Reducing the CO_2 Footprint of Business and Commuter Travel, for Companies, by Using Sustainable Cars

A Case Study at TUI

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Reducing the CO_2 Footprint of Business and Commuter Travel, for Companies, by Using Sustainable Cars

THESIS

submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

in

SUSTAINABLE ENERGY TECHNOLOGY

by

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Abstract

Decreasing the CO_2 footprint related to business and commuter travel for companies presents a multitude of challenges. These challenges range from finding the objections of employees regarding EVs, and ways to overcome them, to determining what an ideal composition of a car fleet would be. At the same time the financial feasibility of all theses challenges have to be taken into account. If no (financial) benefits can be gained, a company is less likely to implement measures to reduce its CO_2 emissions. Building on this, the main aim of this thesis is thus to find the barriers against electric driving for company car drivers in The Netherlands and find ways in which the company can aid in overcoming these barriers. Additionally, this research presents a thorough and general investigation into the yield and costs accompanying the installment of rooftop solar systems. To determine the barriers amongst employees, a quantitative survey was conducted with 176 respondents. The survey was analyzed and generated with the help of TAM, and the results were then used to create three different CO_2 reduction scenarios. After which it was possible to calculate cost and benefits associated with each individual scenario. In doing so the one-off and yearly investment costs were determined for both employer and employee. Based on the research done it is concluded that the barriers against the transition to EVs are similar for company car drivers and private car owners. It is also concluded that the barriers found are similar for all companies in The Netherlands. Furthermore, by driving electrically, while commuting, companies can easily reach a CO_2 reduction of 21.0%. If companies then also use their rooftops to generate electricity, that can be used to charge the EVs, an additional savings can be realized of, in this case, 9.0%

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Preface

This Master thesis represents the final document required to obtain the Master degree of the Sustainable Energy Technology Master of the TU Delft. This thesis is commissioned by TUI Nederland with the purpose of finding a way to reduce the CO_2 emissions related to business and commuter travel. A proposal is made with potential measures the company can take to reach its sustainability goals and what costs accompany this change. Also the benefits of these changes will be discussed.

I would like to express my sincere gratitude to TUI Nederland and, in particular to Melvin Mak and Anita Oosterlee for helping me with all my TUI related questions, the warm welcome they gave me, and the unforgettable moments at the office. Secondly, I would like to thank all of my supervisors Jan Anne Annema, Bert van Wee, and Servaas Storm, but particularly Jan Anne Annema, for providing me with valuable feedback and always making time for me in his busy schedule. I would also like to thank my sisters and friends for their support, and lastly, I would like to thank my parents for their support as well, but also for never giving up on me and lending me a sympathetic ear whenever I needed it. Without their help I would not have been able to graduate.

Xenia Wesdijk
Delft, the Netherlands
December 13, 2019

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Abbreviations

AC	Alternating Current
AM	Air Mass
BEV	Battery Electric Vehicle
BOS	Balance of System
BPM	Belasting van Personenauto's en Motorrijtuigen
BSS	Battery Swapping Station
CBS	Centraal Bureau voor de Statistiek
DC	Direct Current
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
EIA	Energie-investeringsaftrek
EMS	Energy Management System
ETS	Emission Trading Scheme
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHI	Global Horizontal Irradiance
GMST	Greenwich Mean Sidereal Time

HEV Hybrid Electric Vehicle

HFCV Hydrogen Fuel Cell Vehicle

ICE Internal Combustion Engine

ICEV Internal Combustion Engine Vehicle

JD Julian Date

KIA Kleinschaligheidsinvesteringsaftrek

LCC Life Cycle Cost

LCoE Levelized Cost of Electricity

MIA Milieu-investeringsaftrek

MPP Maximum Power Point

MRB Motorrijtuigenbelasting

PHEV Plug-in Hybrid Electric Vehicle

PV Photovoltaic

SDE Stimulering Duurzame Energieproductie

SET Sustainable Energy Technology

SNL Sandia National Laboratory

SoC State of Charge

STC Standard Test Conditions

SVF Sky View Factor

TAM Technology Acceptance Model

TCO Total Cost of Ownership

TPB Theory of Planned Behavior

TRA Theory of Reasonable Action

VAT Value Added Tax

Chapter 1

Introduction

This first chapter start with some background information on the development of zero-emission vehicles and its adoption. Then the research gap that forms the backbone of this thesis is presented. Afterwards, the objective of the project and the resulting research questions are given. Following this, the approach that was taken during this thesis is shortly discussed. Subsequently, the suitability of the project, in relation to the author's master programme, is debated. And, finally, the structure of this thesis is given.

1.1 Background

Ever since the late 1800s electric cars have been around, reaching their peak around 1900 [77]. Around the same time the gasoline powered cars entered the market. They, however, were not as popular as the electric cars because they were more difficult to operate, made a lot of noise, and smelled bad. This all changed in 1908 when it was possible to produce gasoline cars for less money than their electric counterparts. With the introduction of the electric starter (1912), the better road conditions in 1920, and with the price drop in oil the electric cars disappeared again around 1935. Only to slowly return around 1990 with the introduction of the of the Clean Air Act Amendment. The real breakthrough for electric cars did not occur until 2008, due to new cutting-edge battery technology which made it possible to drive longer distances [52]. Moreover, the increasing awareness regarding global warming and the importance of CO_2 reduction, in relation to this, became more apparent. This awareness started with the Kyoto agreement and the Paris Agreement which followed. Following the Paris Agreement, the European Union (EU) stated to reduce its greenhouse gas emissions by 40%, compared to the 1990 values, by 2030 [19]. The Netherlands committed to even stricter goals with a 49% reduction by 2030 and a 95% reduction by 2050 (all compared to 1990 values).

Currently, 21% of the CO_2 emission in the Netherlands is caused by the transport sector, 52% of which can be attributed to passenger transport [15]. In the last couple of years the transition to the use of more clean and renewable energy has taken a flight. With this, more alternatives for traditional fossil fuel based cars have emerged. These alternatives vary from hybrid electric vehicles (HEVs), which still uses gasoline, to zero emission vehicles like the battery electric vehicle (BEV) and the fuel cell based vehicles. If all personal vehicles were to be substituted with zero emission vehicles this would result in a drastic reduction in the amount of CO_2 produced. To stimulate this transition to the zero emission vehicles multiple governments across Europe have used tax incentives, in varying rates. Depending on the specific incentives used, the adoption rates differs across countries.

Norway momentarily has the highest adoption rates of BEVs worldwide, approximately 21% (2018) [7]. This high adoption rate is mainly due to the stimulation policies of the Norwegian government. BEVs are exempted from purchase taxes, VAT (which is 25% in Norway), road taxes, and they are allowed access to bus lanes. Previously BEVs were also exempted from toll charges on roads and ferries, and parking was free for everyone who owned a BEV [7]. This, in combination with the stimulation of charging infrastructure, made the BEV a popular vehicle in Norway. In The Netherlands on the other hand, the share of BEVs is approximately 2.7% (in 2018) [36]. Nevertheless, The Netherlands has the fifth-largest electric-vehicle market, with a total of 145,095 EVs on the road at the beginning of 2019 [57]. Even though this number is still relatively small, it is expected to increase significantly towards 2030 since the Dutch government has decided to ban the sales of all non-electric vehicles by 2030. Policy measures that are currently in place in the Netherlands to stimulate the sales of EVs are similar to those in Norway. Emission free vehicles are exempted from road taxes, and registration tax fees are lower. Another huge advantage of driving EVs in The Netherlands is that The Netherlands has the highest charger density with 19.3 charging stations per 100 km of paved road [51]. For company car owners the Dutch government also has favorable policies for EVs compared to the ICEVs. When company cars are used privately an additional liability tax is applied, this tax percentage for ICEVs is 22% whereas BEV only have a tax rate of 4%, thus promoting the use of BEV in company car fleets. The Dutch government has also implemented policy measures to stimulate company owners to make their company fleet emission free. More about these measures can be found in [62].

1.2 Knowledge Gap

Even though companies can set an example in the transition towards the implementation of zero-emission vehicles, it also poses new problems for the company. Which vehicle types do they need to adopt, how will they solve the problem of charging the vehicles, what kind of charging infrastructure is needed, how to get your employees to make this transition, what are the fiscal and financial benefits and, especially, the drawbacks of implementing all zero emission vehicles.

From the literature study in Chapter 2 it appears that a lot of research has already been done on the barriers and motivators for the transition towards privately owned EVs. However, research on the barriers and motivators for company car drivers lags behind, with only [82] and [25] actually discussing the subject. So, additional research from the perspective of the company car drivers and the managers is considered beneficial. Another extension that can be made to the existing literature is to investigate the particular situation in The Netherlands, since only [25] attempted to do this. The same can be observed from the results regarding the charging infrastructure. [34] and [53] look at how companies can organize their EV fleet and regulate its charging, however, again no papers were found that had studied the situation in The Netherlands. Another potential novelty approach that could thus be taken is comparing this regular charging with the use of battery swapping station (BSS), like was done in [85], or charging through electricity generated directly by rooftop solar systems, but then applying it to the company car fleet scenario. Additionally, the literature study also revealed that just offering a new technology will not necessarily achieve a behavioral change within people. According to the technology acceptance model (TAM), the acceptance is also based on how users perceive a new technology, and how easy they think it is to actually use it. More information on the TAM is provided in Section 2.3.1.

Furthermore, the composition of a renewable vehicle fleet can take multiple forms. Although, as will be mentioned in the literature review, the biomass and hydrogen based vehicles were excluded from this composition, because their development lags behind that of the BEV and HEV, and can thus not be implemented quickly enough. When regarding the comparison of the EVs with the ICEVs a lot of research has already been done. The addition in this field will mostly come from doing a study towards what an optimal combination can be for a specific company in The Netherlands. Since research for this thesis was conducted at the company TUI Nederland, a large company with multiple locations, the suitability of the fleet composition can vary per location. For more information on TUI, its goals, organizational structure, and more, the reader is referred to Chapter 1.5.

From all the papers discussed in the literature review it became obvious that a lot of topics are already discussed in separate papers, but mostly for privately owned EVs. The main addition in this thesis thus originates from combining all of these topics, applying them to a specific company in The Netherlands, and developing a comprehensive advice for companies on how to electrify their vehicle fleet.

1.3 Objective of the Project

This project will consists of two separate objectives, one scientific objective, and a more practical objective. For this practical objective an empirical case study was conducted at TUI Nederland. This particular company was chosen because of its progressive approach towards a more sustainable future. TUI is a large international tour operator with its own airline, and thus a large CO_2 footprint. Since planes are not (yet) capable of flying in a sustainable manner, TUI keeps investing in new aircrafts that produce less emissions. They, for example, invested heavily in the Boeing 737 MAX, the most sustainable aircraft in circulation. The implemented CO_2 reductions are not just limited to their aircraft fleets. Investments were also made at (holiday) destinations and at the offices, resulting in a lower waste production, and the required electricity (for all offices) is generated by windmills. More on the company, their sustainability policy, goals, and approaches, is discussed in Section 1.5. The next step in reducing the CO_2 footprint, of the offices, is to reduce the CO_2

emissions from business and commuter travel, and that will be the focus of this thesis.

With the climate goals set by the Dutch government, selling only zero emission vehicles from 2030 onwards, it can be assumed that the share of EVs will increase significantly in the coming years. It can also be assumed that more fuel cell based cars are going to enter the market, since these cars are also emission free. The rapid increase of these zero-emission vehicles will bring new challenges. Especially for the BEV an entirely different charging infrastructure is necessary. BEVs take longer to charge, and thus more fast chargers are required, but also more chargers in general, so people can always charge their car at home, or at work, where it is standing still for longer periods of time. As for the fuel cell vehicles, these are 'fuelled' in roughly the same manner, and with the same speed, as the ICEVs, but fuel stations have to be significantly adjusted to be able to (safely) store the liquid hydrogen. Furthermore, both car types have a shorter driving range compared to the ICEVs and are currently more expensive than ICEVs. ICEVs can travel roughly 900 km assuming a 60L fuel tank and an efficiency of 1:15. For BEVs the maximum driving range is currently 580 km, however, the average is only around 320 km [31]. Fuel cell based cars also have a driving range of about 600 km. Taking a closer look at the charging of the cars, more specifically the BEVs. The charging of a multitude of electric cars can create sudden peak demands on the grid. Assuming the electricity generated for these vehicles is all renewable, the generation of this renewable energy might not be able to supply a peak at the same time the demand peak arises. New methods for intelligent charging are still under development and might be useful to implement [34].

From the literature review it became apparent that, at this moment, not a lot of research has been done on how companies can best transition towards the use of emission free vehicles. Most of the related research concerns just the transition to one particular emission free vehicle, mostly BEV. However, taking into account cost, vehicle characteristics and government incentives over a longer period of time for the entire mix of emission free vehicles is an addition. Therefore, the practical goal of this thesis is based on the research gap described in the previous section and is then to look into all these, above mentioned, aspects and make a recommendation on how (and how much) a company can reduce its CO_2 emissions of business and commuter travel. The subject of this particular case study is TUI Nederland. This company aspires to reach a CO_2 reduction of minimal 20%, compared to their 2015 values, by the end of 2020. While aiming for this goal aspects like; user preference, vehicles choice, and costs and benefits accompanying this transition, for both employer and employee, were taken into account

It is well known that human kind tends to resist change. Even though most people agree that it is better to drive in emission free vehicles, very few do. Most of the time people refuse to make the transition due to the fact that they believe that BEVs are more expensive, have a shorter driving range, and require longer fueling times [82]. Keeping in mind that research has already shown that the BEVs (in use nowadays) are more than well suited to the driving needs of the average person [79], and with decreasing battery prices, increasing battery achievements, and the rise of fast charges, all these supposed biases should belong to the past [4]. Therefore, a survey was held to analyze what the main barriers still are for refusing to make the transition to emission free vehicles, and see if these are different for company car drives, but also to see what it will take to convince employees to make the transition. While generating the survey, and when processing the results, the TAM was regarded. This framework was used since it can help in understanding how consumers look at a specific innovation and how this affects their acceptance. It can then also aid in finding ways to make this technology more broadly accepted.

To summarize, the scientific objective was to find ways to overcome barriers like; the limited driving range, the long charging time, and the high purchase price, associated with EVs while keeping the TAM in mind.

1.3.1 Research Questions

Keeping in mind the objectives described in the previous section, the following three areas of interest were determined.

- **User preferences**
  Shifting towards vehicles that have a shorter driving range and a larger charging time compared to the traditional ICE vehicles is a transition that users (the employees in this case study) might be hesitant to participate in. With the help of TAM a questionnaire was made to determine how people can be persuaded to make this transition even when they are hesitant.

- **Car fleet composition**
  At the moment the technology for hybrid and electric vehicles is further developed, than that of the fuel cell based vehicles. In future, fuel cell based vehicles might become the better technology. Therefore, the optimal composition to achieve the emission reduction might shift over the coming years. This question uses the results form the first research question to determine the optimal fleet composition and its resulting emission reduction. It also provides an analysis of the costs and benefits that accompany this reduction. For this last part, the results of the last research question are taken into account as well.

- **Rooftop solar system**
  If a lot of people all start to drive electrically and want to charge their cars at the office, this will significantly increase the power demand. For this question a closer look was taken at the possibility of rooftop PV systems to absorb this expected increase in electricity usage and see whether or not this would be a feasible investment for the company.

Based on this detailed description, the following three research questions were composed:

1. What barriers do employees encounter before transitioning to zero-emission vehicles, and how can the company aid in overcoming these?

2. What is a suitable car fleet composition and what are the costs and benefits associated with this composition for both the company and its employees?

3. How can rooftop PV systems help with the expected electricity increase due to EV charging, and is this financially feasible?

1.4 Approach Taken

Based on the literature review, that follows in the next chapter, the following approach was taken during this research project. This section will only show a short overview of how the questions were answered. An extensive methodology, for each research question, is provided in Chapter 3.

For each of the three questions a different approach was taken. However, for all research questions an initial literature study was carried out first. An overview of the approaches taken are schematically shown in Figure 1.1.

For the first research question the literature study focused on finding the motivators and, especially, the barriers employees encounter when it comes to deciding to opt for a zero emission vehicle. The next step was to determine, by conducting a survey among both managers and employees, whether those barriers also arise in this particular case study. The TAM was then used to see how these operational barriers influence the acceptance of employees. From the survey it should also become apparent what motivators employees expect from the company, but also from the government. From the barriers encountered by employees regarding the incorporation of zero emission vehicles into the company car fleet, originating from the survey, a cost-effective, efficient, practical and realistic way was found to overcome them. All of this was then used as input to create multiple CO_2 reduction scenarios in the second research question.

For the second question the literature study focused on finding the distinctions between the different zero-emission vehicles themselves, and the ICEVs. In this comparison analysis costs, performance, expected developments, CO_2 emissions, etc. were contemplated. After this, a overview needed to be created of the current behavior regarding commuter and business travel and the amount of CO_2 related to it. Since the company studied is a multinational company with multiple sites per country, only the headquarters (and not their travel agencies) in The Netherlands are taken into consideration. The required data consisted of a differentiation between company car owners and their travelled kilometers (business and commuter, and private) versus employees who drive their own car to works (only commuter and business related kilometers). The type of car (gasoline, diesel, hybrid, etc.), the costs of the car, and their respective, tailpipe, CO_2 emission were incorporated in the overview as well. From the overview it was then possible to qualify the total amount of CO_2 emissions produced while driving. Subsequently, multiple scenarios, with a variety in their CO_2 reduction levels (compared to 2015), were then established. For these scenarios the previously discussed outputs of the first sub-question were taken into consideration as well. Hereafter, the costs and benefits (government incentives, environmental benefits, etc.) for all scenarios were calculated for both the company and its employees. In this calculation the output of the last research question was included as well.

The literature study for the last question focused on negative influences, on the electricity grid, that accompany the increase in EVs that need to be charged at the office. Based on this literature, the second step was to determine an Energy Management System (EMS) suitable for diminishing the impact on the grid. Subsequently, costs and impacts associated with the renewing of the charging infrastructure were defined. Furthermore, the results of this analysis were taken into account when making the final cost/benefit calculations in the second sub-question.

Finally, after analyzing all the scenarios, by combining the results of the three research questions, it was determined by how much the CO_2 emissions can be reduced and a general roadmap was composed that aids companies in their transition towards a smaller CO_2 footprint.

1.5 Introducing TUI

As was already indicated in Section 1.3, a case study approach was used for this thesis. The company chosen for this was TUI Nederland . TUI Nederland is the oldest and, at the same time, the largest tour operator in The Netherlands. This section provides some insights into its history, organization, and its sustainability goals. With this background knowledge Section 1.6 can state why the company, and more specifically this project, is suitable as a graduation project.

1.5.1 History of TUI

Apart from being the largest tour operator in The Netherlands, TUI Nederland is also the oldest tour operator. The foundation for TUI Nederland has been laid in 1876 when Lisonne, the first travel agency in The Netherlands, was founded. Later, in 1974, Lisonne and other smaller agencies merged and Holland International was founded. It is due to this merger that Holland International, overnight, became the largest tour operator of The Netherlands.

The name TUI Nederland, however, came into existence in 1997 after the merge of Arke and Holland International. Despite the merge, the name Arke remained until 2015. Arke was originally founded in 1934 and has its origins in Twente. Untill today TUI still has an office in Enschede. In 2005 TUI Nederland became the first tour operator that established its own airline, TUIfly (Arkefly in 2005).

Another large brand of TUI is Kras. Kras originally started, in 1922, as a horse and carriage service line from Ammerzoden to Den Bosch. After the war it specialized in day trips and it became part of TUI Nederland in 1999. Currently, Kras still has an office located in Ammerzoden, but it will close its doors in the summer of 2020 and relocate its personnel to the office in Rijswijk.

1.5.2 Organizational Structure

TUI Nederland has over 2,800 employees, and is market leader in The Netherlands. At the same time TUI Nederland is part of TUI Group, one of the worlds largest tour operators which harbors over two hundred different travel brands. TUI Group was founded in 2014 after the merge of the British TUI Travel PLC and the German TUI AG [75].

Currently, TUI Group has travel agencies in 31 countries and more than 67,000 employees, which provide holidays at 180 different destinations. More than twenty million people a year book a holiday with TUI Group and are transported with one of the 150 airplanes that TUI Group has in its fleet, of which TUI Nederland owns nine.

Since TUI Nederland is a large company it also has multiple locations throughout The Netherlands. There are, in total, 4 headquarters and 133 travel agencies. The headquarters are located in Rijswijk, Ammerzoden (Kras), Enschede and Schiphol-Rijk. On this last location (a part of) TUI Fly is situated, since they are responsible for aircraft maintenance. In addition to this, TUI Nederland also has an office in Aruba and one on Curacao. Even though these are technically part of TUI Nederland, they will be disregarded for this study as only the situation in The Netherlands will be analyzed.

In the table below, Table 1.1, an overview of the number of employees per office is depicted. The office in Ammerzoden is left out of this table regarding its imminent closure, which was mentioned in the previous section. Its employees are added to the numbers of Rijswijk. For the sake of completeness the travel agencies are mentioned in this table, they are however disregarded in the course of the investigation, since the main focus of this thesis is on the reduction that can be achieved by the headquarters.

Table 1.1: Organisational overview of TUI Nederland.

Location	**Number of employees**	**Rooftop area [m^2]**
Enschede	322	850
Rijswijk	889	3250
Schiphol	854	Not relevant
Travel agencies	750	Not relevant

Additionally, the table also mentions the surface area of the rooftops of each office. This indication is relevant since an analysis will be done on rooftop PV systems later on in Chapter 6. It has to be noted however, that this area given is not equal to the area available for solar panels, which will be thoroughly discussed in Chapter 6 as well.

1.5.3 Sustainability and TUI

TUI Nederland is currently a front runner is sustainable tourism and they are the only tour operator listed at the renowned Down Jones Sustainability Indices (DJSI). TUI tries to be more sustainable in a multitude of ways and since 1998 they have policies focusing on sustainable tourism as well as on corporate social responsibility. Through these policies TUI has been able to create the largest sustainable inventory when it comes to holiday destinations, but they, for example, also have been able to reduce the use of plastics. Furthermore, between 2008 and 2015 TUI Fly Nederland was able to reduce its emissions by 21%, resulting in emissions of 64.1 gram CO_2 per passenger kilometer [74].

The overall goal is for TUI to flourish in a sustainable manner, while maximizing the positive impacts of her business operations, contributing to a more sustainable world, and still remain offering the best holidays to her customers. Looking at the targets mentioned in their sustainability strategy [74], the goal of this thesis can best be categorized under *step lightly*, which aims to reduce emissions from offices and travel agencies. The next step in this is to reduce emissions related to business and commuter travel, since it is estimated that about 80% of the emissions related to the business operations hail from business and commuter travel. Thus, by reducing these emissions TUI will be well on its way to reaching its own sustainability target.

1.6 Relevance of the TUI Case Study to the Master

At the end of Section 1.5.3 it is mentioned that the next step in reducing TUIs footprint is by reducing emissions related to business and commuter travel. This can be considered as an ideal assignment for a Sustainable Energy Technology (SET) student, because it allows for a practical implementation of knowledge gained during the master. During the master, students gain a lot of information on renewable energy sources like wind and solar. Next to this, also storage technologies, the effects of all this renewable energy on the electricity grid, and even the financial and societal impacts are discussed. Since the knowledge gained is so broad, the master prepares excellently for a job in consultancy. The case study at TUI is basically an assignment a consultant could take up, and therefore it fits really nicely into the SET curriculum. Moreover, in this case study it is imperative to find ways to get employees to drive electrically. This will have to be done by listening to the input of the employees as well, instead of just forcing them towards a new technology. The specific combination of technology and societal preferences, that is required for this case study, makes for an excellent SET thesis in the energy and society track.

1.7 Structure of the Thesis

After this introductory chapter, Chapter 2 first presents the literature review. In this chapter the search criteria are discussed. At the same time the results from the literature study are presented. This chapter also elaborates on the theoretical framework what was chosen for this case study. Following this, Chapter 3 delves into the methodology used to answer each of the three research questions. This also includes a detailed overview of the current traffic flows and related CO_2 emissions of the company studied during this case study. After this, Chapters 4, 5, and 6 present a thorough analysis on, respectively, the first, second and third research question. These chapters also provide the results from the analysis and a short conclusion. Afterwards, Chapter 7 elaborates on the validity, reliability and limitations of this research. Additionally, it also presents a reflection on the work done, and it offers an advice to the company on how to proceed. Lastly, in Chapter 8 a final conclusion is presented. This chapter further discusses what research can be done in addition to this thesis.

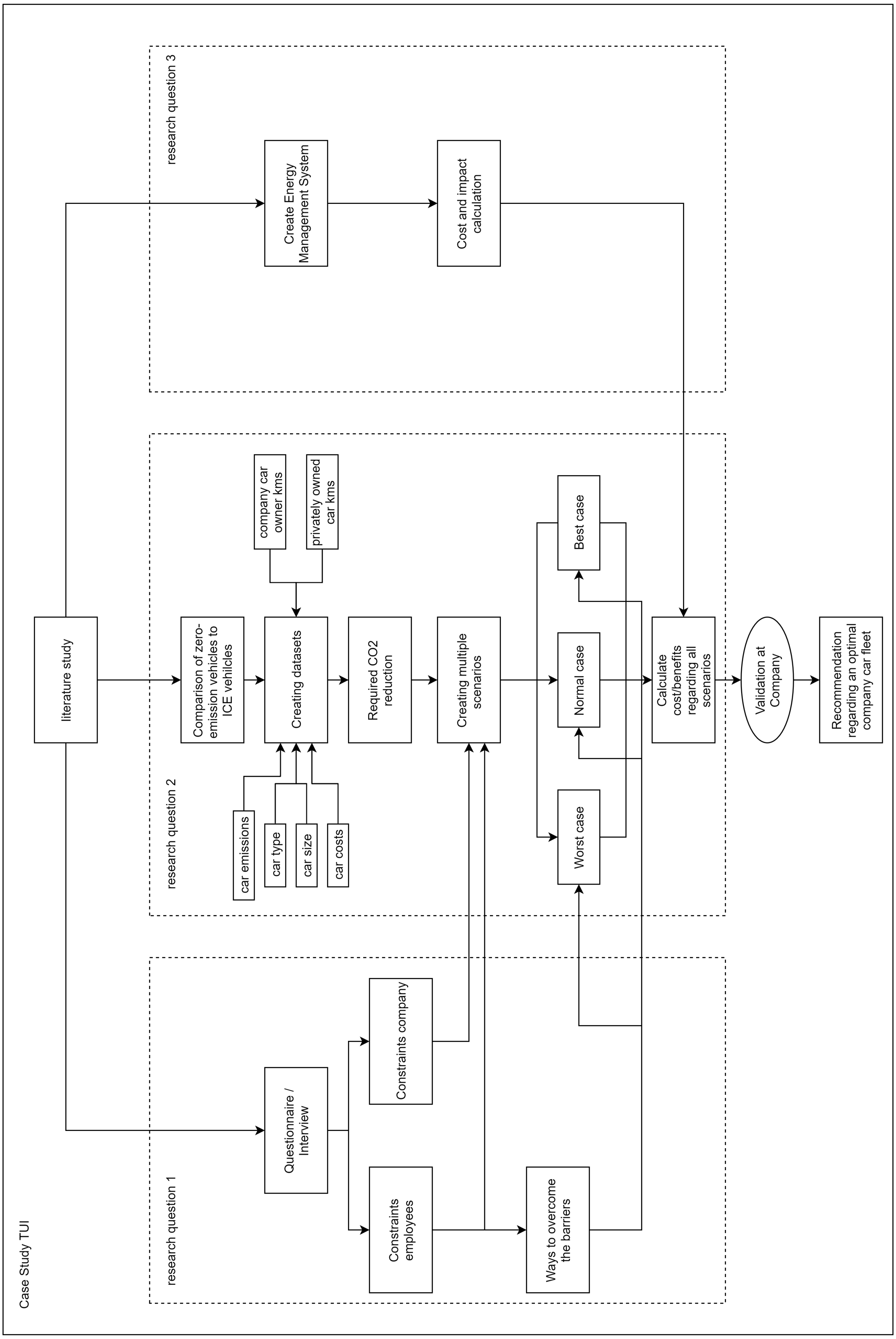

Figure 1.1: Schematic overview of the project approach

Chapter 2

Literature Review

This chapter focuses on an in depth discussion on previous research in order to identify how this thesis project is related to previous research, and how it can improve this research. Since this project touches upon different segments, multiple topics have to be investigated to see where this project can be of additional value. Considering that the employees are the users in this project, they are the ones who will have to adopt to this new driving style that is introduced and therefore, it is important to find what the barriers towards these zero-emission vehicles are for users. In extend, it is important to find motivators for users that stimulate them in their choice for zero-emissions vehicles. Next a more extensive research is required into the all the different zero-emission vehicles and their current and future capabilities. Lastly, the infrastructure regarding the charging of the vehicles was investigated. How did other researchers handle the limitations of the grid. A summary of the topics that were examined is as follows:

- Barriers for users
- Motivators for users
- Different zero emission vehicles
- Charging infrastructure

In the next section the research criteria used to find the papers is discussed. After that, the third section discusses all the findings, per topic, in the order as shown above. Lastly, a short conclusion is provided. This conclusion will elaborate on the most important aspects of the papers, and what these papers have not discussed, in order to find how this specific thesis can contribute to the already extensive list of research done on the subject of zero-emission vehicles.

2.1 Search Description and Selection Criteria

Before being able to define the topics mentioned in the previous section, a global search was done to find more information on EVs (and other zero-emission vehicles) and their usage in company car fleets. To find papers related to this general topic, sites like scopus, researchgate, IEEE, and google scholar were used. Key words for this initial research were: *company car electric*, *electric mobility* and *electric vehicles*. When searching for electric company cars only about 15 results were shown, 5 were eliminated straight away since they were from before 2010, some others had to be eliminated because they were not relevant. Based on the papers found after this initial research, the topics formulated in the introduction, of this chapter, were found. For all papers used, the criteria was that they should not predate 2010. This criteria was set as such since electric, hybrid and hydrogen cars are fast developing technologies, so the information used from the papers should not be outdated.

In order to also find research related to other zero-emissions vehicles and their suitability as company cars, key words like: *company car biofuel based* and *company car hydrogen based* were used, however this either showed no results at all, or no suitable papers were found. The search was then shifted towards more technical details on fuel cell and biomass based vehicles and, thus the IEEE website was used. Here some relevant and recent papers, and book chapters, were found regarding biofuels and the development of fuel cell based cars. The key words used to find these papers were: *fuel cell based vehicles*, *fuel cell development*, *hydrogen based vehicles development*, *biomass for driving*, and *biofuels development*.

Now, only some more research regarding the development of EVs, total cost of ownership (TCO), and their benefits over ICEVs, had to be found. From the initial research on EVs already some papers were found that discussed the TCO, however since these papers did not always take subsidies into account, were not very recent, and not applicable to The Netherlands, another search was done. The key word The Netherlands was never explicitly used, however after this search a couple of papers were found that discussed government incentives and their effects in The Netherlands, which was useful for later. At the same time a lot of research was discovered regarding the TCO. A selection was made of six papers, mostly discussing the situation in Europe, and all of the papers compared the EV to, at least, one other car type (ICEV, HEV, etc.). These particular papers were also selected because they compare the CO_2 emissions from the different car types as well, some even looked at other greenhouse gasses, like for example NO_x. Moreover, some assumed 100% renewable electricity generation for the EVs while others looked at the current electricity mix (5-10% renewable), and some papers looked only at the tailpipe emissions while others look at the well-to-wheel emissions. These six papers proved to be an ideal mix.

Next, information had to be found regarding drivers and barriers for a transition towards zero-emission vehicles. After the initial research on electric company cars, already some papers were found that seemed promising with regard to drivers and barriers. After skimming through a couple of these papers more relevant papers on the subjects were found in the bibliography. Since these papers turned out to be slightly older (before 2010) and were only about privately owned EVs another search was done with the key words: *EV car fleet barriers*, *corporate EV drivers*, and *drivers and motivators EV fleets*. Again, mainly papers emerged about drivers and barriers regarding privately owned EVs, and only two which also regard the company cars. Considering two papers is not enough to do a thorough analysis on drivers and barriers, some papers on the privately owned cars were selected as well.

Lastly, some more background information and research concerning the impact of EVs on the distribution network, as well as how to prevent the grid from overloading, was desired. Key words used to find relevant papers were: *EV charging*, *EV company charging*, and *EV charging strategy*. This yielded enough relevant and recent papers on how large fleets of EVs can be charged. Some papers discussed other possibilities for charging as well, and as a result of these papers another search was done towards *battery charging stations* and *battery swapping*. From this search two interesting papers were found that contemplated the advantages and disadvantages of battery swapping over regular charging at charging stations.

2.2 Findings

Below the findings of the topics mentioned in the introduction of this chapter are discussed. First barriers and motivators for users will be reviewed, then the different zero-emissions vehicles and their characteristics are discussed, and lastly, the implications of the increases in EVs on the charging infrastructure.

2.2.1 Barriers for Users

Before a company can switch to the use of only electric vehicles in their car fleet, it is recommended to find how their employees feel about this change and what potential barriers forestall the intended transition. Literature on these barriers, for company car drivers specifically, is scarce. For this reason mostly papers regarding the barriers for privately owned EVs are studied and it is assumed that most of the barriers will be similar for company car drivers.

