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Analyse af indfasning af elbiler: SP metode og model

Projektet 'ELISA' af DTU Management for kommissionen for grøn omstilling af personbiler

September, 2020

DTU Management Engineering

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Forord

Følgende rapport beskriver ELISA projektet udført af DTU for KEFM/ENS, TRM og FM. Projektet er udført i perioden Jan.–Sept. 2020.

Rapporten beskriver tekniske detaljer vedr. dataindsamlingen og egenskaber ved den endelige stikprøve. Dernæst beskriver rapporten resultater fra en diskret valgmodel, herunder parametre, elasticiteter og betalingsvillighed.

DTU takker for et godt samarbejde i arbejdsgruppen hvor mange gode diskussioner har bidraget positivt til projektet.

Kgs. Lyngby, August 2020

Jeppe Rich, Professor

Abbreviations:

DTU	Danmarks Tekniske Universitet *(EN: Technical University of Denmark)*
KEFM	Klima-, Energi-, og Forsyningsministeriet *(EN: Danish Ministry of Climate, Energy and Utilities)*
ENS	Energistyrelsen *(EN: Danish Energy Agency)*
TRM	Transport- og Boligministeriet (Ministry of Transport and Housing)
FM	Finansministeriet (Danish Ministry of Finance)
ICV	Internal Combustion engine Vehicle
BEV	Battery Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
SC	Stated Choice
MNL	Multinomial Logit
NL	Nested Logit
ML	Mixed Logit
WTP	Willingness-to-pay

Contents

1. Dansk resumé

Følgende rapport beskriver ELISA projektet udført af DTU for KEFM/ENS, TRM og FM. Projektet omhandler i alt fire overordnede aktiviteter, hvor nærværende rapport fokuserer på aktivitet A:

A) Design og opsamling af Stated Preference (SP) data, dvs. data baseret på hypotetiske valgsituationer og estimation af modeller på basis af de indsamlede data
B) Ekspertrådgivning i forhold til hvordan substitution kan håndteres for elbiler i forhold til fremskrivninger af bilparken og dens sammensætning
C) At bidrage med data der kan anvendes til at analysere indfasningen af elbiler under forskellige forudsætninger
D) Modellering af den generelle bilbestand og hvordan denne påvirkes af afgifter og indkomster fremadrettet

Formålet med *Aktivitet A* er at opdatere datagrundlaget for at kunne fremskrive valg af biltype ved at estimere de mest relevante adfærdsparametre, herunder parametre for specifikke attributter for elbiler og plug-in hybridbiler. Data er indsamlet vha. et såkaldt stated choice (SC) eksperiment hvor hver respondent blev bedt om at foretage en række hypotetiske valg imellem 3 biltyper: ren elbil (BEV), plug-in hybrid (PHEV) samt konventionel benzin eller diesel (ICV). stated choice eksperimentet tager udgangspunkt i et efficient design, hvilket var nødvendigt grundet kompleksiteten i valgeksperimentet.

Det er vigtigt at respondenten kan relatere til de hypotetiske scenarier for at kunne afgive præcise svar. De præsenterede scenarier er derfor opbygget omkring det mest sandsynlige næste bilkøb. En vigtig faktor her er hvilke bilsegmenter forbrugeren er mest interesseret i. Sammen med styregruppen blev det besluttet at SC eksperimentet skulle bygges op omkring følgende seks bilsegmenter: Mini, Lille, Medium, Stor, Premium og Luksus/Sport. I den eksisterende litteratur er der i de fleste tilfælde kun benyttet ét segment per respondent. Dette gør det ikke muligt at fange overflytning mellem bilsegmenter (fx fra *stor* til *lille*). Det er imidlertid muligt at afgiftsomlægninger, der rammer specifikke segmenter/biltyper, kan føre til en substitution mellem segmenter og/eller biltyper. I eksperimentet er det derfor besluttet at inkludere flere segmenter per respondent. For at undgå et meget stort antal alternativer (alle kombinationer af 3 biltyper og 6 segmenter) benyttedes en metode, hvor respondenten angiver sandsynligheden for at næste bilkøb tilhørte hvert af de seks segmenter, og kun de to mest relevante segmenter udvælges. Dette giver mulighed for at analysere substitution mellem alle segmenter og biltyper efterfølgende.

I hvert scenarie er hvert af de præsenterede alternativer beskrevet vha. en række variable (attributter), som er tilpasset den enkelte biltype/segment og som varierer systematisk igennem eksperimentet. Efter en litteraturgennemgang og yderligere overvejelser og diskussioner i styregruppen er følgende attributter blevet udvalgt jf. *Table 1:* .

Main design	**House**		**Flat**	
Sub-design	**1**	**2**	**1**	**2**
Car types				
ICV	•	•	•	•
BEV	•	•	•	•
PHEV		•		•
Attributes				
Purchase price [*DKK*]	•	•	•	•
Yearly cost [*DKK/Year*]	•	•	•	•
Operation costs [*DKK/km*]	•	•	•	•
Range [*km*]	•	•	•	•
Acceleration [*s*]	•	•	•	•
Boot size	•	•	•	•
Carbon emissions [g/km]	•	•	•	•
Distance to home charging [*m*] (PHEV and BEV)			•	•
Home charging availability (PHEV and BEV)			•	•
Distance between fast chargers [*km*] (BEV)	•	•	•	•
Charging speed [*km per 10 minutes of charging*] (BEV)	•	•	•	•

Table 1: Inkluderede attributter samt hvilket eksperiment/teknologi de er medtaget i.

Det har været nødvendigt at tilpasse opladningsattributter for BEV og PHEV, så de passer til respondentens muligheder for opladning ved hjemmet. Således er der opbygget forskellige designs til personer med mulighed for opladning på en privat parkeringsplads og dem, som f.eks. bor i lejlighed og parkerer på gaden når de er hjemme. Kun for dem, der ikke har mulighed for at lade på en privat/dedikeret parkeringsplads ved hjemmet, bliver der stillet spørgsmål omkring afstand til nærmeste ladestander fra hjemmet samt sandsynlighed for at disse ladestandere er ledige. Inden for hvert af disse designs, er opladningsattributter ligeledes kun brugt til at beskrive de teknologier, hvor disse er relevante. Således bliver PHEV kun beskrevet med opladningsattributter der beskriver opladning ved hjemmet, mens BEV både er beskrevet med opladningsattributter der beskriver opladning ved hjemmet og opladning på farten.

Som det fremgår, er de endelig designs beskrevet med mange attributter og vi stiller dermed respondenterne over for en kompleks opgave. Idet der er en forventning om at BEV biler på lang sigt bliver dominerende, og for at reducere kompleksiteten for respondenten, blev det besluttet at respondenten skulle stilles overfor 4 scenarier hvor kun ICV og BEV teknologier indgår. Dette efterfølges af 4 scenarier hvor ICV, BEV og PHEV indgår, dvs. respondenten stilles overfor 4 scenarier med 4 alternativer (2 biltyper og 2 segmenter) samt 4 scenarier med 6 alternativer (3 biltyper og 2 segmenter).

Eksperimentet er kodet og udsendt gennem Epinion. Respondenter blev tilfældigt udvalgt fra den danske population med samme metode som benyttes i transportvaneundersøgelsen hvor CPR numre er udvalgt tilfældigt og udsendt via e-boks. Spørgeskemaet blev udsendt som pilot test til 1495 respondenter i maj 2020, hvor der blev opnået en responsrate på 14,8%. Efter mindre justeringer blev de resterende 25.209 invitationer udsendt i mindre sæt. Seneste udsending var 22/6 2020 og der blev samlet set for hovedundersøgelsen opnået en responsrate på 11,7%, hvilket passer med forventningerne.

Denne rapport inkluderer en modelestimation i form af en Mixed Logit Model baseret på de 23.674 observationer fra 2.961 respondenter, den udregnede betalingsvillighed (willingness to pay) for hver attribut samt elasticiteter på tværs af alle biltyper og segmenter for både købspris og rækkevidde. Alle estimerede parametre er signifikante (indenfor et 1% konfidensniveau) og med forventede fortegn. Modellen er overleveret til ENS og der udføres videre rådgivning omkring hvordan modellen implementeres i deres basisfremskrivninger samt evt. hvordan der tages højde for substitution som angivet i *Aktivitet B.*

2. Purpose

This report documents the work on activity A within the overall ELISA project. The overall goal for ELISA is to support the development of a model that can predict market shares for conventional as well as electric and plug-in hybrids in future scenarios. The purpose of activity A is to update the data foundation for a forecasting tool describing vehicle demand by fuel type across car segments which is developed by KEFM/ENS and also relevant for TRM and FM. In addition, the activity includes the estimation of relevant parameters for this forecasting tool. The data update is based on a stated choice experiment that is sent out to a random sample of the Danish population. New car technologies, such as battery electric vehicles and plug-in hybrid vehicles, comes with different features compared to conventional vehicles and the experiment thus specifically targets behavior related to factors such as driving range, charging of batteries and the price of the vehicles. As changes in levels for specific segments or vehicle types can result in substitution effects across both vehicle types and segments, the experiment includes both vehicle types and segments. A discrete choice model that is estimated on the collected data.

3. Literature and experiences

In the following, we review the literature and previous experience. In particular, we identify relevant attributes with respect to the choice of car and consider;

i) how they can be measured,
ii) their relative effect,
iii) their importance.

3.1 Monetary cost attributes

Several cost components can be considered including the purchase cost, operating expenses (variable km costs) and annual costs (e.g., green tax and insurance).

One tempting approach from an application perspective is to include different cost components in a combined 'Total Cost of Ownership' variable, here referred to as TCO. However, it is not obvious that a stated preference experiment would provide realistic trade-offs from cost attributes described by TCO. TCO is not a commonly understood concept among private customers and it is expected that many respondents will have difficulties relating to this concept.

Purchase/leasing price

In a recent literature review of SP studies regarding BEV purchase, Liao, Molin, and van Wee (2017) state that all reviewed studies included *purchase price* and that many studies used a pivoted design with respect to the price. Hence, the values for the purchase price that are presented to consumers are pivoted around a reference price stated by each respondent. Indeed, (Glerum et al. 2013) include both purchase price and *leasing price* but do not include details on how these are calculated. In order to control for uncertainty with respect to value depreciation due to technological development, Bockarjova, Rietveld, and Knockaert (2013) included both purchase price and expected resale price in their choice experiment.

Operation costs

Another important cost attribute is the costs of using the vehicles. It is widely accepted to use approximate *operation costs* by energy costs per km or per 100 km (e.g. Potoglou and Kanaroglou, 2007; Jensen, Cherchi and Ortúzar, 2014). However, there are also examples of combined costs for energy and maintenance (Mabit and Fosgerau 2011) and annual operation costs (Giansoldati et al. 2018).

Where the energy costs for ICVs are easily measured as the cost of fuel, the energy costs for BEVs are more complicated. This is because BEVs can be charged at home and away from home. When charging at home, the costs is often equal to a fixed rate. However, BEV users can also have special agreements with separate charging operators and many different cost structures are possible, e.g. flat rate, variable rate and/or lump sum payment.

When BEVs are charged away from home, different roaming conditions can influence the price as well.

3.2 Technical attributes

Technical attributes describe technical features of the individual vehicles.

Driving range

The limited driving range of many BEVs is often found to be a great barrier for the BEV market share. Driving range has been included in different ways in stated preference surveys. In many studies, driving range only vary for BEVs, while in other studies, the driving range also varies for other vehicle alternatives. The attribute values also vary significantly, e.g. from 30-60 miles (48-97 km) (Hess et al. 2012) to 200-600 km (Giansoldati et al. 2018). Generally, older studies are characterized by limited range because these studies reflected the technology state at the time of the study. However, more recent studies include BEVs with longer driving range.

The functional form of driving range has been debated in the literature. As discussed (Dimitropoulos, Rietveld, and van Ommeren 2013) it is not reasonable to expect that the marginal increase is constant across different reference levels of driving range. In a Meta study they find evidence for a log transformation of driving range. Furthermore, they suggest that driving range can depend on charging activities, charging time and the extent of the charging infrastructure.

Charging infrastructure

Most BEV users are able to charge at home. Several studies suggest that about 70%-80% of all charging events occur at home (Figenbaum and Kolbenstvedt 2016; Franke and Krems 2013; Haustein and Jensen 2018). However, even though long-distance trips represent only a small share of the transport demand of the household, the need for charging while taking these trips is known to have influence on the car purchase decision (Nicholas, Tal, and Turrentine 2017). It has been found that owners of first generation Nissan Leaf BEVs (with a comfortable driving range of 110 km) stays within the one-way distance of their battery range, whereas Tesla owners (with a driving range above 300 km) often exceeds this limitation, i.e. they use fast charging on longer trips. As the battery size for BEVs increase, we can expect to see more long-distance trips. However, such development also dependent on the supply of fast chargers (Nicholas, Tal, and Turrentine 2017).

Currently there is a research gap with respect to the type of infrastructure that will support the transition to long distance BEV trips (Hardman et al. 2018). Several past studies included fuel availability in a single attribute and do not distinguish between BEVs and other vehicles (e.g. Horne, Jaccard and Tiedemann, 2005; Potoglou and Kanaroglou, 2007; Bolduc, Boucher and Alvarez-Daziano, 2008; Achtnicht, 2012). Bockarjova, Rietveld and Knockaert (2013), as one of the first studies, included the detour and waiting time to reach a charging point whereas (Hidrue et al. 2011) only included charging time. In another study (Ito, Takeuchi, and Managi 2013) included charging time and a combined refuel availability and refuel location in one attribute. In order to account for access to private parking space at home, (Jensen, Cherchi, and Mabit 2013) included the distance to the nearest charging option from home and charging at work. Hardman *et al.* (2018) found the work destination to be the second most frequently used charging location.

