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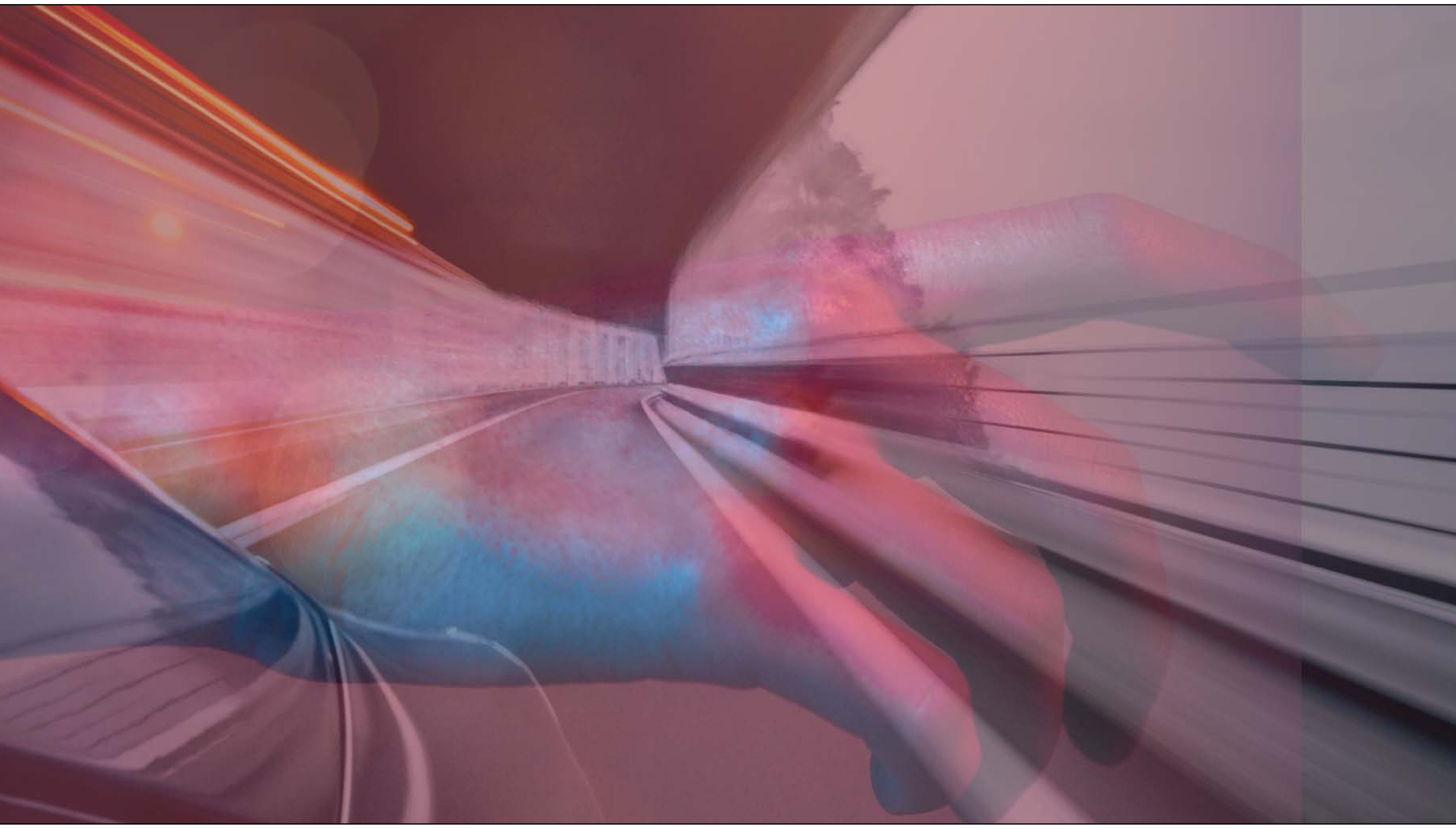

Enhance the user's experience for adoption of future cars

A research study with design guidelines to develop the UI and UX in electric vehicles

Lisa Lindqvist
Mathilda Sörvik

Master's Thesis in Industrial Design Engineering

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Abstract

The expansion of conventional vehicles (CVs) used around the world have come with serious consequences because of the combustion of fossil fuels. A promising solution is the electric vehicle (EV) which have zero emissions during use.

But, the EV is difficult for many people to understand. The user interfaces (UIs) in todays' EVs are not providing the information needed to help the user understand the technical aspects and functionality of the car, which results in a bad user experience (UX). Evidently designers have failed when trying to make a design understandable for the user, a UI that is informative enough and matches the mental models of the driver.

The main goal of this project was to increase the understanding of how the UI and UX should be designed for an EV, which was divided into four main parts. First, a basic insight of the technical aspects of the EV was necessary. The second part of the goal consisted of understanding what the new user behaviours are and the third part was to create knowledge about the desired total UX and how it could be enhanced. Lastly, the fourth part was to provide an understanding of what information in the UI that drivers need when using an EV. The information was gathered by conducting user studies of experienced drivers through interviews and an online survey, interviews with technical experts, a literature study of research that have been made within the area of EV and UX and/or UI and a benchmarking of popular EVs available at the market today.

The results of this project are requirements together with guidelines that forms a stable base on how to design the UI and enhance the experience of EVs. This is built upon findings of new user behaviours among experienced drivers, expressing the need of adoption to new ways of using the car, including more planning and different routines. A user journey was constructed and results show that depending on the maximum range of the EV, the car is used in different ways, what kind of trips that are made and how the range makes the driver feel. Furthermore, three user groups among EVs were found, each of them wants different information at different times. In the report, this is stated as driver specific information, regarding information such as energy usage and understanding of the battery level. Results regarding the overall wished experience are related to environmental reasons and the EV as representing the future. This is connected to what is appreciated when using the EV, such as the performance, silent nature and perceived high technology. The EV shall enhance a sense of freedom and the appreciated aspects shall permeate the UX and entail simplicity for the user.

The project was a master thesis written spring 2018 at Chalmers University of Technology and conducted in collaboration with the company CEVT (China Euro Vehicle Technology).

Preface

This master thesis was written spring 2018, a project covering 30 ECTS credits at Chalmers University of Technology, at the department of Design and Human Factors. The thesis was conducted in collaboration with the company CEVT (China Euro Vehicle Technology) at the department of Connected Car & UX.

The thesis was written by Lisa Lindqvist and Mathilda Sörvik, two students from the Industrial Design Engineering program at Chalmers. Lisa and Mathilda are both originally from outside Gothenburg, Sweden and started at the university in the year of 2012 with a dream to work with user-cantered design. Today they have a great passion for technology, design, and creative solutions for human needs and strive to develop unique and user friendly products affecting people's everyday lives.

EVs and UX felt as an interesting subject to choose since the automotive industry, at the time of writing, was developing in rapid speed with technology that makes it possible to create new user experiences for the driver. EVs is also a product which could help the environment to decrease CO2 emissions in the world and the sustainability aspect of the project was an important part for the writers.

Acknowledgement

We would like to give a big thank you to all employees at the department of Connected Car and UX at CEVT, for support, help and making us feel welcome. A special thank you is directed to Charlotta Roth, our supervisor at CEVT, who has supported us throughout our work, coming with valuable input and helping us in every way. Our work would not have been possible or half as fun without all of you!

Furthermore, we would also like to give a special thank you to Helena Strömberg, our supervisor at Chalmers, with her expertise within the area of electric vehicles, quick answers when help was needed and outstanding supervising skills.

Additionally, we are highly appreciating everyone that have given us of their time by participating in long interviews and answering the survey with both weird and tricky questions, thank you! Not to forget, thank you Sigma Industry West for welcoming us to your nice premises, giving us space to work, for showing interest in our project and for serving top notch coffee.

Lastly, our warmest gratitude's for family and friends, and each other, for support and understanding through all those years as students. Finally, leading to this last project of the master's programme at Chalmers University of Technology.

Gothenburg 2nd of July 2018,
Lisa Lindqvist and Mathilda Sörvik

Terminology

AC	Alternating Current
BEV	Battery Electric Vehicle
CEVT	China Euro Vehicle Technology
CO_2	Carbon Dioxide
CV	Conventional Vehicle
DC	Direct Current
DtE	Distance to Empty
EV	Electric Vehicle
HEV	Hybrid Electric Vehicle
HMI	Human-Machine Interface
HVAC	Heat Ventilation Air Condition system
HW	High Voltage
kWh	Kilowatt-hour
PHEV	Plug-in Hybrid Electric Vehicle
SoC	State of Charge
SoH	State of Health
SoP	State of Power
UI	User Interface
UX	User Experience

Table of Content

1. Introduction

This chapter is introduced by a background of the project, in order to motivate the study and form the basis of the aim and research questioned needed to be answered to fulfil the goal of the project. The collaboration company and target group is presented and demarcations will be stated.

1.1 Background

The following parts give insights in the background of the project and why the project was conducted.

1.1.1 Electric vehicles as a sustainable transportation

One of the greatest achievements of modern technology is the development of the conventional vehicle (CV) and its internal combustion engine. They have helped the modern society to grow by offering the possibility of mobility in everyday life. Today the use of CVs has expanded to an extreme level around the world and have put the planet and human life in a serious situation. Pollution, especially carbon dioxide (CO2) emissions, are a widespread problem all over the world and the combustion of fossil fuels are one of the factors contributing the most to problems as the global warming and the rapid depletion of the Earth's petroleum resources (Naturvårdsverket, 2017). In 2017, the transport sector was accountable for as much as 15% of the world's CO2 emissions (Centre for climate and energy solutions, 2017).

Global concerns about the need of decreasing CO2 emissions have evoke the development of sustainable transportations that are energy-efficient and use cleaner fuels (Bizoza, 2012). As a more sustainable transportation system, battery electric vehicles (BEVs) are considered as a promising solution (Haslam & Waterson, 2013). BEVs does not have the same degree of exhaustions as the CVs since the engine of the BEV gets its power from a battery charged with electricity and is not powered by fossil fuels, which means zero emissions during use.

More and more automotive companies are adjusting to the new trend of electric cars and, soon to be, a crucial development of electric vehicles (EVs). Countries have plans to officially forbid CVs, as for example in Norway where it is planned to ban the sale of petrol cars by 2025 (Staufenberg, 2016) and in the UK both gasoline- and diesel- fuelled cars by 2040. To help the adoption of EVs, researchers and developers have expressed the need of more investigation needed in the area of the UI in EVs to be able to develop a more unified and coherent UX for the driver (Strömberg, 2011).

1.1.2 Problem with the user interface

Big problems of understanding the EV and its power source are evident among persons and they find the energy of the battery being mysterious. The user interfaces (UIs) of today is not helping the driver to understand the actual functions of the EV and neither why the available range is sometimes not behaving as anticipated and is incorrect. Furthermore, EVs do not have the same functionality as CVs, which naturally leads to differences in the UI and the human-machine interaction (HMI) of the vehicle. From a driver perspective such new technology has an impact on the driving task and requires effective and well-designed interfaces (Haslam & Waterson, 2013). There are big challenges for researchers, designers and experts to understand the new user behaviours towards the unfamiliar features in the EVs that the driver must adapt to. Much of previous research have come to the conclusion that there are weaknesses in today's UI in EVs (Strömberg, 2011), it is not enough user friendly which results in a user experience (UX) that is not enough consistent and coherent. The absence of knowledge about what specific information as well as how to present it creates misunderstanding and lack of trust of the EV, which in turn inhibit the adoption of EVs and the decrease of CO2 emissions. Why there is a weakness in EVs' UI today could be explained by Donald Norman's theory of conceptual models and the system image (Cooper, Reimann, Cronin & Noessel, 2014). Norman describes the importance with the link between the designer, the system and the user. When designing products with user interaction the major responsibility rests with the designer to assist the user in understanding the system. The designer needs to provide a coherent design model and a consistent, relevant system image. This means that the designer must first understand the system and the user's mental model of the system to be able to create the UI for the user.

For adoption of the EV the UI, including what and how information is shown, needs to be improved.

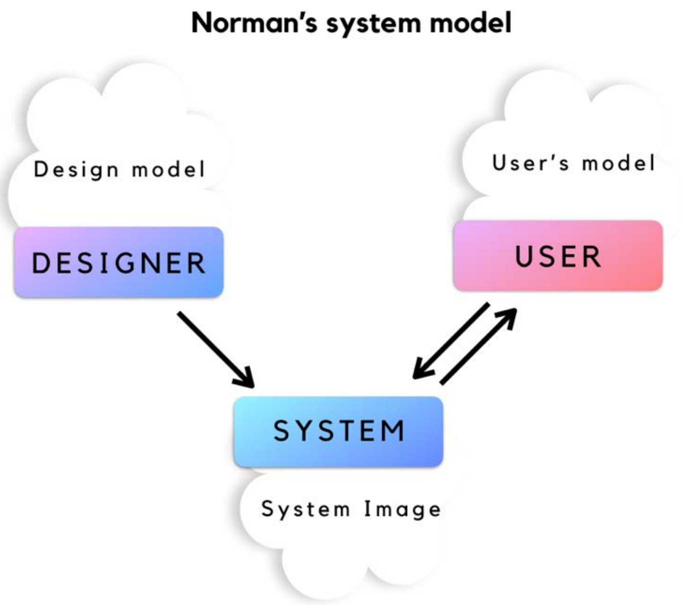


Figure 1.1: Norman's system model.

1.2 Aim and research questions

The aim of this master thesis project is to increase the understanding of how the UI and the UX should be designed for an EV in order to accelerate and facilitate the adoption and improve the use of EV. Greater knowledge about the design suitable for UI in EVs could contribute to pleased users of EVs and a higher level of acceptance of the more sustainable transportation alternative.

The project will result in a set of design guidelines for the UI and UX in EVs. To accomplish the delivery three research question have been set and need to be answered. The research questions are:

1. Technical aspects of the EV; What knowledge about the technical aspects of an EV is important to have when designing a UI for an EV?

2. User behaviours and total user experience; What are the new user behaviours and what is the desired total experience for a user when using an EV?

3. Information in the UI; Which information in the UI of an EV do a driver needs in order to be able to understand the EV and have a pleasant experience?

1.3 Collaboration company and target group

This master thesis project was initiated by the department Connected Cars & UX at the Chinese-Swedish company China Euro Vehicle Technology AB (CEVT). CEVT is owned by the Chinese-based company Zhejiang Geely Holding Group and is developing cars of the future.

The primary target group of this project is experienced users of EVs. Research show that drivers fast become comfortable with the EV which indicates that becoming an experienced driver is mostly a relatively short process. However, also new drivers will be considered, especially since the collaboration company has a brand called LYNK & CO, that is trying to challenge the old automotive industry by an innovative business model that let their customers choose to buy, share, borrow or subscribe to their cars. This new way of availability of cars is forming new groups of users who are able to have access to a car. Lynk & Co’s owner Zhejiang Geely Holding Group sees a need to design the new business model with preferences of the young connected generation in China.

1.4 Demarcations

This study focusses on what information that is presented to the driver in an EV, and how this is done. Where in the car the information is placed will not be taken into account. Possible differences between the information from an EV and a CV are primarily investigated, to enhance a good usability for the driver in the new vehicle with its unfamiliar functions. However, this project will only focus on these functions and other parts which do not differ, as the heat ventilation air condition system (HVAC) and infotainment system, will be out of our scope.

In this project an EV is considered a vehicle electrified with batteries that can be charged from an electric outlet, and especially battery EV (BEV) is the main focus area.

2. Theory

In this chapter the theoretical background of UX and related notions are described. Furthermore, the context of UX and EV is investigated, what research that has already been made in the area and what the results are. During this chapter, related questions will be asked and marked out, and are taken further to the next phases of the project.

2.1 Definition of UX

The term user experience has an official definition (ISO 9241-210:2010) and is defined as "a person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". User experience is seen as a holistic approach to design that occurs before, during and after use. When a person uses a product the user experience includes the user's needs, emotions, perceptions, responses, behaviours and accomplishments, and in the product the interaction design, information, graphic design, usability and accessibility meets (Bussolon, 2016). Depending on different personal standards the user experiences vary between users and situations and can change over time. It also depends on the user's attitudes, skills and personality, and the context of use (Hassenzahl, 2005).

2.2 Adoption of EV and factors affecting it

This part will describe what EV drivers of today are appreciating with the EV and also what barriers there are for adoption of it. In this report *adoption of EV* refers to the interest and desire of changing from common transportation systems of today, such as using a CV, to instead start driving an EV. This phase also concerns all that come with it, as for example the performance that is different, the new driver behaviours that are required and the limited driving range that has to be considered.

Furthermore, new user behaviours are introduced and the importance of understanding how the EV works in order to have a positive UX and remain trustful for the car. Trust will in this report relate to the information that the EV presents to the driver and how this is done, and lastly how it is interpreted by the driver. Trust in this respect is strongly related to the experience of the EV, since lack of trust in this matter easily leads to insecurity and a negative feeling of being out of control.

2.2.1 Positive aspects of EVs

Environmental sustainability

One of the biggest reason for choosing an EV is not seldom because of environmental reasons. It is according to Cocron (2014) reported as the most frequent given answer to why driving an EV would be advantageous according to the users. Reducing CO2 emissions are together with less use of petroleum considered as two important aspects of the environmental issues. Results presented by Egbue and Long (2011) show that especially the latter is very appealing to a majority of people when ranking EV attributes. However, there are different suggestions on how experience and time is affecting the importance of the appraisal of the environmental benefits, Cocron (2014) suggests in his dissertation that this is decreasing over time while he also refers to other research that shows the opposite.

> Are people interested of the source from which the energy comes from when they are charging their EV?

Another finding related to environmental aspects are research showing that when having an electric car, it is used more often than a fossil driven car (Labeye, Hugot, Brusque and Regan, 2016). Shorter trips that before were travelled by other means (e.g. walking or biking) were instead done with the EV, according to a third of the participants in a test presented by Labeye et al. (2016). The reason was assumed by the author to mainly be related to the fact of lower emissions, which decreased possible guilt of using the car instead of walking or biking.

> Do people tend to use the car more often when they have an EV instead of a CV?

Performance and enjoyment of driving

Many drivers appreciate the performance of the EV, especially after trying it for some time drivers express the driving experience as being fun and pleasant according to Cocron's assertion, 2014. He claims that the driving experience is related to time and is increasing with more experience. Furthermore, as many as half of all the participants in a study presented in his report saw the driving experience as a real advantage compared to driving a CV. This result is supported by Wallgren and Strömberg (2014) who say drivers express the EV as a more comfortable way of transportation. However, this does not seem to be a fact, since a test made in UK reveals results where drivers evaluated the performance of the EV negatively after trying it for a period of time (Graham-Rowe et al., 2012).

Charging

After gaining some experience of the EV charging at home instead of filling up the tank with a CV at gas stations are considered an advantage (Cocron, 2014). However, this was something that changed with time, in the beginning of a test period with new EV drivers only 1.3% saw this as an advantage, while after some time this changed to 16.7%. A longer study presented by Labeye et al. (2016) showed that after 6 months as many as 94% of the 36 participants enjoyed charging at home and appreciated that they did not need to go to gas stations anymore.

> Does the user understand if the EV is charging or not?

> What does the drivers charging routines look like?

> How do experienced users perceive the activity of charging? Is it simple/difficult/etc ?

2.2.2 Issues related to EVs

Potential barriers

EVs become more and more common on the market, but still they are relatively new and it is an ongoing project to establish this new product with new user group segments. Research shows that CV users perceive more functional barriers and have less positive attitudes toward EVs compared to users who drive EV themselves. EVs while EV users perceive limited driving range as a barrier, especially to make longer distance trips (Haustein and Fjendbo Jensen, 2017).

The infrastructure of charging opportunities is something that influence the overall impression of the EV and is an important part to improve in making people choose the EV as their option to a daily transport (Salah, 2016). A phenomena that has arisen related to the limited driving range of the EV is *range anxiety*. It is broadly discussed in literature and it is many times suggested to be connected to inexperience of driving EVs. Rauh, Franke and Krems (2015) present a definition of range anxiety as ”a stressful experience of a present or anticipated range situation, where the range resources and personal resources available to effectively manage the situation (e.g., increase available range) are perceived to be insufficient”. The lack of charging stations is a big influencer why people might feel restricted to where they can go and why they sense a level of range anxiety, since lack of it implies that trips need to be planned even more carefully or even skipped.

Other aspects that have been reported as barriers to using an EV are high initial costs and limited usability (Cocron, 2014). This is supported by Egbue and Long (2011) that present a study which shows that these two aspects are the top ones when it comes to what is concerning potential EV users. Other problems presented by Cocron (2014) are long charging time of battery and handling the cable, although this together with an unsatisfying infrastructure were evaluated as less of a barrier after using an EV for three months.

Mental models of batteries

There are many products today that rely on batteries and where the responsibility of recharging lies on the user. A study shows that users do not fully understand how batteries work and that they do not have the accurate mental models of them (Kurani, Axsen, Caperello, Davies- Shawhyde and Stillwater, 2009). In relation to the batteries of an EV the UI of the car do not support the understanding and learning of this energy source. The batteries are considered mysterious (Pontus Wallgren, senior Lecturer at the division of Design & Human Factors, Department of Industrial and Materials Science, interview), even though they are implemented in many of people's everyday products. Not understanding why the energy level of the car behaves as it does, i.e. what effects the energy consumption, could be a contributing factor to experiencing range anxiety and not trusting the car, the driver can easily feel out of control.

Does the driver connect charging the EV with other similar everyday products?

Can we connect and apply the mental models of other chargeable and portable products with the EV?

Range and trust

As described above range anxiety is a popular topic of discussion related to EVs and might be dependent on the level of experience of the driver. According to Rauh et al. (2015) also individual preferences, system features and environmental factors play an important role in this matter. These three categories for example the concern what the person driving the EV is like and how the person perceives the car, if there are systems in the car supporting the driver and in what kind of areas the car is used.

How long distances do users usually drive?

According to Franke (2015) research show that it could be valuable with a degree of influence over the range estimation from a driver's point of view, i.e. being able to control what is taken into account in the range calculations, and also to show what is influencing in a transparent manner. According to Jung, Sirkin, Gür and Steinert (2015) many drivers are today referring to the displayed range as a "Guess-O-Meter", as a result of not accurate information and drivers not trusting it. Their research implies that a level of ambiguity when displaying range might be in favour to let drivers feel trust for the car. Furthermore, a test from another study showed that some users did avoid making some trips due to the limitations of range or showed an overcautious behaviour, by charging the battery more times than needed or charging it to the fullest (top up) before travelling (Chéron and Zins, 1997; Kurani, Turrentine, & Sperling, 1996). The reasons that the range changes are that many factors play an important role when calculating it, which many drivers do not understand. As a result, the information may be judged to not be trustful (Wellings, T., Binnersley, J., Robertson, D. and Khan, T. 2011).

Do experienced drivers of EVs sometimes suddenly get surprised by a sudden drop of the battery level?

2.2.3 Experience and new driving behaviour

New users VS Experienced users

There are differences being new to EVs and having some experience of it. A beginner very fast becomes comfortable handling the car, in a test with beginner EV drivers, over 90% thought that it was easy to learn and handle the car already the first month (Labeye et al. (2016). Even though range is most related to novices of EVs, according to Rauh et al. (2015) experienced drivers also think that range is challenging to handle sometimes but inexperienced drivers might feel a higher level of stress as a reaction to it. It is therefore

How can we design the UI for new users and still maintain a good user experience for drivers with more experience?

Are there different user groups among EV users? How do they differ? For example, are there differences in what information that are needed in the UI and do the wished total experience of the EV differ between them?

crucial to help drivers to learn fast, for example by increasing efficiency and effectiveness of the learning process. Since making shorter trips imply that less range is needed, Rezvani, Jansson and Bodin (2015) claim that the phenomena might not be evident for those using the EV for urban transportation. On the other hand, studies have shown that the current range of EVs could be enough for the daily trips if EV users understand the new way of using the car, which is to charge it whenever it is possible instead of using it as a CV which is to drive until almost empty followed by fill up at public gas stations (Salah, 2016).

Driving style

Since EVs possess new properties there are many new features which leads to new behaviours that the driver must adapt to when changing from a CV to an EV. The tasks which the driver encounters at different levels are presented in a model by Michon (1978, 1985) and are explained in the context of EVs by Labeye et al. (2016).

The first level is related to the need of planning trips and it is suggested that doing so with an EV is different from planning trips with a CV due to the EVs limited range. The driver will have to take into account what route to take and where along the way available charging stations are. This is also discussed by Cocron (2014), and that the issue is related both to novice and experienced EV drivers. However, Labeye et al. (2016) do not agree and instead express the planning as a new behaviour adapted by experienced drivers and that they will understand and adapt the available range into their lifestyle.

The second level presented by Labeye is the tactical one, where the driver will scan the environment while driving and change the behaviour accordingly, for example handling the silent nature of the EV in respect to other drivers and pedestrians. According to research from Cocron (2014) the silent nature of the EV is a two-sided coin, most drivers express the silence as enjoyable while a concern for safety issues for people outside the car are also represented. However, his study clearly showed that the silence in a higher extent contribute to a comfortable use and positive experience of the vehicle rather than the drivers being concerned because of safety reasons, even though research of Labeye et al. (2016) shows that as many as 39% claim that their driving style were changed due to the silent nature of the EV.

What do drivers think of the silent nature of the EV? How does this affect the experience of the EV and the usage?

The driver will at the third level, called operational, handle the new task of regenerative braking that lets the driver recharge the battery in the EV when decreasing speed. His research shows that users in general seem positive to this new feature that directly let them affect their energy consumption. The article of Labeye et al. (2016) presents a study where 36 persons in Paris drove an electric MINI E for six months, results showed that 100% of the participants appreciated the function of driving with only one pedal and that the feature of using regenerative braking were quickly adopted into their driving style. In addition, 19% even claimed that it made them better drivers by better foreseeing braking distances and as a consequence having a softer driving style. The feature of regenerative braking is further discussed by Cocron (2014), insisting that this is something that the driver have to learn, in order to be able to identify the situations where they can get energy back to the battery.

Are people interested in using the function of regenerative braking recharging the battery by braking?

What kind of trips do the driver make with the EV? How long distance are these and where do the user usually drive?

Traditional VS innovative UI

There are both pros and cons with making the UI of an EV more innovative and adapted to the features of the technical nature of the electric car. Results by a study presented by Strömberg et al. (2011) shows that a more innovative interface made some participants feel more insecure, but they understood that it was a new kind of car where the functionality might be different from what they were used to. While they felt more comfortable with a UI that looked more traditional (i.e. like a fossil driven car's UI) it also made them assume it would function in the same way.

Are there needs of improvements regarding whether or not the EV is ready to drive?

Are there any fears that the EV might behave in a different way compared to a CV?

Should the UI of the EV look like it normally does in a CV?

2.2.4 UX and UI is important for EV adoption

In summary of what have been said so far; the driver needs to understand that the EV does not function in the same way as a CV, although a too high level of innovation might lead to insecurity, consequently it needs to be done step by step. Most important, a well-designed UI is needed in order to help the driver and to understand and to enhance a positive UX. In addition to this, the driver has to accept and adapt to a new way of using and driving the EV.

What main experiences do the users of an EV want?

Do users want a unique experience when driving an EV?

2.3 Displayed information

What and how information is displayed in different models in EVs today alters and there are divided opinions and suggestions of how the UI should be design in the EV. Some research have been conducted within the area and are described below.

2.3.1 Prioritised information

A study presented by Nilsson (2013) with 16 drivers being new to EVs resulted in everyone evaluating the estimated range as being the most important information to see. The result showed that the drivers frequently monitored the area of the distance to empty (DtE) together with the power meter, speedometer and state of charge (SoC). Also, Franke (2015) state the importance of the DtE indicator to enhance a good user experience, especially in electric cars that are fully battery driven. As earlier described this feature is many times not considered to be fully trustworthy, consequences could according to Franke (2015) be, for example, that the driver makes decisions that are more time consuming in the end and less good for the purpose or feel more stress about the available range. A study from Strömberg et al. (2011) shows results that some drivers new to EVs think that only the speedometer and SoC are necessary to show all times, while other information mainly are interesting when the battery level is low. In the same study results showed that the eco-meter which displays the instantaneous energy-efficiency, was considered the least relevant piece of information in two tests which were made with different UIs. However, Strömberg et al. (2011) discussed that this might have been coloured by the fact that not all participants understood the function of regenerative braking. Another finding in the study was that participants thought that an auxiliary gauge showing how much (and possibly to what) energy was used for other things than the engine was of interest.

Which information do the driver of an EV need?

How can we help the driver to understand the information needed?

Ambiguity & flexible options

As mentioned earlier a level of ambiguity when displaying range left is better than showing a too precise number, since this number seldom is correct anyway. The range is dependent on many variables, such as the car's load and speed, the weather, and the road conditions etc. It has been proven that showing the number less precise has a positive effect on the driver's trust towards the vehicle (Jung et al., 2015). The same study showed that displaying the range left in a more ambiguous way is even more beneficial in situations that are stressful and critical.

According to the study of Rauh et al. (2015) it might be of importance for the user to have the possibility of adjusting the parameters of the feature displaying the range that is left, i.e. that the user will have some control of which parameters the car shall take into account when calculating the estimating range. Examples given by drivers are to make the period of which the range estimation system take into account shorter, to have a button that starts a new reference period on request or to have two different estimators where one show range based on current consumption and one that takes a longer driving period into consideration. For example, one of the participants in the study stated: “Probably it really needs some time to adjust to another driver. And if you, like me, get in the car and your husband has driven before and there are just 120 km left and you know: you still have 115 or 110 to go, it would be a comforting feeling if it would adapt earlier to my driving style.”.

2.3.2 Attitudes, values and emotions towards EV

This part presents results of how identity and personalities are connected to the use of new products, and especially the EV. Attitudes in general affect decision making and so also when it comes to what products to use and how they will be used. Personal values and how people live their life is a driving force which influence decisions. Those values, interests and also emotions towards new products such as the EV play an important role.

EVs acting as symbols to express identity

Research show that EVs are a mean to express identity. In a study presented by Rezvani et al. (2015) three different categories were found to explain different identity of users of EVs. The first category found was those that felt that using an EV expresses a ”forward-thinking, modern and technology oriented” personality. A second category was those that related the EV to an undesirable slow-moving lifestyle and feelings of embarrassment were found among these people. The third category was those that did not want to be associated with the green environmental sustainability that they thought the EV is related to. According to another study participants after some experience with a EV felt that a driver of an EV expresses a person caring for others and being open minded (Skippon & Garwood, 2011).

Environmental and technology personalities

A study presented by Axsen, Tyreehageman and Lentz (2012) examines how and why consumers may or may not adopt to technical solutions of products that are in favour for the environment. In the test people were as a result divided into five different clusters, all within two main categories; pro-environmental attitudes and those that were the opposite.

In the category pro-environmental attitudes the first cluster consists of so called ”engaged greens”, they are presented as open minded persons who have a big interest in the environment and technology, their life is permeated by this. The second group is ”aspiring greens”, they are also open to changes but less engaged in the environment and technologies than the previous cluster. The third one is ”low-tech greens”, the group least open to changes of all five. They have a low interest for new technology and their environmental interest is suggested to be manifested accordingly, i.e. they prefer to limit some things in life instead of using a new technology as a solution. For example, they would likely prefer to walk or bike rather than buying an EV as a pro-environmental action.

In the second category the first group is presented as ”traditionalists”, they have very little openness to change and is the group that seem to be the last one likely to adopt to pro-environmental technologies. Accordingly, they have low interest in new technologies and they generally do not have an environmental oriented lifestyle. The second and last group within this category is the ”techies”, they are the ones that would be least likely to take pro-environmental actions, but as the name suggest they are very interested in technology. Sometimes these persons will show interest in pro-environmental technologies, but because of the technology itself rather than of an interest for the environment.

Furthermore, this research of Axsen et al. (2012) together with Schuitema, Anable, Skippon and Kinnear (2012) suggest that the pro-environmentals represent an orientation in life that stands for a lifestyle or personal identity. Another identity, presented by Schuitema et al. (2012) is the one called ”car-authority” identity where people more specifically are experts on cars, which could be said originates from the technical orientation presented by Axsen et al. (2012). Car-authority persons are according to the studies not convinced of the possible environmental positive aspects of the EV, while the groups presented by Axsel et al. (2012) with a technical interest but that are not pro-environmental active are likely to adopt to EVs. According to Rezvani et al. (2015) this might suggest that less energy should be put in the communication of the EV as environmentally beneficial and focus more on the technical aspects instead. Furthermore, Rezvani et al. (2015) highlight the importance of also focusing on the emotions towards adoption of EVs in order to overcome some of the barriers, this is supported by Moons (2015) stating that emotions towards the EV may be of importance regarding the intentions of use.

2.4 Conclusions of theory

Findings from the literature review show that there are many barriers for the adoption of the EV. The new user behaviours and driving styles affecting the driver could be seen as difficult to learn, the UIs of today does not support the driver in understanding and learning the properties of the EV. The difficulties in understanding the fundamental part of the EV, the battery, easily leads to misunderstandings which in turn generates a mistrust for the car.

Research studies also indicate that there are big differences between novices and experienced drivers of EVs. Additionally, just as people are different and have different preferences about other products, users could desire different information in the EV too, which will influence the UI. To identify different user groups among EVs seem necessary and adjust the information needed and experience wanted according to them. We have also seen gaps in the literature, when looking more into the wider perspective of the usage of EV. To enhance the UX for the driver it is crucial to understand what people appreciate from their experience with an EV, and also see if there are different times/occasions where some information is more important than others. In addition, we found it interesting to use the fact that people’s personalities, values and beliefs affect their choices and possibly emotions towards EVs and how this might affect what information the different drivers need.

3. Process

This chapter describes the different phases of the project, what methods that have been used and what the results from each part are.

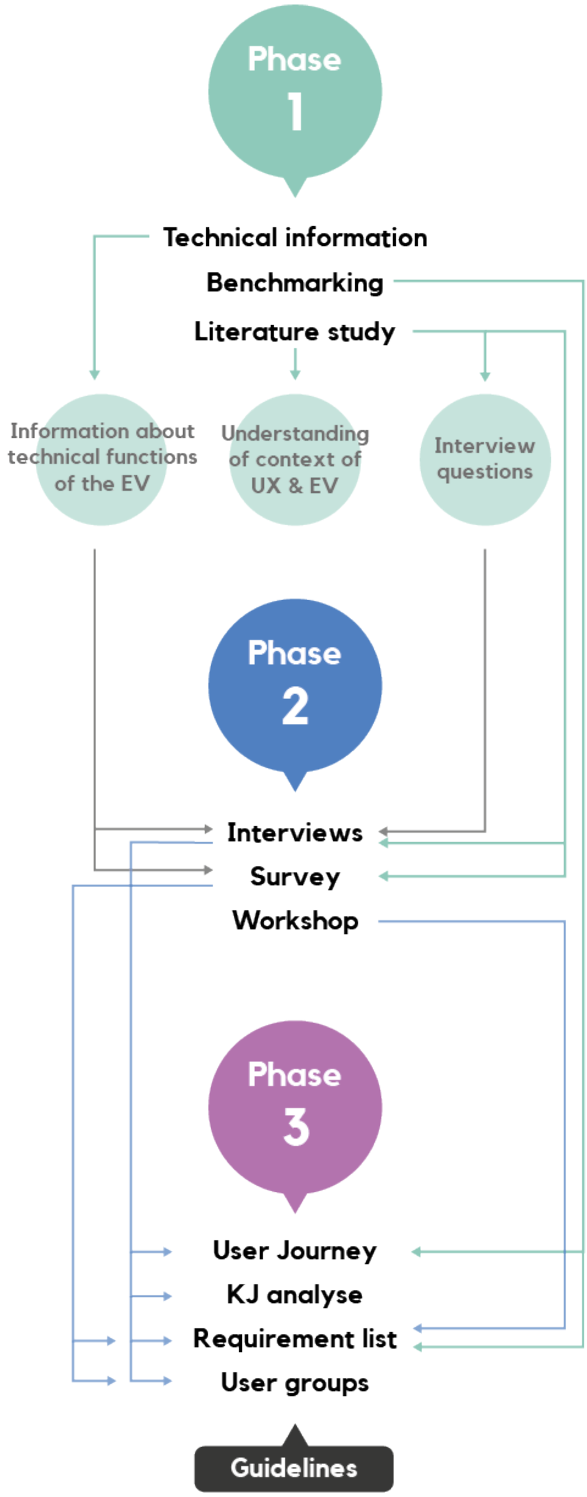
3.1 Process description

The project was divided in three phases which are describe below. The whole process of this project is permeated by a user centred design approach. The expression could be explained by usability and user friendliness (Guðjónsdóttir, 2006) and the way of thinking is based on understanding the users' needs in order to create products and systems that are effective and satisfying in the specific context.

Phase 1 included research from literature to understand the context of UX and EVs, also a technical study was conducted by interviewing experts in the area and gathering information from literature with the purpose of gather and summarise technical information needed for a designer when designing the UI for an EV. Lastly, a benchmarking was conducted in order for us to understand how it is to drive and EV and what and how information is shown in EVs today. This resulted in: a summery about the technical aspects of the EV, an understanding of the context of which the project was performed and what questions that should be asked to experienced EV drivers.

In phase 2 interviews were conducted and a survey was answered by experienced EV drivers. The interviews were analysed through affinity diagrams by using the method *KJ-analysis*, that in turn were used together with answers form the survey and the workshop to construct the requirement list. From the interviews and survey also three different user groups were found and were a crucial part when deciding what information that shall be shown for which users. Furthermore, the benchmarking and interviews enabled the user journey to be constructed.

As seen in the illustration the results from the first two phases formed the basis for phase 3, including the user journey, KJ analysis, requirement list and user groups. The last part of this process is the guidelines, which represents the result from the total data collection and analysis. 3.1



3.2 Phase 1 – Pre-study

This phase of the process includes introducing methods to the project, where a basic understanding of the technical aspects of an EV is being identified and so also the context of UX and EVs.

Technical information about the EV

To get a basic understanding of the parts of an EV and its technical functions interviews with experts within the area, working at CEVT, were carried out. The focus was directed towards the battery of the EV; how it works, how the energy is translated for propulsion of the car and what functions that are consuming most energy during use. Also, literature was added in order to collect enough data to create a summary of the basic technical aspects of an EV, as a help for a designer when designing the UI. Ideas of what to investigate further and write about in the technical summary emerged from the results of the literature study and was also coloured by the benchmarking that had just started. Questions were developed during the try out, about how the EV works and what we, as EV users, like to see and what we did not understand.

Literature study

To get an insight in what research that have already been carried out within the area of UX and EVs a literature study was conducted. By searching in different databases as Scopus and Google Scholar relevant literature were identified. Keywords such as ”electric vehicle”, ”UI in electric car”, ”HMI”, ”driver user interface”, ”instrument cluster” and ”user experience electric vehicle” were used. The intention was to find literature with valuable results for the project and afterwards direct the project’s focus where there were less results from previous research.

Figure 3.1: Mind maps created from the information gathered in the literature study.

Some of the articles were research based on other scientific articles written within the specific area and some were research where both smaller and more extensive user studies had been conducted. Of special interest were those where a study during a longer amount of time was done, since this would not be possible to perform in this project. Relevant information was picked out and categorised from the articles. The information was divided in mind maps and lastly summarised within different topics. The results were used as a base for the project's data collection and formed the questions included in the interviews and the survey for experienced EV users, the results of the literature study are presented in the theory chapter.

Benchmarking

Benchmarking is a method to compare things, comparing your own business or a product with others on the market, where the purpose is to make improvements and gaining knowledge from others (Westling, 2012). When doing research about UX in EVs one important aspect is that we, as researchers, test and experience how it is to drive EVs ourselves in order to understand the interviewees thoughts and experiences. We needed to get an understanding for the task of driving an electric car and what situations that might occur, the experience cannot be gathered from a paper, why a benchmarking was conducted. The end purpose was also to collect information about what and how information is shown in today's EVs. From carpool services and at car dealers the five different models of EVs were booked and driven: Renault Zoe, Volkswagen e-golf, Tesla S, Nissan Leaf and BMW i3. The car models were chosen for the reason that they are common cars on today's market, but those were also the ones that were available to get hold of in the city where the study was conducted.

The test drives lasted for 60-120 min each, were recorded and photos of relevant parts of the car and its UI were taken. The method thinking-aloud protocol (Hanington & Martin, 2012) was used, which is a method where participants performing a task verbalise what they are doing and what they are thinking. During the driving the driver was therefore thinking aloud while the passenger in the car was asking questions about the interactions and experience. When it was possible we switched positions during half of the test to collect as much information as possible and making the discussions of the cars easier and more fruitful. The information was then summarised and categorised in tables to enhance an easy comparison of the EVs.

3.3 Phase 2 – User studies

This phase resulted in a deeper understand about the usage of EVs from experienced users perspective and a user journey was constructed. To reach out to younger participants a workshop was conducted and resulted in insights of what the next generation of drivers think about future transportation.

Interviews

The second phase of the thesis were initiated with interviews as one part of the data collection, to gather information about the users of EVs. Interviewing is a research method to collect peoples' experiences, opinions, attitudes and perceptions by asking them questions (Hanington & Martin, 2012). The purpose of the interviews was to get qualitative data from experienced drivers of EVs. It was important for the project to contact the user group since these users already have experience of being novices to EVs and they have the knowledge about which information and features in the car that are still important and relevant after some experience.

In total 11 interviews were conducted and they lasted for 60-90 minutes each, eight were done face-to-face and three over the phone. During the interviews one person was asking questions and one was typing in answers, the data were also recorded to ensure no losses of information. The interviews were all following the same deep semi-structured template, see Appendix 3. This type of structure of interview allows the interviewer to improvise and adjust the questions depending on the answers to be able to get as much valuable information as possible in the given situation (Hanington and Martin, 2012). The aim was to gather explanations of the user's thoughts about their usage of their EV and find out where these thoughts come from. In this way the study could discover underlying problems with the EV today and identify user groups. The interview template was constructed from the findings of the literature study, in order to ask reasonable questions in respect of the topic of the project and its time frame.

The interviewees were four women and seven men between 30 and 46 years old. The mean value of experience with EV among the persons were three years where minimum was one years and maximum six years. The car model which were represented among the interviews were: Nissan Leaf, Tesla S, Tesla Roadster, BMW i3 and Volvo C30 electric.

Participant	Age	Years of EV experience	Car model
P1	42	3	Nissan Leaf
P2	38	2	Nissan Leaf & Tesla S
P3	42	1	Volvo C30
P4	36	3	BMW i3
P5	42	3	BMW i3
P6	42	4	Nissan Leaf & Tesla S
P7	42	2	Tesla S
P8	30	6	Tesla Roadster
P9	46	-	Nissan Leaf (car sharing)
P10	34	-	Nissan Leaf (car sharing)
P11	43	4	Nissan Leaf & Tesla S

Table 3.1: Information about the participants in the interviews in the user studies.

Survey

The data collection consisted additionally of a survey to be able to compile quantitative data from experienced drivers of EVs, resulting in less bias. The survey was made as an online questionnaire, which is a method to collect information from a large sample of individuals in a short period of time (Martin and Hanington, 2012). The survey was, likewise the interviews, built from the findings of the literature study but it was also formed by the results of the interviews and the benchmarking. It helped to build up the survey with relevant alternatives in order to shorten the response time, however the respondents also had the opportunity in some cases to write a short answer manually if the given options did not match the desired answer. Furthermore, the survey's questions were mainly formed to be comparable between respondents and in order to collect more wide answers, open-ended survey questions were used in seven questions which asked the participants to write sentences to explain their answer.

The structure of the survey was divided into seven parts:
1. Information about the participant, such as age, country, car model, years of EV experience, daily driven distance, how often they drive and reasons for choosing an EV. In total nine questions.
2. What information in the EV that the driver use, if anything is missing and if anything shown today is considered as useless. In total five questions.
3. If there are any interest in monitoring the performance of the car. In total four questions.
4. If information about the energy consumption is of interest and a question about if modes helping to control the energy consumption is used. In total seven questions.
5. If the driver feels trust for the car, in terms of trusting the battery, understanding if the car is on or off and if the driver understands what is affecting the battery level. In total five questions.
6. About the experience and feelings of the EV, questions about the look of it, interior and exterior, thoughts about the silence and if/how this affects the experience. In total four questions.
7. If an electric car was not driven today, the participants were asked why. The final question stated was if the participant considered that there are any big problems with the EV today and in that case what that would be.

The online questionnaire was made in Google Forms, an online survey platform, and to efficiently reach as large number of users of EVs it was distributed by using social media; groups on Facebook and online forums. The groups (16) on Facebook which were contacted were: Elbilar i Norge, Elbilar Sverige forum, Elbilar västra götaland, Elbilar Jämtland, Tesla West Sweden, Tesla Ägare/Entusiaster Sverige, TESLA Owners Worldwide, Nissan Leaf Sverige, Nissan LEAF Owners Group, Kia Soul EV, Kia Soul Owners, Opel Ampera-e Norge, Volkswagen e-mobility, e-up!, e-Golf, GTE., and BMW i3 Worldwide Group. The forums (2) were: electriccarcommunity.com and mybmwi3.com. The aim of the survey was to get a statistic result about which information in the EV that are important and appreciated from experienced drivers of EVs.

By the end of the survey period (one week) data had been collected from 623 individuals, 80 % of whom were men and 20% of whom were woman. From the participants almost 80 %

had the age between 30-60 and the total amount of answers came from 22 countries around the world, mostly from United States, Sweden, Norway, Canada, Denmark, United Kingdom, and Germany. The levels of the experience of EVs differentiated among the participants but all of them had some experience. The car models that were represented among the respondents were mainly Nissan Leaf, BMW i3, Tesla S, Kia Soul, Renault Zoe, Opel Ampera-e, Chevrolet Bolt, and Tesla X.

Finally, questions were summarised and lastly put in diagrams. Different structures of question required different amount of time to summarise and the open answers were going through manually. The answers were categorised for each question, and then put into diagrams. All the questions were at the end either in the form of pie charts or staple diagram in order to be easy comparable. Additionally, comments from each question were picked out in order to receive a more correct picture of the participants' answers. Since some of the questions were follow up question to a previous one and since not all questions were mandatory, the diagrams got different number of respondents. Some are presented in the following chapters and next to them, the number of participants is stated. Furthermore, there are parts of the diagrams that say "other", these are the result of answers that did not answer the actual question or other comments of similar kind that did not contribute to the result.

Workshop

To reach out to the next generation of potential EV users and their thoughts about EVs and future transportation possibilities a workshop with students were carried out. The students were in the age of 16-17 years old and were studying the second year of high school with focus on industrial design. According to Wikberg Nilsson, Ericson and Törlind (2015) a workshop is a creative meeting where people with no connection to the project is exploring the area in a creative way, instruments and tools that could be used are everything from pen and papers to recording equipment such as video cameras.

The workshop lasted for 80 minutes in total and were divided in three main parts with different tasks. The students were divided into six groups with three or four persons in each. During the three parts we, as workshop leaders, were walking around in the room helping the students if it was necessary. The first task had the purpose of giving the students a chance to warm up and feel relaxed, and also to make them get in the state of thinking about technical products and solutions. The task was made as a competition where they for five minutes were supposed to come up with as many products including some technology, that they use today, as possible. The second part of the workshop had the purpose of letting the students brainstorm about describing the car of the future. *How could technology be connected to the car? What would they like to do with their time in this future car?* This was a task conducted for 10 minutes. The third part lasted for 15 minutes, it consisted of three different cases that were randomly divided to the groups of students, as seen in figure 3.1. It was related to EVs and the themes were: the silence of the EV, if the electricity could be illustrated in a way to enhance the feeling of a smart car and how the EV could express environmental sustainability.

Electric cars are more silent than gasoline/diesel cars because they do not have an internal combustion engine. The silence is widely appreciated by drivers and passengers.

How can you make use of the silence of the car? What experiences can this contribute to? Can other senses be enhanced when the hearing is not as overloaded?

The cars of the future should be designed to be as smart and user-friendly as possible. By implementing sensors and other advanced systems, the usage of cars could be better and easier.

If the electric car is the future, can the electricity in the car be expressed as smart? When interacting with the car's system, how can feedback from the car be shown? Show that the technology is there!

In China you rarely see a blue sky, it is vital to have cleaner cities. Many choose the electric car for environmental reasons, because it does not emit carbon dioxide or other hazardous substances.

How can you design the electric car for an experience that permeates sustainability from an environmental perspective?

Figure 3.1. Three themes that were used in the third part of the workshop.

The results were used for the experience part of the EV of this project. It gave an insight in how young persons, potential future EV drivers, think about different technological solutions, the future car and the EV.

Figure 3.2. The students working with the tasks during the workshop.

User journey

A user journey for this project were constructed in order to give an explanation of how driving an EV today can look like, what the driver encounters during a normal (and longer) trip and positive and negative emotions that may occur. A user journey explains how a user interact with a product, over time. The journey is broken down to touch-points where the user's experience and usage of the product of each part is identified and examined (Wikberg et al. 2015). The journey of this project was constructed with the data collected from interviews and survey and had a general view, visualising the everyday trip that the user encounters. User groups were not specifically introduced in the situations of the journey.

3.4 Phase 3 – Analyse of data and guidelines

In this part of the project the data collected from user studies were analysed and compared in order to create a requirement list that could form the basis for guidelines. Different user groups were identified and described, which was a crucial part in this phase in order to describe what information that is needed for different drivers.

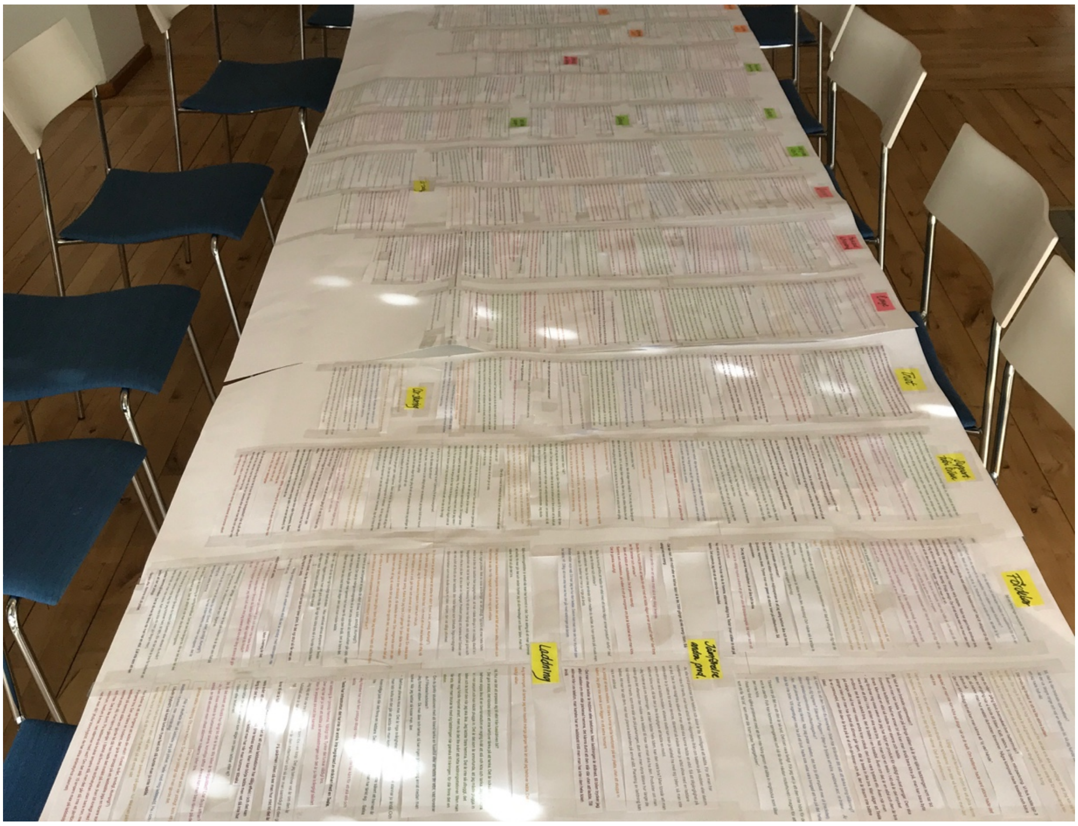


Figure 3.3: KJ analysis.

KJ analysis

After completing the interviews, the data was transcribed and each interview transcript had their own colour. To analysis the data the method “KJ-analysis" was used, as it lets designers organise a huge amount of data and convey it to a clearer overall picture with workable categories (Hanington & Martin, 2012). Each transcript of the interviews was printed and all sentences of interest were cut out and the quotes were placed out with the ones belonging together placed together, forming groups after time. The analysis resulted in 23 groups of interest, these were in turn summarised in order to be easily usable and comparable with the results of the survey.

User groups

From the data collection with users from different parts of the world and different levels of experience, three user groups could be constructed. It was identified that different users need different pieces of information, at different times during their drive. These groups were needed in order to prioritise different pieces of information and what information that shall be shown. The groups identified were named as: User group A - The Natural, User group B - The Nerd and User group C - The Newbie.

Requirement list

Results from the interviews and survey were analysed and compiled into a requirement list, consisting of different categories to clarify where the requirements belong, i.e. energy consumption, charging, support from car etc. Furthermore, the list included information of the purpose of the requirement, our general thoughts about it, which user group it is applicable for (A, B and C) and for some requirement also suggestions of solutions. The requirements are presented in chapter 5, 6 and 7 as results of the findings next to the main texts in respective chapter and the full requirement list could be found in Appendix 1.

