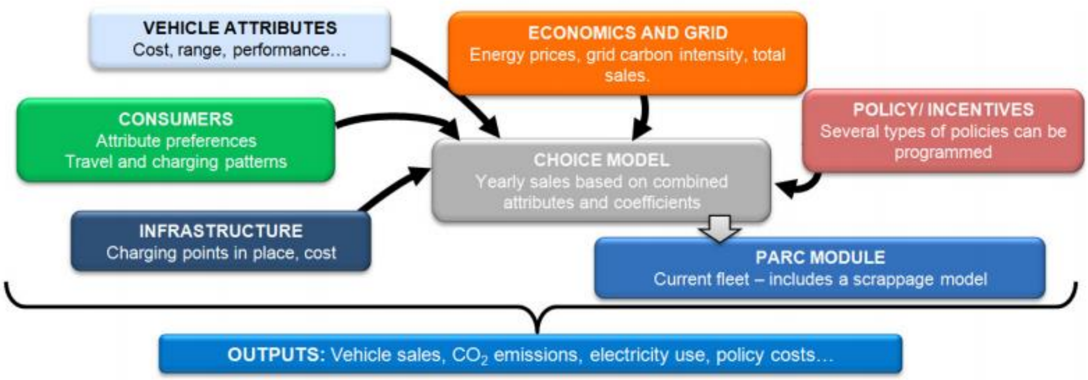
The type of cars (for privately owned cars only) is projected on the basis of a multinomial logit model of which the coefficients were estimated on a combined SP-RP data set (gathered in the context of a different study). The variables included in the model are the purchase price, variable vehicle-use costs per year, the amount of road tax to be paid, the number of variants of each type of car available, alternative specific dummies for weight class x income group and alternative specific dummies for the age of the car. With regard to lease cars, the type of cars is a fixed distribution of car types.

The electric car consumer model: The United Kingdom

The Electric Car Consumer Model (ECCo2) is a consumer choice model developed by Element Energy for the Energy Technology Institute (ETI) in 2010/11. It was extended and updated for the Department for Transport (DfT) in 2012 (Element Energy, 2013; Anable, 2013). It projects vehicle sales by vehicle type and tests the impact of various policy measures, macroeconomic and societal trends, and evolving vehicle attributes on the vehicle type choice of consumers. Vehicle types included are internal combustion engine vehicles (petrol, diesel, stop-start, pure hybrid), plug-in hybrid electric vehicles (PHEV), pure battery electric vehicles (BEVs) and hydrogen vehicles (internal combustion engines and fuel-cell electric). The vehicle choice model is a multinomial logit model that generates market shares for each vehicle type for different consumer segments. This is combined with a vehicle fleet module to forecast the total vehicle stock. It was designed to enhance previous models used by the DfT by including alternative fuel vehicles in the set of available choice alternatives. Figure A.1. provides an overview of model inputs and outputs.

The model is based on data from a consumer preference survey of 2 670 new car buyers in the United Kingdom who responded to a total of 26 700 choice games and additional attitudinal questions. The stated preference data obtained from the choice games gives information on the value consumers put on capital and running costs, vehicle performance (acceleration) and vehicle CO_2 emissions. Additionally, non-financial attributes (range of vehicles, level of refuelling/recharging infrastructure supply, charging time) were assessed. Attitudinal questions were used to define eight consumer groups and establish their specific preferences (i.e. consumer group-specific coefficients for the model). The final design of the survey comprised 100 discrete choice sets. Vehicle running costs were based on survey respondents' stated annual mileage for their primary car. Figure A.2. provides an example of a choice game.

Figure A.1. Overview of the electric car consumer model: United Kingdom



Source: Element Energy (2013).

Figure A.2. Example of a choice game

	Conventional car	Plug-in hybrid electric car	Pure electric car
Purchase price	**£16,000**	**£20,000**	**£18,000**
Running cost	**£900** per year	**£300** per year	**£600** per year
0-60mph acceleration	The **same** as a typical car	**20% quicker** than a typical car	**40% quicker** than a typical car
Range	The **same** as a typical car	Total range the same as a typical car, **40 mile** range in 'electric mode'	**100** miles
Recharging / refuelling time	5 minutes to fill fuel tank	5 minutes to fill the fuel tank, **4 hours** to charge the battery,	**2 hours** to charge the battery
Home / workplace charging	N/A	Charging available at **home and work**	Charging available at **home**
Public infrastructure	Fuel available at all filling stations	Charging points available at **30%** of public car parks / on-street parking spaces	Charging points available at **50%** of public car parks / on-street parking spaces
CO_2 emissions	The **same** as a typical car	**40% lower** than a typical car	**60% lower** than a typical car

For each set of cars we will ask you the following:

Which one of the above cars would you choose if you were replacing your *main* car? ☐ ☐ ☐

Source: Element Energy (2013).