Vehicle performance and characteristics

Several studies also include an attribute describing the driving performance of the vehicles, e.g. acceleration, top speed and size. In the early studies, (e.g. Bunch et al. 1993; Ewing and Sarigöllü 1998), this was especially important as electric vehicles were known as being rather small and slow. Today, electric vehicles perform at least as well as conventional cars and several studies show that drivers appreciate the fast acceleration, the smoothness and the silence of BEVs (Franke et al. 2012; Gärling and Johansson 1998; Jensen, Cherchi, and Ortúzar 2014; Skippon et al. 2016). Furthermore, it is now possible to get an BEV in all size segments. However, as BEVs are still significantly more expensive compared with ICV vehicles, it is particularly relevant to consider size segments in order to investigate potential substitution effects between segments. As an example, a household might be willing to consider a smaller and cheaper BEV over a larger conventional car, if this vehicle is within budget constraints.

It is also likely that households will prefer BEVs due to environmental performance. Previously, such performance has mostly been included as an attribute describing carbon dioxide emissions (Achtnicht 2012; Ito, Takeuchi, and Managi 2013; Jensen, Cherchi, and Mabit 2013) but also simpler definitions for pollution effects have been used, such as the pollution represented as a percentage of a reference vehicle (Hackbarth and Madlener 2013; Hidrue et al. 2011; Potoglou and Kanaroglou 2007).

3.3 Policy attributes

In order to promote the market uptake of BEVs, different countries have suggested different types of incentives. According to a recent literature review (Liao, Molin, and van Wee 2017), several studies consider reductions in purchase price (Glerum et al. 2013; Mau et al. 2008; Potoglou and Kanaroglou 2007) or usage cost reductions (Hackbarth and Madlener 2013; Hoen and Koetse 2014). No studies have found free parking to be effective and only 2 out of 10 studies (Hackbarth and Madlener 2013; Horne, Jaccard, and Tiedemann 2005) has found that access to high occupancy vehicle or bus lanes were effective in promoting BEVs.

4. SP design

In this section we will describe the design process of the stated choice experiment. The experiment is designed to capture substitution between car types (e.g. different propulsion) and car segments (size of cars). We consider the following car types and car segments:

Dimensions	Description
Types	1: Conventional cars (ICVs), 2: Plug-in Hybrids (PHEVs), 3: Battery Electric cars (BEVs)
Segments	1: Mini, 2: Small, 3: Medium, 4: Large, 5: Premium, 6: Luxury/Sport

Table 2: Overview and definition of car types and car segments considered in the study.

The full set of alternatives will consist of all combinations of car types and segments, thus a total of 18 alternatives. For simplicity, each respondent is only presented with a subset of the most relevant alternatives.

4.1 Attributes

The final design included the following attributes:

Cost attributes:

- **Purchase price [*DKK*]**: The purchase market price of the vehicle from new.
- **Yearly cost [*DKK/Year*]**: A fixed yearly cost that reflects expenses for annual taxation and insurances.
- **Operation costs [*DKK/km*]:** The cost related to operation/propulsion of the vehicle.

Car characteristics:

- **Range [km]:** The driving range of the vehicle with full battery or tank. For PHEV, only the battery range varies and the gasoline/diesel driving range is fixed to 600 km.
- **Acceleration [*Seconds*]:** The acceleration time from 0-100 km/h.
- **Boot size:** The size of the vehicle boot defined by the categories, small, medium, large and very large. This solution was chosen over specific storage capacity as simplicity for respondents was considered more important than actual size.
- **Carbon emissions [*g/km*]**: The pollution related to CO_2 emission per km. While other emission types could be relevant, only CO_2 emission are considered as it: 1) keeps the design "simple", and 2) new cars today are labelled with a "CO_2 emission"-label (in g/km) when purchased (e.g., it is expected that the respondent is able to relate to the values presented in the stated choice experiment), 3) because most other related emissions are strongly correlated with CO_2 use.

Charging infrastructure:

- **Distance to home charging [Meter]:** Indicates the distance to the nearest public (slow) charger from home. This attribute is only included for individuals who do not have access to private charging at home.
- **Home charging availability:** Indicates the probability that the nearest public (slow) charger(s) has a vacant plug (and is accessible). This attribute is only included for individuals who do not have access to private charging at home.

- **Distance between fast chargers [km]:** Defines the average distance between public fast chargers in the network.
- **Charging speed [km *per 10 minutes of charging*]:** Indicates the charging speed for public fast chargers. In order be applicable for all BEV car segments and varying battery sizes, it is shown as an average driving distance which can be achieved after 10 minutes of charging.

The attributes *Distance to home charging* and *Home charging availability* are only included for individuals who do not have access to private charging at home, e.g. in a garage/carport either through a dedicated charging unit or an emergency charger (so called 'granny charger'). Further, since these two attributes reflect general infrastructure conditions, these are independent of the specific car and thus have the same value for all BEVs and plug-in hybrid electric vehicles (PHEVs) within each choice task. The attributes *Distance between fast chargers* and *Charging speed* (when fast charging) are only presented for BEVs and, as for home charging attributes, these fast charging attributes have the same value across all BEVs within a choice scenario. The reason for not considering attributes related to fast charging in relation to PHEV alternatives is that PHEVs have only small batteries and is not relevant for this type of charging. Indeed, most PHEVs are not able to fast charging and for longer trips they will usually use their ICV engine.

4.2 Level value

The attribute levels are defined based on existing literature as well as the car models that are available in the market today and is expected to be available in the future. The Danish Authorities have information on all Danish vehicles, and based on this information the levels were defined. Furthermore, some attribute levels were changed to better represent the future car fleet (e.g. longer range for BEVs). The final attribute levels are presented in the Appendix.

4.3 Design versions

The design process is complicated by the fact that conditions are very different across the population. In particular, home charging possibilities will often depend on the respondent's type of house (private house, flat, etc.). To accommodate these differences, two designs where constructed. One design included the two attributes (*Distance to home charging* and *Home charging availability*) while an alternative design did not include these attributes. As PHEV is an alternative where driving range is based on energy from both batteries and gasoline/diesel, it is not obvious how the inclusion of this car type impacts (the robustness of) the parameter estimates. In order to investigate this (and to simplify the task for each respondent), two sub-designs were constructed: a design that only included ICVs and BEVs, and a design that included all three car types (ICV, BEV, and PHEVs). All respondents were presented with four tasks in each sub-design. The advantages of the first design is two-fold: firstly, the design is simpler and expected to be more robust, and secondly it makes it easier for the respondents to relate to the design when starting with only two car types. The most complicated design with three car types is presented last. Clearly, only the second design allows for the estimation of substitution effects for PHEVs. To summarize, a total of four (two main designs each with two different sub-designs) stated choice designs were generated. Table 3 presents an overview of the car types and attributes included in each of these designs, while Figure 4.1 shows an example of the final layout of the actual choice scenarios presented to the respondents.

Main design	House		Flat	
Sub-design	**1**	**2**	**1**	**2**
Car types				
ICV	•	•	•	•
BEV	•	•	•	•
PHEV		•		•
Attributes				
Purchase price [*DKK*]	•	•	•	•
Yearly cost [*DKK/Year*]	•	•	•	•
Operation costs [*DKK/km*]	•	•	•	•
Range [*km*]	•	•	•	•
Acceleration [*s*]	•	•	•	•
Boot size	•	•	•	•
Carbon emissions [g/km]	•	•	•	•
Distance to home charging [*m*] (PHEV and BEV)			•	•
Home charging availability (PHEV and BEV)			•	•
Distance between fast chargers [*km*] (BEV)	•	•	•	•
Charging speed [*km per 10 minutes of charging*] (BEV)	•	•	•	•

Table 3: Overview of constructed stated choice designs.

4.4 Choice set size

One of the main objectives of this study is to account for substitution effects across car types and car segments. This is particularly relevant as BEVs in the current market are more expensive. Hence, opting for a BEV rather than a traditional ICV can shift some consumers to target a smaller car segment due to budget constraints.

As mentioned, in this study we consider 3 car types each containing 6 car segments. It is however not possible to ask respondents to answer all 18 alternatives, each with 7-11 attributes, as such a task will be too complex. Instead, we decided to present each respondent with the two car segments that were most relevant for them. Thus, the “simple” design (design 1) contains 2*2 alternatives, while the “complex” design (design 2) contains 3*2 alternatives. An example of a scenario from design 2 for a person that does not have access to a private home charger is presented in Figure 4.1.

Forestil dig at disse nye biler er til salg som de bedste muligheder i hver bilklasse.

Forklaring af bilklasser:
- ***Mini:*** *fx Toyota Aygo, Kia Picanto, Volkswagen Up*
- ***Lille:*** *fx Peugeot 208, Toyota Yaris, Renault Zoe*
- ***Mellem:*** *fx Ford Focus, Volkswagen Golf, Nissan Leaf*
- ***Stor:*** *fx Ford Mondeo, Skoda Superb, Tesla 3*
- ***Premium:*** *fx Mercedes E-klasse, Audi A6, Tesla S/X*
- ***Luksus/Sport:*** *fx Mercedes S-klasse, BMW 7 serie, Audi A8*

Ny bil	**Benzinbil**	**Benzinbil**	**Elbil**	**Elbil**	**Plug-in Hybrid**	**Plug-in Hybrid**
Bilklasse	Medium	Stor	Medium	Stor	Medium	Stor
Omkostninger						
Købspris	250.000 kr.	430.000 kr.	300.000 kr.	450.000 kr.	225.000 kr.	350.000 kr.
Kørselsomkostninger (Omkostninger per 10.000 km)	1,19 kr / km (11.900 kr)	1,37 kr / km (13.700 kr)	0,68 kr / km (6.800 kr)	0,56 kr / km (5.600 kr)	1,27 kr / km (12.700 kr)	1,11 kr / km (11.100 kr)
Årlige omkostninger (afgifter, service, forsikring)	5.978 kr.	9.083 kr.	5.899 kr.	8.881 kr.	5.072 kr.	7.529 kr.
Beskrivelse af bilen						
Rækkevidde	898 km	1097 km	450 km	550 km	EL: 40 km Benzin: 600km	EL: 25 km Benzin: 600km
Acceleration (0-100km/t)	14 sek	12 sek	5 sek	11 sek	5 sek	9 sek
Bagagerum	Stort	Meget stort	Stort	Meget stort	Stort	Meget stort
CO_2 udledning	91 g/km	98 g/km	33 g/km	35 g/km	138 g/km	150 g/km
			Udledning er beregnet på basis af 70 % vedvarende energi			
Infrastruktur						
Opladningsmuligheder nær hjemmet			Ladepunkt inden for 50m fra hjemmet Ledig 1 ud af 4 gange			
Distance opnået efter 10 min hurtig opladning			35 km	125 km		
Distance mellem hurtigladere på hovedvejnetværket (min 50kW)			*90km*			
Hvilken bil ville du vælge i denne situation?	●	●	●	●	●	●

Figure 4.1: Choice task example with ICV, BEV, and PHEV for individuals who cannot charge at home.

4.5 Final design / Design Type

The designs were generated as efficient designs with zero priors. The reason for using efficient designs is that it allows restrictions on attribute levels for specific attributes. More specifically, for the infrastructure attributes, it was desired to keep levels constant across all (relevant) alternatives within each choice task. That is, if the nearest home charger is 400 meter away, it would be the same independent of the car being an BEV or PHEV. The reason for using zero priors is to maintain robustness of the design as much as possible (Walker et al. 2018/2019).

Each of the final four stated choice designs (listed in Table 3) contained 80 choice tasks. These were divided into 20 blocks of 4 choice tasks each. Hence, each respondent were presented with 2*4 choice scenarios, i.e. four choice scenario from design 1 followed by four choice scenarios from design 2. If home charging is available then they are presented with design 1 and 2 from the “House”-designs, while if home charging is not available they are presented with design 1 and 2 from the “Flat”-designs.

5. Survey description

The coding and hosting of the survey was conducted by Epinion who has a professional setup for online data collections. However, as their standard tool could not handle the stated choice experiment, the users are redirected to another tool, called sawtooth, during the experiment.

The survey begins with an introduction page describing the overall objective of the study. Detailed information about the experiment and the other relevant information (e.g. GDPR) is already described in the invitation letter.

The respondent is asked to read the questions carefully before answering and is informed that it is possible to exit the interview and use the link again later to continue from where the session stopped.

The survey consists of four parts:

1. Intro questions (needed for customizing the SP scenarios)
2. Stated choice experiment
3. Background characteristics and car usage
4. Attitudinal statements

5.1 Part 1: Intro questions and customization

In this part of the survey, basic information for the respondent is collected. Some of this information is used for customizing of the stated choice experiment for each specific user. The sections begins with the following text:

'In this part of the survey, we ask for information about your occupation and cars that you have access to in your household. Besides cars that you may own, this can also be a company car, a leased car, or a car that you often borrow from somebody else.'