Specific information

More specific information that should be shown but different prioritised for the three users were gathered in an additional table, apart from the requirements list itself. For this information it was argued for why and how, to some extent, it should be accessible for the user groups A, B and C.

Guidelines

The requirement list formed a basis for the guidelines that were constructed. These were composed as a final result of this project, as a help for designers when designing the UI for an EV.

4. Technical information about the EV

This part of the project has the purpose of contributing with knowledge about the technical aspects of an EV, which are important to understand when designing the HMI and UI for an EV. The information which is presented in this chapter is findings from the book “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles” written by Eheani, M., Gao, Y., & Emadi A., 2010, and in addition extensive information has been collected from interviews with the experts, within the field of electric vehicles, Johan Hellsing and Niklas Legnedahl.

4.1 The history of EV

In 1881 the first EV was built by Gustave Trouvé in France and had a speed of 15 km/h and a range of 16 km. At that time the technology was not developed enough to compete with horse carriages and the new vehicle did not drag much attention. While the EV continued to develop and the speed increased it became more interesting for the general public. During 20 years the EV competed with gasoline vehicles until the paved roads was constructed and the EV's limited range became a problem. The gasoline automobile's performance kept improving and the EV started to disappear since it was less powerful, more complicated to handle, had less range and also a higher cost. From then and 60 years ahead the EV was only sold as delivery vehicles and golf cars. The question about the importance of caring for the environment was raised during the 1960s and 1970s which lead to that research on EVs started again, still obstacles as the limited range and performance persisted.

During the 1980s and early 1990s a few more highly realistic EVs compared to the earlier creations were developed and this were the start of the modern era for EVs. Despite the innovation, EVs were at that time defined as incomparable with gasoline vehicles due to the battery's far heavier weight for the same amount of energy capacity. The conclusion was then to switch the focus from EV to deeper research on hybrid electric vehicles (HEVs), which have two engines: one petrol and one electric, and HEVs was already after a few years ready for mass production. Therefore, the EVs were in the 1990s almost only used as low-speed and low-range vehicles called neighbourhood electric vehicles (NEVs).

In the context of the development of EVs, it is the battery technology that is the weakest, blocking the way of EVs to the market. Great effort and investment have been put into battery research, with the intention of improving performance to meet the EV requirement. Despite the rapid development of battery technology performance is still far behind the requirements, especially energy storage capacity per unit weight and volume. This poor energy storage capability of batteries has limited EVs to only some specific applications, such as at airports, railroad stations, mail delivery routes, golf courses, and so on. In fact, some research show that the EV will never be able to challenge the CV.

Finally, in the early 2000 automotive companies began producing EVs which had a more excepted performance. In 2004 a small Silicon Valley start-up, Tesla Motors, started to design the EV Tesla Roadster and 2008 it was the first mass produced full battery EV that was highway legal and could travel more than 320 km per charge. In 2010 the Japanese company Nissan released the first modern family EV, Nissan Leaf, and it became very popular.

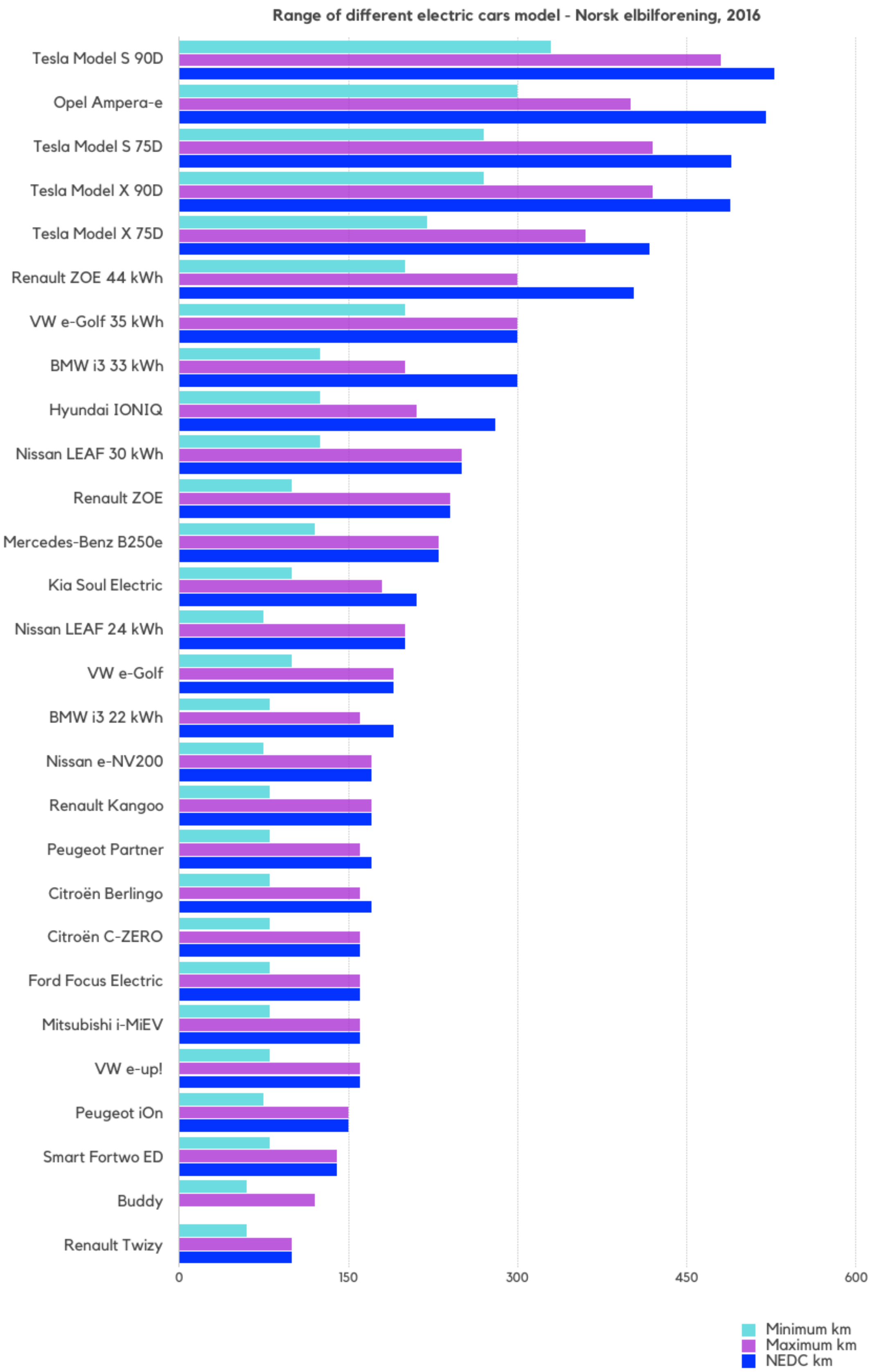


Figure 4.1: Range of different electric car models, from Norsk elbilforening, 2016.

However, it was still some problems of how to charge the car on the go. There was not a developed infrastructure of charging stations which led to the government, automakers and other businesses around the world to invest in order to help build a charging infrastructure, installing residential, commercial and public chargers.

In recent years, advanced vehicle technology research has been made and new battery technology began hitting the market, helping to improve the range, cut battery costs and improving the batteries' performance. Today there are several different types of EVs that customers can choose from which differs in ranges, refuelling options and price. The three main types of EV technology are plug-in hybrid electric vehicles (PHEVs), extended-range electric vehicles (E-REVs) and battery electric vehicles (BEVs). These vary in many ways but in general in the way of regenerate energy, if they have an electric motor and/or combustion engine, the battery capacities and charging capabilities. This project focus only on the BEVs and in the following chapters it will be named as EV. These EVs have different range dependent on the car model. A car with short range can drive approximately 150 km compared to a car with a longer range that can driver around 400 km.

4.2 The differences between EVs and CVs

There are many advantages of EVs compared to CVs, such as absence of emissions, high efficiency, absence of fossil fuels, and quiet and smooth operation. The aspect which is by far the best compared to CVs, and important for the global environmental crisis, is the positive aspects on the environment because of the lack of emissions during use. One of the interviewed technical experts claimed that the EVs should be able to completely replace the CV in the future, with advanced technology and due to countries that plan to officially forbid CVs.

EVs and CVs are similar in functionality but there are some differences. The main difference between them is the powertrain, which has the purpose of the car's propulsion and creates force to drive the car forward. The EV uses an electric motor propulsion and batteries as energy source, while the CV has an internal combustion engine and a fuel tank. There are also different transmission requirements in the powertrains of the vehicles due to the different behaviour of the motors.

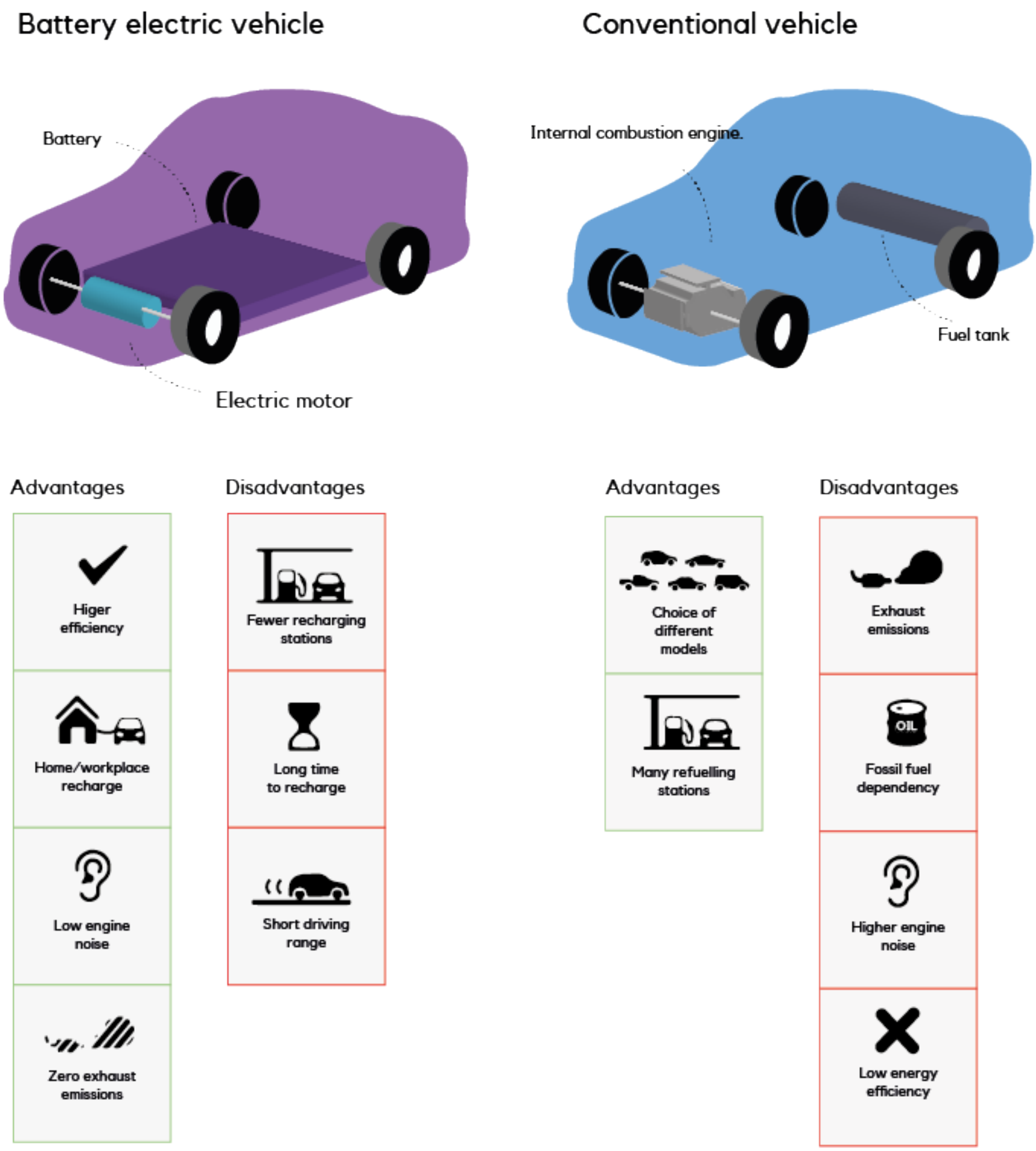


Figure 4.2: Illustration about the differences between BEV and CV (illustration inspired by European Environment Agency, 2016).

EVs are designed today so that the user should not experience any significant difference in functionality from the CV. One part that has been modified to simplify the adoption of the EV is the gas pedal. The EV has a direct response to user input and can deliver high power even in lower speed compared to a CV. The electric motor reacts directly to the user's inputs since the magnet in the motor only change angle, compared to a CV where more things are involved such as the gasoline that needs to start to combust etc. Therefore, it is needed to insert filters in the EV to avoid that the car is too sensitive for user inputs, otherwise the drive would be too irregularly and not smooth.

The benefits of the powertrain should be clearly emphasised, such as the fact that the EV unlike the CV is more silent and it can be used indoors because there are no emitted exhaustions. Some people also think that the EV is easier to manoeuvre than the CV which might could be seen more of in future EVs. Some EV developers are today focusing on designing the EV "smarter" by learning the driver's behaviour, to be able to provide a better driving experience and make the tasks related to driving the new vehicle less complicated.

4.2.1 New parameters to understand in the UI

In the EV there are some new parameters the driver needs to understand.

- State of Charge (SoC) shows the battery level. This is normally shown in percentage.
- Distance to empty (DtE) which is a predicted distance of how long the car can travel with the current amount of energy left.
- State of health (SoH) explaining the condition of the battery compared to its ideal conditions, this will decrease over time and use.
- Energy consumption from driver input describes the energy usage and generation from the battery.

Among the differences from the CV there are new things the user has to learn as new driving behaviour and charging routines. The one pedal drive is one of them which has, to some extent, replaced the brake pedal and now works for both accelerating and braking. With the one pedal drive the driver can make the car go forward when the pedal is depressed and brake when pressure is released. However, there is still a brake pedal, which is there for more aggressive braking and emergencies. Another thing is the regenerative braking, which very much connected to the one pedal drive, and makes it possible to generate energy from the speed of the car. It recovers energy in the situations the driver decreases the speed as when releasing the pressure of the gas pedal and the car starts to slow down. To which extent the car will break when using the regenerative braking can be adjusted. The energy usage and the energy generation are usually displayed in the UI of the car as an energy flow in and out from the battery.

However, it might seem great to save energy but the speed should not be reduced just to generate electricity. The best way of driving energy efficient is to operate the car smooth and avoid braking if not needed. If the speed wants to be kept, it is better to not brake since it takes more energy to increase the speed again compared to the energy that was recovered in the first place, unless the topology of the road is utilize "free" kinetic energy.

Of what is needed to accelerate, the battery gets back 60-70% of the energy when braking and the regenerative function is activated. As an example of the new driving behaviour, it is being better to let the car increase its speed when driving downhill instead of braking to reach the best energy consumption.

4.3 EVs: how do they work?

4.3.1 The main parts of an EV

The BEV includes a number of parts as high voltage (HV) battery, inverter, electric motor, system controller, and auxiliary systems.

The battery of an EV is normally placed flat in the floor, behind the front axle and in front of the rear axle, and the electric motor us usually placed between the wheels. Some EVs do not take the architecture opportunities and still are building based on how the CV looks like. If EVs are being built as electric cars from the beginning, it could be seen as an opportunity regarding more available space and new ways of using the car.

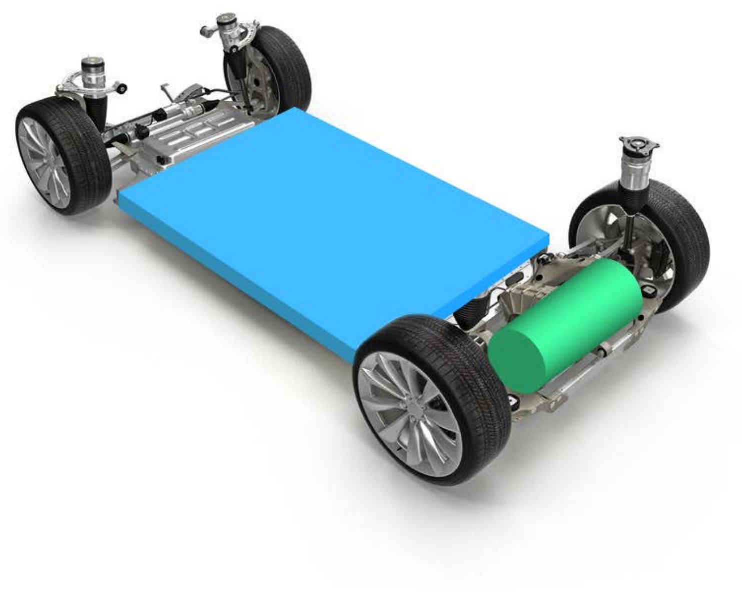


Figure 4.3: The BEV with its battery and engine.

The electric motor converts electrical energy to propulsive force which is necessary to be able to drive forward. The system where the motor is located calls electric drive and its function is to transfer electric energy from an electrical energy storage, which is the battery, to the motor where the energy is converted to propulsive force and results in mechanical outputs. The mechanical outputs are torque important for acceleration and power as the speed of the motor necessary for cruising. During braking/decrease of speed the motor works as a generator. It recovers energy when releasing the pressure of the gas pedal and the car starts to slow down, the car's kinetic energy is then converted into electric energy that is stored in the battery.

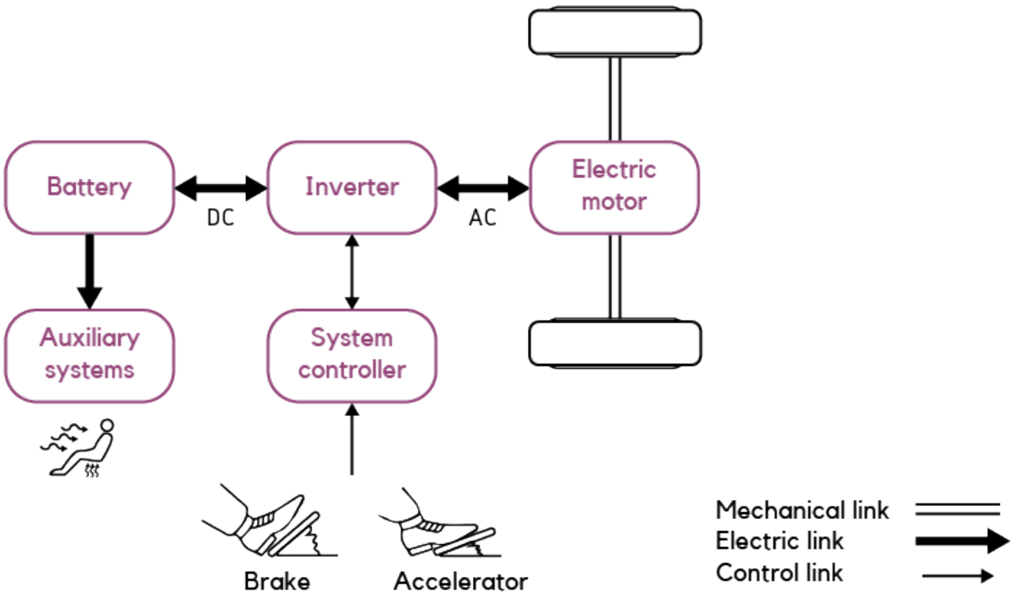


Figure 4.4: Illustration about the BEV's system electric drive where the motor is placed and other parts that are involved in the process of using the car.

Here follows an explanation of how the energy from the battery converts into the car's kinetic energy and the parts that are involved in the process:

1. HV battery

This is a component that stores, receives and delivers electric energy. The battery does not determine how much energy that is transmitted. It sends out direct current (DC) to the inverter, but also receives current when the regenerative brake is in use. That is why there is a backward electric link and the regenerated energy can be restored into the battery.

2. Inverter

The inverter converts current and controls the electricity from the battery to the motor and vice versa. The backward electric link is due to the regenerative braking. The inverter supplies electrical energy in alternating current (AC) to the motor but also supplies electric energy in DC to the battery.

3. Control system

Next to the inverter and the motor there is a control system that monitors all the processes in the electric motor drive. This part possesses the system's "intelligence" and manages the communication between components as the high voltage battery, inverter and the electric motor. Based on the user inputs as acceleration and braking from the gas pedal, the system controller decides how much positive or negative power the motor will have by sending signals to the inverter, which regulate the energy flow between the motor and the battery. The system control must for example constantly monitor the performance of the electric motor, including the regulating of the amount of power and voltage the battery supplies the motor with, the engine speed etc. When the driver increases the speed by pressing down the gas pedal, the control system calculates what level of frequency and voltage that will be sent to the motor.

4. Electric motor

The motor behaviour is controlled by the frequency and the voltage from the control system. The gas pedal determines the amount power which sends a signal to the control system and via the converter/inverter together the battery sends information and current to the electric motor. The motor receives a frequency and voltage, now in AC current, which is transferred into speed of the motor and power. When using regenerative braking the electric motor is used in reverse and is working as a generator. When the pressure on the gas pedal is released the car uses its momentum to recover energy that would otherwise be lost by friction from the brakes and unwanted wasted heat. This way of braking will also extend the life of the braking system since the brakes are not used as much.

5. Auxiliary systems

The auxiliary systems consume energy from the HV battery to control the heater and air condition, and also the 12 V system which provides the radio, seat heating and dashboard with electricity.

4.3.2 Performance of EVs

In CVs it is necessary with gears to increase the speed of the vehicle but in EVs it is not necessary and few EVs have it. CVs use multi speed transmissions in combination with the internal combustion engine and it makes it possible to use a smaller engine and increases the efficiency. In the EV, an electric motor generates 100 % of the torque at a very low speed, compared to the internal combustion engine which only generates low torque at the same speed and to be able to accelerate the CV needs to step down the multi speed transmissions by changing gear. Adding a transmission in the EV would only add on extra weight and are expensive. Instead of a transmission it is better to re-dimension the electric motor to a bigger size or put an electric motor at the front wheel and one at back wheel.

This also explains why the EV is unique with its direct response and acceleration. Acceleration performance is evaluated with the time used to accelerate from a low speed (usually zero), to a higher speed (usually 100 km/h). The EV has a very high power at a low speed which makes it possible to maximise the torque directly from the start and lets the EV accelerate faster. Since the torque is necessary for acceleration the problem with the CV is that it has less effect and torque at low speed which results in that more time is needed to accelerate.

EVs do not need a reverse gear either. The EV only change the direction of the current in the motor. In the neutral mode, no current is sent out to the motor. The inverter is the part making sure that the current is turned and changed into the right direction.

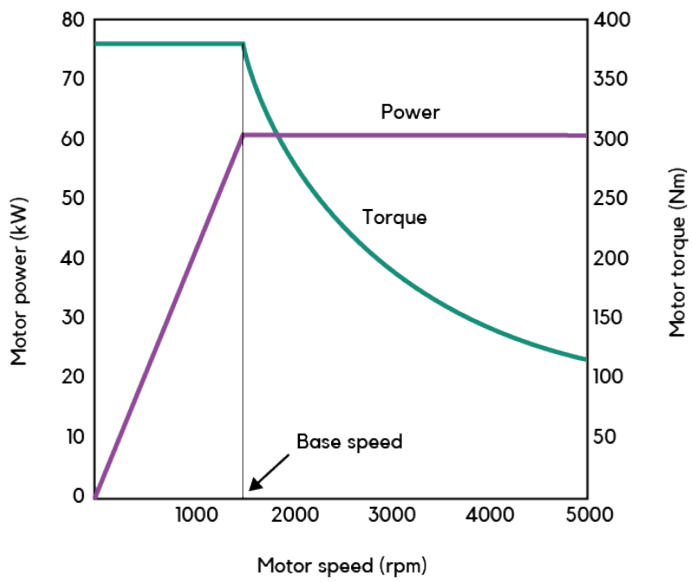


Figure 4.5: An explanation about the BEV’s motor power and motor speed.

4.3.3 Energy consumption

The source that consumes most energy from the battery is the electric motor for propulsion that makes the car drive forward. Depending on the car's speed and other aspects as road conditions, wind, landscape elevations, the weight of the car, and tire settings/pressure makes the energy consumption differ.

In low speed the motor torque is high and is needed for the acceleration. Here the power from the motor, which press the car forward in high speed, is low since the speed is low. In high speed the torque is no longer needed as much and the power is higher instead but keeps linear. This explains why the speed of the motor are not affecting the energy consumption significantly. Still an increased speed effects the energy consumption extremely since it results in a higher air resistance which increases the force A (figure 4.6). For example, if driving in 90 km/h compared to a speed of 130 km/h it will differ approximately with factor of 2 how long distance that the driver will be able to travel.

The weight of the car, see force B, is also an important aspect and cars in general are being built with as low total weight as possible. The driver can influence this aspect depending on how the car is loaded and how many passengers there are, since will affect the energy consumption. Also, road conditions and the tire settings/pressure will affect the friction of the tires and the energy consumption, see force C. Just as the elevation of the road as hills and valleys compared to a flatter landscape.

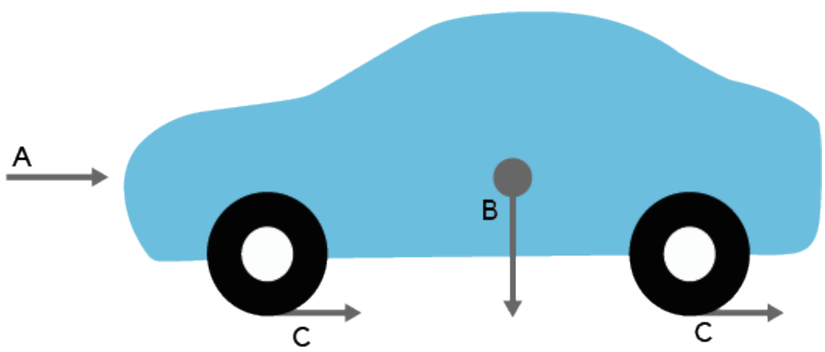


Figure 4 .6: Illustration about how different forces are affecting the car's energy consumption.

Another thing which also have a big impact on the energy consumption is the climate inside the car which concerns the auxiliary system. This include the use of the heater, ventilation, air condition (HVAC), seat heater, and steering wheel heater etc. The weather conditions where the car is used affects how the desired climate inside the car should be, e.g. using AC for cold air or the heater for warm air. At extreme outside temperatures, the energy consumption for the car will be higher in order to keep a comfortable climate inside the car. For some car models the car's energy consumption of the heater can be as high as the motor traction if it is extreme outside temperatures, such as -20 C degrees, and if the car is not pre-heated. In a CV the heater is not as energy consuming as in the EV since much of the heat comes from the internal combustion engine whereas in the EV there is nothing that produces waste heat that could be used for heating up the coupé.

Today, many EVs have modes in the car which help the driver to control the energy consumption, mostly it is restricting the speed of the car and the usage of the HVAC. This can make the driver to not be able to drive as fast as wanted and unable use of high effect of the HVAC which makes it take longer time to reach high/low climate temperatures. Drivers today also use the autonomous cruise control to help control the speed of the car. Unfortunately, many car models with this feature do not take into account driving energy efficient, since it rather controls the speed the driver want to persist.

Units

The unit of energy that is usually used for EVs is kilowatt-hour (kWh). But when evaluating the energy consumption per unit distance, kWh/100km is generally used in Europe while km/kWh or miles/kWh is used in USA and Japan. This can be compared with the CV where the physical unit of fuel volume per unit distance is used, such as litres per 100 km (l/100 km). For EVs the original energy consumption unit kWh is measured at the battery terminals and makes it easier to use kWh/km when calculating the driving range per battery charge.

4.3.4 Energy efficiency

The CV is not as energy efficient as the EV and there is a huge amount of energy from the fuel that turns into the energy waste as heat. There is actually only about 18-25 % of the energy available from the fuel that is used to drive forward. When driving an EV it becomes clear what actually is used for the propulsion.

Since the EV is very energy efficient but also sensitive to external factors effecting the energy consumption, it is hard for EV manufactures to calculate the energy consumption for EVs and usually the distance to empty (DtE). In optimal cases (if driving carefully and if it is 15 degrees outside when neither heater nor AC is needed), it could be possible that the car is being able to drive the distance the car manufacturers have said, for example 200 km. But, in case of a worst situation where the temperature is minus 20 degrees and the heater is turned on, then the car might only reach about 100 km.

The electric energy from the battery is needed for to three things: to overcome rolling resistance/air resistance, to accelerate and to drive any help systems. The energy that can be used to overcome rolling resistance/air resistance and to drive auxiliary systems will never be returned. But in the other way when accelerating it generates kinetic energy which can be stored as electric energy in the battery.

Sensitivity to external factors

The battery is temperature sensitive and only within a narrow range it has full performance. As when it is cold outside the performance is affective, compare to a CV that also has poor performance when the car is cold but the engine of the CV in the other hand produces heat which will higher the temperature after some use.

If the battery is cold, it takes more time to reach full performance. In these temperatures when starting the EV the power is low and the full performance cannot be reached and other systems in the car takes more energy than usual. It is not possible to gain access to all the energy that would be available if the battery was warm. The battery will not be warm by itself, in order to have good performance it is important to add heat to the battery and keep it in a pleasant average temperature. Today there are cooling and heating systems which help controlling the temperature which is nothing the user needs to handle. To prepare the EV for cold weather the best thing is to have the charger plugged in to avoid that the battery reaches a low temperature. If the car has just been used and the battery is warm it takes a while for it to get cold again because of the large size of the battery. However, this does not seem to affect the use of the EV geographically since many EVs are used even in colder climates as in northern Norway.

4.3.5 The battery

The EV has a HV battery and most EVs use lithium-ion batteries, the HV battery consists of many smaller cells. One single unit cannot usually be replaced and the ambition is that all cells should age equally fast. The lithium-ion batteries are based on materials such as cobalt, magnesium, nickel, and graphite. Non are classified as rare earth metals, although some substances are hard to find. The aim for many EV manufactures is to create a “closed loop” recycling system for the battery cells and be able to recycle them into raw materials for future use.

Lithium-ion batteries is mostly used in EVs since these have some advantage compared to other battery types such as higher energy storage capacity and longer lifespans. Still, the battery has a high weight and are expensive. Today, the improvements of battery technologies are a major priority in research of the development of EVs. Much work is being done on lithium batteries in labs and developers are trying new variations on lithium chemistry to provide fire resistance, environmental friendliness, rapid charges, and very long lifespans. EVs must undergo safety testing and standards for limiting chemical spillage from batteries, securing batteries during a crash, and isolating the car from the high-voltage system to prevent electric shocks. The battery is the most expensive part of the EV, but since the production scale of EVs have increased and manufacturers have developed more cost-effective methods the price of lithium-ion batteries is much less compared to a few years ago.

Depending on the car model the capacity of energy storage in the battery differs. If for example an EV model has 100 kWh installed in the battery, it does not mean that the user can use all 100 kWh. To be able to maintain a good life span for the battery, approximately 80 % of the battery can be used for energy storage. This means that the user of this EV model can only use around 80 kWh even if the car manufacturer says that the car has been installed with 100 kWh. The car will not permit the user to use the full capacity since in a longer period of time the customer will be happy with a car that has a longer life span. Instead of giving this information to the user and risk to confuse him or her, the car will show SoC as between 0-100 %, while it in reality it might only be 10-90 % SoC. In addition, the customers are recommended to charge the car not more than 80-90 % to further save the health of the battery.

In the electric drive the control system of the car knows all the time about how much kWh there are in the battery, but the thing that decides if the battery can be used at all is in the end the voltage in the battery. If there is still 3-6 kWh left but the voltage is too low, it will not be able to be used. When the car shows the SoC for the user, this number is only an estimation since the exact amount of energy in the battery is not east to measure in a good way. The number is based on the voltage in the battery and by advanced calculations a try to estimate the amount of energy left in the battery is made, which is named SoC. Normally, the voltage is measured when the battery rests or when it is fully charged or to a high level. After that, the method “coulomb counting” is used (current in and out of the battery) and thus get a value. In the future car manufactures might install sensors which actually measure the correct amount of energy, but there is still more research needed in the area.

Today, the driver only gets information about the SoC and SoH which are described earlier in the chapter, but in reality there is another important parameter called State of Power (SoP). SoP tells how much power the battery can deliver/receive and is important for the control system. SoP is not showed for the driver which can lead to misunderstandings in some situations when the car will not start even when the SoC shows that there is still some battery left. The three parameters SoC, SoH, and SoP decide all three together if the battery can be used or not. If one of them are too low, the battery cannot be used and the EV will not be able to start.

The battery is, as described earlier, sensitive to extreme temperatures, and this is because the SoP is sensitive to this. If the battery is cold, there is a strict limit from the SoP when the battery can be used compared to when it is warmer and the battery can be used despite a low SoC. Since the driver do not get information about SoP, the SoC instead can differ depending on the temperature of the battery. One example is that the SoC could show 0 or 2 % in the evening when the temperature is low, while it in the morning when the sun is up and the temperature is warmer it shows 10 %. This is because the SoP and the voltage was low when it was cold and the car did not allow the driver to start, then the car instead lies for the driver that the SoC is low. This type of situation is something that many people can relate to when handling similar battery products, as the mobile phone where the battery percentage can drop suddenly in extreme temperatures. Compared to a mobile phone the battery of the EV possesses a much bigger volume of material and are therefore not as sensitive concern ambient temperature variations as the phone, which is why it will not surprise the user to the same degree.

Many EVs also have the classic 12 V battery. The 12 V battery originally comes from the CV and have the purpose of starting the gasoline engine in this type of car. In an EV it is used for the radio, seat heating and dashboard etc. Today the energy in the 12 V battery comes from the HV battery. It can seem confusing why there is a 12 V battery, but one of the reasons is the safety aspects. It is classified as dangerous voltage if a battery is above 60 V, which the HV battery is, and if the user would interact directly with it, it could cause harm. In the future, the large battery should be able to generate high as well as low voltage and all the electricity used in the car will then be used from this.

The battery is aging all the time not only during usage, and this is an important aspect in the automotive industry. Temperature is a determining factor for aging when the car is not in use, warm temperature is not good. Depending on the usage of the EV, some state that the battery can be used 10-20 years before it needs to be replaced. After these years the car will probably be scrapped instead of replacing the battery since it is very expensive. There are requirements for how long the battery shall last and the warranty most manufactures are offering is 8 years, but car developers design the battery to last for 15 years. When the maximum energy charging level is limited to 80 % of the original level because of degradation, the life of the battery is considered to be depleted. Although, of course it depends on the needs of the user, if someone only needs a low available range then the car might still work fine for this user’s purpose.

4.3.6 Charging

The charging part is one of the biggest problem of the usage of EVs today. The user needs to take responsibility to charge the car and the charging time is high, which sometimes makes it troublesome. The common way to charge the EV is to plug in a cable connected to an electric source. There are multiple ways of charging and there are different connectors since the manufacturers have not agreed on one standard for all cars. Depending on the car model this procedure can look different and also the speed of charge can vary.

The battery in the EV have to be charged by DC. Therefore, the AC power supplied by the mains must be converted to DC before it can be fed into the battery. The part which converts the current takes valuable space in the car and are heavy, which have led to different ways of placing it. Either it could be placed on-board or as an external part which results in two different chargers.

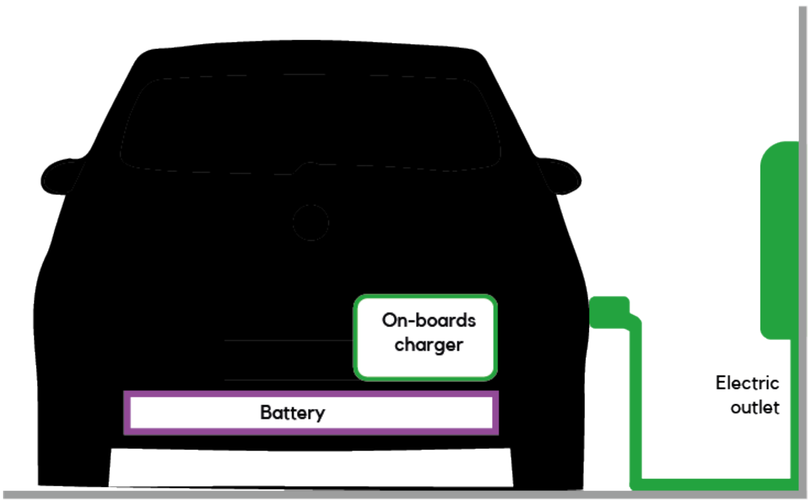


Figure 4.7: Illustration about how BEV can be charged, here with an on-board charger.

The problems with charging are under development and there is much ongoing research in the area trying to make the speed of charge as fast ha possible, and to make it easier for the user. In the future manufacturers want to cut off the task of charging for the user and the car should be able to handle it itself. Developers have recently presented alternative wireless chargers that enable autonomous charging, something more drivers might use for their EVs in the near future.

Internal charger - Internal or “On-board” Charger

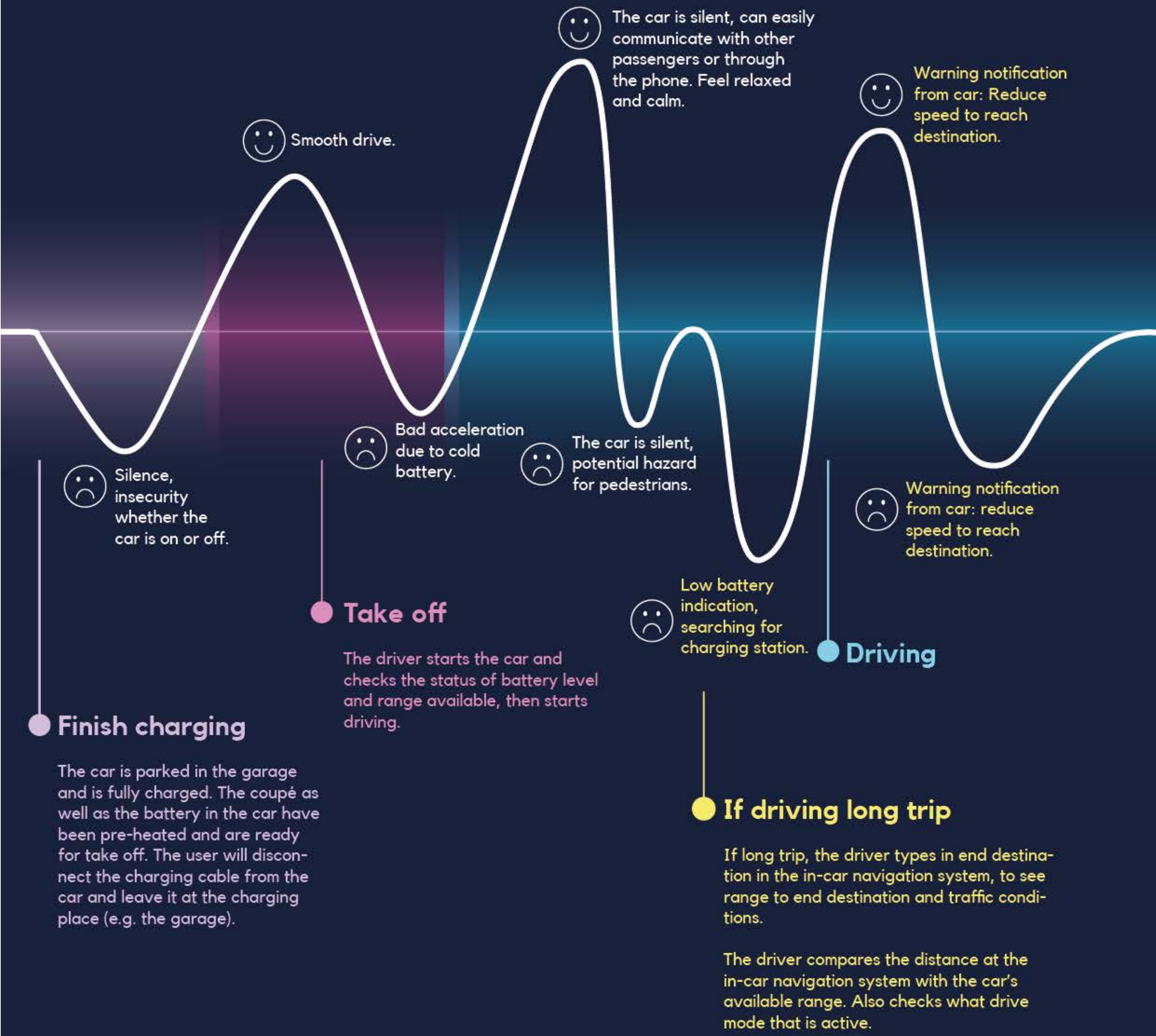
In the on-board charger (OBC) the current transfers from AC to DC inside the component which is built into the car itself. The EV and its OBC manages the charging and internal power flow itself. This charger can directly be connected to a house plug in. Depending how fast the car can charge with AC power it will decide how effective the car can charge. This is why it can take about 4-16 hours to charge the car with an OBC.

External Charger

When the EV possess the function to use an external charger the component which transfer the electricity from AC to DC has moved out from the car to a charging station. This makes it possible to deliver high power, higher speed of charge and simplifies the construction of the charger in the car. The disadvantage of placing the charger in the charging station itself is that it is very expensive. In the external charger 80% of the battery level can be charged as fast as in 20 minutes.

5. User behaviours around the EV

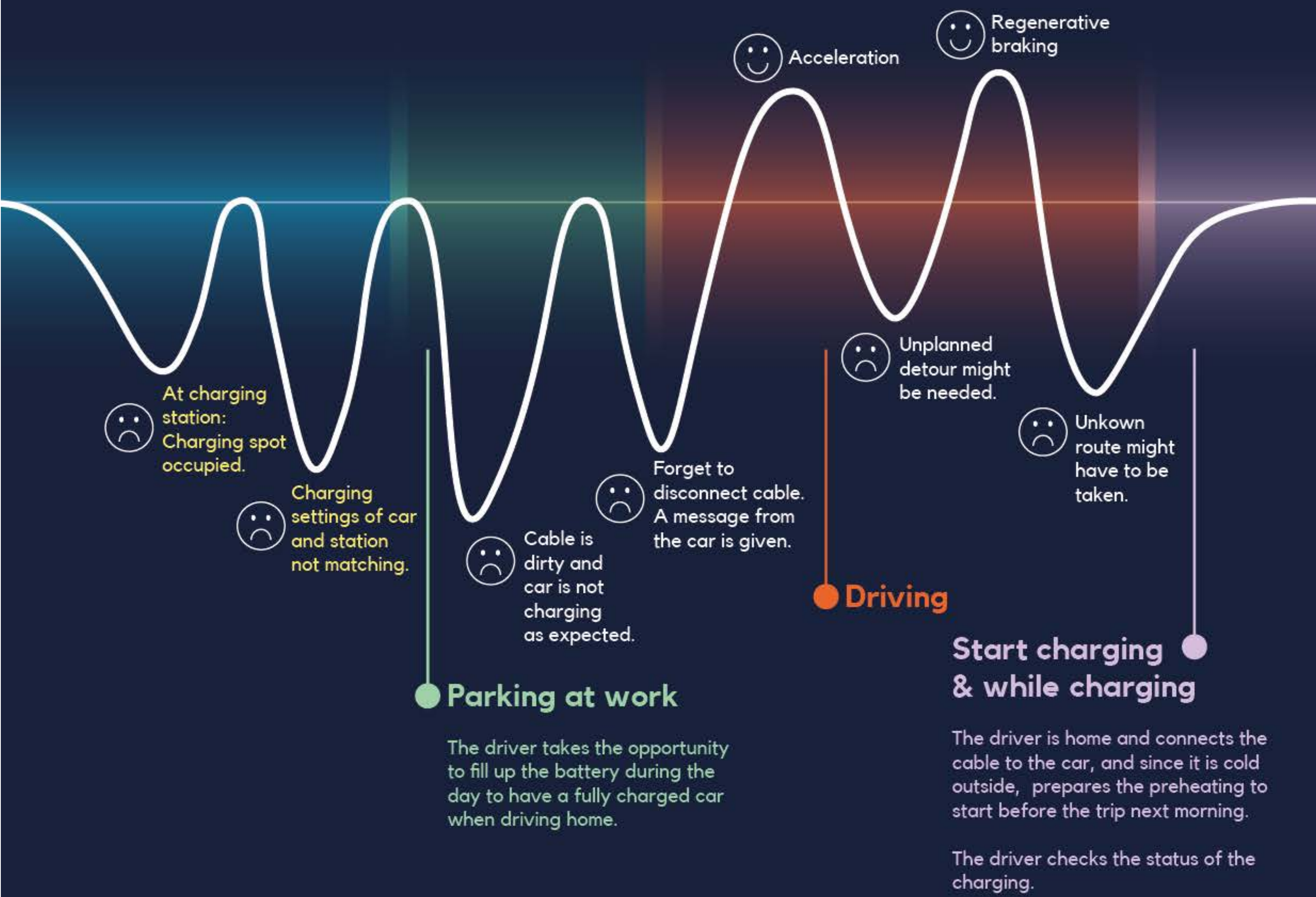
Since the EV function in another way compared to a CV, driving an EV leads to new behaviours and potential problems. Following, a user journey of the most common trip and the related behaviours and problems are presented.



5.1 User Journey

The user journey describes the normal usage of an EV from a user perspective. It gives an explanation of how driving an EV today can look like, what the driver encounters during a normal trip and positive and negative emotions that may occur.

The user journey mostly illustrates the driver's interaction with the EV during a common trip, which we call the "everyday-trip", back and forth to work. This is the normal trip many of the participants in the study use the EV for. According to the interviews, it is 50 km in average and the car is used almost every day, as a car to commute. In the survey the participants drove on average 30-60 km without charging and 85% used the car everyday and 13% used it a couple of times a week.



Depending on the car model of the interviewees, some people also did longer trips (400-800 km). It was clear from the study that the EVs with longer range were used in a different way compared to EVs with short range (150-200 km). A car with long range was for example Tesla, which also was used by many participants in the study as a transportation for road trips during vacations. One interview person said she would rather take her Tesla then fly the same distance since it was much lower travel cost.

Therefore, in the user journey there are some touchpoints considering the more occasionally longer trips (yellow) some users did since it affects the experience and the actions for these users. Other aspects that also affect the journey, such as other people or products, are also considered and contribute to the illustration.

5.2 New user behaviour

The functionality of the EV creates new user behaviour for a user when switching from CV to EV. New user behaviour regarding range, energy consumption, driving style and charging are presented in the following paragraphs.

5.2.1 Driving range is sometimes an issue

In line with other research, presented in theory, range related to EVs is a wide spread problem around the world, see figure 5.1, considering all car models in the research of this study except Tesla. Even though research show that no one would turn down a better range, this study has found that the perceived problem of range is related to the two different occasions of driving presented in the user journey: the everyday trip and the longer trip, in different ways. both which have new different charging behaviours.

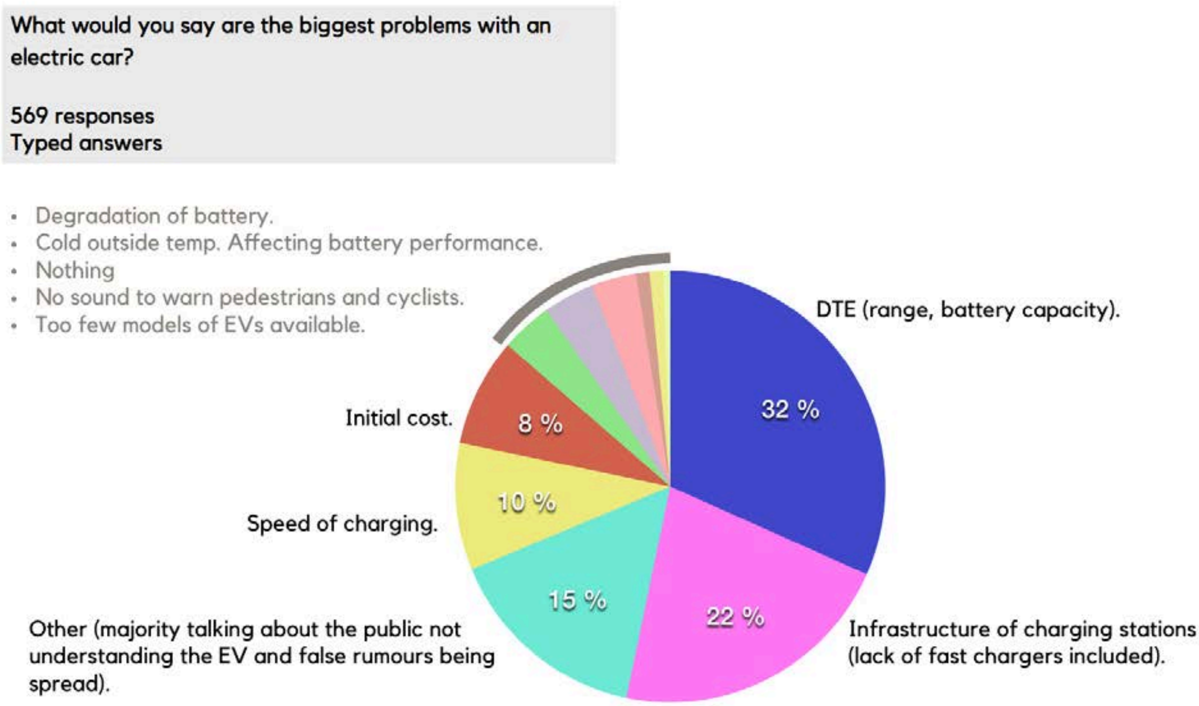


Figure 5.1: What EV drivers think is the biggest problem with the EV.

The available range of the EV is usually enough compared to the everyday trip that is mostly driven and the driver does not feel limited by this range. While driving these very common commute trips the driver does not put much attention on the battery level or the DtE indicator since the route is very familiar. However, with an EV there is still much more need for planning if driving a longer or unknown route, compared to driving a CV since the EV has lower range and the user needs to change his or her behaviour and routines.

Most users charge the EV at home and always try to plug in the charging cable whenever it is possible. This results in a fully charged car every morning, as the car usually is charged during the night. The new user behaviour is accepted among the participants in the study and is confirmed by literature from the theory chapter. Other aspects concerning the planning part for the user and to not waste valuable mileage are to pre-heat the car before start driving. To warm up the car's coupé and battery takes great energy from the battery, especially if it is cold outside. It also takes a lot of energy to drive with cold battery which leads to lower available range and the car's performance is affected. Many users pre-heat the battery while the charging cable still is connected, which save energy that can be spent on traveling instead. The pre-heading is usually set the day before in the car or via an app connected to the EV.

"Once, when I sat in the car with the heat on for 15 minutes. It used a lot of charge."
-Interviewee

Requirement: Enable to set starting time for heating of battery and inside climate of the car.

Driving longer trips requires an EV driver to plan the trip more in detail beforehand or during the way due to the limited range of the car, and it sometimes forces the driver to stop and charge during the way to be able to continue to drive. Depending on which car model that the driver has, and therefore also available range, some drivers choose to not conduct longer trips with their EVs. Since this will result in multiple stops for charging, which is time consuming. The car models which the users usually do longer trips with have a range over 400 km. During longer trips the driver pay great attention to the battery level and DtE. Participants who did not choose do longer trips seem to be positive using the car for longer trips if they would have had a car with longer available range and then to plan the stops did not seem to be a problem.

5.2.2 Greater focus on energy and range

When switching from a CV to an EV the focus on the car's fuel/energy level becomes greater, something that the user may have never thought about before. The difference in fuels and engine also makes the EV with its battery harder to understand technically. During the interviews it became clear that the battery with its chemical energy feels mysterious for people and in general other products' batteries are perceived in the same way. One interviewee said that he did not trust his phone in situations when it is cold outside, which he compared as a product with battery, and explained that the phone's battery could drop suddenly. However, in the survey 98 % answered they trusted the battery in their EV and 78 % wrote they had never been surprised by the battery level, see figure 5.2 and 5.3. Anyhow, in figure 5.2, one tenth of the respondents expressed that they were especially surprised by the car's battery level due to cold weather. This elicit the question how much users actually understand what is affecting the battery level of the EV. Figure 5.4 shows that 84 % of the respondents in the survey understood what are affecting the level, but 9% felt that sometimes the battery level changes suddenly without them knowing the reason. Continuously, 6 % said they did not understand what is affecting the level but would like to know more about it.

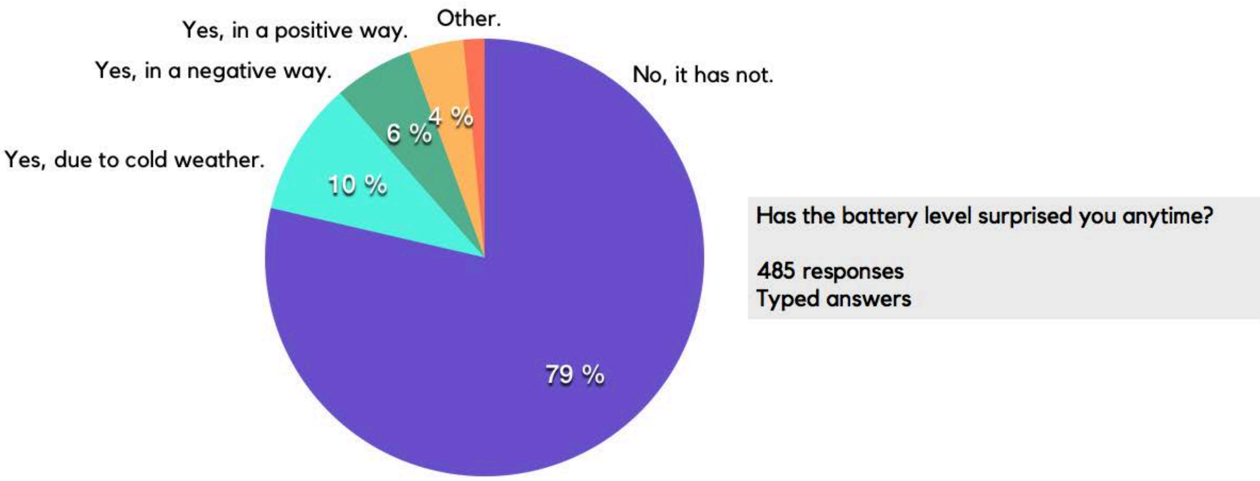


Figure 5.2: EV drivers' experiences if the EVs battery have surprised them.