The United Kingdom transport carbon model

The UK Transport Carbon Model (UKTCM) is a transport,, energy, emissions and environmental impacts model (UKERC, 2010). It covers a range of transport-energy-environment issues from socio-economic and policy influences on energy demand reduction through to lifecycle carbon emissions and external costs. It was developed under the auspices of the UK Energy Research Centre (UKERC) and can be used to test scenarios mixing technological, fiscal, regulatory and behavioural change policies to meet UK climate change and energy security goals. The most relevant modules of the UKTCM for this review are the vehicle stock module, the vehicle scrappage module, and the vehicle technology choice modules.

The vehicle stock module models car ownership on a household basis. The key variables used for modelling household car ownership are:

- household structure (number of adults, number and age of children)
- household disposable income (by year)
- average new car price
- household location (urban and non-urban), linked to public transport availability
- car ownership saturation level (urban and non-urban).

All of the above listed variables are model input parameters, apart from the average new car price. The average new car price in year n+1, on the other hand, is derived based on the average car price in year n. This includes any scenario and policy options applied, e.g. a cost reduction of a technology, graded purchase taxes or rebates.

The households are divided into three “ownership groups”, being households that own at least one car, those that own at least two cars, and those that own more than two cars or having a business car at their disposal. The repartition of households between ownership groups is endogenously modelled and depends on i) the share of the population who cannot drive; ii) the household size; iii) the parking availability (for households in urban areas); iv) the availability of public transport (for households in non-urban areas). The number of vehicles needed for commercial purposes is modelled on the basis of the projected activity level, mainly based on GDP growth rates.

The scrappage module is based on a modified Weibull distribution. Its parameters can be changed by the model user, e.g. to model policy options such as the introduction of long term scrappage incentives.

The technology choice module is based on a discrete choice model using annual vehicle costs and a non-cost factor as explanatory variables. The annual vehicle costs include the vehicle purchase price (after tax, incentives, rebates, etc.; calculated as an annuity over the economic lifetime of the vehicle), fixed costs such as expenses for insurance, maintenance, depreciation, VED, and variable costs such as fuel costs, taxes, road pricing and congestion charges. In addition a non-cost factor (denoted as P in the following) aggregates perceived vehicle performance, consumer preference and market/infrastructure availability of a vehicle technology. In case of established vehicle technologies, P is derived on the basis of historical data (i.e. the UK’s Vehicle Licensing Statistics). For each new or alternative vehicle technology, the non-cost factor follows an S-curve describing the increase of P with time as the technology reaches maturity. P is estimated based on the expected relative market share of the new vehicle technology (in terms of new vehicle sales), compared to some specified conventional comparator or reference technology, that might be anticipated if the annualised costs of the conventional and new technologies were the same. For instance, a medium gasoline car is the reference technology against which all new and alternative medium-sized cars are compared with in terms of their expected performance, preference and market availability. If an alternative technology has the same performance and preference but is expected to lack the refuelling infrastructure even at market maturity then P is lower according to the relative shares in refuelling infrastructure coverage across the nation. While default values for non-cost parameters have been developed based on best available knowledge in the literature and in consultation with policy and industry experts, model users can modify them according to their market expectations or for simple “what-if?” analyses.

The eftec model: United Kingdom

The Eftec Model for the UK Department for Transport (DfT) was developed to investigate the demand for cars and their attributes by Cambridge Economics (Cambridge Economics, 2008). The primary objective was to obtain both own and cross-elasticity estimates for vehicle demand following a change in vehicle attributes, such as purchase price, the fixed costs of motoring (e.g. vehicle excise duty) and the variable costs of motoring (e.g. fuel costs).