In [28] the researchers focus is mainly on the technical and financial barriers that come with the transition towards EVs. Financial barriers are mainly attributed to the cost prices of the EV. People are not willing to pay a significant amount more for EVs compared to ICEVs. Surprisingly, it was also found that implementing tax incentives or other subsidies, to lower the costs for consumers, might have little effect as long as consumers remain having low confidence in EVs. This low confidence can be seen as an operational barrier and was also confirmed by [82]. Both [28] and [80] debate that promoting and informing consumers better on the subject might contribute in overcoming this particular barrier. The importance of correctly informing consumers is also discussed in [13]. From this research it became clear that perceptions of potential users towards EVs are strongly affected by their historical traits, such as lack of performance and safety issues, even though actual users do not encounter these issues (anymore).

In order to be able to correctly inform customers, it first needs to become clear what the operational barriers are, and then the technology acceptance model can be applied. The TAM is a widely used model for determining what kind of operational barriers users experience and how this influences their acceptance [23]. More information on the TAM model and its applicability to this case study can be found later on in Section 2.3.

Looking towards the technical barriers now, the literature in [42] and [12] unanimously mentions the EVs limited driving range, the (still) limited amount of charging possibilities while on the road, and subsequent to that, the longer refueling time compared to ICEV. In [42] these particular barriers and consumers willingness to pay for improved charging time and driving range were examined. It turned out that people are willing to pay varying amounts of money, between \$425 - \$3250, to decrease the fueling time by an hour for about 50 miles of extra driving and between \$35 - \$75 for a mile increase in driving range. Likewise, [26] investigated the willingness to pay for extra miles driven and found similar results: \$66 - \$75 for an extra mile. This research also showed that the marginal willingness to pay actually decreased with increasing driving range, so it turned out that the first couple of miles extra are worth more to consumers. Lastly, some literature including [12] mention the electricity supply as a barrier as well. More elaborate information on the impact of these EVs to the distribution net will be given under charging infrastructure.

2.2.2 Motivators for Users

Other than just barriers, the literature discusses possible motivators for EVs as well. The motivators that are most often debated are all sorts of tax incentives and subsidies provided by governments to make the EVs more cost competitive. Remarkably, the reduction in CO_2 emissions that is associated with driving EVs, is not always viewed as a motivator. Only in [12] the researchers mentioned that the environmental aspects were actually a key motivator for individuals to opt for EVs. This is also confirmed by [42] where it was found that people are willing to pay large amount to reduce emissions. In [49] policy measures for multiple European countries, including The Netherlands, are examined as a way to reduce the initial cost price of EVs. In The Netherlands consumers are exempted from registration and circulation taxes, but not from VAT. Since it was approximated that this results in a savings of 24.5% of the cost price of the EV, it can also be deduced that this policy measure stimulates the purchase of large EVs over smaller EVs. Considering the fact that incentives like these lower the cost price of an EV to roughly the same level (or still slightly more expensive) than their gasoline powered counterparts, it is important for the market prices of EVs to drop before they can achieve a higher market share. [64] confirms that policy measures such as tax incentives or subsidies would increase the share of EVs. Moreover it mentions that if the government were responsible for increasing the charging station density this would have a positive effect on the diffusion of EVs. [47] turns out to be one of the few papers that actually looks at benefits of tax reductions for company cars as well as for private car owners. This paper also concludes that the tax incentives in The Netherlands results in lower CO_2 emissions, 70% of this reduction can be attributed to the stringent and salient tax incentives for company cars. In addition, [25] examined the welfare effects of these Dutch tax policies. It was, again, determined that the policies are very effective in stimulating the EV uptake, however, it also showed that the incentives result in welfare losses. These welfare losses are more than just the forgone losses in tax revenues resulting from the tax benefits, thus these policies might not be economically optimal for society as a whole. Based on these results it has been concluded that company car fleets can have an immense impact on the reduction of CO_2 emission. Therefore, company car fleets are an ideal starting position for increasing the market share of EVs in The Netherlands.

2.2.3 Comparison of Different Zero-Emission Vehicles

Before adopting a certain approach it is important to know how far advanced the different zero-emission vehicle technologies are, what can be expected of these vehicle types in the (near) future, and what the total cost of these vehicles are compared to each other, and to the ICEVs. For this comparison the following zero-emission vehicles are taken into account: Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs), Fuel Cell Electric Vehicles (FCEVs), and biomass based vehicles.

[55], [39], [80], and [84] attempted to find the competitiveness of EVs by analyzing the total cost of ownership (TCO). In order to make a sound calculation of the TCO the following factors have to be taken into account: vehicle purchase price and its resale value, fueling costs, operating and maintenance costs -for BEVs this also entails the replacement costs of the battery-, insurance, vehicle taxes, and incentives and other subsidies for EVs. Even though the goal of these papers is similar, namely finding the TCO of EVs and comparing it with ICEVs, different approaches where taken. In [84], for example, a probabilistic simulation model is made in order to analyze the different TCOs in a 10 year period up to 2025. Results from this particular research show that although the TCO of EVs may become less compared to the ICEVs, it is no indication that consumers actually take this TCO into account before making their purchase. The same was established by [39], where it became clear that vehicle buyers do not take operating costs into account when buying their new vehicle. According to [80] on the other hand EVs supposedly are already cost competitive, but again as in [84] and [39], here it is also recommended that governments continue their incentives to increase the adaption of EVs further.

From [55] the overview of the comparison between the different vehicles types, shown in Table 2.1, can be retrieved. All numbers originally were in dollars and based on 2015 values. Since no additional paper could be found that describes the situation in The Netherlands, the numbers provided by [55] were transformed to euros and kilometers to get a better grasp of the actual meaning of these values given. Furthermore, the lifetime of all vehicles is set to 10.6 years with an annual distance driven of 11,300 miles. Based on these numbers the researchers in [55] concluded that the BEV has a lot of future potential. Considering that the electricity generation for the BEV is largely dependent on fossil fuels (only about 10%

is renewable), the CO_2 emissions related to the BEV can be reduced even further in the future.

Table 2.1: Comparison of different attributes related to the various car types where a lifetime of 10.6 years and an annual distance driven of 11,300 miles are taken into account [55].

	ICEV	**PHEV**	**BEV**
Retail cost [€]	24,960	25,431	29,063
Operation cost [€]	22,537	20,074	21,933
Fuel cost [€]	10,142	4,649	3,098
TCO [€]	57,639	52,617	54,094
CO_2 emissions [g/km]	381.1	198.4	238.5
Total externalities cost [€]	5,521	4,320	3,660

In [3] and [21], among others, the use of biofuels in the transport sector is analyzed. Since the biofuels are currently blended and used in ICEVs, biomass based vehicles are not categorized as zero-emission vehicles. Apart from this, other disadvantages, named by [3] and [21], regarding biofuels vehicles are that the production of the biofuels itself is an energy intensive process and is therefore not considered green, and lastly, the growth of the feedstock used for the production of the biofuels takes up large proportions of land and, in this way, competes for land with our food production. For these reasons, and the fact that the fuels are still not fully developed, and thus cannot be implemented by 2020, biofuels will be left out of this research.

According to [21] and [46] the transition in the transport sector, to zero-emissions vehicles, is expected to result in all-electric vehicles, like BEVs and hydrogen fuel cell powered vehicles (HFCVs), winning the battle. With an efficiency of about 80%, hydrogen production, through electrolysis, offers a promising alternative for zero-emissions vehicles. Other arguments in favor of HFCVs compared to BEVs are their increased range, lower refueling times and its applicability for heavier vehicles like cars and trucks. At the time of writing there are also still a variety of challenges concerning production, distribution, storage, and use of hydrogen according to [86]. Furthermore, even though hydrogen can be produced in a fully sustainable way, through electrolysis, currently 95% of hydrogen is still made of natural gas which results in high carbon emissions, and thus this vehicle can not (yet) be seen as a zero-emission vehicle. According to [86] fuel cells are still in a niche market and as reported by [83] hydrogen fueling stations are still scarce which makes the introduction of the HFCVs, on a large-scale, not something for the near future, but more a long term objective. Due to the fact that fuel cell vehicles cannot be employed on a large scale in the near future, these vehicles types will be left out of the research as well.

2.2.4 Charging Infrastructure

Significantly increasing the number of EVs in the company car fleet will have an impact on the electricity grid. In [32], [38], and [54] the impact of PHEV and BEV on distribution networks is analyzed. These papers concluded that without grid adjustments and scheduled charging regimes, the grid will remain reliable up to a 30% EV permeability. When this percentage is increased the reliability of the grid will decrease and should be enhanced or an intelligent control strategy needs to be implemented. At the same time the expansion of the EV fleet will significantly increase the energy costs for the company. Since most employees are at the office during the day, and thus their cars need charging during the day, companies cannot use the cheaper electricity price at night for the charging of the cars. However, according to [53], there are still ways for the company to implement intelligent charging and thus achieve a minimization in costs. To achieve this cost minimization an EMS was developed in [53] in which forecasts of PV power are used to optimally plan and distribute the power produced, in these panels, to either the grid or the EVs.

Another way of limiting the costs of the EV charging infrastructure for a company is discussed in [34]. It investigates three different charging strategies, a baseline strategy, an intelligent charging strategy and a multi-location intelligent charging strategy. In the baseline strategy the amount of charging stations is limited, due to a minimal investment in charging infrastructure, and cars are charged on first-come-first-serve base. The second charging strategy, intelligent charging, uses an optimal schedule for charging based on the State of Charge (SoC) of the cars battery. The last strategy, multi-location intelligent charging, improves on the second strategy by taking into account secondary locations, mostly employees home, for charging. The researchers concluded that by using the latter two strategies an optimal utilization of the grid can be accomplished and, therefore a reduction in cost compared to the baseline strategy. A further cost reduction can be achieved by generating energy through PV systems and using this energy to (partially) charge the EVs, this is in accordance with [53].

Another way to charge your car, without having to wait hours for the battery to be fully charged, is battery swapping. Battery swapping is done in a battery swapping station (BSS), which is a facility where depleted batteries are left, to be charged, and drivers receive a fully charged battery to continue their journey. Both [22] and [85] claim that battery swapping can also help in overcoming the barrier regarding the long fueling times. Apart from this, battery swapping stations can also help in preventing the grid from becoming unreliable. According to [85] the BSS can aid in smoothing the load profile because it has flexibility regarding the timing of the charging of the batteries. In the paper the optimal design of battery charging/swap stations was based on calculations of the Life Cycle Cost (LCC).

2.3 Research Framework

As was already briefly indicated in Section 2.2.1, the theoretical framework that is used throughout this thesis is TAM. In this section the theory behind the model, the suitability of the model in relation to the case study, and the drawbacks of the model are discussed.

2.3.1 The Technology Acceptance Model

The first technology acceptance model (TAM) was introduced by Davis in 1989 [23]. Back then it was introduced as an information systems theory that could help in determining why users would accept or reject new technologies like computers. It was derived from both the Theory of Reasonable Action (TRA) and the Theory of Planned Behavior (TPB), which can both be described as theories with a psychological basis [50]. After its initial adaptation TAM has been tested and expanded several times. In doing so extended versions of the original TAM were created [33]. These so-called extended TAMs have additional variables that also examine the effect of externalities on the adaptation of a new technology. For this particular case study the original model will be used. An overview of this model is given in Figure 2.1. This overview shows the relationship between a new technology (external variables) and a users expectations of that technology. The expectations are then divided into two factors; perceived usefulness and perceived ease of use. The first relates to how a user thinks this new technology will improves his life, and the latter considers how much effort a user thinks this new technology is going to take. The model also indicates that theses two factors interact with each other, indicating that the perceived usefulness might change after gaining some experience with the new technology.

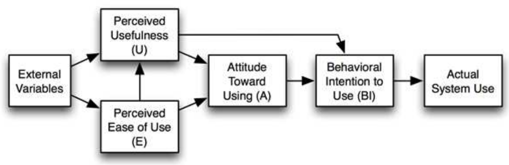

Figure 2.1: Technology Acceptance Model [23]

2.3.2 Suitability of the Model

The research question "What barriers do employees encounter before transitioning to zero emission vehicles, and how can the company aide in overcoming theses?" aims to find both barriers and motivators on zero emissions vehicles; the new technology. To find these indicators a lot of quantitative data can be collected through a survey. The first reason for the suitability of TAM in relation to this question, and thus this case study, is that TAM can be used to examine the answers given to the survey. Since TAM essentially is a tool that helps in understanding how experience can be related to barriers found and the acceptance of a new technology, it is well suited in helping to answer this research question.

Furthermore, since the research question also specifically looks into how a company can help in overcoming the barriers, the TAM is used in an organizational setting. Thus it is suggested that there is a relation between the adapters of the zero emission vehicle and the policies set by the company. This introduces another reason for the suitability of TAM for this thesis. Though TAM originally only appears to be focusing on the acceptance of a certain new technology by individuals, in both [82] and [40] it was also used to determine the acceptance on an organizational level. Since this case study is also going look into the acceptance on both levels, but then for company car fleets, the TAM model is assumed to be well suited for the analysis. Additionally, already existing literature like [82] and [27] implemented the use of TAM as a theoretical model to determine the acceptance of EVs in relation to commercial fleets, because of its key aspect of being able to relate both the perceived usefulness, and the ease of use, to ones attitude towards using a new technology. This is found to also be a key aspect in this study, since both contribute in finding a way to increase the adaption of zero emission vehicles.

2.3.3 Drawbacks of the TAM

One of the main drawbacks of using the original TAM has to do with the implication that when a user had the intention of using a new technology, that they can use the actual system without facing any limitations [33]. However in the case of adopting zero emission vehicles not all that are willing can actually adopt the new technology due to, for example, limited funds. A second criticism on the usage of TAM is that it does not offer explanations on why a technology is adopted or rejected. This brings about the third drawback as well. The model has limited predictive power, so it cannot be used to determine whether or not a new technology will be widely adopted and accepted [18]. Although the model has some drawbacks, it is still the most appropriate theoretical tool to use for this thesis. Due to its combination of both the TPB and the TRA, as was mentioned in Section 2.3.1, and because it can be applied in organizational settings as well (Section 2.3.2).

2.4 Conclusion

In order to find an optimal way to switch to an entirely (or partially) electrical company car fleet, it was found that multiple aspects related to electric driving need to be combined. From the literature study it can be determined that this thesis can have two main contributions, apart from the smaller contribution of adding new, and recent, information to the already existing literature by examining a specific scenario in The Netherlands. The first of these main contributions originates from combining all the aspects, related to the four topics discussed in the previous sections, and applying it to a case study at a specific company. This can be seen as a main contribution since all papers studied only consider one aspect of electric driving and here conclusions will be based on the whole package. It was also found that not a lot of research has been done into companies and electric driving in the first place. The second main contribution comes from the comparison between both the barriers and the motivators for company car drivers and private car owners. This last point is a main contribution because the literature study revealed that barely any, especially recent, studies were done into the company car drivers and their views on EVs. Usually only private car owners and their barriers and motivator were considered, even though [25] revealed that companies can have a huge impact in the reduction of CO_2 emissions, and the uptake of EVs as a whole. A more detailed and concise description of the knowledge gap found in the existing literature was discussed in Section 1.2.

Chapter 3

Methodology

In this chapter the different approaches taken to answer all the research questions are elaborately discussed, as well as the reasoning behind choices made. Firstly, the questionnaire, which is the first research question, is discussed. Next, the costs and benefits regarding a transition towards EVs, the second research question, is going to be debated. In that specific section the company's emissions are elaborately discussed as well. Lastly, in the third and final question, the setup and the financial advantages of rooftop solar panels, are examined.

3.1 Questionnaire

In order to answer the first research question 'What barriers employees encounter before transitioning to zero emissions vehicles, and how can the company aid in overcoming these?' a survey was conducted. This survey was used to gather feedback on what barriers people encounter when transitioning to zero-emission vehicles. In this paragraph the type, the setup and the structure of the survey are discussed as well as how the data were analyzed. As mentioned in Section 1.3, TAM was taken into account while generating the questionnaire.

3.1.1 Type of Survey

In order to find out what barriers employees encounter, what kind of advantages and disadvantages employees expect, and what measures the company can commence to make the transition to zero-emission vehicles, a questionnaire was developed. For this survey a quantitative research method was adopted, instead of a qualitative research method, for a couple of reasons. First, to provide insights into the differences and similarities between the results acquired during the literature study (in Chapter 2.2) [2] and the actual circumstances and opinions of personnel at companies, on the other hand. Secondly, a lot of potential respondents were available to test the general theory, which helps a lot since a general conclusion for the whole company is needed and this cannot be based on only a couple of qualitative interviews. Lastly, it is less complicated and time consuming to approach people this way, instead of having to find enough participants, that were willing to do an interview, and represent the company. The latter would even prove to be more complicated for this particular case study, since the company has multiple headquarters throughout The Netherlands and these would have to be approached as well. Thus, the main focus of the survey is on receiving a lot of feedback and can therefore be seen as quantitative.

Since the survey asked how people feel and think about certain aspects of electric driving, and EVs in particular, no initial knowledge was required from the participants. Furthermore, to ensure a high response rate the length of the survey was limited and it was made anonymous. Due to the anonymity the participants were expected to be more inclined to give their opinions since comments made could not be traced back to individuals. The aforementioned was of special importance for this survey since the participants were asked to give suggestions to, and about, the company, which they were assumed to do less when not anonymous. For all these specified reasons it was decided that the survey would be conducted as an online questionnaire for which the participants received a link via email.

Before compiling the questionnaire the following objectives were determined:

- Determining the barriers employees encounter when they are confronted with a potential shift from gasoline cars to electric vehicles.
- Determining similarities and differences in the answers given in this questionnaire and in previously done research [2].
- Determining, with the help of TAM, which measures TUI can best take in stimulating its employees to transition to zero-emission vehicles.
- Determining if a different approach is needed for private car owners and for company car drivers.
- Determining the willingness of employees to transition towards EVs.

3.1.2 Setup of the Questionnaire

Questionnaires can be constructed in many different ways and with varying lengths. For this questionnaire it was necessary to keep it short and to the point to prevent people from not starting or finishing it. Next to this, the amount of open questions was also deliberately limited to prevent too many irrelevant answers (e.g. answers that are not related to the question), and to make it easy for people to give answers.

The questionnaire consisted of, in total, 22 questions of which participants only had to answer 14-15 or 16-18 questions depending on which category they belong to, private car owner or lease driver. The total amount of questions that had to be answered depended on the answers given. After answering 3 specific questions an extra question might appear, depending on how the participant answered the question. For all these questions, three different question types were used, namely; 2 open questions, 18 multiple choice questions

(3 multi-select multiple choice questions and 15 single-select), and 3 matrix table questions. For the multi-select multiple choice questions the amount of options that could be selected was limited to three for 2 questions. In this way participants had to choose which three options were most important to them. For the other multi-select multiple choice question no such limitation was applied. This was specifically chosen as such, to be able to determine the difference in when people feel like they are experienced and to see what this experience entails, see also Figure I.1 in Appendix I. For the matrix table questions, twice a 4 point Likert scale was chosen and once a 5 point Likert scale. The 4 point Likert scale was deliberately chosen, instead of the 5 point scale, for those specific questions to prevent participants from choosing the neutral option, and force them to decide whether measures will have a positive or negative effect. Apart from the 2 open questions participants also had the option to add an extra answer option by 4 of the multiple choice questions, in case the answers shown did not (closely) correspond with their opinion.

Lastly, it was also indicated in Section 1.4 that the TAM would be used to analyse the answers given to the questions in the survey. By applying this acceptance model on the answers given it would be possible to determine what the company can do to overcome the barriers, also indicated in the survey, and thus make the EVs a more widely accepted technology among its employees.

3.1.3 Structure of the Questionnaire

The questionnaire was composed of four sections, namely an introductory section, a section with demographic related questions, then the main section, and lastly some concluding questions that mark the end of the questionnaire. The reasoning behind the different sections and the questions within the sections was described next. The entire questionnaire can be found in Appendix N.

The first section started with 5 orienting questions. The aim of these questions was to see how much experience the respondents have with EVs and how they quantify their experience, but also to find out what kind of advantages and disadvantages they believe EVs have (see Section 4.2.2: Advantages and Disadvantages of Electric Driving). The final question of this section examined how much influence certain, predicted, barriers have (see Section 4.2.1 Potential Barriers for Electric Driving). In the next section 4 questions were asked related to the demographics within the company. The main reasoning behind these questions was to be able to make deviations based on position within the company, and the respondents yearly income. The last question in this section asked if the respondent drives a lease car or a private car to work. This deviation was made for two reasons. Firstly, the questionnaire was anonymous and it would otherwise be impossible to figure out who belongs to which category, and thus no separation could have been made when processing the questionnaire without this question. The second reason is a more practical one. By making this deviation each category was able to receive questions catered to their (driving) situation. This avoided confusion about which questions should have been answered by whom. In this survey participants were not asked about demographics like age, gender or education, since this information was not relevant for the company, or the research. The goals here was to find general barriers and ways to overcome these. No additional breakdown to age, gender or education was necessary for this. Another reason was that age, gender, and education have already been related to opinions on EVs in a multitude of other research, like for example [82]. Then, in the main part of the questionnaire the more in-depth questions were asked. For the lease car drivers this part consisted of 7 questions and for the private car owners there were 4. Starting with the last category, the first two questions were asked to gain insight into what type of car people wanted and what their budget was. In this way it could be determined whether or not there were EVs available that suited the needs of the respondents (see Section 4.2.3.1: Purchase costs of EVs). The last two questions concentrated on the measures the respondents believe the company could take to stimulate the usage of EVs, and how much influence certain measures will have on their willingness to purchase an EV (see Section 4.2.4: Measurements the Company can Take to Stimulate Electric Driving). The questions for lease car drivers were built up in the same way, there was a part which asked about how much they were willing to pay for a new car and what car they wanted, and again it was asked how much influence certain measures, taken by the company, would have on the decision to opt for an electric lease car. Two additional question were asked for this category, in comparison to the private car drivers. This entailed questions related to the cars that were chosen for the current lease period, and why they did not opt for an electric car back then (see Section 4.2.3: Reasons Against Purchasing an EV). The hypothesis behind these questions was to gain some more insight into the reasoning of the lease car drivers and how this reasoning differs from the private car drivers. The concluding section contained only 2 questions. First, respondents were asked what the main reason was for them to not switch towards an EV. This could help in determining which measures, taken by the company, could prove to be most useful, or which problems should be tackled first. The last question aimed at getting some insight into the future EV use within the company. People were asked whether or not they expected to drive an EV within 2 years and, if not, what their reasoning behind that decision was (see Section 4.2.3: Reasons Against Purchasing an EV). This question can also aid the company in determining how they can tackle the problem, of reducing their CO_2 emissions, best. Thus, it will also be used to create multiple CO_2 reduction scenarios in Chapter 5. The time limit of 2 years was purposefully chosen, since, at the moment of compiling the questionnaire, TUI still had a little less than 2 years left to reach its own sustainability goal of reducing their CO_2 emissions related to business and commuter travel.

In the table below, Table 3.1, a short summary is shown on the information discussed above. The table shows how many questions each section contained and what the goal of that specific section was.

3.1.4 Data Processing

As already mentioned in Section 3.1.1, the questionnaire was on a quantitative base, thus the results acquired were first processed in a descriptive manner. This was mainly done by generating graphs and plots out of the answers given and then providing additional informa-

Table 3.1: Overview of the setup of the questionnaire.

Section	Number of Questions	Goal
Introduction	4-5	Getting an overview of the barriers, concerns and experiences regarding EVs.
Demographic	4	Getting insights into what differentiates the respondents, e.g. position within the company and salary.
Main **Lease Driver** **Private Car Owner**	 6-7 4	Getting more in-depth information on measurements TUI needs to take, according to its employees, to stimulate electric driving.
Ending	2	Finding out if people are willing to switch to EVs or what they still need (from the company) before transitioning.

tion on what can be seen and what the reason might be for the results shown in these graphs. By cross-referencing the answers of different questions it was then possible to find relations between the given answers. Based on this, potential explanations were given as to what the reasons could be for certain similarities or differences. Also, some recommendations were made based on the results, these will provide starting points for the continuation of this research. In addition, the last question of the survey was used as input for determining CO_2 reduction scenarios for the company in Chapter 5. More specific information on the creation of these scenarios is given in Section 3.2.2.

Since the questionnaire also contained a couple of open-ended questions, these will be processed separately. In order to be able to do this in a structural way, all answers were written down on individual sheets. This made it possible to easily find answers that could then be sorted into the same category. After the sorting process it was possible to see if the answers to the open-ended questions were in accordance with the other answers given in the questionnaire or if new conclusions, and such, can be generated through these answers.

3.2 Car Fleet Composition

In order to answer the second research question 'What is a suitable car fleet composition and what are the costs and benefits associated with this composition for both the company and its employees?' an extensive investigation was done into the cost and benefits regarding electric driving. Before being able to analyse the costs and benefits it had to be determined what the car fleet composition would be. From the literature study in Section 2.2.3 it was already determined that the hydrogen technology is not evolved enough to be part of the car fleet composition for the coming years. The same was concluded for biomass based vehicles, which leaves the electric vehicles as the only suitable option for the car fleet composition in the coming four to five years. To determine which part of the entire car fleet needs to be electrified, the answers to the last question of the survey, set out for the first research question, were used. More on this is given in Section 3.2.2. Before a closer look is taken at the scenarios and the costs and benefits, first more information is given on the current situation at the company. Some insight into the transport policy, the traffics flows, and the related emissions is given. Then when the car fleet composition is known it is possible to determine the costs and benefits associated with this transition. In determining these costs the results of the last research question will also provide some input, since this question showed that the potential charging costs can be lower when a company decides to install a rooftop solar system.

3.2.1 Traffic Flows and Related Emissions

Due to the fact that TUI has multiple locations in The Netherlands and works closely together with other countries within TUI Group, especially TUI Belgium, there is a lot of work related distance travelled each the year. This section will highlight TUIs transport policy, analyse the current composition of the company car fleet, and find all the CO_2 emissions related to business and commuter travel.

3.2.1.1 Transport Policy at TUI

While deciding on the locations of the 4 headquarters the accessibility of the offices was taken into account as well. Most locations can be reached easily by public transportation as well as by car. The one exception to this is the headquarters located in Ammerzoden. Since this site is not so easily reached by public transportation, most employees opt for driving their car to work. There is no saying in how this will change when these employees are relocated to Rijswijk.

Like most employers in The Netherlands, TUI also offers her employees a travel allowance for both business and commuter travel. TUI offers a couple of different arrangements depending on the type of transportation used, and the distance travelled. For all employees travel expenses for commuter travel by public transportation are fully reimbursed. In order to stimulate the use of public transportation, and other emission free ways of transportation, TUI offers no reimbursement of travel cost for, one way, trips shorter than 10km. Another measure taken to stimulate pollution free travel for shorter commuter distances is het Fietsplan. Instead of getting a monthly travel allowance an employee can opt for het Fietsplan and will then get a compensation for a maximum of € 749,- when procuring a new bike. If public transportation is not a viable option, and an employee has to travel by car, then a reimbursement of 9 cents per kilometer is granted. In case a private car is used for business trips a reimbursement of 19 cents per kilometer is applied [76].

3.2.1.2 Company Car Fleet

TUI Nederland leases the cars for their company car fleet from two different companies, namely Arval and Wittebrug. Cars stemming from Wittebrug are destined for the travel agencies only, so for the purpose of this study only the cars from Arval will be analyzed. At the reference date, April 26, 2019, TUI leases 154 cars from Arval out of which 44 are pool cars. Out of these 154 cars there are 58 that are fueled by diesel, 67 are fueled by gasoline, and there are 29 electric vehicles out of which only 5 are actually fully electric, the other 24 are (plug-in) hybrid vehicles. In Table 3.2 an overview is given of the number of cars that are driven by the lease car drivers, broken down to fuel type. It also indicates the average CO_2 emitted per kilometer driven for each of the fuel types.

Table 3.2: Overview of the lease fleet and its emissions.

Fuel type	**Number of cars driven by lease drivers**	**Average CO_2 emissions [g/km]**
Diesel	32	93.3
Gasoline	52	121.7
Hybrid	23	63.3
Electric	3	0
Total	110	97.9

In Table 3.2 it can be seen that the average CO_2 emissions of the lease car fleet is 97.9 gram CO_2/km. If the pool cars would also be included this value would rise to 100.4 gram CO_2/km. This increase can be explained by the fact that among the pool cars there are some vans. These are, on average, larger and heavier, and thus have higher emissions. Another explanation is that some of the pool cars are older cars from which the lease contract has already expired with the employee, but are adopted as a pool car. Either way, the total emissions are higher than they were in 2016, when it was only 97.0 gram CO_2/km for the entire lease car fleet (pool cars included). The small increase can partly be attributed to the increase in the size of the lease car fleet, from 144 in 2016 to 154 in 2019, but mostly it follows a general trend. According to [48] the average CO_2 emissions from cars, in The Netherlands, keeps rising even though there are more EVs and hybrids on the road. This appears to be related to the fact that people have more money to spend, and therefor can afford to buy the bigger cars they want, which also pollute more.

Every employee entitled to a lease car falls in one of the three categories specified in Table 3.3. As shown in this table, with each category comes a certain maximum amount up to which a driver is permitted to choose a car. It is also allowed to go over this indicated amount by 25%. These additional costs, however, have to be taken on by the driver himself and are not on account of the company. Table 3.3 also indicates how many of the current lease drivers fall within a certain category. This overview will be used for both the processing of the questionnaire in Chapter 4 as well as for the costs calculations for the company that will be analysed in Chapter 5.

Table 3.3: Overview of the distribution of the different lease categories and its corresponding monthly lease amount [76].

Lease category	Maximum monthly lease amount	Number of people
C	€821	48
D/E/F	€933	44
Board member	€1,162	8
Unknown	-	10

3.2.1.3 Emissions at TUI

Now, a closer look will be taken at the traffic flows within the company and the emissions accompanying it. A distinction is made between the lease drivers on the one hand and the private car owners on the other, but also between the different headquarters of TUI in the Netherlands. Separately mentioned is TUI Fly, later, in this section, the reason for this separation is going to be laid out.

Since TUI does not individually track the kilometers driven for its employees, it was difficult to obtain accurate numbers on commuter and business travel. A list was obtained indicating the ways people travel to the office. This list also indicated the commuter distance for each employee, and the amount of days they work per week. Using these numbers made it possible to calculate the total commuter travel (third columns) and the average commuter travel (fourth column) per employee. The results of this are shown in Table 3.4 for the lease car drivers, and in Table 3.5 for the people who drive their own car to work.

As mentioned, no specific data was available for the total amount of kilometers driven for business travel. An estimation, however, was made over 2018 which resulted in 122,992 km. In contrast, this 122,992 km is only 0.75% of the total distance driven for business and commuter travel. Because of this, the number for business travel will be neglected for the rest of this research. Another reason for this is that fact that once people start to drive electrically, business related travel will also become emission free.

After finding the total amount of kilometers driven it was possible to determine the emissions produced by commuter travel. The fifth and sixth columns of Table 3.4 and 3.5 show the average emissions per driver and the average emissions per office in ton CO_2 per year, respectively. For Table 3.4 the emissions were found by using the average CO_2 emissions of the lease car fleet (97.9 gram of CO_2/km) that was found in Table 3.2. Adding up the values resulted in a total emission of 170.76 ton CO_2 per year by the lease car fleet alone. For the private car emissions it was not possible to determine the average emissions for TUI alone, since the car type and related emissions are not known of the private car owners. So, for this group the European average of 117.8 gram CO_2/km (in 2016) [35] could be used, resulting in a total CO_2 emission of 1706.15 ton CO_2 per year.

Adding the total tons of CO_2 emissions from both Table 3.4 and 3.5 results in a total CO_2

Table 3.4: Average data for lease drivers at TUI Nederland.

	Number of cars	**Total commuter travel [km/year]**	**Average commuter travel per lease driver [km/year]**	**Average CO_2 emissions per lease driver [ton/year]**	**Average CO_2 emissions per office [ton/year]**
Rijswijk	64	936,265.5	14,629.1	1.432	91.66
Enschede	21	296,451	14,116.7	1.382	29.02
Divers	17	305,208	17,953.4	1.758	19.88
TUI Fly	8	206,325	25,790.6	2.525	20.20
Total	110	1,744,249.5	15,856.8	1.596*	170.76

∗ In Table 3.2 it was specified that 3 cars of the company car fleet are already electric, thus the amount given here is the total average CO_2 emissions per office divided by 107 cars.

Table 3.5: Average data for private car owners at TUI Nederland.

	Number of cars	**Total commuter travel [km/year]**	**Average commuter travel per private car owner [km/year]**	**Average CO_2 emissions per private car owner [ton/year]**	**Average CO_2 emissions per office [ton/year]**
Rijswijk	216	2,383,425	11,034.4	1.300	280.77
Enschede	152	1,270,957	8,361.6	0.985	149.72
Divers	15	155,430	10,362	1.221	18.318
TUI Fly	421*	206,325	25,790.6	2.525	1257.36
Total	804	14,483,461	18,014.3	2.122	1706.15

∗There are more TUI Fly employees who travel by car, but for only 421 the distance of the commute was known.

emission of 1877 ton per year for all commuter travel at TUI Nederland. A 20% reduction of these emissions would imply a reduction of 376 ton CO_2 per year which would, theoretically, mean that about 177 people have to start driving electrically.

From both Table 3.4 and 3.5 it can be seen that, on average, the people falling under the category 'TUI Fly' drive larger distances. There are two explanations for this. Firstly, most of these people have to travel to one of the airports (Schiphol, Rotterdam-The Hague Airport Eindhoven Airport or Groningen Airport) on a regular basis, and they do not necessarily live nearby one, or all of these, hence the larger commuter distance. Secondly, after the renovation of the office in Rijswijk a lot of the employees located at Schiphol were transferred to the office in Rijswijk, and now thus have a larger commute.