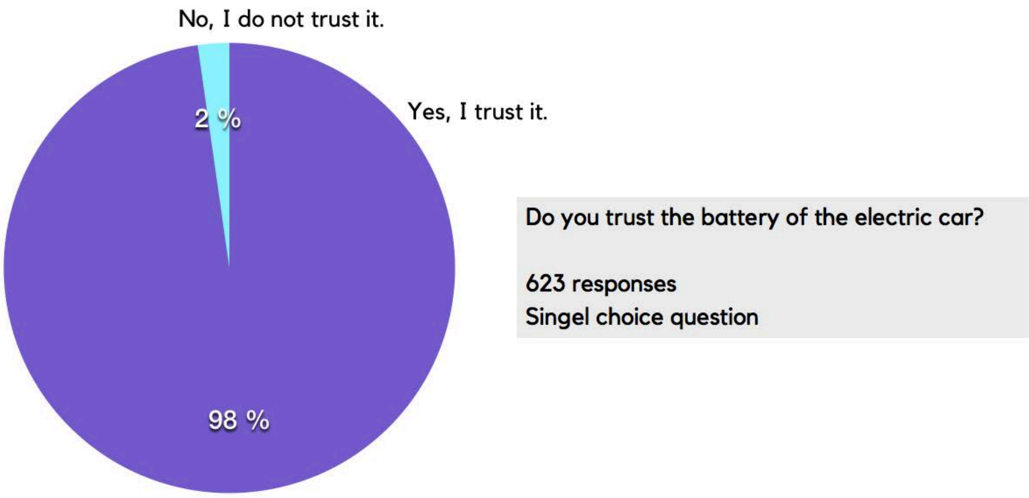


Figure 5.3: If EV drivers have trust in the EV's battery.

The problem concerning that the user does not understand what affects the battery can be one of the reasons why the well-known expression range anxiety exists, which can be read about on page 22 in the theory chapter. Our study indicates signs of this phenomenon from drivers with less experience, both from users with cars which had longer range and from user with cars which had shorter range. One example is an interviewee who described a situation where he was forced to drive in 50 km/h at highway to be able to reach a charging station. The reason was that he could not drive in the high speed (130km/h) he drove since the energy consumption is too high, which he learned after some experience. Another interviewee explained the differences in use of the EV between him and his wife who has less experience. She got more worried and stressed compared to him in situations where the battery was low and there was a chance by mistake take a detour, that consequently would use more energy and then not to be able to reach the destination.

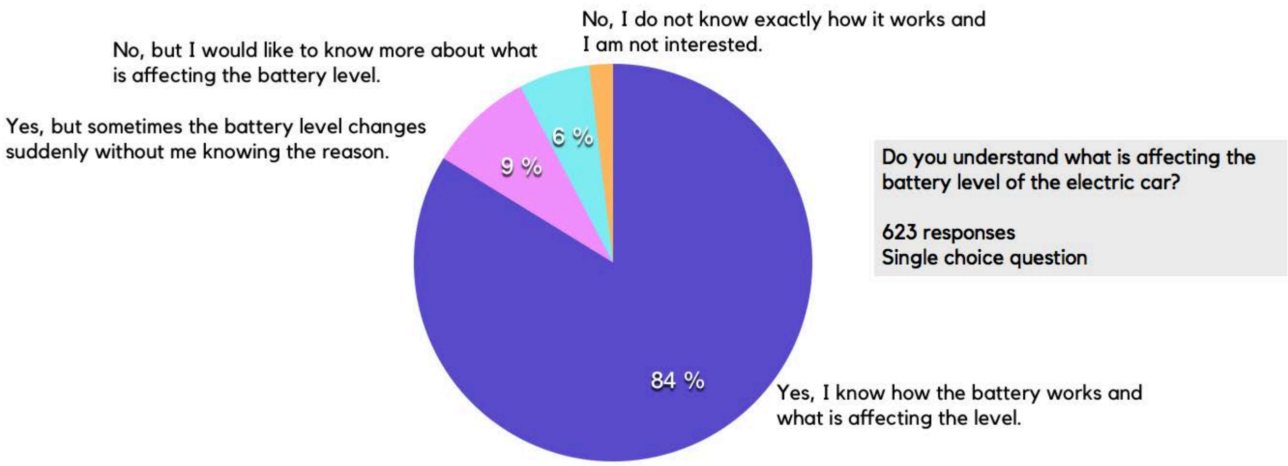


Figure 5.4: If EV drivers think they understand what is affecting the battery level in the EV.

However, it appears that this problem is evident in some situations for experienced drivers also and then especially for cars with short range. Another of the interviewees said that she always intentionally plans to keep a comfortable margin left on the battery level to maintain calm and to not worry. This directs to the expression of an overcautious behaviour, which can be linked to range anxiety which are more described in the theory.

"I take a chance sometimes that the battery will be enough, but then it could be that you have to drive in 50 km/h at the highway. Then I turn off everything, AC, radio and it is freezing cold."
-Interviewee

"I am never at the verge, so I never worry."
-Interviewee

Another situation where range anxiety emerged in our study was when the driver had low battery level and a new route was driven. In this situation the driver possesses general knowledge about the calculation of range, but since the route is new the road's elevation changes and speed limits are unknown for the driver. If the driver does not use an in-car navigation system the car’s predicted range is in this case very mistrustful for the driver, since it is known that the calculation of predicted range is a difficult. The service to give as accurate range to the driver as possible vary greatly depending on the car model. It was clear from our result, see figure 5.1, that EV users do not trust the predicted range shown in the car, and many participants in the survey referred to it as ”guess-o-meter”. The guess-o-meter can be paired specifically together with Nissan Leaf where many of its users were disappointed about the predicted range, this can be substantiated with some of the literature presented in theory, see page 23. In contrast, a good example of showing the information more correct is Tesla which many of the participants in the study have expressed a positive attitude towards. Tesla is one of few car models which has been able to predict the range more precise then others, according to our research people tend to trust the range estimation of Tesla to a greater extent. To understand what is affecting the calculations of range in an EV, see chapter 4 page 57.

Requirement: Maximum range shall not be less than X km.

5.2.3 Saving energy

Among EV drivers there are different reasons for the attempt of saving energy in the battery, but something that reflects in different users’ behaviour was in the situation where the car had a low range and the goal was to reach a destination. The persons who used a car with a long range were eager to save energy when they were driving long distances, and by that reduced the amount of charging occasions. Other people try to save energy for environmental sustainable reasons which can be connected to the grouped called ”engaged greens” from the study presented by Axsen et al. (2012) in the theory chapter at page 27. These persons’ mind-set can be described as they in general do not want to spend more energy than needed. The third reason for the attempt of saving energy could be seen among the interviewees, and it was related to many of the persons who drove an EV with short range. Those drivers were keen to save energy in some situations, as for example if they knew they might do some extra trips later that day or that the distance home to the workplace back and forth was exactly the car’s available range.

To save energy, people had many ways to do this. Many of the ways were "correct" and we understood that people had learned what in the car that consumed energy and what actions were needed in order to reduce the energy consumption. When people wanted to save energy, the speed of the car was usually reduced, experienced drivers tried not to accelerate as much as before, and the comfort of the car was often less prioritised as they shut off the heater, AC and seat heating. People accepted less comfort when driving with a short-range car. At the same time, participants in the interviews also expressed disappointment about the strict energy usage to be able to maintain an acceptable range. One interview with a user of the car model BMW i3, described that his routine was to always shut off the heater, which lead to a very cold climate in the car and he was freezing during the winter. He felt he could not allow himself the same comfort as with his other car, which was a CV.

"When I have to save energy in the battery it gets colder in the coupé than you could imagine, feel that I have to lower the energy consumption to make sure that I will get home."
-Interviewee

From aspects concerning the EV's energy consumption and sustainability approach we have seen that it is relevant that the car shall have smart solutions that save energy, but still not compromise the comfort. During the interview with one of the technicians the need of research of smart solutions which are driven by limited energy were expressed, research in this area have not been needed until now since CVs have been used mostly. The HVAC system brings great comfort for the user, but it is also consuming a lot of energy in the EV. One idea is to heat specific parts of part of the driver's body, instead of heating up the whole coupé of the car. This could save a lot of energy and therefore also range, and at the same time result in maintained comfort for the driver. The EV can also be built in a way were the focus on isolation is bigger, to keep the heat. Another thing is to use low energy consuming lights, like LED. Chapter 7 is further discussing the energy consumption from an information point of view, to make the drivers understand what and how energy is used.

Requirement: The car shall be isolated to maintain the quietness even in high speed.

Requirement: The car shall be possible to use comfortably with a low energy use.

The study also shows that EV users express that they actually want to drive fast with their electric car, one participant said he wants to drive as fast as with his other car, Volvo XC60. But the drivers normally do not do this, due to limited range. A new driving behaviour, almost required, for EV users is to instead of driving fast have a driving style that is in favour for low energy usage to reach as far as possible. Yet, several drivers say they do miss to drive in higher speeds.

Both in the survey and in the interviews, people said that in some occasion they turn off the mode that restrict and help them to control the energy consumption (in many cars called ”eco mode”), in order to be able to increase the speed rapidly for a second, both in necessary situations where acceleration is needed and also just for fun. One participant, who is environmentally friendly and belongs to the group called "engaged greens" said that she turns off the eco mode sometimes to enjoy the performance of the car, as the rapid response when accelerating, but since she felt it was against her sustainable approach she only did this very rarely.

"Aware of saving energy, you cannot drive in 140 km/h at the highway."
-Interviewee

However, something that was seen as the opposite way of saving energy and that was expressed by other participants with a pro-environmental attitude but less than the engaged greens, was that the car was used more often than before when they drove a CV. This was a common mind-set among the participants in the study, just as seen in previous research presented in theory.

"I appreciate the performance of the EV and that it does not feel environmental-disgusting to use the car. It is okay to drive shorter distances, going to the supermarket an extra time."
-Interviewee

5.2.4 One pedal drive

The two new user behaviours the driver needs to learn, one pedal drive and the regenerative braking, seem to be appreciated among drivers. During the benchmarking when we had the opportunity to test drive EVs, we felt that these functions were a new experience but after some minutes it became natural.

The one pedal drive was very different between the different car models and we think it is important that the drivers themselves can adjust the hardness in the break of the pedal. Sometimes there was a situation where the car was braking hard and it resulted in the opposite of a smooth drive. The participants in the interviews said that one pedal drive felt useful, and that it made them feel like they did not have to use the brake pedal as much anymore.

Requirement: Enable the driver to adjust the responsiveness of the brake in "one pedal drive".

5.2.5 Regenerative braking

The regenerative braking was an interesting feature to study since it was expressed very different visually among the car models. Many of the UIs in the car models that were driven in the benchmarking were not intuitive and we felt that they did not show correct information. It was not clear how much amount of energy that was used by the motor to drive forward and how much energy that was actually regenerated back to the battery. The interviews showed results of that the visual representation of regenerative braking was appreciated, since participants said that they got happy when it showed green when they had regenerated energy.

"Some cars are very good at showing it, how many kW that is going in and out. But I think it should be promoted to 'roll' out the energy, not braking, to use the energy that you have... It should be simple.
-Interviewee

"Nice to see how much the car is charging when releasing the gas and how much energy that is going back into the car. Nice to see the energy flows. Of special interest when you have limited energy, if you have a car with low range or if you are travelling longer. I am interested of seeing it, but I am not adjusting my driving to it."
-Interviewee

5.2.6 Eco coaching

Some of the car models had eco-coaching which was received differently among the participants. The drivers of Nissan Leaf, which was a car model well represented among the people in the survey, showed a negative attitude towards the design when being an experienced driver. Nissan Leaf indicated the level of eco driving by building up trees in the UI together with a circle that was filled in depending on the driving style, which no one of the participants in the interviews could explain thoroughly. Most drivers claimed that they looked at this information when they were new to the EV, they felt that it was rewarding to see when they drove more environmental friendly. However, after some time they did not use it and the feelings towards the function instead become negative.

"It is like a video game, ooh now I get a tree! How good I am. I want many trees. Nice when it is shown visually."
-Interviewee

5.2.7 Charging

Many of the participants in the interviews were very positive to their charging routines. They usually charged at night at home with their fixed charger connected in the garage. But when this was not the situation and they needed to bring the cable and charge at a charging station there could be problems. The infrastructure of charging stations available and speed of charging were the second biggest problems with EVs today according to the survey (see figure 5.1). In general, the drivers who seem to not agree on this, drives a Tesla and therefore have access to Tesla's additional infrastructure of chargers around the world. However, the actual charging procedure of using a cable and connecting it to the EV does not seem to be an issue according to most participants. Interviews showed that the participants that did not have a fixed place for their cable outside their vehicle (e.g. the garage), and instead took it with them in the trunk, found it a bit troublesome to use. It was found to be dirty at many times, which was not appreciated when touching it and placing it inside the car when not used. According to the benchmarking and one of the interviewees, it was also found to be clumsy to handle.

"Damn the charging cable have to be disconnected too, then you go out and disconnect it, and then it was dirty! I got a bag to it, but I never use it. I had to replace the cable 2-3 times because it did not bear water."
-Interviewee

Requirement: Enable fast charging.

When driving longer trips with the EV there will be stops at charging stations and the driver needs to wait while the car is charging. This is one of the few times when the driver feels restricted about the longer charging time compared to fill up a CV. Many charging stations have fast chargers and to charge 80 % of the battery takes around 20 min. To make the charging time as short as possible when making stops during long trips or emergency stops is important for the overall user experience of EVs in these cases. However, if the EV users are driving a longer distance and have planned the charging stop beforehand our study shows that EV drivers have accepted the longer waiting time in these situations. The people who drove a Tesla in the interviews clearly expressed that they needed to make a stop anyway at the same time as the car demands to charge since the driver needs to take a pause from driving after some hours or, for example, there are needs to use the bathroom. It was only when the stop was unplanned and was perceived as something that there was not time for, as it was considered a bigger issue.

"I need to plan my trip more. It is no problem. And we who have kids have to stop for a break anyway. But, you have to firstly check if it is possible to charge where you plan to do it."
-Interviewee

Sometime in the future the way of charging the EV will probably change and the car will be able to charge through induction in the ground instead. This means that there is no need of the fast chargers or charging stations since the infrastructure might include these charging inductors in areas where the EVs are usually used, as in front of red lights or on highways. To make this clearer; the EVs could be able to charge while they are used which will save a lot of time for the user (Fagan, 2017).

Requirements: Enable to charge without need of bringing the cable in the car.

Requirement: Enable to charge car without cable.

Requirement: The charging time should be minimised as much as possible.

"In the big picture, not a problem. But of some reasons it was a problem... It is dirty because it has been hanging outside and been lying on grass and it often got some mud on it, and then it is supposed to be put in the trunk."
-Interviewee

Requirement: The cap to the charging port shall always be possible to open in a simple way.

Requirement: Car shall be easily chargeable.

6. Total user experience of the EV

This part of the project presents results related to the UX of the EV, why people choose EVs and how it is considered as a mean of transportation related to new user behaviours. Furthermore, results of how the UX could be increased, regarding aspects as the silence of the EV and taking advantage of the unique properties, and also how the EV identity could be expressed are presented.

6.1 Why people drive EV?

Our studies show that people choose to drive an EV of multiple reasons, as seen in figure 6. The most outstanding being of environmental reasons, that the EV is connected to the future, it is cheaper to drive than a CV, for the performance and because it is perceived as fun to drive.

6.1.1 Environment and symbolism

The two most popular reasons why people choose to drive an EV are for a more sustainable environment and that people identify the EV as the future, as seen in figure 6.1. This was also found to be a general way of thinking among the interviewees, they agreed on the EV as something that symbolises the future. Comments such as it stands for someone that cares for other people, want to be ahead, that you feel cleaner and have a ”greener consciousness” were mentioned among the participants. Over 35% associated the environmental benefits, as the zero emissions, to their kids. Two of them mentioning that they should not have to breath in the toxic air from combustion of fossil fuels and that they want to contribute to a better environment for them.

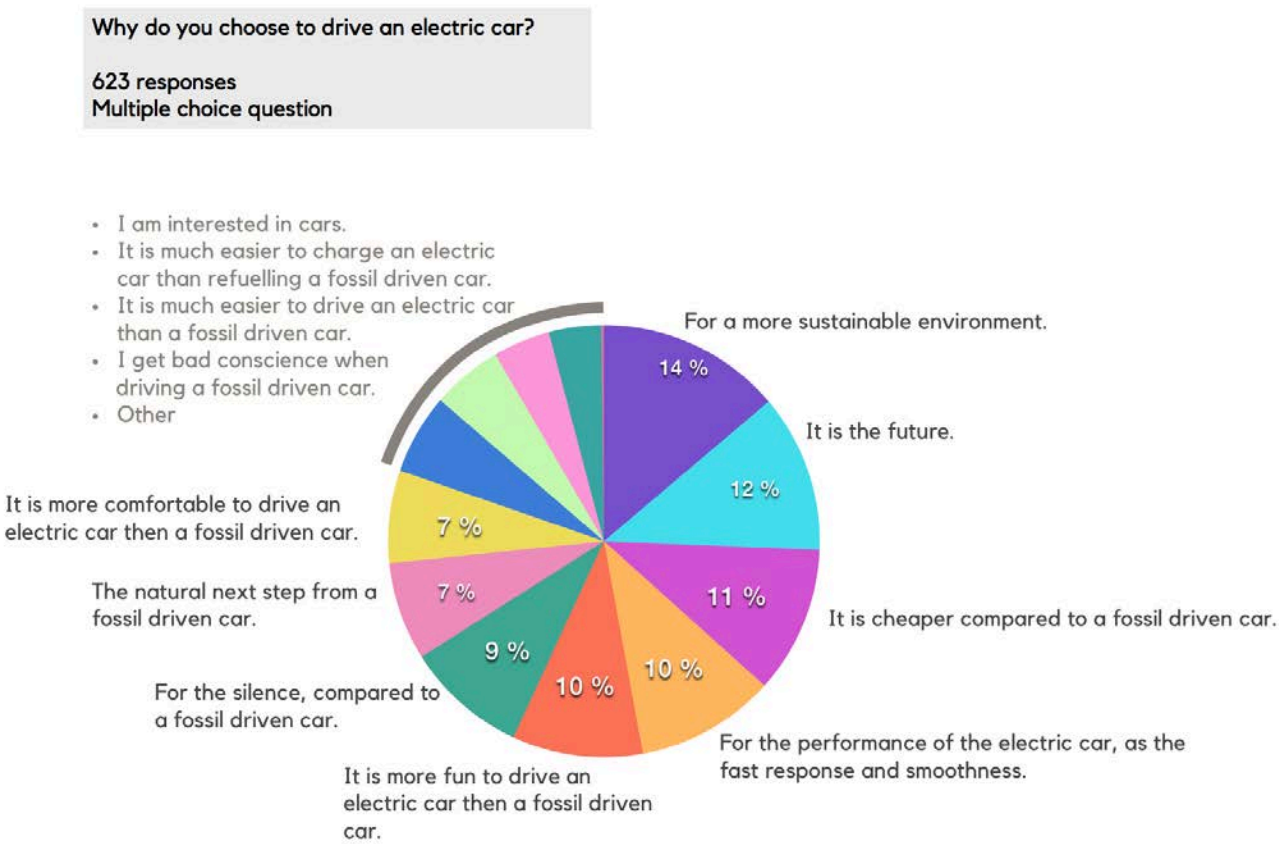


Figure 6.1: Why people choose to drive EV.

"I got a bad conscience when I had dropped off the kids at school, all the cars stood there spitting out exhaustions and the kids were at the swings just beside, toxic."
-Interviewee

"At our street there will be less exhaustion, especially when it is cold outside. In my absolute close surroundings there are no emissions."
-Interviewee

All of the participants in the interviews also did something else in their private life that was in favour for the environment. This was mostly related to waste sorting and not buying too many products, but also producing energy at home or investing in green electricity were mentioned. In general, the interest for technology was evident to some extent, however it was not the focus in what products that were bought within the family. The quality and need of the actual product were more important than a possible new high-tech object.

6.1.2 Feelings of proudness

The environmental benefits together with the forward thinking makes EV drivers feel proud by their choice and sometimes actual proudness when driving the EV on the streets were expressed, one interviewee said *"I rather think that those that do not, are idiots"*. After a time it seems that for many of the participants in the study, the EV is the only choice of car, it seems to have resulted in a new mind-set. A new way of thinking, where the CVs are seen in a new light was evident among several of the interviewees, e.g. noticing how much exhaustion they contribute to, the bad smell and the loud engines.

"I feel ashamed when I am traveling in an ordinary car"
-Interviewee

"One have taken a step towards a greater consciousness"
-Interviewee

EVs are so strongly connected to future thinking that going back to a CV after seems unthinkable, both according to answers from the survey and interviews. The participants do not comment the look of the EV as an advantage since many mentions that they even dislike the look of it, with exceptions for Tesla S and BMW i3 where participants have expressed positive attitudes of the exterior. However potential negative feelings about the look does not seem to prevent or scare away the ones now experienced with EV, since it stands for something else, something more that is much more important.

"Other cars smell bad. It feels ancient to drive a fossil car... Do people really buy these kinds of cars anymore?"
-Interviewee

6.2 Increase the UX

By enhancing the aspects that are considered as positive with the EV the UX could be increased. The silence of the car and the performance were features that should be taken into account.

6.2.1 The silent car

According to this study and supported by literature in the theory chapter the silence in the EV is very much appreciated by users, as many as 99% think it is enjoyable (figure 6.2). However, even if drivers do not tend to perform other tasks thanks to the decreased noise level, they feel much more relaxed and calm, and perceive the drive as more comfortable compared to driving a CV (figure 6.3). This was in combination with the decreased level of vibrations in the EV, together it enhanced the experience of driving.

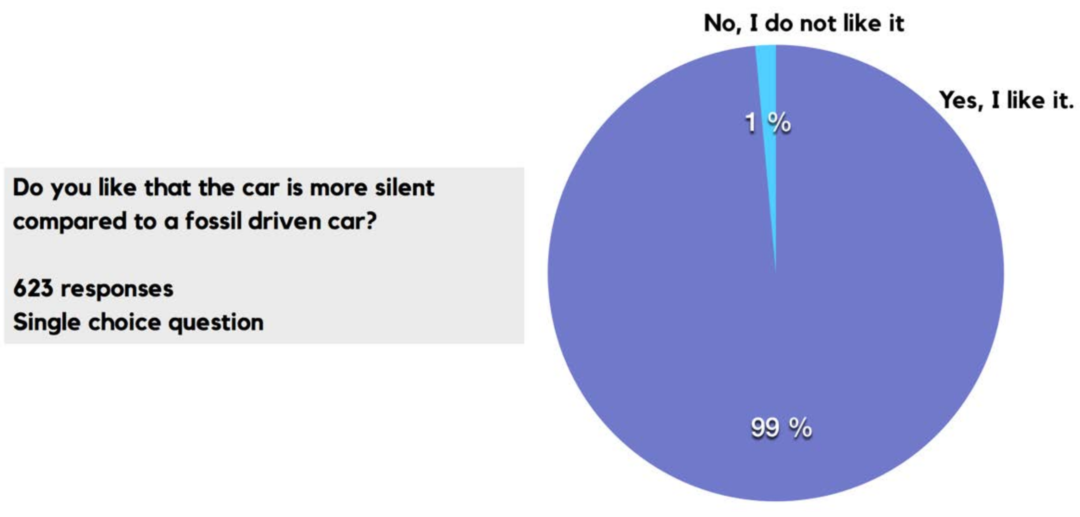


Figure 6.2: What EV drivers think about the silent nature of the EV.

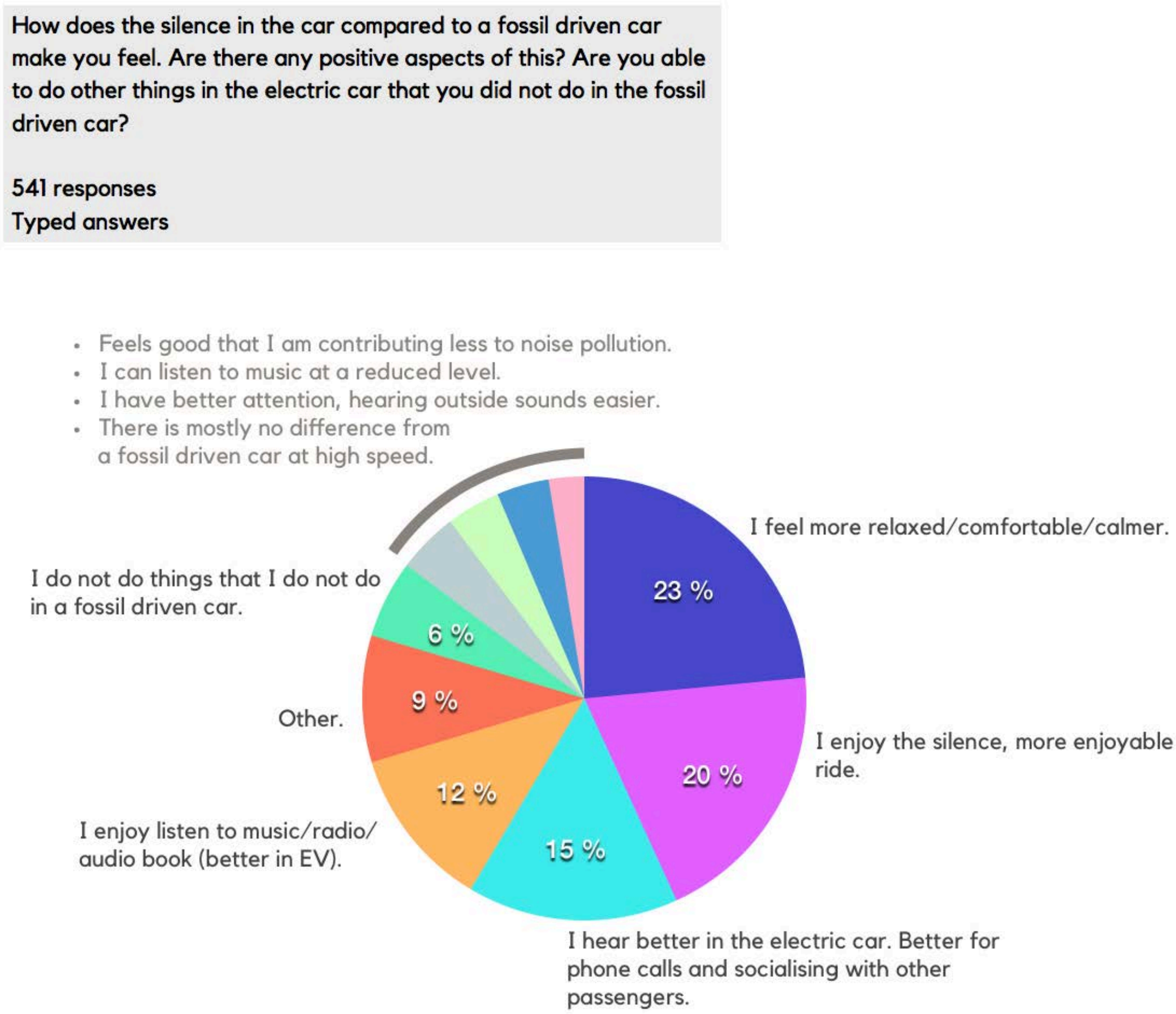


Figure 6.3: How the silence in the car make the EV drivers feel.

Many drivers stated that they could enjoy music better and converse in a better way, both with other passengers in the car and through the phone. This sets higher standards for a good sound system in the car, which are supported by the younger participants in the workshop who thought that a quality stereo would take advantage of the silence in the car.

Requirement: A good sound system shall be installed in the car to give a pleasant experience of music.

"Listen to music, looking at the surroundings. Talking in the phone, answering texts, reading my e-mail. I like driving, so nice to just sit there in the silence, I also like to listen to music with a good sound system. I enjoy material choices, scents in the car".
-Interviewee

Other comments, rarer but still evident, were those about perceiving the surrounding clearer and having a higher degree of attention and awareness due to the silence. Both in the interviews and survey there were drivers stating that this had made them better drivers, since they know the car could be difficult for people outside to hear and be a potential danger. The potential danger of driving a silent car were also clear in the benchmarking when we tried the EVs, although answers from the user studies and previous studies presented in theory show evidence on that this does not seem to trump the positive feelings that emerged as a result of the silence. As the literature propose, most experienced drivers say it may be a worry at the beginning, but not after some experience.

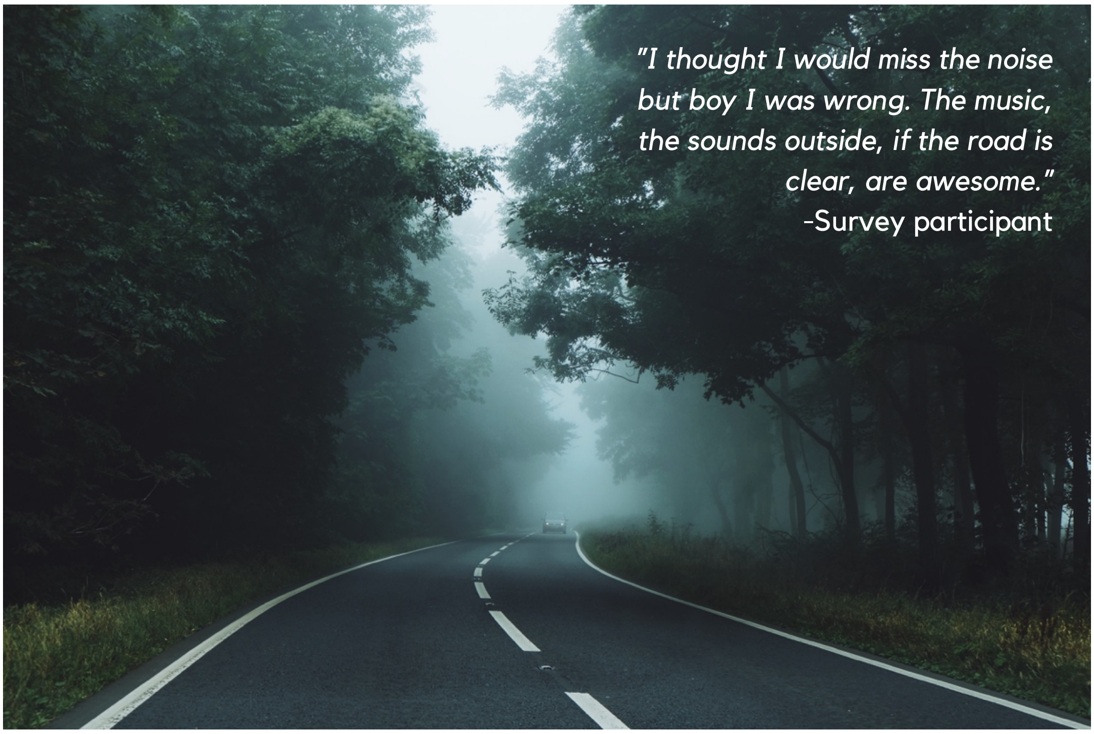


Figure: Alone car driving in silence. Where the driver, for example, enjoy listening to the music in the car.

"I have become a better driver. Need to watch the surroundings because people do not hear me."
-Interviewee

Requirement: The car shall be discoverable by people and animals outside in the vicinity.

However, the drivers agree on the EV basically being on the same noise level as most CVs when driving at higher speeds. The lack of isolation and the vibrations from the road make the positive feelings of the silence in the EV mainly be restricted to when driving in lower speeds. Also, the quality of the road's surface plays a significant role, when driving on a newly paved road drivers expressed a feeling of floating or a feeling of the road disappearing under the car.

"For example, a distance where they had changed the asphalt recently and when you drive on it is like a whole new world! You cannot hear anything."
-Interviewee

Requirement: The car shall be isolated to maintain the quietness even in high speed.

Requirement: Minimise the level of vibrations inside the car.

Requirement: Systems in the car, such as climate control, should not contribute to unnecessary sound.

"Silence is the sound of the future, the sound of fossil cars is embarrassing. Outdated tech."
-Survey participant

6.2.2 A free ride

Another reason why choosing an EV is that it is perceived as fun to drive (see figure 6.1), related to this is the performance of the car which is very appreciated; the direct response from the power train, high rate of acceleration and smooth transitions between speed contributes to a good UX.

"I remember the first time I drove it. Such a high! Such enormous power! And that it does not shift gear… Directly when you touch the gas it starts driving!
-Interviewee

Requirement: Use the unique properties that an EV enables thanks to its technical nature.

Therefore the car shall encourage a drive that is experienced as ”free”, i.e. not making the driver feel restricted, but still maintaining a low energy usage since the range many times can be perceived as limiting. When being in a mode that is restricting the car’s performance, i.e. low energy usage mode, it shall be possible to be easily skipped out from for a moment and deactivating it, because of safety reasons but also because drivers sometimes want access to the full performance since they think it is fun to accelerate hard.

Requirements: The car shall encourage a feeling of a "free" drive, e.g. not showing info that make the driver feel limited.

Requirements: The car shall encourage to a sense of freedom.

The sense of freedom is connected to the previous part where the effects of the silence is presented. Many drivers enjoy the actual drive more when using an EV, both because of features such as better acceleration but also because of the calm feeling and better attention to the surroundings. The workshop showed supporting results of a desire to have a better experience of what is going on outside the car in lower speed, to see more of nature, such as green fields and animals.

"It makes me listen to the outside"

-Survey participant

Furthermore, the interviews showed that when autopilot is available, it is very much appreciated. This also contributed to a sense of freedom and the participants using it claimed that it made them do other things that they would not do if they would drive themselves, like reading the news or scrolling through Facebook. Evidently, the silent nature of the EV, the performance and a degree of self-driving make the drivers experience increase to a higher positive level.

Requirement: Autopilot function shall be available.

6.3 Interior & exterior expressing EV identity

Many people are proud of driving an EV (see figure 6.4), mainly of environmental reasons together with the symbolic meaning of it representing the future, which argue for the EV to also look as an EV. Even if many drivers are positive to this almost as many thinks that it is not necessary that it does. However, as seen in figure 6.4 there are only a few (8%) that have a directly negative response to this. In the survey 54 % answered that they want the car to look like an electric car from the inside ("yes"-answers in figure 6.5) which is an interesting result since this is only affecting the driver's experience of the EV. The mind-set of a sustainable approach together with leading technology could be an interesting way of expressing the uniqueness of the EV.

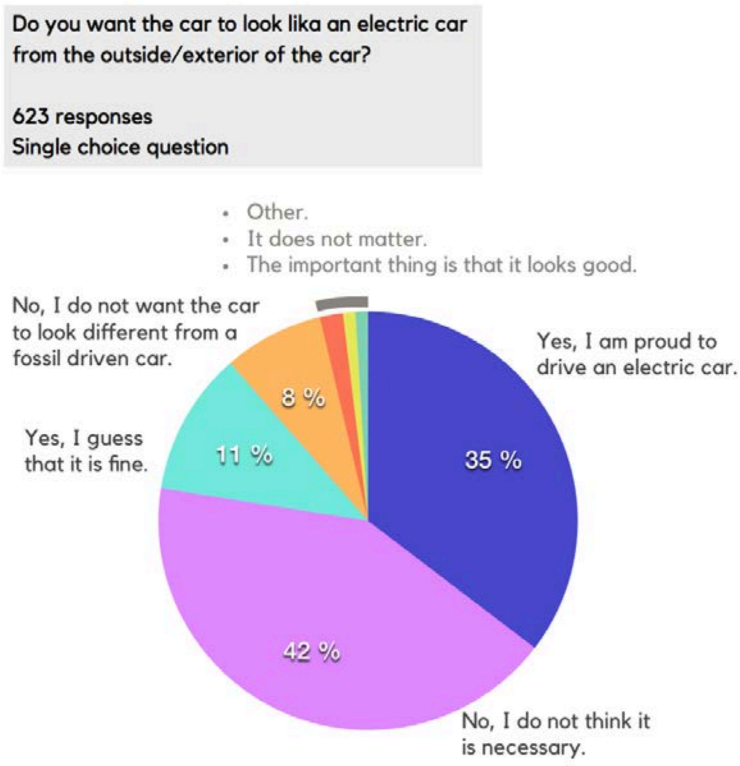


Figure 6.4: What do EV drivers want an EV to look like from the outside.

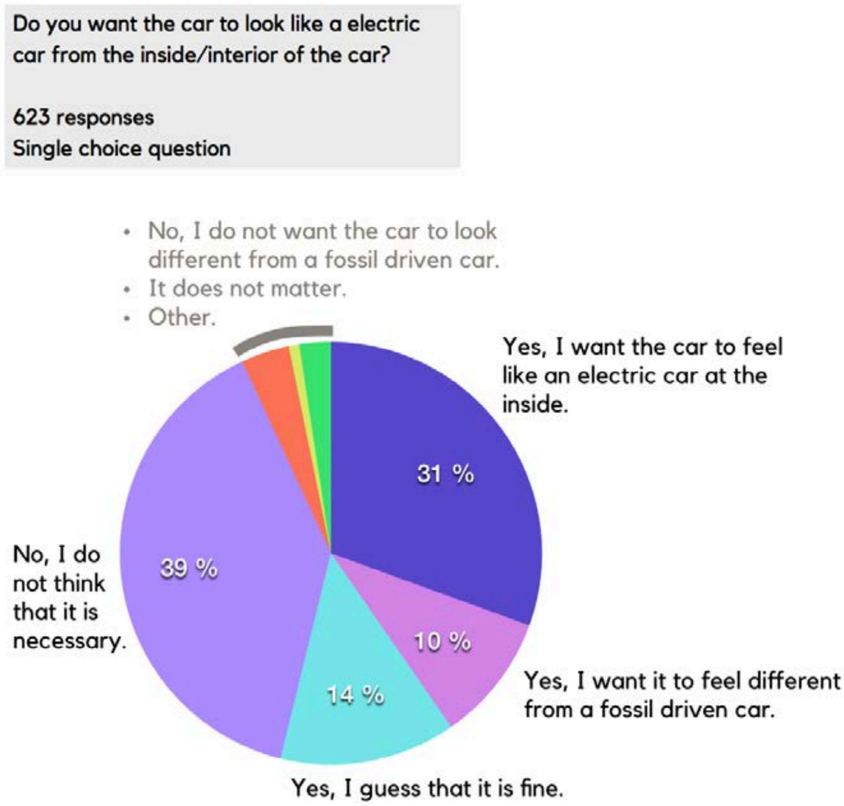


Figure 6.5: What do EV drivers want an EV to look like from the inside.

6.3.1 Colours that express the EVs identity

Today the EV often express its identity through blue visual lines in both the interior and exterior of the car to show that the car is powered by electricity. This was something that was noticed during the benchmarking, and the blue lines was a common theme for most cars that were driven. However, our study indicates that the colour does not have to be blue. When the participants in the interviews were asked what colours they thought of if describing electricity, it varied. A couple said red, and other colours represented was grey, green, yellow and also blue. An interesting comment about letting blue representing the EV, was that in China it is essential to reduce the pollutions to see a blue sky again. The interviewees also had a hard time to visualise energy, but a general result was that it possesses properties such as being powerful, dynamic and positive. However, since the results were differing much specific conclusions in this matter could not be made.

Figure 6.6: Picture of blue details on EVs driven during the benchmarking. Left picture BMW i3, right picture Nissan Leaf.

6.3.2 New opportunities of designing the interior

The EV is not constructed in the same way as a CV, which has created new opportunities to design the interior of the EV differently. There are many advantages, in terms of space, the architecture of the car and proportions. This opens up possibilities as, for example, having a flat floor and relocating the engine since it no longer has to be in the front of the car.

Requirement: Take advantage of the new construction possibilities compared to fossil driven cars.

"You can have a better coupé experience; I think that is cool".
-Interviewee

Many experienced EV drivers do not appreciate the classic instrument cluster which has been used in CVs for many years. Some interviewees commented that the traditional way of showing information in the car is no longer useful because there is no need to monitor the meters anymore. They want it as clean and simple as possible, physical interaction as click buttons and similar controls belong to the past. Once again, people expressed that they want the EV to feel futuristic and modern, and not conventional.

It is a nice tradition in the automotive industry to add instruments that are of no use… I think that an electric car needs much less instruments. It barely needs nothing!
-Interviewee

Requirement: The UI should be presented in a modern way that support the technical nature of the EV and that is not inspired by the UI of a CV.

6.3.3 Sustainable approach

The younger participants in the workshop highlighted the yearning of simplicity and thought through choices of materials, as well as big windows for lots of light emissions to illustrate an environmental sustainable thinking approach. This was also seen from one participant in the interviews owning a BMW i3 who expressed proudness of the car's interior design. BMW is one of few car companies that has focus on designing an EV that permeates sustainability in many levels of the car, which also we experienced when test driving the car during the benchmarking. Many of the materials in the BMW i3 are made of renewable resource and when sitting in the car seat it elicits feelings from the natural materials and the driver can experience the BMW i3's environmental sustainable focus. To create an overall user experience which includes a sustainable thinking approach it could be appreciated by EV users and it is one way of distinguishing EVs from other cars on the market.

Figure 6.7: Picture of the interior of BMW i3.

"BMW has went for making the car as environmentally friendly as possible, the car is more thought through"
-Interviewee

Requirement: The exterior and interior of the car should support the mind-set of the driver's sustainability approach.

In addition, according to the results of our study the majority of the participants seem to have pro-environmental attitudes, a term described by Axsen et al. (2012) further discussed in the theory. In the interviews, 100% belonged to this category. Most of these participants would fit into the clusters of ”aspiring greens”, and possibly also ”engaged greens”. However, the literature by Rezvani et al. (2015) suggested to put less focus on the environmental benefits of the EV to communicate the car. Perhaps it is a good idea to reach out to the broader public, still according to our results many users of today are as stated pro-environmental and putting less focus on environmental benefits might result in loosing these user groups. Consequently, further research should be made before coming to conclusions in this important matter. Furthermore, Rezvani et al. (2015) emphasise the importance of focusing on emotions towards the EV. This is supported by this study since todays users of EVs show evidence of strong positive emotions towards the use of EVs, and clearly strong negative emotions of going back to a CV.

6.3.4 Innovation and a simplicity approach

Other ways of making the look of the EV unique and be differentiated from CVs are to express innovation and simplicity through new technology. This approach goes in line with the perception of the car as representing the future (figure 6.1). Participants in the study related the EV to a product that is high-tech, modern and less complicated compared to a CV. As one interviewee said, this could be shown through the user interaction, the car can make the driver feel that the technology is there and that the car is "smart". Another person said that many car companies are working on making the EV more intelligent. By using artificial intelligence (AI) the car can learn the driver's behaviour and provide help in situations that the drivers are normally handling him/herself.

To be in the forefront of new technology and show this to the driver can be another way of expressing the EVs identity. For example by using advanced aid systems and autonomous driving, together with intuitive and simple interfaces. One third of the interviewees said a developed infotainment system and exterior lighting could be important as a mean to express the EV. The younger participants in the workshop also express the importance of a good sound system in the car.

"Yes, it should look and feel as cutting edge technology, not like old school technology."

-Survey participant

Requirement: The exterior and interior of the car shall support the mind-set of the driver's thoughts about the EV symbolising the future.

6.3.5 Express the EV by the user interaction

By removing things that represent the traditional CV, new ways to interact with the systems will be found. This user interaction could through the user feedback express that the car is an EV. One example is to give feedback of animated light and sound, which can be associated with electricity to highlight that the car's fuel is electricity. How to express the electricity can be combined with the earlier discussion in this chapter about shape and colour. Another idea which could reinforce the impression of the EV as a modern car is to use light, sound, scents and haptic feedback to activate the driver's different senses as feedback connected to the user interaction.

7. Important information in the EV

Today many car models of EVs build their UI similar as for a CV. But since the EVs do not have the same functionality as CVs there should be differences in the UI because there are differences in the human-machine interaction. New features the driver needs to take into account of are among many: the car's energy consumption and efficiency, the status of the car as the battery level and range available, eco coaching and charging information. Literature shows that it is hard to understand the new user behaviours towards the unfamiliar features the driver must adapt to (Proff and Kilian, 2012) and this study has found that how the UIs are designed in the EVs today are not optimal and have some weakness.

This chapter has it purpose to bring more knowledge about how to design the UI in an EV. It will go through the new user behaviours and the technologies which have an impact on the driving task and the user experience. It presents which information in the UI of an EV a driver needs in order to be able to understand the EV and have a pleasant experience. This chapter has a structure based on the user journey described in the previous chapter. It will follow the user of an EV and explain the user experience in situations of the everyday trip and party also situations of the longer trip. Other situations influencing the results are when new routes are driven and when the battery level is low.

7.1 User groups and user modes

With results from the interviews and survey three user groups and three usage situations were found. Results showed that different kinds of users want and need different information and should have it presented in different ways, they desire different experiences. The three user groups are described as The Natural (User group A), The Nerd (User group B) and The Newbie (User group C), according to their relation of using an EV. Drivers of user group A and B are the ones used to drive an EV and they have one or more years of experience, while driver in the user group C are new to the concept of EV. He or she might be a user of car sharing or have recently bought an EV.

Three usage situations reflect three different occasions of driving presented in the user journey: the everyday trip, the longer trip and the new route. The everyday trip is the most common trip and represent what the car mostly is used for. Considering the more occasionally longer trips it was found that it is valuable to have a long-distance mode since there are different user needs during these trips compared to the everyday trip. The third kind of trip is not equally visible in the user journey but is also made occasionally. It is when the driver has to take a route that is unknown of some reason, for example because of traffic conditions or when visiting a new place.

The user groups have created the three related user modes, A, B and C, which differ in the visual way of showing information and the choice of what information to see to suit the user groups. To avoid misunderstandings an explanation follows of what we refer to user mode, since this term might be used in cars today. Many cars refer the term drive mode to adjustments that can be made concern the car's performance and interface to suit the driver's preferences. Many of these help the driver to control the energy consumption, which is of special interest when driving a fully electric car. We have called these adjustments for energy usage modes instead, see chapter 7, and how the information is presented in the UI we have called user modes. After identifying the different user groups, it was clear that they were in need of different information and also how this information should be presented, the user modes A, B and C were created and the modes relates only to the information in the UI.

Requirement: Different user modes should be possible to choose from.

User group A - The Natural

Simplicity, easiness, car suits itself, no technical interested in the car, wants a "clean" UI, only most important information should be shown, receive information when it is needed, notifications instead of monitoring.

Can choose whether information about energy consumption through driving inputs and overall energy consumption (AC, heat etc.) shall be shown or not. The information should be shown in a visual way.

"I prefer the information to be shown to me as simple as possible, and not too much at once. I do not understand kW and I prefer to see it visually"

Technical interest:

Simple UI:

Support from car:

Notifications instead of monitoring:

Own car,
has experience

Group A

The Natural

User group B - The Nerd

Wants to see technical information and monitor because of curiosity and fun. Wants to learn to adjust the driving to different conditions, to influence the performance of the car and has a bigger tendency to enjoy competing about low energy consumption.

What information that are shown are to a higher degree customisable. In default mode more information are shown than for person A and C, and it is presented in a more technical and less visual way.

Technical interest:

Simple UI:

Support from car:

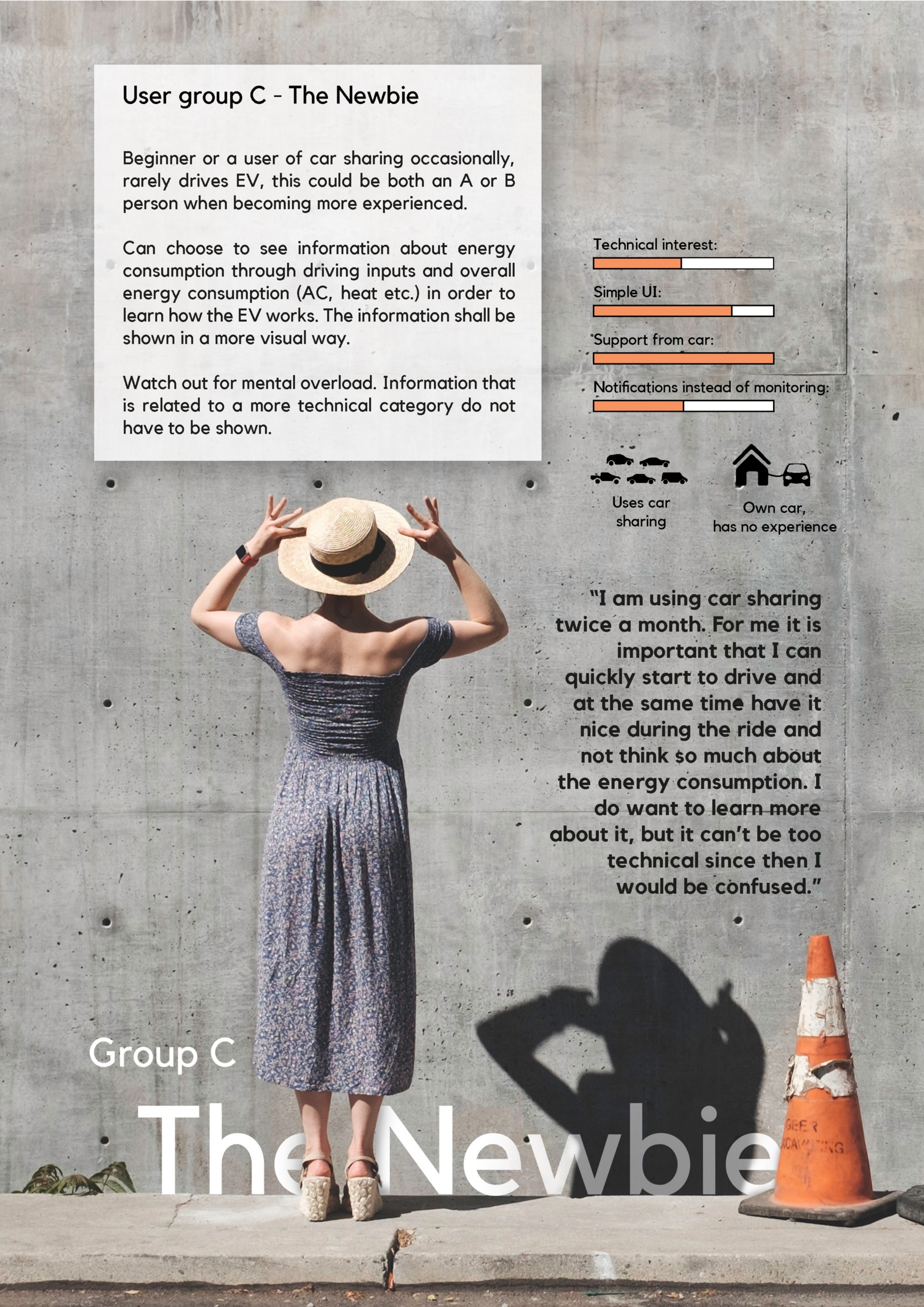
Notifications instead of monitoring:

Own car,
has experience

"I think the performance of my car is interesting to see while I am driving. The car's battery is also important and I like to see the battery health.
Sometimes I challenge my wife in energy consumption on how much kWh minimum could be used driving to the store."

Group B

The Nerd



User group C - The Newbie

Beginner or a user of car sharing occasionally, rarely drives EV, this could be both an A or B person when becoming more experienced.

Can choose to see information about energy consumption through driving inputs and overall energy consumption (AC, heat etc.) in order to learn how the EV works. The information shall be shown in a more visual way.

Watch out for mental overload. Information that is related to a more technical category do not have to be shown.

Technical interest:

Simple UI:

Support from car:

Notifications instead of monitoring:

Uses car sharing

Own car, has no experience

"I am using car sharing twice a month. For me it is important that I can quickly start to drive and at the same time have it nice during the ride and not think so much about the energy consumption. I do want to learn more about it, but it can't be too technical since then I would be confused."

Group C

The Newbie

7.2 Info shown before drive

When the charging is finished and the driver is ready for take-off different cars have particular ways of showing the actual start of the engine. The silent nature of the car is mostly appreciated by drivers, but in some situations it might lead to some problems, as knowing if the car is on, off or in accessory mode. At this part of the user journey the driver might intend to make a longer trip that in many cases include more planning, which the car shall support.

7.2.1 On/off & accessory mode

Requirement: Inform the driver in a clear way that the car is ready to drive.

When entering the EV the driver needs to understand the state of the car, if it is turned on/off or if it is in accessory mode. When the car is on it is ready to drive and when the car is off everything is shut down. The accessory mode is a mode which lets the driver use some of the car's systems, as the radio but it is impossible to start driving. It can be difficult to understand which mode that is active and results from the study show that 22 % had in some situations problems to understand if the car is on or not as seen in figure 7.1. Different car models have their own way of welcoming the driver. Some cars start the car's screens directly when the driver enters the car and some turn on the screens and radio when the driver presses a start button. The problem is that the driver does not know if the car is in accessory mode or if it is on/off. This can lead to the driver pressing down the pedal to start driving when it is not possible or leave the car on while walking away from the car.