Relevant data on vehicle attributes for building the model was obtained through

- a bespoke survey of households that had recently purchased a new or nearly-new vehicle. The survey identified the manufacturer (make), model, and engine capacity of vehicle purchased, as well as cost attributes (e.g. purchase price, expected depreciation schedule, fuel efficiency, cost of repairs, search and transaction costs) etc.
- a database (called JATO dataset) that catalogues detailed lists of vehicle attributes such as manufacturer, model, version name, transmission, number of doors, body type, engine capacity, size (seating capacity, length, width, wheelbase, weight, boot volume), performance (power, acceleration, maximum speed), safety (airbags), fuel consumption, and CO_2 emissions.

Vehicle choice was modelled based on a mixed logit approach.

The California light-duty vehicle conventional and alternative fuel response simulator model: California

The California Light Duty Vehicle Conventional and Alternative Fuel Response Simulator (CALCARS) was developed by the Resource Systems Group for the California Energy Commission (CEC, 1996; RSG, 2010). It projects the number and type of personal cars and light-duty trucks, their annual vehicle miles travelled (VMT) and their fuel consumption in California. It was first developed in 1996 and has since undergone periodic updates. It consists of four modules, projecting i) the number of vehicles; ii) vehicle replacement; iii) vehicle type choice; iv) vehicle use.

To determine vehicle ownership and type choice it uses a nested multinomial logit structure by combining stated and revealed preference data (SP and RP data) to forecast the penetration and use of both conventional and alternative fuel vehicles (AFVs). Coefficients for vehicle characteristics such as range, fuel availability, and emissions are estimated simultaneously with "conventional" characteristics such as operating cost and vehicle price. The most recent combined SP/RP survey was completed in January 2009, after rapid increases in gasoline prices. Stage one of the survey covered RP questions to identify current vehicle holdings and use; Stage two covered stated preference experiments customised to the survey respondent to determine vehicle choice behaviour. A total of 105 possible vehicle types were covered in the survey (seven fuel types, being gasoline, diesel, hybrid electric, plug-in hybrid, compressed natural gas, Flex-fuel, battery electric; and fifteen body styles, ranging from subcompact cars to pick-up trucks). In the stated preference survey design, each choice option was described by around ten attributes, depending on the type of vehicle. These attributes included vehicle age, purchase price, purchase incentive (such as tax credit, rebate, free public parking, high occupancy vehicle lanes), maintenance costs, fuel efficiency, fuel costs, fuel availability, refuelling time, driving range, acceleration.