An overview of the survey questions included in this part are found in Table 4 below:

ID	Description	Type	# categories
q1	Primary occupation	Categorical	17
q2	Car availability in household	Categorical	5
q2a	Description of cars in household	multiple	
	Car segment	Categorical	6
	Ownership type	Categorical	7
	Model year	integer	
	Propulsion	Categorical	6
q3	Parking options at home	Categorical	20
q4	Parking options at work	Categorical	12
q15	Accessibility to charging at home	Categorical	4
q15a	Accessibility to charging at work	Categorical	4

q6	Future car changes in household (replace existing, additional car or no changes)	Categorical	3
q6a	Description of next car in household		
	Ownership type	Categorical	7
	Condition	Categorical	3
	Propulsion	Categorical	6
	Expected time for change	Categorical	3
q7	Probability for each car segment	Multiple	6x6

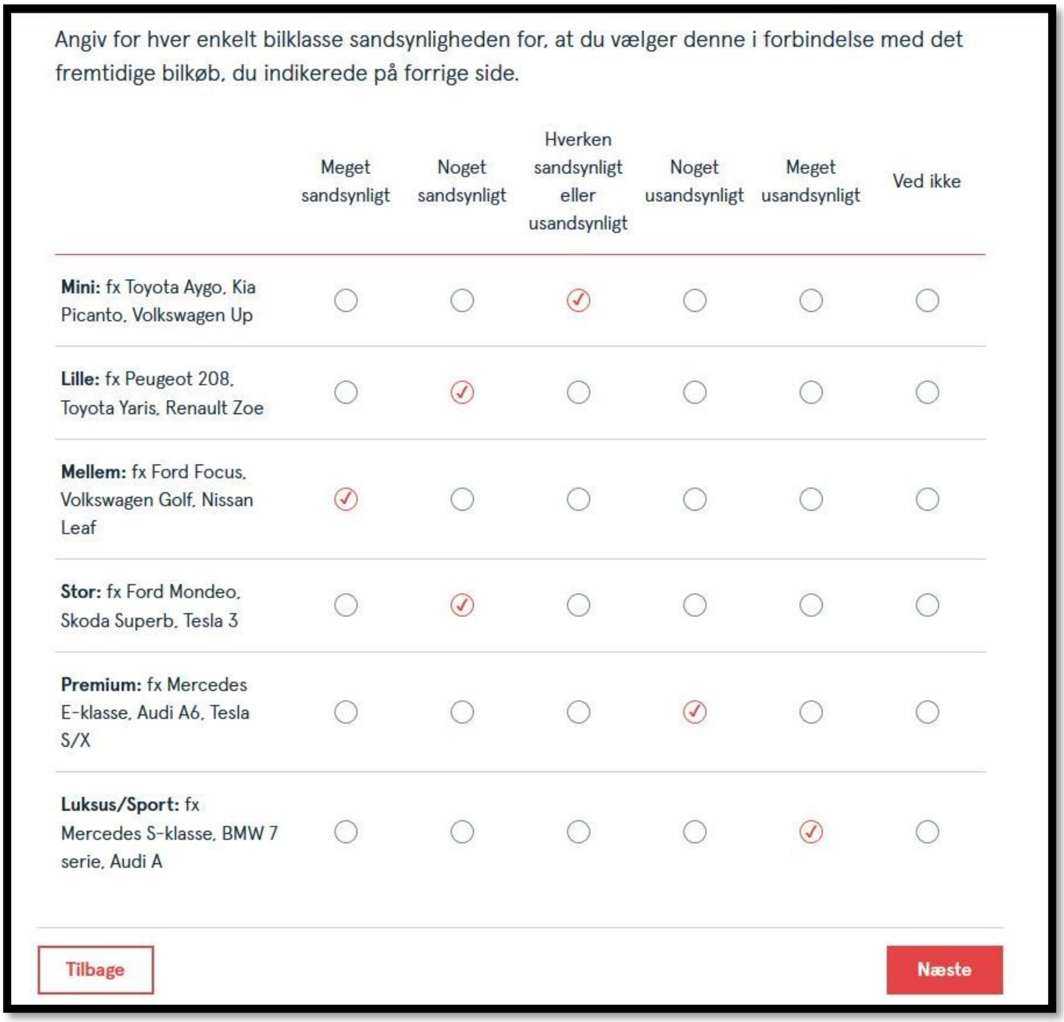
Table 4: Intro questions included in part 1.

q1 is about primary occupation and the categories are similar to the corresponding categories for the Danish National Travel Survey (TU). If a respondent selects a category that indicates that the respondent does not go to work, then following questions about charging at work are not presented. Subsequently, the respondent is asked to describe the available cars in the household. Question q2 is regarding the number of available cars and the answer can be one of the categories: 0, 1, 2, 3 or “more than 3”. For each of the available cars, the respondent is now asked to indicate the car segment, type of ownership, model year and propulsion.

The parking opportunities at home and at work are asked in question q3 and q4. Note that work parking options are only asked if ‘primary occupation’ indicates that the respondent goes to work. We ask specifically for charging options at home and at work in q15 and q15a respectively. Here the respondent can indicate if a charger has already been installed at home or if it is possible or not. For charging at work, the respondent can indicate whether these are accessible and close to the work location.

In q6 the respondent is asked to indicate the likely next car purchase scenario in the household. It is possible to indicate “I will replace car X”, “I will acquire another car” and “I do not have plans of acquiring a car”. If “replace” is chosen, it is possible to indicate which one of the cars in the household are most likely to be replaced. In q6a, the respondent is asked to further describe the car. It is possible to define type of ownership, condition (new or used), propulsion and when this event will most likely take place.

Finally, for each car segment in the survey, the respondent is asked (q7) to indicate the likelihood that the next car in the household will belong to a given segment as seen in Figure 5.1. This is used to select the two car segments that will be included in the stated choice experiment. The cars with the highest likelihood will be included. In case of cars being equally likely, one of them will be randomly selected.



Angiv for hver enkelt bilklasse sandsynligheden for, at du vælger denne i forbindelse med det fremtidige bilkøb, du indikerede på forrige side.

	Meget sandsynligt	Noget sandsynligt	Hverken sandsynligt eller usandsynligt	Noget usandsynligt	Meget usandsynligt	Ved ikke
Mini: fx Toyota Aygo, Kia Picanto, Volkswagen Up			✓			
Lille: fx Peugeot 208, Toyota Yaris, Renault Zoe		✓				
Mellem: fx Ford Focus, Volkswagen Golf, Nissan Leaf	✓					
Stor: fx Ford Mondeo, Skoda Superb, Tesla 3		✓				
Premium: fx Mercedes E-klasse, Audi A6, Tesla S/X				✓		
Luksus/Sport: fx Mercedes S-klasse, BMW 7 serie, Audi A					✓	

Tilbage | Næste

Figure 5.1: Question on relevance of car segments.

5.2 Part 2: Stated choice experiment

Right before the stated choice experiment, the respondent is presented with two pages of information. In the first page, it is stated that the respondent now proceeds to the second part where he/she will face a number of car options and that these options beside conventional cars, also include BEVs and PHEVs. Then follows a brief presentation of these technologies. On the second page, the respondent is reminded about the details for the most likely car purchase as indicated in part 1 and that he/she should pretend to be in that situation now.

After the introduction each respondent is presented with 2*4 stated choice tasks, in which the respondent is asked to select the option he/she would prefer in a real-life situation. As discussed previously, the first four choice tasks contains four alternatives (2 ICVs and 2 BEVs), while the subsequent four choice tasks contains 6 alternatives (2 ICVs, 2 BEVs, and 2 PHEVs). For individuals, who in question q15, indicated that they have (the possibility of installing) a home charger, the "House" main design was used. If on the contrary, they indicated that this is not possible, the "Flat" design was used.

5.3 Part 3: Background characteristics

After the stated choice experiment was completed, respondent and household characteristics were collected. In the sample data, we already have information about the age of the respondent, gender and home location.

ID	Description	Type	# categories
q8x	Highest finished education	Categorical	11
q8a	Number of persons in household	Integer	
q8	Description of other persons in household		
	Relation	Categorical	3
	Gender	Categorical	3
	age group	Categorical	12
	Possession of driver's license	Categorical	2
q8_2	Own possession of driver's license	Categorical	2
q9	Annual household income before tax	Categorical	12
q10	Annual mileage for each available car in household	Categorical	7
q11	Frequence of purpose usage for each car	Multiple categories	3x5
q12	Frequency of trip distances for each car	Multiple categories	6x6

Table 5: Background questions included in part 3.

For each member of the household, we ask about the relation to respondent, gender, age group and driver's license status. Furthermore, for each car (current) in the household, we ask about the car usage, e.g. yearly mileage and frequency of trips for certain trip purpose.

5.4 Part 4: Attitudinal statements

The final part of the survey collects information based on attitudinal statements. The statements have been developed in previous research projects at DTU. The complete list of attitudinal statements are presented in Table 6. Respondents were asked to rate their agreement to each of the statements on a 1-5 Likert scale where 1=completely disagree, and 5=completely agree. The attitudinal statements are distributed randomly across three survey pages.

ID	Attitude statements
1	The need for charging makes electric cars very unpractical for use in everyday life.
2	Ensuring that an electric car is always charged makes it inconvenient to use.
3	Using an electric car requires a careful planning of activities.
4	It is fun to drive an electric car.
5	The fast acceleration of an electric car is an exciting experience.
6	I'm fascinated by the technology of electric cars.
7	Electric cars are not suitable for my lifestyle.
8	My next car will be an electric car
9	Using an electric car for longer distances is difficult due to a lack of charging stations along the motorway.

10	An electric car is well suited to carry out my daily tasks.
11	The development of public incentives for electric cars is very unpredictable in Denmark/Sweden.
12	The resale value of electric cars is very unpredictable.
13	People who are important to me are considering to buy an electric car.
14	If I buy a car, I feel morally obliged to choose a car that minimises carbon emissions and air pollution.
15	I feel obliged to take environmental consequences of vehicle use into account when choosing a car.
16	People who are important to me think that electric cars should play an important role in our transport system.
17	People who are important to me think that my next car should be an electric car.
18	People who are important to me own an electric car.
19	When driving an electric car, I'm always (would always be) worried about running out of charge.
20	I (would) feel embarrassed when driving an electric car.
21	I (would) feel proud of having an electric car.
22	Driving an electric car expresses (my) openness for new technologies.
23	Driving an electric car is easily compatible with my habits.
24	Future political support for electric cars is very uncertain in Denmark/Sweden.

Table 6: Full list of attitudinal statements presented to the respondents.

6. Data description

The respondents were drawn randomly from the Danish population using the same sampling method as applied for the Danish National Travel survey. That is, CPR numbers are drawn randomly and invitations are sent via digital ‘e-boks’ invitations. For testing purposes of the survey, a pilot were launched in May 2020. In the pilot, 1496 invitations were send out. Of these, 222 were answered (response rate 14.8%). This test led to minor adjustments for the attribute levels for PHEV and a further presentation of the operation costs per 10,000 km as respondents did not seem to evaluate this costs realistically in the pilot. After initial validation of the responses from the revised survey, we launched the full sample in June 2020 in batches of 4000 invitations per day. Table 7 contains a full overview of sent invitations including the date and day of week.

	#	Date	Day	Invitations sent
Pilot	1	2020-04-27	Monday	100
	2	2020-05-04	Monday	100
	3	2020-05-06	Wednesday	550
	4	2020-05-19	Tuesday	745
		Pilot total		**1,495**
Final sample	5	2020-06-08	Monday	1,000
	6	2020-06-10	Wednesday	4,000
	7	2020-06-15	Monday	4,000
	8	2020-06-17	Wednesday	4,000
	9	2020-06-18	Thursday	4,000
	10	2020-06-19	Friday	4,209
	12	2020-06-22	Monday	4,000
		Sample total		**25,209**

Table 7: Schedule of survey invitations

In total 25,209 invitations were sent out for the main sample, and 2,961 responses were either completely or partially completed by 29 June, i.e. 10 days after the last invitations were sent out. This correspond to a response rate of 11.7% which is in line with expectations. **Error! Reference source not found.** presents some descriptive statistics comparing the full representative sample against the final sample of respondents. Overall the distribution of the respondents who answered the survey seems to match the distribution of the sample well. However, young individuals seems to be slightly underrepresented, while middle-aged and older individuals are slightly overrepresented. In addition, males are overrepresented and females are underrepresented slightly.

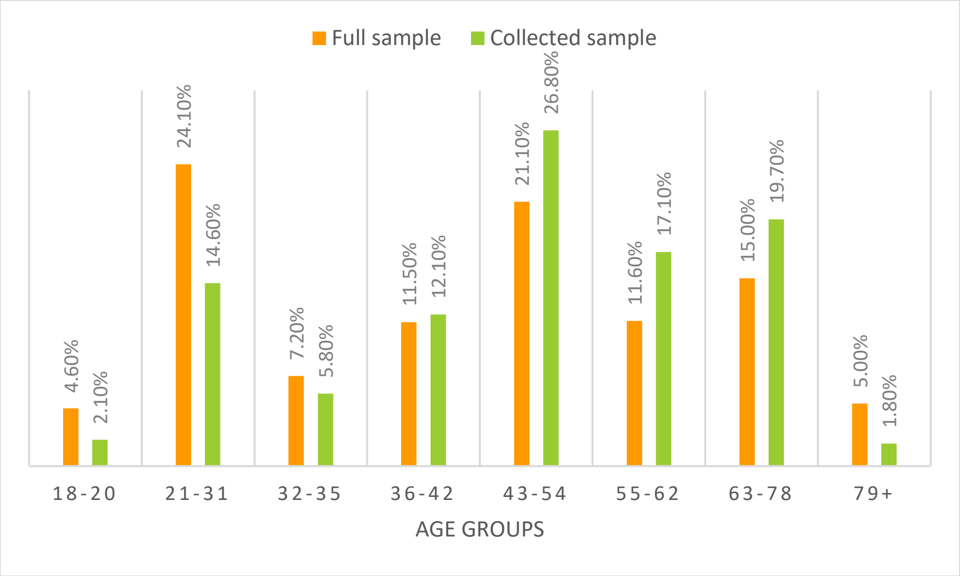


Figure 6.1: Comparison between full (representative sample) and final collected sample with respect to age.