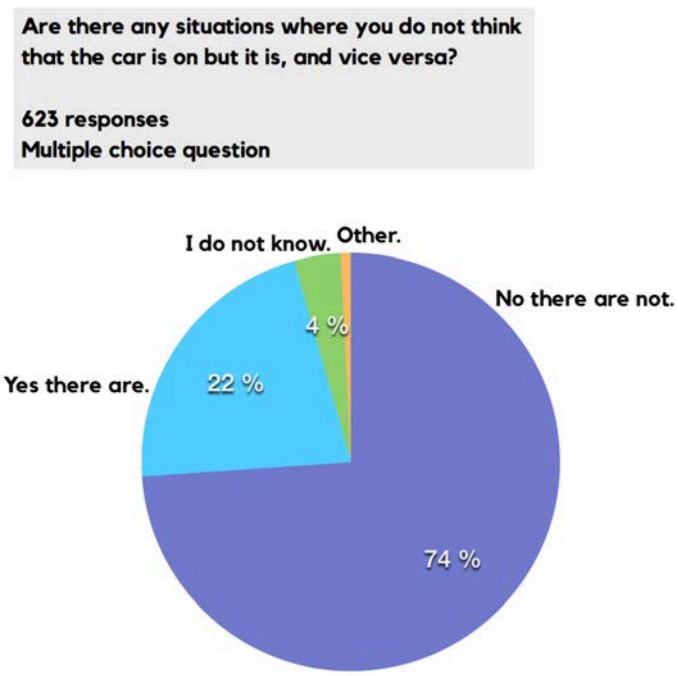


Figure 7.1: Survey answers about understanding if the car is on or not.

One reason why this could be a problem is that the car does not give feedback of the normal sound of an engine and the vibrations when the engine starts, as the CV with its clear engine sound and haptic feedback. There are also few EV models which still have the keyhole and the user input of a rotation of the car key, which is an old but ”normal” way of starting the car. In the benchmarking the car model Volkswagen e-golf was the only car which had the traditional key with a keyhole to start the engine. Many EVs instead have a start button that is connected to the brake pedal, which in addition to the silence of the engine confuses the driver.

It is also seen in this study that UIs of todays' EVs can be a reason to this problem since usually the accessory modes have similar expressions as the on-mode. It is important not to make the driver feel stupid, by clearly distinguishing the modes the driver can understand which mode that is active. Positive things with some of todays' UIs are the feedback that show the driver that the car change its mode to on-mode, e.g. often a melody is played and/or the display is lightening up all the different functions in the cluster for a few seconds. However, how the driver perceives the feedback from the EV can change with experience since some of the participants in the study said they found it just a little bit difficult in the beginning.

"It has three levels of being "on", which we needed a bit of time to understand."

-Survey participant

Furthermore, the problems are sometimes also evident when leaving the car, since some participants stated that they forgot to turn the car off. Some car models leave the screens on or keep playing the radio even if the car is turned off, until the driver has stepped out and closed the door, which could be a cause of confusion.

When the car is in on-mode, there are different ways in today's UIs to show the driver that the car is ready to start driving. Many EVs have a “ready icon” placed in the cluster which is shown all the time for the driver. Participants from the interviews who drove the car model Nissan Leaf and BMW i3 said that they have never noticed the symbol, so showing it might not be very effective. This study has come to the conclusion that feedback explaining that the car is ready to drive is only necessary to be shown when the driver puts the car in on-mode and the ”ready” information should not be shown while driving since it only takes valuable space in the cluster.

Picture 7.1: To the left, the UI of BMW i3 with the text ”ready”. To the right, the UI of Nissan Leaf with a ready icon in the shape of a small car and arrow.

7.2.2 Long trips

This project has found that there is a need for a specific mode that could be used during longer travels. If the user groups are taken into account, user group A for example has higher demands on the UI during these trips compared to the everyday trips. Therefore, the first thing the driver could do when going on a longer trip is to select a long-distance mode that has special adjustments in the UI that simplifies the longer travel. This mode is not defined in this project but may, for example, include making the range more prioritised in the UI, adjusting the energy usage mode where performance will be restricted and suggest charging opportunities along the way as described above.

Requirement: The car shall support the driver in planning long trips, X km.

Requirement: The car shall monitor the driving style and analyse this to enable the destination to be reached, notify driver to change driving style if needed.

The next step the driver does is to plan where to go. Today, some EVs help the driver to plan the trip when the final destination is typed into the in-car navigation system, which was considered a very positive feature during the benchmarking. The system analyses the route and gives information about were the driver needs to stop and charge during the way, what time it is when reaching the end destination and what level the battery has at that time so the driver can plan when to charge next. In addition to this, the car monitors the driving and will notify the driver if changes in speed need to be made to reach the end destination, e.g. by decreasing speed because the energy consumption is too high. This is a very good help for the driver and decreases the total mental workload and stress, in addition to this it would be beneficial if the car could monitor several parameters of the driving style, for example ask the driver to drive more smoothly in order to reach the end destination.

7.3 Info shown while driving

The biggest phase of the user journey is the actual driving. First it is presented what specific information the different user groups need related to their nature and the type of trip or situation. Further, more general information about energy consumption related to the drive and findings related to range are presented and discussed.

Firstly, this shall be clarified: when information is displayed to a driver in an UI, there is always a limited number of parameters that the driver can focus on at the same time. There is literature that describe how to design UIs to avoid mental overload for the user, especially important in the context of a driver UI where the safety factor needs to be prioritised. In this project we have chosen to not focus on the number of parameters displayed simultaneously, which are normally fighting over the small area where information is displayed in the car. Instead, we have identified what information that are important to the driver, which in turn can help designers prioritising the size of displays and placement of the information in the car's UI.

Requirement: The UI shall support the driver's trust to the EV by showing correct and understandable information.

7.3.1 Driver specific information

This paragraph describes the specific information that were found to be important for the driver, prioritisation of information have been identified for the different user groups and in what situations the information is appropriate to be shown to the driver. The most special and interesting situations are those described in the user journey: driving longer trips that needs more planning, situations when the battery level is getting low and when driving new and unknown routes. In these situations, the driver can feel a higher stress level and want to control the energy consumption in order to maximise range.

To a large extent the results are motivated on the basis of the diagram from the survey. To read more about the structure of the survey and its questions this could be found at page 24.

Additionally, user group B should to a higher extent have the possibility of choosing what information to see, since there is a greater variation between the users what is considered as important and interesting technical information. While user group A only wants the most prioritised information to be shown and does not want to see information just out of fun. The following result is a suggestion based on the findings of this project.

In the descriptions it is said if the information shall be prioritised or not for the driver. The levels used are ”less prioritised” or ”prioritised” and are indicating how clear it shall be presented in the UI compared to other information, based on size, colours etc. Additionally, the information could be prioritised sometimes and sometimes not, depending on the situation, as illustrated in table 7.1.

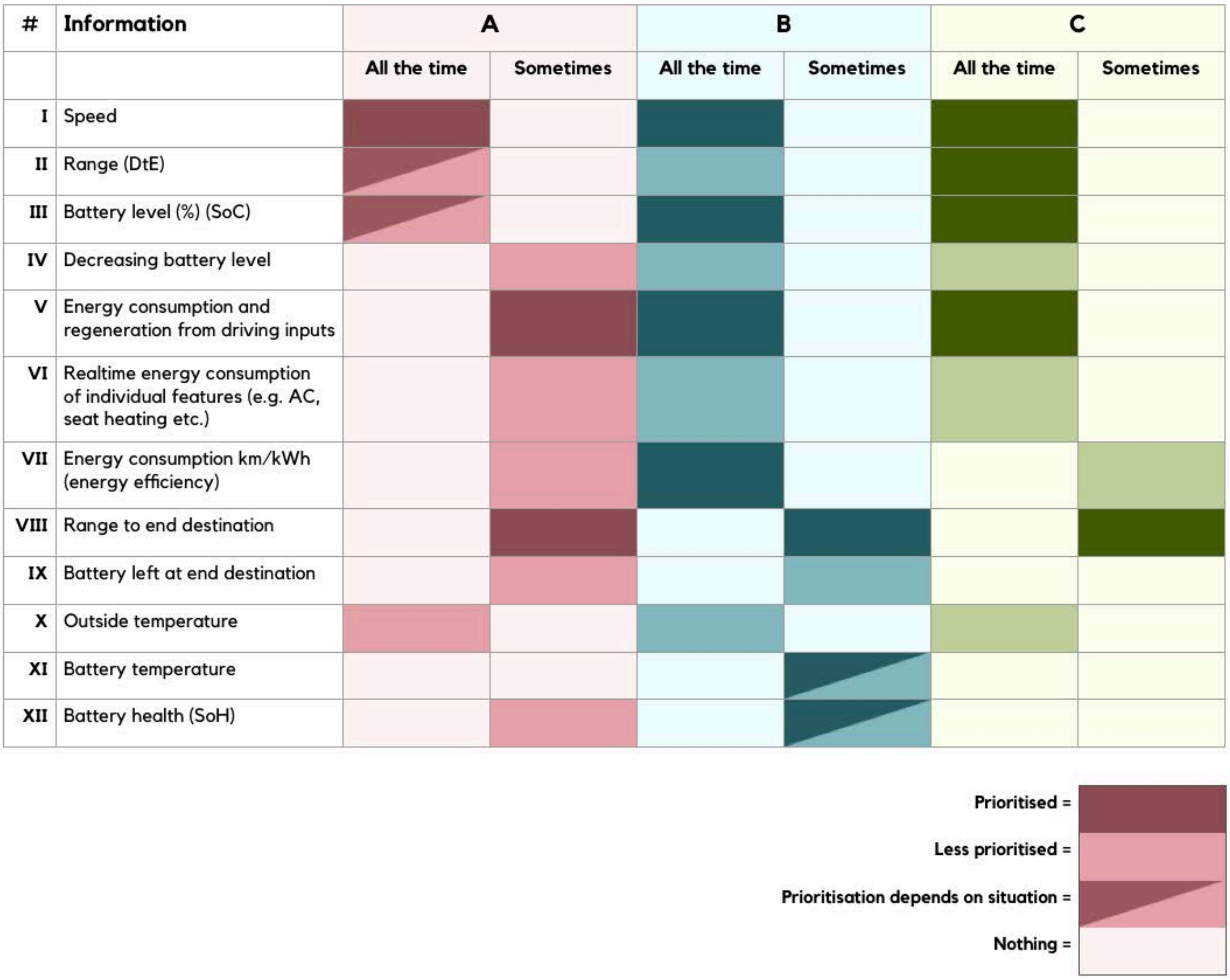


Table 7.1: Driver specific information related to the user groups.

Requirement: Only show the most important and prioritised info to the driver.

I. Speed

The first information that was very important for the driver to have available while driving was the car's speed. This result was clear from both interviews and the survey, where most of the respondents mentioned speed as one of the top parameters that they want to see as represented in figure 7.2 and 7.3.

The information is of high priority and therefore shown for all users at all times.

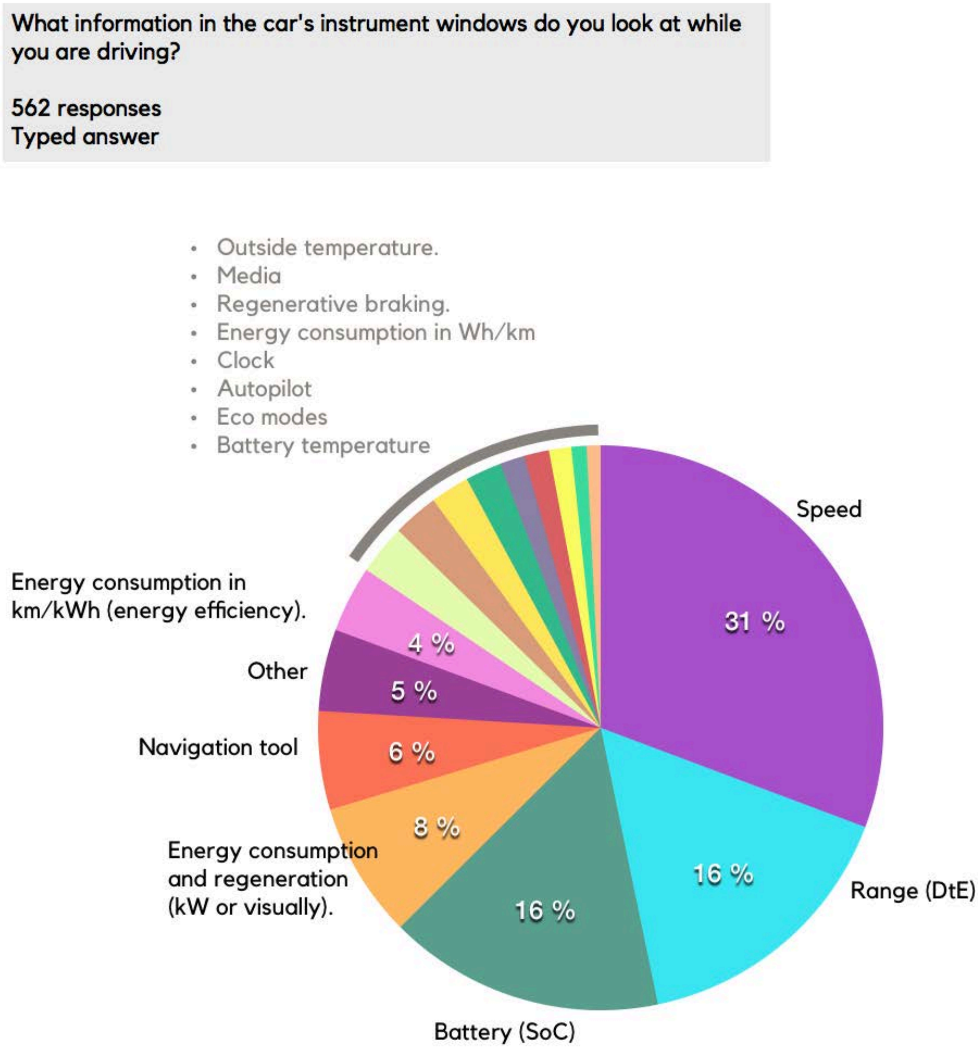


Figure 7.2: Survey answers from the question what information that drivers look at while driving.

Many states the reason of this being the regulations by law, speed limits. What was not equally discussed but of great importance is the speed having great influence over the energy consumption, increasing the speed from 100 km/h to 120 km/h makes the energy consumption increase significantly.

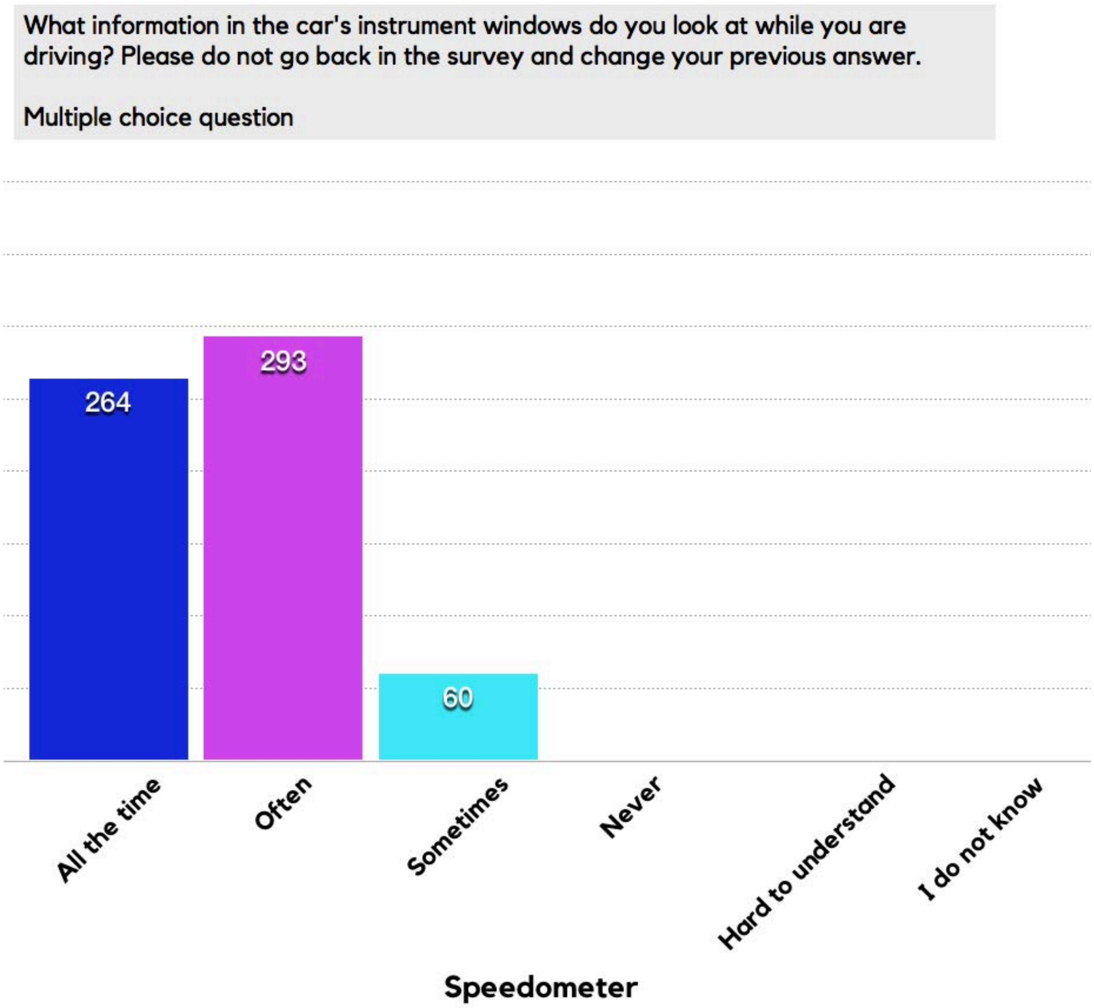


Figure 7.3: Answers from survey what information that the driver looks at while driving.

II. Range (DtE)

How prioritised this info should be being related to the car's maximum range, and this information is perceived as more needed when driving a car with lower range. It is also related to what kind of trips that are made. In today's EVs DtE is often shown incorrect which leads to not trusting it, it is important that the car shows the correct information and make the calculations based on several parameters.

The range and battery level are connected and are basically describing the same thing, energy left to make the car move or to use other systems of the car. However, these parameters are expressed differently and may be interpreted differently in different situations. For example, when driving in high speed the range will drop but the battery (shown in %) will still be the same but decrease with a higher rate. This might be confusing for the driver and formed the basis of point IV below.

"Receive feedback by the range that changes depending on how fast I am driving. In this way it is possible to find a good speed".
-Interviewee

The results do not show any general clear distinction if the range or battery level is most important for the drivers. According to figure 7.4, 57% say they prefer DtE and 40% the battery level. However, according to additional results the information of range should be prioritised as follows.

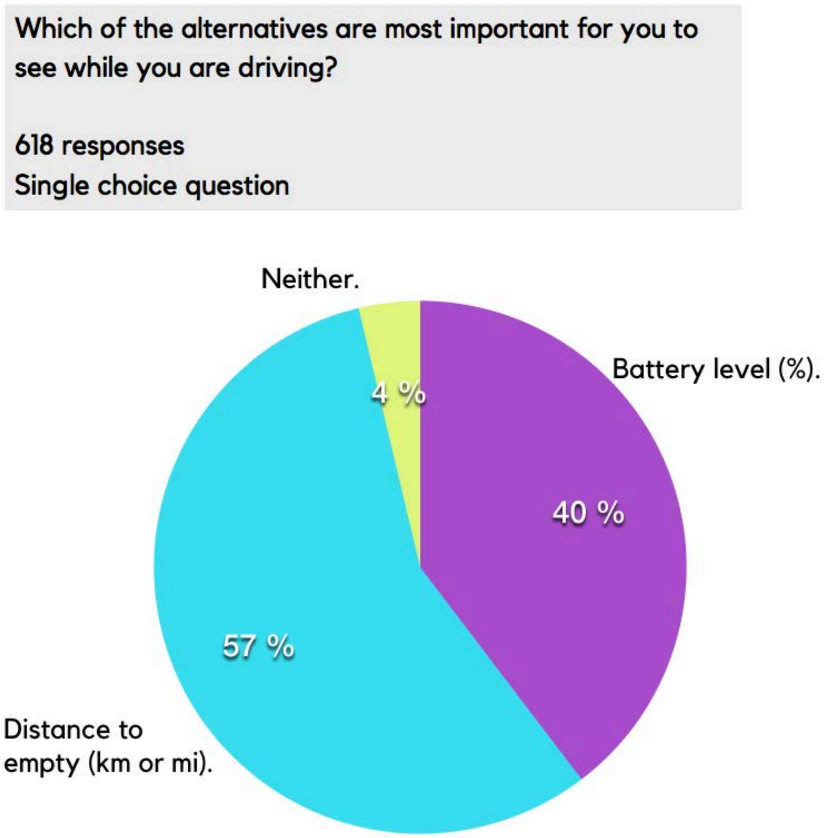


Figure 7.4: Survey answers about if battery level or range is most important to see while driving.

User A - Wants this information all the time. It shall be prioritised sometimes; at take-off, longer trips and when the battery is getting low. Driver A relates the fluctuations in range (depending on the speed) to the energy consumption, since she will get more range if the speed is lower and adjust the driving to this.

"Especially when the range is starting to get low it is important, also in the morning when starting to drive, then you see how much charge you have."
-Interviewee

User B - Wants this information all the time but less prioritised. Figure 7.5 represent all the participants that have answered ”yes” to the question if they want to monitor the car’s performance while driving, i.e. mostly persons with a higher technical interest. According to the responses represented in the diagram driver B does not want the range information to be as prioritised as driver A and C, since they prefer to also calculate the range themselves from other data available.

"I want to see the average consumption. It tells me if I drive efficiently or not and makes it possible to calculate remaining range more accurately than the GOM (i.e. Guess-O-Meter)."
-Survey participant

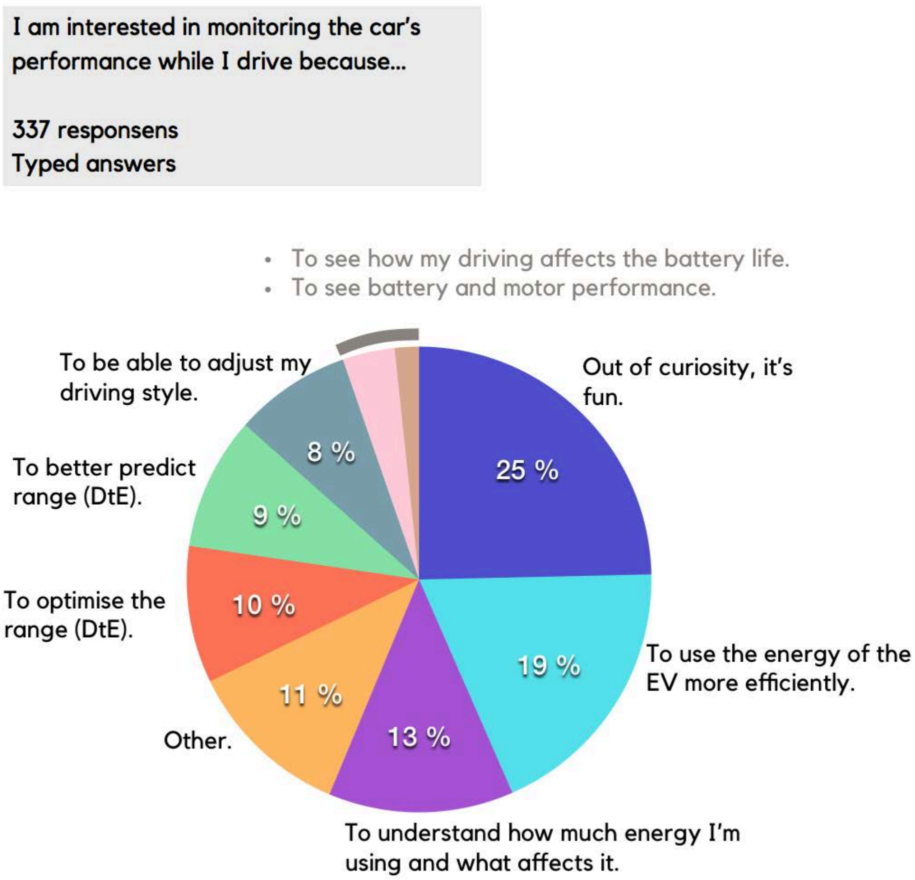


Figure 7.5: Survey answers about why drivers want to monitor the performance of the car.

User C - Wants this information all the time and always prioritised. Since the lack of experience otherwise makes it impossible for the C driver to know how far they can get on the charge available.

"It was more important with the range when you were new to EV. But then you know, with more experience, that it will be fine."
-Interviewee

III. Battery level in % (SoC)

According to our study drivers tend to trust the battery more than the range indicator, no results show on actual de-trust. Figure 7.6 shows that 6% thinks that the DtE indicator is directly useless, while the battery level is not represented among the useless information.

Drivers relate charging their car with other similar products. Several of the interviewees mentioned charging their mobile phone as very similar, which is something that they do every day and as a result, are very used to. An idea is therefore that people tend to think that they understand the level of the battery better, since they everyday are interacting with it. It is a possible reason to why the battery level is perceived as more trustworthy than the range. Even though this goes against the fact that the battery is rather mysterious in many people's eyes, which was mentioned during some of the interviews. Comments such as sudden drops of level or shut downs of, for example, the phone were mentioned.

Are there any information in the electric car that you think are useless? What would that be?

396 responses
Typed answers

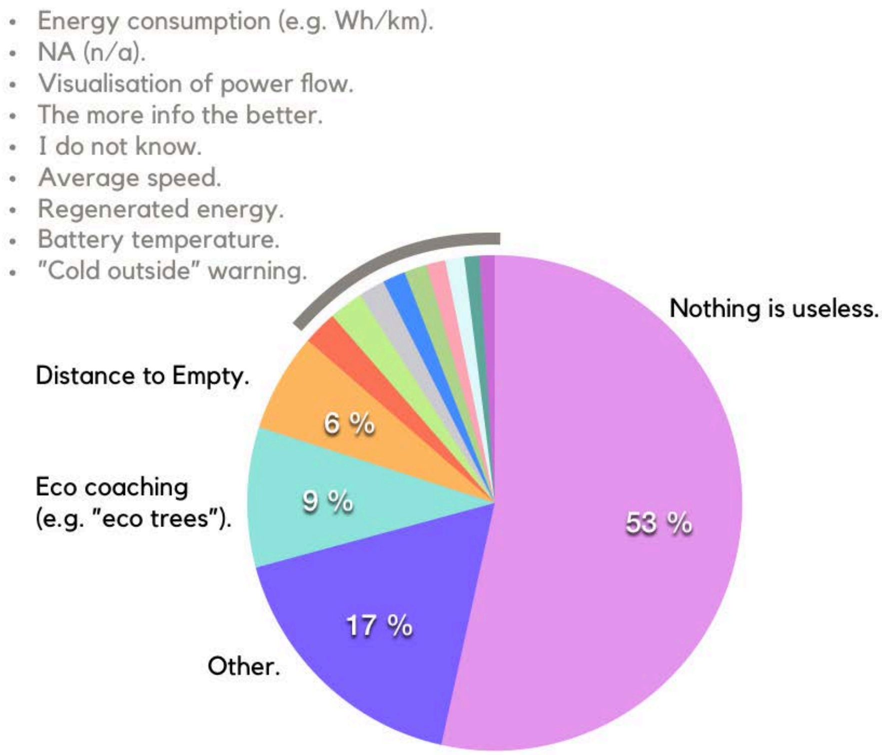


Figure 7.6: Survey answers to if driver find any information in the EV being useless.

Results expressed in figure 7.7 shows that the battery level should be visible in some way for all users, only 26 drivers of 623 respondents claimed that they never use it. Therefore, when it is shown, it shall be prioritised. Furthermore, the battery level shall always be prioritised for all users when charging, to make it clear that it is a battery that is charging in order to enable use of the car and to clarify how much of the batteries capacity that is filled.
User A - Wants this information all the time, it shall be prioritised sometimes; figure 7.7 indicates that most drivers want to see it often or sometimes, as in line with showing range also the battery level is more desired to see when battery level is getting low for driver A.

"I feel most comfortable with percentage if comparing with kW."
-Interviewee

User B - Wants this information all the time and always prioritised. They trust the battery level more than the range, and one of these alternatives need to be visible. The battery level can help driver B in calculating the estimating range. Together with improvements presented as point 4 below, this will be possible to perform in an easier and better way.

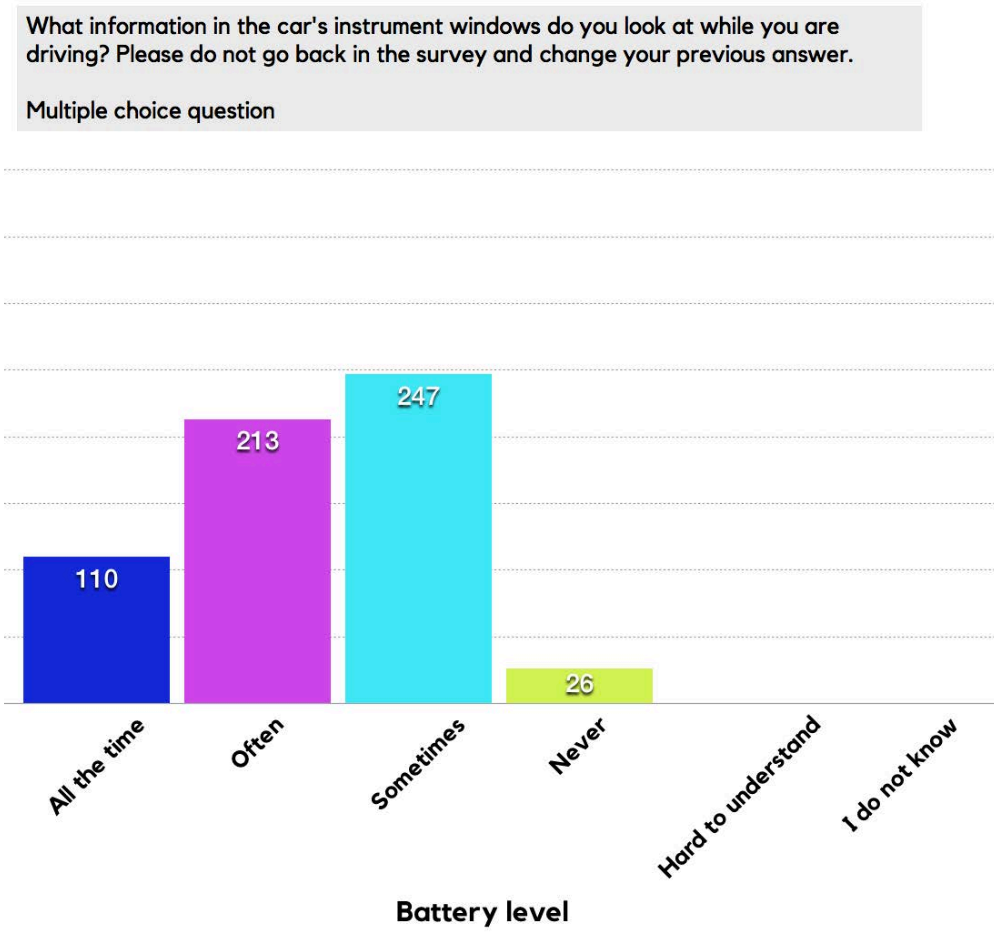


Figure 7.7: Survey answers to how often drivers look at the battery level while driving.

User C - Wants this information all the time and always prioritised. They are beginners of EVs and should have the possibility to learn how it works, and by showing a battery level it is indicated that the car has a battery and is driven by electricity and not fossil fuel.

IV. Decreasing battery level

Depending on different factors the battery level will decrease with different speeds, high speed and low outside temperatures are examples of factors affect it.

User A - Information shall be shown sometimes; in specific situations, i.e. when driving in high speed or when it is low outside temperatures that are affecting the battery level. This information shall be less prioritised.

"I is difficult to understand how extremely much energy that it takes to drive fast, I get surprised every time! It is a mystery that the battery goes away when driving in high speed."
-Interviewee

User B - Information shall be shown at all times but be less prioritised. User B always want to see the speed of which the battery decreases with because of interest and in order to better predict range and drive more efficiently, as seen in figure 7.5.

User C - Information shall be shown at all times but be less prioritised. It is beneficial for user C to see this information at all times, even when there is not an extreme energy consumption, in order to have the possibility of learning how the EV behave due to different circumstances.

An idea is to show if speed and/or low outside temperature highly affect the energy consumption and making the battery level decreasing much faster, by including symbols close to the battery. Then the user can understand why the energy consumption is high, in addition the level of consumption shall be explained. For user A this shall be done in a more visual way and for User B more exact with numbers. In this example, it is the speed that is increasing, with lower at the top illustration and higher at the bottom (the DtE have in total decreased from 160 to 90 km). In addition, the level of energy is visualised with small lightning that in reality will also be animated to look like lightning, but in a discrete way. When the energy consumption is higher the lightning will be more intense and affect a bigger area, as seen in illustration 7.1.

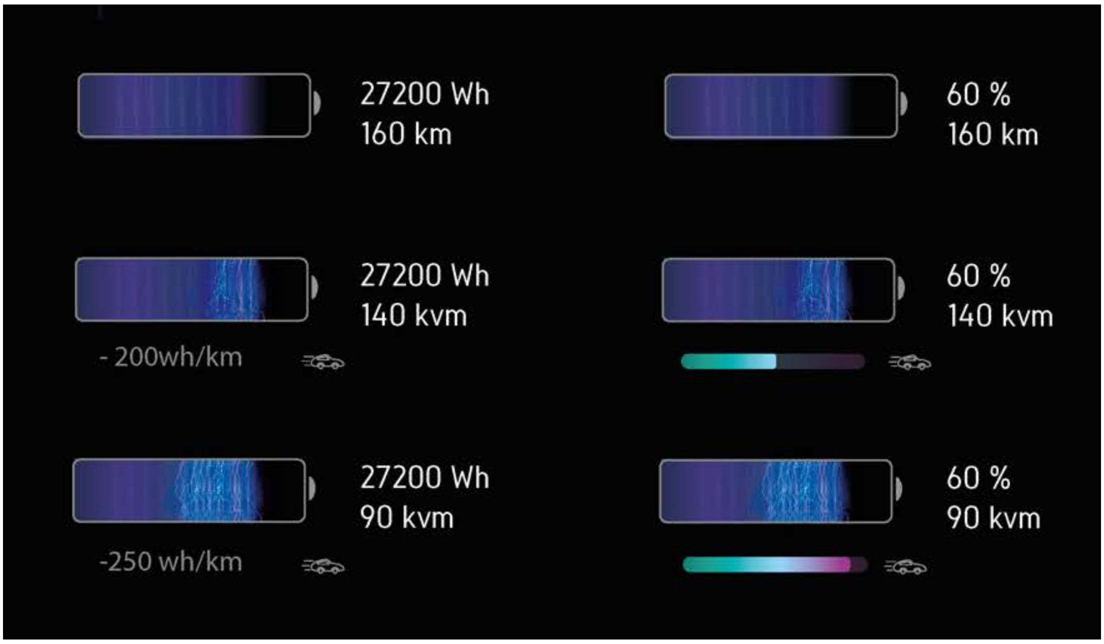


Illustration 7.1: Idea to show when speed and/or low outside temperature highly affect the energy consumption and making the battery level decrease much faster.

V. Energy consumption and regeneration from driving inputs (instantaneous)

According to figure 7.8 there is a general interest about receiving information about the energy inputs and outputs to the battery. Furthermore, figure 7.2 shows that 8% look at the energy consumption information while they are driving, this is as seen supported by figure 7.9. For all users it is important that it is easy to understand that the energy from regeneration is not as much as the consumption when accelerating. According to the benchmarking, many of today's cars show this type of information in an unclear way, and are in a way deceiving the user to think that braking is always a good thing, since you ”get energy back”.

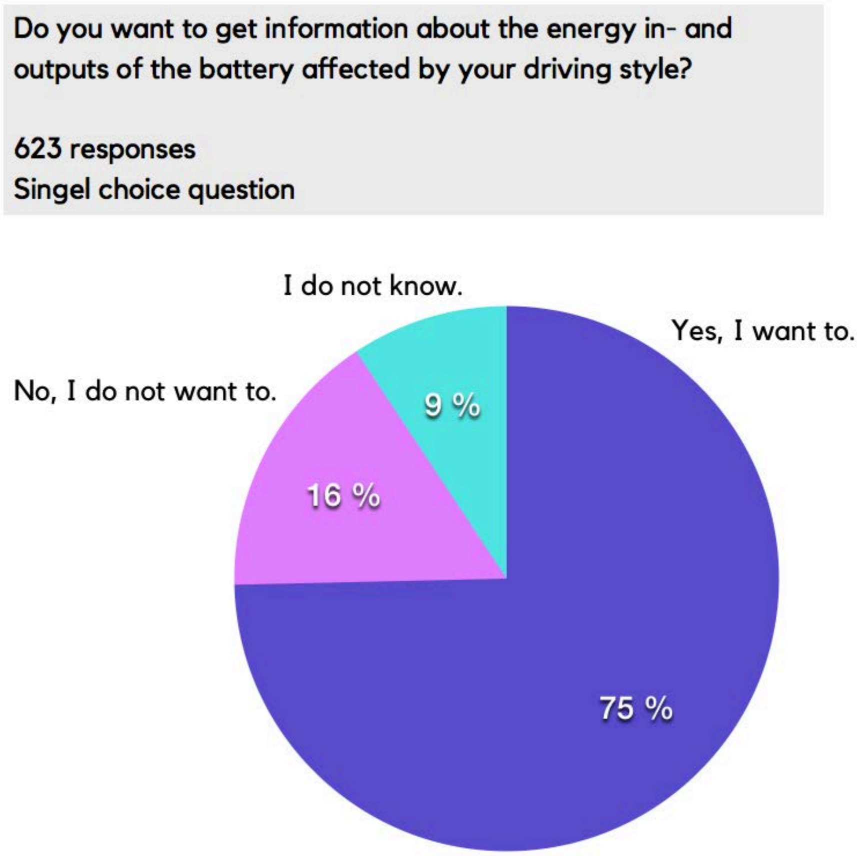


Figure 7.8: Answers from survey if the driver wants information about the energy in – and outputs.

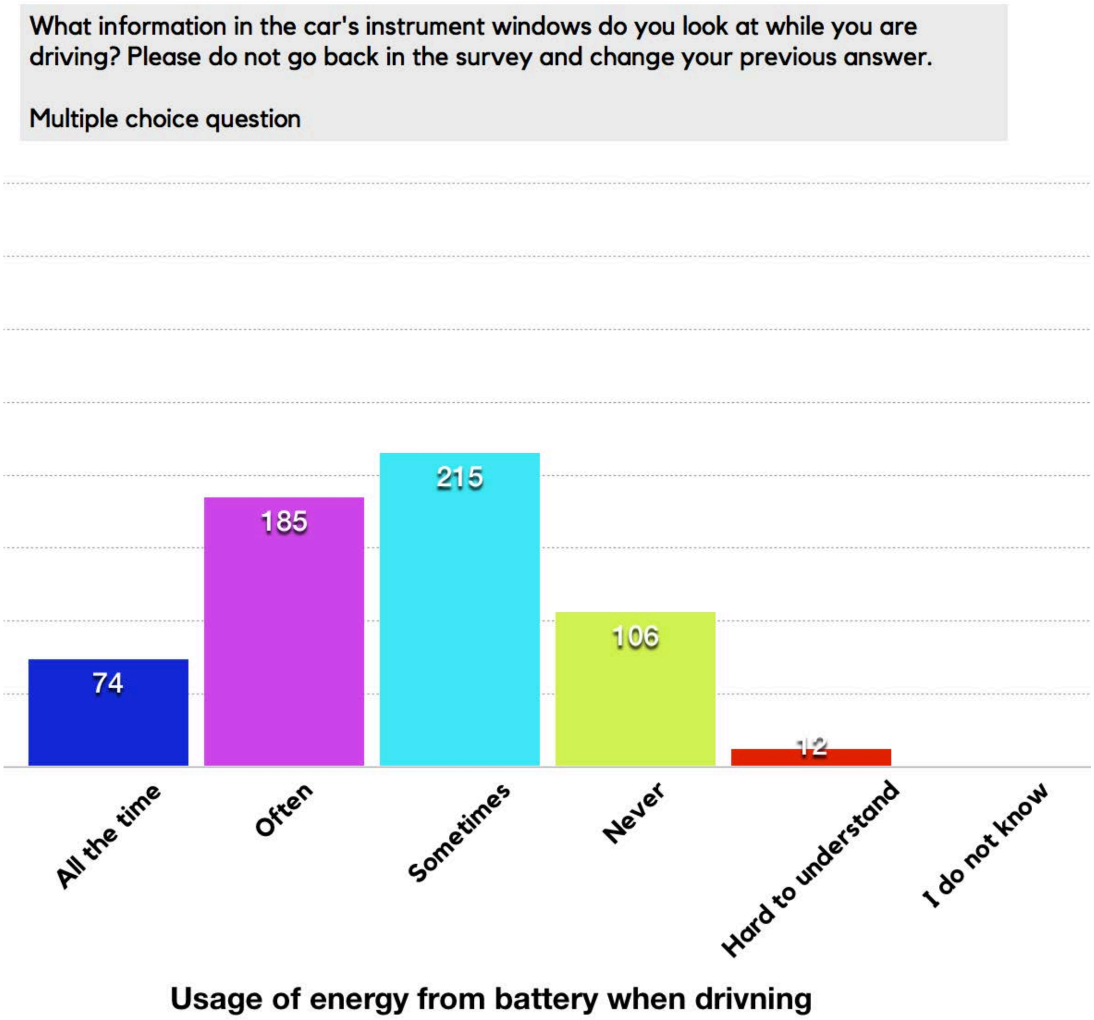


Figure 7.9: Aswers from survey if and how often drivers look at information about energy usage.

User A - Wants this information sometimes, it shall be prioritised when shown. Driver A wants to keep the UI as simple and clean as possible, and the only times when information about energy consumption from driving inputs and regeneration is of interest is when battery is getting low or when driving longer trips. In figure 7.9 it is shown that many drivers want this information in order to improve the driving style to minimise energy usage, which is a desire for driver A at those special situations in order to maximise range.

User B - Wants this information all the time and it shall be prioritised. Figure 7.10 and 7.11 show answers from participants that have first said yes when asked if they want to monitor the performance of the car, i.e. this is answers from mostly B drivers. What they desire the most to monitor is, as seen in figure 7.10, the energy consumption (22%) and the persons wanting to monitor the regeneration are 7%. Even if the energy consumption is relating to all systems and not only consumption from the driving input, it is well represented. Since the driving input is one of the biggest influencers to the consumption this can be considered as an important information to show for user B.

The information is also something that the users wish to see at all times or sometimes, as it stands for 94% of the 387 responses (figure 7.11). As said for user A, figure 7.9 shows that they want to see this information at specific situations in order to improve their driving style and maximise range. But B users want this information at all times in order to improve driving style so that they can maximise their range and adapt their driving to different conditions whenever they want even though they are not low on battery, since they think it is fun and they have a bigger technical interest of the functions and the performance of the car.

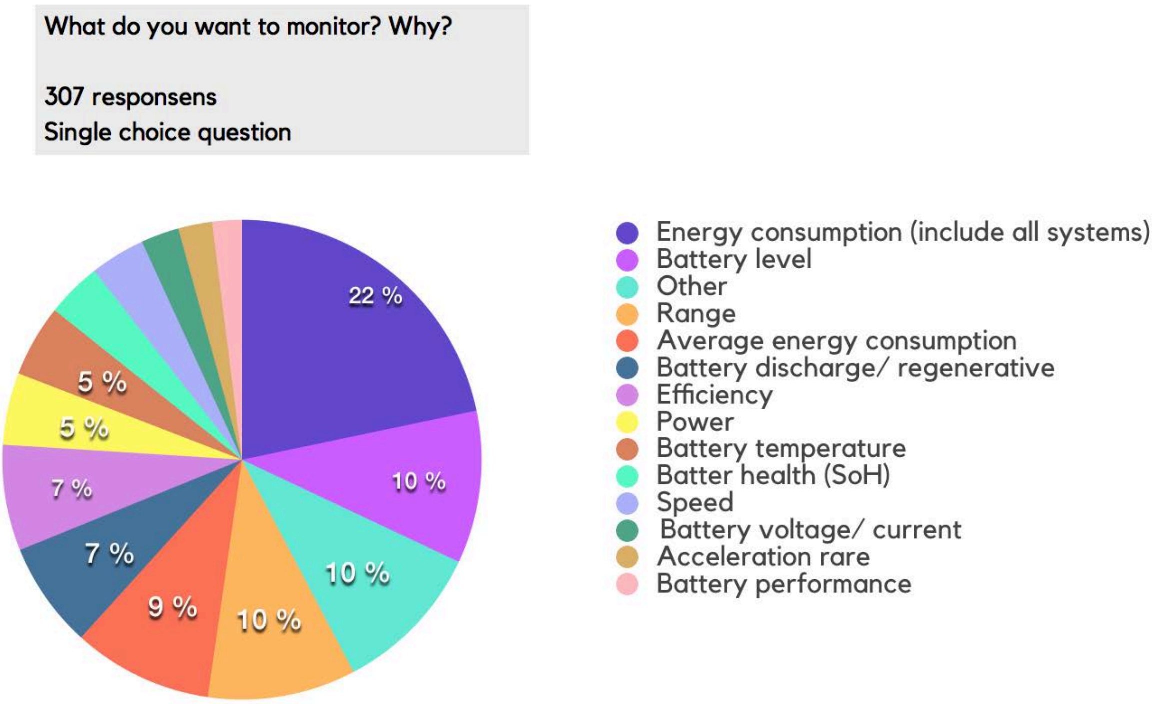


Figure 7.10: Answers from survey what information drivers would like to monitor.

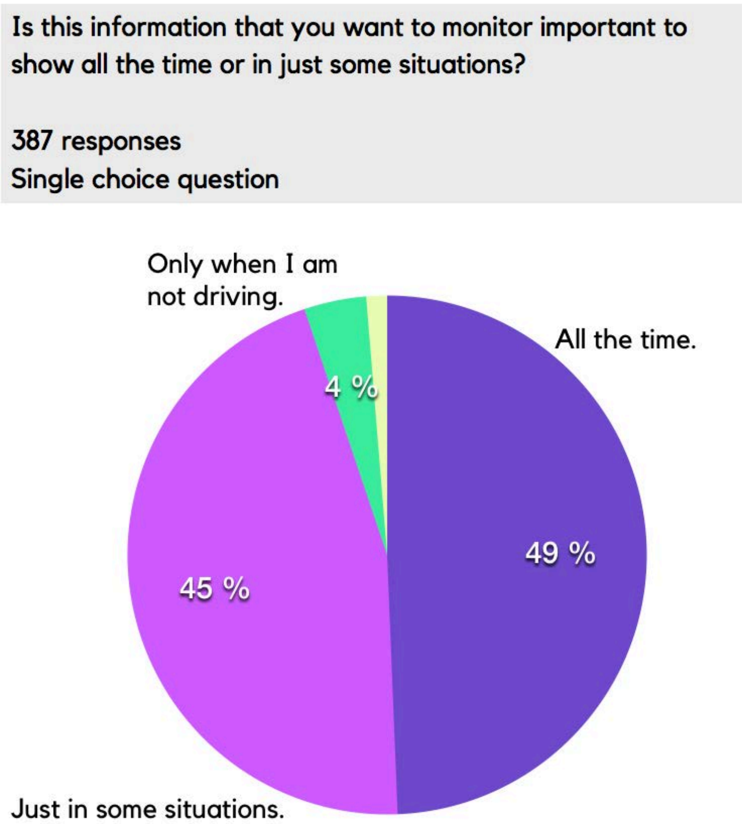
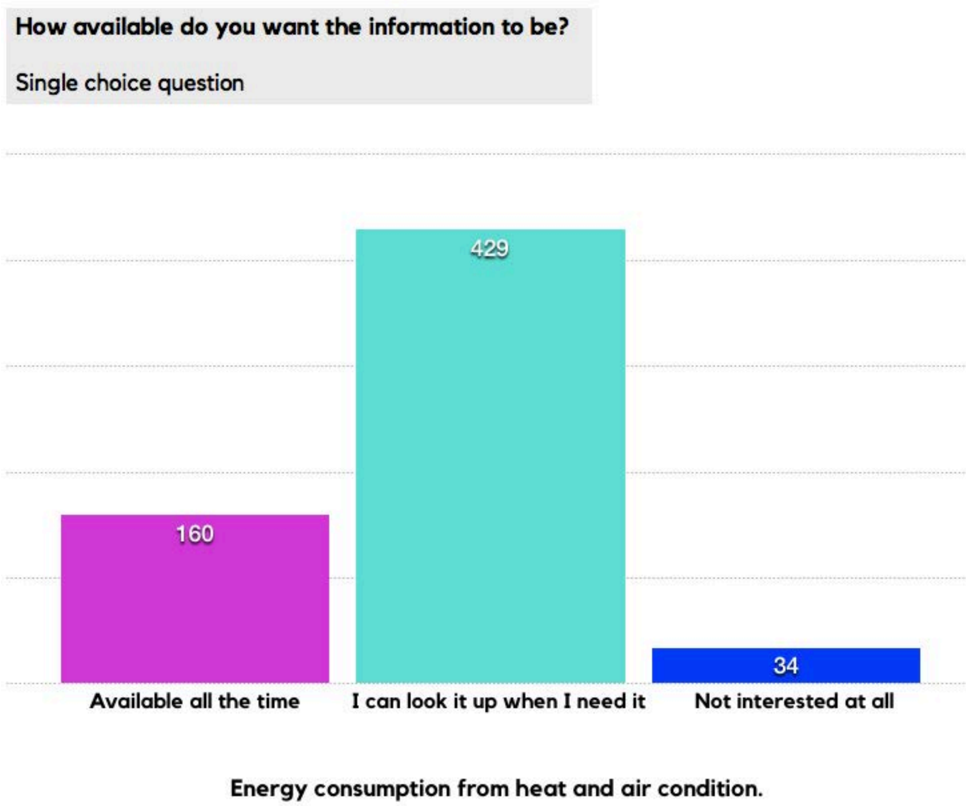


Figure 7.11: Answers from survey about how often information should be shown.

User C - Should have access to this information at all times, and it shall be prioritised. The energy input highly affects the energy consumption, driver C shall as a beginner to EV have the possibility of learning how different driving styles affect the energy consumption. It is also important that user group C understand that it is possible to charge the battery while decreasing speed, why also information about the regeneration shall be easily accessible.

VI. Real time energy consumption of individual features (e.g. AC)

Different features in the car consume energy and to understand the total consumption these individual aspects are important. For example, using the HVAC to heat up the coupé is a real energy consumer. As seen in figure 7.12, most persons are interested in seeing this information sometimes or all the time. Although, if this info should be shown or not is very much related to the capacity of the battery, if the car has a low maximum level of energy available consumption from AC, seat heating etc. will affect the total energy level much more than if the car had a higher level.



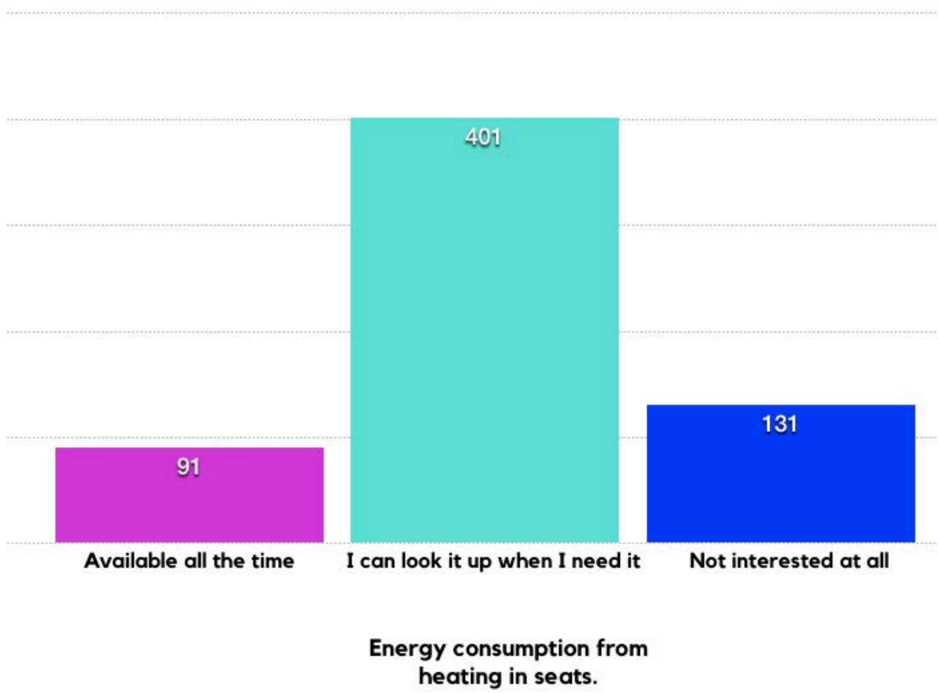


Figure 7.12: Answers from survey about how available information should be.