3.2.2 Scenario Justification

For determining the car fleet composition the amount of CO_2 reduction is taken into account. In Section 3.2.1.3 it was mentioned that TUI strives towards a 20% CO_2 reduction by 2020. In order to determine whether or not this 20% reduction is achievable, and if so, how, a closer look was taken to the results of the questionnaire.

The last question of the questionnaire asked was whether or not the employees were willing to transition towards EVs within the next two years. The answers given to this question can now aid in the creation of multiple CO_2 reduction scenarios. Looking back at the question, people had the option to choose between four different answers, namely: '*Yes*', '*No, I would rather wait till TUI presents favorable terms*', '*No, I would rather wait till the purchase price of EVs drops*', and '*No, I think shifting towards EVs is too much of a hassle and I would rather not switch at all*'.

From Figure 4.9 in Chapter 4 the distribution between these answers could be determined. An overview of this distribution is now given in Table 3.6. Based on the percentages given in the table it is then possible to determine three different CO_2 reduction scenarios. In Section 5.1 all of these scenarios are elaborately discussed. Here it is only mentioned that based on Table 3.6 a so called worst, medium and best case CO_2 reduction scenario were created.

Table 3.6: Overview of the distribution on the answers given to the last question of the questionnaire. Results are retrieved from Figure 4.9.

	Lease car drivers	**Private car drivers**
Yes	25%	2%
No, I will wait till TUI presents favorable terms	43%	21%
No, I will wait till EVs become less expensive	18%	58%
No, its too much of a hassle, I rather not switch to an EV at all	15%	19%

3.2.3 Associated Costs and Benefits

Now that the different scenarios are determined, the next step was to calculate the costs and savings that accompany each scenario for both the employees and the employer.

Before all of the cost and benefit calculations can be made, it is important to understand where all the costs and savings originate from. This section elaborates on all the costs and benefits associated with the transition. A division was made between costs and benefits for the company and for its employees. Then, for the employees, a division was made between lease drivers and private car owners, since these categories have different costs associated with a transition to EVs, as well as different benefits.

As mentioned at the beginning of this chapter, the PV analysis also provides some inputs for this last research question. This however, will not come back until Chapter 5.2. In that chapter the calculations were made on the measures discussed here, and thus the lower electricity price, related to the installment of the PV systems, was taken into account.

Now, first a closer look is taken at the costs and benefits for the company.

3.2.3.1 Company

Costs
Depending on how fast the company wants to reduces its emissions, and on whether or not it wants to make its entire company car fleet emission free, there are cost involved in trading in the ICEVs for EVs. If TUI were to terminate a lease contract prematurely, then the lease company needs to be compensated for the losses they suffer on these cars. This compensation depends on the amount of days that were still left on the contract and the list price of the car. For every day the contract is terminated early, the lease company charges a certain amount of money. This amount differs per vehicle and is set at the start of the lease contract. Other costs for TUI consists of the cost accompanying the stimulating measures TUI wants to implement to encourage its employees to transition towards EVs. Lastly, the additional costs of leasing an EV have to be considered. Since the purchase price of EVs is, in general, higher compared to that of a similar ICEV, the monthly lease amount is also higher. This cost item differs from the potential measure where the company compensates its employees for the higher lease price of EVs. It differs since the measure is more about compensating the personal contribution lease drivers might have to pay when leasing a vehicle outside of their lease category (see Section 3.2.1.2 again for more information on this), whereas this cost item just looks at the higher lease prices of EVs. So, in summary, this cost item looks at additional costs of EVs that fall within the ranges of the lease category and the measures at the amount above it.

Benefits
Besides the costs, there are also (monetary) benefits for the company in transitioning to EVs. First of all, by announcing to electrify their company car fleet and taking an active stance in stimulating its employees to drive electrically, TUI is expected to receive some positive advertisement, which will have a positive influence on the TUI brand (in The Netherlands). Second, by achieving the 20% CO_2 reduction at the end of 2020 TUI will have reached its own objective as stated in their business strategy. To put a monetary value on this CO_2 reduction a future scenario is assumed where a carbon tax is in place. By using this tax a monetary value can be placed on reducing ones CO_2 emissions. To estimate the cost per ton of CO_2 a closer look is taken in to the current EU emission trading scheme (ETS). At the day of writing the emissions were trading at €25.93 per ton CO_2 [63]. The third benefit is a monetary benefit. The Dutch government provides subsidies and benefits to

companies that invest in sustainable technologies. For the particular case of EVs there is the Milieu-investeringsaftrek (MIA) [62]. Even though the company is not buying these EVs themselves, it is still possible to apply for this subsidy. This has to be done through the lease company, which will then result in a (small) reduction of the monthly fees TUI has to pay the lease company. The fourth and fifth benefit are the exemption from taxes related to the purchase of cars (Belasting van Personenautos en Motorrijtuigen), BPM, and taxes related to the ownership of cars (Motorijtuigenbelasting), MRB, respectively, which also results in lower (monthly) lease prices. Lastly, under costs the higher purchase price of EVs was mentioned, but a benefit of EVs on the other hand is that the fuel costs are lower compared to ICEVs. This lower fuel price will especially be beneficial when large distances are travelled, which is usually the case with the company car drivers.

With the lower fuel costs, the MIA subsidy, and the exemptions from BPM and MRB, the monthly lease prices are expected to increase only slightly in comparison to ICEVs, depending on the vehicle chosen.

Now a closer look is taken at the benefits and costs for the employees when they start driving EVs. A separation is made between the lease car drivers and the private car owners, since each category has its own costs and benefits.

3.2.3.2 Private Car Owners

Costs
As for the private car owners, since they pay for the entire car themselves, the additional cost will hail from the higher initial purchase price of the EV compared to its ICEV counterpart.

Benefits
The private car owners can also profit from certain benefits. They also do not have to pay BPM or MRB taxes when they purchase an EV. Next to this, private car owners can also benefit from a subsidy when purchasing an EV. This subsidy is a, yet to be determined, fixed amount of money. In the Dutch climate agreement of June 2019 no amount was determined for this subsidy [69]. It only mentioned that the subsidy will be phased out again by 2026 due to the expectancy that EVs are more affordable by then. However, it is rumored that the subsidy is going to be half the amount that was proposed in the concept climate agreement of December 2018 [68], which would amount to €3,000 in 2020. Other benefits for the private car owners come from the measures TUI can take to encourage this group to transition to EVs, for example free charging or a charging station at home. Lastly, if TUI were to not pay for (all of) the fuel costs for this group, then there is still a benefit to be obtained through fuel cost savings, since electricity is a less expensive fuel compared to gasoline.

3.2.3.3 Lease Car Drivers

Costs
For lease car drivers, on contrary, there are hardly any additional costs for leasing an EV instead of an ICEV. Only when an EV is chosen that is outside of their assigned lease budget

(see again Table 3.3 in Section 3.2.1.2), there can be an additional cost, usually ranging from €0 to €200 based on the current overview of company car drivers at TUI. Furthermore, if the company decides to buy and place a charging station on the property of its lease driver, then the costs for the placement and installment are added to the financial costs of the car. In this way the charging station falls under the additional tax liability as well, and thus slightly increase the taxes lease drivers have to pay.

Benefits
Financially, the lease car drivers can benefit a lot from choosing to lease an EV over an ICEV. Currently the additional tax liability for electric company cars is 4%, in contrast to the 22% tax rate that people have to pay that drive gasoline cars. So, even though the monthly lease price of the cars might be (slightly) higher, which also increases the taxes that have to be paid over the lease car, the total taxes are lower due to the significantly lower tax rate for EVs. Furthermore, this category can also benefit from the measures TUI can take to encourage the transition towards EVs among its employees, and thus save costs for e.g. installing a charging station.

All the above mentioned benefits and costs are further specified in Chapter 5.2 where a monetary value was given to all that was mentioned. By doing so an overview was generated and the total cost that accompany the intended transition towards EVs could be laid out.

3.3 PV Analysis

To be able to find an answer to the thrid and last research question 'How can PV systems help with the expected electricity increase due to EV charging, and is this financially feasible?' an extensive investigation was done into the electricity usage of TUI and how this is expected to increase when more people drive, and need to charge, an EV. Moreover, it was analyzed whether or not rooftop PV panels are capable of generating enough energy to cover the charging needs of these EVs and if, at the same time, costs can be saved by generating the electricity this way instead of having to purchase more kWh from the electricity company.

3.3.1 Structure of the PV System

As was already mentioned in Chapter 1.5, TUI has multiple headquarters spread throughout The Netherlands. For this PV study only the offices in Rijswijk and Enschede were analyzed since TUI does not have to pay a separate electricity bill for its location at Schiphol. All calculations that were done in Chapter 6 were performed for both TUI Rijswijk and TUI Enschede. However, only a detailed analysis will be shown for TUI Rijswijk to avoid unnecessary duplication of work. For TUI Enschede thus only an summation of the final results will be given.

In order to calculate the maximum output of the PV systems the software program Matlab was used. Multiple scripts had to be written and by combining all of these a final AC output was estimated for each location. In Figure 3.1 a schematic overview is given of the scripts written and how they relate to each other. In the figure the yellow blocks indicate the scripts/code written in Matlab, and the blue blocks represent imported data (e.g. Meteonorm Data), or fixed data that were found or calculated beforehand (e.g. system size, longitude). The Matlab scripts written for this PV system analysis were partially based on assignments made during the course ET4378 [45]. Before delving into the analysis and its results, a short setup will be given on how the scripts came to be, how they are related, and the reasoning behind them.

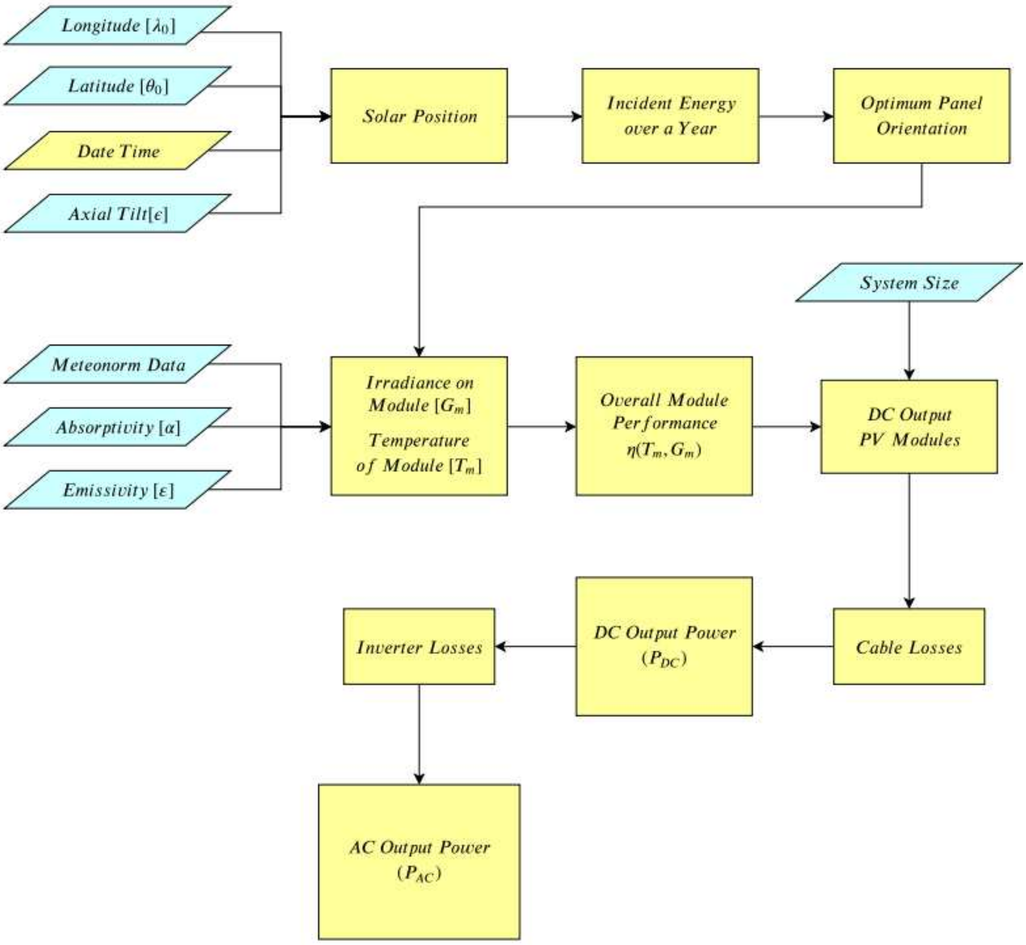

Figure 3.1: Flowchart of how the generated (Matlab) scripts and files relate to each other.

From the schematic overview it can be seen that a lot of intermediate steps were taken, and a lot of data had to be collected before the output of the PV system could be determined. First off, it was essential to take a close look at the location (longitude and latitude) and the suitability of the rooftops of both buildings. This last part proved to be imperative in determining the amount of solar panels each building could hold, and thus in determining the system size.

Before anything could be done with this system size, a solar calculator was made. This solar calculator determined the position of the sun, relative to a certain location on earth, in this case TUI Rijswijk. The calculator also made it possible to determine the energy incident, on that specific location, over an entire year. This, in turn, helped in finding the (fixed) optimal orientation a solar panel should have at that particular location.

Using the system size, the optimal orientation, and all relevant meteorological data, made it possible to obtain a very accurate estimate of the output the PV systems can generate at each location (block: *DC output PV modules* in Figure 3.1). The relevant meteorological data were collected through the Meteonorm software tool. With this tool it was possible to gather all kinds of meteorological data varying from the temperature at a certain location to the wind speeds at the same location. Due to licensing issues only the data for the office located at Rijswijk could be collected, and thus this same data had to be used for the PV system calculations for TUI Enschede as well. This was deemed acceptable since The Netherlands is a small country, and thus the collected meteorological data will not differ too much between both of these locations.

After obtaining the DC output of the PV modules, the cable losses were examined. Knowing these losses made it possible to calculate the power input to the inverter (block: *DC Output Power*, by subtracting the cable losses from the PV output. The Sandia National Laboratory model (SNL) [67] (Appendix G) was then used to determine the relation between the DC input of the inverter and the AC output. In other words, with the help of this SNL model the inverter losses, and thus the inverter efficiencies, were calculated. Once the inverter losses were subtracted, from the power entering the inverter, the final system output was found. All of the steps taken are shown in Figure 3.1.

Once the system output was known, it as important to get a better understanding between this (AC) output and the electricity usage of each office. In order to do so, an excel sheet was obtained with data from the electricity company Vattenfall, that currently supplies all the electricity for the TUI offices. In this excel sheet the monthly electricity usage of each office was shown, as well as costs related to this consumption, this also included the costs related to the transportation of the consumed electricity.

In addition, estimations were made on the electricity usage of a single EV, and the effect the electrifying of the entire lease fleet will have on the total electricity usage of the offices. Here the situation for TUI Rijswijk was analyzed, since it has a larger lease fleet and lower electricity usage which will make the impact EV charging has, on the total electricity usage, more apparent.

Lastly, after finishing the system design and finding the total output of the system, calculations were made on what the system would cost, what the payback time would be, and what the electricity price would be for this sustainable energy source, the so called Levelized Cost of Electricity (LCoE). Since the PV system is specifically designed for a company all of the component cost are given excluding VAT, and only subsidies and grants companies can apply for were looked into. In the next section a more detailed description is given on the cost analysis performed for the PV systems developed.

3.3.2 Setup of the PV Cost Analysis

Multiple scenarios were created to show the impact of, for example, subsidies and enhanced system performances, on the payback time of the PV system. In the first scenario the current situation (2019) will be analyzed. This is also the main scenario and will thus be thoroughly discussed in Section 6.5. For the other scenarios the same basic formulas were used as given in Section 6.5, only the inputs, and thus the outputs, will slightly differ. A summation of the (new) inputs, and the final payback time were summarized for each scenario at the end of Section 6.5.1.

Since subsidy rates and prices are very volatile in The Netherlands (changing with every new government), a couple of different scenarios were created to see the impact of these changing rates on the payback time, in contrast to the base scenario of 2019. Considering that it was already known that the Energie-investeringsaftrek (EIA) [8] will be nullified in 2024 [1], the second scenario takes hold in 2025. Here the Kleinschaligheidsinvesteringsaftrek (KIA) [10] was kept at its current rate, and the grant Stimulering Duurzame Energieproductie (SDE+) [61] was reduced by 50%, since it is likely that this will be lowered once the total installed PV capacity is increased. Besides changes in subsidies there are also going to be differences in system efficiency, and the costs related to the PV system components. A closer look will specifically be taken at the prices of the modules, the inverters, and the mounting system. According to Swansons Law [72] the costs of PV panels drops by roughly 20% for every doubling of the amount of the PV panels deployed. Furthermore, it is expected that the efficiency of the PV modules will increase, and that the cost related to the Balance of System (BOS) components (e.g. inverter and mounting system), and the PV module itself, will decrease. Lastly, a worst case scenario was created. In this scenario it was assumed that there are no more subsidies provided, at all, for installing PV systems and producing sustainable energy. In this scenario the only savings will originate from the reduction in electricity cost. This scenario will again take hold in 2025, because it is not expected that subsidies are phased out by next year.

Since both of these additional scenarios are set in 2025 it had to be taken into account that the cost of electricity is another variable that can fluctuate with time. Though it is harder to define a fixed amount for this variable in the (near) future, it is expected that the electricity costs are going to increase in the coming years. Making it even more profitable for companies to produce their own energy. Reasons for the expected increase of the electricity costs can be found in [20]. As mentioned, no fixed amount can be assigned to the electricity costs in, for example, 2025. So, calculations were made with a yearly increase of 1%, 5%, and 10% relative to the (base) value in 2019. A more detailed explanation and overview can be found in Section 6.5.1.5.

Chapter 4

Results of Questionnaire

In this section the results of the questionnaire are presented. First the response of the questionnaire is analyzed. Then the results of the multiple choice questions are given together with a possible explanation for these outcomes. Following this the open-ended questions and their significance is laid out. Lastly, a concluding section presents the most important results obtained from the survey which are then used as input for the second research question.

4.1 Response of the Questionnaire

Before delving into the results obtained from the questionnaire, first a closer look was taken at the response. An overview of the number of people approached and the corresponding response is depicted in Table 4.1. Secondly, the table also shows the distribution between the categories of lease drivers on the one hand, and people who drive their own car to work on the other hand. When examining the ‘approached’ and ‘response’ percentages for each category it can be seen that they differ only slightly. The response among the lease car drivers is somewhat larger than that of the private car drivers, since the response percentage is higher than the percentage of participants approached for lease car drivers. Additionally a chi-square goodness of fit test was done to determine if the obtained response represents the actual population. After calculations, see Appendix B, a p-value of roughly 25% was found, since the p-value is larger than 5% it can be said that the difference is insignificant [71], and thus that there is no significant discrepancy between the ratios of participants approached and the actual response [24], which is in accordance with what the first impression of the percentages already showed. Table B.1 in Appendix B also shows that for the lease car drivers there were slightly more respondents than expected. Later on it was discovered that two respondents from this category already driver an EV. If these answers were left out due to a potential bias (positive or negative), then this category would still have more respondents than expected. It can thus be said that the response of this particular group, and the questionnaire as a whole, is then still representative (p-value $> 5\%$).

The second table, Table 4.2, shows the distribution of the response between the different positions within the company. For these groups a large discrepancy is visible. The chi-test confirms this in Appendix B, since the resulting p-value is very small. This indicated that the null hypothesis needed to be rejected and thus that there is a significant discrepancy between both ratios. Roughly seen there is a 100% response rate amongst the board members, a 50% response amongst the managers, and only a little over 25% of the employees responded. Later on it is discussed what this suggests for the reliability of the survey results.

Table 4.1: Overview of the response of the questionnaire.

	Approached		**Response**	
	Number	**Percentage**	**Number**	**Percentage**
Private Car	458	80.6 %	136	77.3 %
Lease Car	110	19.4 %	40	22.7 %
Total	568	-	176	31.0%

Table 4.2: Overview of the distribution between the different positions within the company.

	Approached		**Response**	
	Number	**Percentage**	**Number**	**Percentage**
Board	3	0.5 %	3	1.7 %
Manager	101	17.8 %	53	30.1 %
Employee	464	81.7 %	120	68.2 %
Total	568	-	176	31.0 %

Furthermore, the total response of the questionnaire is given in Table 4.1, and is 31.0%, however, just this percentage does not say much on the representativeness of the questionnaire. To be able to assert whether or not the questionnaire is representative the following four criteria need to be met [58]:

- The number of respondents in the sample needs to be large enough.
- The ratio between the response and the people approached needs to be high enough.
- The rendering of the respondents needs to correspond with that of the total population.
- There are no systematic differences between the participants and those who did not participate.

Starting with the first point. In order to determine if the sample size is large enough a formula is used that calculates the sample size needed based on the population. When assuming a standard confidence level of 95%, and thus a degree of allowed error that is 5%, and a total population of 568, the sample size should consist of 229 respondents. The true response is, however, lower with only 176 participants, and it is thus questionable if this can be viewed as representative. Next, the degree of allowed error for the actual response is calculated. Again a confidence level of 95% is assumed, resulting in an allowed error of 6.14%. Seeing as the dispersion in the (most important) answers given is relatively low, as will be shown and discussed later on, this higher allowed error is acceptable. More extensive calculations on the sample size and allowed error can be found in Appendix A.1 and A.2, respectively.

For the second point the ratio between the people approached and the respondents needed to be examined. As mentioned, the response rate is 31.0% which is not too high, but also not too low. Considering that, for this survey, the entire population that drives a car to work is approached and not just a section of this population, makes that the ratio between people approached and respondents is more than acceptable.

As for the third point, Table 4.1 already showed that the people approached (which is the total population) has a similar distribution as the group of respondents. The same cannot be said for Table 4.2 however. Here the deviations between the positions of the participants approached and the respondents is rather high. Especially the one between managers and employees. This, however, does not directly imply that this criteria is not met. In contrast to Table 4.1, were the participants approached are equal to the entire population of people who travel to work by car, this is not the case in Table 4.2. Here the approached board members, managers and employees do not make up the entire population.

The last criteria that needed to be checked was whether there were systematic differences between the participants and those who did not participate in the survey. To be able to check if there was a difference, the non-response needed to be analyzed. Since the survey was conducted in an anonymous way participants could be as critical as they wanted to be without repercussions. Therefore, it can be assumed that the people who did not participate do not have a more negative attitude towards the company, or new EV policies compared to those who did participate. As for the people who might have a very positive attitude towards EVs, it can be assumed that most of them probably participated in the survey since they have no reason to hold back on their feedback. Another reason for expecting them to participate is that they would not pass up the opportunity to give valuable feedback when having a positive attitude towards the subject. When examining why a lot of people did not respond a couple of possible causes were found. First, and most important, the company uses a lot of interns which means that employees regularly receive invitations to participate in surveys and that they tire of filling out all these surveys. Furthermore, the survey was sent by HR Support, and even though they were given a subject for the email invitation, they chose one that read 'survey sustainability'. Due to this poorly chosen subject people ignored the email without even opening it and seeing what the survey was about. Also indicated by someone was that the day the survey was launched was chosen poorly, since it was sent on a Friday, from a public email address, people who are not present tend to ignore such emails as they get a lot of general email updates on Friday. Originally, it was decided to send out all the email invitation on Monday, but this got delayed due to illness of the person responsible for sending the email. Moreover, the company is rather large with multiple locations throughout the Netherlands, so a lot of people do not know who you are and are then usually less inclined to do someone a favour. Due to the reasons given for the non-response, it can be concluded that there are no systematic differences between the participants and those who did not participate, and thus it can be said that this criteria is also met.

Since all criteria were met it can be verified that the results of the questionnaire are representative for the entire company.

4.2 Survey Results

In this section the most important results from the survey are laid out. All other, less trivial, results can be found in Appendix I. Firstly, the closed questions are analyzed, and then the open-ended questions. The results of the open-ended questions are grouped together in 6 and 5 sections for private car drivers and lease car drivers respectively.

4.2.1 Potential Barriers for Electric Driving

One of the introductory questions asked how people feel about a set of potential barriers against electric driving. Answers could be given on a 5 point Likert scale ranging from ‘Very important’ to ‘Not important at all’. The graphs shown in Figure 4.1 and Figure 4.2 indicate how people feel about these barriers, compared to their experience with EVs, and their yearly income, respectively. Additionally in Appendix I, Figure I.1 gives an overview of the difference between how lease and private car drivers feel about these barriers. In Appendix I, Figure I.2, it is then shown how experienced people think they are with EVs and where that experience originates from.

From Figure 4.1 it can be seen that the more experience people claim to have with EVs, that the barriers that are usually mentioned (*e.g. driving range, (public) charging*, and *purchase price* ([42], [12])) are viewed as less important. An explanation for this phenomenon could be that the general public has a (too) negative perception of EVs, which is then revised after gaining more hands on experience with electric cars ([28], [80]). Another notable difference in experience levels is visible in the barrier *possibility to charge at work*. More experienced people think this barrier is more important than the less experienced people. An explanation for this could be that with more experience people know how long it takes to fully charge the car and they would like to do this while at work, when the car is not in use, and then be able to drive home without having to charge somewhere along the way.

The most notable difference is however the distinction between the opinions of the people with a reasonable amount of experience and a lot of experience on the barriers; *purchase price, available cars (=EV supply)*, and *the influence of extreme weather conditions on the performance of the car*. The survey does not give an explanation as to why the given answers vary this much for these specific barriers. For the barrier of the *purchase price* one would actually expect that the purchase price becomes less important with increasing experience,

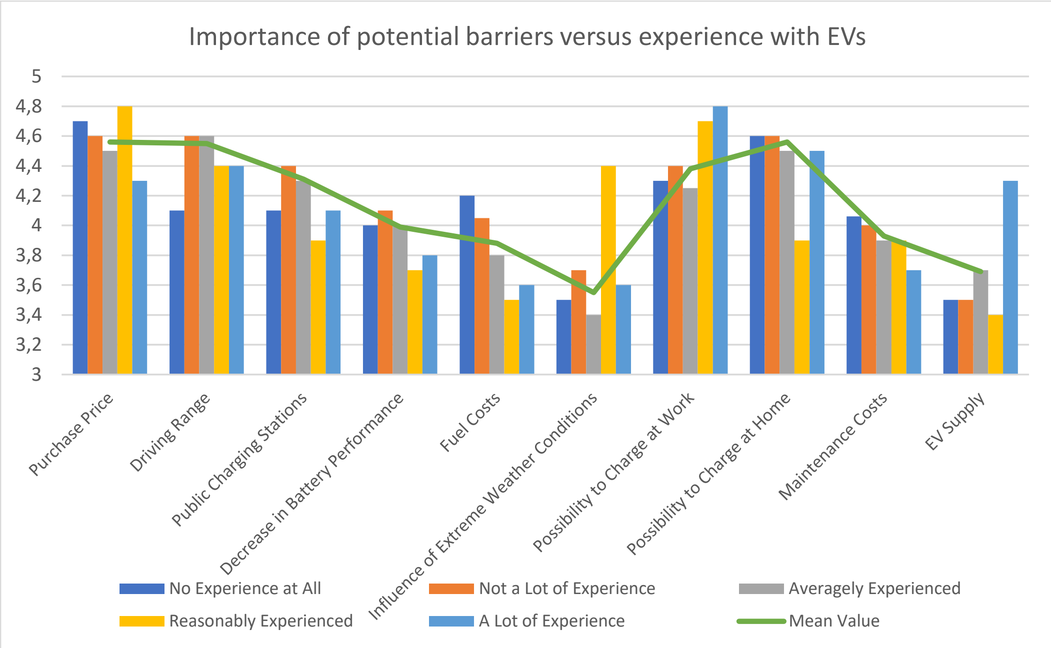

Figure 4.1: Results of the importance of the potential barriers versus the experience the participants feel they have with EVs.

since Figure I.3 in Appendix I indicates that, in general, people with more experience also have a higher yearly income.

In Figure 4.2 the barriers are compared to the yearly (gross) income. This graphs shows what was briefly discussed above, that the *purchase price* becomes less important when income rises. This can easily be understood when considering that the purchase price of an EV is roughly €10,000 higher compared to a regular gasoline car. This €10,000 is of course more affordable when your income is higher. Also noteworthy is the difference in answers given by people with higher incomes (€72,000 and higher) for the barriers; *driving range* and *public charging stations*. In both cases the higher incomes value these potential barriers as being more important compared to the lower incomes. A feasible explanation for this can be found in the position of the employees within the company. People with higher income have, for the most part, a higher position, e.g. manager (see Figure I.4 in Appendix I). This entails that they are more likely to have a lease car (see also Figure I.13 in Appendix I) and usually have to travel more between the offices in The Netherlands and Belgium. For people who regularly drive large distances a larger drive range and more public charging stations are crucial.

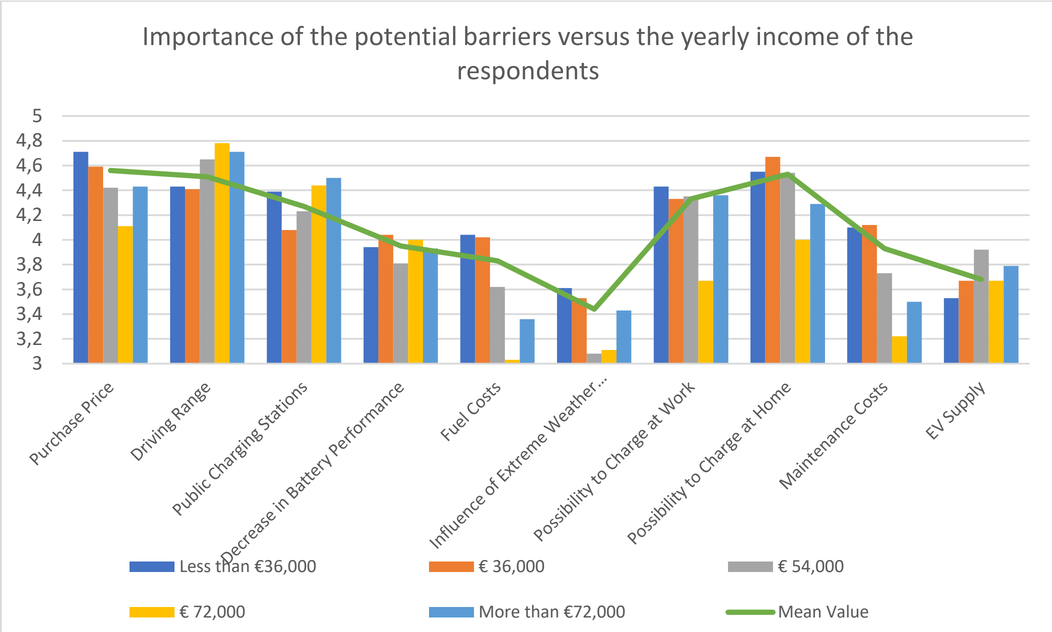

Figure 4.2: Results of the importance of the potential barriers versus the yearly income of the respondents.

4.2.2 Advantages and Disadvantages of Electric Driving

In the third and fourth question the participants were respectively asked what they think the advantages and disadvantages of EVs are. In the Appendix I, Figure I.5 and I.6, a histogram is given on the distribution of the advantages and disadvantages, respectively. Here only the three most mentioned benefits and drawbacks will be given.

Top 3 advantages:

1. Less CO_2 emissions 31.1 %
2. Lowers the dependency on fossil fuels 22.6 %
3. Lower costs for fuel 19.3 %

Top 3 disadvantages:

1. Charging time 29.8 %
2. Driving range 28.2 %
3. (public) charging possibilities 14.3 %

Next, Figure 4.3 and Figure 4.4 show the distribution of the advantages and disadvantages, respectively, against the experience the respondents have with EVs. In the graph with the advantages, Figure 4.3, it is striking to see that the more experience people claim they have, the more advantages they see in EVs. Where the people without experience only mentioned the 'known' advantages([42], [12]), people with experience also see benefits in

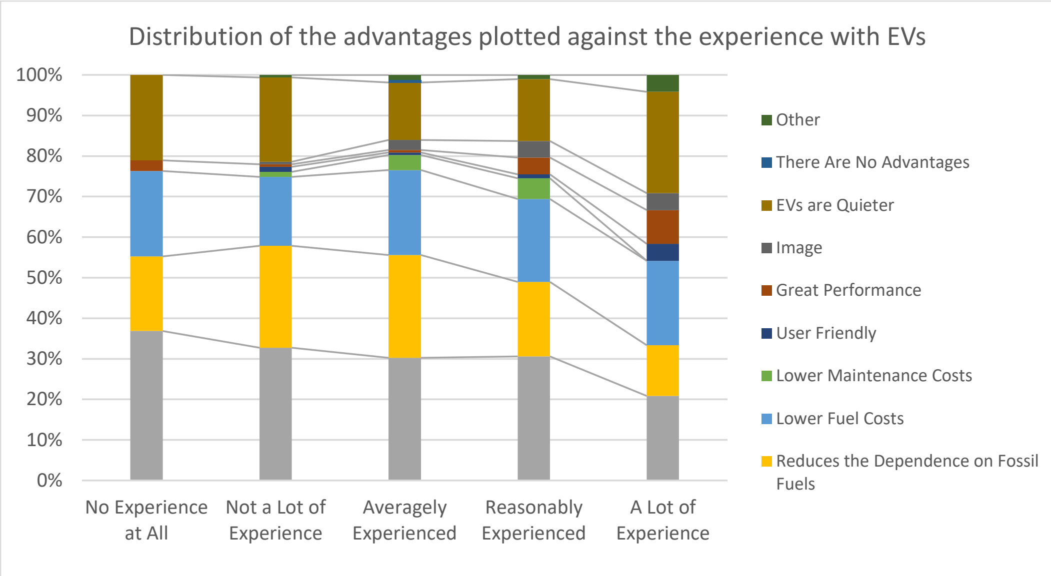

Figure 4.3: Distribution of the advantages, named by the respondents, plotted against the experience they think they have with EVs.

the *user friendliness* and *lower maintenance costs*. Therefore, a decreases in the percentage of participants that mention the advantage of *less* CO_2 *emissions*, is established.