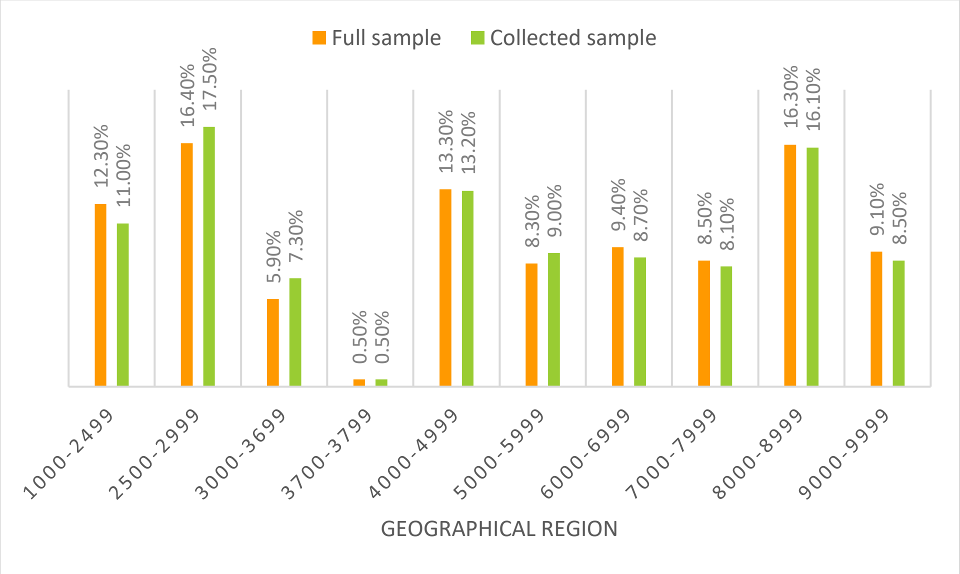


Figure 6.2: Comparison between full (representative sample) and final collected sample with respect to geographical region.

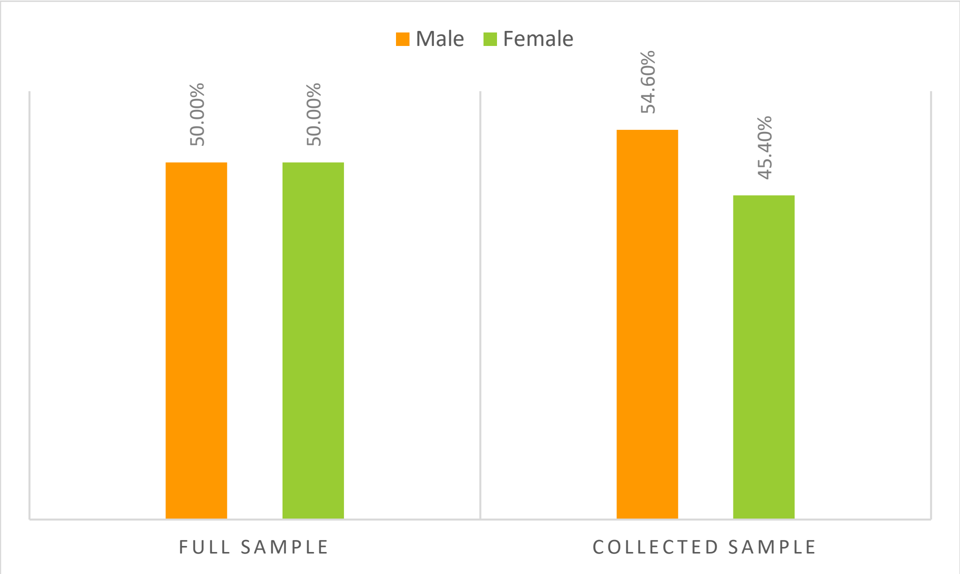


Figure 6.3: Comparison between full (representative sample) and final collected sample with respect to gender.

For home charging units, this is a question that was directly asked in the questioner and exist only for the final sample. A tabulation of the sample properties are provided in Appendix A.

HOME CHARGING UNIT	Nobs	Pct.
Possible	1586	53.6%
Not Possible	1375	46.4%

Table 8: Final share of home charging units

It is interesting to consider the share of households with home charging opportunities. Figure 4.1 and Table 8 shows that slightly more than half of the sample can charge at home (either because they have a home charger installed or because they have the possibility of installing one). Interestingly, one fifth of the sample do not know if it is possible to install a home charger (in which case they are presented with the “Flat”-design). It is possible this may represent people who share parking facilities with their neighbors and where no decision has been taken regarding the installation of charger facilities.

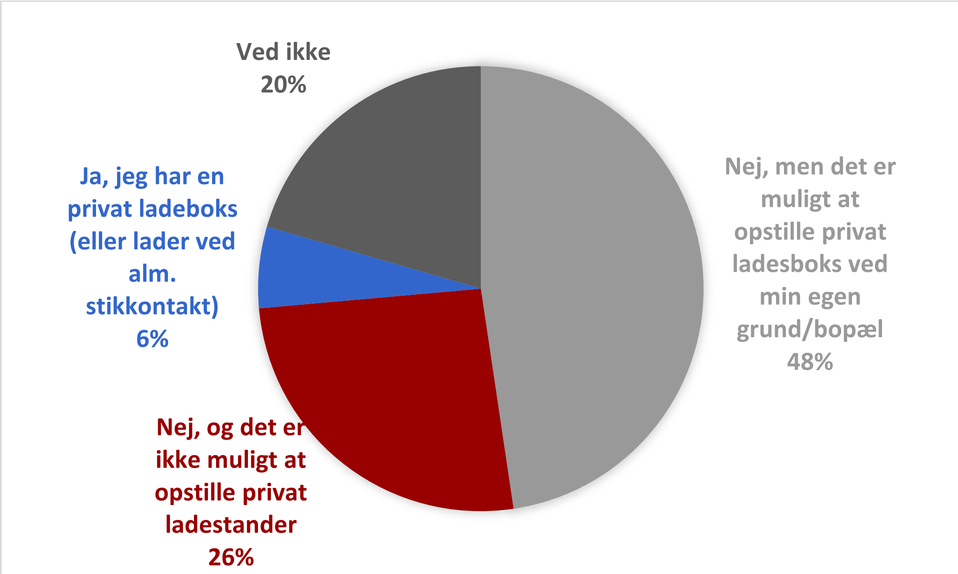


Figure 6.4: Charging possibilities at home.

Table 9 shows the sample shares across car types and car segments of the chosen alternatives in the scenarios. The choices seem to be fairly well distributed across both car segments and car types. For all car types, the highest market share is for medium sized cars. The distribution across car segments are fairly similar for design 1 and design 2.

	MINI	LIL	MEL	STOR	PREM	LUK	Total
ICV	6.50%	9.23%	15.22%	6.65%	3.65%	0.79%	**42.03%**
BEV	5.30%	6.69%	17.39%	9.20%	2.79%	0.58%	**41.94%**
PHEV	2.29%	2.83%	7.24%	2.83%	0.63%	0.20%	**16.03%**
Total	**14.09%**	**18.74%**	**39.85%**	**18.67%**	**7.07%**	**1.57%**	**100.00%**

Table 9: Sample shares across car types and car segments

Figure 6.5 shows the distribution of the propulsion technology within each of the four designs. As expected we see that the share of individuals choosing BEVs is higher for individuals who can charge at home compared to individuals who cannot.

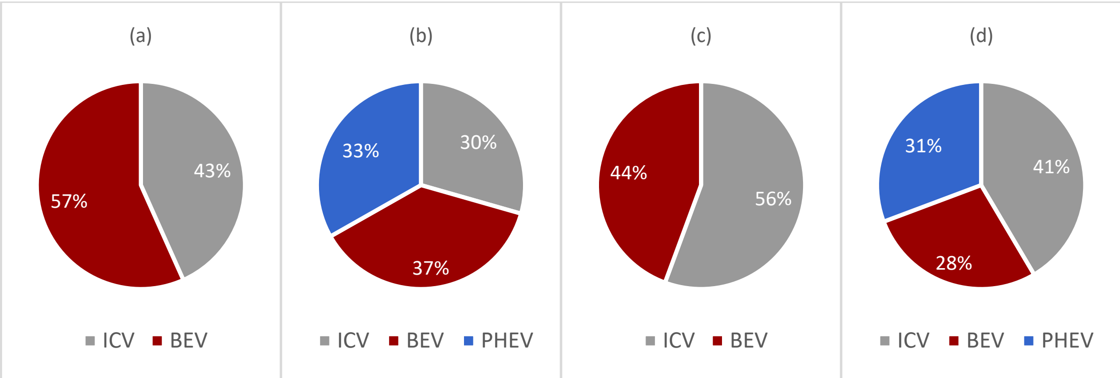


Figure 6.5: Stated “technology” market shares for each of the four design types: (a) House, 4 alternative, (b) House, 6 alternatives, (c) Apartment, 4 alternatives, (d) Apartment, 6 alternatives.

Finally, one key aspect of this study is to be able to capture the substitution effects across car segments. As previously mentioned, only two car segments were selected within each car type. Table 10 reveals that all possible combinations of car segments are present in the data. As expected, respondents mainly consider car segments that are next to each other, e.g. “small and medium” car segments. The most frequent combinations of car segments is “medium and large” (1554 occurrences in the sample), while the least frequent combination is “mini and luxury/sport” (38 occurrences in the sample).

	Mini	Small	Medium	Large	Premium	Luxury/sport
Mini		815	312	184	66	38
Small	815		1216	208	110	98
Medium	312	1216		1554	240	158
Large	184	208	1554		570	132
Premium	66	110	240	570		220
Luxury/sport	38	98	158	132	220	

Table 10: Overview of car segment combinations presented in the stated choice experiment.

7. Method

7.1 Choice theory

In order to model individual choices and estimate user preferences, we apply models based on random utility maximization, i.e. each individual is assumed to have a random utility function for each alternative, and individuals are assumed to choose the alternative with the highest utility.

The utility for individual n, alternative i, and choice task t is given by:

$$U_{nti} = V_{nti} + \eta_{ni} + \varepsilon_{nti}$$

where V_{nti} is the systematic part of the utility, η_{ni} is a normally distributed error terms that account for panel effects for observations from the same respondents as well as unobserved heterogeneity among alternatives, and ε_{nti} are IID extreme value type 1 error terms. This model is known as a mixed logit (ML) model. Following Train (2009), the choice probability that individual n chooses alternatives $i = (i_1, \dots, i_t, \dots i_T)$ over t choice tasks is given by:

$$P_{ni} = \int \prod_{t=1}^{T} \frac{\exp(V_{nti} + \eta_{ni})}{\sum_{j=1}^{J} \exp(V_{ntj} + \eta_{nj})} f(\eta) d\eta$$

The model is estimated by maximising the simulated likelihood based on the function:

$$LL = \sum_{n=1}^{N} \sum_{i=1}^{I} \ln({P_{ni}}^{y_{ni}})$$

where P_{ni} is approximated by simulation, $y_{in} = (y_{in1}, \dots, y_{inT})$ and $y_{in} = 1$ if alternative i, i.e. the series of alternatives in i, is chosen by individual n, 0 otherwise.

7.2 Utility specification

In the following, we specify the functional utility form for the choice model.

The full set of alternatives will consist of all combinations of three fuel types and six car segments. Therefore the model considers 18 alternatives as depicted in Figure 7.1. Note that the figure organizes fuel type at an upper level and segment at the lower level. This is only chosen to give an overview and does not necessarily represent the choice structures captured later in the final model.

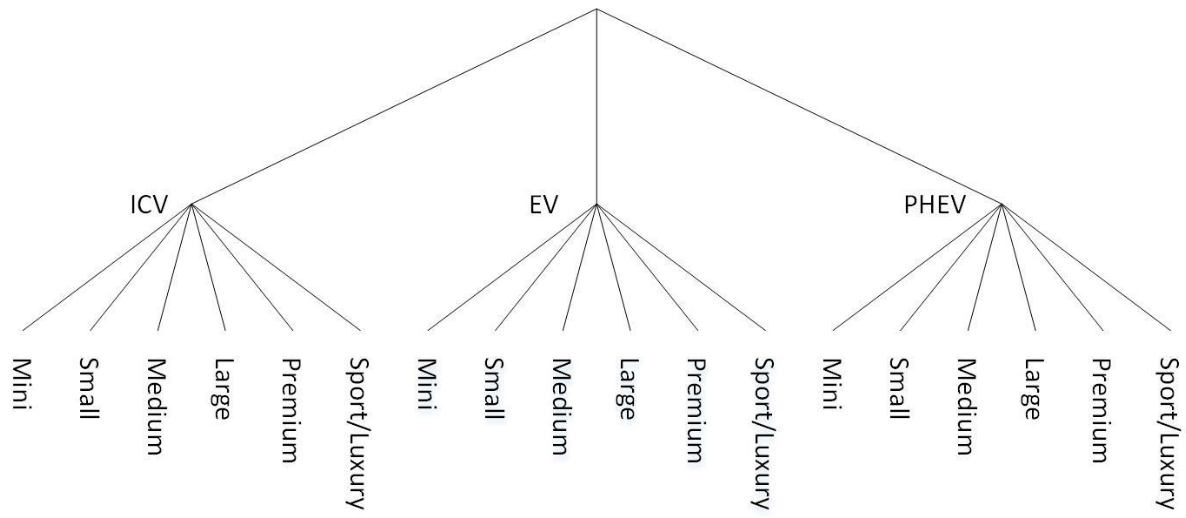


Figure 7.1: Choice structure for type and segment.