User A - Wants this information sometimes and less prioritised. At longer trips or when battery is low, in order to affect the range and extend it. I shall be used when these features that use energy are active and info is needed. This info shall also be showing since Driver A wants to learn what sources that drain the battery. This information shall be easily comparable with information from point V in driver specific information, in order to get a perspective for the energy consumption of functions that are other than the propulsion of the car.

User B - Wants this information all the time, but less prioritised. This information is wanted in tower to better predict range, for fun and to drive more energy efficient as seen in D24. It is not as prioritised as point V in driver specific information since these functions use less energy than propulsion of the car.

User C - Shall have access to the information at all times, but less prioritised. User group C should have the possibility of learning how the EV works, what sources that drain the battery and how much this consumption is related to the propulsion of the car.

VII. Energy consumption km/kWh (energy efficiency)

In figure 7.2 it could be see that several participants have stated that the energy consumption expressed as km/kWh is something that they look at while driving. 387 participants said that they are interested in monitoring the car's performance (mainly B users) and of the 307 answering the question why, 22% claimed that they are interested in the energy consumption, including all systems, see figure 7.10. Receiving this information as specifically km/kWh is very specific according to answers from the interviews, therefore this type of info is related mostly to B users.

User A - Wants this information sometimes and less prioritised. At longer trips or when battery is low, in order to affect the range and extend it.

User B - Wants this information available all the time and prioritised. As seen in figure 7.5, that consists mostly of answers from B users, they want to monitor this because of curiosity/fun and to drive more efficiently. Figure 7.11 express the wish of many users of having access to this information at all times.

User C - Shall have access to the information sometimes, and less prioritised. Prioritised for these users is to understand how the EV works, this specific information is not needed for that. But, as a next step or when traveling longer distances it could be useful since user group C does not know yet what an efficient driving style looks like.

VIII. Range to end destination

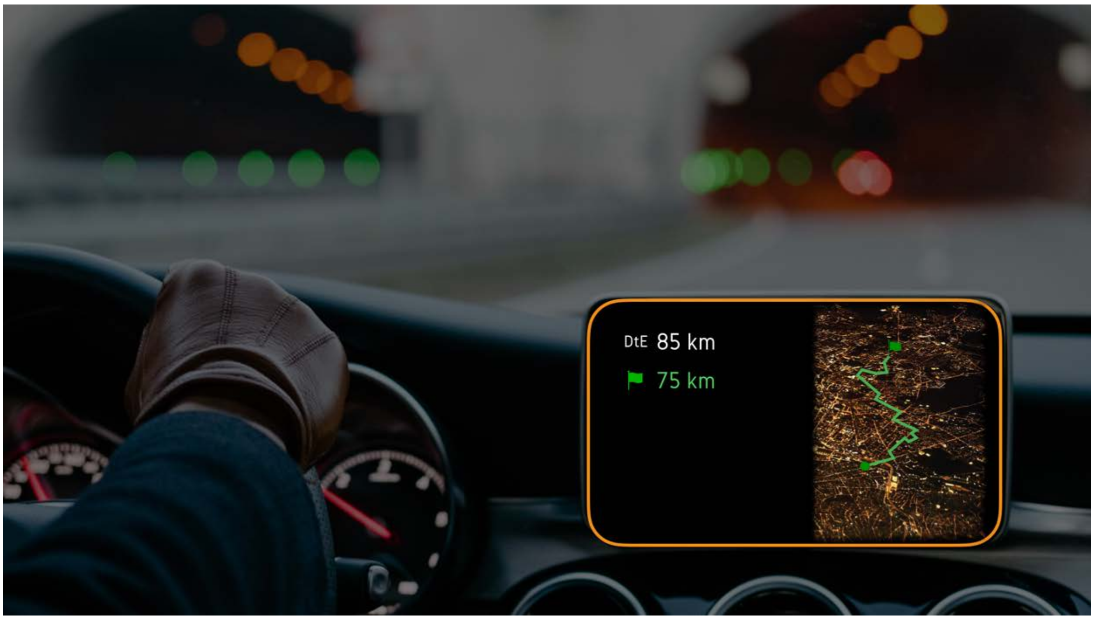
According to answers from several participants in the interviews, range to end destination is important to show sometimes. Mainly in situations where the driver wants to compare the final distance with the car's available range, see requirement 49.

User A - Wants to see this information sometimes and it shall be prioritised. User A compare this information with available range of the car when they do certain trips, i.e. longer or unknown trips.

User B - Wants to see this information sometimes and it shall be prioritised. User B compare this information with available range of the car when they do certain trips, i.e. longer or unknown trips.

User C - Wants to see this information sometimes and it shall be prioritised. User C need this information more often than A or B since they have no, or little, experience of the behaviour of the EV and its available range.

In many of the EVs today the available range of the car and the range to end destination is shown at separate places, often even at different screens. Since drivers many times want to compare those numbers an idea is that this information shall be placed close to each other in order to be easily comparable, as seen in picture 7.2.



Picture 7.2: Example of comparison of DtE with distance to final destination.

IX. Battery left at end destination

This was found to be appreciated information during the interviews and benchmarking. The results were gathered form participants driving Tesla and from when we tried the Tesla S ourselves, where the navigation tool had this feature was available. This will help the driver to plan a trip and decrease the risk of stress.

User A -This shall be shown sometimes and at those times be less prioritised. This is only needed when planning trips where going somewhere where the distance is unknown, and it is considered less important than showing distance to end destination.

User B - This shall be shown sometimes and at those times be less prioritised.

User C - How this shall be shown for driver C depends on which situation the user is in. If using car sharing, the driver does not need this information at all, since the user generally will not do trips that are long enough in order to need a recharge. However, if the user has an EV of their own, this information shall be available when planning trips where going somewhere where the distance is unknown, but the information shall be less prioritised.

X. Outside temperature

As seen in figure 7.13 drivers say that they look at the outside temperature sometimes or more often. Also, according to figure 7.6 only a few of the participants in the survey stated this information as useless. Another argument that were found in this study that supports displaying this information, is that extreme outside temperatures highly affects the speed of which the energy level of the battery decreases with. It is important that the driver connect low outside temperatures with the battery level decreasing faster, in order to contribute to a correct mental model of how the EV works. As described in requirement X. However, the outside temperature is rather stable, i.e. it does not change fast, and therefore the information shall not be prioritised in the UI.

User A - This shall be shown at all times but be less prioritised.

Driver B - This shall be shown at all times but be less prioritised.

User C - This shall be shown at all times but be less prioritised.

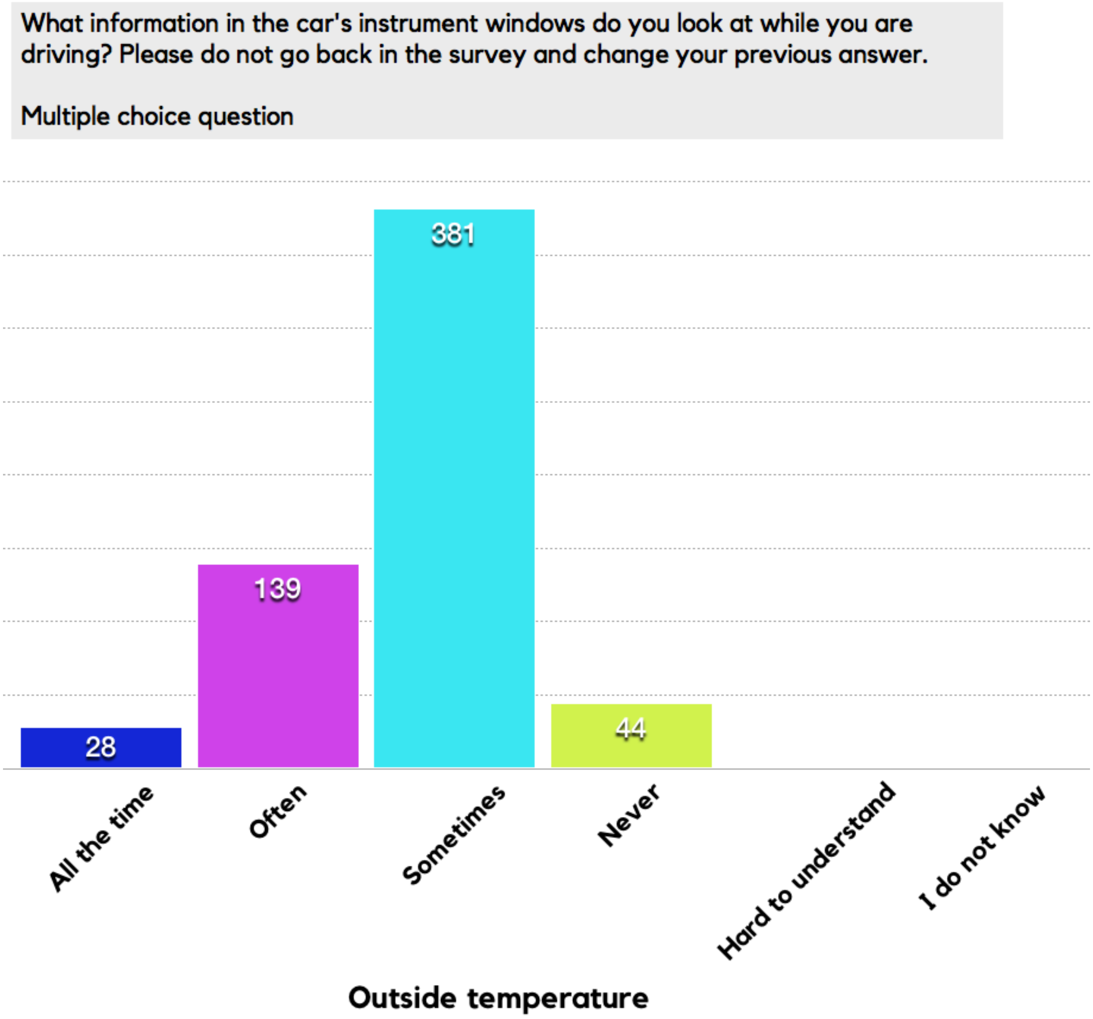


Figure 7.13: Survey answers about if and how often drivers look at the information about outside temperature.

XI. Battery temperature

Temperature of the battery is affecting the performance of the car and therefore affecting the driving, e.g. low battery temp affects the acceleration. See further explanations about the battery temperature affecting performance in chapter 4, Technical information about the EV. This information is not crucial for the user but important for those that want to have 100% control over the car's performance and also to have the possibility to foresee potential upcoming problems with the battery. As seen in figure 7.18 most of the participents do not look at this information at all, however many do want to have access to it sometimes and our interpretation based on the comments from the survey is that those are B drivers. Interesting is that 38 persons answered that they do not know if they look at this information, this could be because they do not even know if this information is shown in their UI. According to the benchmarking some EVs do and some do not.

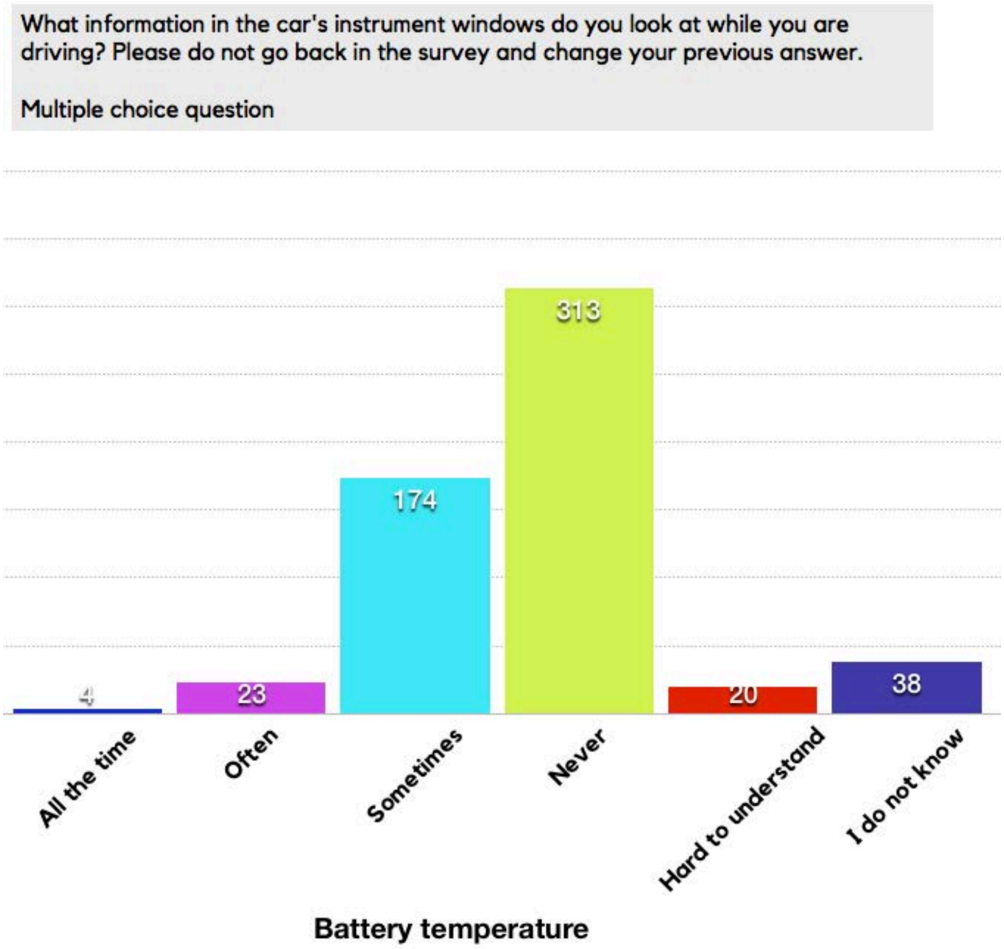


Figure 7.14: Survey answers about if and how often drivers look at the information about battery temperature.

User A - Do not want this information at all. User A typically wants notifications of what is wrong if it is needed, and also what to do in those cases. For example, if battery temperature is too high and driver needs to stop the car or if battery temperature is too low resulting in problems when driver tries to accelerate hard.

User B - Wants this information sometimes according to figure 7.15. It shall be prioritised sometimes and sometimes not. Figure 7.16 indicates that as many as 25% claim that they miss the information of the battery temperature in the EV, this is as stated before interpreted to be B users, since A user's value other information higher that are directly important to their driving and energy consumption. However, according to figure 7.15, most persons do not want to see this information all the time. Therefore, it shall be possible to pick out when needed but if the battery temperature deviates from the normal the information shall be shown and prioritised, since driver B wants to know why the performance of the car is affected and wants to monitor the fluctuations of the battery temperature.

User C - Do not want or need this information at all. They are beginners and only need the most important information, they do not need to know the exact temperature of battery. Notifications of what is wrong and what to do shall be shown if necessary.

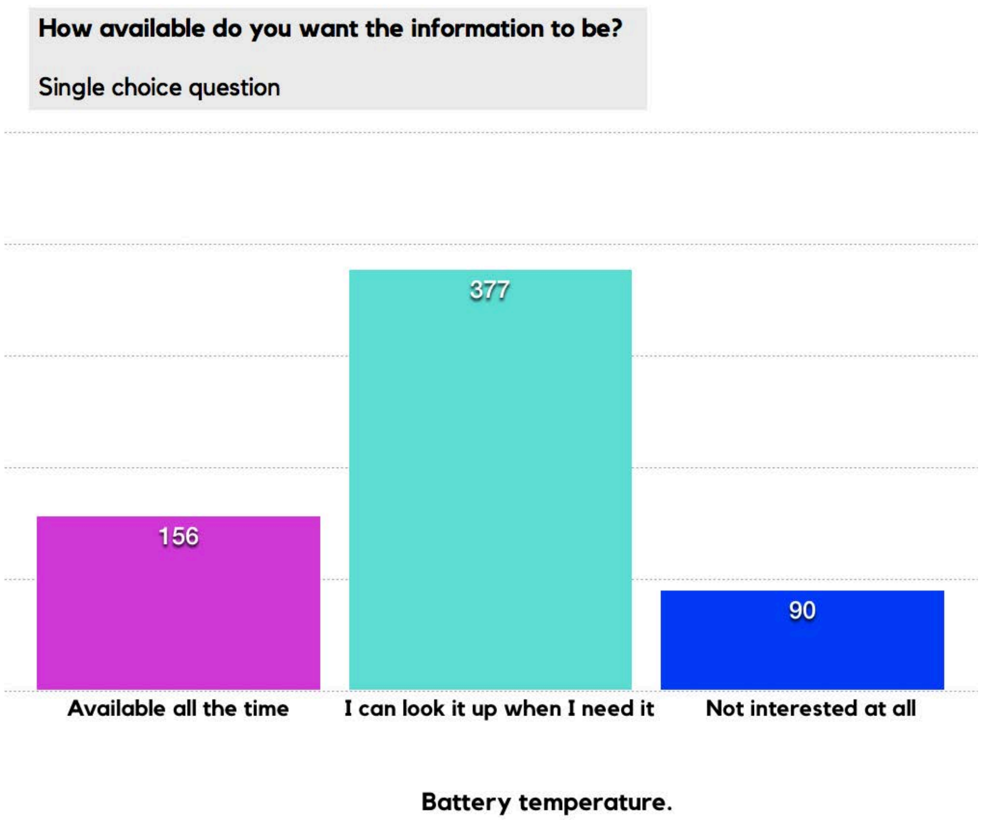


Figure 7.15: Answers from survey about how available information about battery temperature should be.

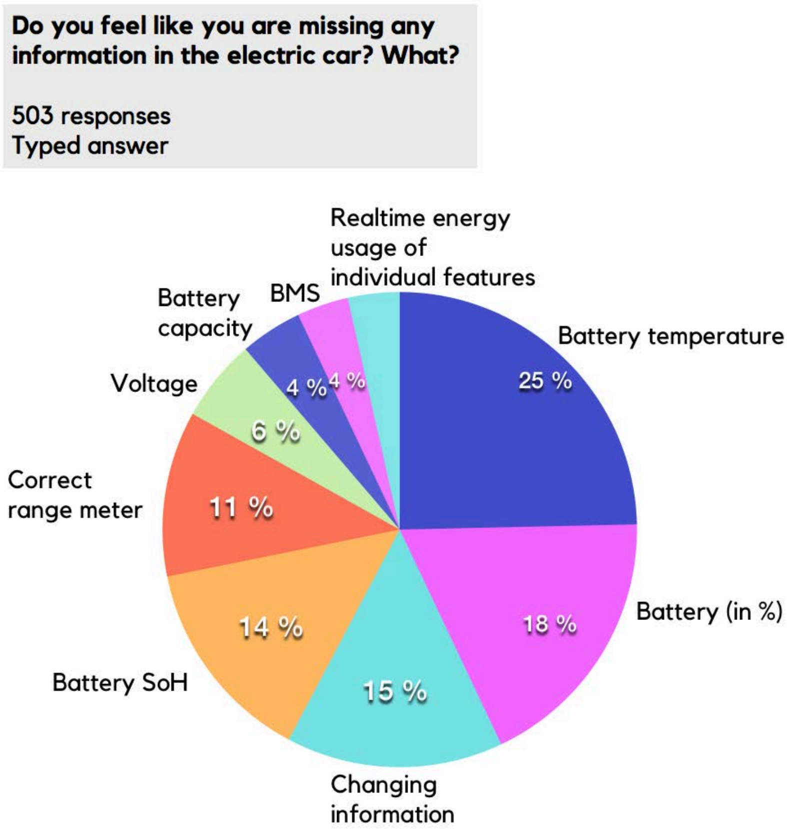


Figure 7.16: Answers from survey if drivers think that any information is missing in todays EVs.

XII. Battery health (SoH)

The battery is as said by one of the interviewees, the ”heart of the car”. The SoH is interesting for the user to see when needed, since it is affected by the driver’s charging routines and gives information about the health of the battery (battery degradation).

Requirement: Give notice when battery needs attention.

User A - Wants this information sometimes and less prioritised. This info needs to be available at times when wanted and if something is wrong and needs to be fixed the driver needs to be notified.

User B - Wants this information sometimes, and sometimes prioritised. The battery health does not have to be monitored, User B only wants to check it occasionally. However, if something is wrong with the battery this information will be shown and it will be highly prioritised.

User C - How and if this shall be shown for driver C depends on which situation the user is in. If using car sharing, the driver does not need this information at all. However, if the user has an EV of their own, this information shall be available at times when wanted.

7.3.2 Energy consumption

Overall usage

According to the benchmarking, in many of today's cars the energy consumption is focused on the consumption from the propulsion of the car. If the user desire to see the energy use from separate sources, in the report called real time energy consumption of individual features (e.g. AC, seat heating etc.), he or she can in some cars go through menus in the centre stack display (CSD) to receive it. As seen in figure 7.10, as many as 22% out of 307 participants want to monitor the overall energy consumption. As said before, this diagram mainly represents B users since this is the second question to ”do you want to monitor the performance of the car”. Consequently, it is mostly B users that desire to see this because of their technical interest and wanting full control of the car. However, it is also important for driver A at certain situations explained earlier; when driving unknown routes, longer trips or when battery level is low, in order to feel in control over the EV.

Requirement: Show the overall energy consumption.

Requirement: Show how external factors, such as road conditions affect the range and battery level.

Requirement: Show how extreme outside temperature and high speed effect the range and battery level.

This shall also include energy consumption from changes in road conditions, such as geographical differences (i.e. hills), extreme outside temperatures and high speed. The two latter ones are further discussed in requirement 23 and are as stated highly affecting the battery level. A consequence could be that the driver experience range anxiety if making a trip where the exact distance and road conditions are unknown. In today's UIs this information is not shown which results in the driver not understanding why the range could drop sudden or why the battery level might decrease faster than normal. As stated earlier, there is a big difference in energy consumption if driving in 100 km/h or 120 km/h. It is therefore important to make the driver understand this, in order to let him or her affect the energy consumption as wanted, e.g. decrease the speed to save battery.

Requirement: Enlighten and encourage the driver of the most energy efficient driving style.

Energy efficient driving style

As a result of the interviews with technicians it was found that the most energy efficient driving style is not what the EVs are encouraging today. According to the information in today's UIs it seems like it is a very positive thing to brake in order to use the regenerative function, however it means that the driver many times brake in vain and then need to accelerate again to come up to the desired speed. Many EVs of today encourage (some more than others) the braking by indicating that an improperly amount of energy is regenerated. If this is by purpose by the designers of these UIs or a misunderstanding or lack of knowledge from their part is not clear. The car model Renault Zoe was one of the EVs that did not show this intuitive and it illustrated the regenerative function as shown in picture 7.3. It is clear that this is misleading the user to think that about as much energy that are used when accelerating is also regenerated when braking, which is not true.

Picture 7.3. Renault Zoe, picture to the left illustrating what happens when accelerating and to the right illustrating what happens when braking.

It is important to encourage the driver to the most energy efficient driving style to maximise range, and the basis of this style is to not brake and/or loose speed if it is not necessary. The following quote is one of the few participants of the interviews that have understood what a more energy efficient driving style looks like despite how the car shows it.

"It is a nice to be at the 'green'. But you really do not want to be at the green, you always want to be at the part of consumption or no consumption to drive as optimal as possible."
-Interviewee

A feature of today's cars that according to previous research are appreciated are one pedal drive. In some EVs, this function could be adjusted in terms of how much the car shall brake when the acceleration pedal is released. If the car allows a high degree of braking force it is not in favour to obtain the most energy efficient driving style. The feature of one pedal drive is a part of this projects requirement list, however it could be contradictory to having an energy efficient driving style since it could lead to fewer occasions when the car is just rolling without and extra resistance from the car. It is of importance to find a balance between these two demands, to keep the drive as energy efficient as possible but still maintain a comfortable drive.

Energy usage modes

Cars often have different modes that the user can choose from to adjust the performance, e.g. restricting the acceleration and/or heat from ventilation system to save energy and suit the driver's preferences. Giving some control over the energy consumption to the systems of the car can help the driver to have focus on other things and decrease the stress level and to feel more relaxed. The modes have different names and settings and some have some sort of comfort mode for everyday driving, eco mode to save energy and sport mode which increase the driving experience of the performance. Normally one of the modes is a default mode, which is often not changeable and need to be changed each time the driver starts if other modes are more in favour. One interview person expressed the need of setting his own default mode, since he did not use the one that was chosen to be default.

"Not so smart of BMW i3 to always start at 'COMFORT' mode, I want to drive at 'ECO PRO. I cannot choose this to be the default mode."
-Interviewee

Requirement: Different levels of energy use support shall be available.

In the benchmarking it was found that several cars named these modes by using the word "eco". This is a word that include so much more than energy saving, it is also a "strong" word with much value in it, why we consider it as not appropriate for this purpose. Therefore, we have chosen to call this energy usage modes.

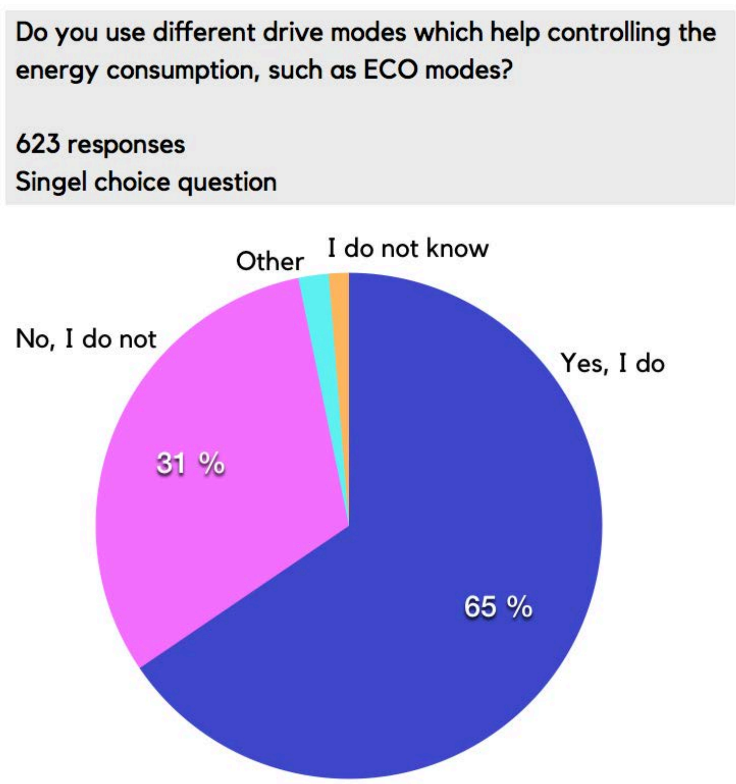


Figure 7.17: Survey answers if drivers use ECO modes.

This feature shall be available for the driver to use, according to figure 7.17 65% of the participants in the survey say that they use these kinds of modes, which was further supported by many of the interviewees. However, it should as mentioned be named differently in order to make the user understand what the mode is for, i.e. help controlling the energy consumption. This is of interest for all user groups, but user B shall be able to adjust the energy usage modes to a greater extent than what is needed for driver A and C, since B wants as much control of the cars performance as possible. In figure 7.17, of the 31% that do not use ECO modes, 30% claim they want full control of the energy consumption themselves.

Therefore, an example of what this function could look like is as follows. The user points at the coloured bar in order to decide to what degree the car shall restrict the energy consumption. The blue-green colour to the left indicate that the energy usage will be low, i.e. the car is minimising the energy consumption. While the purple-red colour to the right indicate that the energy usage will be high, i.e. that the car will not restrict the energy consumption. As seen in illustration 7.2, the left alternative has less options than the right one, because it is designed for user group A that wants everything as simple as possible. However, user group B do want to have full control and therefore have access to make more adjustments, for example as according to the illustration.

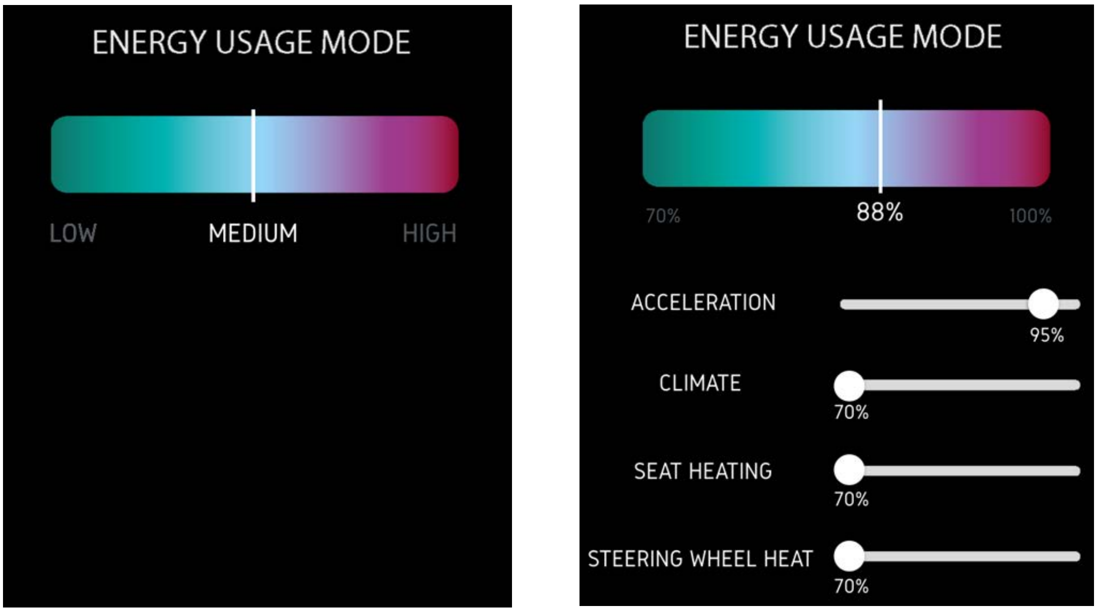


Illustration 7.2: Idea on how to show energy usage mode.

Energy usage history

In today's cars energy usage history is normally accessible in some way, either in the car and/or through an app. As seen in figure 7.18, 86% of the participants want to have access to this information sometimes, which relates to both A and B users.

Requirement: Possibility of showing distance of last trips.

Requirement: Show statistics and information about energy usage history.

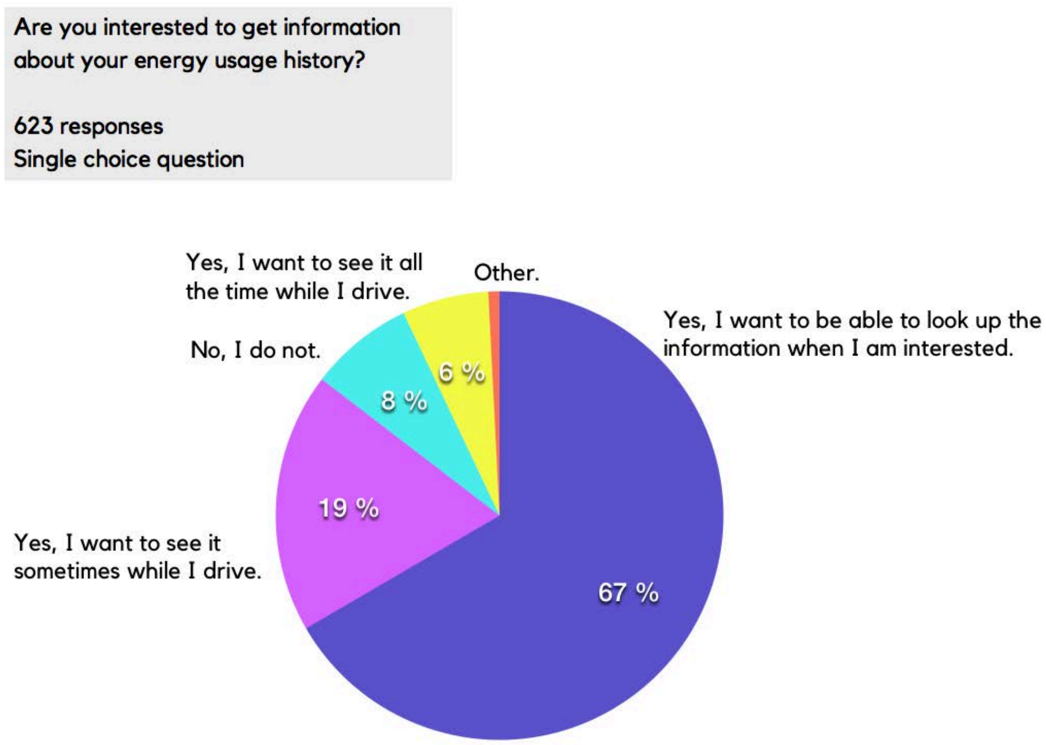


Figure 7.18: Answers from survey about if drivers want to get information about their energy usage history.

This information shall therefore be available for the user, however it does not have to be during the drive. Some drivers use this information to learn how to drive more energy efficient and improve their driving style, while others just want it out of curiosity. Using this information is according to the survey generally related to B drivers. Energy consumption is for some brands used as a competition tool, as for BMW, by connecting BMW EV drivers via an app. This is not used to any greater extent among experienced drivers but there is some that think it is fun. Also competition among family members using the car was evident in the research results.

Related to the history of energy use is other information related to previous driving. Enable to see distance of the last couple of trips is useful for the driver in their journey in learning how the EV works and how long trips they usually do, and relate this to their car's available range.

7.3.3 Range and battery level

Accuracy and accessibility

In today's EVs the DtE indicator is as accessible all the time despite situation or type of travel. According to our research this information shall be shown differently when driving the everyday trip, when taking a new route, when driving long distances or when battery level is getting low. In those situations, the driver is more unsure if the range will be enough and consequently need the information about available range more accessible. Interviews show the results that during the everyday trip, the driver only take a quick look at the range just at take off with the EV.

Requirement: Make DtE more accessible when the DtE is getting low.

Requirement: Show DtE more precise when the DtE is low.

Requirement: Do not show DtE more precise than what is possible.

Requirement: Calculate the DtE as accurate as possible.

Requirement: Make DtE more accessible when driving new destinations.

Further, information from previous researchers, presented in the theory chapter, say that information should be shown in a more ambiguous way in order for the driver to trust it better, and that this might be even more important when the driver is experiencing a critical situation and are feeling stressed. According to the requirements constructed from our research the DtE information shall not be shown in a more precise way than what is possible, which could result in that the information have to be shown with a degree of ambiguity. Interviewees expressed the need of more precise DtE information when the DtE is getting low, why the requirement of showing the information more precise when the battery level is getting low were constructed. However, this is evidently going in the opposite direction than the research of Jung et al. (2015). Why this need to be researched further.

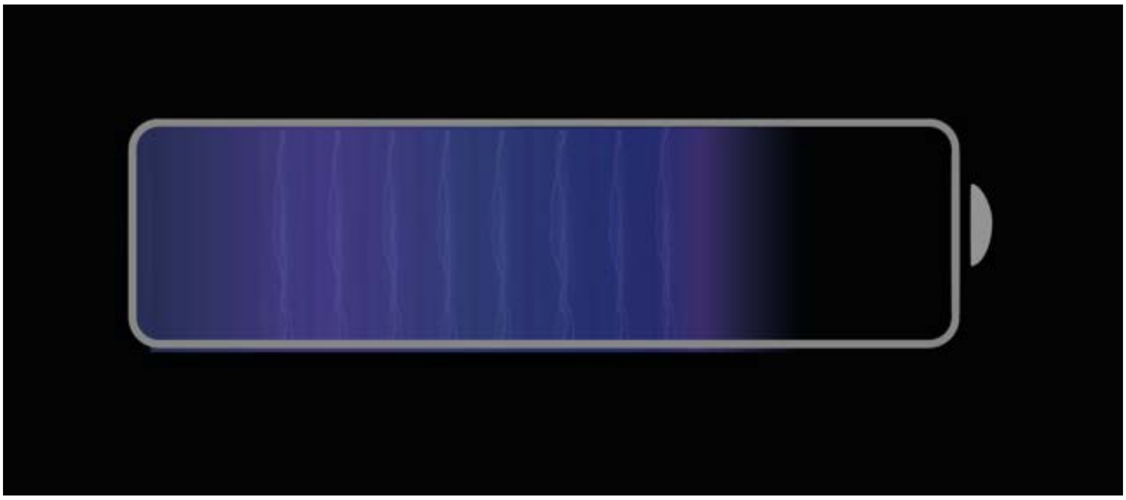


Illustration 7.3: The level of the battery is shown blurry since it cannot be calculated exactly.

Requirements: Possibility to create a personal driver profile.

Requirements The computer in the car shall learn the driver's normal driving style/ energy consumption.

According to the issue about today's EVs DtE often is shown incorrect which leads to not trusting it, one idea is to use driver profiles to calculate the range better. Today it is common with driver profiles which can bring a more pleasant experience when entering the car and the settings as music and seat adjustments change to the driver's profile pre-set settings. This lets the car be more personalised and lets different drivers with their specific needs and routines form the car's UI and interior. Using driver profiles in EVs could be an effective way of learning the driver's driving style, since people have different driving styles which leads to different energy consumptions. If the car can learn the driver's input, the car will be able to predict energy usage and range better. In the study 26 persons answering the survey expressed the range information as being useless as it is today, see figure 7.6. This will make the calculations made from different driver profiles valuable since there is a big need of giving a correct estimation about the remaining range of the car. History of driving style could also be saved and accessible for the driver to evaluate individual energy consumption, discussed further later in this chapter.

Comparing DtE with distance to final destination

Two of the situations where the driver might be in need of the range being higher prioritised in the UI is as mentioned earlier when traveling new routes or longer distances. The car's predicted range and the distance to the final destination are two parameters which has been seen as important for the user to switch between and compare. The reason for this driver behaviour could be connected to a wish for feeling in control over the car's range and to avoid range anxiety. Our suggestion is to place these two parameters close to each other so the driver can easily compare them and feel in control. However, it is needed to dig deeper into the reasons of what is actually the underlying problem, since our solution might only scratch on the surface of an unsolved user need.

Requirement: Possibility of comparing the DtE with the distance to final destination.

Critical levels of the battery and searching for charging opportunities

Today's EVs show the driver when the battery is considered to have reached a level where charging is needed soon, for example by colouring the battery indicator red. This is important in order to make the driver aware of that the situation might be critical soon if the car is not charged. Interviewees talked about their experiences and it was appreciated that the car also assist the driver in saving energy when reaching critical levels by restricting the performance of the car to minimise the speed. At this point some drivers might experience stress and feeling anxious over if the destination or a charging station will be reached. Therefore, the car shall also assist the driver in suggestion a proper charging station to charge at, at those point of critical battery level, to remove a task and so decreasing the risk of a hazardous situation caused by high stress level.

Furthermore, it shall be possible to search for charging stations with the systems of the car. The benchmarking showed positive results from being able to do this and according to comments from the survey it was considered beneficial. Although, several participants commented the fact that also gas stations were a part in this search, which is unnecessary. Figure 5.1 shows that 22% mention the infrastructure as being a big problem with EVs, many comments in this section were related to the need of also receiving additional information about the charging place when fining them by searching online, such as if the chargers are available and functioning at that time or not, and the availability of fast chargers.

Requirements: Show driver when battery level has reached a critical level.

Requirements: Force the driver to drive in a lower speed when X% of the battery is left.

Requirements: If the battery is under X % the car shall recommend a proper station to charge at.

Requirements: Possibility of searching for charging stations in the centre stack display.

"I want information online about the charging station; charging speed, charging effect, kWh required to charge, time when charging is done, which chargers suits for the car..."
-Survey participant

7.4 Charging

Charging is part of the user journey at the beginning, in the middle if making longer trips and in the end, when the driver puts the car to rest before using it again the next morning. Following, different findings about the charging is presented.

7.4.1 Charging routines and notifications

Most charging is done at home, at those times drivers rarely encounter problematic situations. However, it happens that the charging suddenly stops or that the driver thought the cable was plugged in properly and it was not. This could be a serious problem since it might result in the driver not being able to use the car as planned the next day. Most of the everyday trips are made to work and if the car is not charged the chance is big that the user will be late. Therefore, the car shall, for example through an app in the phone, give notice if the charging has stopped unexpectedly.

Requirements: Give notice if charging stops unexpectedly.

Requirements: Indications and feedback showing that charger is or is not properly plugged in.

Requirements: Indication showing that the car is charging.

"It was a bit problematic one night at the hotel when the power was out and the car had not charged."
-Interviewee

Requirements: Give notice when normal charging behaviour is not followed.

Requirements: Reminder to the driver to charge the car.

Moreover, the driver shall also be notified if normal charging behaviour is not followed. The requirements list show that the driver shall have the possibility of creating and using a personal driver profile, which shall include that the car learns this driver's driving style and habits, such as the charging habits. So when the normal charging behaviour deviates from the normal, the car can notify the driver. As an example, the driver normally starts charging the car at night between 18.00 and 21.00 but one evening he or she forgets. The car will then notify the driver, e.g. through an app, and he or she can determine whether or not the car needs to be charged this night.

Requirements: The car shall control itself to what level the battery should be charged to remain in as good health as possible.

Requirements: The driver shall be able to choose to what level the battery shall be charged.

All EVs have a restricted part of the battery that cannot be filled with energy since it would be worn out extremely fast. But with the part that is chargeable, the driver has the possibility of choosing to what level the car shall be charged, normally the recommended charge is 80 % of the batteries capacity in order to keep a good SoH. User B typically wants to control this him- or herself and shall be able to set a default mode that fits the preferences of that person. However, driver A and C normally do not want to change these kinds of parameters which means that when the car is in one of these modes, the systems of the car will control to what level the battery shall be charged. The system will be supported by if the driver has chosen the car's long-distance mode when he or she will make a long trip, since the car in those cases will top up the battery with 100% charge.

7.4.2 Charging station

Problems expressed about charging at stations are not only related to if the chargers will work, if fast chargers are available or if they are taken, but also if the chargers are easy to understand. Users have expressed difficulties in matching the ampere level of the charger with the one of the car. One person in particular who talked about this drove BMW i3 and had to match different ampere levels of the charger with levels of the car describing the same thing with but with ”minimum”, ”medium” and ”maximum”, according to the interviewee. This was found troublesome since it is difficult to know what is matching when the same things are described in different ways. It order to simplify the matching of the charging the design shall be coherent, i.e. indications of the charger shall be the same at those of the car. Furthermore, the car shall provide the driver, at the charging occasions, with information that could be of interest for the driver. Such as how fast the car is charging, time until it has reached the desired level of charge, how many kilometres the current charge is equivalent to etc.

Requirements: When charging, give info about charging time, speed (Power), battery level (% and/or km) etc.

It is a bit stupid... At the chargers it is said "ampere", but then I cannot compare it with minimum, medium and maximum, what should be with what? If it is said 10 ampere at the charger, what shall I take then?"
-Interviewee

Requirements: Enable to set starting time for heating of battery and inside climate of the car.

The performance of the car is affected if the battery is cold, it also takes much energy to use the air ventilation system in the EV to heat up the air in car. Which is why it is a good idea to pre-heat the battery and the climate in the car before a trip if it is cold outside. Then the car is in most cases still connected to a charging unit, this is also positive since it is better to use energy from outside the car than the energy from the charged battery in order for it to last longer.

"I use the pre-heating so that the car and the battery is heated up."
-Interviewee

8. Design guidelines

In this chapter the final result is presented, it could be seen as a summary of all parts and results of this project and they are for designers to use when designing a UI for an EV, to enhance a positive UX experience.

8.1 Guideline 1

Evoke a sense of freedom by highlighting the unique properties of the EV

The atmosphere inside the car while driving.

Drivers appreciate the positive aspects of the EV such as performance of the car, the silent nature and high technology. The car shall evoke a sense of freedom for the user while driving by highlighting these aspects. These feelings need to permeate in the overall user experience of the car and entail simplicity for the user.

• The EV shall use the unique properties that an EV enables thanks to its technical nature. By its performance such as the direct response and smooth transition between speeds the car shall give a fun and comfortable ride. These properties of the EV should not be removed unless the user wants to increase the filter resistance.

• The silence elicits good feelings for the user and shall be maintained even in high speed. It shall create an atmosphere in the car where the driver is relaxed and feel free to converse, experience quality sound of music and also enjoy the silence itself. In addition, the car shall be designed and built to support less vibrations reaching the driver, resulting in a smooth and relaxed ride. To enhance the sensation of freedom and take a step further with the aspect of silence, the design of the interior of the car could encourage this by implementing a large sunroof that lets in light, sunshine, and fresh air if wanted to give a feeling of openness and freedom.

• EVs are often connected to high technology and positive aspects related to this that evoke a sense of freedom, are new features such as autopilot, intuitive interfaces and high quality sound systems. Also by using sensors, artificial intelligence and smart details which adjusts automatically to the driver's preferences could highlight the EV's uniqueness and the technology being present.

Includes the following requirements:

1. The car shall encourage a feeling of a "free" drive, e.g. not showing info that makes the driver feel limited.
3. Use the unique properties that an EV enables thanks to its technical nature.
4. Autopilot function shall be available.
5. The car shall be isolated to maintain the quietness even in high speed.
6. Minimise the level of vibrations inside the car.
7. Systems in the car, such as climate control, should not contribute to unnecessary sound.
8. A good sound system shall be installed in the car to give a pleasant experience of music.
14. The car shall encourage to a sense of freedom.
68. Enable the driver to adjust the responsiveness of the brake in "one pedal drive".

"Drivers appreciate the positive aspects of the EV such as performance of the car, the silent nature and high technology. The car shall evoke a sense of freedom for the user while driving by highlighting these aspects. These feelings need to permeate in the overall user experience of the car and entail simplicity for the user. "

Guideline 1

8.2 Guideline 2

Design an appearance of the car that reflects the user's mind-set

The expression of the interior and exterior of the car.

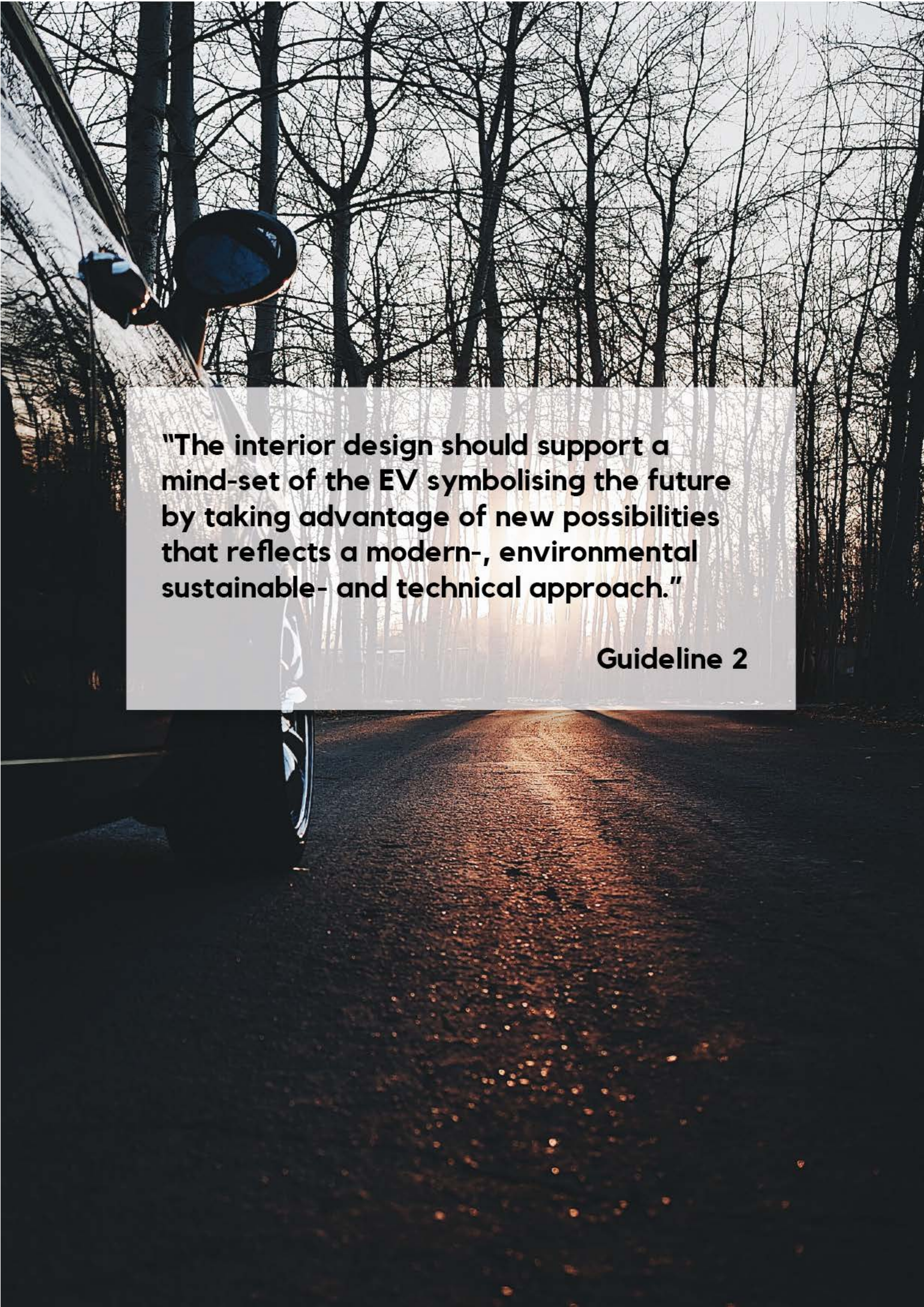
The interior design should support a mind-set of the EV symbolising the future by taking advantage of new possibilities that reflects a modern-, environmental sustainable- and technical approach.

• The car shall express being at the forefront of technology which should influence the UI where now the classic instrument clusters belongs to the past. Take the opportunity of designing new architectures of the interior, as increased space for the user and enable new ways of using the car, since it does not need to be built as a CV.

• Make the user feel that the technology and electricity is there by connecting the users's different senses as sight and hearing. Add lights, sounds or vibrations in the interior, exterior and user interactions to make the overall experience of the EV more "alive" and "smart".

• In the design of the EV the sustainability environmental approach is important in order to meet the EV user's needs. Take account of the user's values of the EV's positive effects of sustainability and his or her sustainable attitudes in the everyday life. This could be approached by designing the car's interior with materials that "breath" and create an atmosphere of fresh air. Natural materials that reflect a more sustainable approach as textiles and wood could be a substitute to plastic made from oil, that could contribute to negative feelings for drivers with a sustainable mind-set. Have BMW i3 as a benchmark which is a pioneer for this sustainable approach of EVs.

Includes the following requirements:
11. The UI should be presented in a modern way that support the technical nature of the EV and that is not inspired by the UI of a CV.
9. Take advantage of the new construction possibilities compared to fossil driven cars.
12. The exterior and interior of the car shall support the mind-set of the driver's thoughts about the EV symbolising the future.
13.The exterior and interior of the car should support the mind-set of the driver's sustainability approach.



"The interior design should support a mind-set of the EV symbolising the future by taking advantage of new possibilities that reflects a modern-, environmental sustainable- and technical approach."

Guideline 2

8.3 Guideline 3

Make the charging simple and effortless to establish an easy everyday procedure

Improve the three situations related to charging: planning, charging and waiting.

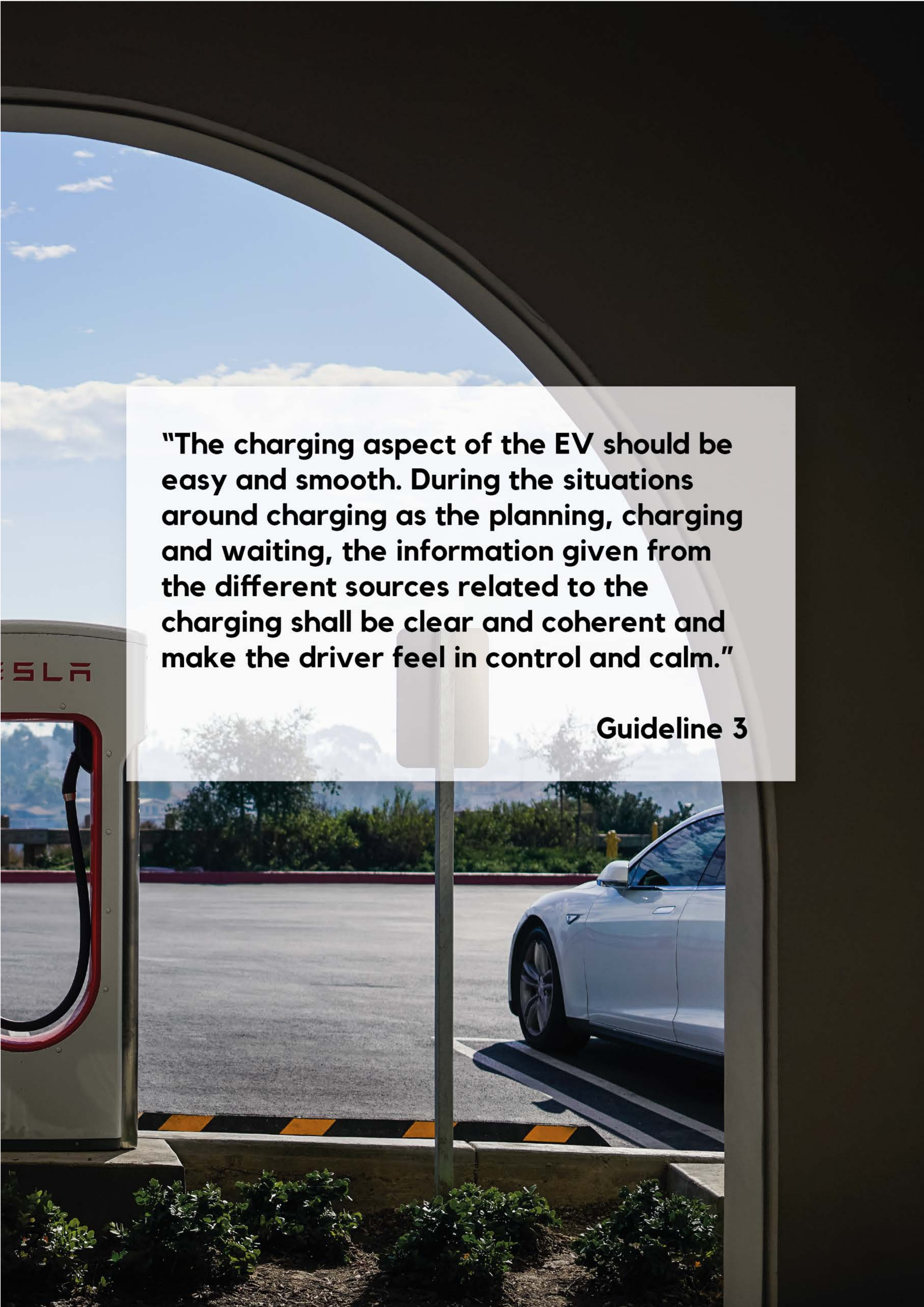
The charging aspect of the EV should be easy and smooth. During the situations around charging as the planning, charging and waiting, the information given from the different sources related to the charging shall be clear and coherent and make the driver feel in control and calm.