For the graph with the comparison of the disadvantages in Figure 4.4, again differences between people with no experience and a lot of experience can be perceived. In this case it can be seen that *the charging time* becomes a more essential disadvantage. It has almost doubled in importance compared to people who have no experience at all. A logical explanation for this is that people have now experienced charging and its inconveniences. For the *purchase price* it is actually the other way around, it becomes less imperative when people gain experience with EVs. A reason for this can potentially be explained by income again. People with more experience have a higher income and can therefore afford more expensive cars, see also Appendix I, Figure I.3. It could also be that when people gain experience with EVs they actually also value and appreciate these vehicles a bit more, thus implying that they believe the cars are worthy of the higher purchase price.

4.2.3 Reasons Against Purchasing an EV

One of the last questions asked in the questionnaire is about the main reason, respondents have, to not want to purchase an EV. Figure I.7 in Appendix I, shows the distribution of these main reasons. From the figure it becomes apparent that the reasons that are mentioned the most are; *the purchase price is too high* (52.8%), and *the driving range of the vehicle is limited* (23.9%).

Next, in Figure 4.5, the distribution is shown between lease and private car drivers for

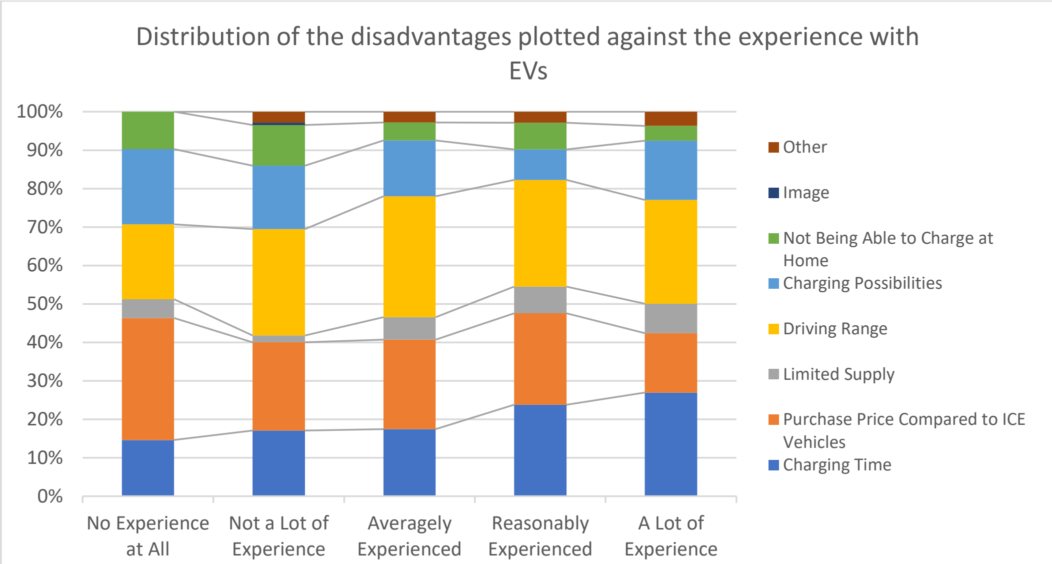

Figure 4.4: Distribution of the disadvantages, named by the respondents, plotted against the experience they think they have with EVs.

this question. The difference in perspective between company car owners and private car owners is especially striking when looking at reasons; *EVs are too expensive*, and *an EV is too much of a hassle*. This divergence can however be explained logically. Things that can be described as 'too much of a hassle' regarding EVs are usually things like; maintenance, battery changes, resale values, and other new features of electric cars. In the case of lease drivers, they do not need to worry about any of this, since the company pays for all of it, and it is all arranged by the lease company. The same cannot be said for private car owners, they have to consider all these things when purchasing an EV, which makes it more complicated and expensive for this group to own an EV. The same goes for the purchase price being too high. Private car owners have to pay for everything themselves and thus spending an extra €10,000 on a new car is likely unaffordable to most. This is not an issue for lease car drivers, since they do not have to pay for the car (or only a small amount), and they actually have to pay less in additional tax liabilities in comparison to leasing gasoline cars. This, and the exemption from road taxes for EVs, might actually make driving an EV cheaper for lease car drivers than driving a gasoline car. A closer look at the actual costs and savings for both categories will be taken in Chapter 5.

The variation between the other reasons is mostly equal, except for *there are not enough public charging stations*. This particular reason is mentioned slightly more by lease car drivers. As already mentioned before, this can probably be explained by the fact that lease car drivers have to drive more regularly during the day when other people are at the office, this makes the amount of charge stations available a more critical reason. Normally people are at the office and can then charge their car. Lease drivers travel more during the (working)

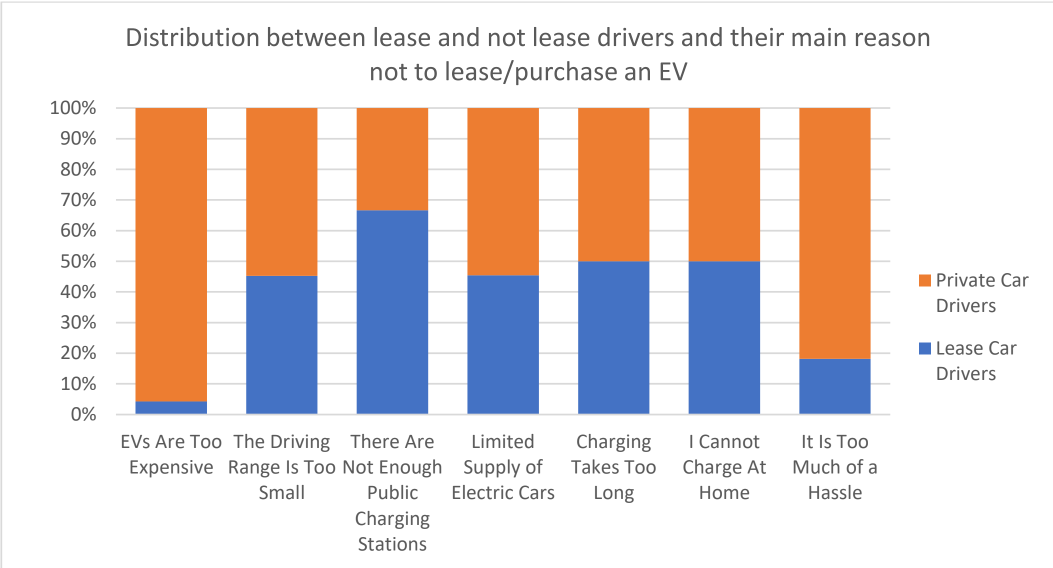

Figure 4.5: Distribution between the lease and private car drivers and their main reason not to lease/purchase an EV.

days and thus need to charge as they go since they do not have long hours at the office to charge, thus increasing the importance of the availability of charging stations (on the road).

Next, the answers shown in Figure I.7 of Appendix I were cross-referenced with the answers shown in I.6 of Appendix I. At the beginning of the questionnaire respondents were asked to indicate what they believe are the disadvantage of EVs (Figure I.6). They could select a maximum of three reasons. As mentioned, at the end of the questionnaire they had to indicate what their main reason was not to purchase/lease an EV (Figure I.7). By cross-referencing these answers it was possible to see whether or not the main reasoning behind not purchasing/leasing an EV was also given as an disadvantage of EVs (in general) at the start of the questionnaire. Results of this comparison are shown in Figure 4.6. Since respondents could indicate three disadvantages at the start, it was expected that their main reasoning behind not purchasing/leasing an EV would also have been mentioned as a general disadvantage of EVs. However, it turned out that this was not the case. From Figure 4.6 it can be seen that only about 84% of the respondents, that indicated that their main reason for not leasing/purchasing an EV was the high purchase price, had actually also mentioned that the high purchase price is a disadvantages of EVs. The same goes for all the reasons; they are more often mentioned as the main reason for not driving an EV then that they were seen as a disadvantage of EVs. Only the *limited driving range* was indicated as a disadvantage by all respondents that specified that this was their main reason not to drive an EV.

As was already viewed in Figure 4.5, the fact that EVs are more expensive is not one of the main reasons why lease drivers are not driving electrically. From this figure it can be seen

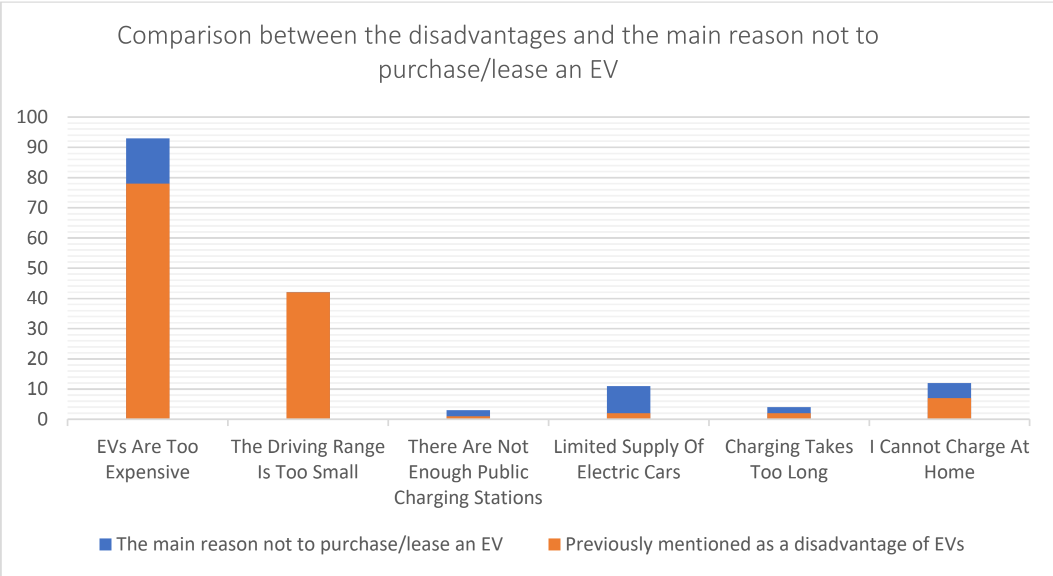

Figure 4.6: Comparison between disadvantages mentioned and the main reason for people not to purchase/lease an EV.

that a combination of the driving range and the amount of charging stations available are indicated as the most important reasons not the lease an EV. The lease drivers, who signed their lease contract less than 2 years ago, were asked why they did not opt for an EV at the time. Most of them replied that they could not choose an EV, because they were not available, or outside of their price level. Other reasons given are in accordance with the results shown in Figure 4.5. More on this can also be found in Section 4.2.5.

4.2.3.1 Purchase Costs of an EV

Since it was expected that a lot of people, especially from the private car drivers category, would mention that a large barrier for them is the high purchase price of EVs compared to gasoline cars, it was asked how much they expect to spend when purchasing a new car. The resulting answers from the question are shown in Table 4.3. The third column in the table shows how many respondents said that the high purchase price is the main reason not to purchase an EV. The last column gives the percentage of respondents who indicated that EVs were too expensive compared to the total respondents for that price level.

When comparing Table 4.3 with Table I.1 from Appendix I, it can be seen that for most people (92) the purchase price of EVs (starting from roughly €22,000) is too high. Here it has to be mentioned that even though the questionnaire specified that a second hand car should not be considered for the 'new car' budget, some of the respondents most likely did, since it is quite difficult to purchase a new car for less than €10,000. For the 28 respondents who want to spend between €20,000 and €30,000 it is already possible to purchase an electric car, albeit a smaller type with a smaller range. Table 4.3 also shows that there are

16 respondents who are willing to spend €30,000 or more. This specific group has a lot of options regarding the purchase of an EV (keep in mind that the table provided in the Appendix is just an indication and is not even nearly complete). From these 16 respondents the third column in Table 4.3 shows that 9 indicated that they feel that the purchase price of an EV being too high was their main reason not to purchase an EV. However, the table in the appendix indicates quite the contrary, they can afford an EV with the budget set for buying a new car.

Table 4.3: Overview of the amount of money people are willing to spend when purchasing a new car and the number of people who indicated that their main reason for not buying an EV is that it is too expensive

	Number of people	**Mentioned 'too expensive' as the main reason not to purchase an EV**	**Percentage**
< **€10,000**	40	35	87.5%
€10,000 - €15,000	36	25	69.4%
€15,000 - €20,000	16	9	56.3%
€20,000 - €25,000	19	8	42.1%
€25,000 - €30,000	9	3	33.3%
€30,000 - €35,000	6	4	66.7%
€35,000 - €40,000	4	1	25.0%
€40,000 - €45,000	5	4	80.0%
> **€50,000**	1	0	0.0%

4.2.4 Company Measurements to Stimulate Electric Driving

For this situation a breakdown was made between the two categories (lease/private car drivers) in order to better distinguish the needs and wants for each category. Also analyzed is the differentiation between the influence of the measures for the different positions within the company.

When looking at both boxplots, Figure I.8 and Figure I.9 in Appendix I, for the potential measures TUI can take to encourage electric driving, it can be concluded that most of the proposed methods can have a positive effect on the decision to switch to an EV, since these score an average of 2.5 or higher on a 4 point Likert scale ranging from 'No influence at all' to 'A lot of influence'. It has to be noted that for each category the proposed measures differ slightly, since the lease drivers already have some privileges that are now proposed to private car owners.

4.2.4.1 Private Car Driver

In Figure I.8 in Appendix I the boxplot is shown that indicates the effect the potential measures have on the willingness, of the private car owners, to transition to a zero-emissions vehicle. The plot shows the range within which the answers are given, and the X indicates the average results of each measure.

Surprisingly, the measure on *informing people on electric cars* scores the lowest, indicating that it will only have a little influence on the decision to transition towards an EV. This is unexpected since the papers studied during the literature study showed that after receiving more information on EVs, and experiencing them, people tend to get more positive ([28], [80]). Perhaps this measure would be received more positive when it had been made more obvious that it would not just be receiving information, but also testing an EV. From the boxplot it also becomes clear that the proposals to acquire a *charging station at home, being able to charge for free at work*, and *a doubling of the travel allowance per kilometer* score the highest, indicating that these will exert the most positive influence. Surprisingly, the measure of gifting people a €2,500 benefit scores lower than expected. It was expected to score higher than, for example, getting a free *charging station at home*, since the cost of buying and installing a charging station are lower than €2,500. This difference can probably be explained by the fact that the respondents believe that the procurement and installment of a charging station are more expensive than €2,500. It could also be that people expect they still have to pay (income) taxes over this €2,500 and that they will then end up with less that what is needed for the charging station. Additionally, it could also be related to convenience. If the company decides to place the charging station then the employees do not have to decide on which charging station, from what company, etc. It is easier when all these things are arranged by someone else (here: the company).

Figure 4.7 shows how participants score the potential measures based on their yearly income. For the income group €72,000 there was only one respondent, and it could therefore be discarded. The income group of more than €72,000 had two respondents, it is thus still displayed in the figure, but the group is too small, compared to the other groups, to draw any conclusions based on their answers.

From the figure it can be concluded that the lower income groups score the potential measurements at roughly the same level. It is interesting to note that the group with an income of €54,000 are less positive regarding all measures compared to the lower income groups. A reason for this could be that most measures are of a financial nature which is more appealing to people with a lower income who might not be able to afford to buy their own charging station, for example.

In Appendix I, Figure I.10, a similar graph is shown as the one depicted in Figure 4.7, however now the comparison is made based on the position of the participants within the company. For the most part the scores are similar for the managers and employees, but for three measures (*parking spot, information on EVs*, and *a subsidy of €2,500*) the scores differ slightly. For the contribution of €2,500 this can be due to the fact that managers usually earn more money than the employees and they therefore do not need this subsidy as much (see also Figure I.4 in Appendix I). For the other two measures no real explanation can be found within the scope of this survey.

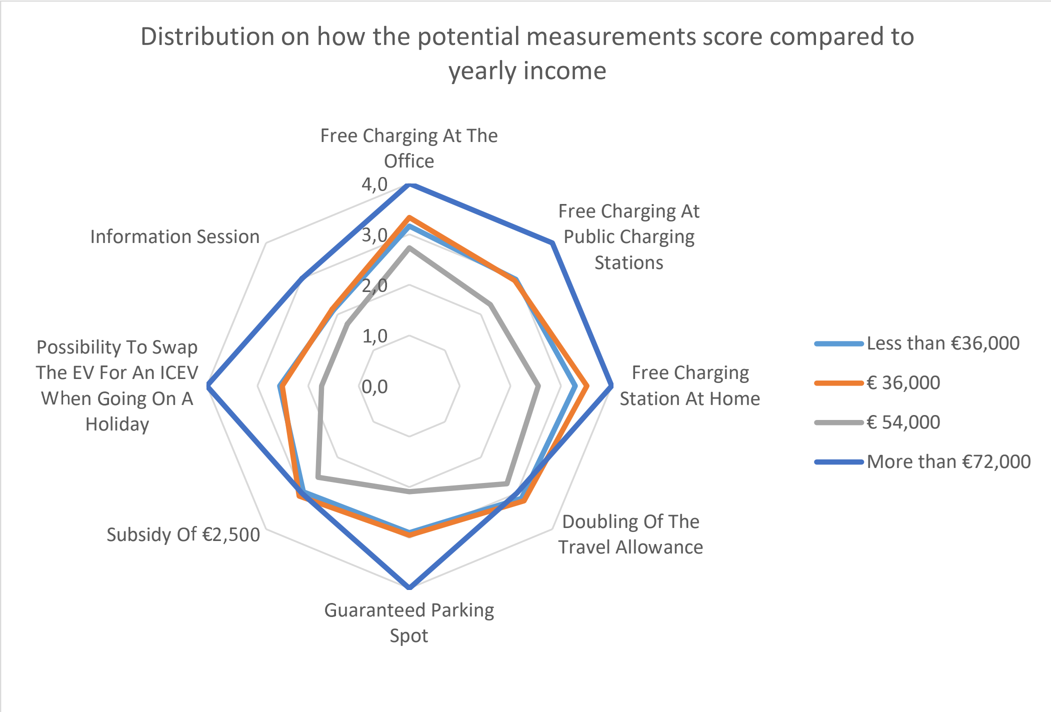

Figure 4.7: Distribution on how the potential measurements, that can be taken by the company, score compared to the yearly income of the private car drivers.

Participants also had the possibility to give their own suggestions on what measures might prove fruitful, these will be examined in Paragraph 4.3.

4.2.4.2 Lease Car Drivers

In Figure I.9 in Appendix I, the boxplot is shown with the scores for the potential measures that can be taken for lease drivers to transition to EVs. Just as for the private car drivers, the X again indicates the average score for that particular measure. Here the highest scoring measures are; *receiving a charging station (for free) at home, being compensate for the additional leasing costs of the EV*, and *obtaining a €2,500 subsidy*.

Noteworthy is that obtaining a one-time-only *compensation of €2,500* is rated as having less influence compared to *receiving a charging station at home*. Here it was again expected that participants would rate this measure higher for the same reason described in the previous section. The same explanation, as was given in the previous section, on this different expectation is also applicable to the company car drivers. Furthermore, as expected, the measure to compensate the difference of the EV lease price compared to a regular gasoline car scores high. This was expected since most people do not really mind driving electrically as long as they do not have to pay more for it than they currently do.

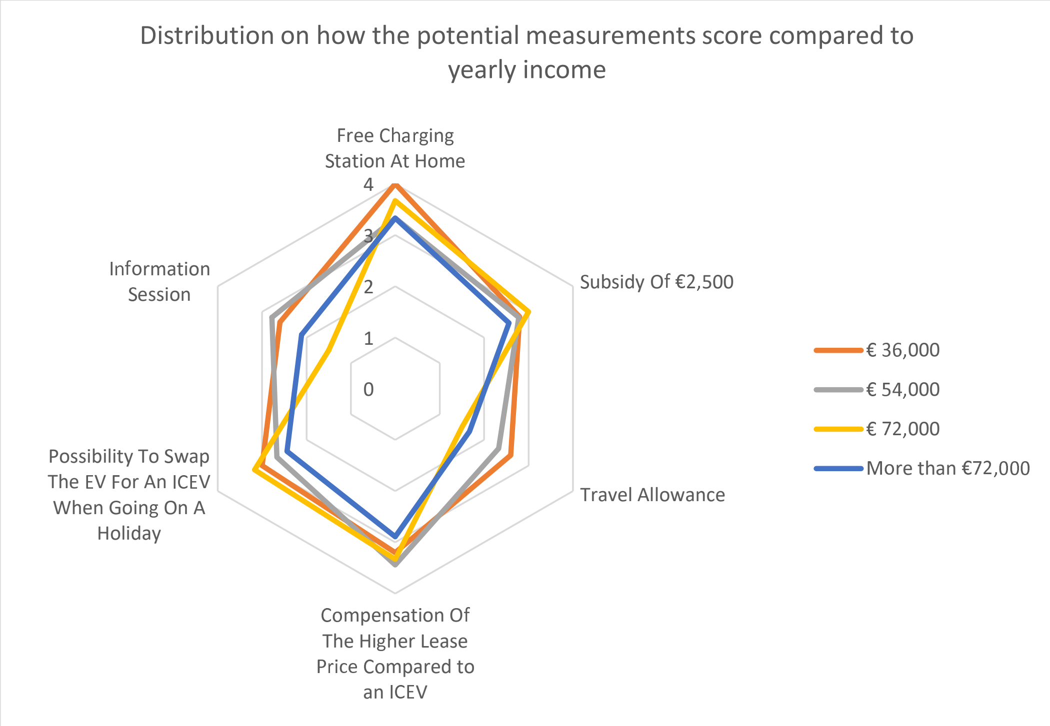

Figure 4.8: Distribution of the influence of the potential measures the company can take to stimulate the transition towards EVs compared to the yearly income of the lease car drivers

The scatter plot shown in Figure 4.8 indicates how much influence the lease car drives feel that the proposed measures will have on their willingness to transition to an EV, distributed to each income group. The results of the lowest income group are left out of the plot due to the fact that there was only one respondent in this group. In general it can be noticed that all measurements were scored similarly for all income groups. Exceptions to this are; *receiving information on EVs* and *receiving a travel allowance per kilometer driven*. In both cases the higher income groups rate these measures as having less influence. However, this does not immediately imply that higher incomes do not need the travel allowance because of their higher income, since they do rate other measures, like the one-time-only contribution of €2,500, similar to the other income groups.

For the lease car drivers a plot is made for the comparison between positions as well. The plot can be found in Figure I.11 of Appendix I. When comparing the answers given by the managers and the employees it can again be seen that they are similar for most proposed measures. Only for *travel allowance* and *information session* do they differ. In both cases the managers believed these measures to be of lesser influence. On the difference in score for the *information session* no assumption can be made with the results acquired through this survey. For the travel allowance the difference can again be attributed to the difference in income. For the plot in Figure I.11 the group of board members is sufficiently large and can be considered as well. Their answers were relatively similar, however, they attach more value to *informative sessions* and *being able to switch your EV for another car when going on vacation*. The first difference might be attributed to their position. They may feel very strongly about informing their employees on the advantages of EVs to persuade them to drive electrically. For the second measure, it is probably just a personal preference, since this particular group is smaller, one very positive (or negative) preference has more weight compared to the larger groups of the other functions. The last noticeable difference is that board members value the compensation of €2,500 as being of less influence. This could again be explained by the fact that their income is higher and they themselves do not need this compensation in order to be able to afford an EV.

Participants could again share their suggestions for measurements that can be taken. These will be examined in Paragraph 4.3.

4.2.5 Expecting to Drive Electric Within 2 Years

For one of the closing questions the participants were asked whether or not they will be driving an EV within two years from now. Two graphs were generated with answers to this question. The first one, shown in Figure 4.9 shows the answers separated for lease car drivers and private car drivers. The second is a comparison based on income and is shown in Figure 4.10.

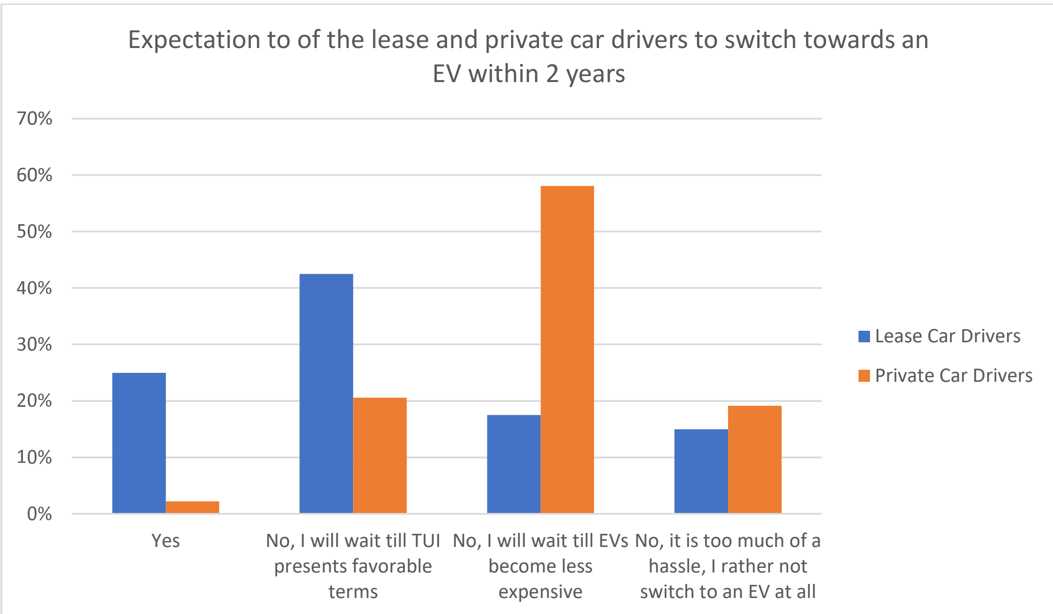

Figure 4.9: The expectations of the lease drivers and the private car drivers to switch towards driving electrically within 2 years.

In accordance with the results already presented in Figure 4.5, the lease car drivers are more prone to switch to EVs in the near future. It can also be noted that the lease car drivers think they benefit more from the measures proposed by TUI in contrast to the non-lease drivers. The non-lease drivers rather wait till the EVs become less expensive. With 58% this is thrice the amount of lease car drivers that chose this option. This noteworthy difference can be attributed to the fact that there are more benefits to leasing an EV (e.g. lower additional tax liabilities) and it is also proportionally not that much more expensive compared to having to lease an ICEV.

Figure 4.10 compares the answers of the question, if people see themselves driving electrically within 2 years, to the income of the respondents. From this it can be seen that the higher incomes are more inclined to drive an EV. A logic explanation for this is the fact that they earn more money and can thus afford an EV more easily, but another reason is that most of the people falling into the higher income categories are also lease drivers, who already are more prone to opt for an EV. This last explanation is confirmed by Figure I.12 in Appendix I.

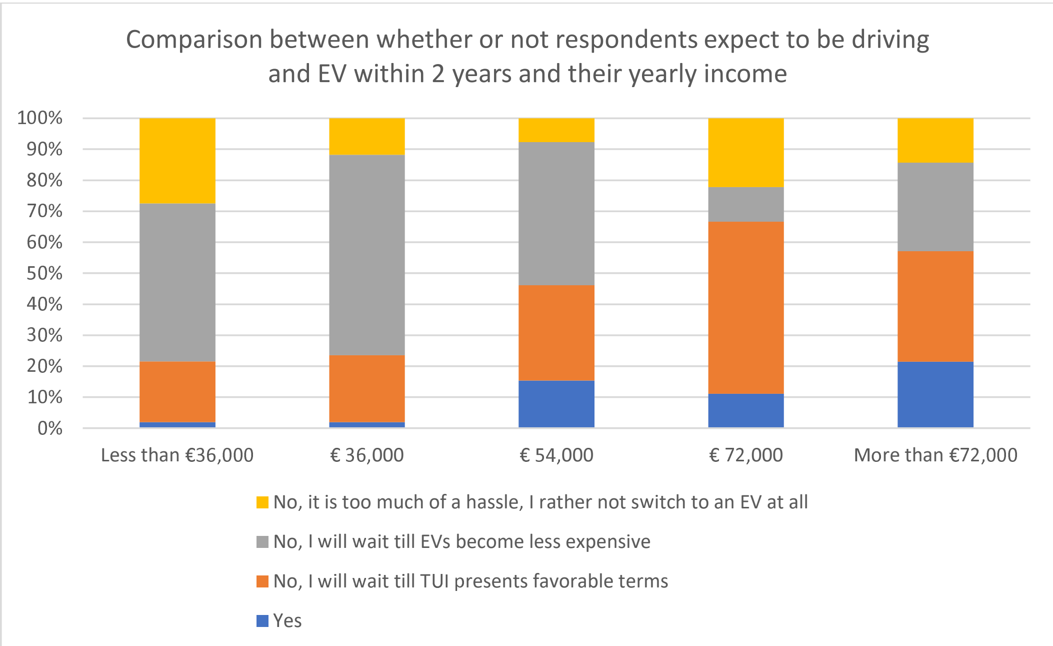

Figure 4.10: Comparison between whether or not, and why not, respondents expect to be driving an EV within 2 years and their yearly income.

Unfortunately it also becomes visible that the respondents from the lower income groups would rather wait for the EVs to become cheaper, then that they wait for TUI to implement favorable terms. This is considered as unfortunate because most of the people who fall under these income groups drive their own cars to work, implying that it is going to be cumbersome to get these people to transition towards electric cars.

4.3 Analysis Open-Ended Questions

As mentioned previously, the questionnaire had 2 open-ended questions. In the first, the private car drivers could provide suggestions for measurements TUI can take to encourage electric driving, and thus reduce the CO_2 emissions. In the other question the same thing was asked of the lease car drivers. A complete list of answers, for both categories, is provided in Appendix I.3. Below, in Section 4.3.1 and Section 4.3.2, an overview of the answers given, sorted into a couple of categories, can be found.

4.3.1 Private Car Drivers

Out of the 136 participants that drive their own car to work 76 filled out this question. Out of these 76 answers, 68 were found useful. The other 8 reactions were either completely useless; *You cannot force people to buy an electric vehicle*, or not something TUI can actually change; *Lower the purchase price, extend the driving range of an EV*. The other feedback can be spread across the categories indicated below;

- **(private) lease** (29x)
  Respondents mentioned making (private) lease available to non-lease drivers who want to drive electrically. Also mentioned was driving in a car with the logo and name of the company on it to lower the lease price.
- **Costs** (18x)
  Subjects indicated ways to lower the purchase costs for them, e.g. a higher financial contribution from the company, or higher travel allowance when driving electrically. Other suggestion were related to an increase in salary.
- **Providing (more) information** (7x)
  Respondents pointed out that the company should give more information on the advantages of electric driving, but also on the necessity of it.
- **Availability** (5x)
  Here respondents mentioned that the company should provide some electric cars for its employees to test.
- **Electrifying company cars** (3x)
  Respondents also suggested to make all pool cars electric and to compel the lease drivers to drive electrically.
- **Other**
  Here suggestions were given that do not fall under either of the categories mentioned, e.g. stimulating employees to go travel to work by train, investing in a solar- or windfarm, or shifting towards hydrogen cars instead of electric cars.

The biggest category of suggestions is to make (private) lease available to all who want to drive electrically. Even though it was made a separate category, it can be linked to the category costs, since it is currently a lot more economical to lease an EV than to have to purchase one. It is not surprising to see that most suggestions from private car drivers are regarding lowering the costs to purchase/drive an EV, since Figure 4.6 already showed that the purchase price is the main barrier in transitioning to zero-emissions vehicles for this group.

4.3.2 Lease Car Drivers

Out of the 40 participants that drive a lease car, 30 gave a suggestion regarding measurements the company can take to stimulate lease car drivers to drive electrically. Out of these 30 there were 2 people who indicated that they already drive an electric car. The other feedback was again spread across the categories illustrated below;

- **Costs of leasing** (10x)
  Respondents indicated that people that opt for an EV should get some discount on their personal contribution. It was also mentioned that the policy regarding the differentiation of the lease levels (given in Table 3.3) needs to become more flexible.
- **Proactive policy regarding EVs** (8x)
  The lease drivers also mentioned that more information on the benefits of electric driving needs to be communicated. More importantly, they suggested that more EVs need to be incorporated into the total (lease) car selection list and that the company needs to, proactively, inform the lease drivers on their electric options well before their current contract expires.
- **More charging stations** (5x)
  Here the respondents indicated that more charging stations need to be provided, both at home and around the offices.
- **Possibility to change the current lease contract** (2x)
  Respondents pointed out that lease drivers who want to switch towards an EV should get the opportunity, without having to pay a fine for terminating their current lease agreement.
- **Other**
  Offering polluting cars as lease options, stimulate working at home, and shift to hydrogen vehicles.

The biggest category is related to the costs of leasing. People feel like they should be compensated in some way when opting to drive electrically. Others feel that all lease drivers should be able to choose an EV even if that car is outside their indicated lease level. Currently there are multiple price levels for lease drivers, higher levels can choose more expensive cars and have to pay a lower personal contribution. Due to this policy electric cars are only sparsely offered to people who fall into the lower lease levels, which respondents would like to see changed.