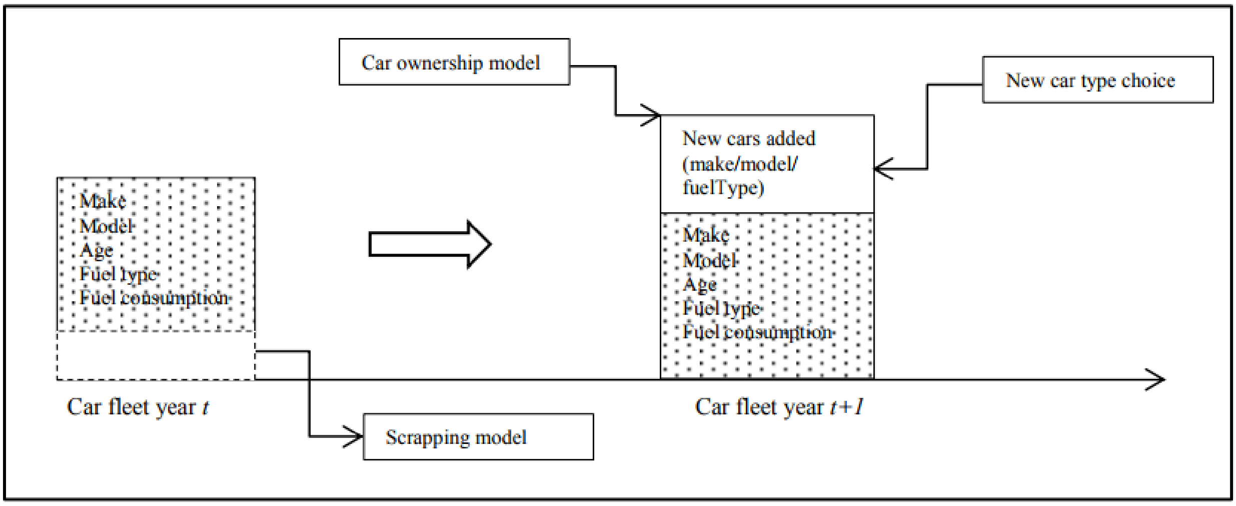
The Swedish car fleet model

A car fleet model was developed for the Swedish Transport Administration to facilitate the evaluation of policies affecting the car fleet composition in 2006 (CTS, 2014; Figure A.3.). The model system consists of three separate sub-models; a car ownership model, a scrapping model and a new car purchase model. Great effort was made when developing the new car type choice model using both revealed preference as well as stated preference data in the estimation process. The last model update (i.e. calibration) took place in 2012, based on 2011 vehicle data.

The car fleet model system annually updates the stock of the cars by subtracting scrapped cars and adding new cars. The car ownership model is based on individual car ownership entry and exit probabilities driven by socio-economic variables and petrol costs (the only policy variable in that model). The scrapping model is a simple aggregated model, originally based on 2000-04 car registration data. It gives the percentage of the stock to be removed each year. The percentage varies depending on the car make and age. A household will scrap a car when the gained value from scrapping that car will be more than its obtained price in the used car market. The car type choice model distinguishes three consumer groups, being private buyers and company car buyers, with or without a leasing contract. The shares of privately bought or company bought cars each year are exogenous in the model.

For each of the three segments, a choice set of more than 300 different car alternatives was established on the basis of vehicle registration data that includes information on socio-economic characteristics of the current and previous owners (such as age and gender) on selected car attributes such as model year, production year, registration date, date of previous transfers, type of purchase (i.e. private vs. company). Additional information on car characteristics (such as price, alternative fuel refuelling facilities, resale value and safety) was compiled on the basis of data obtained from motor journals, traffic safety classifications from an insurance company, and from the Swedish Consumer Agency. To allow the introduction of new choice options (i.e. alternative fuel vehicles or vehicles with new characteristics), different stated preference surveys for the different consumer groups were conducted. The final discrete choice models that were established for the different consumer groups follow a nested approach.

Figure A.3. Overview of the Swedish car fleet model



Source: RSG (2010).

Common model characteristics and findings

Most models above focus on modelling the household vehicle fleet market. This is because this market is better understood than the commercial vehicle fleet market. Vehicle purchase decisions can be explained by individual choice behaviour and preferences. Purchases of company cars may be more driven by economic factors; however, the type of company car considered (e.g. perk car, shared car, company fleet car) will also play a significant role for decision making. The UK TCM and the Swedish vehicle fleet model are the only identified exceptions: they specifically cover commercial/company vehicles. The UK TCM follows a comparatively simple approach for forecasting commercial vehicle ownership rates (i.e. based on macroeconomic trends, mainly GDP growth). The Swedish fleet model considers commercial vehicles also in their vehicle type choice model, based on data obtained via stated preference surveys. More information on what format/how commercial fleet managers (or others) contributed to the respective survey could not be identified. The potential impact of future shared (public) vehicle fleets (or shared mobility in general) on car ownership or vehicle type choice has not explicitly been considered in the models reviewed Table A.1. provides an overview of some of the key characteristics of the reviewed models.

For *methodology* applied, all vehicle type choice models apply a discrete choice model, either based on a 'standard' multinomial logit approach or on a nested logit approach. The nested approach reflects that a consumer may be more likely to choose among a certain sub-set of cars that have similar characteristics, than to change to a car that belongs to a different sub-set. Such varying substitution patterns across different car groups cannot be reflected to a similar extent in the more standard multinomial logit models. Vehicle ownership models are typically based on macroeconomic trend analysis (e.g. based on GDP and/or travel activity projections). Some models (e.g. the CALCARS model) also use a discrete choice model approach for forecasting car ownership. Again, this is then limited to the household market. Socio-economic characteristics of households then first define (via a discrete choice model) how many vehicles a household will own (or buy) in a given year. In a second step the same or similar household characteristics are used to establish the most likely vehicle type that a household will buy if really faced with a purchase decision in the respective year.