• As the charging is normally done every day, the procedure should be efficient and the interactions with the charging cable as few as possible. During charging the car will keep the driver updated that it is properly done or if something differs from the normal. This could be shown in the UI of the car or even better in a portable device as an app, since normally the user is not near the car while it is charging.

• It should be simple to choose charging settings where settings of the charging place, personal preferences and the car matches. In the best case the car will handle the charging settings by itself, choosing the best available charging option due to the situation and availability.

Includes the following requirements:

15. Enable to charge without need of bringing the cable in the car.
16. Enable to charge car without cable.
17. The charging time should be minimised as much as possible.
18. Easy to charge at charging stations were there could be multiple cars charging and different choices of charging available.
27. Give general info about the car's status and enable control over different parameters. (Choice of ampere level, stop/start charging...)
46. Possibility of searching for charging stations.
56. The driver shall be able to choose to what level the battery shall be charged.
61. Indications and feedback showing that charger is or is not properly plugged in.
62. Indication showing that the car is charging.
63. Indicate when charging is complete.
64. When charging, give info about charging time, speed (Power), battery level (% and/or km) etc.
69. The cap to the charging port shall always be possible to open in a simple way.
75. Car shall be easily chargeable.



"The charging aspect of the EV should be easy and smooth. During the situations around charging as the planning, charging and waiting, the information given from the different sources related to the charging shall be clear and coherent and make the driver feel in control and calm."

Guideline 3

8.4 Guideline 4

Design the car as a helping hand to avoid stressful situations.

Give directions to avoid emergencies, when something is wrong and as a preventive action.

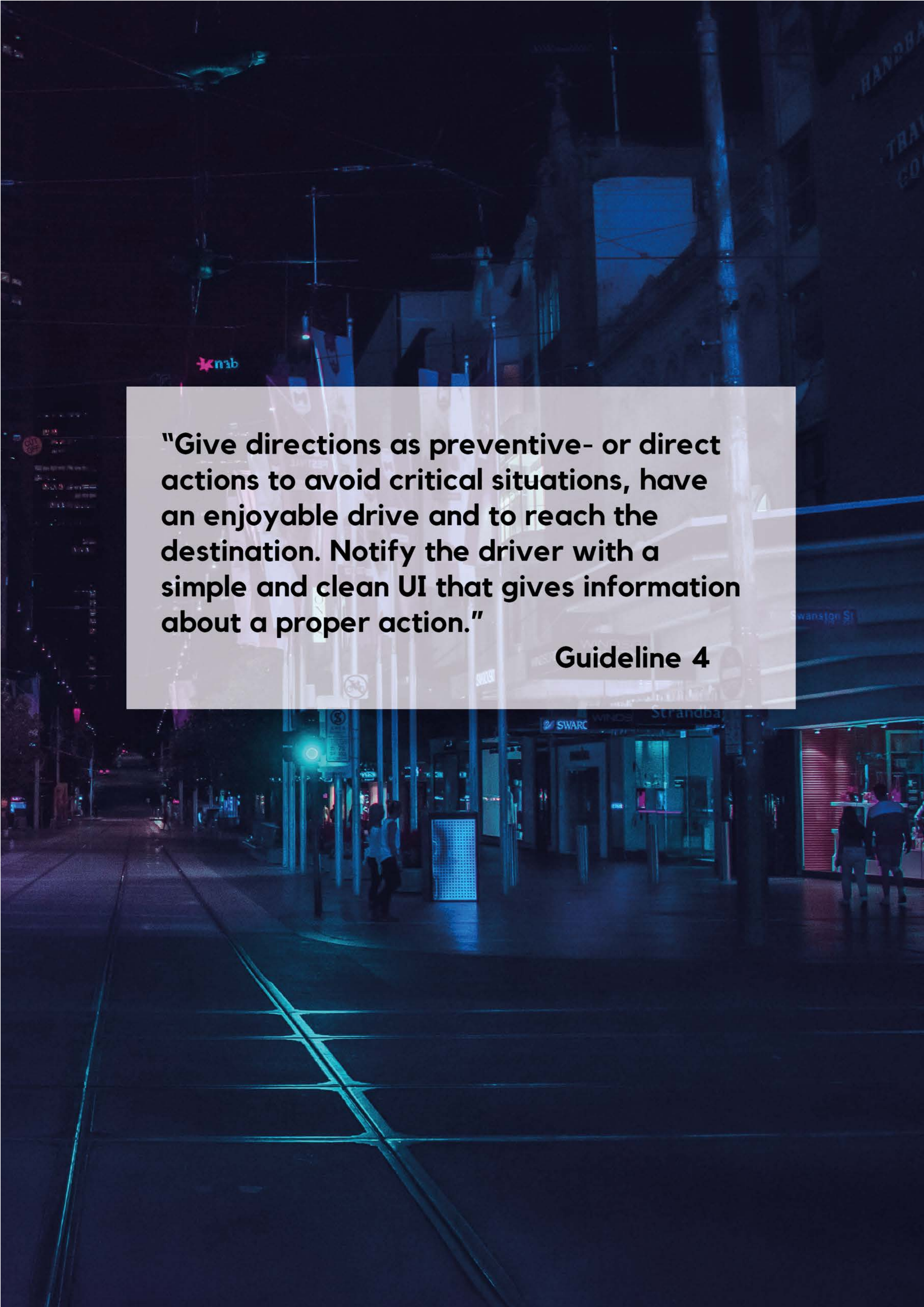
Give directions as preventive- or direct actions to avoid critical situations, have an enjoyable drive and to reach the destination. Notify the driver with a simple and clean UI that gives information about a proper action.

• If the driver's charging behaviour deviates from the normal the car should remind the driver to have a ready and fully charged car when it is needed to enjoy a nice ride with maximum range.

• The EV should be smart and handle technical problems itself. The driver shall feel that the car has control and he/she knows the car will ask for help if it is needed. If problems occur that the car cannot handle and that could cause damage to the car, the driver will be notified. The notification should be clear with proper instructions of actions needed.

• In situations where the driver needs help, the car will give suggestions or force for changes. This will release tasks from the driver and enhance a feeling of relaxation and calmness, and reduces stress. For example, when the battery level reaches a level below X %, the maximum speed will be limited to Y km/h.

Includes the following requirements:
19. Give notice when battery needs attention.
28. Give notice when normal charging behaviour is not followed.
39. Show driver when battery level has reached a critical level.
47. The car shall monitor the driving style and analyse this to enable the destination to be reached, notify driver to change driving style if needed.
48. If the battery is under X % the car shall recommend a proper station to charge at.
50. Remind driver to have the car ready (pleasant climate inside car and battery temp) before drive.
51. Force the driver to drive in a lower speed when X% of the battery is left.
58. Block possibility of driving with charging cable connected to car.
59. Notify driver if trying to drive car with cable plugged in.
60. Reminder to the driver to charge the car.
65. Give notice if charging stops unexpectedly.



“Give directions as preventive- or direct actions to avoid critical situations, have an enjoyable drive and to reach the destination. Notify the driver with a simple and clean UI that gives information about a proper action.”

Guideline 4

8.5 Guideline 5

Educate the driver how the energy consumption works

Show correct information in the UI as a direct response to the driver input.

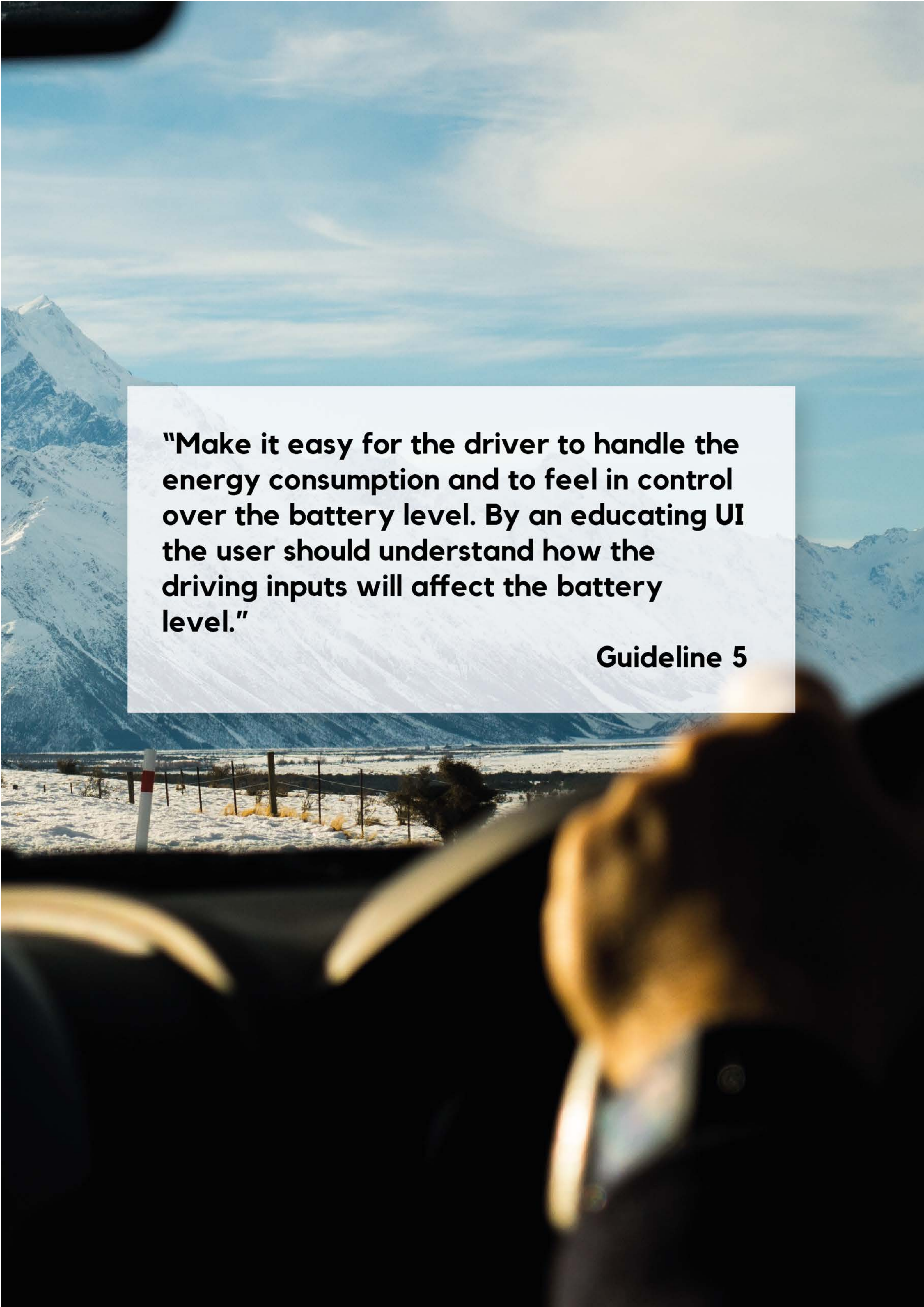
Make it easy for the driver to handle the energy consumption and to feel in control over the battery level. By an educating UI the user should understand how the driving inputs will affect the battery level.

• Show correct and educating information in the UI to enlighten and encourage the most energy efficient driving style to save energy and therefore also available range. By displaying the true amount of energy usage and generativity from the driving input, graphical and written, this can make the driver learn the energy inputs and outputs of the battery. This can challenge some drivers in a fun way and for others it can help them in situations, such as low battery, to save energy but also to make them feel they save natural resources.

• In some situations, it can be hard to understand how the battery level is changing. It is important to help the driver to feel in control of the energy consumption and give tools that the driver can use to enable recognition of the level of consumption, and detect differences from the normal driving behaviour. This could be designed as a scale, where the driver can learn on what level he or she are normally at during the everyday trip. Or it could be presented as how much battery percent/range that could be saved if the driving style is changed.

• Give knowledge about what sources and situations that affects the level of range to give feelings of control, increase driving experience and enabled a comfortable ride. This could be showing as information in the UI where the different energy sources are displayed creating a better realistic picture what is draining energy from the battery. It can also show information about the situation where the battery is extra affected as when it is cold outside temperature, bad road condition, strong headwind or driving uphill.

Includes the following requirements:
22. Show the overall energy consumption.
23. Show energy consumption and regeneration from driving inputs.
25. Show how extreme outside temperature and high speed effect the range and battery level.
26. Show how external factors, such as road conditions affect the range and battery level.
66. Enlighten and encourage the most energy efficient driving style.



"Make it easy for the driver to handle the energy consumption and to feel in control over the battery level. By an educating UI the user should understand how the driver inputs will affect the battery level."

Guideline 5

8.6 Guideline 6

Simplify for the driver

Take account of that drivers are individuals and have their own needs and driving styles.

The car shall be smart and learn the driver's behaviour. It shall show coherent information that do not confuse and at the same time take the mental models and interests of the driver in account. It shall help the driver with tools that controls the energy consumption and enable comfortable long trips.

• The driver appreciates simplicity. The car shall help the driver by learning the driver's behaviour to enable a more accurate predicted DtE. A personalised driving experience could be possible by designing for different user groups, since they need different kinds of information and it should be presented in different ways to enable a good understandable UI.

• Help the driver with tools that controls the energy consumption and help planning trips. This relieves the driver from having focus on energy consumption and he or she can feel more relaxed. During longer trips the car will show information that assists in planning the route with needed charging stops.

• For the user group B there should be available to add extra information in the UI related to the performance of the car that make the driver B happy and satisfied. It could be to show SoH, energy usage history and other parameters and/in different units related to the performance.

Includes the following requirements:
10. SoH easily accessible when wanted.
24. Show statistics and information about energy usage history.
32. The computer in the car shall learn the driver's normal driving style/ energy consumption.
37. Possibility of showing distance of last trips.
43. Minimise the number of actions required to start driving and stopping/parking the car.
44. Different drive modes should be possible to choose from. (A,B,C)
45. Possibility to create a personal driver profile.
53. Different levels of energy use support shall be available.
54 Rewarding driver for energy efficient driving style over time in a "calm" and visual way.
55. The car shall control itself to what level the battery should be charged to remain in as good health as possible.
57. Indications of the charger shall be the coherent with the information in the car.
74. The car shall support the driver in planning long trips, X km.

"The car shall be smart and learn the driver's behaviour. It shall show coherent information that do not confuse and at the same time take the mental models and interests of the driver in account. It shall help the driver with tools that controls the energy consumption and enable comfortable long trips."

Guideline 6

8.7 Guideline 7

Make the usage of the EV smooth and keep the driver happy

Be aware of the user's context and goals. Be efficient and give the information needed.

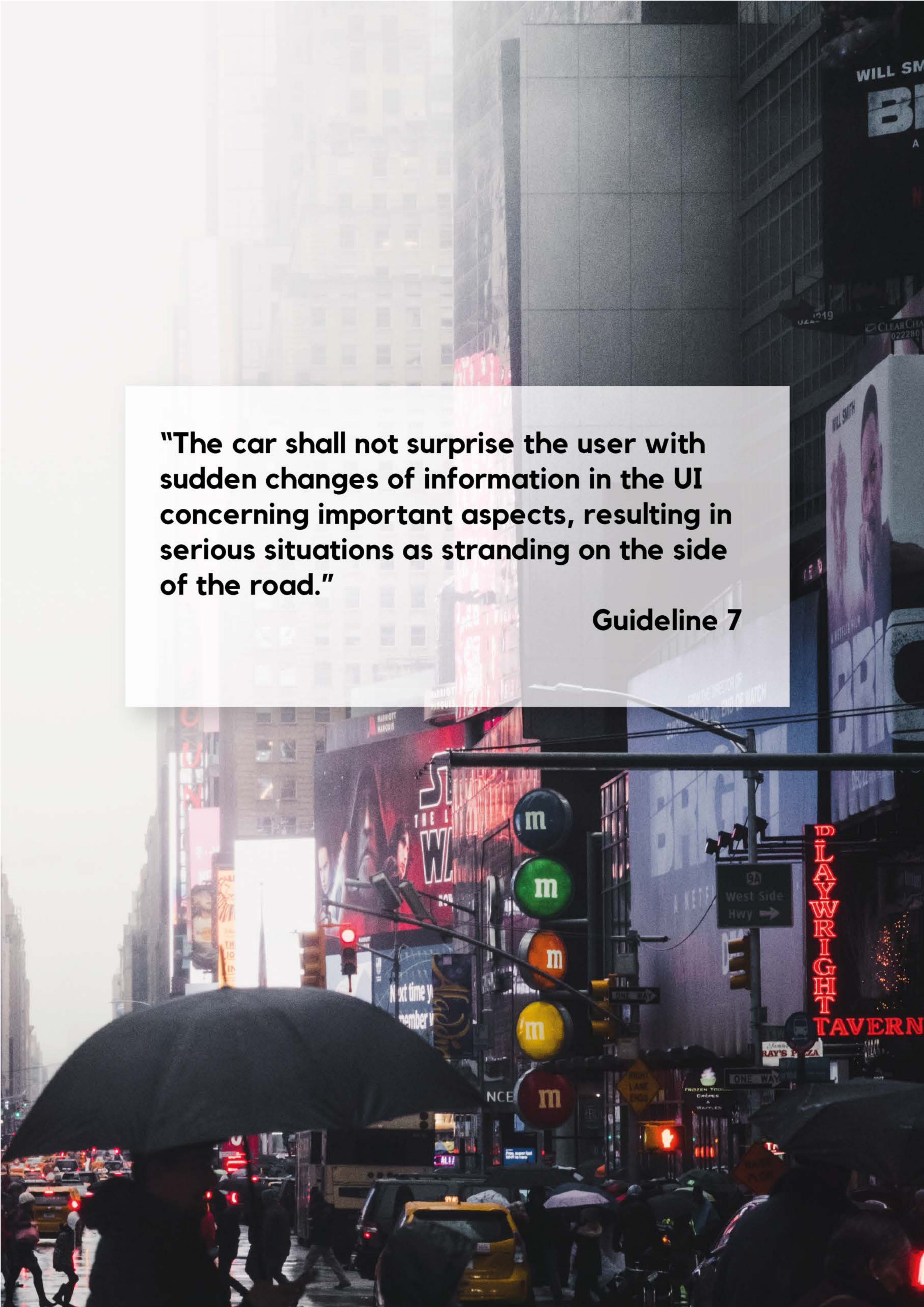
The car shall not surprise the user with sudden changes of information in the UI concerning important aspects, resulting in serious situations as stranding on the side of the road.

• Always try to make the driver updated about the energy level and energy consumption. The DtE should be calculated as accurate as possible but should not be shown more precise than possible. It could result in a negative experience for the driver if the amount of energy left is not at the level as he or she thought it would be.

• When there are extreme differences in the ambient temperature, as when the car is parked inside but is supposed to be used outside, this will be taken into account when displaying the DtE when the driver enters the car, since this is the moment when he or she look at the DtE.

• Aim to make the maximum range for the EV high (>X km) since low range limits the usage of the car and could create stress. In addition, the charging shall be efficient and it should be possible to fast charge the car.

Includes the following requirements:
33. Calculate the DtE as accurate as possible.
36. If the temperature from where the car is parked and the outside temperature differs more than X degrees this will be taken into account when calculating the range.
40 Enable to set starting time for heating of battery and inside climate of the car.
67. Maximum range shall not be less than X km.
70. Enable fast charging.
73. Do not show DtE more precise than what is possible.



"The car shall not surprise the user with sudden changes of information in the UI concerning important aspects, resulting in serious situations as stranding on the side of the road."

Guideline 7

8.8 Guideline 8

Be there for the nervous driver

Avoid situations where the driver gets uncomfortable or calm him or her if those situations occur.

Do not create any misunderstanding with the information in the UI for the driver. The information shall be clear and take stressful situations into account when displaying information.

- The UI shall support the driver's trust to the EV by showing correct and understandable information. Show the most important and prioritised info to the driver and place the information in groups that are used at the same time by the driver, as for example there should be a possibility of comparing the DtE with the distance to final destination.

- Keep the driver comfortable in situations where he or she needs help with the car and relieve him or her from stress caused by worrying of potential accidents due to the silent nature of the car.

- In situations when the battery is low or when the user is driving to a new destination, the UI shall adapt to these situations and keep the driver comfortable. This could be done for example by showing DtE more precise.

Includes the following requirements:
2. The car shall be possible to use comfortably with a low energy use.
10. The car shall be discoverable by people and animals outside in the vicinity.
34. Show DtE more precise when the DtE is low.
35. Make DtE more accessible when driving to new destinations.
41. Inform the driver in a clear way that the car is ready to drive.
42. The UI shall support the driver's trust to the EV by showing correct and understandable information (speed, battery level etc.)
49. Possibility of comparing the DtE with the distance to final destination.
52. Enable help in emergencies.
72. Only show the most important and prioritised info to the driver.

"Do not create any misunderstanding with the information in the UI for the driver. The information shall be clear and take stressful situations into account when displaying information."

Guideline 8

9. Discussion

In this chapter a discussion of the project follows. It is related to the aim, methodology and outcomes of the project together with suggestions of how to take it further.

9.1 Results supporting a better design of the UI and the overall UX of EVs

This project has succeeded in providing knowledge about how the UI and UX should be designed for an EV to improve the adoption and use of it. Results about which information that shall be shown is argued for and through an extensive user study that provided statistically significant results, trustworthy conclusions could be made for most suggestions of improvements. Apart from other studies conducted in the area, different occasions where different pieces of information are needed have been identified and included. User groups were found, and it was stated that there is an urge and need of different kinds of information depending on what user group the driver could be identified with, and that this information shall be presented in different ways. Including this in the design of the UI will enhance the UX and help users to understand the EV better and therefore facilitate the adoption of the new technique.

The results of this project further present information about how to enhance the overall UX. It is clear what drivers of EVs are relating the EV to: environmental sustainability and the EV as symbolising the future. According to the studies the future thinking is strongly related to new technology, why both these different aspects are important to include in the overall design of the EV. Further aspects that today are considered as positive and that are strongly related to the EV are as a result of this report suggested to be respected, amplified and utilized. Such as the silent nature, performance and taking advantage of new interior architecture possibilities. In summary, the project is considered to have met the other part of the aim of increasing the overall UX, further the results from each research question and used methods are discussed in more detail.

9.2 The research questions

Following discussions in relation to the three research questions are being made.

9.2.1 Technical aspects of the EV

When a UI will be designed for an electric car, or any product, there is a need to have an overall picture of the product's system. We have tried to give a clear picture of the EV as a technical product and focused on the aspects which can result in important information placed in the UI of an EV. These aspects come from the thoughts from experienced drivers in the study together with ours as industrial designers.

As a designer of an EV, it could be an easy start to look at and get inspired by how other UIs in EVs are designed today. But, our study has found that how todays UIs in EVs present information is many times not the best, and sometimes it even leads to dishonesty towards the driver. Not showing the correct information could lead to misleading of the user and higher energy consumption. In addition, the UI influences the driver's inputs which can also lead to wrong driving behaviours. Therefore, we have built our suggestions for improvements from a technical perspective of how the EV works, rather than from a benchmarking.

Something else which can further lead the designer in a wrong direction are the many similarities between the ordinary CV and the EV. The EV, which many times looks like a CV but does not function the same way, can create confusion for the driver. These dissimilarities have been highlighted in our study and the new features in the car has been described. These features shape the new information that could be added in the UI of an EV.

In order for us to build a basic knowledge base for designers of the technical parts of an EV, we wanted to bring knowledge about the missing pieces. As described in Norman's model (Cooper et al. 2014) it is important that designers can create a more simple and accurate image of the system for users, which is why it is important that the designer actually understands the system. With our two interviews with technicians, we created the chapter about how the EV works technically and how the different user inputs affect the systems of the EV.

9.2.2 User behaviours and total user experience

The results of this project are built on a deep user study which has created a good picture of today's usage of EVs. The project started off with a wide literature study, which brought the possibility of formulating well substantiated questions to the user study. The user study resulted in answers from experienced EV drivers, which not only provided information about what aspects that are necessary to consider for an experienced driver but also to some extent for novices. Since many of the users had been new to EVs not so long ago.

Much of our results are supported by literature. Our idea about the EV representing the future was something which permeates the whole project. The research by Strömberg et al. (2011) discussed this subject and supported neither a traditional interface nor an innovative one. Their suggested reason for why not the innovative interface worked was because of the user feeling unsure and uncomfortable. Our study did not include any tests concerning this, but an innovative approach to the design of the EV is highly supported by many users. The EV as a symbol of the future had meanings in many levels. It did not only concern the physical aspects of the car as buttons and control panels, it also related to the desired and appreciated feeling when driving. To let the symbolic meaning of future thinking be a part of the overall interaction with the car, would be an interesting aspect to research further.

The silence of the EV was found to be highly appreciated by as good as everyone participating in the interviews and survey, this was triumphing the fact that the silent car might be a hazard for pedestrians. Many drivers stated that they had even become better drivers since they started using the EV, because they had to be more aware and keep better attention to their surroundings. This is also supported by findings of Cocron (2014) where drivers insinuated similar thoughts when saying that they were more actively looking for people around the car to avoid accidents.

9.2.3 Information in the UI

The amount of answers from the survey was of great importance for the arguments regarding the information presented in the UI. It made it possible to identify what information that is most prioritised in what situations, which plays a significant role in order to design the UI and to understand and enhance the experience of it. According to our literature study, it seems like not much research have been made in this area.

However, if drivers perceive range as a limiting factor of the EV has been studied in previous research. Our study indicated that range is a crucial factor, but mostly related to certain occasions, such as when making longer trips, when the battery level is low or when taking an unknown route. The research by Ruah et al. (2015) and also Jensen, Church and Mabit (2013) focuses on whether or not the range is perceived as an experiential barrier after gaining experience with the EV, while our study instead points out the importance of different situations during use where drivers perceive the range as something they have to consider.

We have in addition to this found user groups that want and need to see information in different ways, something we have seen in literature too, but not very similar to the groups of this study. Our user groups clearly differ from each other and are based on the results of the user study, the focus lies on the specific information itself for each group and when it is needed. While groups presented by Axsen et al. (2012) are pointing out differences regarding environmental and technical approaches among persons. Even if this study also showed evidence of environmental and technical groups existing, those findings were not separately used in identifying what information to show. Perhaps the view of this project together with the one of Axsen et al. (2012) could be used to provide a better and more detailed picture of the usage and what information that shall be shown to the driver.

In general, the findings are based on situations and users, that different drivers need different pieces of information at different times, as stated above. For example, the research of Strömberg et al. (2011) strengthen the results that both the DtE and the SoC indicator is needed. However, this report presents more knowledge of this information being related to type of driver and travel. Similar to the results showing that some people have a hard time to understand technical information like unit Watt, also stated by Strömberg et al. (2011), only in this research it is mainly related to user group A. Since the results were so strongly pointing at different user groups need different information, we believe it is important to consider dissimilarities among persons when deciding what information to show in the UI and how it shall be done.

The DtE indicator have proven to be of high importance and most car models are still lacking in their calculations of it, since many EV drivers do not trust the indicated estimated range. These difficulties are among others discussed by Jung et al. (2015) that compares different suggestions from other researchers of how the calculations could be done. Jung et al. (2015) specify the difficulties as being related to the impossible task of calculating range when the driving context changes, for example when the driver choose to take a hilly road instead of the normal flat one. Even though our research has not found an answer to this it strengthens the recommendations of not showing the DtE more accurate than what is possible, i.e a level of ambiguity is needed, as also supported by the research of Jung et al. (2015). Further, one of the features recommended as a result of this project is to let the driver choose to have a personal profile. Not only to provide comfortability but also to enable better prediction of range. As said earlier, the EV should be perceived as smart, which include taking into consideration the different driving styles and energy consumption habits of different drivers, which is of special importance if the EV are used for car sharing. Even though this does not solve the issue of predicting the range 100% correct each time, it will certainly improve it and also enhance the feeling of the smart technique being present.

The whole study is based on both qualitative and quantitative data. These sources complement each other well which gave a distinct result. However, as the result lacks insights about other users than those taking part in the user study of this project, we cannot claim the result being the complete right one regarding the problems of adoption of EVs. Among many other users, we lack the perspective from younger people, the next generation of EV users. The group of users we were able to contact mostly included male in the ages of 30-60. It is not a coincident we got in touch with these users, which could be described as early adopters and partly early majority. Since the EV is still a new product, these represent the larger part of the users. We contacted most of them at forums on the internet, which many of the early adopters use to share their thoughts with like-minded people. This influence the results since those persons are the ones most interested in their EV of different reasons, and they are the ones that have in a quite early stage adopted to this new way of transportation. Which is why it would also be of great interest to talk to persons that are not a part of these forums and also those that choose to not drive and EV, which is further discussed below under “future work”.

9.3 Methods used in this project

The project was for a start partly shaped by the findings of the literature study, since this was the first thing conducted and completed in the project. What articles that were found and available at that moment created the base of the questions asked to the interviewees. Which imply a possibility of the project going in another direction if other articles would have been found. However, some parts of the benchmarking were made at the same time which also provided input to the next steps of the project, perhaps it could have been useful to finish this before conducting the interviews, in order to be able to create a more specific interview template.

Many of the questions in the interviews were wide and open for the interviewees to discuss about, for good and bad. This resulted in some questions getting more attention than others depending on the participant, considering the time aspect available for each interview this lead to different questions being answered in different interviews. However, the result was still judged as good since they provided a deeper understanding to the quantitative data provided by the survey.

How the questions were posed in the survey affected the outcome, in order to receive a correct and fair result it is important that they, to the furthest extent possible, are interpreted in the same way among participants. The survey of this project should therefore have been tested properly by experienced EV drivers before it was published. After it was completed we noticed some problems with formulations from our part and the choice of words, for example: one question included the word ”useless”, which is very strongly emotive and should have been reconsidered. Although, there were many people that expressed that the survey posed good questions about their situation regarding the use of the EV. Furthermore, even though it was of great value with many people answering the survey, we were not prepared for the amount of work it took to go through answers that for several questions were typed in by each participant, and by ourselves sorted out and put into diagrams. It took much time but at the same time those typed in questions provided extra value by adding more qualitative data to the study.

Conducting a benchmarking early in the project was considered valuable, since it helped us to get an insight in how it is to drive an EV and what real EV users really experience. Us being new to this transportation was considered positive since we could go into the role of a novice driver without previous knowledge about EVs, and really test the level of usability of different functions and explore the car. What could have been made better was to, after the first drive, state specifically what to look for in each car. There was a template as a guide what to look for, but not enough specific. This would have made the summary and comparison of the different cars easier (see appendix 2).

The workshop did not provide as much and fruitful results as expected. It was well prepared but with inexperience of holding workshops it is difficult to foresee how the real situation will be and how tasks are perceived and conducted by groups. How the tasks were formulated should have been tested on other non-EV drivers before the workshop, also preparations of how to guide the participants if they got stuck or if they come into side tracks should have been done.

9.4 Future work

Another finding of the survey that are not presented in this report, is the issue of social resistance. Many EV drivers express this as being one of the biggest problems when it comes to the use of EV. People around them that do not understand what this new mean of transportation is and people that are stuck into traditional ways of thinking of what a car should be. This was not taken further in this project since we have only spoken to experienced EV drivers, which can only contribute to one side of the coin. We also received answers from many parts of the world, and even if the issue was represented in many or all of them, we could not draw any conclusions if the issue is equally spread in the world. Cocron (2014) express equal results of societal resistance in Germany and that this could be a problem to the adoption of EVs. This is an important question that needs to be research further, in order to improve the adoption of EVs.

Another form of resistance is related to the EV as a new kind of technology. After the research and analyses in this project it is understood that this is an important question regarding adoption of EVs, but unfortunately not investigated or discussed in this report. The issue is presented by Rezvani et al. (2015), where it is discussed that people's anticipations on new technology are affecting their choices, since there is a worry of product obsolescence. The anticipation of the technology developing at high speed could create resistance of buying the one available today. Perhaps there is a worry from the potential EV users side that the invested money will decrease rapidly as the EV gets older, when new EVs are constantly entering the market.

Furthermore, a next step of this work would be to also include non-EV drivers in the study and collect an equal amount of data from them. It is just as interesting and important to understand why people choose to not buy an EV and the potential preconceptions there are about them as to understand why people choose to drive EVs. To also include more younger participants in the study would be of importance to reach out to the next generation of drivers and to understand what they want from future transportation as the young connected generation they are.

The results presented are suitable not only for the collaborating CEVT in this project, but also for other car manufacturers around the world. The project has taken new EV drivers into account, and it has been pointed out as being of special interest since LYNK & CO is a brand focusing on car sharing. However, this is not unique and as many products are used more and more frequently for sharing, many automotive companies may adjust to the trend. Also, the main focus of the project was not directed towards the new drivers but the experienced ones, since drivers quickly becomes familiar with the EV. Lastly, the ideas developed in this work would need to be tested and evaluated in order to know if they are valuable. For now, the concepts that are visualised are only thoughts and ideas on how the information that was stated as important could be shown.

10. Conclusions

Here the most interesting findings from the project is presented and areas of future research are suggested.

The aim of this project was to understand the new user behaviours related to EVs and what and how the total UX could be understood an enhanced. Related to this, was to find what information that shall be shown to the driver in the UI in order to reach a well-designed UI for the driver, for him or her to have a pleasant experience. The EVs are today considered to symbolise the future, this together with environmental arguments, and pleasant driving in terms of silence and performance are the main reasons for choosing it. This is important to follow when designing the EV, and so it is included in the guidelines created in this project. To enhance a good UX and to make a well-designed UI for different users, it is also important to understand and respect that different users have different needs and desires, why three different user groups were defined and was used as reference points when creating the requirements.

The aim of this project is considered to have been met. Although, the investigated area would be in favour of further research, in order to make sure to completely achieve the goal of a well-designed UI that make the driver understand and like the EV. There are some specific areas related to this where further research need to be made, such as; to understand what the most energy efficient driving style is and how to encourage this in a simple and understandable way. Also, how to inform the driver of the relation between the energy consumption and the range, and the level/speed of which they are decreasing with. Furthermore, a greater variation of users participating in the data collection would be necessary to reach a result where not only the most interested persons of EVs are considered.

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Appendix

Appendix 1 – Requirement list

User Experience requirements

Range/ energy consumption

		Prioritization & User Group	
1	**The car shall encourage a feeling of a "free" drive, e.g. not showing info that makes the driver feel limited.** For fun and comfortable ride and give user control over usage of the car. E.g. when driving short distances, energy is not prioritized. *The driver wants to feel in control and utilize the performance of the car, i.e. accelerate because it's fun.*	Low	A + B + C

Physical aspects of the EV

2	**The car shall be possible to use comfortably with a low energy use.** To give a high level of UX, and to get a longer range. *Smart solutions that save energy could be heating specific parts of the body, e.g. back, but, feet, hands etc. Also low energy consuming lights like LED should be used.*	High	A + B + C
3	**Use the unique properties that an EV enables thanks to its technical nature.** People appreciate this. Enable direct response from the powertrain, enable a high rate of acceleration, a smooth transition between speeds. *Have direct response when accelerating (contributes to a good UX).*	High	A + B + C
4	**Autopilot function shall be available.** People appreciate this and its give feeling of future technology. This feature shall take the energy consumption in account, i.e. drive in an energy efficient way. *EVs are the "future", and should therefore include new technology such as auto pilot function. Drivers trust it and appreciate it, it makes them do other things during the drive (reading news).*	High	A + B + C

5	**The car shall maintain the quietness even in high speed.** The silence is appreciated and is unique for EVs, but it disappears at high speed since it is not isolated enough. People enjoy the silence itself. Example how: The car shall be isolated to maintain the quietness even in high speed. Can we take advantage of the new experiences of the things that drivers appreciate with the silence? For driver B, keep the natural sound from the electric engine. *Easier to have conversations (people in the car and phone calls). The quietness is relaxing and calming, it enables a new music experience (better and lower level of sound).*	High	A + B + C
6	**Minimise the level of vibrations inside the car.** This is strongly related to the silence and together they will elicit a good feeling. *The combination with quietness and no vibrations is very appreciated, (relaxing).*	High	A + B + C
7	**Systems in the car, such as climate control, should not contribute to unnecessary sound.** The more silence nature of the EV is appreciated by drivers. *Since the EV is quiet thanks to the electric motor other systems need to be quiet too in order to maintain a quiet environment in the car.*	High	A + B + C

Range/ energy consumption

8	**A good sound system shall be installed in the car to give a pleasant experience of music.** Since there is a higher level of silence, listening music is more appreciated. *Many people enjoy listening to music in the car even more than in fossil cars since the EV is more quiet. D10 and D 11 shows that media is prioritized to show.*	Medium	A + B + C
9	**Take advantage of the new construction possibilities compared to fossil driven cars.** This will give opportunities for new architectures of the car and enable new ways of using the car. *New planning of the interior, saving space, due to the electric motor that enables new ways of constructing the car.*	High	A + B + C

10	**The car shall be discoverable by people and animals outside in the vicinity.** Drivers feel unsure whether the car will be noticed and cause harm. Example how: Sound signals. *Driver's express they have become better drivers since they have better attention of the traffic because their car is silent not as easy detectable as other cars.*	High	A + B + C

Experience of car

11	**The UI should be presented in a modern way that support the technical nature of the EV and that is not inspired by the UI of a CV.** The EV do not function in the same way as a CV and therefore other information can be presented. The EV include new technology which should influence the UI. Example how: Show the user's interaction connected to electricity. *Many experienced EV drivers do not appreciate classic fossil fuel car instrument clusters. Also the physical interaction ways (buttons, controls etc) should be looked over.*	High	A + B + C
12	**The exterior and interior of the car shall support the mind-set of the driver's thoughts about the EV symbolising the future.** The drivers agreed that EV symbolize the future and therefore the car shall reflect this. The car shall express being at the forefront of technology. Example how: Good infotainment system and exterior lights. Sensors, smart feature as seats adjusting to the driver automatically, light automatically turned on etc. Make electricity a part of the overall experience to make the car more ”alive” and ”smart”. Connect sound and light to the interactions with the car. ”The technique is there”. *Symbolising future because of lack of exhaustions and the quietness which makes the EV more environmentally friendly, it's quiet. Many of the interviewed persons also had an interest of new technique.*	High	A + B + C

13	**The exterior and interior of the car should support the mind-set of the driver's sustainability approach.**	Medium	A + B + C

Many of the interviewed persons chose an EV primarily because of positive effects of sustainability, also this way of thinking was permeated in their everyday life.

Example how: Ideas: The car's interior material shall "breath" and should create an atmosphere of fresh air. E.g the materials could be natural as textile. A car with lots of plastic made from oil could contribute to a negative feeling for the driver with sustainable mind-set.

Many of the interviewed persons chose an EV primarily because of positive effects of sustainability.

14	**The car shall encourage to a sense of freedom.**	Medium	

Drivers appreciate many positive aspects of the EV such as performance of the car, sustainable environment approach (fresh air) and high technology that entail simplicity for the user and elicit feelings of freedom. These feelings need to permeate in the overall usage of the car and shall not be removed/replaced by adding other features.

Example how: Have a large sunroof that lets in light, sunshine, and fresh air if wanted. Gives a feeling of openness and freedom, the silence of the car will be experienced in a another way. Have a (transparent?) screen in the roof showing the blue sky that is wanted and needed in China.

Charging the car

15	**Enable to charge without need of bringing the cable in the car.**	High	A + B + C

Many drivers find the charging easier when not bringing the cable. The cable is clumsy to handle, is sometimes dirty etc. Since charging is done everyday this action affects the driver. Let novices as user group C feel safe without bringing the cable.

Drivers find it troublesome, it gets dirty, it takes up space etc.

16	**Enable to charge car without cable.**	High	A + B + C

Charging is normally done everyday and some people find it time consuming to use the cable.

Drivers find the cable troublesome to handle.

17 **The charging time should be minimized as much as possible.** High A + B + C

Charging is done rather often and when doing charging stops along the way on a trip this stop shall be as efficient as possible to save time.

Many people think that the speed of charge is a problem with EVs.

18 **Easy to charge at charging stations were there could be multiple cars charging and different choices of charging available.** Medium A + B + C

To make the charging as efficient, safe and simple as possible. Example of charging settings could be to change the ampere level.

Easy to choose charging settings that fit the charging place and personal preferences. In the best case the car will handle the charging settings by itself, choose best available charging option due to the situation and availability. (Multiple cars at the same station, info at station matches info at car).

Information requirements

Info battery- State of Health (SOH)

19 **Give notice when battery needs attention.** High A + B + C

Simple and clean UI.

- Give info about proper action.
- Give info about cause of problem and proper action. In situations: When the battery has a problem. When car cannot fix problem itself. Direct and prioritised.

User do not want to pay attention to the battery,"it should take care of itself". Interviewer: What's wrong and what to do (drive in to the edge and stand still for a while). That's all I need to know.

20 **SoH easily accessible when wanted.** Medium B

Of interest. Give info about the performance status and accessible charging level. In situations: When needed. Easily accessible when needed.

"Heart of the car".

Energy consumption -Overall

22 **Show the overall energy consumption.** High A + B + C

To help the driver to feel in control of the energy consumption and to give knowledge and bring trust. Sources affects level of range. This is described in the report in paragraph Driver specific information for A,B & C users.

The total and divided in specific sources and level of consumption. + Use as a competition feature.

In situations: Prioritised for cars with low range, when battery is low and when travel long distances.

Example how: Simple UI (A + C) Technical info (kW) Graph (B). Other thoughts: For driver A this is shown in km and for driver B it is shown in kW (or kWh). Show in a ”calm” way, not elicit stress. This could also use as a tool to compare how much energy the driver save if the e.g. AC shuts down.

Power train, speed (air resistance), climate control, other as extra weight, tire pressure, steering wheel heat, seat heat, road conditions, weather conditions. If this can be controlled an increased driving experience can be enabled, e.g. driver might not have to turn off heat. Also this make the driver feel in control of his/her energy consumption —> trust. When driving longer or new distances, possibility of making extra drives during the day, low battery or for persons with a general interest of saving energy.

Energy consumption - Driving style

23 **Show energy consumption and regeneration from driving inputs.** High A + B + C

Fun/ of interest/ needed to save energy and to save natural resources. This is described in the report in paragraph Driver specific information for A,B & C users.

A measurement or visual scale that lets the driver understand and recognise the level of consumption. In situations: Prioritised for cars with low range, when battery is low and when travel long distances.

Example how: kW (B), Simple UI. Show in a ”calm” way, not elicit stress. Interviewer: You can see how much energy you use and get back by looking at the semicircle in the BMW i3. What you can understand is that you do not get back as much energy as you use. This is seen by the fact that it does not turn as much in both directions.

Hard to understand energy consumption variation when driving fast. Also, the driver should be able to recognize the level of consumption from his normal driving behaviour.

Energy consumption - Energy history

24	**Show statistics and information about energy usage history.**	Low	A + B + C

For fun and to learn how to drive energy efficient.

In situations: When wanted.

Energy consumption - External factors affecting the energy level

25	**Show how extreme outside temperature and high speed effect the range and battery level.**	High	A + B + C

As an explanation why the battery level and range is decreasing faster.

In situations: When low outside temperature.

Example how: This could be shown as the battery level sinking faster than normal with a certain speed.

The driver can be surprised of battery level (negative/ positive way). In extreme temp and high speed, the battery level is highly affected and more energy is used, which not every driver understands.

26	**Show how external factors, such as road conditions affect the range and battery level.**	Low	B

These factors affect the battery level and help driver B to better estimate range.
In situations: When the road conditions affect the battery level.

Weather as wind and outside temperature, road conditions.

Information in portable device as an application in a phone

27	**Give general info about the car's status and enable control over different parameters.**	Medium	A + B + C

To feel in control and trust over the car. Choice of ampere level, stop/start charging ect.

28	**Give notice when normal charging behaviour is not followed.** To have a charged car when needed. *If driver's behaviour deviates from normal, as for example if the driver forgets to plug in the car at night.*	Medium	A + B + C
30	**Show engine speed.** For fun.	Low	B

Range/energy consumption

32	**The computer in the car shall learn the driver's normal driving style/ energy consumption.** To enable a more accurate DtE.	-	A + B + C
33	**Calculate the DtE as accurate as possible.** Because many drivers do not trust the DtE. *Many of the participants in the survey thought they could not trust the DtE, many referred it to Nissan Leaf's "Guess-O-meter (GOM)".*	High	
34	**Show DtE more precise when the DtE is low.** In these situations, the driver wants more precise information about the range. *Goes against previous research that says that showing the info in a more ambiguous way is in general good, but even more beneficial in critical situations.*	Medium	A + B + C
35	**Make DtE more accessible when driving to new destinations.** In these situations, the driver are more unsure about the range and want more information about it. Example how: The car notice thanks to the navigation system.	Medium	A + B + C

36	**If the temperature from where the car is parked and the outside temperature differs more than X degrees this will be taken into account when calculating the range.**	Medium	A + B + C

Since the driver look at the range when starting trips, at this moment it is important to give the accurate range estimate direct.

Drivers usually look at the range when entering the car, since low temperature highly affects the range the actual temperature where the car will be driven should be the temp used when calculating the range.

37	**Possibility of showing distance of last trips.**	Low	A + B

To learn about the energy consumption and out of interest.

Of special interest for EVs since the range is more limited than for CVs. However, this info shall not be prioritized to show in cluster since people do not claim that they use it.

Range/energy consumption - Low energy level

38	**Make DtE more accessible when the DtE is getting low.**	Medium	A + B + C

In these situations, the driver is more unsure about the range and want more information about it.

In situations: When low range/ battery.

39	**Show driver when battery level has reached a critical level.**	High	A + B + C

To make the driver aware of the low battery level and soon needs to be charged.

Notify the driver C in greater advance compared to A and B drivers when running out of range. Due to less experience the ability to estimate the car's range is low.

In situations: When low range/ battery.

Related to max range of car, this decides the level of battery % when the car shall give notice.

Physical aspects of the EV

40	**Enable to set starting time for heating of battery and inside climate of the car.** Because it is energy consuming to drive with cold battery which leads to lower available range and its performance is affected.	High	A + B + C
41	**Inform the driver in a clear way that the car is ready to drive.** To make the driver understand and not feel stupid. In situations: All the time. *The driver needs to understand when the car is ready to drive. The car could have "accessory"-mode (leaf) where few functions as radio and navigation can be used, but driving is not possible. .*	High	A + B + C

Experience of car

42	**The UI shall support the driver's trust to the EV by showing correct and understandable information.** Increase the level of a positive experience and decrease stress and insecurity. *A general requirement, fulfilling the other will increase this one. Decrease stress and insecurity.*	High	A + B + C
43	**Minimise the number of actions required to start driving and stopping/parking the car.** The car shall be simple and intuitive to use. Use the technical advantages that an EV entail, skip unnecessary steps that are required in e.g. a CV. *The driver appreciates the simplicity and do not want several steps needed to start driving.*	High	A + B + C
44	**Different drive modes should be possible to choose from.** Different user groups need different kind of information and it should be presented in different ways to enable a good understandable UI. A, B or C users.	High	A + B + C

Driver

45	**Possibility to create a personal driver profile.** Makes it easier for the driver and car will be able to predict energy usage better (due to different driving styles) and better predict range. Save history of driving style and settings.	High	A + B + C

Support from car - Navigation tool/charging stations

46	**Possibility of searching for charging stations.** For the driver to feel trust that he/she will reach the destination and simplify this kind of task. Info about charging station shall be updated (if it works, how many there available, available effect, what kind of charging available…).	High	A + B + C
47	**The car shall monitor the driving style and analyse this to enable the destination to be reached, notify driver to change driving style if needed.** As a help for the driver to make him relaxed and calm (trust) that he will reach the destination. This shall be done in enough advance for the driver to feel safe and reach its destination. X km, X %. How long before the battery is out should the driver be noticed? What is a good margin at the battery to feel safe, and feel trust? *E.g. the car tells the driver that he/she needs to decrease speed to 80 km/h reach the destination.*	High	A + B + C
48	**If the battery is under X % the car shall recommend a proper station to charge at.** As a help for the driver to make him relaxed and calm (trust), release him from tasks to reduce stress. If there is need of a changing driving style, as a lower speed, to be able to reach charging station this shall be notified to the driver.	Medium	A + B + C
49	**Possibility of comparing the DtE with the distance to final destination.** To let the driver feel in control. But is there a under laying requirement? *Avoid range anxiety.*	High	A + B + C

Support from car- Prepare for drive

50	**Remind driver to have the car ready (pleasant climate inside car and battery temp) before drive.**	High	A + B + C

To save energy when using the car which enable the maximum range and to enable the best performance of the car.

Climate control is battery draining. Good temp of battery gives better performance.

Support from car - Low energy level

51	**Force the driver to drive in a lower speed when X% of the battery is left.**	High	A + B + C

To be able reach a charging place.

Example how: Possibility of showing symbols: One interviewee liked the red ”turtle” in the Volvo C30. Or maybe it should only be a test message? Do we need both?

Lower speed mean that the EV uses less energy.

52	**Enable help in emergencies.**	Low	A + B + C

To let the driver feel relaxed that if an emergency situation occur, he knows how to get the help needed.

Example how: As a function in the car. E.g as a button, ”service…”

Energy usage mode

53	**Different levels of energy use support shall be available.**	High	A + B + C

This function is appreciated among EV driver. This helps the driver to have less focus on energy consumption and feel more relaxed.

The driver can choose a mode as default. The ”middle mode” will from the beginning be chosen as default. —If in a ”lower energy use” mode, this shall in an easy way be simple to deactivate for a moment. (Ex. if driver wants to accelerate hard and immediately for safety or fun reasons). D20

Example how: Instead of ”eco” and ”eco+” we can have a scale of colours (yellow-orange-red) or what level of energy use the driver wants (low-medium-high). Since this is not an info that driver need to see all the time it does not have to be included in cluster. Might be placed close to gear shift, it’s related to the drive mode. Eco is word has different means a in economy or ecologic (to save money or save to save the environment), this is discussed further in the report.

Not using connection to ”eco” , this word includes so much more than just using less energy and the word itself might lead to the function not being used.

Energy coaching

54	**Rewarding driver for energy efficient driving style over time in a "calm" and visual way.**	Medium	C

To learn and encourage to an energy efficient driving style.

Charging the car

55	**The car shall control itself to what level the battery should be charged to remain in as good health as possible.** To let the battery of the car be in as good health as possible for as long time as possible. Not let the driver feel responsible about this, release an extra task for the driver. Should the battery level be shown as 100% even if it's not? Example how: If battery level is shown as 100% even if it's only 80%, when driving longer distances you might want it to charge actually 100%, how should this be shown? A battery that is ”blowing up almost” or like an extra bar over the normal battery. Provided you plan your trip in the app or CSD, where to go and when, the car will know if it is far and if it should load properly, 100% for this trip. *It's not healthy for the battery to be charged to 100% everyday, this is something that driver A and C do not want to control themselves.*	Medium	A + C
56	**The driver shall be able to choose to what level the battery shall be charged.** Driver B wants to fully control the car, since B has the knowledge needed. Should the battery level be shown as 100% even if it's not? Same as for A and C or different? *It's not healthy for the battery to be charged to 100% everyday, this is something that driver B wants to have control over.*	Medium	B
57	**Indications of the charger shall be the coherent with the information in the car.** To maintain a coherent design, the charging options of the charging station shall match those of the car, the ampere level shall be described in the same way in order to make the user understand how to connect these two. *Drivers find it difficult to use chargers where the charging options to not match those of the car, the ampere level.*	Medium	A + B + C
58	**Block possibility of driving with charging cable connected to car.** Damage to the car and cable can occur.	High	A + B + C
59	**Notify driver if trying to drive car with cable plugged in.**	Medium	A + B + C

To know what action is needed in order to start driving.