4.4 Conclusion

Back in Section 3.1.1 four objectives were determined for this questionnaire. With the help of these objectives it is now possible to answer the, in Section 1.3.1 determined research questions ‘What barriers do employees encounter before transitioning to zero-emission vehicles, and how can the company aid in overcoming these?’.

From the questionnaire it was found that the most important barriers (scoring 4.0 or higher on a 5 point Likert scale) were; *purchase price*, *driving range*, *possibilities for charging (home, office and public)*. However, in Section 4.2.1 it was also devised that the barriers differ with experience, income and driver category. Through the questionnaire it was also determined that all suggested measures can have a positive effect on encouraging employees to transition to EVs. The measures that were seen as having the most positive impact (scoring a 3.0 or higher on a 4 point Likert scale) were; *free charging at the office*, *free charging station at home*, and *doubling of the travel allowance* for private car drivers and *free charging station at home* and *compensation in the higher lease price* for company car drivers.

Based on the analysis done in this chapter it can be concluded that there indeed is a significant difference in the answers given by the private car owners and the lease drivers. This difference was mainly found in the answers related to the potential measures the company can take to stimulate the use of EVs, but also in the question about which barriers people were expected to encounter. As for the barriers both categories encounter when transitioning towards zero emission vehicles, the answers did not really differ too much (see again Figure I.1). The main differences could be found in the barriers; *purchase price*, *fuel costs* and *maintenance costs*. Lease drivers attach less importance to these barriers because they are not responsible for these costs since the company pays for it. On the other hand, it was determined that lease drivers are more concerned about the driving range of the vehicles and the charging possibilities. Generally speaking, the same barriers were mentioned as done in previous research. A difference between this survey and previously done research was mainly found in the effect a informative session was expected to have on respondents attitude towards EVs. When looking into the measures TUI can take to overcome the barriers it was determined that both categories value a financial contribution, of some sort, from the company. The lease car drivers valued *receiving a free charging station at home* slightly higher in comparison to private car owners. Lastly, it was found that 25% of the lease drivers, and only 2% of the private car owners, expect to drive electrically within two years. Another 43% of the lease drivers and 21% of the private car owners could be persuaded to drive electrically within two years, if TUI presents favorable terms. 18% of the lease drivers and 58% of the private car owners would rather wait until the EVs become less expensive. About 15% of the lease drivers and 19% of the private car owners admitted that electric cars are too much of a hassle and that they would rather not make the transition at all. These percentages can now be used to create multiple CO_2 reduction scenarios in Chapter 5.1.

Chapter 5

Car Fleet Composition

The aim of this chapter is to determine three different possible reduction scenarios for the company. For each scenario it is given what the potential CO_2 reduction is, and how many people (from which category), need to switch to EVs. Additionally, it is determined what the costs and benefits are in each scenario for both the company and its employees. For the employees a distinction is made between the lease car drivers and the private car drivers. Lastly, a short conclusion is given that presents the costs and benefits for the company in all scenarios.

5.1 CO_2 Reduction Scenarios

In this section the three different reduction scenarios will be discussed. As was already mentioned in Chapter 3.2.2, the scenarios are based on the answers given to the last question of the questionnaire. To determine the amount of people willing to switch towards EVs, the percentages given in Table 3.6 had to be converted to number of people. In order to do this it was assumed, as was discussed in Section 4.1, that the respondents of the questionnaire represent the entire population. In this way the percentages from Table 3.6 could be multiplied with the people approached for the questionnaire to find how many are willing to transition, per category. With these numbers it was then possible to determine the CO_2 reduction for each scenario.

An overview of the reductions that can be achieved per scenario and the amount of people that need to switch per driver category are indicated in Table 5.1 below. The following three subsections provide some more detailed information on the scenarios described in the table.

5.1.1 Worst Case

For the worst case scenario it was decided that no one is forced to switch to an EV and only the people who indicated to be willing to switch, within 2 years, were taken into account. For the lease drivers 25% indicated to be willing to transition and for the private car owners only 2%. This resulted in 27 lease drivers and 9 private car owners that were willing to

Table 5.1: Overview of how the scenarios are composed and by how much the emissions can be reduced.

	Number of transitioning drivers		Emissions saved (in [ton CO_2/year]) by		Total reduction in [ton CO_2/year] and in [%]	
	Lease	**Private**	**Lease**	**Private**	**Amount**	**Percentage**
Worst Case	27	9	43.1	19.1	62.2	3.3
Medium Case	74 107	105 105	118.104 170.76	222.81 222.81	340.924 393.57	18.2 21.0
Best Case	107	238	170.76	505.04	675.8	36.0

make the change to EVs. Using the tables given in Section 3.2.1.3 (Table 3.4 and 3.5) made it possible to determine the amount of CO_2 emissions that will be reduced if these people stopped driving their gasoline or diesel car. For this worst case scenario it resulted in a reduction of 62.2 ton CO_2 per year, which is a reduction of 3.3%.

5.1.2 Medium Case

The basis of this scenario was again provided by the last question of the survey. This time, however, also the respondents that indicated they were willing to make the transition when TUI provides favorable terms were taken into account. It was found that a total of 43% of the lease drivers and 21% of the private car owners were willing when TUI provides favorable terms. This results in an additional 143 people driving electrically and a supplementary CO_2 reduction of 278.7 ton/year. Adding this to the reduction in the worst case scenario results in 179 employees driving electrically and a total CO_2 reduction of 340.9 ton per year which is a 18.2% reduction.

For this case, however, it can also be taken into account that all the lease drivers will be forced to switch to EVs. Forcing all lease drivers to switch to an electric vehicle results in a reduction of 170.76 ton CO_2 per year. Which, on its own, is already a reduction of 9.1%. If this were also to be taken into account for this scenario, the total reduction in the medium case scenario could amount to 21.0%, which is a reduction of roughly 394 tons of CO_2 a year.

5.1.3 Best Case

The best case scenario builds on the assumption that all lease car drivers switch to EVs. Additionally, half of the respondents that indicated to wait until EVs become less expensive is taken into account. Since 29% of the private car drivers indicated they wanted to wait, an additional 133 people will start to drive electrically in this scenario. Resulting in a total reduction of 675.8 ton CO_2 per year, which is equal to 36.0%.

For this best case scenario it was purposefully decided not to make everyone switch to EVs. First of all, it would not be realistic to expect all of the private car owners to start driving electrically. Secondly, it would also not be realistic to expect this all to happen before the end of 2020 since a lot of additional cost accompany the transition of all its employees.

5.2 Costs and Benefits of Electrifying the Car Fleet

In this section the costs and benefits associated with the transition to zero-emission vehicles are thoroughly discussed. In Section 3.2.3 it was already briefly indicated which costs and benefits accompany the transition towards EVs for both the company and its employees. Here, in the next few sections, monetary values are discussed. Firstly, a closer look is taken at the company, then the private car drivers are analyzed, and lastly, the lease car drivers. For all of the calculations and assumptions in this chapter, the medium case scenario was taken into account. In this scenario a 21.0% CO_2 reduction is obtained, 107 lease drivers, and 105 private car owners will switch to EVs. At the end of the each subsection an overview is given of all the costs and benefits related to this scenario, for that specific group (company, employee). At the end of the chapter in Table 5.9 and Table 5.8 and an overview is given for all costs and benefits in each scenario.

5.2.1 Company Costs

In Section 3.2.3.1 it was determined that there were three cost categories for the company, namely; costs related to terminating lease contracts early, costs related to the implementation of stimulating measures, and costs related to higher monthly lease fees.

Starting with the first point. As mentioned in Section 3.2.1.2 all of the company cars are leased through the lease company Arval. On their website a complete overview is given on all the cars that are leased, their specifications, theirs costs, and all other relevant information. Using all of the information provided by Arval made it possible to calculate what the average cost per car will be when prematurely terminating the lease contract. In Appendix H.1 the process of calculating the costs is discussed in more detail and an overview is given in Table H.1 and H.2. The last column of Table H.2 in Appendix H.1 shows the average amount that has to be paid per car. Adding up all these values gives a total of roughly €829,275 that would have to be paid if all the lease car contracts would be terminated before the predetermined end date.

Next an overview is given of all the costs associated with the measures, proposed in the questionnaire, that can be taken to stimulate people to drive electrically. A division was made between lease car drivers and private car owners. This was done because the suggested measures differ for each group.

5.2.1.1 Lease Car Drivers

In the survey there were six measures proposed that the company can take to stimulate its lease car drivers to transition to zero-emissions vehicles. Below the six measures are given along with some supplementary information and an estimation of the costs associated with the measure.

- **Receiving a free charging station at home**
  Where possible TUI can provide charging stations for its employees. The costs of the placement and installment of these charging stations varies, depending on what type of charging stations needs to be placed. Fast charges, duo chargers and smart chargers are, for example, more expensive than a regular charging station. According to [78] buying and installing a charging station can vary from €600 - €2,000.

- **Receiving a compensation in the higher lease price of EVs**
  In Appendix H.3 it was assumed that the company will pay, on average, €63 per month per lease driver if this measure is applied. This will result in an additional €756 per driver, per year. The aforementioned amount can only be seen as realistic when the more luxurious and expensive cars are exempted.

- **Possibility to swap the EV for an ICEV when going on a holiday**
  There are lease companies that facilitate the swapping of an EV for an ICEV, for example Athlon. Depending on the amount of days, the car type and the mileage needed during the holiday, Athlon offers three bundles of respectively €50, €100 and €150 per month. If the bundle is not used, or there is a certain amount remaining at the end of the lease term, then this surplus will be refunded [6].

- **Providing an information session on EVs**
  Prices for this particular measures can vary a lot. If a professional speaker is hired to do this then prices can vary from as little as €1,000 up to €15,000. So an average amount of €8,000 is assumed [70].

- **Receiving a subsidy of €2,500**
  In the medium case scenario all the 107 lease drivers that do not currently drive electrically are expected to switch to an EV. This then results in a total cost item for this measure of €267,500.

- **Receiving a travel allowance of €0.09 per km**
  As was given in Chapter 1.5, Table 3.4 the total amount of km driven by all lease car drivers is roughly 1,744,249.50 km in total per year. Compensating this would result in accumulative expense of €156,983.

A summation of the costs per measure for the lease car drivers, and in total, is given in Table 5.2 below. In the table it is assumed that all lease drivers switch to EVs. In this way it is possible to give an overview of the maximum costs related to the transition for this group.

From the table it can be seen that if TUI were to implement all of these suggested measures at once, than an one-off investment of €339,700 - €489,500 is required. There are also yearly costs associated with the transition, these amount to €302,075 - €430,475.

Table 5.2: Overview of the average and total costs for the proposed measures to stimulate the lease car drivers to transition towards EVs.

Measurement	Costs [€]	Number	Total costs [€]
Free charging station at home (procurement and installation)	600 - 2,000	107	64,200 - 214,000
Compensation in higher monthly lease price	756	107	80,892 (per year)
Subsidy	2,500	107	267,500
Swapping when going on a holiday	50 - 150 (per month)	107	64,200 - 192,600 (per year)
Information session	8,000	1	8,000
Travel allowance	0.09/km	1,744,249 km	156,983 (per year)

5.2.1.2 Private Car Drivers

For the private car drivers there were eight measures proposed to stimulate the transition to zero-emissions vehicles. Some of these measures are the same as the ones presented for the lease car drivers, so the costs (per driver) are also equal to what was presented in the previous section. For these specific measures no additional information is provided, only an overview of the costs for the private car drivers is given in Table 5.3. The eight proposed measures were:

- **Receiving a free charging station at home**
  The same estimation is used as was done for the lease drivers in the previous section. Though it was not explicitly mentioned that the company would not only pay for the installation and placement of the charging, but also for the cost of charging, it will still be assumed since charging at other locations is also free of charge. In Appendix H.5 it was calculated that the costs for charging at home are roughly €109 per year, per driver.

- **Being able to charge for free at the office**
  Charging at the office is cheaper than at public charging station, so its favourable for the company to provide enough charging stations for all of its employees that drive electrically. The price for charging is equal to the electricity price which comes down to either €0.064 or €0.12 per kWh. In Appendix H.5 it was calculated that, if all the charging is done at the office, the costs are roughly €273 per year, if the energy provided by the rooftop solar systems are optimally used.

- **Being able to charge for free at public charging stations**
  For public charging calculations were made in Appendix H.5 as well. Here is was assumed that the distribution between fast and regular charging is equal, resulting in a cost item of about €82 per driver per year.

- **A guaranteed parking spot near the office**
  This specific measures would not require an initial investment, albeit a policy change regarding parking might need to be implemented.

- **Receiving a subsidy of €2,500**
  In the medium case scenario 105 private car owners are expected to transition to EVs, thus this measures requires a total investment of €262,500, per year.

- **Receiving a doubling of the travel allowance**
  Using the average distance travelled per private car owner per year from Table 3.5, the increasing of the travel allowance from €0.09 to €0.18 per km would result in an additional cost item of €1,621 per driver per year.

- **Possibility to swap the EV for an ICEV when going on a holiday**
  Even though this measure was also proposed to lease car drivers, the actual implementation and thus the costs differ for this group. Since this group does not have a lease car which can be swapped, it is an option to provide a rental car for this group. The price for this was set to €1,655 per driver, per year. An overview of how this amount came to be and what is included can be found in Appendix H.4.

- **Providing an information session on EVs**
  Here no monetary value will be attributed to this measure, since that was already done in Section 5.2.1.1 for the lease drivers and they can all be informed in the same session.

Table 5.3: Overview of the average and total costs for the proposed measures to stimulate the private car drivers to transition towards EVs.

Measurement	**Costs [€]**	**Number**	**Total costs [€]**
Free charging station at home (procurement and installation)	600 - 2,000	105	63,000 - 210,000
Free charging at the office	205- 380	105	21,525 - 39,900
Doubling of the travel allowance	€0.09/km	1,891,501.5 km	170,235.14 (per year)
Free public charging	1,078 - 2,188	105	113,190 - 229,740 (per year)
Subsidy	2,500	105	262,500
Guaranteed parking spot	0	105	0
Swapping when going on a holiday	1,655	105	173,775 (per year)
Information session	8,000	1	8,000

In Appendix H.5 it was mentioned how the charging is estimated to be divided amongst these three options. In Table 5.3 the costs are shown for each way of charging (public, home and at the office). Adding all these costs results in a charging fee of €452 per private car owner, per year.

The last cost item for the company that was indicated in Chapter 3.2.3.1 were the higher monthly lease prices associated with EVs. Chapter 3.2.3.1 already indicated how this amount differs from the measure where the company might compensate for the extra personal contribution of the higher lease prices of EVs. This higher monthly lease price was found to be, on average, €162. In Appendix H.3 it was indicated how this additional lease price was calculated. This cost item will then amount to roughly €213,840 per year.

5.2.2 Company Benefits

Chapter 3.2.3.1 also mentioned six ways in which the can company benefit from the electrification of its car fleet. The monetary benefits can mainly be found by looking at the benefits stemming from electrifying the lease car fleet. The other two benefits, *reaching the CO_2 reduction target* and *positive advertisement* are harder to express in a monetary value. So, as was already mentioned, for the first benefit a scenario is analyzed where CO_2 emissions are taxed. To estimate the cost per ton of CO_2 a closer look is taken in to the current EU emission trading scheme (ETS). At the day of writing (October 26, 2019) the emissions were trading at €25.93 [63] per ton CO_2. Additionally, the Dutch government (recently) decided stricter measures regarding the taxation of CO_2 emissions are necessary to keep in line with the goals set during (and after) the Paris Agreement (2015). This stricter measures were presented in the Dutch climate agreement [69]. In this report it was decided that a supplementary carbon tax will be placed on industries in addition to this ETS. Starting from 2021 the (total) carbon tax is set to be €30 per ton CO_2. From 2021 onwards this amount rises to €150 per ton CO_2 (in a linear fashion) in 2030 [69]. An overview of the money saved, under the 21.0% reduction scenario (for 2020-2030) is given in Table 5.4. Even though such a carbon tax is not (yet) in place for all companies, but only for industries, it can still be used as an indicator on costs that can potentially be saved in the future. For the calculation of the total benefits (Table 5.5) the current value at which the emissions are trading (€25.93) was taken into account.

Table 5.4: Overview of the yearly benefits that can be saved on the carbon tax from 2020 tot 2030 (in the medium case scenario).

Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Savings	€10,206	€11,807	€17,055	€22,302	€27,550	€32,798
Year	**2026**	**2027**	**2028**	**2029**	**2030**	
Savings	€38,045	€43,293	€48,540	€53,788	€59,036	

As for the second benefit (*reaching the CO_2 reduction target*), no monetary value was assigned to this, since no accurate way could be found to calculate it.

Next, a closer look is taken at the MIA subsidy. As already mentioned in Chapter 3.2.3.1, the lease company has to apply for this subsidy. In doing so a savings of €2,700 per EV can be realized over the lease period of the car, usually four years. If all 107 non electric lease cars would be swapped for EVs, then a total savings of €288,900 can be obtained, which is €72,225 on a yearly basis. Additionally, the placement of charging stations, at the homes of the lease car drivers, also falls within the scope of the MIA. From this a supplementary benefit a value of roughly €135, per charging station, can be obtained.

Furthermore, the fuel costs will be lower for EVs. In Appendix H.6 a thorough analysis was done into the cost of charging an EV versus the cost of using gasoline. From this analysis it was determined that driving electrically can save the company up to €1,414 per lease driver, per year.

Lastly, the savings through the purchase and ownership taxes were examined. Using the average emissions of the lease car fleet (97.9 gram CO_2/km), that was calculated in Table 3.4, and the table provided by the 'Belastingdienst' in [11], an average BPM was found of €2,322 per car and thus a total savings of €248,454 over the entire lease car fleet. This comes down to a yearly savings of €62,114. As for the MRB, this particular tax is set based on the weight of the car and the fuel type. According to the "Centraal Bureau voor de Statistiek" (CBS) cars weigh, on average, 1,114 kg [14]. Using this number and the calculator found on the website of the 'Belastingdienst' [9] results in monthly tax of €43. So, up until 2024 (when the MRB tax rate is 0%) the company can save €55,212 per year for the entire lease car fleet.

In Table 5.5 an overview is given of the total costs and benefits for the company. For the costs a subdivision is made that shows what the costs were related tot the transition of the lease car drivers and which to the private car owners. an additional deviation shows which of the costs are related to the transition lease drivers and which to the private car owners. From this it can be concluded that 73% - 78% of the costs are associated with the transition of the lease drivers. This high share is mainly related to the high costs associated with prematurely terminating the lease contracts, which on its own it responsible for 46% - 55% of the total investment required. At the same time also most of the yearly benefits can be related to the lease drivers. Where the distribution between lease driver and private car owner is still roughly equal for the initial investment costs, this is absolutely not the case the yearly savings. About 98% of the yearly savings in this medium case scenario are related to the lease car drivers.

Table 5.5: Overview of the costs, benefits and results for the company when transitioning towards EVs (in the medium case scenario).

	Investment (one-off)		**Investment (yearly)**	
	minimum	**maximum**	**minimum**	**maximum**
Costs	**€1,494,475**	**€1,791,275**	**€907,385**	**€1,035,785**
- Lease	€1,164,975	€1,314,775	€515,915	€644,315
- Private	€329,500	€476,500	€391,470	€391,470
Benefits	**€28,620**	**€28,620**	**€351,055**	**€351,055**
- Lease	€14,445	€14,445	€345,277	€345,277
- Private	€14,175	€14,175	€5,778	€5,778
Result	**€1,466,332**	**€1,762,655**	**€556,330**	**€684,730**

Now that all costs and benefits for the company are discussed, a closer look can be taken at both the costs and the benefits for the employees. Again a distinction was made between the lease drivers and the private car owners.

5.2.3 Private Car Owners Costs

As previously determined in Chapter 3.2.3.2 the only cost associated with transitioning to EVs for private car owners stem from the higher purchase cost of the car itself. From the questionnaire it could be determined that on average people are willing to spend roughly €20,000 on a new car (see Table 4.3 in Chapter 4). Now, taking a closer look at Table 3.5 in Chapter 1.5 again, it can be determined that employees at Rijswijk drive on average 245 kilometer per week, for Enschede this is 186 km and for TUI Fly this is 563 km. From this it can be determined that for people working at the office (either Rijswijk or Enschede) it suffices to have an EV with a real-life driving range of 300 km. From Table I.1 in Appendix I it can be seen that, for example, the *Volkswagen ID.3* and the *Opel Corsa-e* meet this requirement. The costs of these car vary from €30,000 for the Volkswagen to €34,999 for the Opel. Thus determining that the additional costs for purchasing an EV are about €10,000 to €15,000. Of course there are also cars available that are less expensive and cars that are more expensive that were not included in Table I.1, hence an average of €12,500 is taken into account for this cost item.

5.2.4 Benefits for Private Car Owners

As benefits for private car owners, among others, the exemption from BPM and MRB when buying an EV were mentioned in Section 3.2.3.2. In Section 3.2.1.2 it was determined that, on average cars produce 117.8 gram of CO_2 per km. Using this and the table provided in [11] it was calculated that a little less than €4,929 has to be paid as BPM. As for the MRB, the same method was used as described in Section 5.2.2, resulting in a monthly tax of €43. This can result in a total savings of €2,967 per driver until 2026 when the MRB tax rate is 100% again [69]. A total savings, through both tax regulations, can be achieved of €7,896 over the lifetime of the car. Adding to this the government subsidy that is estimated to be €3,000 [68], starting from 2020, results in a total savings of roughly €10,896 when transitioning to an EV (in 2020). When transitioning later, this number is lower due to less years of profiting from the 0% MRB tax. However, transitioning later may also result in a lower initial purchase price of the EV, so these are all considerations that have to be taken into account.

Another benefit over the use of ICEVs is that the ‘fueling’ of the vehicle is cheaper when the vehicle has an electric drive train. In Appendix H.5 it was calculated that private car owners spend, on average, about €2,114 per year on gasoline. It was also calculated (in Section 5.2.1.2) that the company would have to pay about €452 per year if they were to pay for the charging of all the EVs of the private car owners. This same amount can be assumed as charging costs for the private car drivers themselves, resulting in a fuel cost savings of €1,662 per year. On the other hand, if TUI were to pay for the charging costs of the EVs of the private car drivers, then the private car drivers will even save €2,566 per year.

Lastly, there is also a benefit to be gained from the potential measures TUI might take. If all the proposed measures were implemented a one-off savings can be realized of a maximum of €4,500 (charging station and €2,500 subsidy). Then there are also measures that results in yearly savings. These amount to a total of €3,276 if the charging costs are left out. If the company decided to also pay for all of the charging of the private car owners, then an additional benefit of roughly €452 per year can be achieved, and thus a total yearly benefit of €3,728 for every private car owner.

In Table 5.6 all the costs and benefits for the private car drivers are summarised. From the table it can be concluded that, including all the proposed stimulating measures from TUI, private car drivers stand to gain €2,896 and an additional maximum of €5,842 per year.

Table 5.6: Overview of the costs, benefits and results for the private car owners when they transition towards EVs (in the medium case scenario).

	Investment	**Yearly costs**
Costs	€12,500	-
Benefits	€15,396	€5,842
Result	€2,896	€5,842

5.2.5 Lease Car Drivers Costs

Lease drivers hardly have any additional costs for choosing to lease an EV over an ICEV. One of the costs that do accompany this transition, is the fact that the own contribution might be higher since the lease price of the EV might be slightly higher. As was specified in Section 3.2.3.3, there are different categories of lease drivers and in each category one is allowed to lease up onto a certain amount see Table 3.3. If the lease price is higher, then the additional cost fall under the own contribution of the lease car driver. Under company costs it was already indicted what the costs are for the company if it decides to pay this contribution as well. If TUI were to decide not to implement this specific measure, then the lease car drivers will have to pay the additional costs of leasing an EV themselves. Depending on the lease car category and the type of car that is chosen, these additional costs result in, a maximum addition of €175 per month, which is €2,100 per year, per driver. In Section 5.2.1.1 it was calculated that, for the company, these costs amount to only €63. This difference can be explained by the fact that the €175 is a maximum amount each lease driver might have to pay, whereas the €63 is an average over all lease car drivers. In the last case it could be that some drivers keep the monthly lease well within their lease category, and only some go over, and even when they go over, it will not always be the maximum amount.

The other cost item that was specified for lease car drivers in Section 3.2.3.3 was the additional tax liability when the company decides to place and install a charging station at the homes of the lease car drivers. In Appendix H.7 it was calculated that this additional tax liability results in a maximum one-off cost item of €41.40. If a lease car driver falls within a lower tax bracket, then this cost item is slightly lower.

5.2.6 Benefits for Lease Car Drivers

One of the main benefits for the lease car drivers is the lower additional tax liability rate for EVs over ICEVs. Currently the tax rate for EVs is 4% whereas the rate for ICEVs is 22%. According to the climate agreement of June 2019 [69], this rate will slowly be raised from 2020 onwards, until it is at the same level as ICEVs (22% in 2026). In Table H.3 and H.4 in Appendix H.8 a comparison was made between the cost associated with this additional tax liability for both Vs and ICEVs. Assuming all lease car drivers transition in 2019, fall under the 38.10% bracket, and lease a car of, on average, €40,000, they were to pay €3,553 for an ICEV and €610 for an EV. This results in a yearly savings of €2,943.

When comparing the monetary benefits from leasing an EV over an ICEV described above, with the additional cost described in Section 5.2.5 above, it can be seen that, in most cases, the monetary benefits are higher than the costs associated with transitioning to an EV.

Other benefits for lease drivers come from the potential measures the company can take to stimulate the transition to zero-emissions vehicles. If the company were to implement all of the measures described in Section 5.2.1.1 a total one-off benefit of maximal €4,500 can be obtained for the lease car drivers. As for the yearly savings, these amount to a maximum of €5,321 per year. This is without compensation for the charging of the EV, since the company also paid for the fueling costs of the ICEVs and it can thus not be seen as a benefit of the EV over the ICEV.

Table 5.7 gives an overview of the total costs and benefits that accompany a transition to EVs for the lease car drivers. The last row of the table shows that lease drivers can gain a maximum of €4,459 and an additional €6,164 on yearly basis if TUI were to implement all of its proposed measures.

Table 5.7: Overview of the costs, benefits and results for the company car drivers when they transition towards EVs (in the medium case scenario).

	Investment	**Yearly costs**
Costs	€41.40	€2,100
Benefits	€4,500	€8,264
Result	€4,459	€6,164

5.3 Conclusion

From Table 5.6 and Table 5.7 it can be seen that both the private car owners and the lease car drivers stand to save (and gain) money when transitioning to an EV. It has to be taken in account though that these savings (and the costs for the company) were based on the fact that the company is going to implement all the potential measures that were suggested in the questionnaire. The total cost and savings for each group can thus differ based on which measures the company decides to implement, and which they will not.

Since the costs and benefits for the lease and private car drivers were on a per driver basis in Table 5.6 and Table 5.7, these stay the same for each of the three scenarios described in Chapter 5.1. The costs and benefits related to the company do change with each scenario since the costs and benefits are dependent on the amount of people transitioning to EVs. When more or less of its employees start to drive electrically the costs for the company will increase or decrease accordingly. Table 5.8 shows the one-off costs and benefits for all three scenarios. The last row of the table indicates the initial investment needed to accomplish the CO_2 reduction related to that specific scenario. Table 5.9, on the other hand, shows the yearly costs and benefits for the company associated with all three scenarios. Here the last row indicates the resulting yearly costs for the company. To find the values related to the best and worst case scenario, the same method was used as for the medium case scenario described in this chapter.

Table 5.8: Total one-off costs and benefits for the company in each of the scenarios.

Company			
	Worst case	**Medium case**	**Best case**
Minimum one-off costs	€328,857	€1,494,952	€1,906,775
Maximum one-off costs	€379,257	€1,791,275	€2,389,775
One-off savings	€4,860	€28,620	€46,575
Costs of the CO_2 reduction	€323,997 - €374,397	€1,466,332 - €1,762,655	€1,860,200 - €2,343,200

Table 5.9: Total yearly costs and benefits for the company in each of the scenarios.

Company			
	Worst case	**Medium case**	**Best case**
Minimum total yearly costs	€161,187	€907,385	€1,403,247
Maximum total yearly costs	€193,587	€1,035785	€1,531,647
Yearly monetary benefits	€87,621	€351,055	€358,372
Costs of the CO_2 reduction	€73,566 - €105,966	€556,330 - €684,730	€1,044,785 - €1,173,275

From Table 5.8 and Table 5.9 it can be seen that the increase in cost between the medium case and best case scenario is less than the increase between the worst and medium case.

This can be attributed to the fact that there is almost a sixfold increase in transitioning employees from the worst case to the medium case, whereas the increase from the medium to the best case is less than twofold. More transitioning employees relates to higher costs regarding both the proposed measures as well as the costs related to terminating the lease contracts prematurely and the higher costs for the new (EV) lease contracts. Another noteworthy thing that can be seen when looking at both tables is that the yearly savings only slightly increase when going from the medium case to the best case scenario. This can be explained by the fact that almost all of the company's yearly savings are related to the lease car drivers. This was proven in Section 5.2.2 were it was given that, in the medium case scenario, 98% of the yearly savings were related to the lease car drivers. In the best case scenario this is still 96% even though there was no increase in lease drivers between both scenarios, and a more than twofold increase in transitioning private car drivers.

Chapter 6

PV Analysis

The aim of this chapter is to present a thorough analysis on the possibility of a rooftop solar system for TUI Rijswijk and TUI Enschede. First a location survey is presented to check the suitability of the roofs, but also to figure out the optimal orientations for the solar panels. Then, the next subsection gives an overview on the current electricity usage and the expected increase of this usage in the situation were more people start to drive electrically. Following this, a system design and size are established as well as the components that are required for the PV system. Knowing which components need to be used, makes it then possible to determine the losses of all separate components, and eventually the entire PV system. This is all followed by a cost analysis that also looks into the payback time of both PV systems under different conditions. Lastly, it is concluded whether or not the systems are profitable and what the advantages and disadvantages are of the systems.

6.1 Location Survey

In this section a closer look is taken at the geographical and meteorological data that is needed in order to be able to accurately design a PV system, with the highest possible yield.

6.1.1 Geographical Data

When designing a PV system, the geographical data needs to be analyzed first to see if a certain roof is suited for the placement of such a system. Moreover, it needs to be determined whether or not shading plays an important role, and how the system should be designed when keeping in mind the shadows cast by surrounding obstacles (buildings, etc.).

For both locations there is practically no shade casted on the roofs during the entire day. This goes especially for the location in Enschede, there are no buildings in its vicinity that are higher than where TUI has its office located. For the building in Rijswijk there are some shadows casted, by other parts of the building, when the sun is at its lowest point. This impact is, however, going to be minimal between 10.00 - 15.00, when most of the energy will be yielded.

6.1.2 Meteorological Data

The meteorological data were essential in determining how, where, and how many solar panels needed to be placed to generate a certain electricity yield. Firstly, before all of this could be calculated, the Meteonorm Software tool was used to gather all relevant (hourly) weather data for the coordinates belonging to the offices in Rijswijk and Enschede. The exact latitudes and longitude used were retrieved from Google Maps and were 52.039°N and 4.328°E for TUI Rijswijk, and for TUI Enschede this was 52.2045°N and 6.889°E. With this data it was possible to track the position of the sun over an entire day and plot its position for every hour. Figure 6.7 in Section 6.3.2 shows the position of the sun, throughout the year, for the office in Rijswijk. In Appendix C an overview is given of the formulas used to calculate the position of the sun.

Secondly, the data were used to calculate the yearly irradiance on both locations. This yearly irradiance is necessary to determine how much energy can be yielded from the sun. The total irradiance depends on the Global Horizontal Irradiance (GHI), the Direct Normal Irradiance (DNI), the Diffuse Horizontal Irradiance (DHI) and the Sky View Factor (SVF), but also on the position and tilt of the module. The diffuse irradiance can be seen as that part of the irradiance that is scattered when it enters our atmosphere, but still reaches the surface of the solar panel. The direct irradiance is the direct beam of light that remains after scattering of the diffuse irradiance, and the global irradiance is then a summation of the direct and the diffuse irradiance [67]. Combining these factors with the coordinates of the PV systems made it possible to calculate the irradiance that falls on the system while facing a certain direction (azimuth) and having a specific tilt angle. The results of this irradiance calculation are shown in the heat map of Figure 6.1. The figure also indicates what the optimal orientation is for a solar panel to receive the maximum amount of irradiance on its surface. For the location in Rijswijk the optimal azimuth is 205°, and optimal tilt is 25°, for Enschede this is 208° and 26°, respectively. The exact formulas that were used to perform these calculations can be found in Appendix D.

6.2 Load Description

In this section the energy consumption of both locations was analyzed, as well as the energy use of EVs. An estimation on the number of EVs that need to be charged on a daily basis was made to get an indication of the energy consumption stemming from charging EVs.