The basic utility function varies between different car types, e.g. BEV charging facilities are included for BEV, but not in ICV. Within car types, all car segments follow the same generic utility function. The utility functions for individual *n*, car type *i*={ICV, BEV, PHEV}, car segment *j*={mini, lille, mellem, stor, premium, luxury} in choice task *t* are defined as:

$$
\begin{aligned}
U_{nijt} \; &= ASC_i + \eta_{ni} && + ASC_j + \eta_{nj} && \\
&+\beta^{PurchaseCost} && * PurchaseCost_{nijt} && \\
&+\beta^{YearlyCost} && * YearlyCost_{nijt} && \\
&+\beta^{OperationCost} && * OperationCost_{nijt} && \\
&+\beta^{Acceleration} && * Acceleration_{nijt} && \text{ICV, BEV, \& PHEV} \\
&+\beta_i^{BootSize,Medium} && * BootSize, Medium_{nijt} && \\
&+\beta_i^{BootSize,Large} && * BootSize, Large_{nijt} && \\
&+\beta_i^{BootSize,VeryLarge} && * BootSize, VeryLarge_{nijt} && \\
&+\beta^{CO2} && * CO2_{nijt} && \\
&+\beta_{BEV}^{Range} && * Range_{nijt} * BEV\_Dummy_{\,nijt} && \text{BEV \& PHEV} \\
&+\beta_{PHEV}^{\ln(Range)} && * \ln(Range_{nijt}) * PHEV\_Dummy_{\,nijt} && \\
&+\beta_i^{HomeDistNearestCharger} && * HomeDistNearestCharger_{nijt} * (1 - ICV\_Dummy_{\,nijt}) && \\
&+\beta_i^{HomeChargeAvailability} && * HomeChargerAvailability_{\,nijt} * (1 - ICV\_Dummy_{\,nijt}) && \\
&+\beta_i^{PrHomeChDummy} && * PrHomeChDummy_{\,n} && \text{BEV} \\
&+\beta^{PublicChargingInfrastructure} && * PublicChargingInfrastructure_{nijt} * && \\
& && Range\_Dummy_{\,nijt} * BEV\_Dummy_{\,nijt} && \\
&+\beta^{PublicChargingSpeed} && * PublicChargingSpeed_{nijt} * BEV\_Dummy_{\,nijt} &&
\end{aligned}
$$

Where

- ASC_i and ASC_j are alternative specific constants for car type and segment respectively.
- η_{ni} and η_{nj} are normally distributed error components that captures correlation across repeated observations from the same respondent (panel effect) as well as correlation across car types and segments (substitution effects). σ_{ii} and σ_{jj} are the corresponding

parameters to be estimated. Note that each alternative include error components for all car types and segments (although several are normalized for theoretical identification).

- BEV_Dummy_{nijt} and $PHEV\_Dummy_{nijt}$ are dummy-indicators that are 1 if i=BEV and i=PHEV respectively, 0 otherwise.
- $PrHomeChDummy$ is a dummy-indicator which is 1 if respondents was presented with the “house” design, 0 otherwise. Thus dummy-indicator reflects if respondents have a private charger at home (or has the possibility to install one).
- $Range\_Dummy$ is a dummy-indicator which is 1 if the driving range <=200, 0 otherwise
- $HomeChargeAvailability$ is indicates how many times out of 4 the nearest (public) home charger is available when needed. In the model values 1,2,3, and 4 are used which correspond to a 25%, 50%, 75%, and 100% probability of the charger being available

The specification is advanced in the sense that is allows for panel correlation and unobserved correlation among alternatives. Some other considerations have been

- Cost should be generic across alternatives as specific cost coefficients would break the link to utility theory
- We do not allow for systematic heterogeneity, which would be possible. The only socio-economic characteristics included is the access to home charging.
- We have tested various non-linearities similar to Mabit and Fosgerau (2011) and Ziegler (2012).

8. Results and validation

8.1 Model estimation

This section presents results for the final ML model as specified in Section 7.2. Estimation results are presented in Table 11 and Table 12. The model contains 51 estimated parameters based on 23,674 observations from 2,961 respondents. To reduce the dimensionality of the model, we decompose the alternative specific constants into type and segment specific constants (using *ICV* and *Stor* as reference).

The model captures linear effects from the cost, car characteristics, and charging infrastructure attributes. It is seen that all parameters have the expected signs and are significant at a 1% level (p<0.01).

In the work with the utility specification more advanced utility functions including non-linear effects and interaction effects has been explored, especially for the interaction between charging infrastructure and driving range. E.g. in the initial model estimated, the distance between fast charging stations was not significant at a 1% level (p<0.01). This was likely due to an average effect of the battery size, where BEV owners with large batteries are less concerned about the infrastructure, while it might be more important for owners of smaller BEVs. Thus, in the final model, this attribute was only estimated for BEVs with a range of 200 km or below.

Model summary	
Number of estimated parameters:	51
Sample size:	2961
Observations:	23674
Final log likelihood:	-22576.33
Akaike Information Criterion:	45254.66
Bayesian Information Criterion:	45560.32
Final gradient norm:	5.0452E-02
Number of draws:	1000
Algorithm:	CFSQP
Number of iterations:	107
Optimization time:	2 days, 1:12:28.970827

Table 11: Model summary

Name	Unit	Value	Rob. Std err	Rob. t-test	Rob. p-value
Alternative Specific Constants					
ASC_BEV		-3.4382	0.1929	-17.8277	0.0000
ASC_PHEV		-2.3677	0.2564	-9.2327	0.0000
ASC_MINI		1.2000	0.3500	3.4283	0.0006
ASC_LIL		0.1143	0.2349	0.4867	0.6264
ASC_MEL		1.0741	0.1384	7.7630	0.0000
ASC_PREM		-0.3717	0.1863	-1.9954	0.0460
ASC_LUK		-0.5671	0.4379	-1.2950	0.1953
Cost Attributes					
B_PurchaseCost	1/DKK	-6.8740E-06	0.0407	-16.8829	0.0000
B_YearlyCost	1/(DKK/year)	-1.2310E-04	0.0184	-6.7014	0.0000
B_OperationCost	1/(DKK/km)	-0.5928	0.1021	-5.8059	0.0000
Car Characteristics					
B_Range_BEV	1/km	0.0031	0.0002	15.3159	0.0000
B_Range_PHEV	1/km	0.3045	0.0526	5.7923	0.0000
B_Acceleration	1/(sec. to 100 km/t)	-0.0311	0.0054	-5.8132	0.0000
B_Size_MegetStor		0.5412	0.1062	5.0975	0.0000
B_Size_Mellem		0.2465	0.0768	3.2090	0.0013
B_Size_Stor		0.3438	0.1053	3.2666	0.0011
B_CO2	1/(g/km)	-0.0032	0.0005	-6.0410	0.0000
Charging Infrastructure					
B_HomeDistNear	1/m	-0.000473	0.0175	-2.7079	0.0068
B_HomeChAv	1/(out of 4)	0.3469	0.0337	10.2912	0.0000
B_HomeCharDum_BEV		1.8806	0.1939	9.6979	0.0000
B_HomeCharDum_PHEV		1.5600	0.1984	7.8622	0.0000
B_ChInfra	1/km	-0.0022	0.0712	-3.1564	0.0016
B_ChSpeed	1/(km/10 min)	0.0042	0.0005	9.0800	0.0000
Choleski factors					
Sigma_BEV_BEV		3.9704	0.1088	36.4768	0.0000
Sigma_PHEV_BEV		2.4414	0.1232	19.8156	0.0000
Sigma_PHEV_PHEV		2.8902	0.0990	29.1975	0.0000
Sigma_MINI_BEV		0.4396	0.3731	1.1784	0.2386
Sigma_MINI_PHEV		-1.0758	0.2298	-4.6807	0.0000
Sigma_MINI_MINI		8.3261	0.5133	16.2222	0.0000
Sigma_MINI_PREM		-3.3518	0.3939	-8.5089	0.0000
Sigma_MINI_LUK		2.3327	0.2738	8.5184	0.0000
Sigma_LIL_BEV		-0.1728	0.3388	-0.5099	0.6101
Sigma_LIL_PHEV		-0.6592	0.2442	-2.6990	0.0070
Sigma_LIL_MINI		5.4140	0.3202	16.9092	0.0000
Sigma_LIL_LIL		2.2521	0.4092	5.5034	0.0000
Sigma_LIL_PREM		-2.8264	0.5190	-5.4455	0.0000
Sigma_LIL_LUK		1.4465	0.3679	3.9324	0.0001
Sigma_MEL_BEV		-0.0125	0.1344	-0.0931	0.9258
Sigma_MEL_PHEV		-0.1105	0.1065	-1.0376	0.2995
Sigma_MEL_MINI		2.3869	0.2606	9.1579	0.0000
Sigma_MEL_LIL		1.2921	0.4217	3.0636	0.0022
Sigma_MEL_MEL		-0.3016	0.2474	-1.2194	0.2227
Sigma_MEL_PREM		-0.6065	0.2299	-2.6385	0.0083
Sigma_MEL_LUK		0.6190	0.3313	1.8685	0.0617
Sigma_PREM_BEV		-0.0847	0.1968	-0.4305	0.6668
Sigma_PREM_PHEV		-0.0485	0.2069	-0.2344	0.8146
Sigma_PREM_PREM		2.5605	0.1952	13.1173	0.0000
Sigma_LUK_BEV		-0.2397	0.5443	-0.4404	0.6596
Sigma_LUK_PHEV		0.2396	0.2950	0.8122	0.4167
Sigma_LUK_PREM		-2.4593	0.4869	-5.0507	0.0000
Sigma_LUK_LUK		4.9098	1.0589	4.6367	0.0000

Table 12: Estimation results based on a mixed logit model with error components and linear attribute effects.

The specification for driving range is obtained from several tests with both generic and alternative specifications across BEV and PHEV. As such, a technology generic specification would be preferable, but since driving range has rather different meaning for the two alternatives, it makes sense to keep them alternative specific. Indeed, for BEV, the user is highly dependent on the provided driving range on electricity, while for the PHEV user, it is possible to continue on the driving range provided by the fossil fuel engine. As seen in Figure 8.1, the best specification was obtained with a ln specification for PHEV while a linear specification was obtained for BEV.

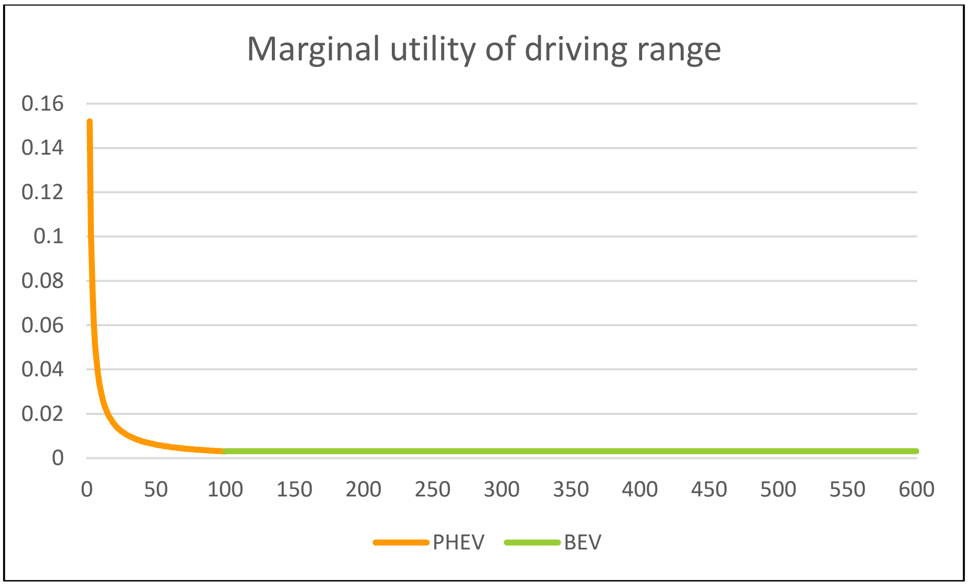


Figure 8.1: Marginal utility of driving range.

Note that the model includes several coefficients for error components (In the table named “Sigma”). The parameters are estimated on the base of normally distributed error terms. The naming convention indicates to which utility function the parameters belong as well as which normal distribution it is based on. The name convention has the following structure: Sigma_X_Y. This indicates that the parameter is included in the utility function of X, where it is multiplied to the draws belong to the normal distribution Y. The coefficients correspond to the Choleski factor of the Variance-Covariance matrix among the error components.

8.2 Variance-Covariance Matrix (substitution effects)

In order to interpret the substitution effects related to the Sigma-parameters, we compute the associated Variance-covariance matrix and the corresponding correlation matrix, see Table 13 and Table 14, based on Choleski factors. The following can be noted:

- BEV and PHEV have a positive substitution compared to ICV.
- BEV and MINI have a positive substitution compared to ICV STOR.
- PREM have a negative substitution with respect to MINI, LIL, MEL, and LUK compared to STOR. The latter is somewhat surprising.
- The substitution between MINI, LIL, and MEL is high.