60	**Reminder to the driver to charge the car.** To enable a fully charged car at next trip. Example how: As a notification in the cluster. *When car knows it is ”home”, thanks to navigation tool.*	Medium	A + B + C
61	**Indications and feedback showing that charger is or is not properly plugged in.** In order to let the car charge. Example how: Sound, haptic, light… *Direct feedback when plugging in, indication showing that the charger is correctly plugged in.*	High	A + B + C
62	**Indication showing that the car is charging.** For the driver to feel trust that the car is charging. *Data must be correct and updated to bring trust. During charging the driver often is not by the car.*	High	A + B + C
63	**Indicate when charging is complete.** To let the driver that the car fully charged. *When car is charged to the level wished.*	High	A + B + C
64	**When charging, give info about charging time, speed (Power), battery level (% and/or km) etc.** For interest and/or for driver to have possibility of estimating when the charging is completed. Example how: Different info will be shown in different ways for A. B and C.	Medium	A + B + C
65	**Give notice if charging stops unexpectedly.** To enable a fully charged car when needed. *If charging stopes unexpectedly. If the electricity stops, without noticing.*	High	A + B + C

Energy Consumption - Driving style

66	**Enlighten and encourage the most energy efficient driving style.**	High	(A) + B + C

To save energy and range. In situations: When driving. Prioritised for cars with low range, when battery is low and when travel long distances.

Example how: kW (B), Simple UI. This requirement can be merged together with previous requirement.

To ”roll out the energy”, i.e. not braking and then accelerating again. Interviewer: It's a nice feeling to be on the green. But you really do not want to lie on the green, you always want to consume energy or do nothing at all to drive optimally. You want to charge as little energy as possible, because when you charge, you convert the energy ineffectively, instead, try to roll out the energy. But if you're on a hill and it's illegal to drive faster and you have to brake then you're glad to get into the green.

General requirements

Physical aspects of the EV

67	**Maximum range shall not be less than X km**	High	A + B + C

Not let the driver feel limited to the range and avoid some trips as a consequence of this.

Survey says that daily trips are in most cases between 30-60 km.

68	**Enable the driver to adjust the responsiveness of the brake in ”one pedal drive”.**	Medium	A + B + C

This effect the driver’s experience when driving the car. It is important that this feature is customisable since users have different preferences.

This is connected to the level of regeneration of energy when decreasing speed.

69	**The cap to the charging port shall always be possible to open in a simple way.**	High	A + B + C

To enable charging and give a high level of UX. Even at low temperatures, the cap should not freeze.

70	**Enable fast charging.**	High	A + B + C

To give a high level of UX, save time.

Both as a technical aspect of the car and also have fast chargers as a part of the infrastructure.

Support from car - Software updates

71	**Possibility of software update without going to a service station.**	Medium	A + B + C

To make this regular event more convenient for the driver.

Info to the driver

72	**Only show the most important and prioritized info to the driver.**	High	A + C

Decrease mental load with less info which distract the driver. This will give a higher UX.

Some info (as rear cameras) should be active and showing when needed.

To create a simple and clean interface that enhance the feeling of a high automation level and to decrease mental load. See separate list of what info that is prioritized.

Range/ energy consumption

73	**Do not show DtE not more precise than what is possible.**	High	A + B + C

To enhance trust.

Take specific parameters into account (road conditions, driving distance etc). If not a precise number can be shown the information shall be shown in a more ambiguous way.

Example how: The Bolt car, that have a max and min when showing range.

A number that is too precise is not trustworthy, because the DtE can not include unforeseen data that effects the range in the calculations. With experience the driver learn how DtE function behaves

Support from car - Navigation tool, charging stations

74	**The car shall support the driver in planning long trips, X km.**	High	A + B + C

To enable as comfortable trips as possible.

Show charging stations along the chosen road when using the navigation tool, how long the stops need to be etc.

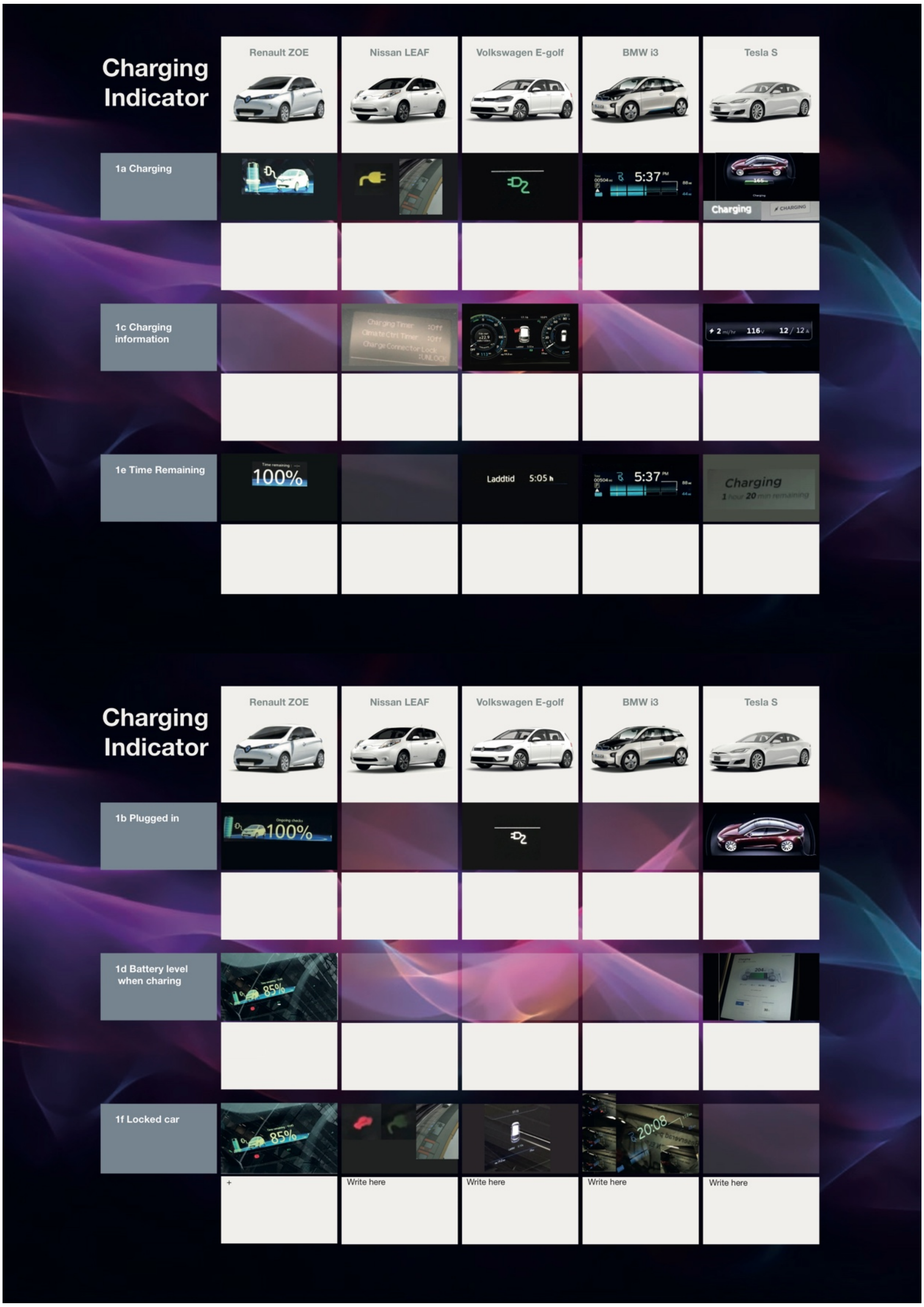
Charging the car

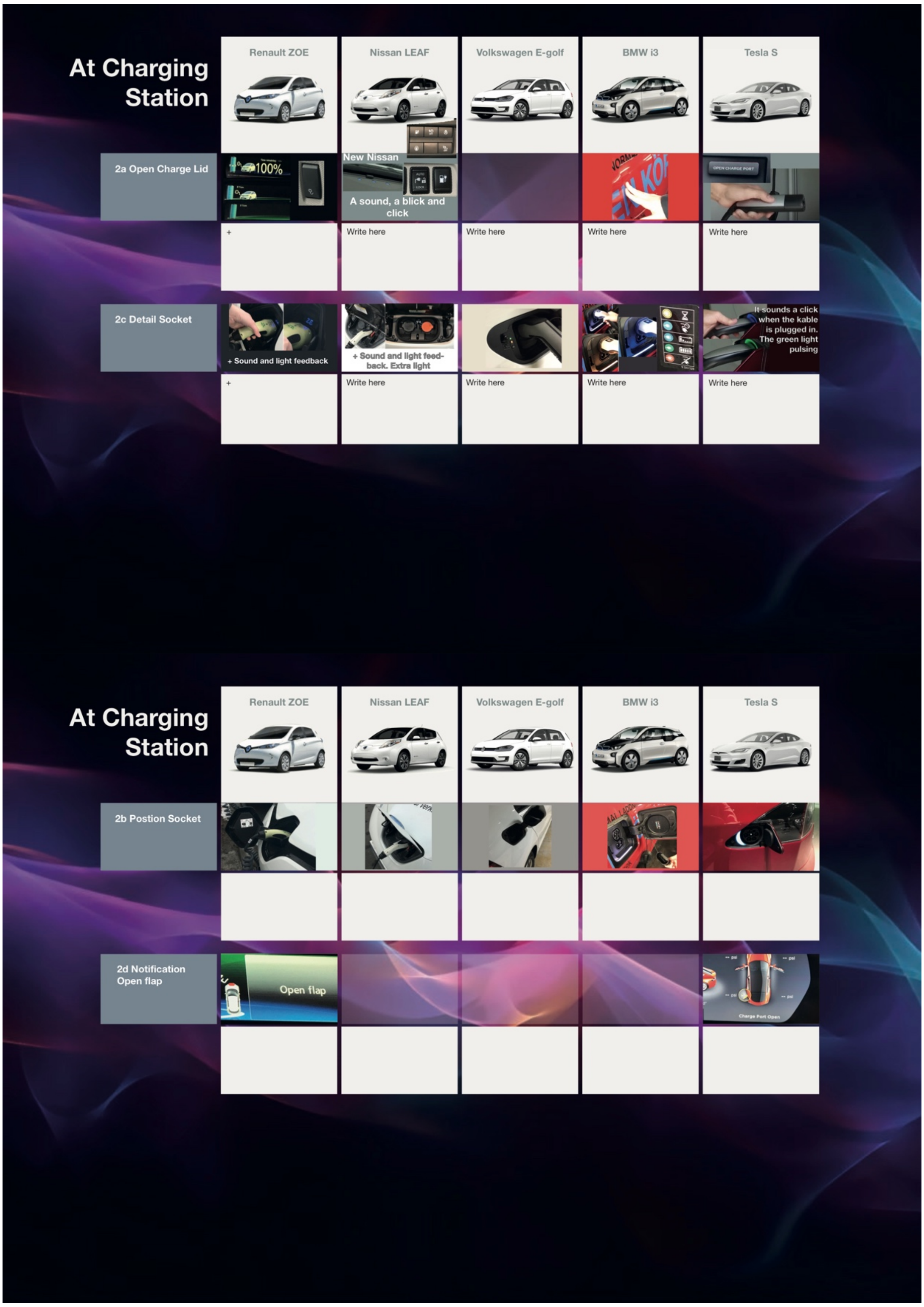
75	**Car shall be easily chargeable.**	High	A + B + C

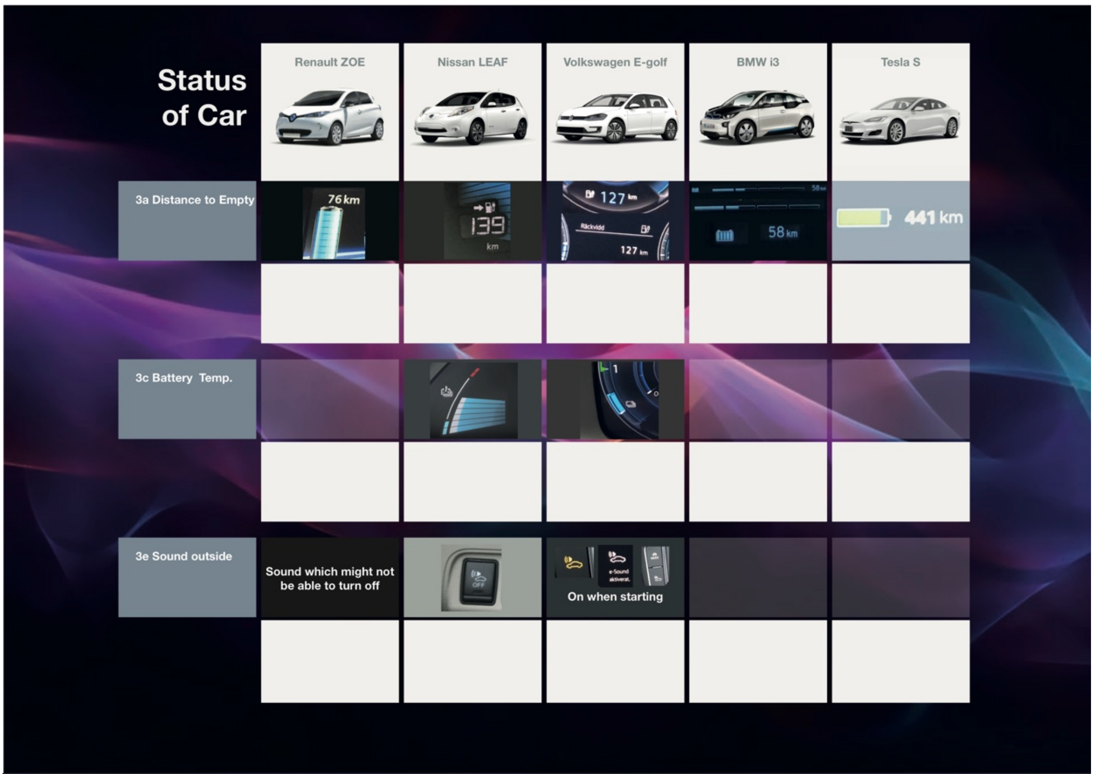
It saves time and reduce stress since it is an action that is performed every day.

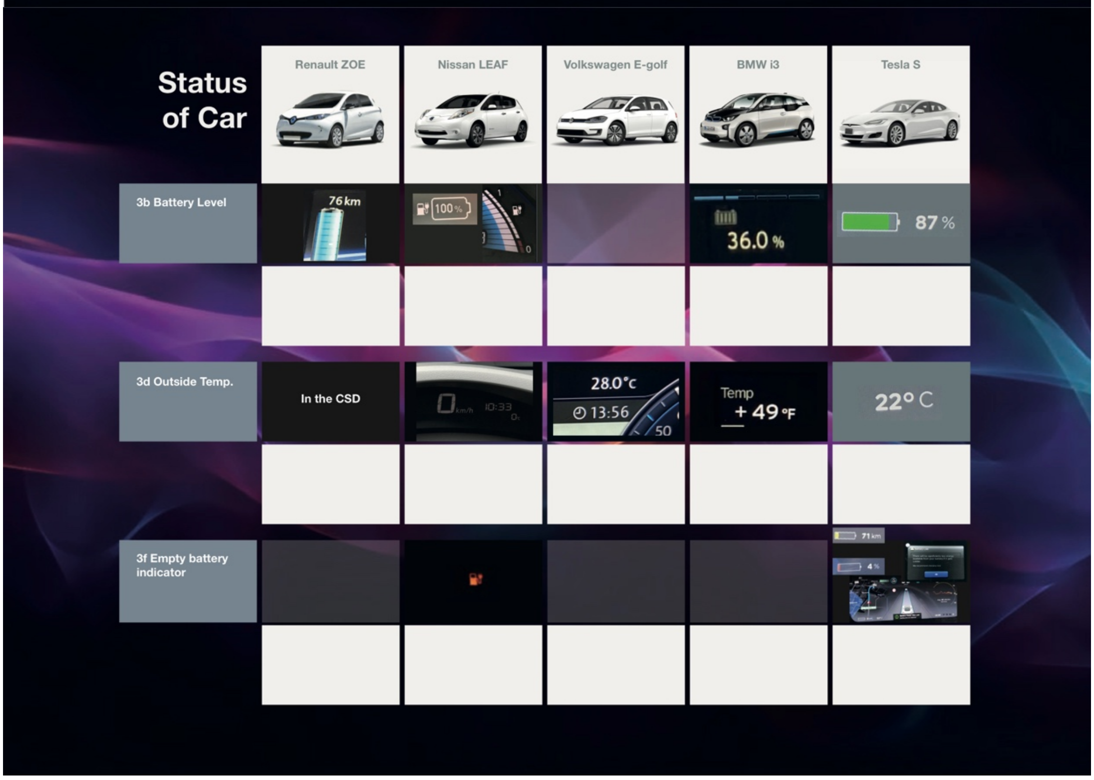
Car is normally charged and used everyday which is why it needs to be as simple as possible to perform the charging.

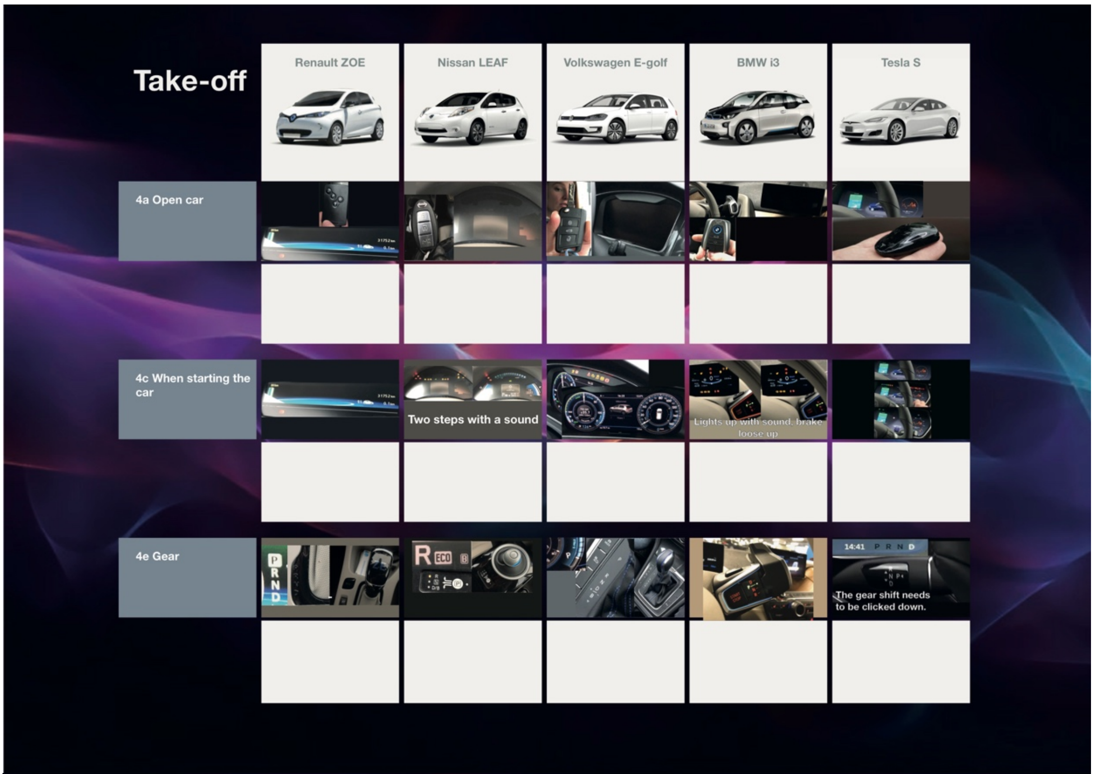
Appendix 2 – Benchmarking



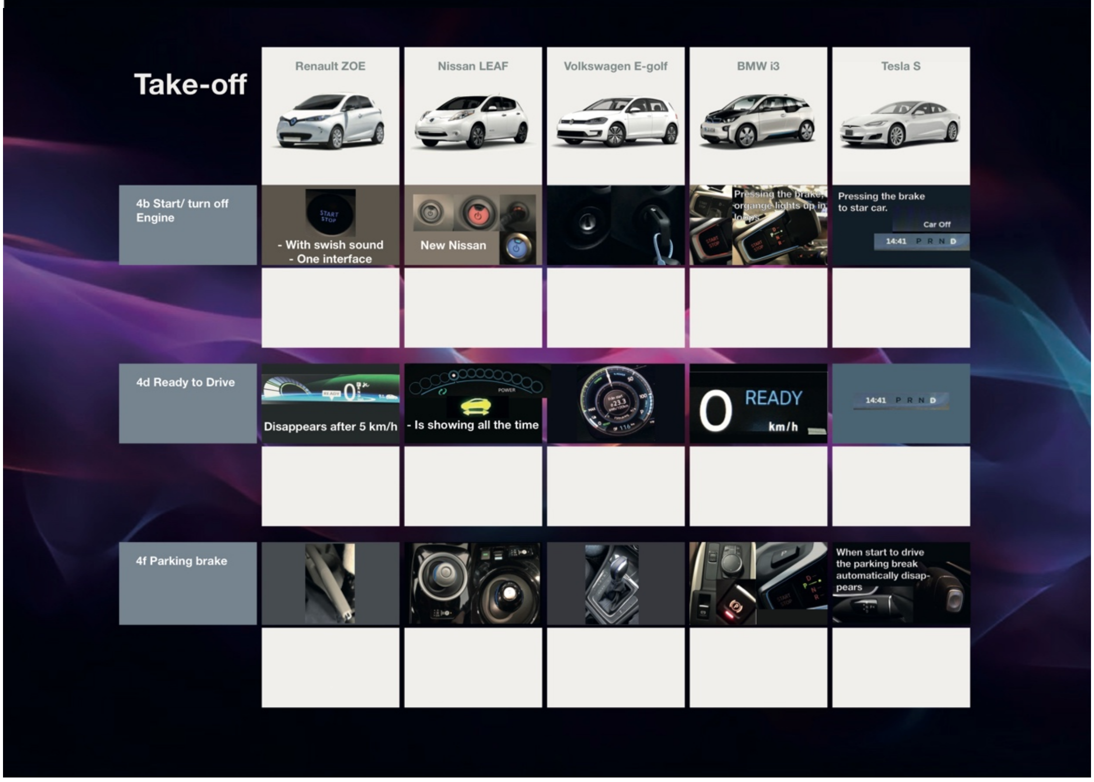

At Charging Station
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
2a Open Charge Lid
100%
New Nissan
A sound, a blick and click
+
Write here
Write here
Write here
Write here
2c Detail Socket
+ Sound and light feedback
+ Sound and light feed-back. Extra light
It sounds a click when the kable is plugged in. The green light pulsing
+
Write here
Write here
Write here
Write here
At Charging Station
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
2b Postion Socket
2d Notification Open flap
Open flap


Status of Car
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
3a Distance to Empty
76 km
139
km
127 km
Räckvidd
127 km
58 km
441 km
3c Battery Temp.
3e Sound outside
Sound which might not be able to turn off
On when starting

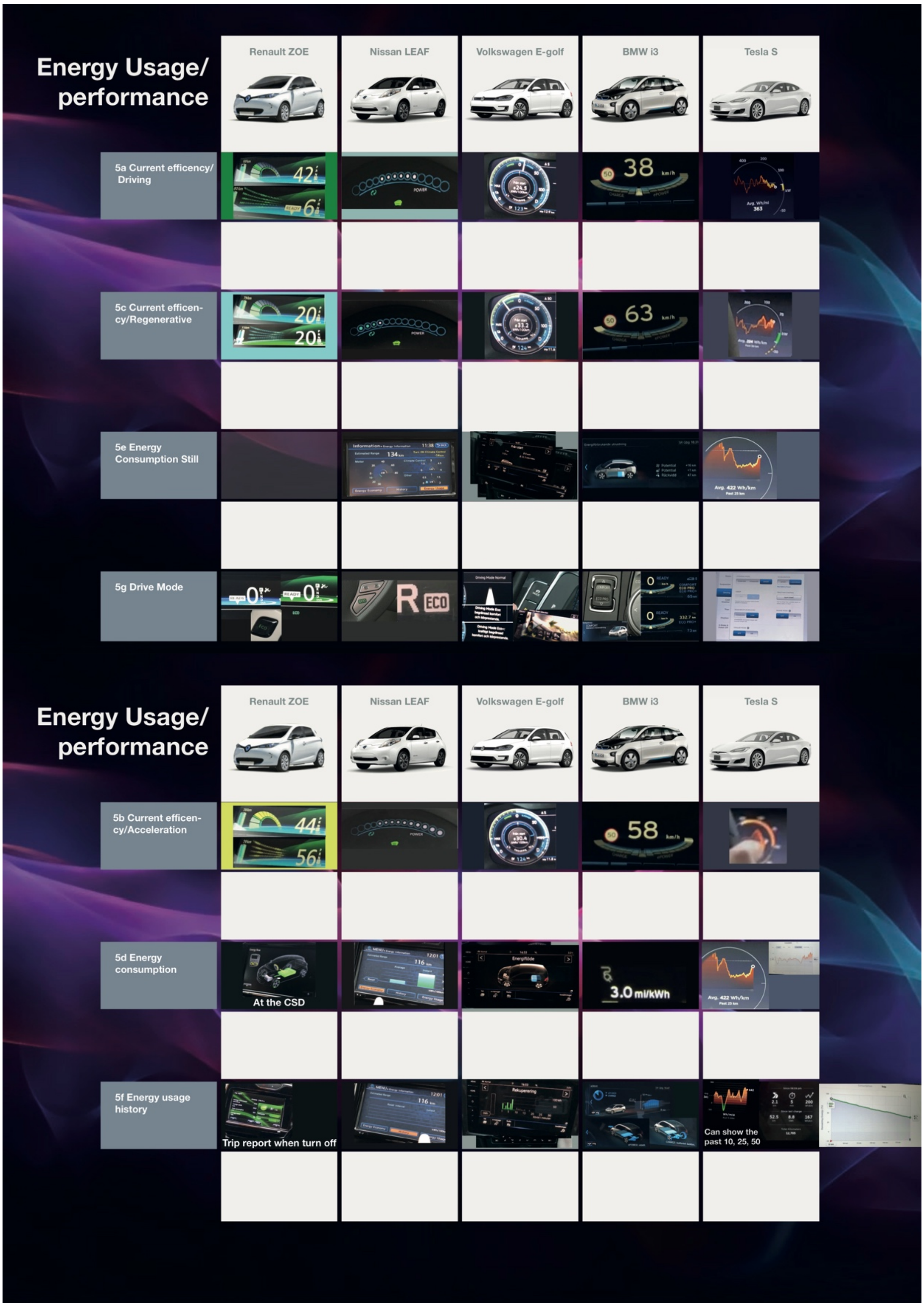

Status of Car
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
3b Battery Level
76 km
100 %
36.0 %
87 %
3d Outside Temp.
In the CSD
28.0°C
13:56
50
Temp
+ 49 °F
22° C
3f Empty battery indicator



Take-off
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
4a Open car
4c When starting the car
Two steps with a sound
4e Gear
The gear shift needs to be clicked down.



Take-off
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
4b Start/ turn off Engine
- With swish sound
- One interface
New Nissan
Pressing the brake to star car.
Car Off
4d Ready to Drive
Disappears after 5 km/h
- Is showing all the time
READY
km/h
4f Parking brake
When start to drive the parking break automatically disappears


Energy Usage/ performance
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
5a Current efficency/ Driving
5c Current efficen-cy/Regenerative
5e Energy Consumption Still
5g Drive Mode
Energy Usage/ performance
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
5b Current efficen-cy/Acceleration
5d Energy consumption
At the CSD
3.0 mi/kWh
5f Energy usage history
Trip report when turn off
Can show the past 10, 25, 50


Energy Usage/ performance
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
5h Energy coaching when not driving
Five screens avalible
5j Change layout of dimmer
This also gives different sounds when using "blinkers".
5l Display
88%
Total 00022 mi
5n E Display
Driving Distance 9999.9 km
Elapsed Time 14:11
3.0 mi/kWh
Energy Usage/ performance
Renault ZOE
Nissan LEAF
Volkswagen E-golf
BMW i3
Tesla S
5i Eco Coaching while driving
38
MAX 69
5k Display
Energy Economy
39208 km
278.0 km
5m Display
Average Speed
47.9 km/h
Temp + 49 °F

Appendix 3 – Interview template

Förberedelser:
- Fråga vilka bilar personerna har erfarenhet av. Skriv ut alla olika UI och ta med i färg till intervjun.

Intro

Berätta kort för intervjupersonen om vår utbildning och projektet vi håller på med (teknisk design, UX och elbil).

Berätta hur intervjun är strukturerad
Vi kommer börja med inledande frågor om dig och kort om vilken erfarenhet du har av elbil.

Vi kommer fokusera på hur du upplever bilen som helhet samt hur du tolkar och uppfattar en del av den information som visas. Vi kommer inte gå in på laddningsstationerna, infrastrukturen, hur laddningen fungerar hemma etc.

Om det är några frågor du inte vill svara på så får du såklart hoppa över dessa.

Information om intervjupersonen
1. Namn
-
2. Ålder
-
3. Vad jobbar du med?
-
4. Vad gör du på fritiden? *Intressen? Hur reflekterar dessa i din vardag? Påverkar det val av bil?*

Mentala modeller
5. Vad är energi för dig?
-

6. Om jag ber dig att beskriva energi visuellt, hur det ser ut, vad skulle du säga då? Känsla? Kan man ta i det? Hårt eller mjuk? Dynamiskt eller statiskt?
-

7. Svara snabbt det första du kommer att tänka på, på följande frågor:
Vilken färg har energi? Vilken form har energi? Egenskaper?
-

Allmänt om att köra bil
8. Hur många år har du kört fossildriven samt elbil?
-
9. Äger du en bil idag?
-
Om Ja: Vilken typ av bil? Hur använder du den? *Hur brukar ett normalt användande av bilen se ut på en dag/vecka/månad? Hur ser resorna ut? Hur långa brukar sträckorna*

vara som du vanligtvis kör? Använder du mest bilen själv eller kör du med sällskap i bilen?

Använder du bilen oftare nu när du har en elbil? *Fler resor?*

-

Om nej: Vid vilka tillfällen använder/har du använt du elbil då?

-

10. Varför valde/väljer du att använda elbil istället för fossildriven bil? *Vad är viktigast för dig när du använder en elbil? För/nackdelar?*

-

11. Symboliserar elbilen något för dig?

-

12. Om man tycker att miljöaspekter är viktigt: Är detta något som du tycker är viktigt generellt sätt? (IDEO or SOCIO pleasure)

Om ja: Kan du ge andra exempel på saker i din vardag som visar detta? Vad är det som är viktigt? Vill du bli associerad till en person som tänker mycket på miljön. *Finns det några ekonomiska aspekter kopplat till detta?*

-

Om nej: Om du ändå har/kör elbil, vill man känna sig duktig eller bara välja de miljövänligaste alternativet?

-

13. Är det viktigt med den senaste tekniken för dig? Varför? Har du vänner runt omkring dig som delar samma åsikter? (Vill du visa utåt eller bara ha för dig själv? (IDEO or SOCIO pleasure))

-

14. Har du någon gång skämts för att du kör elbil?

Om nej: är du stolt över att köra elbil? Vill du visa upp det?

-

Ändring av beteende

15. Minns du vad din första reaktioner var när du började köra elbil? Har dessa känslor/reaktioner ändrats med tiden?

-

16. Hur var det att anpassa sig till elbil från fossildriven bil?

-

17. Finns det några andra skillnader från när du var ny för elbil och nu?

-

Range anxiety

18. En sak som kan vara annorlunda från en fossilbil är att sträckan på en laddning jämfört med en tankning skiljer sig stort, har du någon gång känt dig hindrad att åka en viss sträcka på grund av detta?

-

19. Känner du att du måste/vill köra på ett visst sätt för att kunna köra den sträcka du vill köra?

-

Energy usage
20. Är du intresserad av att spara av batteriets energi? Varför? Hur gör du för att spara energi?
-

21. Vet du vilka saker som generellt sett drar mest energi i elbilen?
-

Regenerative braking
22. Vill du se din energiförbrukning när du kör? Varför? Påverkar detta din körning? Hur? Känns det bekvämt att köra på detta sätt?
-

23. Brukar du använda cruise control? Varför? *Vad tycker du om det?*
-

24. Förstår du om och hur energiförbrukningen fungerar, hur din input till systemet påverkar både användningen och lagrandet av energi?
-

25. Kan du se om du får tillbaka energi till batteriet och hur mycket? Hur?
-

26. Vill du se hur bra ”energimässigt” du kör? *Coachning för att köra energismart.*
 Om ja: Hur får detta dig att känna?
-
 Om nej:
-

Battery and charging
27. Känner du att du litar på batteriet (nivån) på elbilen du har kört? Skiljde detta sig från när du var ny för elbil och nu när du har mer erfarenhet?
-

28. Har du någon gång blivit överraskad över batterinivån?
-

29. Vill du se hur batteriet i bilen ”mår”?
-

30. Vill du övervaka bilens performance/status medan du kör? *Ha all information tillgänglig alltid, även när allt är som det ska.* Eller vill du endast bli meddelad då något är fel samt indikation på vad du ska göra just då?
-

31. Hur länge tror du/räknar du med att batteriet kommer att hålla? Tror du att du kommer behöva byta det någon gång?
-

32. Hur tycker du att det fungerar att ladda din elbil? (Enkel, svårt, smidigt, klumpigt?)
-

33. Hur ofta brukar du ladda bilen? Brukar du ladda fullt batteri eller sänker du nivån?
-

34. Är det enkelt att förstå hur långt tid det är kvar tills bilen är färdigladdad? Litar du på siffran?
-

35. Är det enkelt att förstå när bilen har laddat klart?
-

36. Underlättar det att ha telefon som säger om bilen laddar eller ej?
-

37. Om du jämför situationen med att ibland tanka en fossilbil eller att ladda din elbil, vad föredrar du? Fördelar/nackdelar?
-

38. Vill du se i DIM om du snabbladdar eller laddar med enfas? Vill du se hur lång tid det är kvar?
-

39. Är du intresserade av att får reda på vart energin som du laddar med kommer ifrån?
-

40. Skulle du kunna jämföra att ladda din elbil med att ladda någon annan produkt? *Varför? Vad finns det för likheter och olikheter?*
-

Förståelse av bilens UI

Information i DIM
41. Vilken information är viktig för dig att se när du kör elbil?
-

42. Vad var viktigt när du var ny men kanske inte efter mer erfarenhet?
-

VISA DIM (be att få filma)

43. Vilken information av den som visas brukar du använda medan du kör?
-

44. Är det något av det som visas här som är svårt att förstå?
-

45. Är det något av det som visas som var svårt att förstå i början men som du nu förstår?
-

Om vi tittar på de olika enheterna i klustret.
46. Förstår du olika enheter kopplat till symboler, staplar, diagram etc?
-

47. Finns det tillfällen som du känner att viss information är viktigare än annan? Olika stadier av körningen; start, under körning, stadskörning, motorväg…
-

48. Hur uppfattar du funktionen att få tillbaka energi till batteriet här? Hur kopplar du detta till batterinivån hos bilen?
-

49. Är det någon information som du inte använder dig av?

Om ja: Känner du att den tar uppmärksamhet från dig?
-

Om nej: Bidrar den till någon annat? Bör den finnas kvar?
-

50. Vad tycker du om mängden information som visas på samma gång? *Är det för mycket info som visas? Är det rörigt?*
-

EV upplevelsen

Nu kommer vi in på sista delen av intervjun som handlar om vilken känslan/upplevelsen är när du kör en elbil.

51. Gör du något annat medan du kör bil? Vad?
-

52. Vad vill du får ut av en körning/trip/resa när du använder en elbil? (Upplevelse, natur, musik, bara åka från A-B, roligt att köra). Om du tänker på skillnaden mellan en fossildriven bil och en elbil, är det något som du speciellt du uppskattar med elbilen i dessa situationer?
-

53. Har användandet av elbil förändrat upplevelsen av att köra bil?
-

54. Känner du att den tiden du avverkar i bilen har förändrat ditt sätt att tänka kring bilåkning? *Känner du dig lugnare? Säkrare? Piggare? Bilen är tystare att köra, snabbare accelerering, regenrative brake… Är dessa känslor/upplevelser positiva/negativa?*
-

55. Vad är den önskade upplevelsen?
-

56. Tycker du att elbilen och fossilbilen ska se olika ut inuti? *Unikt?*
-

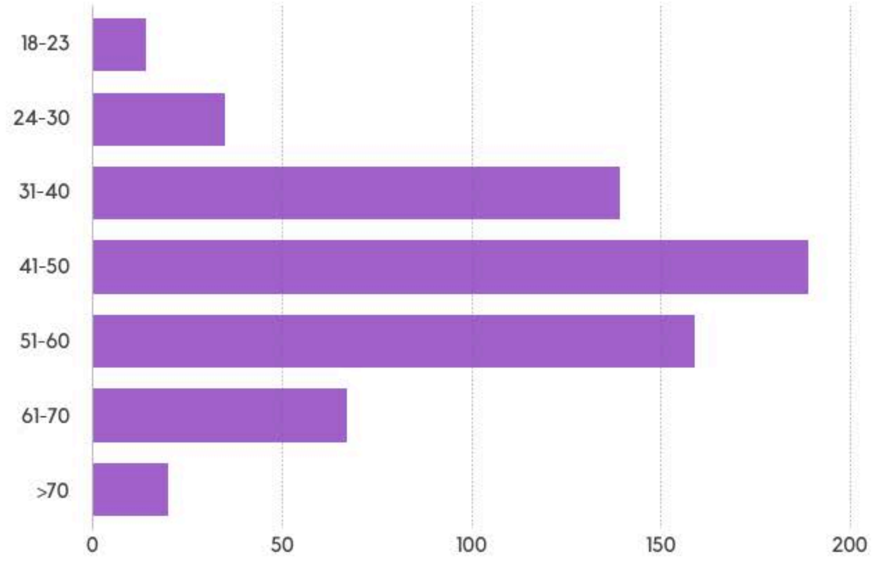
Valfritt avslut: (beroende på erfarenhet av elbil)
57. Har du några tips till andra bilföraren hur man kan optimera sitt elbilsanvändande?

Appendix 4 – Survey summary

Question 1

Age?

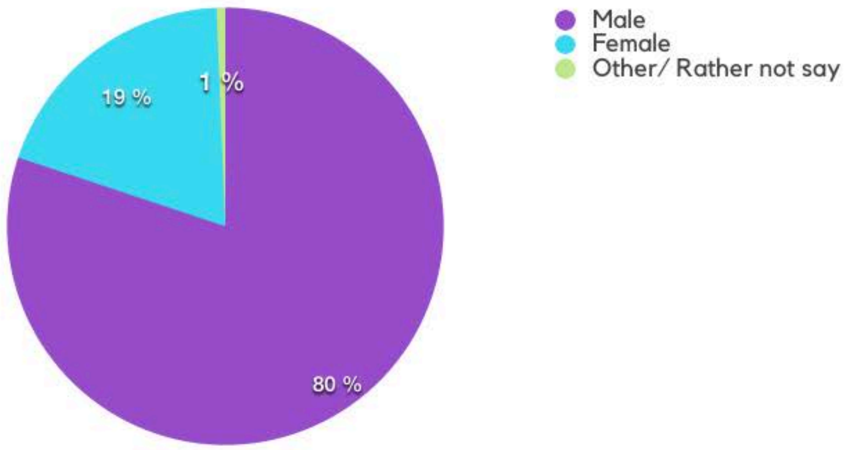
623 responses
Single choice question



Question 2

Gender?

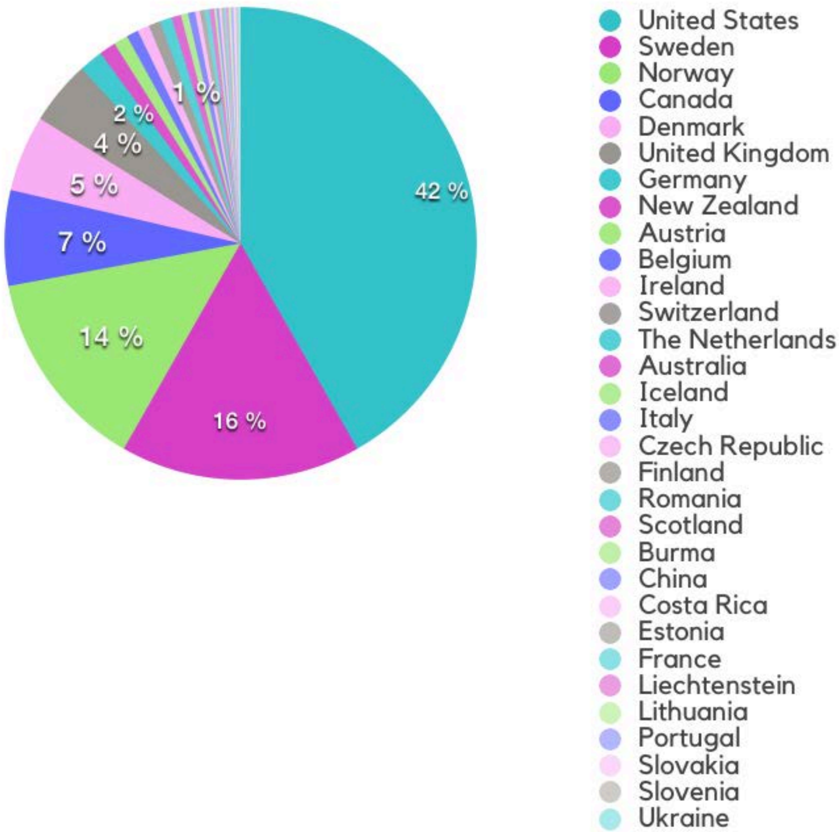
623 responses
Single choice question



Question 3

Country you live in?

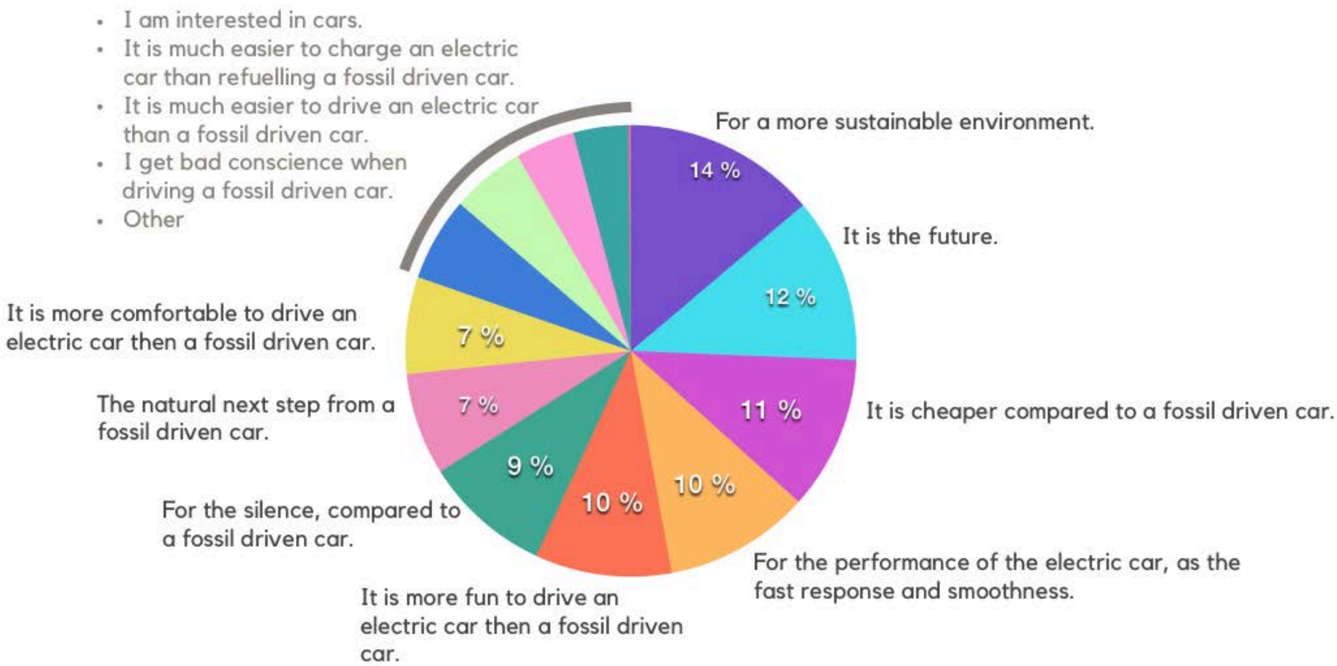
616 responses
Single choice question



Question 4

Why do you choose to drive an electric car?

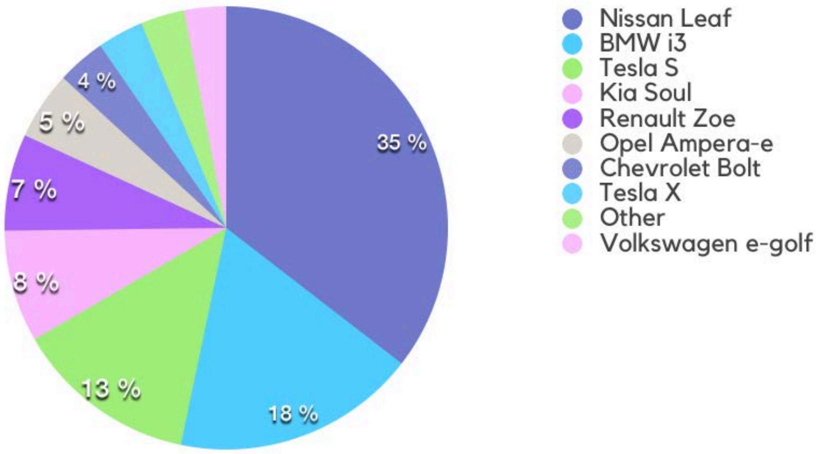
623 responses
Multiple choice question



Question 5

Which electric car do you have most experience of? Please answer following questions in this survey with this car in mind.

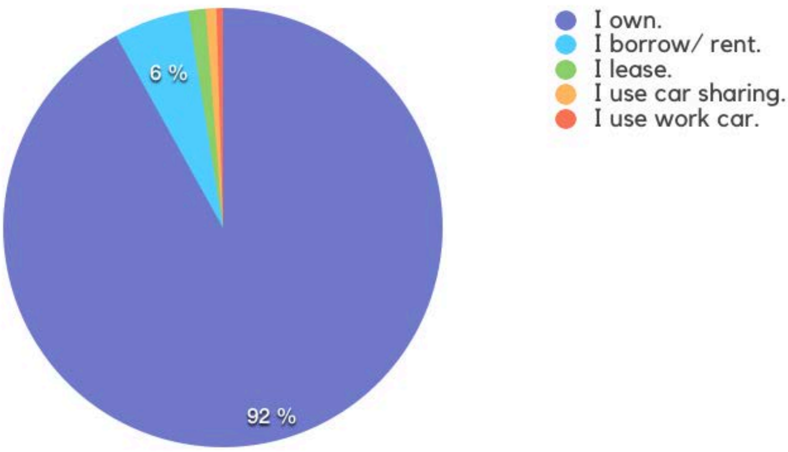
623 responses
Single choice question



Question 6

How do you have access to the electric car?

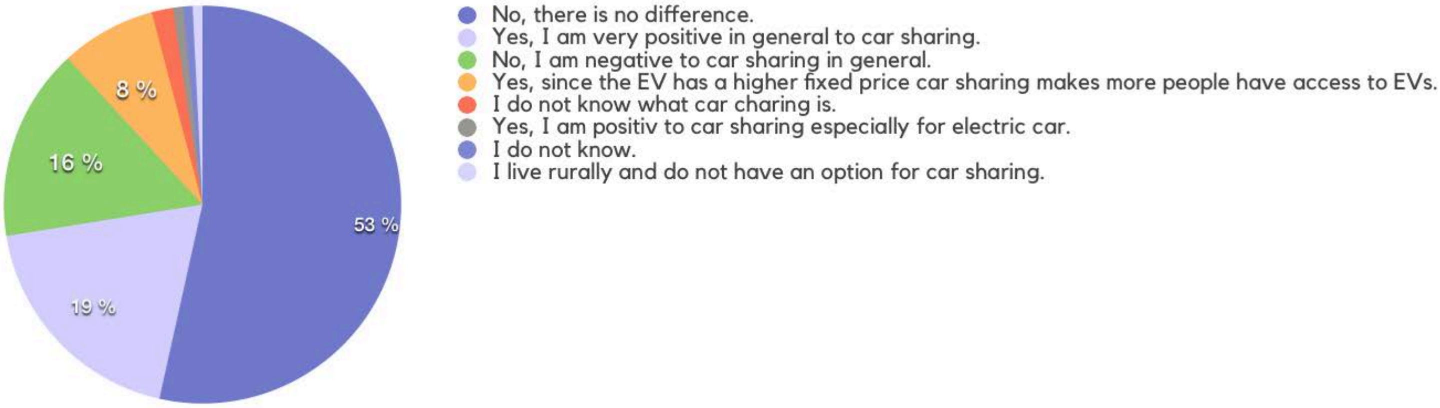
623 responses
Multiple choice question



Question 7

Do you feel that you are more open to car sharing for electric cars compared to fossil driven cars?

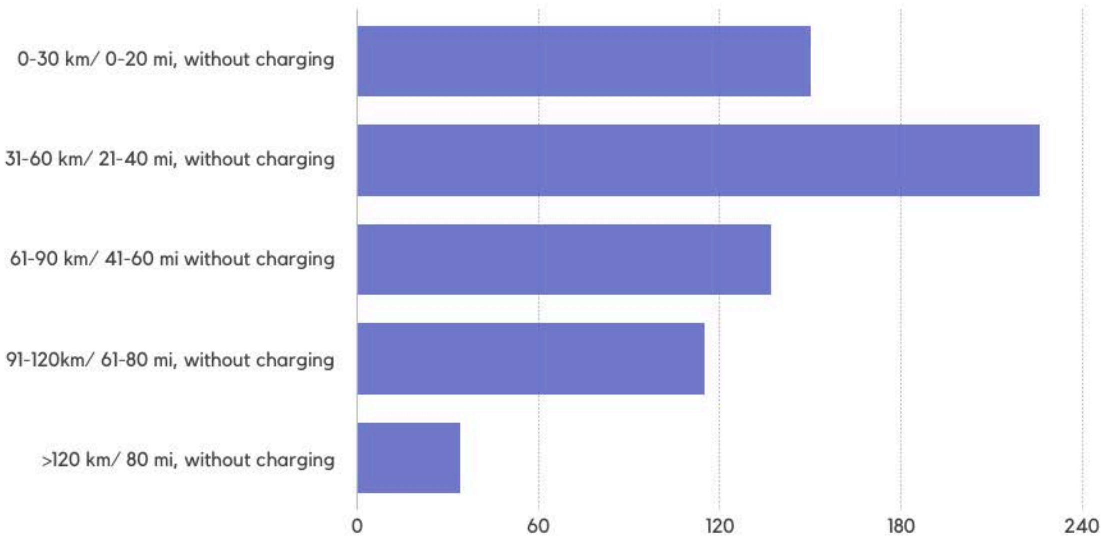
623 responses
Single choice question



Question 8

What is the distance that you usually drive during a day?

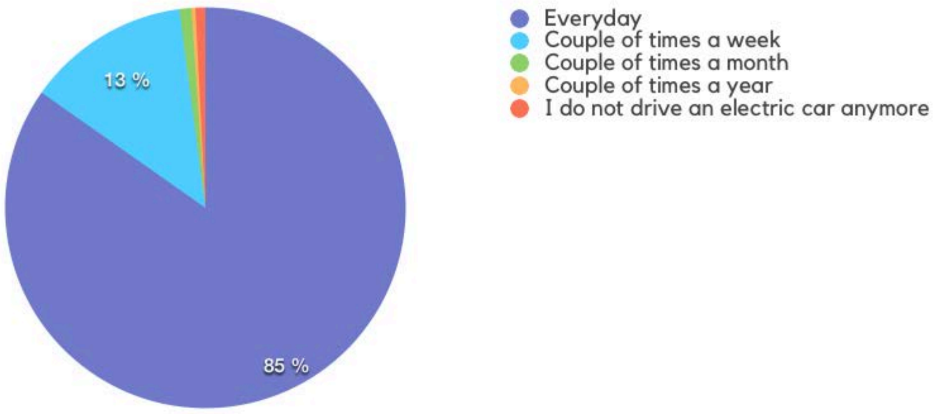
618 responses
Single choice question



Question 9

How often do you use an electric car?

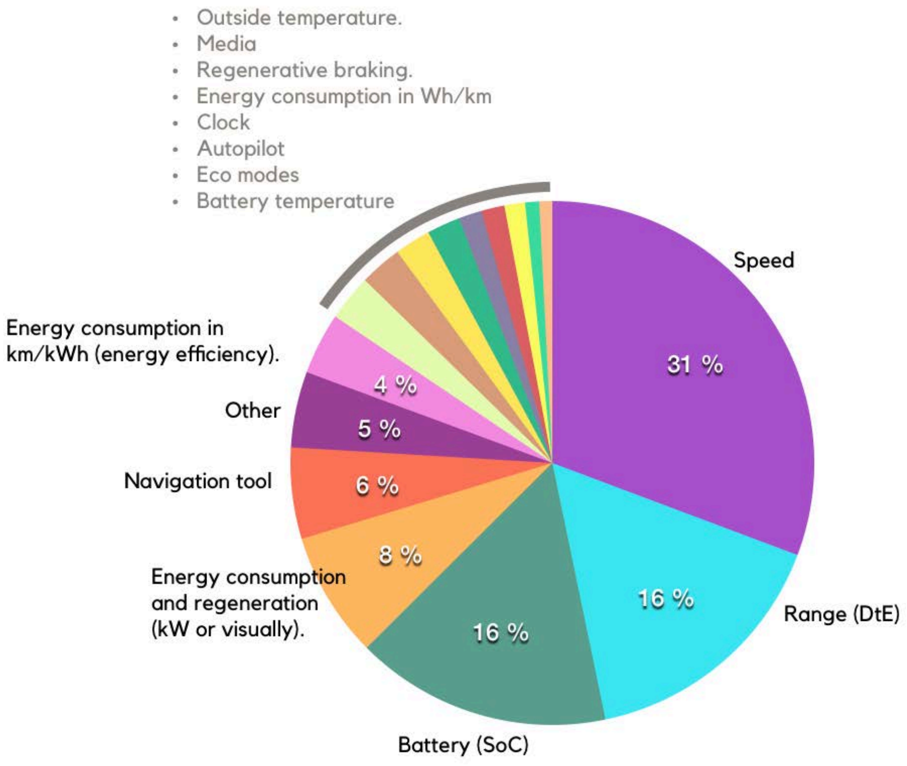
623 responses
Single choice question



Question 10

What information in the car's instrument windows do you look at while you are driving?