6.2.1 Energy Consumption of the Office

Data for the total energy consumption during the year were gathered from the electricity company Vattenfall and can be found in Figure 6.2 for Rijswijk and in Figure 6.3 for Enschede. Since only monthly data were available the values were interpolated to get an overview of the daily energy use. Results of this interpolation are shown in Figure 6.4 where the load profile, that can be assumed for an ordinary day, is given. From the figure it becomes visible that the office is highly occupied between 8.00 and 16.00. It can also

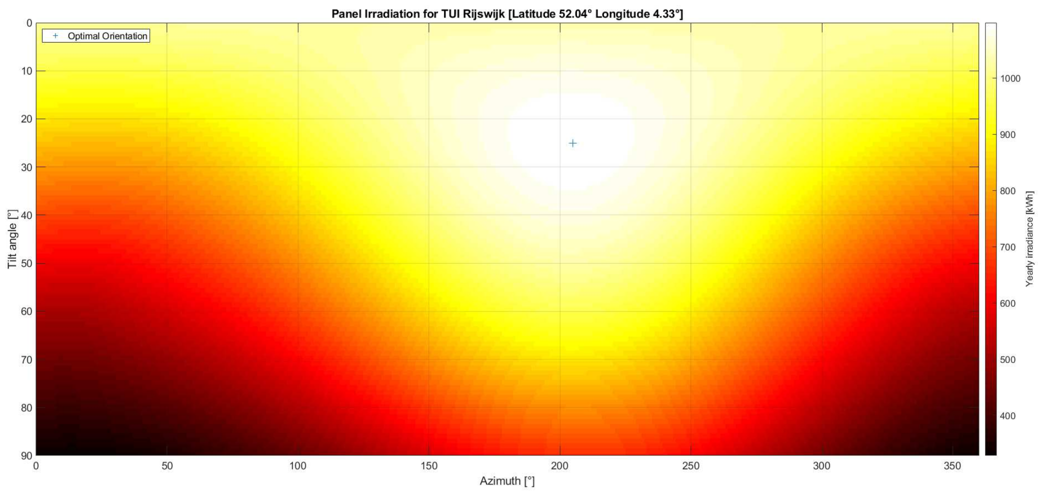

Figure 6.1: Heatmap indicating different irradiance levels for varying module orientations.

be seen that even at night there is a constant power consumption. Nonetheless, it has to be noted that the data for Rijswijk are estimations, from August onwards. This is due to the fact that the Rijswijk office has been completely renewed and made energy efficient during 2017 and 2018 and has only been reoccupied since December 2018. Because of this, only data from January until July (2019) were available. The other months were estimated based on the reduction in the energy consumption (>67%) for the first half of 2019, compared to the consumption before the renovation, which was 2016. A total energy consumption of almost 440 MWh is estimated for Rijswijk for one year. For Enschede this yearly energy consumption is roughly 1,256 MWh. The large difference between the electricity consumption of both offices can be explained by the fact that the office in Rijswijk has been made energy efficient, whereas the one in Enschede has not.

From calculations in Appendix D, it was found (and made visibile through the heatmap in Figure 6.1) that the total irradiance on a roof tilted and facing the optimum is 1,098 kWh/m^2. Since the total area of the roof is roughly 3250 m^2, the total irradiance on the roof would then amount to 3568.5 MWh. When assuming a total efficiency of a PV system of 15% the total available energy for Rijswijk would amount to roughly 535 MWh. At first sight it appears that enough energy can be generated by PV panels to sustain the entire office, however (as mentioned before), not the entire area of the roof is available for PV panels. Additionally, areas are lost, due to (partial) shading, geometry of the roof and spacing required between the panels. This estimated amount will never be realistic. A more realistic estimation of available rooftop area will be given in Section 6.3.2.

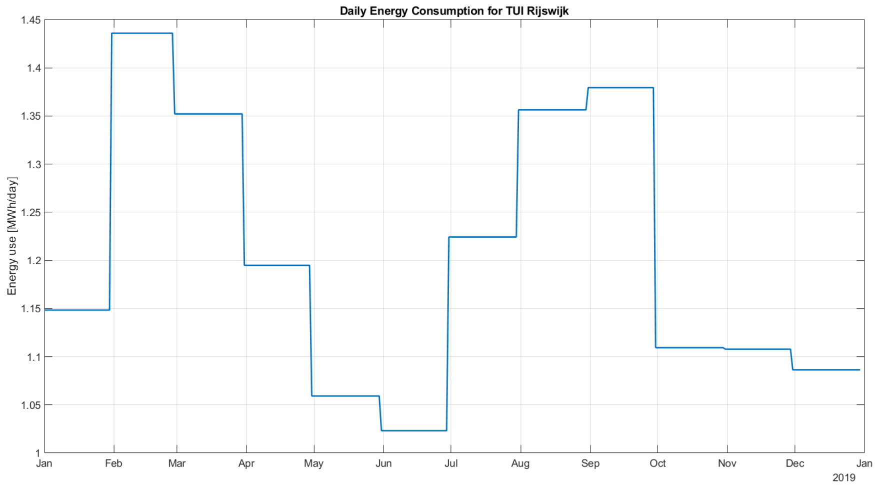

Figure 6.2: Overview of the yearly energy consumption for TUI Rijswijk.

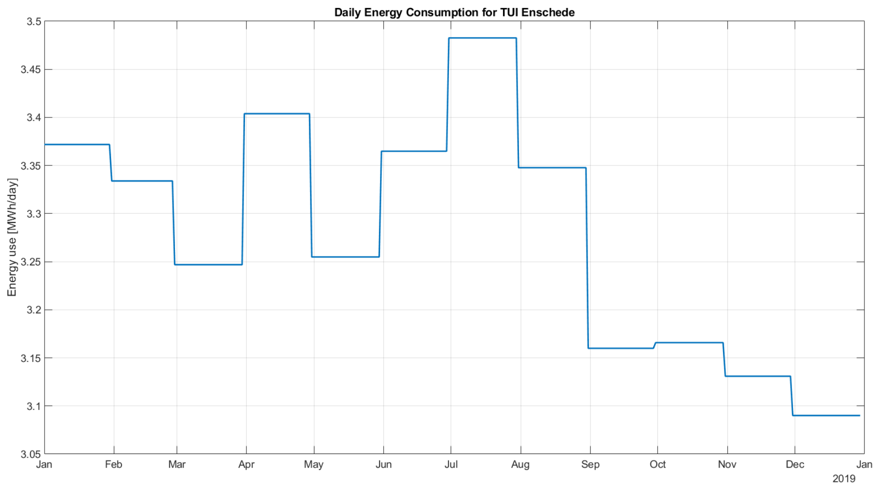

Figure 6.3: Overview of the yearly energy consumption for TUI Enschede,

6.2.2 Energy Consumption of EVs

Assuming that mode 2 one-phase chargers (7.4 kW) are available at the office for charging the EVs and also assuming people, on average, drive an EV with a 64 kWh battery, the charging of a single EV can be graphically depicted as is done by the purple line in Figure 6.5. In the (near) future TUI also plans to install fast chargers. This will change the curve in the figure since the cars are then fully charged faster, however the total amount of electricity required for the charging will not change. Looking again at Figure 6.5 it can be observed that

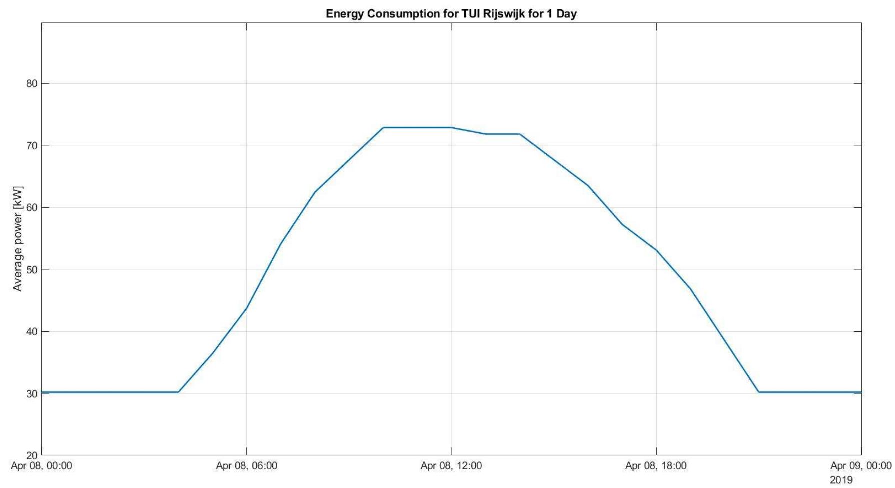

Figure 6.4: Estimation of a daily load curve for TUI Rijswijk.

the charging of the EVs will have a significant impact on the total electricity consumption of the company. If, for example, all 64 lease drivers were to drive electrically, and needed to charge their cars at the same time, the total electricity consumption will be about 6 times higher (for Rijswijk) compared to the situation where no EVs need to be charged. In Figure 6.5 this is indicated by the difference between the yellow line (=normal load) and the red line (=total load including EV charging).

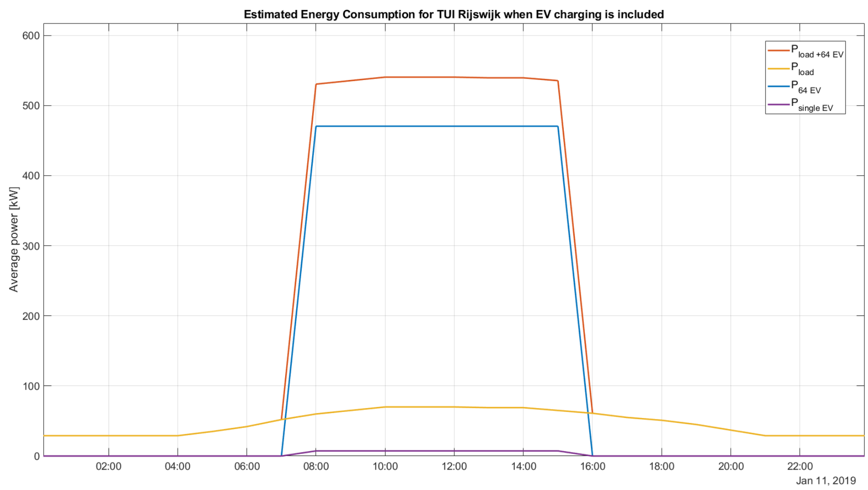

Figure 6.5: Total estimated energy consumption for TUI Rijswijk including the energy consumption for 1 and 64 EVs and the current energy consumption.

The situation above, charging 64 EVs at the same time, is very unlikely to happen. In Section 3.2.1.3 it was already mentioned how many kilometers the lease drivers have to drive to and from work, each year, for both Rijswijk and Enschede. The total amount driven is approximately 936,265.6 km for TUI Rijswijk and 296,451 km for TUI Enschede. Assuming that EVs use about 0.176 kWh per kilometer driven [31], and that about 80% of the time the EVs are going to be charged at the office (other times the charging is done at home, on the road, or at the offices in Belgium), this results in an additional electricity need of about 131.8 MWh and 41.7 MWh for Rijswijk and Enschede, respectively.

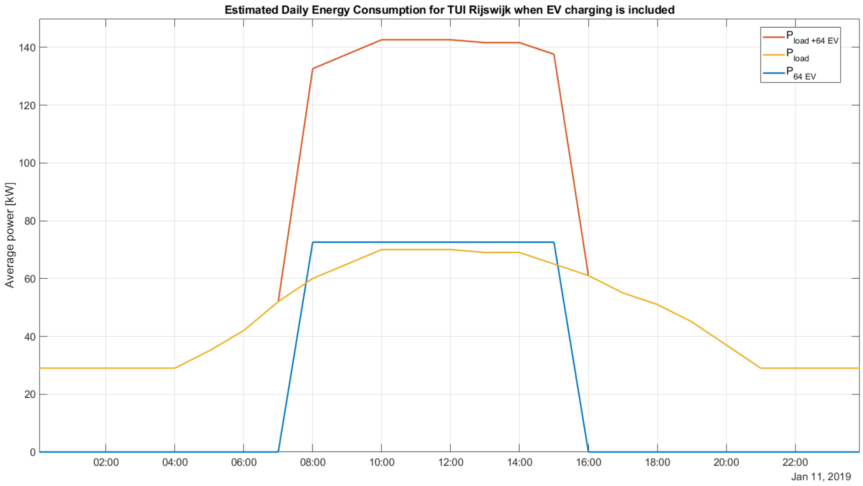

Figure 6.6: Estimated total energy consumption, for TUI Rijswijk, when realistic numbers are used for the energy needs of EVs.

Converting this to a daily electricity consumption resulted in an additional, daily, electricity need of roughly 586 kWh for Rijswijk. In Figure 6.6 it can be seen that the electricity needed for the charging of the EVs exceeds the regular electricity needs (blue versus the yellow line) and that the total electricity consumption will roughly be doubled (red line).

Finally, in Table 6.1 an overview is given on the energy needs for both Rijswijk and Enschede. Assumptions here were based on the actual kilometers driven by the lease drivers for both locations that were already discussed in this section. It has to be noted that for these numbers only the lease car drivers were considered to switch towards EVs. Of course, the energy demand will further increase when all people, who currently drive a car to work, start driving electrically.

6.3 System Design

In this section all components required for the PV system are analyzed. This entails the PV modules, cables, and the inverter. Also an analysis on the space available for solar

Table 6.1: Overview of the current electricity consumption and the estimated energy consumption when EVs are included, for both TUI Rijswijk and TUI Enschede.

	TUI Rijswijk	**TUI Enschede**
Current Energy Consumption (yearly)	440 MWh	1,256 MWh
Estimated Energy Consumption for EVs (yearly)	131.8 MWh	41.7 MWh
Total Estimated Energy Consumption (yearly)	571.8 MWh	1,297.7 MWh

panels will be made. After this analysis, the system design and components needed for both systems is given.

6.3.1 PV Modules

Before a specific PV module was chosen, a couple of requirements were evaluated. First of all, a large and stable amount of electricity needs to be generated in order to be able to compensate for the additional load induced by the charging of the EVs. Another important aspect were the costs of the individual panels. In order to achieve a higher return on the investment, and a lower payback time, lower panel costs were preferable. Based on these requirements the *Panasonic HIT N330* PV module was chosen. The Panasonic HIT series have proven to be highly reliable and have a stable performance over time. Another huge advantage is that this specific module generates 27% more power compared to other solar cells of the same size [59]. Lastly, due to their smaller size (and higher output) the balance-of-system costs are also lower compared to other modules. The most important characteristics of the solar panel are given in Table 6.2 below. These values will later be used to design the PV system topology. An overview of all characteristics of the module can be found in the datasheet in Appendix K.

6.3.2 Rooftop Analysis

Before placing the PV system on the roof it is important to know where to place the different components and how many PV panels can be placed. Since the roof of both buildings is flat it is relatively easy to place the panels and point them towards their optimal direction. Both buildings are located at such a position where they do not suffer from shading by surrounding buildings. They are also high enough to not experience shading from trees and other obstacles located on the ground as was already briefly mentioned in Section 6.1.1.

To prevent mutual shading, shade casted onto a panel by the panel in front of it, the length of the shadow of the panel was determined. Since it is important to have the panels shade free on all days between 10.00 - 15.00, when the largest amount of irradiance is casted onto the panels, the solar elevation and azimuth are taken at 10 AM and 15 PM on December 21^{st} since this is the shortest day of the year, implying that the sun is at its lowest position

Table 6.2: The most important characteristics of the Panasonic HIT N330

Electrical Data (under STC)	
Maximum power (Pmax)	330 [W]
Maximum power voltage (Vmp)	58.0 [V]
Maximum power current (Imp)	5.70 [A]
Open circuit voltage (Voc)	69.7 [V]
Short circuit current (Isc)	6.07 [A]
Solar panel efficiency	19.7 [%]
Dimensions	
Length	1.59 [m]
Width	1.053 [m]
Height	0.035 [m]

and thus casts the largest shadows. Figure 6.7 was used to find the elevation (altitude) and azimuth of the sun. Inserting these parameters, and the location and tilt of the module, in Formula 6.1 resulted in a distance required of 3.88 m between the panels.

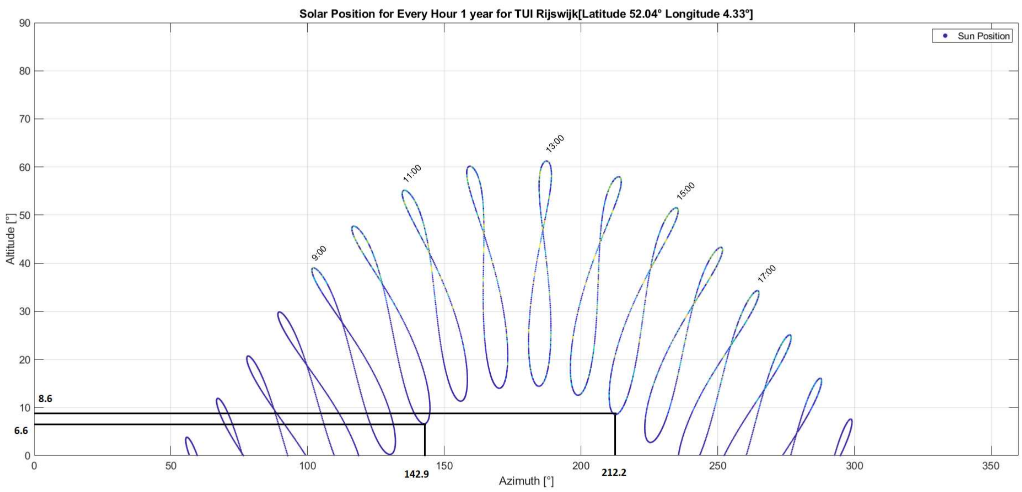

Figure 6.7: Position of the Sun for every hour for an entire year.

$$d = l \cdot (cos(\theta_M) + sin(\theta_M) \cdot cot(a_S) \cdot cos(A_M - A_S)) \quad (6.1)$$

With the help of Figure 6.8, where the available area on the roof and its measurements are indicated, the solar panel dimensions of Table 6.2, and the distance required between the panels, it was calculated that the rooftop in Rijswijk can fit up to 202 PV panels. In the same way it was calculated that the rooftop in Enschede can fit up to 90 solar panels. The final configuration of the panels is elaborately discussed in Section 6.3.5.

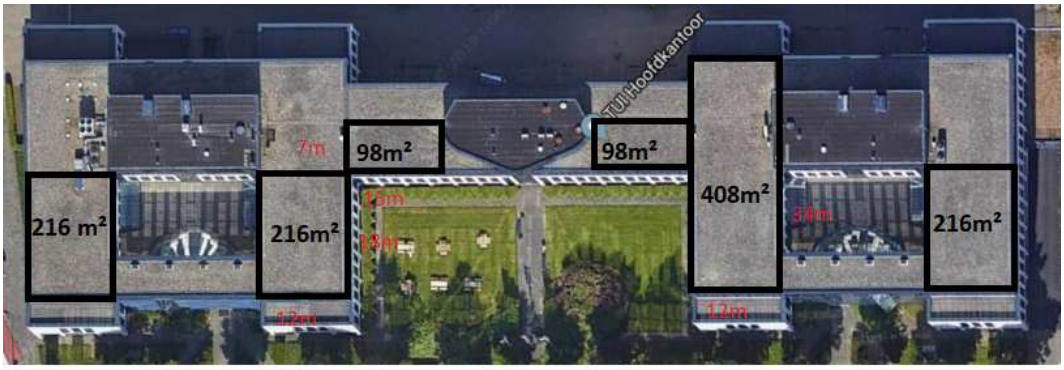

Figure 6.8: Overview of the available area on the roof in Rijswijk

6.3.3 Balance of System

The entire PV system contains more components than just the PV modules discussed previously. Other components involved in obtaining an optimal yield from the modules are the cables, the inverter(s), the mounting structure and the kWh meters. Since the first two can have a major impact on the system performance they will be discussed in the course of this section. As for the mounting structure it suffices to say the *Steel Ballasted Mounting* [30], with a tilt angle between 10° - 60°, is used and no additional kWh meter is installed, since there are already smart meters present at both locations, which are capable of processing the energy that is delivered back to the grid (in case necessary).

6.3.4 Cables

As mentioned, cables are an essential part of every PV system. Both AC and DC cables are required. DC cables are needed to let the power flow from the PV panels, which produce a DC current, into the inverter. Since the inverter converts the DC power into AC power, AC cables are needed to then transport the power from the inverter into the load or grid.

For the DC cables it is important to use a cable with a large cross section (A) since this reduces the losses in the cable according to Formula 6.2. From the formula it also becomes apparent that the losses can be reduced by the conductivity (σ). The most used materials for cables are copper and aluminum with a conductivity of 59.6 $S \cdot m/mm^2$ and 35.5 $S \cdot m/mm^2$ [67], respectively. Due to the higher conductivity of copper and a large cross section of 10 mm^2, the DC cable chosen was the *Twin core Solar DC cable PV1-F* [41]. For the DC cables it was estimated that roughly 1,250 m is needed for Rijswijk and 450 m for Enschede.

The specifics behind these numbers were gather from Figure 6.8.

$$P_{loss_{cable}} = I^2 \cdot \frac{1}{\sigma} \cdot \frac{l}{A} \tag{6.2}$$

To reduce further transportation losses the inverters should be placed close to the fuse box, thus reducing the required cable length of the AC cable and further losses. When placing these components close to one another a AC cable length of about only 20 m was needed for both locations. The chosen AC cable is the *Waskonig XMVK 5x2,50mm* [29]. In Section 6.4.1.1 a further analysis will be made on total losses due to the cables.

6.3.5 Inverter

For the PV system in Rijswijk the *Sunny Tripower 25000TL* [66] inverter was chosen, and for the location in Enschede the *Growatt 30000TL3-S* [37] inverter. The main prerequisite for choosing any inverter is that it needs to be able to withstand the maximum power that can be generated by the solar panels. Next to this it is also crucial to check the allowed input voltage, and the maximum input current since these determine how many PV panels can be connected in series and parallel, respectively. A huge advantage, and part of the reason these inverters were chosen, is that they each have two built in maximum power point (MPP) trackers, forcing each PV system to perform at its optimal conditions. The most important parameters of both inverters are given in Table 6.3, and a complete overview can be found in the datasheets in Appendix L and M for the Sunny Tripower and the Growatt, respectively.

Table 6.3: Inverter specifications [66], [37].

Input	**Sunny Tripower 25000TL [66]**	**Growatt 30000TL3-S [37]**
DC Rated Power [W]	25,550	37,500
Maximum input voltage [V]	1,000	1,000
MPP voltage range [V]	390 - 800	450 - 800
Max input current [A] (per input)	33	34
Number of independent MPP inputs	2	2
Strings per MPP input	3	4
Maximum efficiency	98.1%	98.4%

Next, the inverter data for the Sunny Tripower 250000TL (Table 6.3), the data of the PV module (Table 6.2), and the estimation that the roof can place up to 202 PV panels were used to calculate the amount of inverters needed and the placement of the PV panels. Since 202 PV panels can produce a maximum rated power of 66,660 W it became obvious that a single inverter was not enough and a total of three inverters were needed for the Rijswijk office.

When looking at the MPP voltage range of the inverter, and the V_{mp} of the PV module (Table 6.2) it was calculated that a maximum of 13 panels could be placed in series. To determine the amount of panels that can be placed in parallel, a closer look was taken at the maximum allowed input current per MPP input, and the I_{mp} (from Table 6.2). From this it followed that up to 5 panels can be placed in parallel per MPP tracker, so a total of 10 panels could be placed in parallel per inverter. Using all of the knowledge given above, it was determined to create two arrays of 13x5 panels, where, in both cases, this was split in 13x3 panels for the first MPP tracker and 13x2 panels for the last MPP tracker. For the third inverter the setup differs slightly and each MPP tracker has a 12x3 array to attached to it. This setup was created in such a way that more panels in series is preferred over a setup where more panels are connected in parallel. This was chosen since theory [67] indicated that it is preferable to connect as many modules in series as possible, because in such a way the current is limited on the DC side, and thus the cable losses stay low. An overview of the final PV system setup for Rijswijk is shown in Table 6.4. The same approach as described above was used for the system at TUI Enschede, and a summarization of these results are given in Table 6.5.

Table 6.4: Setup of the PV system in Rijswijk, per inverter.

Sunny Tripower 25000TL			
	Inverter 1	**Inverter 2**	**Inverter 3**
Panels used	65	65	72
Maximum power input	21,450 W	21,450 W	23,760 W
Series connected	13	13	12
Parallel connected	5	5	6
String distribution	$3 * 13$ $2 * 12$	$3 * 13$ $2 * 13$	$3 * 12$ $3 * 12$

Table 6.5: Setup of the PV system in Enschede.

Growatt 30000TL3-S	
Panels used	90
Maximum power input	29,700 W
Series connected	12 / 9
Parallel connected	8
String distribution	$6 * 12$ & $2 * 9$

In section 6.4.1.2 an analysis is made on the system losses caused by the inverters.

6.4 Performance Analysis

So far the components discussed were rated at their standard test conditions (STC). Considering that these test conditions can never be completely met in real-time, due to, for example, changing weather conditions, it is imperative to see how the different components will react. In this chapter the losses related to system components are evaluated, and the yield, both AC and DC side, is determined.

6.4.1 Losses Analysis

The difference between STC and real world conditions is mainly caused by losses in the PV system. Losses can be attributed to different circumstances, like shade and dirt, or to certain components like the cables or the inverters. In this section the losses in the cables and inverter(s) will be discussed.

6.4.1.1 Cable Losses

To be able to calculate the power losses in the cables, Formula 6.2 was used. Using the cable specified in Section 6.3.4 and its parameters shown in Table 6.6 and Table 6.7, it was possible to calculate the losses due to the cable for the situation in Rijswijk and Enschede. With the help of the formula and the parameters presented it followed that, for the situation in Rijswijk, the cable losses for each string are 71.73 W for inverter 1 and 2 and 37.75 W for inverter 3, which is 1.67% and 0.95% respectively. For Enschede only one inverter is used, but since different string lengths were applied the cable losses in the first strings are 37.75 W and for the last two strings this is 30.20 W, which resulted in 0.95% and 1.02% respectively.

Table 6.6: Parameters used for calculating the cable losses, per string, for Rijswijk.

Sunny Tripower 25000TL			
	Inverter 1	**Inverter 2**	**Inverter 3**
Cable length (l)	$2 \cdot 95$ m	$2 \cdot 95$ m	$2 \cdot 50$ m
Cable cross section (A)	10 mm^2	10 mm^2	10 mm^2
Conductivity of copper (σ)	59.6 S $\cdot$ m/mm^2	59.6 S $\cdot$ m/mm^2	59.6 S $\cdot$ m/mm^2
Flowing current (I)	15 A	15 A	15 A
Maximum of PV Panels	4,290 W	4,290 W	3,960 W

6.4.1.2 Inverter Losses

As was shown in Table 6.3 the inverters have a maximum efficiency 98.1% and 98.4%. However, since the inverter efficiency depends on its DC input voltage, which is not constant due to its temperature dependence, it has a variable efficiency. Using the Sandia National Laboratories (SNL) model [67] and the extended inverter data provided by SNL, it was possible to determine the real-time average efficiency of each inverter. This model does

Table 6.7: Parameters used for calculating the cable losses, per string, for Enschede.

Growatt 30000TL3-S		
	String 1-6	**String 7 & 8**
Cable length (l)	2 · 50 m	2 · 40m
Cable cross section (A)	10 mm^2	10 mm^2
Conductivity of copper (σ)	59.6 S · m/mm^2	59.6 S · m/mm^2
Flowing current (I)	15 A	15 A
Maximum of PV Panels	3,690 W	2,970 W

not only take the losses related to the DC input voltage into account, also known as the self-consumption losses, but also the Ohmic losses, e.g. losses that are a function of the resistance, and also losses associated with fixed voltage drops, and switching mechanisms, in the semiconductors.

The formulas used for the SNL model can be found in Appendix G, and the results of the calculations in Table 6.8 for TUI Rijswijk and Table 6.9 for TUI Enschede. From these tables it can be concluded that the actual efficiency is slightly lower than the theoretical values given in the datasheet, namely 97.8% and 97.6% versus 98.1% for Rijswijk and 97.3% versus 98.4% for Enschede.

6.4.2 PV Modules

As was already briefly mentioned, PV modules are always tested under the so-called Standard Test Conditions (STC). In this test environment the cell temperature is kept constant at 25°C, the irradiance incident on the module is kept at 1000 W/m^2, and lastly, the air mass 1.5 spectrum (AM1.5) is used. In real-life it is, however, not possible to keep the temperature and the irradiance at constant levels. The spread of the irradiance over an entire year was given by the data retrieved from Meteonorm. The actual, varying temperature of the PV module could not be obtained so easily and had to be calculated. The formula that was used for this is given by Formula 6.3. This formula is the result of the fluid-dynamic model by Fuentes [67]. A more detailed explanation on how this fluid-dynamic model works, and the calculations used to arrive at Formula 6.3 can be found in Appendix E.

$$T_M = \frac{\alpha G_M + h_c T_a + h_{r,sky} T_{sky} + h_{r,gr} T_{gr}}{h_c + h_{r,sky} + h_{r,gr}} \tag{6.3}$$

The model, by Fuentes, accounts for the heat transfer related to the incident solar irradiance, the radiative heat exchange between the surface of the top of the module and the surrounding air, the convective heat exchanged between the surrounding air and the front and back side of the PV module, and the conductive heat transfer between the module and its mounting structure [67]. This last contribution was neglected in this scenario, because the area of the contact points of the module are too small.

Now that the varying module temperature (T_M) is known, the effect of this on the output voltage of the PV module needed to be calculated. As indicated by the datasheet in Appendix K, the voltage output of the module tends to decline when the temperature rises and the current then increases. The formulas used for calculating the effect of the temperature on the voltage, current, power, and the overall efficiency can be found in Appendix F.1. The effect of the varying temperature on the output voltage and module efficiency are shown in Figure J.2 and J.1 in Appendix J.

As already mentioned, the irradiance also contributes heavily to the (power) output of the PV module, and thus the overall efficiency. This can be seen by the relation between the efficiency and the irradiance as depicted in Formula 6.4.

$$\eta(25°C, G_M) = \frac{P_{MPP}(25°C, G_M)}{A_M \cdot G_M} \tag{6.4}$$

The formulas needed to arrive at Formula 6.4 are given in Appendix F.2.

When knowing both the dependency of the module on the temperature (Formula 6.3), and the irradiance (Formula 6.4), the overall module efficiency could be determined for all available irradiance and temperature data. The formula that was used here is given by Formula 6.5. The k in this formula has a value of -0.258%/°C as indicated by the datasheet in Appendix K.

$$\eta(T_M, G_M) = [1 + k(T_M - 25°C)] \cdot \eta(25°C, G_M) \tag{6.5}$$

In the next section the time dependent properties were implemented and used to calculate the final output of the PV array, of which the results are shown in Table 6.8 and Table 6.9.

6.4.3 DC and AC Yield of the System

In order to calculate the total DC yield of a PV system, the irradiance that falls on all panels needed to be calculated over the course of an entire year. The irradiance is dependent on the tilt and orientation of the solar panels which were already determined in Section 6.1.2. Using this and the performance of the PV panels (which was analyzed in the previous section) made it possible to calculate the DC output of the solar panels. Then, by subtracting the cable losses, the DC yield was calculated and, finally, the inverter losses were deducted to then attain the total output of the PV system (= AC yield). The results of these calculations are shown in Table 6.8 for TUI Rijswijk and in Table 6.9 for TUI Enschede. For a schemativ overview of the entire process, the reader is referred back to Figure 3.1 in Section 3.3.1.

Now, knowing the full performance of the PV system, this can be compared to the estimated load as given in the section on the load description. An overview of the produced and required energy is given in Table 6.10 and made graphically visible in Figure 6.9. From this it could be concluded that not enough electricity can be generated to sustain the electrification of the entire lead car fleet. Still, about 64,668 kWh needs to be additionally bought from the electricity company. In the next section a financial analysis will be made to determine

Table 6.8: Yield data for the PV system, per inverter and total, for TUI Rijswijk.

	Inverter 1	**Inverter 2**	**Inverter 3**	**Total**
Panels used	65	65	72	202
PV panels output (DC)	22,416 kWh	22,416 kWh	24,830 kWh	69,663 kWh
DC yield (after cable losses)	22,042 kWh	22,042 kWh	24,594 kWh	68,678 kWh
AC Yield	21,552 kWh	21,552 kWh	24,012 kWh	67,116 kWh
Inverter efficiency	97.78%	97.78%	97.63%	97.73%

Table 6.9: Yield data for the PV system, per string and total, for TUI Enschede.

	String 1-6	**String 7 & 8**	**Total**
Panels used	72	18	90
PV panels output (DC)	24,883 kWh	6,221 kWh	31,104 kWh
DC yield (after cable losses)	24,647 kWh	6,158 kWh	30,805 kWh
AC yield	24,132 kWh	5,841 kWh	29,973 kWh
Inverter efficiency	97.91%	94.86%	97.3%

whether or not it is still useful to install a rooftop PV system when it will not cover the entire (estimated) EV load.

Table 6.10: Overview of the energy produced and required for TUI Rijswijk and TUI Enschede.

	TUI Rijswijk	**TUI Enschede**
Total Energy Required for EV Charging	131.8 MWh	41.7 MWh
Total Energy Production	67.1 MWh	29.97 MWh
Energy Required from the Grid	64.7 MWh	11.73 MWh

6.5 Cost Analysis

In this section the focus is on the economic aspects of both PV systems. First the payback time, and then the levelized cost of electricity are calculated for each system. These calculations will determine whether or not building either PV system is financially feasible.