Var-Covar	BEV	PHEV	PREM	LUK	MINI	LIL	MEL
BEV	15.761	9.687	-0.336	-0.953	1.747	-0.687	-0.050
PHEV	9.687	14.306	-0.347	0.108	-2.048	-2.327	-0.351
PREM	-0.336	-0.347	6.563	-6.289	-8.561	-7.198	-1.545
LUK	-0.953	0.108	-6.289	30.275	19.317	13.965	4.506
MINI	1.747	-2.048	-8.561	19.317	87.400	58.560	23.495
LIL	-0.687	-2.327	-7.198	13.965	58.560	44.906	18.520
MEL	-0.050	-0.351	-1.545	4.506	23.495	18.520	8.230

Table 13: Variance-Covariance-matrix. Positive substitution pattern (with respect to “Stor ICV”) marked in blue, while negative substitution is marked in red.

Correlation	BEV	PHEV	PREM	LUK	MINI	LIL	MEL
BEV	1	0.645	-0.033	-0.044	0.047	-0.026	-0.004
PHEV	0.645	1	-0.036	0.005	-0.058	-0.092	-0.032
PREM	-0.033	-0.036	1	-0.446	-0.357	-0.419	-0.210
LUK	-0.044	0.005	-0.446	1	0.376	0.379	0.285
MINI	0.047	-0.058	-0.357	0.376	1	0.935	0.876
LIL	-0.026	-0.092	-0.419	0.379	0.935	1	0.963
MEL	-0.004	-0.032	-0.210	0.285	0.876	0.963	1

Table 14: Correlation-matrix. Positive substitution pattern (with respect to “Stor ICV”) marked in blue, while negative substitution is marked in red.

8.3 Predicted market shares

The model is also validated by calculating the average predicted market shares which is presented in Table 15. As seen they correspond very well with the sample shares presented earlier in Table 9. However, the sample shares in a choice experiment do not necessarily correspond to real market situation, which is also clear in the current study. Thus, a calibration is needed.Table 15: Predicted market shares from the model.

	MINI	LIL	MEL	STOR	PREM	LUK	Total
ICV	7.24%	9.13%	15.95%	6.46%	3.29%	0.66%	42.72%
BEV	5.10%	6.74%	16.92%	9.00%	3.07%	0.70%	41.52%
PHEV	2.53%	3.01%	6.54%	2.60%	0.79%	0.29%	15.76%
Total	14.86%	18.88%	39.41%	18.06%	7.14%	1.65%	100.00%

Table 15: Predicted market shares from the model.

8.4 Willingness to pay

We derive willingness-to-pay (WTP) measures for the various attributes as the trade-off between the marginal utility of each attribute and the marginal utility of money related to purchase price. For a few attributes this depends on the attribute. In that case we calculate the value for each individual in the sample and average the values. The resulting WTPs are presented in Table 16.

			90% confidence interval	
WTP	**Unit**	**Mean**	**Lower bound**	**Upper bound**
Yearly Cost	[DKK/(DKK/year)]	17.91	13.66	23.94
Operation Cost	[DKK/(DKK/KM)]	86,235.38	56,291.73	119,999.69
Range: BEV	[DKK/KM]	457.20	399.26	539.65
Range: PHEV (all segments)	[DKK/KM]	1,066.10	699.55	1,394.05
Acceleration	[DKK/sec.]	4,531.05	2,545.28	5,955.25
Boot Size: Mellem	[DKK/(size min)]	35,862.60	32,418.79	40,640.94
Boot Size: Stor	[DKK/(size min)]	50,016.77	45,213.77	56,681.01
Boot Size: Meget Stor	[DKK/(size min)]	78,738.03	71,176.99	89,229.10
CO2	[DKK/(g/KM)]	460.77	302.71	588.43
Home Distance Nearest Charger: (BEV + PHEV)	[DKK/m]	68.77	23.89	126.20
Home Charging Availability: (BEV + PHEV)	[DKK]	50,461.16	40,431.74	60,969.26
Charging Infrastructure (BEV)	[DKK/KM]	226.10	62.69	370.39
Charging Speed (BEV)	[DKK/(KM/10 min)]	612.58	478.82	788.84

Table 16: WTP measures for attributes with respect to purchase price.

The WTP measures in Table 16 all have the expected signs.

- There are two WTP measures related to range. The results show that WTP for extending a PHEV range by 1 km is higher than the WTP for BEV range. We have implicitly assumed that the WTP for ICVs is equal to zero. A previous Danish study (Mabit and Fosgerau 2011) estimated an average WTP of 105 DKK/km for a generic log specification evaluated at 685 km. While this was a slightly different sample collected in 2007-08, the figures are comparable.
- Concerning, acceleration the results also agree with the previous study where WTP for acceleration was found to be 4531 DKK/SEC.
- Yearly cost is evaluated higher in the present study at 17.9 DKK/(DKK/year). The earlier study Mabit and Fosgerau (2011) estimated a value of 4 DKK/(DKK/year). However, the yearly cost variable in the previous study also included operating costs (recalculated to yearly cost) based on individual driving expectations, which could partly explain the difference. However, when compared with Greene (2010), the value of 17.9 DKK/(DKK/Year) is considered high.
- The WTP for operating costs at 86,235 DKK/(DKK/km) indicates that a person that does not depreciate future expenditures is willing to pay 86,235 DKK for a saving of 1 DKK/km. This means that the person has a break-even point at 86,235 km. This is

lower than previous RP studies base on Danish data (Arnberg et al. 2008) who estimate 317,000 km as break-even point, and Mabit (2014) who estimate a value of 308,000 to 436,000 km). However, as both of these studies are based on respondents who only buy new cars, it makes sense that they are somewhat higher. It may also likely depend on the fuel price at the time of collecting the study. Today, the fuel price has been low for several years and expectations might be that this continues.

- The WTP for CO2 indicates that a person driving 15,000 km per year for 10 years in the same car has a WTP of 69.2 DKK per ton CO2 (as 461*0.15=71).
- On average, the respondents are willing to pay resp. DKK 35,863, 50,017 and 78,738 for a boot size of medium, large and very large compared to a small boot.
- For BEVs with a driving range of 200km or less, the respondents are willing to pay 226 DKK for each reduced km between fast chargers at the main road network.
- Charging speed is evaluated at 613 DKK for reach extra km obtained from 10 minutes of charging.

8.5 Elasticities

To further validate the model we compute elasticities for selected key attributes. An elasticity is a measure of model sensitivity to changes in attributes. More specifically, the elasticity measures the percentage change in demand as a percentage change in and attribute, and can be calculated (approximately) as:

$$E_{x_{ij}}^{nij} = \frac{\left(P_{nij}^{new} - P_{nij}^{old}\right)/P_{nij}^{old}}{\left(x_{nij}^{new} - x_{nij}^{old}\right)/x_{nij}^{old}}$$

We simulate elasticities by increasing attribute x by 10%, and calculate elasticities as:

$$E_{x_{ij}}^{nij} = \frac{\left(P_{nij}^{new} - P_{nij}^{old}\right)/P_{nij}^{old}}{(110\% - 100\%)/100\%} = \frac{P_{nij}^{new} - P_{nij}^{old}}{P_{nij}^{old}} * 10$$

In the following we present elasticities for purchase price and driving range. We present the full 18x18 matrix containing all alternative as well as some aggregated matrices containing demand elasticities for car type ($E_{x_i}^{i}$) and car segments ($E_{x_j}^{j}$). This is to ease interpretation and to make it more straightforward to comparison with existing literature (as few studies captures substitution between both car types and segments). Table 23 (in the Appendix B) presents the full elasticities for all alternatives, while Table 17 presents the aggregated elasticities for car types and Table 18 presents the aggregated elasticities for car segments.

Attribute	Elast: ICV	Elast: BEV	Elast: PHEV
Purchaseprice: ICV	-0.519	0.264	0.290
Purchaseprice: BEV	0.264	-0.594	0.352
Purchaseprice: PHEV	0.265	0.322	-0.673
Range: ICV	N/A	N/A	N/A
Range: BEV	-0.149	0.325	-0.194
Range: PHEV	-0.039	-0.048	0.093

Table 17: Direct and cross elasticities for car types

Attribute	Elast: MINI	Elast: LIL	Elast: MEL	Elast: STOR	Elast: PREM	Elast: LUK
Purchaseprice: MINI	**-0.022**	0.027	0.005	0.003	0.001	0.001
Purchaseprice: LIL	0.025	**-0.104**	0.043	0.006	0.003	0.005
Purchaseprice: MEL	0.01	0.077	**-0.139**	0.189	0.025	0.018
Purchaseprice: STOR	0.006	0.009	0.088	**-0.349**	0.113	0.019
Purchaseprice: PREM	0.002	0.005	0.011	0.053	**-0.221**	0.027
Purchaseprice: LUK	0.001	0.004	0.004	0.007	0.017	**-0.207**
Range: MINI	**0.006**	-0.007	-0.002	-0.001	0	0
Range: LIL	-0.007	**0.031**	-0.013	-0.002	-0.001	-0.002
Range: MEL	-0.003	-0.022	**0.038**	-0.053	-0.007	-0.005
Range: STOR	-0.001	-0.002	-0.02	**0.074**	-0.022	-0.004
Range: PREM	0	-0.001	-0.002	-0.008	**0.032**	-0.004
Range: LUK	0	0	0	0	-0.001	**0.016**

Table 18: Direct and cross elasticities for car segments

The elasticities all seems plausible and have expected signs. When looking at the elasticities across fuel types we see that the own price elasticities are of similar size. We also note that BEVs have more substitution to PHEVs than ICVs, and that the opposite is also true, i.e. PHEVs have more substitution to BEVs than ICVs. Concerning the range elasticities across fuel types, the own range elasticity is much higher for BEVs than for PHEVs, which make sense as BEVs are more dependent on range.

Concerning elasticities split on segments, we see that own price elasticities vary partly due to market shares but also that large cars seem to be most sensitive to own price. It is also apparent that neighbouring segments have higher cross price elasticities as would be expected. The range elasticities are numerically much smaller, which highlight that while range is important to vehicle choices its overall influence on vehicle choice is much lower than the effect of purchase price. Again the pattern that neighbouring segments are most affected by changes in a specific segment appears in the results.

It is generally difficult to compare with literature as there exist very few studies with a similar setup. Most SP studies focus on vehicle choice conditional on segment, e.g. Mabit (2011), Fjendbo et al. (2013). Exceptions to this are Hess et al. (2012) but they do not present any elasticity calculations.

There are several things to note about the elasticities. First, they are calculated on the choice sets incorporated in the SP data. This means that substitution is not only affected by the final model but also by the two car segments that each respondent considered. Therefore the elasticities might change when applied in a context with a full choice set. Given that the elasticities will be affect irrespective of this when applied in another context with different attribute levels and market shares we have decided to present the elasticities in the SP context only. Second, the overall scale of the error term in a discrete choice model is never separately identified. This means that the overall scale of the elasticities is dependent on the hypothetical nature of the SP, which may not reflect how the scale would have been in a RP setting. So in principle we have only found the relative sizes of elasticities, i.e. the patterns identified above are valid, whereas they might need an common scaling to adjust the model to the real world.

It would be possible to settle this scaling issue if we had earlier studies based on RP data that presented elasticities. The main problem is that only few studies present elasticities and that these elasticities depend on the definition of choice alternative. An example is Cambridge Econometrics (2008) who establish elasticities that are numerically much larger than ours. This is natural and cannot be used for scaling as their analysis is based on much more disaggregated vehicle types, which again lead to higher elasticities.

9. Conclusion

This report document work that relates to data collection and model estimation for the ELISA project. The overall goal for ELISA is to support the development of a model that can predict market shares for conventional as well as electric and plug-in hybrids in future scenarios.

A specific aim has been to update the data foundation to facilitate the estimation of such model and predict vehicle demand by fuel type across segments. The report includes the estimation of this model and present the relevant parameters.

A stated choice experiment that use an efficient design and include a series of relevant attributes describing battery electric cars, plug-in hybrid cars as well as conventional gasoline and diesel cars was developed. The experiment was distributed to a random sample of 26,704 respondents of which 2961 answered. This resulted in a total of 23,674 choice task observations.

In order for the respondent to be able to relate to the presented scenarios and make the stated choice experiment as realistic as possible, the design was customized to respondents. Such customization included that the most likely future car purchase (as asked about) is used as a mean to pivot the design with respect to this reference value. Hence, the SP introduce relative changes with respect to the reference value. As changes in levels for attributes for specific car types or segments can result in substitution effects between car types or segments, the two (out of six in total) most relevant car segments for each respondent were included in the experiment. Based on an extensive literature review, the developed experiment included attributes specifically relevant for BEV and PHEV, such as driving specific attributes, pollution and charging. The survey took into account that not all respondents have access to charging at a dedicated parking spot when parked at home (e.g. respondents living in apartments) and that not all attributes are relevant for all car types included in the experiment (e.g. BEV charging infrastructure is not relevant for conventional gasoline and diesel cars).