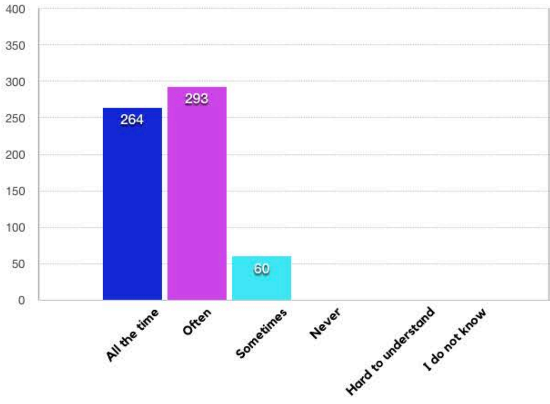
562 responses
Typed answer



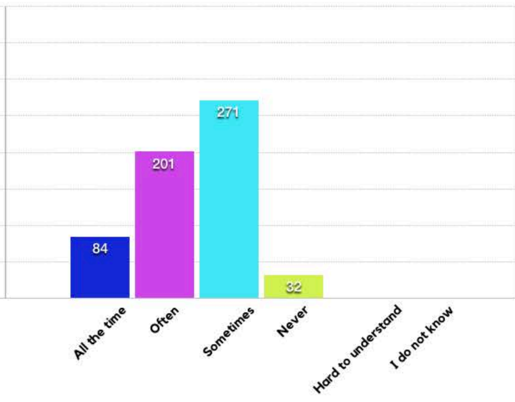
Question 11

What information in the car's instrument windows do you look at while you are driving? Please do not go back in the survey and change your previous answer.

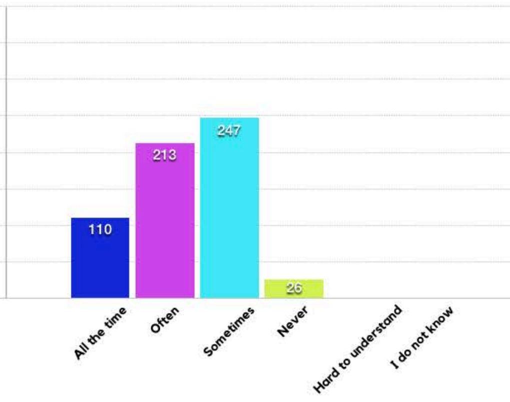
Multiple choice question



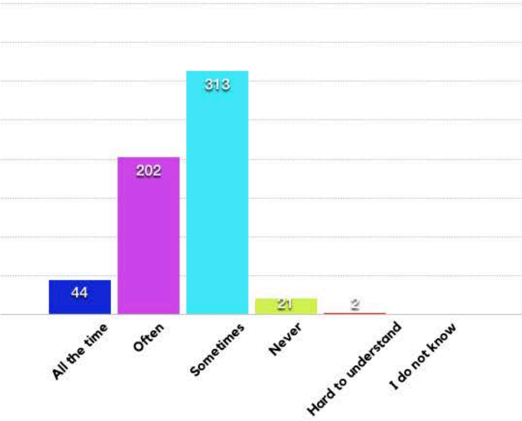
Speedometer



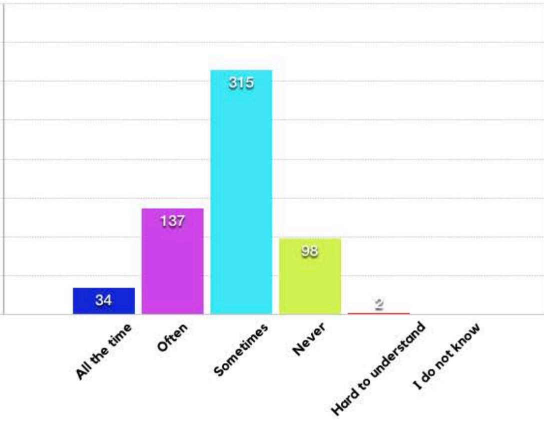
Distance to empty



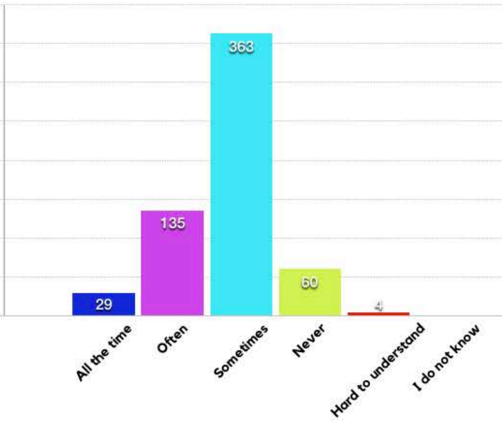
Battery level



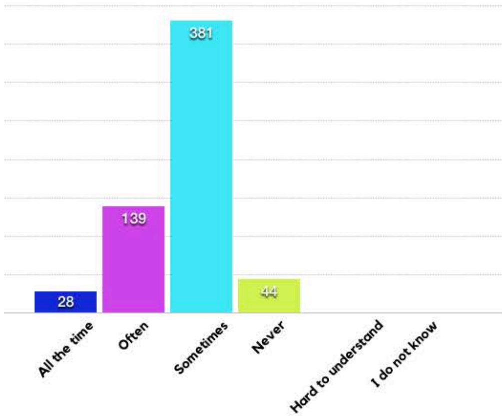
Entertainment, as music/ radio



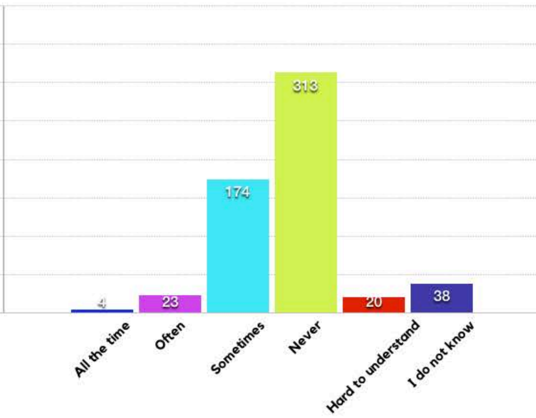
Navigation



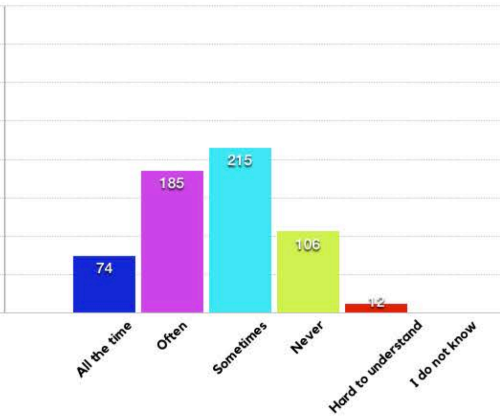
Time



Outside temperature



Battery temperature

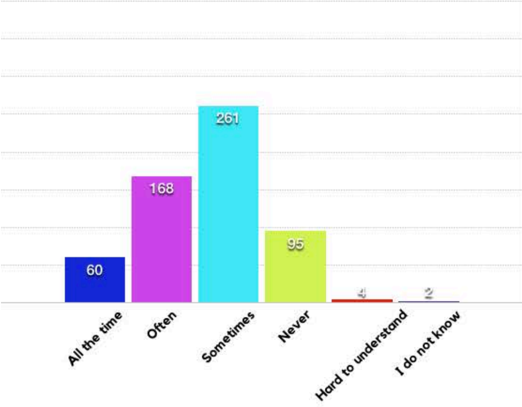


Usage of energy from battery when drivning

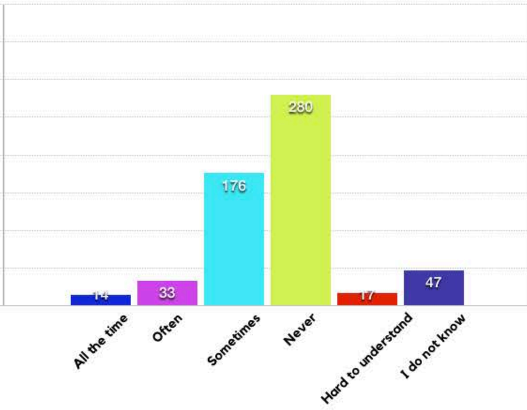
Question 11 CONTINUED

What information in the car's instrument windows do you look at while you are driving? Please do not go back in the survey and change your previous answer.

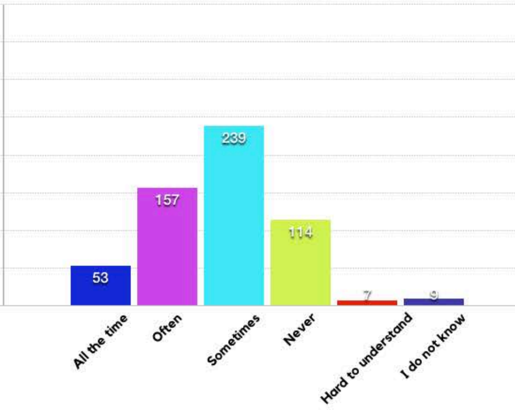
Multiple choice question



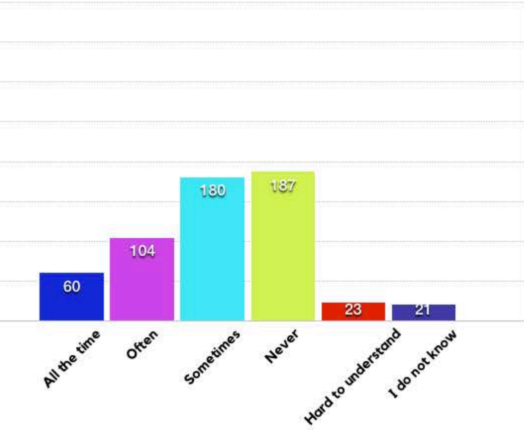
Recharge of battery when driving (regenerative braking)



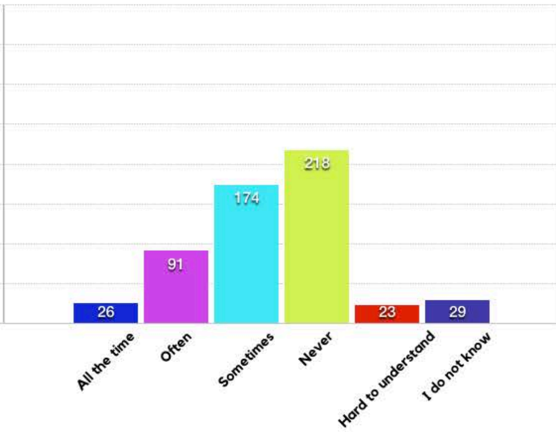
Eco coaching



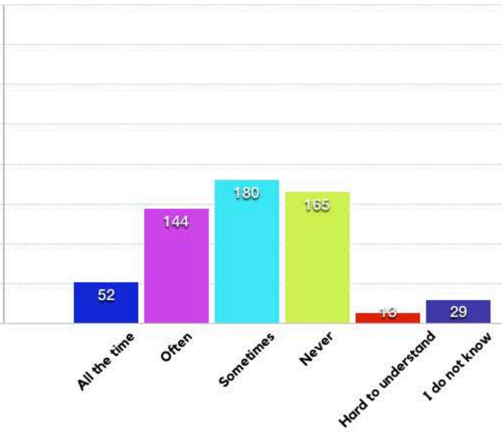
Energy consumption



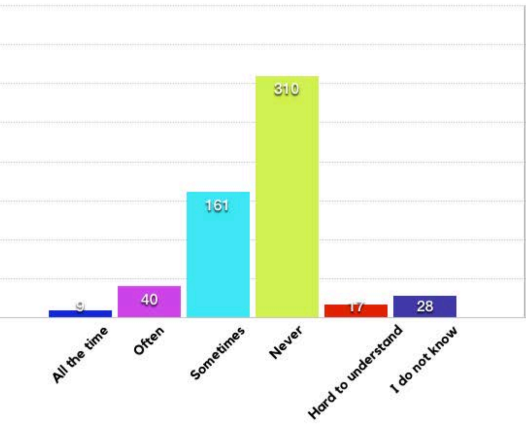
Energy consumption in km/kWh or mi/kWh



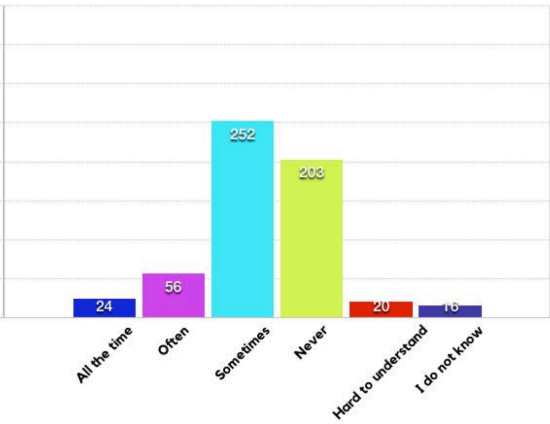
Energy consumption in Wh/km or Wh/mi



Speed limit indication



Average speed

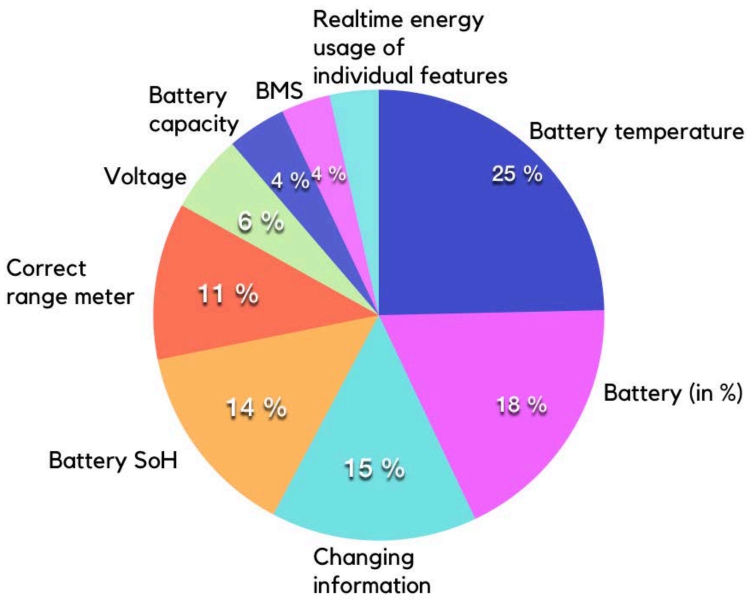


Driving mode

Question 12

Do you feel like you are missing any information in the electric car? What?

503 responses
Typed answer

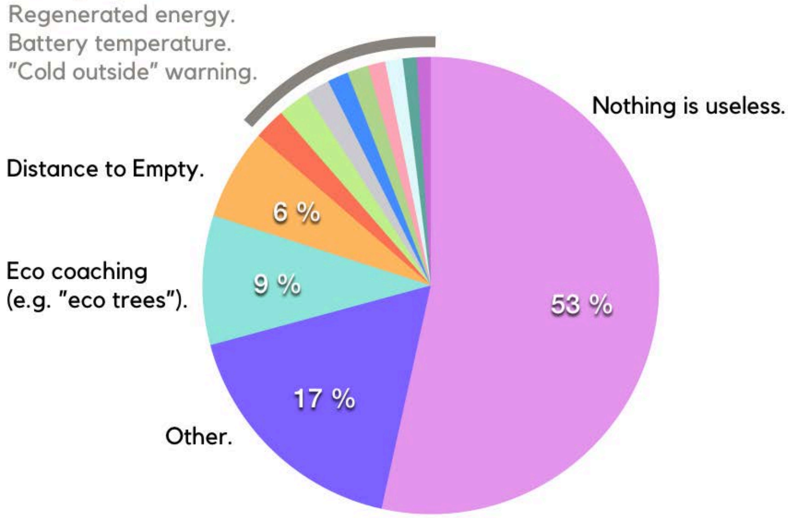


Question 13

Are there any information in the electric car that you think are useless? What would that be?

396 responses
Typed answers

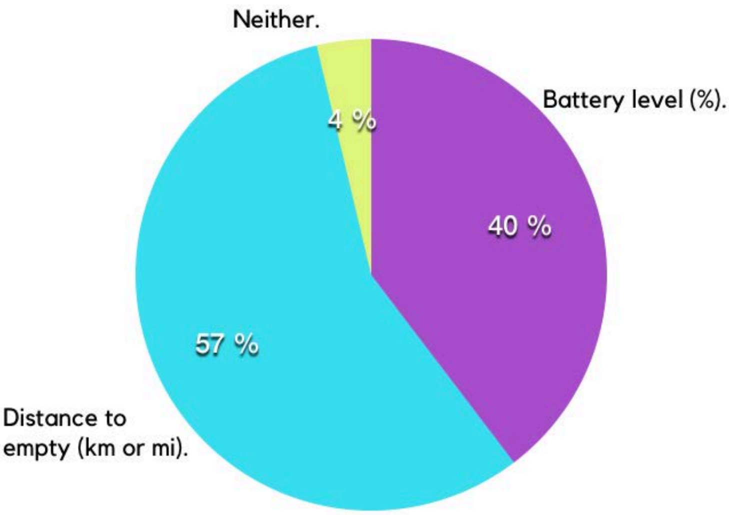
- Energy consumption (e.g. Wh/km).
- NA (n/a).
- Visualisation of power flow.
- The more info the better.
- I do not know.
- Average speed.
- Regenerated energy.
- Battery temperature.
- "Cold outside" warning.



Question 14

Which of the alternatives are most important for you to see while you are driving?

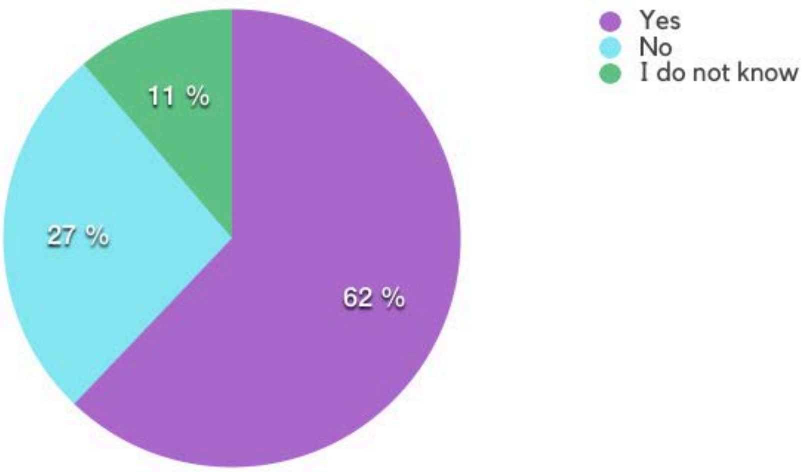
618 responses
Single choice question



Question 15

Are you interested in monitoring the car's performance in the instrument windows while you are driving?

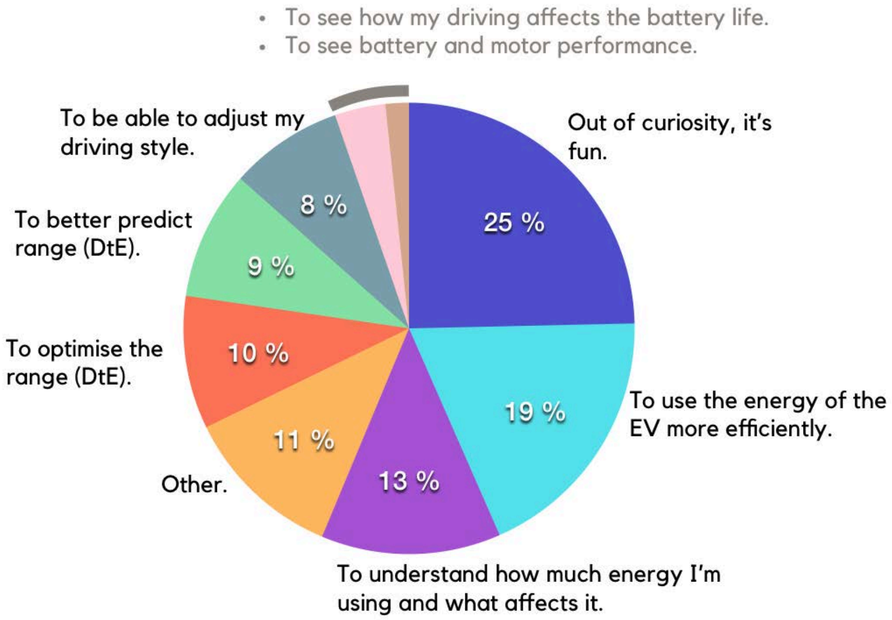
623 responsens
Single choice question



Question 16

I am interested in monitoring the car's performance while I drive because...

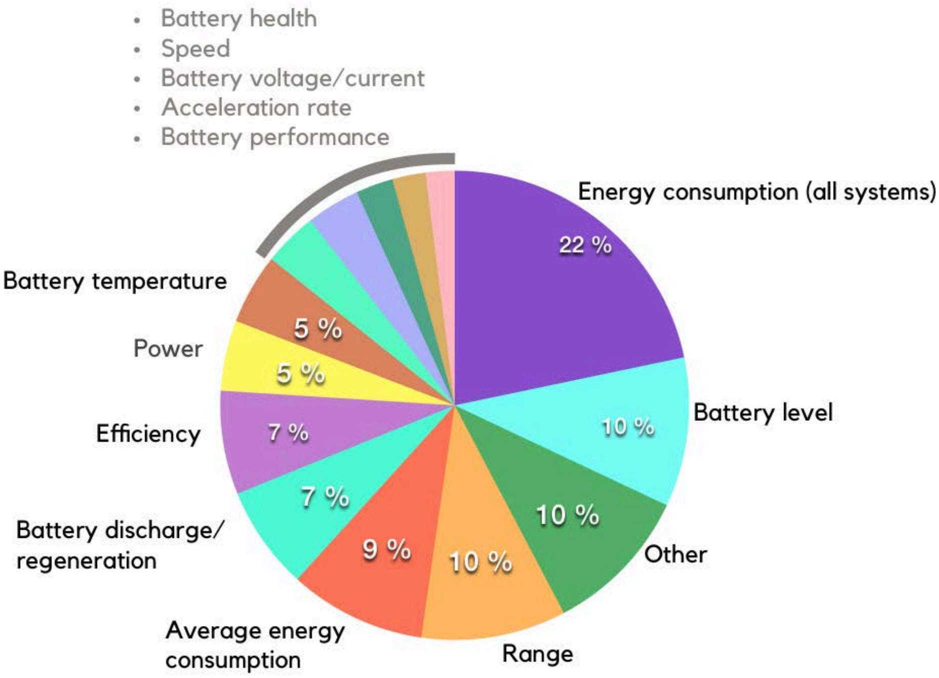
337 responsens
Typed answers



Question 18

What do you want to monitor? Why?

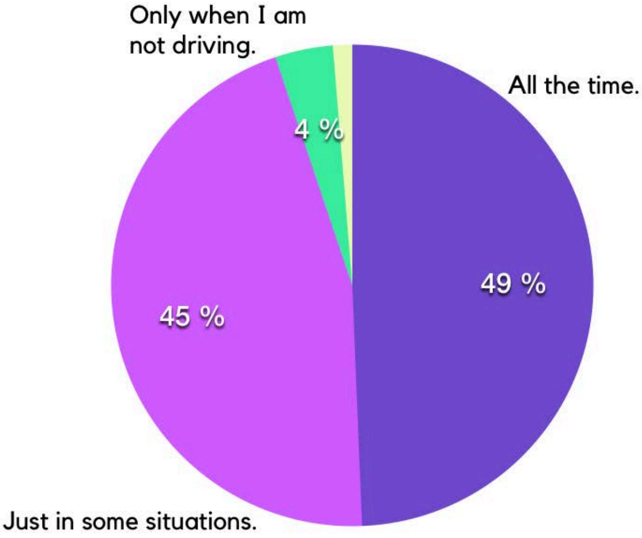
307 responses
Single choice question



Question 19

Is this information that you want to monitor important to show all the time or in just some situations?

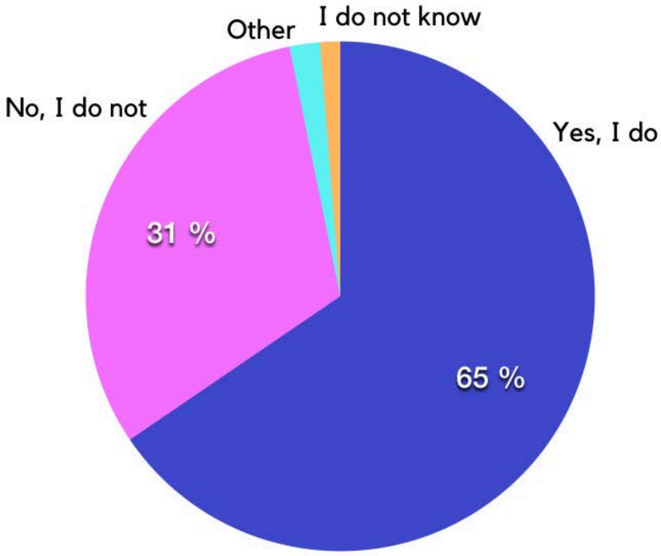
387 responses
Single choice question



Question 20

Do you use different drive modes which help controlling the energy consumption, such as ECO modes?

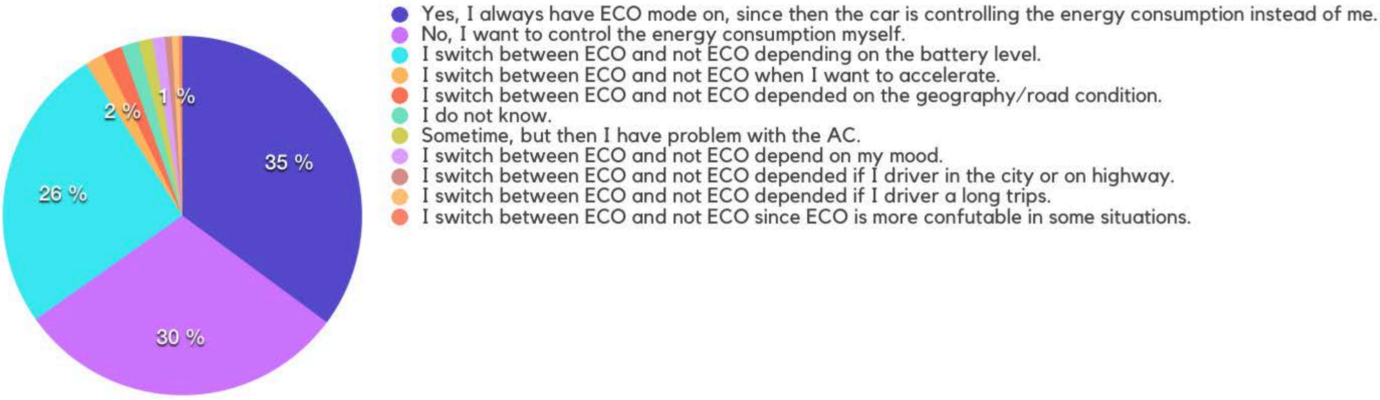
623 responses
Singel choice question



Question 21

Do you use different drive modes which help controlling the energy consumption, such as ECO modes?

623 responses
Singel choice question



Question 22

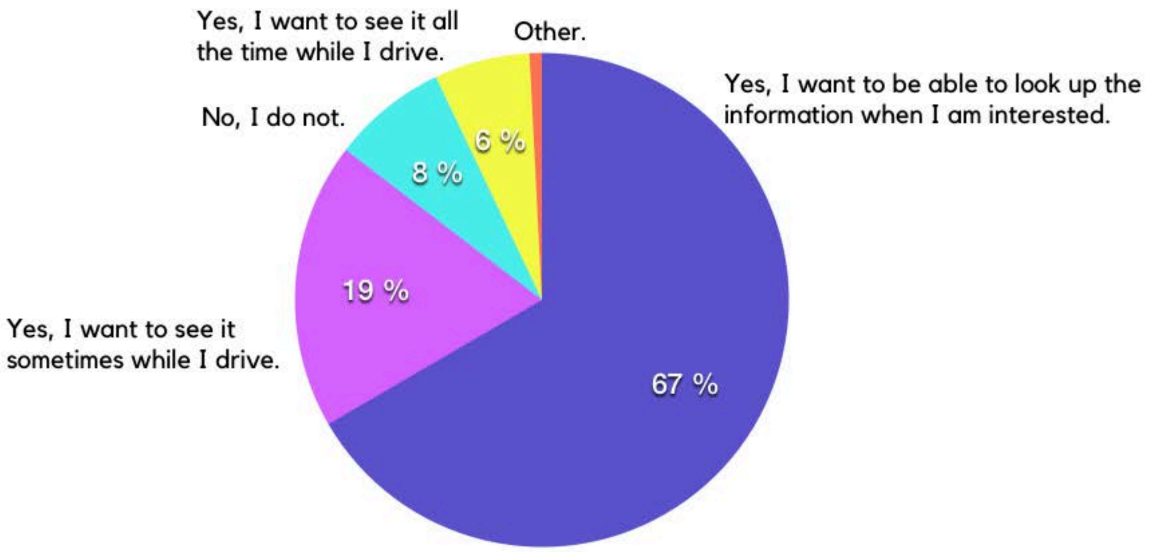
Are you interested to see the overall energy consumption of the car? As for example how the heat and air condition affects the battery level.

623 responses
Singel choice question

Question 23

Are you interested to get information about your energy usage history?

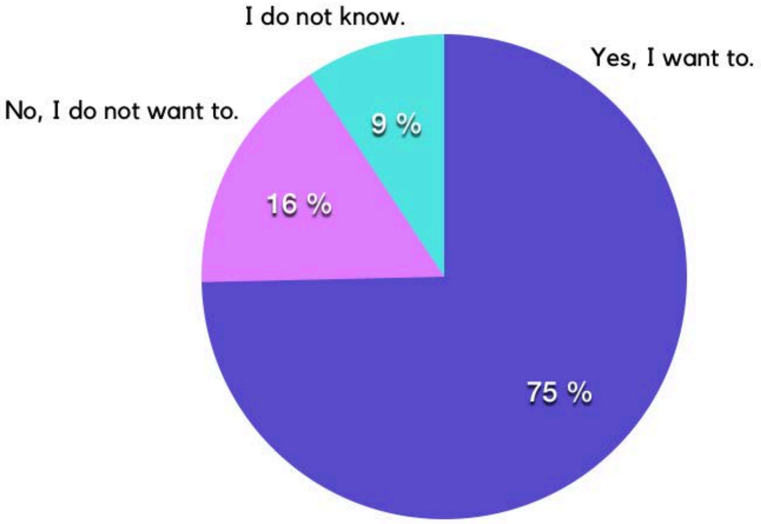
623 responses
Single choice question



Question 24

Do you want to get information about the energy in- and outputs of the battery affected by your driving style?

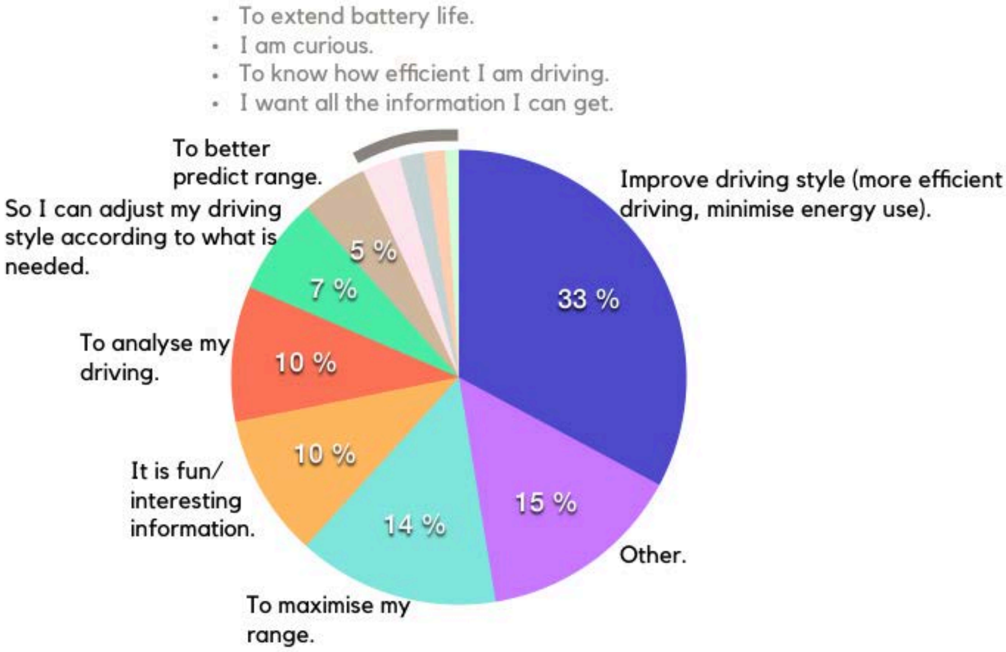
623 responses
Singel choice question



Question 25

Why do you want to get information about the energy in- and outputs of the battery affected by your driving style?

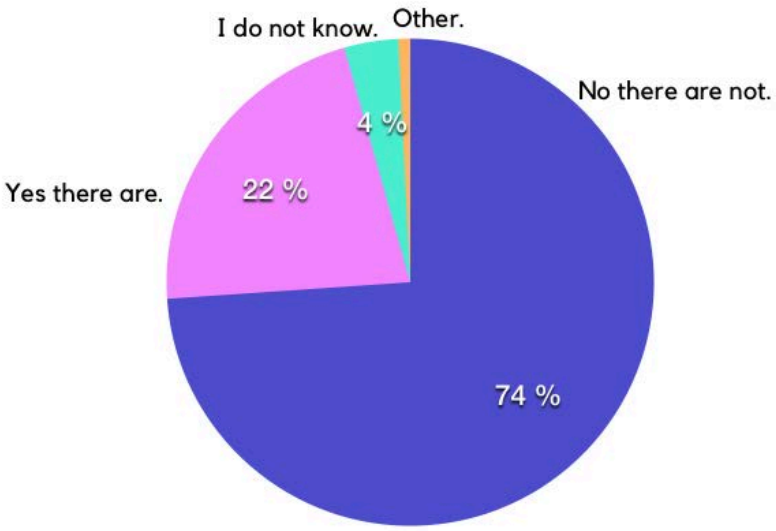
401 responses
Typed answers



Question 26

Are there any situations where you do not think that the car is on but it is, and vice versa?

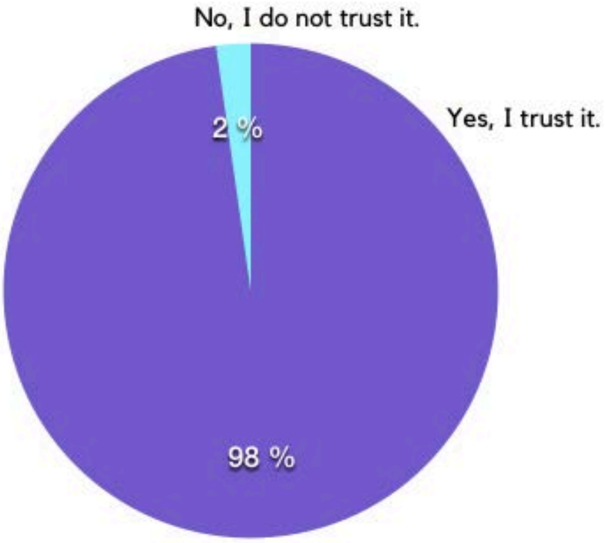
623 responses
Multiple choice question



Question 27

Do you trust the battery of the electric car?

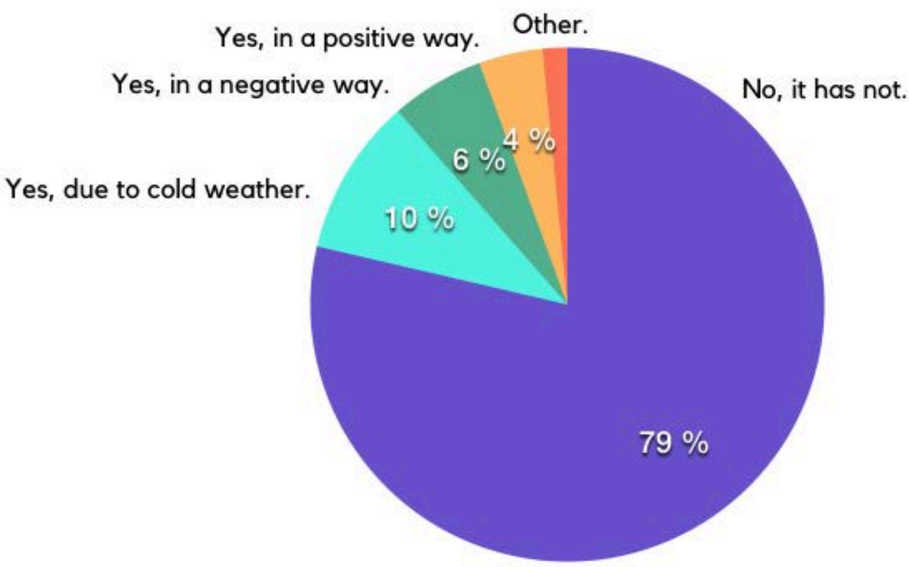
623 responses
Singel choice question



Question 28

Has the battery level surprised you anytime?

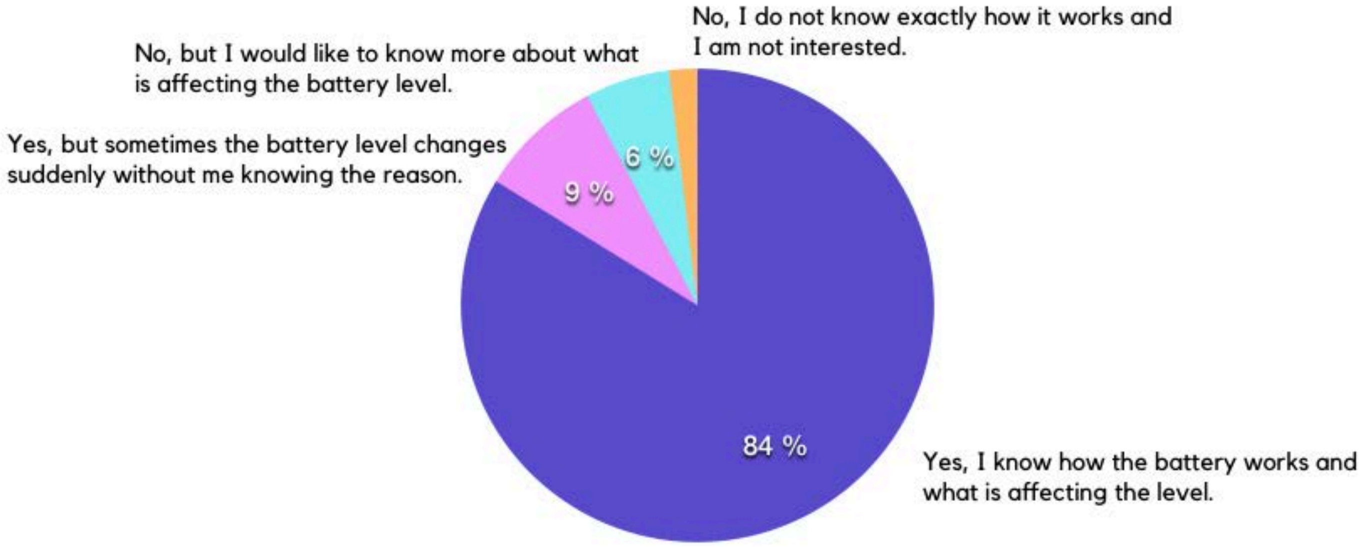
485 responses
Typed answers



Question 29

Do you understand what is affecting the battery level of the electric car?

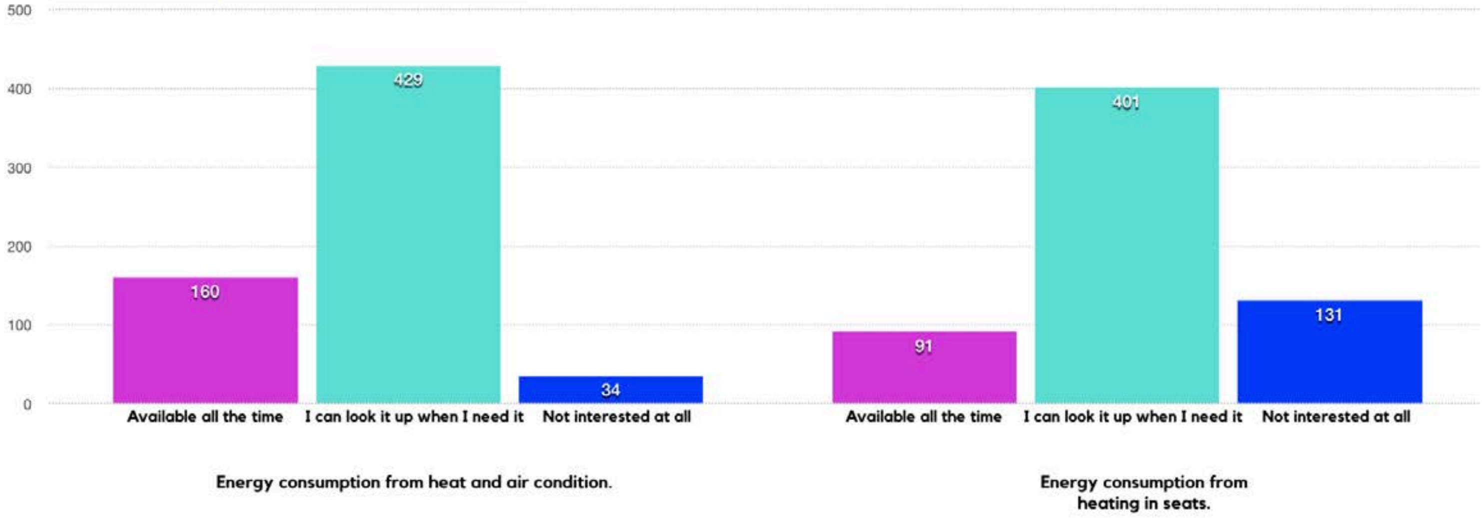
623 responses
Single choice question

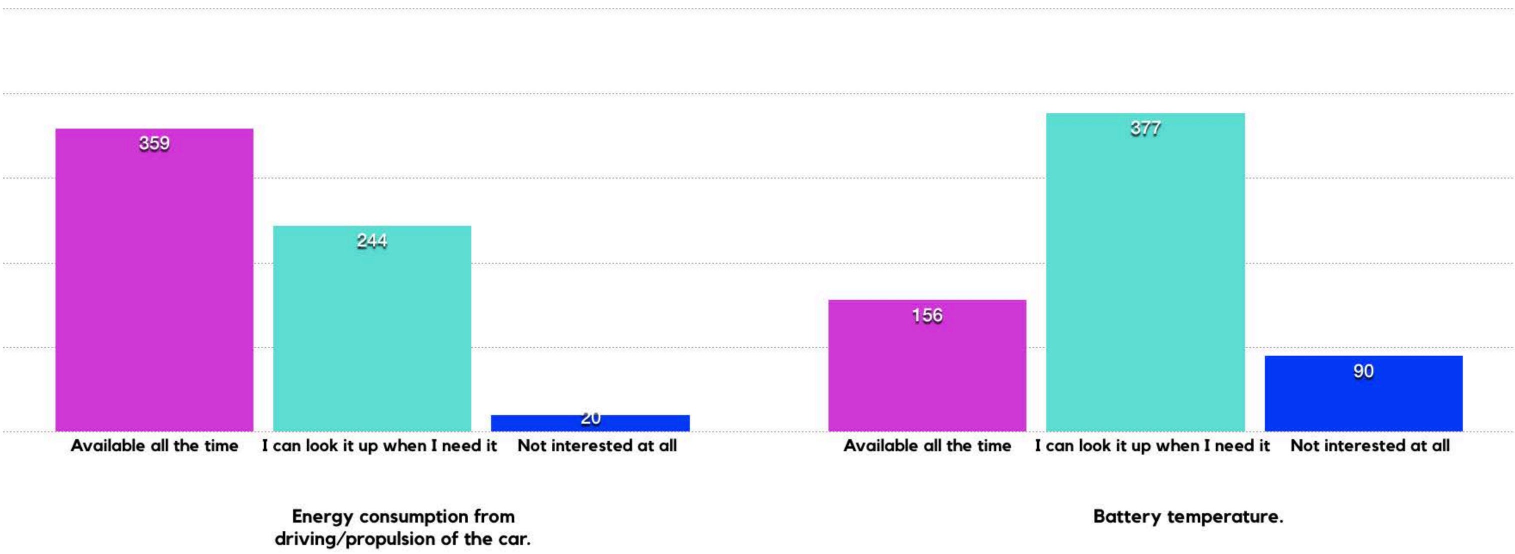


Question 30

How available do you want the information to be?

Single choice question

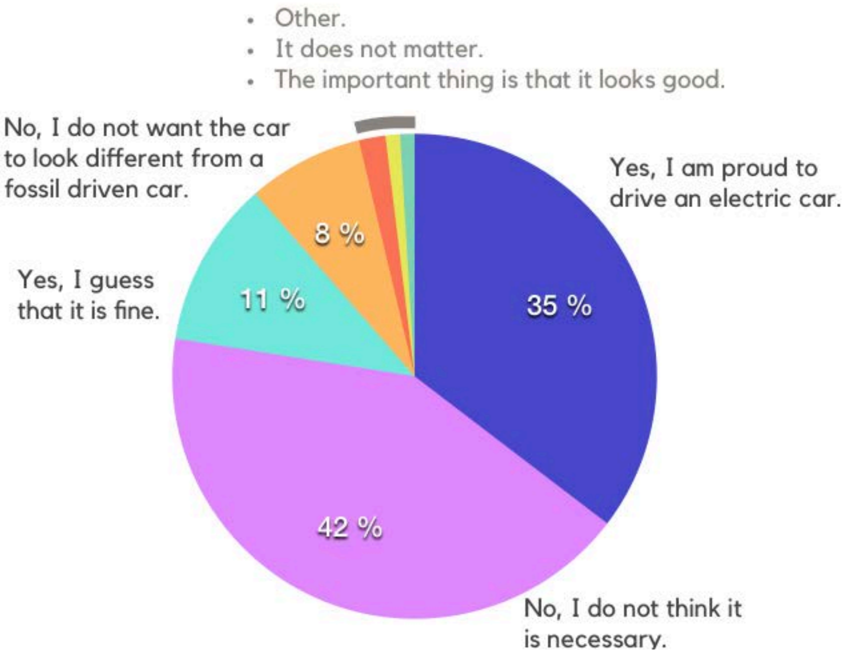




Question 31

Do you want the car to look lika an electric car from the outside/exterior of the car?

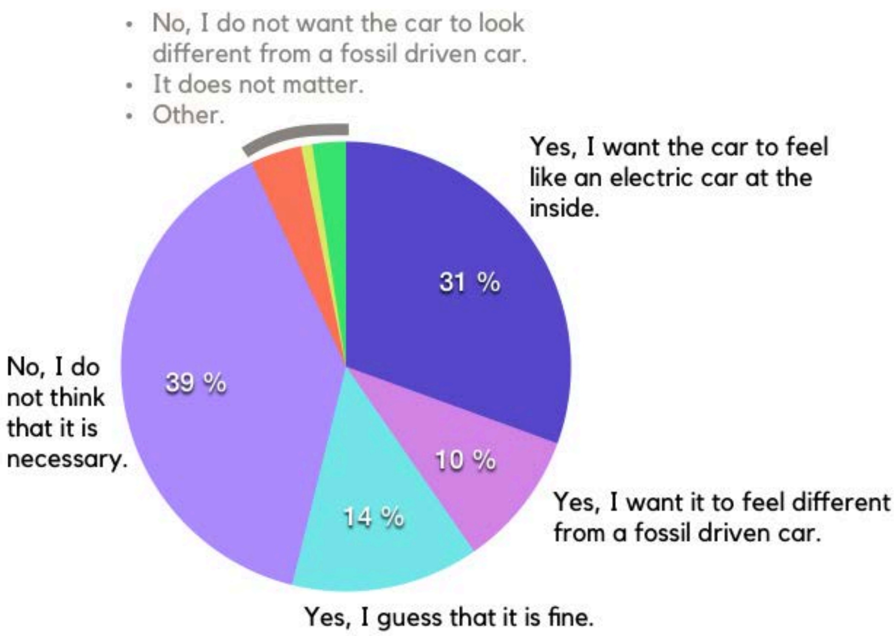
623 responses
Single choice question



Question 32

Do you want the car to look like a electric car from the inside/interior of the car?

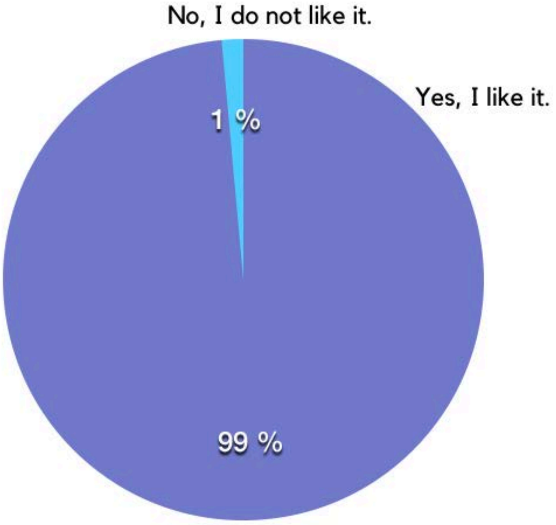
623 responses
Single choice question



Question 33

Do you like that the car is more silent compared to a fossil driven car?

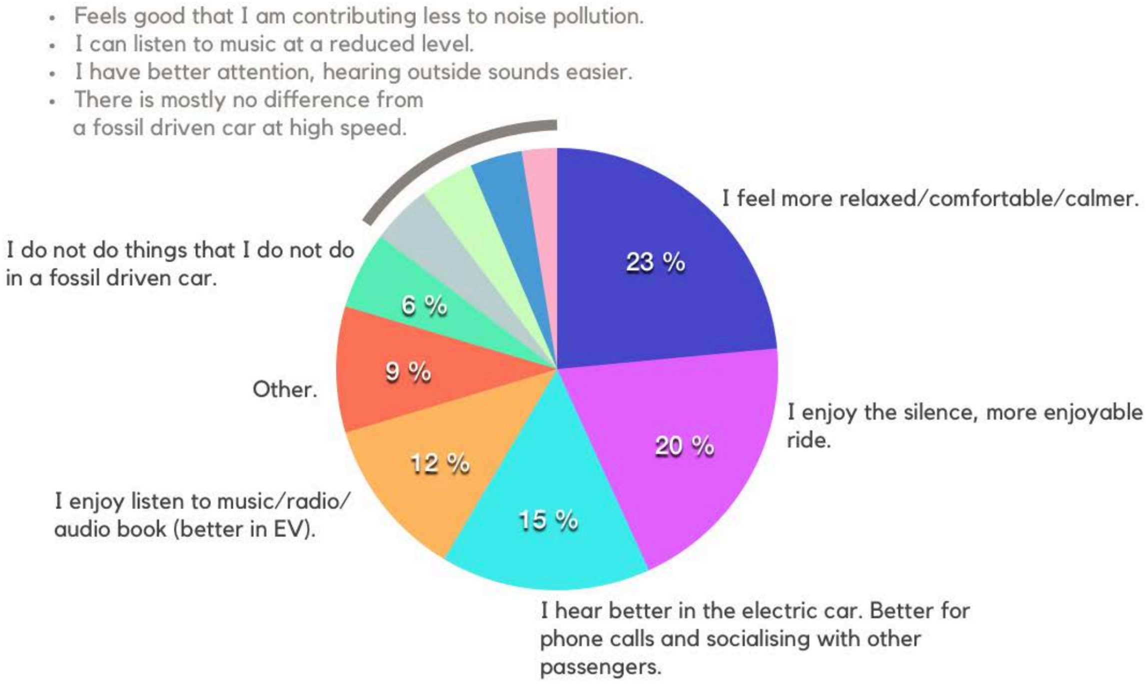
623 responses
Single choice question



Question 34

How does the silence in the car compared to a fossil driven car make you feel. Are there any positive aspects of this? Are you able to do other things in the electric car that you did not do in the fossil driven car?

541 responses
Typed answers



Question 35

What would you say are the biggest problems with an electric car?

569 responses
Typed answers