6.5.1 Payback Time

To be able to calculate the payback time of the PV systems all costs of the involved components needed to be considered as well as the savings. Savings can be related to no longer

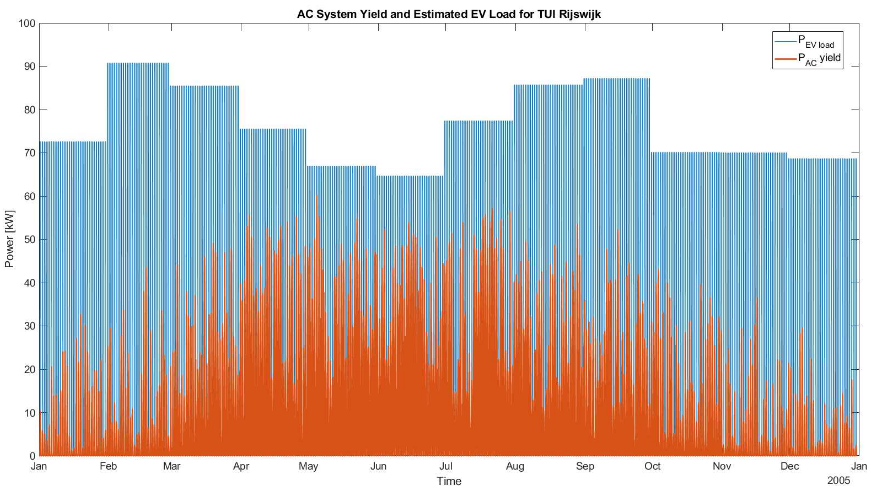

Figure 6.9: Overview of the yearly AC system yield and the EV induced load for TUI Rijswijk.

having to purchase a certain amount of electricity from the electricity company, but savings can also be obtained through subsidies.

6.5.1.1 Total Initial System Investment

In Table 6.11 and Table 6.12 the costs of the different system components are given. From these tables it becomes visible that a large share of the initial investment costs originate from the modules itself and the estimated labor costs. The labor costs are estimated to be around €50,- per panel [81]. Taking everything into consideration resulted in a total system cost of €67,594 for TUI Rijswijk and €29,997 for TUI Enschede.

Table 6.11: Total Initial investments costs for the rooftop PV system in Rijswijk.*

System Components	**Price [€]**	**Quantity**	**Total Cost [€]**
Modules	192.56	202	38,897.12
Mounting System	29.37	202	5,932.74
DC cable (per meter)	1.96	1250	2,450
AC cable (per meter)	2.03	20	40.60
Inverter	2,391	3	7,173
Other			3,000
Labor			10,100
Total			67,593.46

∗ All of the given prices are excluding VAT.

Table 6.12: Total Initial investment costs for the rooftop PV system in Enschede.∗

System Components	Price [€]	Quantity	Total Cost [€]
Modules	192.56	90	17,330.40
Mounting System	29.37	90	2,643.30
DC cable (per meter)	1.96	390	764.40
AC cable (per meter)	2.03	20	40.60
Inverter	2,718	1	2,718
Other			2,000
Labor			4,500
Total			29,996.70

∗ All of the given prices are excluding VAT.

6.5.1.2 Operating and Maintenance Cost

Next to these initial costs there are also operating and maintenance costs that need to be taken into account. A huge benefit of solar panels is that they require very little maintenance and that the panels have a lifetime of 25 years. The only maintenance the solar panels do require, is that they need to be cleaned and inspected once a year, which will result in a yearly expense of roughly €1,030 [87] for Rijswijk and €470 for Enschede. Other maintenance costs required come from the replacement of the inverter and the cables. Both have a lifetime of 10-13 years [87], and thus need to be replaced once during the lifetime of the solar panels. The replacement of these components amounts to roughly €9,664 and €3,523 for TUI Rijswijk and TUI Enschede, respectively.

6.5.1.3 Subsidies

Subsidies are another essential aspect that influence the payback time of the PV system. In The Netherlands there are a couple of grants and regulations companies can apply for, when investing in sustainable sources for company usage. One of these is a grant called SDE+ [61]. Through this arrangement a subsidy can be granted to companies who produce sustainable energy. In Table 6.13 it is shown that there are different amounts available, depending on whether the energy produced is also consumed, or is fed back into the grid. The table also shows the savings that can be obtained through this subsidy for the PV systems in Rijswijk and Enschede. This subsidy is provided on a yearly basis. Since it was concluded that the systems do not produce enough energy for the charging of all EVs (Table 6.10, it is assumed that all energy produced is also consumed. Therefore, Table 6.13 only shows the savings for own use.

Apart from the SDE+ subsidy there are two other financial regulations which the company can apply for, these are called the KIA [10] and EIA [8]. In both cases a certain amount of the investment can be deducted from the profits earned by the company. In this way the profits of the company are scaled down which, in turn, reduces the amount of taxes that have to be paid. For the KIA this is a fixed amount, and for the EIA it is 45% of the total

Table 6.13: SDE+ subsidies amounts and savings when applied to the PV system in Rijswijk and Enschede.

Subsidy for own use of energy	0.069 €/kWh
Subsidy for delivering energy to the grid	0.041 €/kWh
Savings for own use Rijswijk	67,116 kWh · 0.069 €/kWh = €4,631
Savings for own use Enschede	29,973 kWh · 0.069 €/kWh = €2,068

investment. The indicated amounts for both the KIA and EIA are given in Table 6.14. Since both regulations are one-off savings, and can only be employed in the same year the solar system is installed, these savings should be subtracted from the initial investment.

Table 6.14: Deductible amounts for the KIA and EIA, and the total savings these subsidies entail.

KIA savings	€16,051
EIA savings	45 % · €67,594 + €29,997 = €43,916
Total deductible amount	€59,967
Total savings ∗	25% · €59,967 = €14,992

∗ 25% tax rate in The Netherlands for profits over €200,000 per year [14].

In Table 6.14 the last row indicates the total savings for both offices, however, since a payback time for each individual PV system needed to be calculated, the one-off savings per system were required. To be able to determine these, the share of the energy output of the systems were compared to the total energy output. The system in Rijswijk is responsible for roughly 69% of the total energy collected by both systems, and thus a one-off savings of €10,384 is attributed to that system. TUI Enschede then has a one-off savings of €4,608.

6.5.1.4 Annual Savings

Knowing the total cost and subsidies of each system, the last factor needed, before calculating the payback time, was the annual savings for each system. A total of 67,116 kWh and 29,973 kWh is produced by the PV systems in Rijswijk and Enschede, respectively. Seeing as TUI pays, on average, €0.135 per kWh for TUI Rijswijk, and €0.115 per kWh for TUI Enschede, the total savings amount to €9,061 for TUI Rijswijk, and €3,447 for TUI Enschede. With this in mind the payback time was calculated using Formula 6.6, resulting in a payback time of t = $\frac{67,594-10,384}{4,631+9,061} = 4.2$ years for TUI Rijswijk and t = $\frac{29,997-4,608}{2,068+3,447} = 4.6$ years for TUI Enschede. The longer payback time for TUI Enschede can be attributed solely to the lower electricity cost, since the initial investment and the savings are proportional to those for TUI Rijswijk due to the fact that the same components were used in both systems.

$$payback\ time,\ t = \frac{Initial\ Investment - One\ Off\ Savings}{Annual\ Total\ Savings} \tag{6.6}$$

6.5.1.5 Payback Time under Different Circumstances

As mentioned in Section 3.3.1, the payback time was also investigated, taking into account different circumstances. Again Formula 6.6 could be used, however some updates were needed for both the savings and the initial investment. Starting with the initial investment costs that were shown in Table 6.11 and 6.12 for TUI Rijswijk and Enschede, respectively. The same 'components' and quantities were also needed in the 2025 scenario. In [44] extensive research was done into the cost of different PV system components up until 2025. According to this research the costs related to the PV module, the inverter and the mounting system will be reduced by 2025, each with different rates. At the same time it is expected that the efficiency of the PV module will increase to 21.5% in 2025. This will, in turn, increase the efficiency of the entire PV system and thus increase the AC (and DC) yield of the system. A higher system yield also implies that more savings can be obtained, since even less energy has to be bought from electricity companies. Since no extensive research was found on the increase or decrease of cable cost, the cost were kept at the same level as in 2019. Considering these cost make up only a small part of the initial investment, this reasoning was found to be acceptable. The labor costs are also kept constant. On the one hand it is expected that these decline, since the system can be constructed faster when the builders are more experienced, on the other hand the expected increase in wages will level out this difference. In Table 6.15 a summary is given on the decrease of certain cost, and their expected cost in 2025.

Table 6.15: Summary of the price changes, in 2025 [44], of PV components compared to 2019.

	Costs in 2019	**Estimated cost in 2025**	**Average unit cost in 2025**
PV module cost	0.584 €/Wp	0.27 €/W - 0.37 €/W*	€105.60
Inverter cost - Rijswijk - Enschede	0.096 €/W	0.081 €/W*	 €2,025 €2,430
Mounting cost	29.37 €	-7%	€27.31

∗It was not indicated whether these values are including or excluding VAT. In order to not paint the picture too bright, it was assumed that these values are already excluding VAT.

For the mounting cost it was indicated by [44] that there would be a cost decline of about 15% in 2025 compared to 2015 values. Since it is currently 2019, a cost decline of 7% was used for this situation. Now taking the values of Table 6.15 into account made it possible to create Table 6.16 where the (estimated) initial investment costs of the entire system are shown for TUI Rijswijk and TUI Enschede for 2025.

Table 6.16: Initial investment cost for the PV system in 2025 for TUI Rijswijk and TUI Enschede.*

System Components	Price [€]	Total Cost TUI Rijswijk [€]	Total Cost TUI Enschede [€]
Modules	105.60	21,331	9,504
Mounting System	27.31	5,517	2,458
DC cable (per meter)	1.96	2,450	764.40
AC cable (per meter)	2.03	40.60	40.60
Inverter Rijswijk	2,025	6,075	-
Inverter Enschede	2,430	-	2,430
Other		3,000	2,000
Labor		10,100	4,500
Total		48,513.80	21,697

∗ All of the given prices are excluding VAT.

Also indicated was the PV module efficiency increase from 19.7% to 21.5% in 2025. Using this new efficiency leads to an increased system yield of 73,366 kWh for TUI Rijswijk and 32,798 kWh for TUI Enschede in 2025. Knowing this new system output made it then possible to calculate the updated annual savings.

In section 3.3.1 it was already briefly mentioned that the electricity prices are expected to rise in the (near future), and that rates of 1%, 5% and 10%, per year, will be evaluated. In Table 6.17 an overview is given of the electricity price in 2025 under the varying rates. The last column of the table then indicates the savings for each office under the varying rates and with the new systems yields taken into account.

Table 6.17: Electricity prices and their related savings (in 2025) for TUI Rijswijk and TUI Enschede.

	Electricity price in 2019 [€/kWh]		Electricity price in 2025 [€/kWh]		Savings in 2025 [€]	
	Rijswijk	Enschede	Rijswijk	Enschede	Rijswijk	Enschede
1%	0.135	0.115	0.143	0.122	10,513.35	4,003.81
5%	0.135	0.115	0.181	0.154	13,271.91	5,054.53
10%	0.135	0.115	0.239	0.204	17,546.27	6,681.92

The last thing now needed, in order to calculate the payback time in varying scenarios, is the savings that can be obtained through subsidies and grants. As indicated, the KIA subsidy remains equal to the 2019 scenario, see table 6.14, or it will be nullified. For the SDE+ subsidy a 50% reduction in estimated which will result in the amount indicated in Table 6.18. Table 6.18 also shows the savings that can be obtained through the SDE+ subsidy for both TUI Rijswijk and TUI Enschede. In Table 6.18 the subsidy for delivering energy to the grid is left out, in comparison to Table 6.13, since neither office will actually be delivering energy back to the grid.

Table 6.18: Estimated SDE+ subsidies amounts and savings when applied to the PV system in Rijswijk and Enschede for 2025.

Subsidy for own use of energy	0.035 €/kWh
Savings for own use Rijswijk in 2025	73,366 kWh · 0.035 €/kWh = €2,567.81
Savings for own use Enschede in 2025	32,798 kWh · 0.035 €/kWh = €1,147.93

Now that the subsidies, costs, savings, and output for the PV system in 2025 are known, it is possible to calculate the payback time for the different scenarios described in Section 3.3.2. Formula 6.6 was again used for these calculations and the results are depicted in Table 6.19 below. To make sure the table is complete and to show the impact subsidies have on the payback time, the payback times for 2019, with and without subsidies, were also included in this table.

Table 6.19: Overview of the payback time of the PV system for both TUI Rijswijk and TUI Enschede under varying circumstances.

	Payback time TUI Rijswijk [years]	**Payback Time TUI Enschede [years]**
2019	t = 4.2	t = 4.6
2019, no subsidies	t = 7.5	t = 8.7
2025, no EIA & SDE+ halved		
1% Electricity Price Increase	t = 3.5	t = 4.0
5% Electricity Price Increase	t = 2.9	t = 3.3
10% Electricity Price Increase	t = 2.3	t = 2.6
2025, no subsidies		
1% Electricity Price Increase	t = 4.6	t = 5.5
5% Electricity Price Increase	t = 3.7	t = 4.3
10% Electricity Price Increase	t = 2.8	t = 3.3

From this table it can be concluded that subsidies have a substantial influence on the payback time of the solar system. If the government would stop providing subsidies and grants, the payback time for both TUI Rijswijk and TUI Enschede would be almost doubled. Another thing that can be concluded by looking at the payback times, provided in the table, is that the payback times are, on average, lower in the future. This can be attributed to the lower initial investment and higher savings, due to more electricity generation by the increased efficiency of the PV systems. The last thing that can be concluded is that, logically, the payback time of the systems decrease when the electricity price increases. This is said to be logical, since higher electricity prices from the electricity companies, results in more costs saved through producing your own electricity.

6.5.2 Levelized Cost of Electricity

The levelized cost of electricity (LCoE) are the costs required to build and operate an energy system, here the PV systems, divided by the total energy production of the system over its lifetime [67]. The formula used to calculate the LCoE is shown below in Formula 6.7. With the help of this formula the costs of the entire PV system can be allocated over the total lifetime, and in this way it can be compared with the cost charged (per kWh) by the energy company.

$$LCoE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \tag{6.7}$$

In Formula 6.7, F_t represents the fuel expenditures. However, since the fuel needed to power this system is free (the sun), F_t is equal to zero. Furthermore, the r from Formula 6.7 stands for the discount rate. The discount rate is used to translate future values into present values, e.g. it discounts future costs.

Since solar panels do not produce a constant power output over their lifetime, due to the deterioration of the performance, the so-called degradation rate of the panels had to be taken into account. This degradation rate reduces the power produced, every year, by a certain amount. In the datasheet in Appendix K, it is shown that, after the first year the PV module had a degradation rate of 0.45% per year. A summation of all the parameter data already given, and the data needed to calculate the LCoE is given in Table 6.20.

Table 6.20: Parameters required for calculating the LCoE of both PV systems.

	TUI Rijswijk	**TUI Enschede**
Initial Cost (I_t)	€67,593.46	€29,996.70
Half Lifetime Replacement Cost (I_{12})	€9,663.60	€3,523
Operating & Maintenance Cost per Year (M_t)	€1,030	€470
Lifetime (t)	25	25
Discount Rate (r)	0%	0%
Energy Yielf in Year 1 (E_1)	67,116 kWh	29,973 kWh
Degradation Rate	0.45%	0.45%

With the data provided in Table 6.20 a LCoE of 0.0648€/kWh and a LCoE of 0.0637 €/kWh were calculated for TUI Rijswijk and TUI Enschede respectively. In comparison, since TUI pays roughly 0.135€/kWh for its electricity in Rijswijk and 0.115€/kWh in Enschede, an electricity price reduction of 52% and 45% was achieved for TUI Rijswijk and TUI Enschede respectively.

As was already mentioned, and indicated in Table 6.19, the discount rate is currently equal to zero in The Netherlands [43]. It has been zero for a couple of years now, and it is estimated to stay zero until the end of 2020 [73]. A high discount factor indicates that a particular investment has a high risk. Thus, if the a discount rate is 0% (or smaller), as is the case here, this should prove favourable to investors. Even though the discount rate is currently favourable, this might not be true after 2020. To see what the impact is of different discount rates on the LCoE of the solar system, Table 6.21 was created. In order to perform the calculations for the LCoE, Formula 6.7 and the values from Table 6.19 were used.

Table 6.21: Overview of the effect of multiple discount rates on the LCoE.

Discount rate	**0%**	**1%**	**2%**	**5%**	**10%**	**11%**	**12%**
LCoE [€/kWh]	0.0648	0.0699	0.0753	0.0930	0.1254	0.1321	0.1388

From Table 6.21 it can be seen, as was already stated, that lower discount rate are preferable since they keep the LCoE lower. The table also shows that when the discount factor becomes 12% that the LCoE becomes higher than the electricity price that has to be paid to the electricity company. This indicates that, for Rijswijk, the project is financially feasible, and can thus be seen as a smart investment, until the discount factor is 12% or higher.

6.6 Conclusion

From the extensive PV and cost analysis performed in this chapter it can be concluded that a solar system of about twice the size would be needed to sustain the electrification of the entire company car fleet. Even though the designed system would not be capable of generating enough electricity to sustain the entire (company) car fleet, it still turned out to be a good investment.

As shown by the payback analysis, if the systems were implemented now, then a payback time of 4 to 5 years for TUI Rijswijk and TUI Enschede can be reached, respectively. An even lower payback time can be achieved when the installment of the PV system is postponed until 2025. This can be attributed to the cost decline of components required for the PV system, but also to the output increase due to an efficiency increase of the panels. Even if there were no more subsidies or grants provided by the government, then the payback time still proves to be acceptable with only an addition of half a year for TUI Rijswijk and roughly a year for TUI Enschede, compared to the 2019 situation.

Another indication of the PV system being a good investment was given by the LCoE calculated for both TUI Rijswijk and TUI Enschede. It turned out the costs per kWh were 52% and 45% lower for Rijswijk and Enschede, respectively, compared to what TUI currently needs to pay per kWh to the electricity company. By performing a sensitivity analysis with different discount rates (for TUI Rijswijk), it was found that as long as the discount rate is below 12% the investment remains financial feasible, since the LCoE remains smaller than the costs charged by the electricity company. Combining the payback time, the LCoE, and the fact that the electricity prices will only rise in the future, makes the installment of the rooftop PV systems a financial feasible and just investment.

Chapter 7

Discussion

A detailed discussion of each individual research question was already provided at the end of the respective chapters. This chapter thus only provides a short summation of the main conclusion(s) for each question. Additionally, it is discussed how these conclusions relate to previously done research on the respective subjects. Then, a reflection is given on the work done by determining the reliability and limitations of this work. Simultaneously, a closer look is taken at the generelizability of the results presented in this case study. Lastly, this chapter provides an advice, on how to proceed, to the company (TUI) where this case study was conducted.

7.1 Answering the Research Questions

In this thesis a case study approach was used to determine how companies can reduce their CO_2 emissions related to business and commuter travel. Early on it was decided to only look into EVs as a zero-emission vehicle since literature showed that other options like, FCEVs and biomass based vehicles, are not (yet) developed enough.

Looking at the first research question, it set out to determine which barriers employees encounter when transitioning to EVs and if a company can help in overcoming these barriers. Answers to this question were found by doing a quantitative survey amongst the employees. The TAM (Section 2.3.1) was used as the underlying theoretical framework for the generation and evaluation of the answers given in the survey. In the survey a division was made between people who drive their own car to work and the company car drivers. The results showed that the most important barriers, for all drivers, are the purchase price, the driving range of the EV, and the (limited) possibilities for charging (home, office and public). Taking a closer look into the division of both categories it was found that the barriers for the private car drivers are the same as given above and are also similar to previously done research like [82], [12], [42]. For the company car drivers on the other hand it was found that the purchase price is of less importance to them, and the driving range and charging possibilities matter most. Thus finding a (small) difference between the barriers of both categories.

As mentioned, the survey also provided insights into ways for companies to overcome these barriers. Both categories would really like for the company to provide a charging station at their homes. Additionally, company car drivers would like a compensation in the higher lease costs. Private car drivers, on the other hand, would like to be able to charge for free at the office. From the assessment of the proposed measures a noteworthy difference was found, in comparing to what was found in literature. Where [28] and [80] claim that information sessions can aid in overcoming operational barriers, the survey indicated the opposite, and this measure was rated lowest by both driver categories. Section 7.2 elaborates a bit more on what the reason(s) can be for this difference.

For the second research question a closer look was taken at how much CO_2 reduction (related to business and commuter travel) a company can realize and what the costs and benefits are of this reduction. Here the answers to the last question of the survey were used as an input. By applying the TAM framework to this question it can be said that if employees have the behavioral intention to use a new technology (which they indicated in that particular question), then this technology will actually be used. Applying this theory to the last question resulted in an achievable CO_2 reduction of 3.3% (worst case scenario). If the company is then also willing to provide additional (financial) stimulants, then a CO_2 reduction of 21.0% can be realized. After determining the number of transitioning employees, the cost and benefits were calculated for both company and employees. From these calculations it was then found that employees stand to gain a lot, financially, if all measures are implemented. This implies that the company will not have to implement all measures to still get enough of its employees to make the transition willingly. Remarkably, no literature was found that specifically looked at what it would take, financially, from a company point of view. Only privately owned EVs and its related costs and benefits were examined. Overall, the results presented for this group, in this thesis, are similar to those offered in other literature where different countries were analyzed ([82]). All results show that (privately) owning an EV (TCO) is cheaper compared to the ownership of an ICEV, especially when more miles are driven ([39] [55]).

The last research question looked at how rooftop PV systems can help with the increasing electricity need resulting from the charging of EVs. At the same time it considers the financial feasibility of such a system for companies. From the extensive analysis in Chapter 6 it was determined that, even though the system is not large enough to cover the entirety of EVs that need charging, it is still a good investment due to the low payback time and 52% reduction of electricity cost per kWh. The major impact of the charging of the EVs that was found during the PV analysis is in alignment with that discovered in other literature like [32], [38], and [54]. In [53] it was indicated that additional costs can be saved by using an optimal distribution of the energy from the panels to either the EVs or back to grid. It however appears to not be applicable to the current situation for companies in The Netherlands. This has to do with the fact that users (here: companies) pay a fixed amount for electricity and also receive a fixed amount when delivering back to the grid. Thus, strategically delivering back when energy prices are high (as suggested in [53]) is not an option for companies like this.

7.2 Limitations and Reliability of the Research

Even though the questionnaire was checked by multiple parties at the company, it still contained some dubious answer options. When asked about which measures, provided by the company, can help in overcoming the barriers one of the answer options for the private car drivers was the possibility to charge for free at the office. This is seen as dubious because, later on, it turned out that charging at the office is already free for all employees. However, since this measure was rated second highest by the respondents, it is clear that this is not a known fact to all employees. Nevertheless, because not all companies offer free charging for EVs on their grounds it can be seen as a good thing that this answer option was given as well. These companies now know about an additional measure that can stimulate the uptake of EVs in their car fleet. A second potential flaw of the questionnaire, that was discovered when processing the results, was already briefly discussed in Chapter 4 and indicated in the previous section. The information session was scored very low in comparison to literature that claimed it can be seen as a great way to overcome operational barriers. Probably more information should have been provided on what such an information session can entail, and that it also includes actually experiencing all aspects of an EV. Another disadvantages of the questionnaire used is that it contains a lot of closed questions. In Chapter 3 the reasoning behind this was discussed, but it can still be seen as a disadvantages since it might guide the respondents in a certain direction of answering.

The final limitation of this research is that the data regarding commuter travel (collected from TUI) was not accurate or complete. Not for all employees (especially TUIFly) it was known what their commuting distances are, for others no indicating was given on the amount of days they work, and others work on multiple locations which was also not indicated. Because of the incomplete and inaccurate data it is hard to say if the real distance travelled is equal, higher or lower than the Dutch average (13,000 km per year [16]). This is seen as a limitation because it cannot be said how this distance travelled might relate to other companies. If larger distances are driven it is logical that the driving range and charging station density are important barriers for transitioning to EVs. Whereas this might be less so when the distances travelled are smaller.

7.3 Reflection on the Research

Finally, a closer look can be taken at the generalizability of the results presented in this thesis, starting with the survey. In Chapter 4 it was determined that the results from the questionnaire are representative for the entire company, however, this does not immediately imply that the results are applicable to other companies. By examining the results of this research and previously done research (regarding barriers) it can be seen that both are similar. Because of this there is no reason to assume that the barriers will differ a lot for employees at other companies. Additionally, as a company, TUI is also not that different from others. In fact, due to the high rate of competitiveness in the tourism branch, and the setbacks with the Boeing 737 MAX, resulting in lower profits, it might actually be more difficult to make the transition in comparison to other companies due to its financial status. Moreover, due to the similarity of the barriers to previous research, it can also be assumed that the ways to overcome them will be similar for all companies as well. It will then depend on the financial situation whether or not a specific company can actually implement the measures. The nature of the implemented measures, like e.g. the financial stimulants for employees, can nonetheless still differ amongst companies. Companies will have to make their own decisions in this matter, but are nevertheless able to follow the example set throughout this thesis. All in all, there is no reason to assume this research is not applicable to other Dutch companies. Here an emphasis is placed on the nationality since The Netherlands has the highest EV charger density and it is a relatively small country which results in lower commuting distances, which fits nicely with the lower driving range of EVs compared to ICEVs.

As for the PV analysis, the conclusion are not one-on-one transferable to other companies, but the method used, can also be applied to other companies. In doing so other companies will also be able to reduce their costs related to the charging of EVs. In this particular research the rooftop PV analysis was done to support the increasing electricity usage through the charging of EVs. However, when a company does not have a car fleet, or all of their employees travel in a sustainable way, then the solar system can still be beneficial. As was seen in Chapter 6 the systems can reduce the costs of electricity by about 50% depending on its size.

7.4 Advice to the Company

This section elaborates on the validation session held at the company and, based on (among others) this session, an advice will be presented for the company.

7.4.1 Validation Session at the Company

Before publishing the results of this thesis a validation session was held at the company to gain some feedback on the findings this research has provided. Present during this meeting were the sustainability, facility and human resource managers. During this session some practical problems regarding the implementation of an all electric car fleet were mentioned. One of the issues raised was the fact that not all employees have their own private driveway or carport where the company can potentially place a charging station. If this is not the case, then the company would have to place the charging station on public ground which poses a potential problem with availability, since everyone is allowed to charge at a public charger. This was seen (by some) as a disadvantages since this way the company would invest in a charging station for its employees that might not be available to the employee at all times and, in this way, the purpose of this potential measure is lost.

Other practical issues that were raised were regarding the installment of the rooftop solar system to provide the energy needed for charging the EVs, and the potential installment of fast chargers at the office. Currently, the network at TUI does not have the capacity to handle the current flows that accompany these heavy duty systems. The transformers will first need to be replaced to be able to handle the larger current flows. This replacement requires the office to shut down for a couple of days which will bring about the practical problem over where to house roughly 800 employees for these days.

During the validation session it was also made clear that by implementing all of the potentially stimulating measures, the company would grant its employees a lot of additional financial benefits. One of the larger contributions in these yearly benefits for transitioning drivers would originate from the higher travel allowance. Because of this, and the fact that is was not (one of) the highest ranked measures, it was already decided that this measure will not be implemented when trying to stimulate people to make the transition.

Based on the results presented in this thesis and the validation session at the company, it is now possible to present an advice for the company on how to proceed, which will follow in the next paragraph.

7.4.2 Advice for the Company

Based on the results discussed throughout this thesis, the advice to TUI would be to use this thesis, and in particular the medium case scenario where all the lease car drivers transition, as a starting point for reducing the emissions related to business and commuter travel. It is also recommended to do the transition of the lease car fleet more gradually, instead of all at once. Due to the amount of fines related with terminating the lease contracts prematurely it is suggested that TUI starts by only offering EVs as a lease car for the contracts that end from now onward. Additionally, they can offer any lease driver, that is willing to transition, the possibility to transition to an EV right now. This will limit the amount of fines that have to be paid. Moreover, TUI should make all of its pool cars (vans excluded) electric or hybrid. In this way employees who still think these cars are 'too much of a hassle' can experience these cars themselves and hopefully some of thier barriers will be taken away. For the pool cars, hybrid vehicles should remain an option since charging at the TUI locations in Belgium is not always an option.

Because of the potentially high financial gains that employees can receive when implementing all of the proposed measures it is also advised to not offer a doubling of the travel allowance or the subsidy of €2,500. The travel allowance is currently used to pay for the gasoline needed to fuel the car, but this will not be necessary anymore if TUI pays for charging the EV. Therefore it is recommended that, in the future, when EVs are price competitive with their ICEV counterparts, the travel allowance should be abolished for everyone. If there is no more travel allowance, or a very low one, and TUI pays for charging this might provide an extra stimulant for people to transition towards EVs. As for the €2,500 subsidy, the questionnaire indicated that this measure was not one of the highest ranked measures. Furthermore, this subsidy can also be seen as an unfair 'reward' for the polluters (employees that drive a car to work) by the employees that already travel in more sustainable ways to work, like, for example, by train or bike.

From the feedback session it was gathered that there were mostly practical problems with the placement of the charging stations, which is the highest ranked measure. On this matter it is advised to just put the charger on public ground, if this were the only option left. In doing so TUI can make a statement in wanting to work towards a more sustainable future. They can potentially also put some advertisement, like their logo, on the charging station. In this way it will pay itself back in no time through costs saved on advertisement.

Finally, considering TUI's claim of being a sustainable tour operator, it is also advisable to reconsider the placement of solar panels on the rooftop of the building in Rijswijk. Apart from the low payback time and the savings resulting from this system, it will also make a grand statement which will result in a lot of positive advertisement. It will also put TUI back on the map as a sustainable tour operator.

Chapter 8

Conclusions and Future Work

In this chapter the main findings of this case study are discussed as well as some recommendations. At the end of this chapter these recommendations and ideas for future research are discussed more elaborately.

8.1 Conclusions

The main aim of this thesis was to investigate how companies can reduce their CO_2 emissions of business and commuter travel, and if rooftop PV systems can help in reducing the costs related to this transition. Based on the analysis done in this thesis it can be concluded that a significant reduction in emissions is possible, if only a company is willing to invest and commit to the intended transition. The (financial) results of the cost and benefit analysis indicate that a company does not necessarily has to implement all measures proposed to encourage employees to drive electrically. Just by implementing some of the measures employees stand to gain financially, and this will likely be enough for them to make the transition.

Using the TAM framework to generate, and analyze the answers given to, the quantitative survey, that was held at the start of this research, made it possible to determine the barriers against electric driving, and more importantly, find ways to overcome these. According to the survey, the main concerns of employees are the limited driving range, the higher lease price, and the (limited) possibilities for charging the vehicle. The survey also proved useful in providing ways to overcome these barriers. In detail, for company car drivers this entails receiving a free charging station to be able to charge at home and getting a compensation in the higher lease prices. Providing a charging station at home does bring some challenges regarding liability and ownership when the receiver does not have its own private driveway. Further research will be necessary to determine how employees can still benefit from a charging station provided by their employer when the station cannot be placed on private property and everyone is thus allowed to use it. For the private cars drivers an additional way was found to overcome the barriers, namely; being able to charge for free at the office. Lastly, the survey also provided insights into the willingness of employees to transition to

EVs. It was found that there is still a considerable amount of employees who do not want to make the transition in spite of any (financial) effort a company puts in. This raises the question on how to motivate this particular group of people. A partial answer was found through the survey. From the feedback the open-ended questions provided it was found that some people still have (unjust) biases against EVs. These need to be taken away for this group to ever be willing to transition to EVs. Therefore, it was assumed that most employees can benefit a lot from an information (and testing) session, even though they, themselves, indicated that such a session was not necessary. More research on how best to organize such a session and what proves to be most efficient is left for future studies.

Furthermore, this research also indicated that implementing a carbon tax for all Dutch companies, instead of only for large (polluting) industries, will likely have little effect on the speed of the electrification of car fleets in general. The savings that can be obtained by not having to pay this tax are low compared to the costs a company has to make when stimulating its employees to drive electrically. Additionally this research also illustrated that rooftop solar systems can considerably reduce the costs associated to the charging of the electric vehicles. It was proven that, at current discount rates (0%), a PV system can provide energy at roughly half the rate of the electricity company, which will make the system pay itself back within 4.2 years. As long as the discount rate keeps the LCoE below the electricity costs charged by an electricity company, the investment in solar systems can be seen as financial feasible. Seeing short payback times and a low LCoE is expected to increase support for solar systems across all companies (in The Netherlands), even when they do not plan on electrifying their car fleet. Since the research was conducted at a specific company with a specific rooftop layout, this does not mean that the outcome can be generalised. If other systems produce smaller yields due to a smaller area being available for solar panels, or other car fleets are larger, the impact of the cost reduction for the charging of EVs has to be adjusted as well.

Based on the research done, no reasons were found for this research to not be applicable to other companies in The Netherlands. Especially the results of the questionnaire can be seen as generalizable, since there is no reason to expect employees to feel different towards EVs, and their barriers, at other companies. As for the costs and benefits associated with the transition, and the realization of rooftop solar systems, the approach used in this thesis can be administered by all (Dutch) companies. The final results will however differ and depend on what measures are taken by a certain company. For the cost and benefit analysis this depends on how many people can be persuaded to transition, but also on what measures a company chooses to implement. As for the solar systems, the yield and resulting cost reduction from such a system is different for all locations and system sizes.

In short, this particular case study shows that by transitioning to EVs, in a smart and feasible manner, a company is relatively easily capable of significantly reducing its CO_2 emissions related to business and commuter travel. These emissions can then be even further reduced if the energy required for charging of the vehicles is produced by solar panels. At the same time a company using solar panels can also reduce its costs related to charging, since power produced by solar panels is always less expensive than buying it from electricity companies.