A final model has been estimated while DTU and ENS have had an ongoing correspondence about the further development of the specification and the implementation of the forecasting model. The final model is a mixed logit model that for each individual assigns probabilities to each of the 18 alternatives. Consumers are on average willing to pay 1066 DKK per extra km of driving range for a PHEV and 457 DKK/km for a BEV.. The preference for driving range for PHEV was found to be non-linearwhereas the preference for driving range for BEV was found to be linear. The model furthermore indicate a significant effect for other car performance attributes such as acceleration, carbon emissions and boot-size.

Finally, plausible results are obtained for the charging infrastructure. A consumer would pay 613 DKK for each extra km obtained from 10 minutes of charging. Despite several tests, it was not possible to find a non-linear specification that explains behavior with regard to charging speed better. When charging at home for a respondent that does not have a private parking spot, the respondent would be willing to pay 69 DKK for each meter closer to home from the charging location and 50,000 DKK for each extra 25% of availability probability of this charging location. The model only indicated a significant effect of a more dense network of fast chargers for BEVs with a driving range of 200km or less. It might be because the maximum distance used in the experiment (120 km) is sufficiently low so that this is never really an issue for BEVs with high driving range above 200km.

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10. Appendix A

	SAMPLE		FINAL RESPONSE	
	26704		2961	
AGE	**count**	**Percent**	**count**	**percent**
18-20	1220	4.6%	62	2.1%
21-31	6425	24.1%	432	14.6%
32-35	1914	7.2%	171	5.8%
36-42	3077	11.5%	359	12.1%
43-54	5629	21.1%	793	26.8%
55-62	3095	11.6%	507	17.1%
63-78	4014	15.0%	583	19.7%
79+	1330	5.0%	54	1.8%
GENDER				
Male	13359	50.0%	1618	54.6%
Female	13345	50.0%	1343	45.4%
POSTAL CODE				
1000-2499	3275	12.3%	327	11.0%
2500-2999	4383	16.4%	518	17.5%
3000-3699	1566	5.9%	217	7.3%
3700-3799	137	0.5%	14	0.5%
4000-4999	3554	13.3%	390	13.2%
5000-5999	2229	8.3%	266	9.0%
6000-6999	2515	9.4%	259	8.7%
7000-7999	2262	8.5%	239	8.1%
8000-8999	4359	16.3%	478	16.1%
9000-9999	2424	9.1%	253	8.5%
HOME CHARGING UNIT				
Possible			1586	53.6%
Not Possible			1375	46.4%

Table 19: Sample characteristics compared against invitations.

11. Appendix B

		Purchase price [DKK]			Yearly cost [DKK/Year]			Fuel costs [DKK/km]			Range [km]			Acceleration [sec]			Boot size
	Levels	ICV	BEV	PHEV	ICV	BEV	PHEV	ICV	BEV	PHEV	ICV	BEV	PHEV	ICV	BEV	PHEV	ICV/BEV/PHEV
Mini	1	84,000	90,000	84,000	3,458	3,610	3,500	0.81	0.49	0.75	735	100	20	10	7	7	Small
	2	100,000	100,000	120,000	3,891	4,061	4,000	0.91	0.55	0.85	812	130	40	12	9	9	Small
	3	120,000	125,000	135,000	4,323	4,512	4,500	1.01	0.61	0.95	855	180	60	14	11	11	Small
	4	145,000	160,000	150,000	4,755	4,963	5,000	1.11	0.67	1.05	898	230	80	16	13	13	Small
Small	1	150,000	180,000	160,000	4,300	4,441	4,385	0.88	0.51	0.85	735	180	20	10	6	6	Small
	2	165,000	200,000	180,000	4,837	4,997	4,933	0.99	0.57	0.95	898	250	40	12	8	8	Small
	3	185,000	220,000	200,000	5,375	5,552	5,482	1.11	0.63	1.06	997	350	60	14	10	10	Medium
	4	200,000	240,000	220,000	5,912	6,107	6,030	1.22	0.70	1.16	1097	450	80	16	12	12	Medium
Medium	1	210,000	245,000	225,000	4,783	4,719	4,509	0.95	0.55	0.93	735	180	20	10	5	5	Medium
	2	250,000	260,000	250,000	5,381	5,309	5,072	1.07	0.62	1.04	898	300	40	12	7	7	Large
	3	287,500	275,000	287,500	5,978	5,899	5,636	1.19	0.68	1.16	997	450	60	14	9	9	Large
	4	325,000	300,000	325,000	6,576	6,489	6,200	1.30	0.75	1.27	1097	550	80	16	11	11	Extra Large
Large	1	350,000	310,000	350,000	7,267	7,104	6,692	1.00	0.56	0.99	735	250	25	8	5	5	Large
	2	430,000	350,000	430,000	8,175	7,992	7,529	1.12	0.63	1.11	898	350	50	10	7	7	Large
	3	470,000	450,000	502,500	9,083	8,881	8,366	1.25	0.70	1.23	997	450	75	12	9	9	Extra Large
	4	500,000	500,000	575,000	9,992	9,769	9,202	1.37	0.77	1.36	1097	550	100	14	11	11	Extra Large
Premium	1	510,000	510,000	580,000	10,166	11,511	9,955	1.04	0.69	1.12	735	285	25	6	4	4	Extra Large
	2	550,000	540,000	650,000	11,437	12,950	11,199	1.17	0.77	1.26	898	350	50	8	6	6	Extra Large
	3	575,000	575,000	750,000	12,708	14,389	12,444	1.30	0.86	1.40	997	450	75	10	8	8	Extra Large
	4	600,000	700,000	800,000	13,979	15,827	13,688	1.43	0.94	1.54	1097	600	100	12	10	10	Extra Large
Luksus/Sport	1	1,000,000	1,000,000	1,000,000	10,114	11,511	9,955	1.40	0.72	1.30	735	285	25	6	3	3	Extra Large
	2	1,200,000	1,200,000	1,200,000	11,379	12,950	11,199	1.58	0.81	1.47	898	350	50	8	5	5	Extra Large
	3	1,400,000	1,400,000	1,400,000	12,643	14,389	12,444	1.76	0.90	1.63	997	450	75	10	7	7	Extra Large
	4	1,600,000	1,600,000	1,600,000	13,907	15,827	13,688	1.93	0.99	1.79	1097	600	100	12	10	10	Extra Large

Table 20: Examples of car models currently available for the different car types and segments

		Carbon emissions [g/km]			Distance to home charging [m]	Home charge availability [Available out of 4 times]	Dist. between fast chargers [km]	Max charging speed [km/10min]
	Levels	BEV	ICV	PHEV	BEV/PHEV	BEV/PHEV	BEV	BEV
Mini	1	0	70	70	50	1	30	35
	2	13	100	100	300	2	60	75
	3	25	115	115	450	3	90	100
	4	50	130	130	600	4	120	150
Small	1	0	84	77	50	1	30	35
	2	15	120	110	300	2	60	75
	3	30	138	127	450	3	90	100
	4	60	156	143	600	4	120	150
Medium	1	0	91	84	50	1	30	35
	2	17	130	120	300	2	60	75
	3	33	150	138	450	3	90	100
	4	65	169	156	600	4	120	150
Large	1	0	98	91	50	1	30	60
	2	18	140	130	300	2	60	85
	3	35	161	150	450	3	90	125
	4	70	182	169	600	4	120	160
Premium	1	0	98	91	50	1	30	60
	2	18	140	130	300	2	60	85
	3	35	161	150	450	3	90	125
	4	70	182	169	600	4	120	160
Luksus/Sport	1	0	98	91	50	1	30	60
	2	18	140	130	300	2	60	85
	3	35	161	150	450	3	90	125
	4	70	182	169	600	4	120	160

Table 21: Level values for each combination of car type and segment.

variable	min	mean	max	std
Purchaseprice_BEV_MINI	90000	118686.4	160000	26966.76
Purchaseprice_ICV_MINI	84000	112456.71	145000	22880.58
Purchaseprice_PHEV_MINI	84000	122497.9	150000	24233.1
Purchaseprice_BEV_LIL	180000	209705.64	240000	22281.12
Purchaseprice_ICV_LIL	150000	174925.9	200000	19072.65
Purchaseprice_PHEV_LIL	160000	189468.52	220000	22447.91
Purchaseprice_BEV_MEL	245000	270020.49	300000	20396.12
Purchaseprice_ICV_MEL	210000	268014.02	325000	42802.79
Purchaseprice_PHEV_MEL	225000	272062.42	325000	37981.19
Purchaseprice_BEV_STOR	310000	403222.18	500000	75918.06
Purchaseprice_ICV_STOR	350000	437043.26	500000	56117.88
Purchaseprice_PHEV_STOR	350000	465761.4	575000	83617.3
Purchaseprice_BEV_PREM	510000	580497.51	700000	72022.71
Purchaseprice_ICV_PREM	510000	558817.37	600000	32862.05
Purchaseprice_PHEV_PREM	580000	690854.06	800000	85938.93
Purchaseprice_BEV_LUK	1000000	1299690	1600000	223442
Purchaseprice_ICV_LUK	1000000	1297600.6	1600000	223290.7
Purchaseprice_PHEV_LUK	1000000	1304644	1600000	221836.8
Operationcost_BEV_MINI	0.49	0.58	0.67	0.07
Operationcost_ICV_MINI	0.81	0.96	1.11	0.11
Operationcost_PHEV_MINI	0.75	0.90	1.05	0.11
Operationcost_BEV_LIL	0.51	0.60	0.70	0.07
Operationcost_ICV_LIL	0.88	1.05	1.22	0.13
Operationcost_PHEV_LIL	0.85	1.01	1.16	0.12
Operationcost_BEV_MEL	0.55	0.65	0.75	0.07
Operationcost_ICV_MEL	0.95	1.13	1.30	0.13
Operationcost_PHEV_MEL	0.93	1.10	1.27	0.13
Operationcost_BEV_STOR	0.56	0.67	0.77	0.08
Operationcost_ICV_STOR	1.00	1.19	1.37	0.14
Operationcost_PHEV_STOR	0.99	1.17	1.36	0.14
Operationcost_BEV_PREM	0.69	0.81	0.94	0.09
Operationcost_ICV_PREM	1.04	1.24	1.43	0.15
Operationcost_PHEV_PREM	1.12	1.33	1.54	0.16
Operationcost_BEV_LUK	0.72	0.85	0.99	0.10
Operationcost_ICV_LUK	1.40	1.67	1.93	0.20
Operationcost_PHEV_LUK	1.30	1.55	1.79	0.18
Yearlycost__BEV_MINI	3610	4288	4963	501.3
Yearlycost__ICV_MINI	3458	4101	4755	482.6
Yearlycost__PHEV_MINI	3500	4232	5000	560.9
Yearlycost__BEV_LIL	4441	5277	6107	621.4
Yearlycost__ICV_LIL	4300	5097	5912	599.3
Yearlycost__PHEV_LIL	4385	5209	6030	615.8
Yearlycost__BEV_MEL	4719	5602	6489	660.0
Yearlycost__ICV_MEL	4783	5682	6576	668.4
Yearlycost__PHEV_MEL	4509	5354	6200	629.4
Yearlycost__BEV_STOR	7104	8436	9769	992.1
Yearlycost__ICV_STOR	7267	8631	9992	1015.6
Yearlycost__PHEV_STOR	6692	7927	9202	936.3
Yearlycost__BEV_PREM	11511	13668	15827	1611.3
Yearlycost__ICV_PREM	10166	12078	13979	1426.8
Yearlycost__PHEV_PREM	9955	11840	13688	1394.7
Yearlycost__BEV_LUK	11511	13626	15827	1625.1
Yearlycost__ICV_LUK	10114	11973	13907	1407.6
Yearlycost__PHEV_LUK	9955	11847	13688	1375.1
Range_BEV_MINI	100.0	160.2	230.0	49.6
Range_ICV_MINI	735.0	824.8	898.0	60.1
Range_PHEV_MINI	20.0	49.8	80.0	22.1
Range_BEV_LIL	180.0	305.0	450.0	101.9
Range_ICV_LIL	735.0	931.9	1097.0	133.2
Range_PHEV_LIL	20.0	50.1	80.0	22.0
Range_BEV_MEL	180.0	370.9	550.0	141.4
Range_ICV_MEL	735.0	931.3	1097.0	133.4
Range_PHEV_MEL	20.0	49.9	80.0	22.5