The main *data sources* used in the vehicle-type choice models under consideration are vehicle registration data (to identify consumers' revealed preferences) and tailored surveys (to identify consumers' revealed and stated preferences). Tailored surveys that include stated preference 'choice games' allow the exploration of decision behaviour with regard to new vehicle options that may not have been on the market in the past (e.g. alternative fuel vehicles, or vehicles with new specifications and/or prices). They are therefore especially valuable if trying to assess future choice behaviour when new vehicle models will enter into the market. When vehicle registration data is used, data are typically complemented with supplementary information that allow identifying more vehicle characteristics than what is logged in the registration data (e.g. information on purchase prices, maintenance costs, insurance costs stemming, for example, from journals, insurance providers or online sources) – vehicle characteristics that are typically highly relevant for decision makers.

The vehicle *choice options* that are considered vary significantly across the reviewed models and depend on the purpose of the specific model. Most models disaggregate the whole car fleet into several vehicle fuel types and several size classes, quickly resulting in more than 100 choice options. The UK Eftec model even considered more than 2 000 car options, defined by their make, model, body type, fuel type, engine size. On the other hand, the UK ECco model analysed the choice between four vehicle fuel types only (battery electric, plug-in hybrid, fuel cell and conventional).

Table A.1. Comparison of key model characteristics of reviewed models

	Choice modelled	Consumers considered	Main method	Main data source	Choices considered	Other
The Netherlands: **DYNAMO**	Car ownership; Vehicle type	Private households	Discrete choice models: mulitnomial logit nested mulitnomial logit	Data from the Dutch Centre for Vehicle Technology and Information Combined stated preference-revealed preference data set (gathered in the context of a different study)	*Car ownership module:* 0 vs. 1 or more; 1 vs. 2 or more *Car type module:* sixty types (for privately owned cars; defined by three fuel types, five age categories, four weight categories)	Info based on version 1.6 of the model (2006); version 3.0 exists since 2015
The United Kingdom: **ECCo model**	Vehicle type choice	Private households	Discrete choice model (MNL)	Tailored stated preference survey (Plenty of attitudinal questions for eight consumer types)	conventional vehicle battery electric vehicle plug-in hybrid electric vehicle fuel cell electric vehicle	Combined with a scrappage model to forecast actual sales numbers
The United Kingdom: **Transport Carbon Model (TCM)**	Vehicle ownership and vehicle type (among others)	Private households and commercial fleets	Ownership: macroeconomic model (driven by GDP, travel demand etc.) Vehicle technology: Discrete choice type approach	Travel demand forecasts (stemming from 'earlier' TCM modules) UK vehicle licensing statistics Data on vehicle characteristics/prices by technology	600+ vehicle technology/size combinations	One of the few examples of a model that explicitly also considers fleet vehicles (however, based on simpler approach than household choice model)
The United Kingdom: **Eftec model**	Vehicle type	Private households	Discrete choice model (MNL)	Household survey Additional dataset (JATO) to identify vehicle attributes	2 000+ alternatives (defined by make, model, body type, fuel type, engine size..)	Market shares predicted on basis of price/cost forecasts
California, The United States: **CALCARS**	Vehicle ownership, type, replacement and use	Private households	Vehicle ownership and type: Discrete choice model (nested mulitnomial logit)	Tailored revealed preference /stated preference survey carried out for the study	Vehicle type choice module: 105 vehicle technology/size combinations (7 fuel types, 15 body styles)	'Old' model (1996) that is periodically updated to integrate new vehicle type options.
Sweden: **Swedish car fleet model**	Vehicle ownership, vehicle type choice	Private households and companies	Vehicle ownership: Forecasts of socio-economic trends and fuel prices Vehicle type: Discrete choice model (nested mulitnomial logit)	Vehicle registration data (revealed preference) Tailored stated preference surveys Other sources to complement info on vehicle characteristics (e.g. motor journals to obtain price info)	300 car alternatives (defined by make, model and fuel type)	One of the few examples that explicitly considers company care

Understanding Consumer Vechicle Choice

This report presents a model that helps to better understand how consumers in France choose their cars. It presents the results for different scenarios for the future development of the French vehicle fleet and projections for related CO_2 emissions to 2050. The model distinguishes conventional, plug-in hybrid, battery-electric and fuel cell cars. It looks at the privately-owned as well as company car fleets and considers non-monetary factors for vehicle choice. Among these are personal preferences, the availability of recharging infrastructure for electric vehicles, and policy incentives such as subsidies or preferential vehicle use rights. The methodology and the data used for this new passenger car fleet model are described in detail.

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