Range_BEV_STOR	250.0	400.6	550.0	112.6
Range_ICV_STOR	735.0	932.9	1097.0	133.9
Range_PHEV_STOR	25.0	62.0	100.0	27.9
Range_BEV_PREM	285.0	419.2	600.0	117.3
Range_ICV_PREM	735.0	930.1	1097.0	133.6
Range_PHEV_PREM	25.0	62.5	100.0	28.1
Range_BEV_LUK	285.0	422.7	600.0	119.0
Range_ICV_LUK	735.0	934.9	1097.0	134.6
Range_PHEV_LUK	25.0	64.0	100.0	28.7
Acceleration_BEV_MINI	7.0	10.0	13.0	2.2
Acceleration_ICV_MINI	10.0	13.0	16.0	2.3
Acceleration_PHEV_MINI	7.0	10.0	13.0	2.2
Acceleration_BEV_LIL	6.0	9.0	12.0	2.2
Acceleration_ICV_LIL	10.0	13.0	16.0	2.2
Acceleration_PHEV_LIL	6.0	9.0	12.0	2.2
Acceleration_BEV_MEL	5.0	8.0	11.0	2.2
Acceleration_ICV_MEL	10.0	13.0	16.0	2.2
Acceleration_PHEV_MEL	5.0	8.0	11.0	2.2
Acceleration_BEV_STOR	5.0	8.0	11.0	2.3
Acceleration_ICV_STOR	8.0	11.0	14.0	2.2
Acceleration_PHEV_STOR	5.0	8.0	11.0	2.2
Acceleration_BEV_PREM	4.0	7.0	10.0	2.2
Acceleration_ICV_PREM	6.0	9.1	12.0	2.2
Acceleration_PHEV_PREM	4.0	7.0	10.0	2.2
Acceleration_BEV_LUK	3.0	6.3	10.0	2.6
Acceleration_ICV_LUK	6.0	9.0	12.0	2.2
Acceleration_PHEV_LUK	3.0	6.2	10.0	2.6
CO2_BEV_MINI	0.0	22.4	50.0	18.6
CO2_ICV_MINI	70.0	103.9	130.0	21.9
CO2_PHEV_MINI	70.0	104.5	130.0	22.1
CO2_BEV_LIL	0.0	26.1	60.0	22.2
CO2_ICV_LIL	84.0	124.1	156.0	27.0
CO2_PHEV_LIL	77.0	114.4	143.0	24.5
CO2_BEV_MEL	0.0	28.7	65.0	24.0
CO2_ICV_MEL	91.0	135.6	169.0	28.8
CO2_PHEV_MEL	84.0	124.5	156.0	26.6
CO2_BEV_STOR	0.0	30.5	70.0	26.0
CO2_ICV_STOR	98.0	145.1	182.0	31.0
CO2_PHEV_STOR	91.0	134.5	169.0	29.1
CO2_BEV_PREM	0.0	30.5	70.0	25.7
CO2_ICV_PREM	98.0	145.1	182.0	31.0
CO2_PHEV_PREM	91.0	134.9	169.0	28.8
CO2_BEV_LUK	0.0	30.7	70.0	25.8
CO2_ICV_LUK	98.0	145.0	182.0	30.9
CO2_PHEV_LUK	91.0	134.2	169.0	28.6
Size_BEV_MINI	2.0	2.0	2.0	0.0
Size_ICV_MINI	2.0	2.0	2.0	0.0
Size_PHEV_MINI	2.0	2.0	2.0	0.0
Size_BEV_LIL	2.0	2.5	3.0	0.5
Size_ICV_LIL	2.0	2.5	3.0	0.5
Size_PHEV_LIL	2.0	2.5	3.0	0.5
Size_BEV_MEL	3.0	4.0	5.0	0.7
Size_ICV_MEL	3.0	4.0	5.0	0.7
Size_PHEV_MEL	3.0	4.0	5.0	0.7
Size_BEV_STOR	4.0	4.5	5.0	0.5
Size_ICV_STOR	4.0	4.5	5.0	0.5
Size_PHEV_STOR	4.0	4.5	5.0	0.5
Size_BEV_PREM	5.0	5.0	5.0	0.0
Size_ICV_PREM	5.0	5.0	5.0	0.0
Size_PHEV_PREM	5.0	5.0	5.0	0.0
Size_BEV_LUK	5.0	5.0	5.0	0.0
Size_ICV_LUK	5.0	5.0	5.0	0.0
Size_PHEV_LUK	5.0	5.0	5.0	0.0
Homechargeravailability_BEV_MINI	1	2.5	4	1.1

Homechargeravailability_PHEV_MINI	1	2.5	4	1.1
Homechargeravailability_BEV_LIL	1	2.5	4	1.1
Homechargeravailability_PHEV_LIL	1	2.5	4	1.1
Homechargeravailability_BEV_MEL	1	2.5	4	1.1
Homechargeravailability_PHEV_MEL	1	2.5	4	1.1
Homechargeravailability_BEV_STOR	1	2.5	4	1.1
Homechargeravailability_PHEV_STOR	1	2.5	4	1.1
Homechargeravailability_BEV_PREM	1	2.5	4	1.1
Homechargeravailability_PHEV_PREM	1	2.5	4	1.1
Homechargeravailability_BEV_LUK	1	2.5	4	1.1
Homechargeravailability_PHEV_LUK	1	2.5	4	1.1
Homedistnearestcharger_BEV_MINI	50	350.3	600	201.2
Homedistnearestcharger_PHEV_MINI	50	352.2	600	201.9
Homedistnearestcharger_BEV_LIL	50	350.9	600	201.8
Homedistnearestcharger_PHEV_LIL	50	350.8	600	202.8
Homedistnearestcharger_BEV_MEL	50	349.9	600	203.7
Homedistnearestcharger_PHEV_MEL	50	351.0	600	203.3
Homedistnearestcharger_BEV_STOR	50	347.7	600	205.7
Homedistnearestcharger_PHEV_STOR	50	352.0	600	202.8
Homedistnearestcharger_BEV_PREM	50	349.9	600	201.6
Homedistnearestcharger_PHEV_PREM	50	346.3	600	200.5
Homedistnearestcharger_BEV_LUK	50	348.4	600	204.2
Homedistnearestcharger_PHEV_LUK	50	342.9	600	206.2
Charginginfrastructure_BEV_MINI	30	74.8	120	33.5
Charginginfrastructure_BEV_LIL	30	74.7	120	33.5
Charginginfrastructure_BEV_MEL	30	75.1	120	33.5
Charginginfrastructure_BEV_STOR	30	75.5	120	33.4
Charginginfrastructure_BEV_PREM	30	75.0	120	33.8
Charginginfrastructure_BEV_LUK	30	74.4	120	33.8
Chargingspeed_BEV_MINI	35	89.3	150	41.9
Chargingspeed_BEV_LIL	35	90.4	150	41.5
Chargingspeed_BEV_MEL	35	90.0	150	41.8
Chargingspeed_BEV_STOR	60	107.9	160	38.2
Chargingspeed_BEV_PREM	60	108.0	160	38.1
Chargingspeed_BEV_LUK	60	107.6	160	38.2

Table 22: Average attribute values presented to the respondents

Attribute	elast: ICV MINI	elast: ICV LIL	elast: ICV MEL	elast: ICV STOR	elast: ICV PREM	elast: ICV LUK	elast: BEV MINI	elast: BEV LIL	elast: BEV MEL	elast: BEV STOR	elast: BEV PREM	elast: BEV LUK	elast: PHEV MINI	elast: PHEV LIL	elast: PHEV MEL	elast: PHEV STOR	elast: PHEV PREM	elast: PHEV LUK
Purchaseprice: ICV MINI	-0.062	0.020	0.004	0.002	0.001	0.001	0.026	0.005	0.001	0.001	0.000	0.000	0.026	0.004	0.001	0.000	0.000	0.000
Purchaseprice: ICV LIL	0.018	-0.188	0.033	0.005	0.002	0.004	0.003	0.064	0.007	0.001	0.000	0.001	0.004	0.067	0.006	0.001	0.000	0.000
Purchaseprice: ICV MEL	0.006	0.049	-0.398	0.142	0.017	0.016	0.001	0.009	0.120	0.025	0.003	0.003	0.001	0.011	0.130	0.026	0.003	0.002
Purchaseprice: ICV STOR	0.003	0.006	0.060	-0.649	0.072	0.015	0.000	0.001	0.010	0.108	0.012	0.003	0.001	0.001	0.012	0.126	0.013	0.001
Purchaseprice: ICV PREM	0.002	0.003	0.009	0.046	-0.329	0.022	0.000	0.001	0.002	0.008	0.085	0.004	0.000	0.001	0.002	0.010	0.099	0.003
Purchaseprice: ICV LUK	0.001	0.002	0.003	0.005	0.010	-0.423	0.000	0.000	0.000	0.001	0.002	0.087	0.000	0.000	0.001	0.001	0.002	0.058
Purchaseprice: BEV MINI	0.018	0.002	0.000	0.000	0.000	0.000	-0.080	0.018	0.003	0.002	0.001	0.001	0.024	0.003	0.000	0.000	0.000	0.000
Purchaseprice: BEV LIL	0.003	0.052	0.005	0.001	0.000	0.001	0.016	-0.279	0.030	0.004	0.002	0.004	0.004	0.069	0.006	0.001	0.000	0.000
Purchaseprice: BEV MEL	0.002	0.011	0.123	0.023	0.003	0.003	0.007	0.057	-0.425	0.126	0.017	0.014	0.002	0.016	0.159	0.029	0.004	0.002
Purchaseprice: BEV STOR	0.001	0.002	0.014	0.134	0.017	0.003	0.004	0.007	0.067	-0.563	0.081	0.015	0.002	0.002	0.019	0.172	0.022	0.002
Purchaseprice: BEV PREM	0.000	0.001	0.001	0.007	0.075	0.003	0.002	0.004	0.008	0.035	-0.377	0.020	0.001	0.001	0.002	0.009	0.112	0.003
Purchaseprice: BEV LUK	0.000	0.001	0.001	0.001	0.002	0.090	0.001	0.003	0.002	0.004	0.010	-0.435	0.000	0.001	0.001	0.001	0.003	0.071
Purchaseprice: PHEV MINI	0.024	0.004	0.001	0.000	0.000	0.000	0.033	0.007	0.001	0.001	0.000	0.000	-0.079	0.020	0.004	0.002	0.001	0.000
Purchaseprice: PHEV LIL	0.004	0.057	0.006	0.001	0.001	0.001	0.004	0.074	0.008	0.001	0.001	0.001	0.017	-0.244	0.027	0.005	0.002	0.002
Purchaseprice: PHEV MEL	0.001	0.010	0.132	0.027	0.004	0.003	0.001	0.011	0.159	0.033	0.005	0.004	0.007	0.056	-0.429	0.136	0.019	0.007
Purchaseprice: PHEV STOR	0.001	0.001	0.011	0.126	0.016	0.002	0.001	0.001	0.012	0.138	0.017	0.003	0.004	0.006	0.058	-0.720	0.087	0.006
Purchaseprice: PHEV PREM	0.000	0.000	0.001	0.005	0.062	0.002	0.000	0.000	0.001	0.006	0.078	0.003	0.001	0.003	0.006	0.031	-0.505	0.009
Purchaseprice: PHEV LUK	0.000	0.001	0.001	0.001	0.003	0.110	0.000	0.001	0.001	0.001	0.003	0.127	0.001	0.003	0.002	0.005	0.013	-0.223

Table 23: Direct and cross elasticities wrt. purchase price for car types and segments.

Attribute	elast: ICV MINI	elast: ICV LIL	elast: ICV MEL	elast: ICV STOR	elast: ICV PREM	elast: ICV LUK	elast: BEV MINI	elast: BEV LIL	elast: BEV MEL	elast: BEV STOR	elast: BEV PREM	elast: BEV LUK	elast: PHEV MINI	elast: PHEV LIL	elast: PHEV MEL	elast: PHEV STOR	elast: PHEV PREM	elast: PHEV LUK
Range: BEV MINI	-0.012	-0.001	0.000	0.000	0.000	0.000	0.049	-0.012	-0.002	-0.001	0.000	0.000	-0.016	-0.002	0.000	0.000	0.000	0.000
Range: BEV LIL	-0.003	-0.037	-0.004	-0.001	0.000	0.000	-0.012	0.188	-0.022	-0.003	-0.002	-0.003	-0.003	-0.049	-0.005	-0.001	0.000	0.000
Range: BEV MEL	-0.001	-0.008	-0.086	-0.017	-0.002	-0.002	-0.005	-0.039	0.265	-0.083	-0.012	-0.009	-0.002	-0.012	-0.109	-0.021	-0.003	-0.001
Range: BEV STOR	-0.001	-0.001	-0.008	-0.068	-0.009	-0.002	-0.002	-0.004	-0.035	0.264	-0.039	-0.007	-0.001	-0.001	-0.011	-0.087	-0.012	-0.001
Range: BEV PREM	0.000	0.000	-0.001	-0.003	-0.028	-0.001	-0.001	-0.001	-0.003	-0.013	0.135	-0.007	0.000	0.000	-0.001	-0.004	-0.041	-0.001
Range: BEV LUK	0.000	0.000	0.000	0.000	-0.001	-0.017	0.000	0.000	-0.001	-0.001	-0.002	0.080	0.000	0.000	0.000	0.000	-0.001	-0.012
Range: PHEV MINI	-0.008	-0.001	0.000	0.000	0.000	0.000	-0.011	-0.002	0.000	0.000	0.000	0.000	0.027	-0.007	-0.001	-0.001	0.000	0.000
Range: PHEV LIL	-0.001	-0.013	-0.001	0.000	0.000	0.000	-0.001	-0.017	-0.002	0.000	0.000	0.000	-0.004	0.055	-0.006	-0.001	-0.001	0.000
Range: PHEV MEL	0.000	-0.002	-0.021	-0.005	-0.001	-0.001	0.000	-0.002	-0.025	-0.005	-0.001	-0.001	-0.001	-0.009	0.068	-0.021	-0.003	-0.001
Range: PHEV STOR	0.000	0.000	-0.001	-0.013	-0.002	0.000	0.000	0.000	-0.001	-0.014	-0.002	0.000	0.000	-0.001	-0.006	0.069	-0.008	-0.001
Range: PHEV PREM	0.000	0.000	0.000	0.000	-0.004	0.000	0.000	0.000	0.000	0.000	-0.005	0.000	0.000	0.000	0.000	-0.002	0.035	-0.001
Range: PHEV LUK	0.000	0.000	0.000	0.000	0.000	-0.004	0.000	0.000	0.000	0.000	0.000	-0.004	0.000	0.000	0.000	0.000	0.000	0.009

Table 24: Direct and cross elasticities wrt. driving range for car types and segments.