8.2 Future Work

There are a couple of things that can be considered for future research. Firstly, a multitude of zero emissions vehicles were considered at the start of this research, most of which got discarded due to their lack of development. In future works, these technologies, especially the hydrogen vehicles, can be reviewed again and at the same time it can be investigated if people respond better to this technology. The similarities of this vehicle in comparison with ICEVs might be what persuades the employees that are still hesitant or unwilling to transition towards zero emission vehicles. Secondly, the literature study briefly touched upon the implementation of battery charging stations for companies, instead of using charging stations. Due to the limit amount of time available for this thesis it was decided to not look further into how this can be applied on a company scale, which leaves it open for future research to be studied. Then, as was already briefly indicated in the previous section, a future study could look into ways to stimulate the particular group of people who are not willing to transition. How can this specific group be persuaded to drive electrically and are the potential costs involved in this worth it or should companies just wait until no more gasoline cars are sold. Or are these people maybe willing to transition to hydrogen cars. Some food for thought. Another point for future research is investigating the possibilities of smart charging and what is, and is not, useful in company applications. It can not be expected that companies have as many charging stations available as there are employees driving electrically.

Moreover, the literature study also indicated that charging costs can be limited for companies when any form of smart charging is implemented. Apart from reducing costs a smart charging infrastructure can also aid in limiting the amount of charging stations that are needed and help in determining which gets priority in charging.

The last possibility for future research that this thesis will name is the applicability of vehicle-to-grid in relation to all the electric vehicles. Electricity prices, especially those related to renewable energy, can be very volatile. If a lot of energy is produced and when demand is low, the prices will be low as well. The opposite is also true, when there is a peak demand, and less energy available, then the prices will be high. By using the vehicle-to-grid (and additionally the grid-to-vehicle) technology, a company can potentially charge its EV fleet when the prices are low and then, when the electricity prices are higher decide to use some of the energy stored in the batteries of the EVs. Research has already been done into this technique for home owners, now it could be interesting to see if it can also benefit companies, assuming the energy prices are not fixed.

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Appendix A

Sample Size and Error

A.1 Sample Size Calculations

Formulas used for calculating the sample size [17]:

$$Sample\ Size = \frac{(Zscore)^2 \cdot p \cdot (1-p)}{Degree\ of\ Allowed\ Error^2} \tag{A.1}$$

$$Sample\ Size\ adjusted = \frac{(Sample\ Size)}{1 + \frac{(Sample\ Size - 1)}{Population}} \tag{A.2}$$

Known variables:

- Total population: 568
- Confidence level : 95%
- Degree of allowed erros: 5%
- Z-score: has a default value of 1.96 for a confidence level of 95%
- p: 0.5

First Formula A.1 is used to calculate the sample size. When using the values, given above, in the formula a result of 381.16 is obtained, see Formula A.3.

$$Sample\ Size = \frac{(1.96)^2 \cdot 0.5 \cdot (1-0.5)}{0.05^2} \tag{A.3}$$

Since, in this case, the total population is known, Formula A.2 needs to be used in order to obtain the actual sample size needed. After filling in the formula an adjusted sample size of 229.41, which is rounded to 229, is found. See also A.4 below.

$$Sample\ Size\ adjusted = \frac{(384.16)}{1 + \frac{(384.16-1)}{568}} \tag{A.4}$$

A.2 Degree of Allowed Error

In order to calculate the allowed error Formulas A.1 and A.2 can be used again. The known variables are also the same as indicated in above, but now the amount of respondents is also known and can be added to the list:

- Sample size adjusted (= respondents): 176

With this variable known, Formula A.2 can be used to calculate the sample size, as indicated below in Formulas A.5 till A.7.

$$176 = \frac{(Sample\ Size)}{1 + \frac{(Sample\ Size - 1)}{568}} \tag{A.5}$$

$$176 = \frac{568 \cdot (Sample\ Size)}{567 + Sample\ Size} \tag{A.6}$$

$$Sample\ Size = 254.57176 \tag{A.7}$$

Now that the sample size is known, Formula A.1 can be used to calculated the degree of allowed error. Filling in all known value results in:

$$254.57 = \frac{(1.96)^2 \cdot 0.5 \cdot (1 - 0.5)}{Degree\ of\ Allowed\ Error^2} \tag{A.8}$$

This then results in a degree of allowed error of:

$$Degree\ of\ Allowed\ Error = \sqrt{\frac{(1.96)^2 \cdot (0.5)^2}{254.57}} = 0.0614 \tag{A.9}$$

Which is equal to 6.14%

Appendix B

Chi-Square Goodness of Fit Test

The Chi-square test is used to calculate whether or not the sample data matches the population. The formula [71] used to calculated is shown below:

$$\chi^2 = \sum \frac{(O-E)^2}{E} \tag{B.1}$$

with

- O = Observed value
- E = Expected value

In Table 4.1 values are shown for the response. This response is equal to the observed values needed to calculate the chi-value. The expected value can be found by multiplying the percentage of approached people, for each category (80.6% and 19.4%), with the total response (176). The values are given in Table B.1 below.

Table B.1: Observed and expected values for the lease and private car drivers

	Observed	**Expected**
Private Car	136	142
Lease Car	40	34

Using these values the formula becomes as follows:

$$\chi^2 = \frac{(136-142)^2}{142} + \frac{(40-34)^2}{34} = 1.31 \tag{B.2}$$

Since the degrees of freedom is equal to n-1, and here there are 2 categories, there is only 1 degree of freedom. With this knowledge the table shown in Figure B.1 can be used to find the p-value related to this chi-square value. Here a p-value of roughly 0.25 = 25% is found. According to theory [71] a p-value smaller than 5% (0.05) indicates that a difference is significant.

For Table B.2 the same is done to find the expected values and again Formula B.1 can be used to determine the chi-square value, see B.3 below.

Table B.2: Observed and expected values for board members, managers and employees

	Observed	**Expected**
Board member	3	1
Manager	53	31
Employee	120	144

$$\chi^2 = \frac{(3-1)^2}{1} + \frac{(53-31)^2}{31} + \frac{(120-144)^2}{144} = 23.6 \tag{B.3}$$

In this case there are 3 variables and thus the degree of freedom is equal to 2. Using the table given in Figure B.1 again, gives a p-value that is smaller than 0.01 = 1%. Since the p-value <5% the chi-square test indicates that there is a significant difference between the values.

Percentage Points of the Chi-Square Distribution

Degrees of Freedom	Probability of a larger value of x^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.28	19.68	24.72
12	3.571	5.226	6.304	8.438	11.340	14.85	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.037	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.42	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.89	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	66.98	74.40	79.08	88.38

Figure B.1: Chi-square distribution values [60]

Appendix C

Sun's Position

In order to express to position of the Sun, relative to Earth, an ecliptic coordinate system can be used [67]. Firstly, the elapsed time since Greenwich noon (January 1st 2000), described by D, needs to be calculated. To do this, the Julian date (JD) is related to D. The Julian date defines the number of days that have passed since 24 November 4717 BC.

$$D = JD - 2451545.0 \tag{C.1}$$

The mean longitude and anomaly (q and g, respectively) of the Sun are calculated with the help of D. The longitude is corrected to the aberration of the light and given in Formula C.2. As for the anomaly, it is corrected for the varying speed of the Earth and given in Formula C.3.

$$q = 280.459^\circ + 0.98564736^\circ \cdot D \tag{C.2}$$

$$g = 357.529^\circ + 0.98560028^\circ \cdot D \tag{C.3}$$

Next, the ecliptic longitude was calculated by Formula C.4.

$$\lambda_S = q + 1.915^\circ \cdot \sin g + 0.020^\circ \cdot \sin 2g \tag{C.4}$$

Since it is beneficial for PV systems to express the Suns location using a horizontal coordinate system, these ecliptic coordinates need to be transformed. To do this, first an angle is defined so the transformation can be made from the ecliptic to the equatorial coordinates as shown in Formula C.5.

$$\varepsilon = 23.429^\circ - 0.00000036^\circ \cdot D \tag{C.5}$$

Finally, the local mean sidereal time θ_L has to be calculated. In order to calculate this, first the Greenwich mean sidereal time (GMST), given in Formula C.6 and the Terrestrial Time (the number of centuries past since Greenwich noon) T, given in Formula C.7 need to be calculated.

$$GMST = 18.697374558 \cdot h + 24.06570982441908 \cdot h \times T^2 \tag{C.6}$$

$$T = \frac{D}{3625} \tag{C.7}$$

The local mean sidereal time is then found by using Formula C.8 below.

$$\theta_L = GMST \cdot \frac{15^\circ}{h} + \lambda_0 \tag{C.8}$$

After all these calculations only the longitude and latitude of the observer (λ_0 and ϕ_0, respectively) are still needed to determine the exact position of the Sun for a given location and time. The resulting azimuth and altitude of the Sun are indicated by A_S (Formula C.9)and a_S (Formula C.10), respectively:

$$\tan(A_S) = \frac{-\sin(\theta_L)\cos(\lambda_S) + \cos(\theta_L)\cos(\varepsilon)\sin(\lambda_S)}{-\sin(\phi_0)\cos(\theta_L)\cos(\lambda_S) - (\sin(\phi_0)\sin(\theta_L)\cos(\varepsilon) - \cos(\phi_0)\sin(\varepsilon))\sin(\lambda_S)} \tag{C.9}$$

$$\sin(a_S) = \cos(\phi_0)\cos(\theta_L)\cos(\lambda_S) + (\cos(\phi_0)\sin(\theta_L)\cos(\varepsilon) + \sin(\phi_0)\sin(\varepsilon))\sin(\lambda_S) \tag{C.10}$$

Appendix D

Yearly Irradiance

The yearly irradiance incident on a PV panel was calculated for the position of the module [67]. Both the azimuth and altitude of the module, A_M and a_M respectively, were calculated relative to the Suns position. To do this the formulas below were used. Firstly, it is important to know the altitude of the module. This can easily be calculated with Formula D.1 below, where θ_M represents the tilt of the PV panel.

$$a_s = 90 - \theta_M \tag{D.1}$$

Now, the irradiance on the PV module can be described by Formula D.2 and is made up of the sum of three different components of the radiation.

$$G_M = G_M^{dir} + G_M^{diff} + G_M^{ground} \tag{D.2}$$

G_M^{dir} is denoted as the direct component of the radiation, which is related to the Direct Normal Irradiance (DNI) and the angle of incidence as shown in Formula D.3. The Formula for calculating the angle of incidence is depicted by Formula D.4.

$$G_M^{dir} = DNI \cdot \cos\gamma \tag{D.3}$$

$$\cos\gamma = \cos(a_M)\cos(a_S)\cos(A_M - A_S) + \sin(a_M)\sin(a_S) \tag{D.4}$$

G_M^{ground} is the radiation component that reflects the irradiance reflected by the ground. It is derived from the Global Horizontal Irradiance (GHI), the Sky View Factor (SVF), and the albedo of the ground, which is given by α. The dependency on these factors is shown in Formula D.5.

$$G_M^{ground} = GHI \cdot \alpha \cdot (1 - SVF) \tag{D.5}$$

The GHI and SVF from Formula D.5 can be calculated using the two equations shown below.

$$SVF = \frac{1 + \cos\theta_M}{2} \tag{D.6}$$

$$GHI = DNI \cdot \cos a_S + DHI \tag{D.7}$$

Finally, the G_M^{diff} component is calculated by Formula D.8. G_M^{diff} is the diffuse radiation component is de radiation collected from the scattered light beam. It is derived from the Diffuse Horizontal Irradiance (DHI), the SVF, and the GHI.

$$G_M^{diff} = DHI \cdot SVF + GHI \cdot \frac{(0.012(90^\circ - a_S) - 0.04) \cdot (1 - \cos\theta_M)}{2} \tag{D.8}$$

Appendix E

Fluid Dynamics

To be able to accurately calculate the solar module temperature TM, the convective and radiative heat exchange, and the heat received by the irradiation were combined in Formula E.1. [67].

$$T_M = \frac{\alpha \cdot G_M + h_c \cdot T_a + h_{r,sky} \cdot T_{sky} + h_{r,gr} \cdot T_{gr}}{h_c + h_{r,sky} + h_{r,gr}} \tag{E.1}$$

In this formula α represents the absorptivity of the module, G_M is the irradiance from the Sun, the ambient temperature is given by T_a, and the sky and ground temperature are given by T_{sky} and T_{gr} respectively. The absorptivity is defined in Formula E.2.

$$\alpha = (1 - R) \cdot (1 - \eta) \tag{E.2}$$

The cloud coverage influences the value of Tsky. When the coverage is above 6 okta, T_{sky} is equal to the ambient temperature (T_a). If it is below 6 okta, T_{sky} can be defined as in Formula E.3.

$$T_{sky} = 0.0552 \cdot T_a^{3/2} \tag{E.3}$$

Since the equations for $h_{r,sky}$ and $h_{r,gr}$ are also a function of the module temperature they must be solved iteratively. h_c from Formula E.1 represents the total convective heat transfer which, in turn, consists of the convective heat transfer on the top and rear surface,h_c^T and h_c^B respectively.

$$h_c = h_c^B + h_c^T \tag{E.4}$$

To calculate the convective heat on the top surface first the forced and free convective heat transfer need to be determined. For the forced component a distinction has to be made between laminar and turbulent convective heat transfer. The formulas are given by Formula E.5 and Formula E.6, respectively.

$$h_{forced}^{lam.} = \frac{0.86 \cdot Re^{-0.5}}{Pr^{0.67}} \cdot \rho \cdot c_{air} \cdot w \tag{E.5}$$

$$h_{forced}^{turb.} = \frac{0.028 \cdot Re^{-0.2}}{Pr^{0.4}} \cdot \rho \cdot c_{air} \cdot w \tag{E.6}$$

In both formulas Re represents the Reynolds number which expresses the ratio of the inertial forces to the viscous forces:

$$Re = \frac{D_h \cdot w}{v} \tag{E.7}$$

w is the wind speed, v the kinematic viscosity. D_h describes the hydraulic diameter of a module with length L and width W and is given in Formula E.8.

$$D_h = \frac{2 \cdot L \cdot W}{L + W} \tag{E.8}$$

The Reynolds number indicates where the boundary between the laminar and turbulent flow lies. This boundary lies at 120000. If Re is higher, then the turbulent flow is dominant otherwise the laminar flow is dominant.

Now the free convective heat flow needs to be determined. This can be done with the equation in E.9.

$$Nu = \frac{h_{free} \cdot D_h}{k} = 0.21 \cdot (Gr \times Pr)^{0.32} \tag{E.9}$$

In this equations Nu is the Nusselt number, Gr is the Grashof number, and Pr is Prandtl number. Where Gr can be calculated by the formula below:

$$Gr = \frac{g \cdot \beta(T - T_a) \cdot D_h^3}{v^2} \tag{E.10}$$

In Formula E.10, β represents the volumetric thermal expansion coefficient of air which can be estimated by Formula E.11. g on the other hand is the gravitational acceleration of Earth, which is a known constant.

$$\beta = \frac{1}{T} \tag{E.11}$$

Now that both the forced and free components of the convective heat transfer are known, the convective heat transfer on top of the module can be calculated by Formula E.12.

$$h_c^T = \sqrt[3]{h_{forced}^3 + h_{free}^3} \tag{E.12}$$

The convective heat transfer on the rear surface can be calculated with Formula E.14, and is defined by multiplying h_c^T with R, as in Formula E.13 below.

$$h_c^B = R \cdot h_c^T \tag{E.13}$$

R represents the ratio of the actual heat loss to the ideal heat loss at the back side of the module.

$$R = \frac{\alpha \cdot G_M - h_c^T \cdot (T_{INOCT} - T_a) - \varepsilon_{top} \cdot \sigma \cdot (T_{INOCT}^4 - T_{sky}^4)}{h_c^T \cdot (T_{INOCT} - T_a) + \varepsilon_{back} \cdot \sigma (T_{INOCT}^4 - T_{ground}^4)} \tag{E.14}$$

Appendix F

Module Performance

F.1 Effect of the Temperature on the PV Module

When the temperature of the module deviates from STC ($25°C$) this has consequences for the performance of the PV module. This effect is expressed by the temperature coefficients that are provided in the datasheets, by PV manufacturers. Knowing the temperature coefficients of the parameters; V_{OC}, I_{SC}, P_{MPP} and η, makes it possible to use Formulas F.1 - F.4 [67] to estimate the V_{OC}, I_{SC}, P_{MPP} and η for all cell temperatures (T_M).

$$V_{OC}(T_M, G_{STC}) = V_{OC} + \frac{\partial V_{OC}}{\partial T}(STC)(T_M - T_{STC}) \tag{F.1}$$

$$I_{SC}(T_M, G_{STC}) = I_{SC} + \frac{\partial I_{SC}}{\partial T}(STC)(T_M - T_{STC}) \tag{F.2}$$

$$P_{MPP}(T_M, G_{STC}) = P_{MPP} + \frac{\partial P_{MPP}}{\partial T}(STC)(T_M - T_{STC}) \tag{F.3}$$

$$\eta(T_M, G_{STC}) = \frac{P_{MPP}(T_M, G_{STC})}{G_{STC}, A_M} \tag{F.4}$$

A_M in F.4 represents the area of the module, and the differential equations in F.1, F.2, and F.3 are the previously discussed temperature coefficients.

F.2 Effect of the Irradiance on the PV Module

The effect of the varying irradiance on the module (G_M) can be found using Formulas F.5 - F.7 [67].

$$V_{OC}(25°C, G_M) = V_{OC} + \frac{nk_BT}{q} ln(\frac{G_M}{G_{STC}}) \tag{F.5}$$

$$I_{SC}(25°C, G_M) = I_{SC}(STC)\frac{G_M}{G_{STC}} \tag{F.6}$$

$$P_{MPP}(25°C, G_M) = FF \cdot V_{OC}(25°C, G_M) \cdot I_{SC}(25°C, G_M) \quad \text{(F.7)}$$

With the equations given above the resulting module efficiency, under STC and a varying G_M, was found and is depicted by Formula F.8.

$$\eta(25°C, G_M) = \frac{P_{MPP}(25°C, G_M)}{A_M, G_M} \quad \text{(F.8)}$$

From this formula it can be seen that there is a linear relation between the power output of the PV system en the irradiance incident on it. The output will thus be lowered when the irradiance on the module is lower.

F.3 Overall Module Performance

Knowing the dependency of the module on both the temperature and the irradiance, it was possible to form a formula for the final efficiency of the module at all temperatures and light intensities.

$$\eta(T_M, G_M) = [1 + k(T_M - 25°C)] \cdot \eta(25°C, G_M) \quad \text{(F.9)}$$

The value for k can be found in the datasheet of the PV module.

Appendix G

SNL Model

In the SNL model the relation between the DC input power and the AC output power of an inverter is given by equation shown below in Formula G.1 [67].

$$P_{AC} = [\frac{P_{AC_0}}{A-B} - C(A-B)] \cdot (P_{DC} - B) - C(P_{DC} - B)^2 \tag{G.1}$$

The coefficients A, B, and C are defined by Formula G.2, G.3, and G.4, repsectively.

$$A = P_{DC_0}\,[1 + C_1(V_{DC} - V_{DC_0})] \tag{G.2}$$

$$B = P_{S_0}\,[1 + C_2(V_{DC} - V_{DC_0})] \tag{G.3}$$

$$C = C_0\,[1 + C_3(V_{DC} - V_{DC_0})] \tag{G.4}$$

The parameters in the above shown equations represent [67]:

P_{AC}: AC output power from the inverter in [W].

P_{DC}: DC input power of the inverter in [W].

V_{DC}: DC input voltage in [V].

P_{AC_0}: The maximum rated AC power (upper limit) in [W].

P_{DC_0}: DC power level at which the rated AC power is achieved in [W].

V_{DC_0}: DC voltage level at which the rated AC power is achieved in [V].

P_{S_0}: Self-consumption of the inverter in [W]

C_0: The curvature showing the relation between the AC and DC power at the reference operating condition in $[\frac{1}{W}]$

C_i: The empirical coefficient in $[\frac{1}{V}]$

Appendix H

Car Fleet Composition

H.1 Terminating Lease Contract Early

Per lease car Arval gives an indication of the additional price that has to be paid for every day the lease contract is terminated prematurely. Also given are the amount of days still left on the contract. Since both these costs and days left differ for each car, it was decided to use average values. The average values were taken for every six months, so every six months a certain set of contracts end, and then the average values for the amount of days left and the costs associated with this were taken. An overview of this can be found in Tables H.1 and H.2. In the first table it is given how many months and days there are still left in the contract. An average is taken of all the cars, per half year. In the last two columns of this table it is given how many cars there are for each half year period and the distribution in percentages, respectively. In the second table the average daily costs for terminating the contract earlier are given. Using these values and the previous calculated average amount of days left, made it possible to calculate the average total amount that has to be paid when the contract is terminating before the end date. This is depicted in the third column of Table H.2. The last column shows the average total amount that has to be paid if all contracts, for that specific time period, are terminated early.

H.2 Compensating the Personal Contribution

From Table 3.3 in Section 3.2.1.2 it can be seen that the lowest lease driver category can choose cars up to €821 per month, without having to pay any additional costs themselves. From the Arval website it could then be determined that the available EVs range from roughly €820 (Nissan Leaf 40kWh) to €1,017 (Opel Ampera-e Business Excutive). For the other categories, the maximum amount is €1,082 (Tesla Model 3, 50kWh), if all the more luxurious cars like the Jaguar and Tesla (75kWh) are excluded from the proposed compensation regulation. Using the first two driver categories people currently have to pay between €0 and €195.60 if they belong to category C and between €0 and €148.86 for category D/E/F. Assuming that people, on average, were to lease a Hyundai Kona 64kWh

Table H.1: Overview of the average amount of days left on the contract per period and the number of cars for each period.

Period until contract expires	**Average amount of months until contract expires**	**Average amount of days until contract expires**	**Number of vehicles**	**Percentage**
0.5 years	3.6	109.8	23	21.5%
1 years	7.7	234.85	20	18.7%
1.5 years	16.1	491.05	7	6.5%
2 years	21.6	658.8	12	11.2%
2.5 years	28	854.0	4	3.7%
3 years	33.5	1,021.75	10	9.3%
3.5 years	39.3	1,198.65	13	12.1%
4 years	45.3	1,381.65	18*	16.8%
			107	

∗ Here the cars that are already electric are left out of this calculation since these cars do not need to be traded in.

Table H.2: Overview of the average and total costs for terminating the contract early.

Average amount of days until contract expires	**Average daily price (per car) for terminating the contract earlier in [€]**	**Average total amount (per car) until contract expires**	**Average total costs for all cars in [€]**
109.8	13.23	1,452.65	33,411.04
234.85	15.32	3,597.90	71,958.04
491.05	13.21	6,486.77	45,407.39
658.8	12.63	8,320.64	99,847.73
854.0	9.53	8,138.62	32,554.48
1,021.75	8.72	8,909.66	89,096.60
1,198.65	10.91	13,077.27	170,004.53
1,381.65	11.54	15,944.24	286,996.34
		829,276.15	

Comfort, or similar (∼ €884), the company would have an additional cost item of €63 per month per lease driver. This can be seen as an reasonable assumption, since most category C drivers might go over, but almost all category D/E/F drivers will be able to lease an EV without going over the amounts specified in Table 3.3 for their category.

H.3 Additional Lease Costs

Apart from compensating the personal contribution there are also the additional costs from leasing EVs that have to be considered. Currently, the average monthly costs for the lease car fleet of TUI is about €714. Examing the EVs that are offered by Arval reveals that, on average, the EVs will have a monthly fee of €920. Table 3.3 can now be used to determine what the company will pay, on average, for each lease car (without the compensation that was calculated above). Using the amount of people per category, and the fact that the C category can lease up to €821 and the D/E/F up to €919, it could be determined that the monthly fee will be, on average, €876 per lease car. By subtracting the old average (€714) from the new found value, an additional monthly fee of €162 per car was found.

H.4 Swapping Possibility for Holidays

Private car owners that want to swap their EV when going on a holiday can not swap their car at the lease company. TUI can choose to provide a rental car for this group for the duration of the holiday. Figure H.1 below shows a viable option. In this scenario a large stationwagon is rented from Sixt for the duration of three weeks in July. The total costs of this period, including some necessary insurances, amount to €1,655.

H.5 Charging Costs for Private Car Drivers

Assumptions:

- 80% charging at the office, 15% charging at home, 5% charging at public charging stations.
- Each private car owner drives 18,014.3 km per year, see Table 3.5 in Chapter 1.5.
- EVs use about 0.176 Kwh per km [31].
- Electricity price for charging at the office is, on average: €0.125/kWh.
- Electricity price through solar panels: €0.065/kWh. This was calculated in Section 6.5.2.
- Electricity price for charging at home: €0.23/kWh.
- Electricity prices for public charging [78]:
  - regular: €0.34/kWh.
  - fast charging: €0.69/kWh.
- In Table 6.10, Section 6.4.3 it was determined that solar panels can provide roughly 97.07 MWh per year.
- 105 private car owners will switch towards an EV.
- A gasoline car drives 15 km for every liter of gasoline.
- The gasoline price is €1.76 per liter [5]

Using these assumptions it could be determined that about 3.17 MWh is needed per year, for each private car driver. If this electricity comes entirely from the grid, then it would result in a cost item of €380. If the solar panels would be responsible for all of this, then this cost item would only be €206.

In Chapter 6 it was already assumed that about 80% of the time the vehicles will be charged at the office. In the medium case scenario it is assumed that 105 private car owners switch, so this would result in an additional electricity need of 266.3 MWh for all the transitioning private car owners. From Chapter PV it was determined that rooftop solar panels will be able to produce roughly 97 MWh on a yearly basis, which is 36.4% of the electricity needed for the private car owners. If 97 MWh came from solar panels and the other 169.2 MWh from regular (net) charging, then the total costs for charging at the office will amount to €21,156.63. This will come down to about €261 per driver per year.

Then assuming 15% of the charging is done at home, then a total of 49.9 MWh per year will be charged at home, resulting in a yearly cost item of roughly €11,485. This amount to €109 per private car owner, per year.

The last 5% will be charged at public charging stations, which is 16.6 MWh. For public charging is is also assumed that half of the time fast charging will be used and regular charging the rest of the times. Using these and the assumption given above will result in a yearly amount of €8,572 for all private car drivers, and thus roughly €82 per private car driver.

If all these charging costs are accumulated this results in a yearly cost item of about €464 per driver.

From the assumptions above it could also be estimated that private care drivers currently use about 1,200 liter of gasoline per year. This amount to a cost item of €2,114 on a yearly basis.

H.6 Charging Costs for Lease Car Drivers

Assumptions:

- 80% charging at the office, 15% charging at home, 5% charging at public charging stations.
- Each lease driver drives up to 15,856.5 km per year, see Table 3.4 in Chapter 1.5.
- EVs use about 0.176 Kwh per km [31].
- Electricity price for charging at the office is, on average: €0.125/kWh.
- Electricity price for charging at home: €0.23/kWh.

- Electricity prices for public charging [78]:
  - regular: €0.34/kWh.
  - fast charging: €0.69/kWh.
- All lease drivers (110) drive electrically.
- A gasoline car drives 15 km for every liter of gasoline.
- The gasoline price is €1.76 per liter [5]

Although the assumptions indicated above are similar to the ones for the private car drivers, the difference is that charging through the PV systems can no longer be taken into account for the lease car drivers. This is due to the fact that all the produced electricity is already consumed by the EVs of the private car owners.

Using the assumptions above it could be determined that a lease car driver needs roughly 1,057 liter of gasoline per year. This amounts to €1,861 per driver, per year. When a lease car driver switches to an EV, about 2.79 MWh of electricity is needed each year. Using the distribution indicated under the assumptions, this 2.79 MWh will cost roughly €447. So, the transition towards EVs saves roughly €1,414 per year, per lease car driver.

H.7 Costs for Lease Car Drivers

The placement and installment of the charging station was estimated to be between €600 - €2,000. Knowing that the tax additional tax liability is 4% in the case of electric cars, and knowing that highest tax bracket in the Netherlands has a rate of 51.75%, results in a maximum one-off cost item of €2,000*4%*51,75% = €41.40.

H.8 Benefits for Lease Car Drivers

In order to calculate the benefit a lease driver will have from the lower additional tax liability rate for EVs, a couple of variables have to be known, namely; *financial value of the car* and *tax bracket the employee falls under*. In Table H.3 a comparison is given on the tax liability that has to be paid for an EV and ICEV. For this table it is assumed that someone falls within the 38.10% tax bracket. In Table H.4 the same was done, but then for the 51.75% tax bracket. The lowest tax bracket of 36.65% was left out, since the survey showed that the lease driver earn more than €20.384 per year, which is the upper limit of the lowest tax bracket. As for the financial costs of the car, different amounts were taken to show how the tax liability changes over the years. In [69] it was indicated that the tax liability rate will increase from 4% in 2019 to 12% in 2021, and eventually to 22% in 2026. When calculating the tax values it was also taken into account what the maximum value of the EV is that falls under the 4%, 8% and 12% rate. These are €50,000, €45,000, and €40,000 respectively. After 2021 the amount remains €40,000.

Table H.3: Overview of the additional tax liability for different rates, when the 38.10% tax rate is applied.

	Additional tax liability per year			
Financial value of the car	ICEV (22% tax rate)	EV (4% tax rate in 2019)	EV (8% tax rate in 2020)	EV (12% tax rate in 2021)
€30,000	€2,514.60	€457.20	€914.40	€1,371.60
€40,000	€3,552.80	€609.60	€1,219.20	€1,828.80
€50,000	€4,191	€762	€1,790.70	€2,667
€60,000	€5,029.20	€1,600.20	€2,628.90	€3,505.20

Table H.4: Overview of the additional tax liability for different rates, when the 51.75% tax rate is applied.

	Additional tax liability per year			
Financial value of the car	ICEV (22% tax rate)	EV (4% tax rate in 2019)	EV (8% tax rate in 2020)	EV (12% tax rate in 2021)
€30,000	€3,415.50	€621	€1,242	€1,863
€40,000	€4,554	€828	€1,656	€2,484
€50,000	€5,692.50	€1,035	€2,432.25	€3,622.50
€60,000	€6,831	€2,173.50	€3,570.75	€4,761

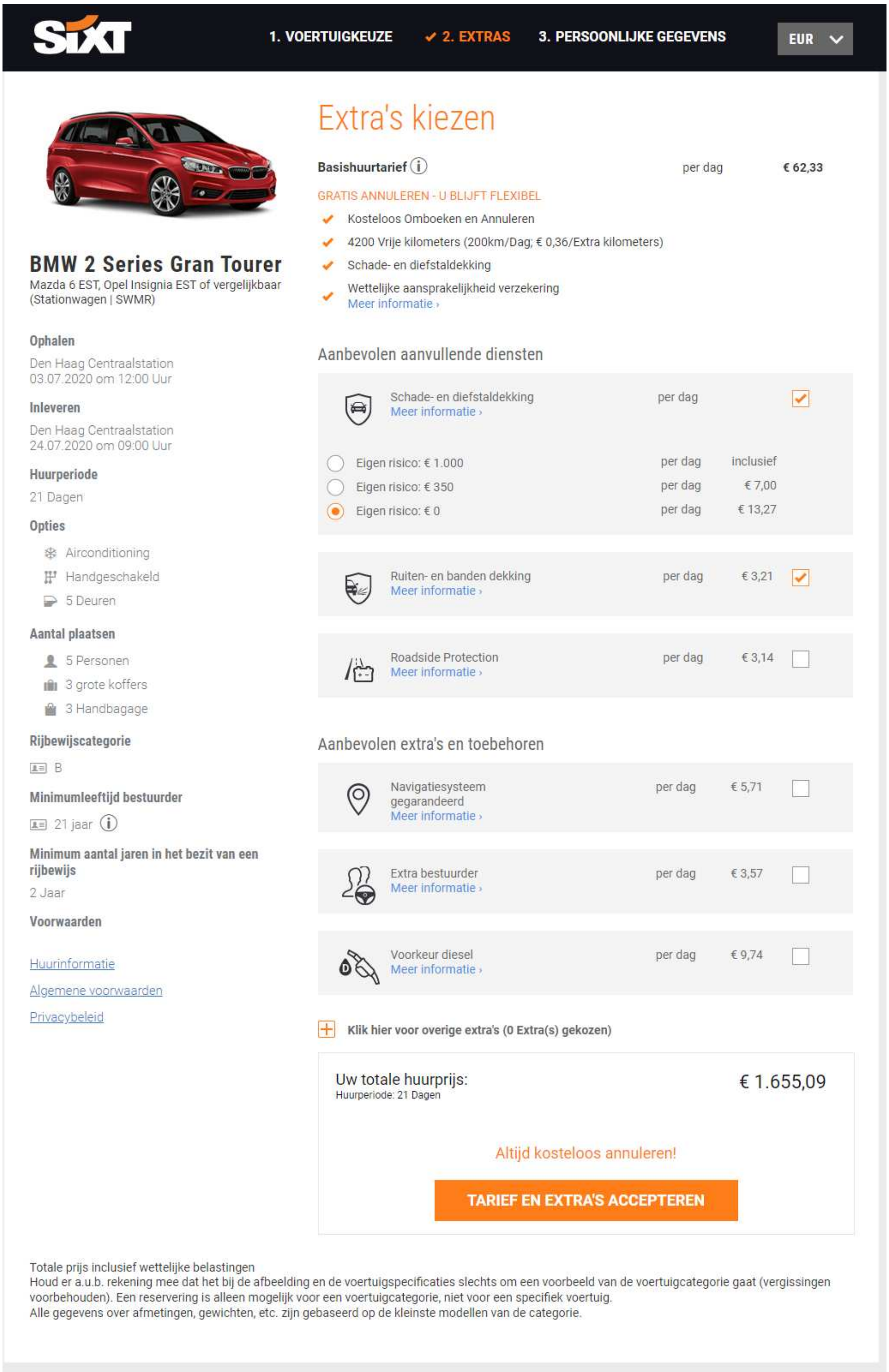


Figure H.1: Specifications of the optional rental car [65]

Appendix I

Extra Results from the Questionnaire

I.1 Graphs

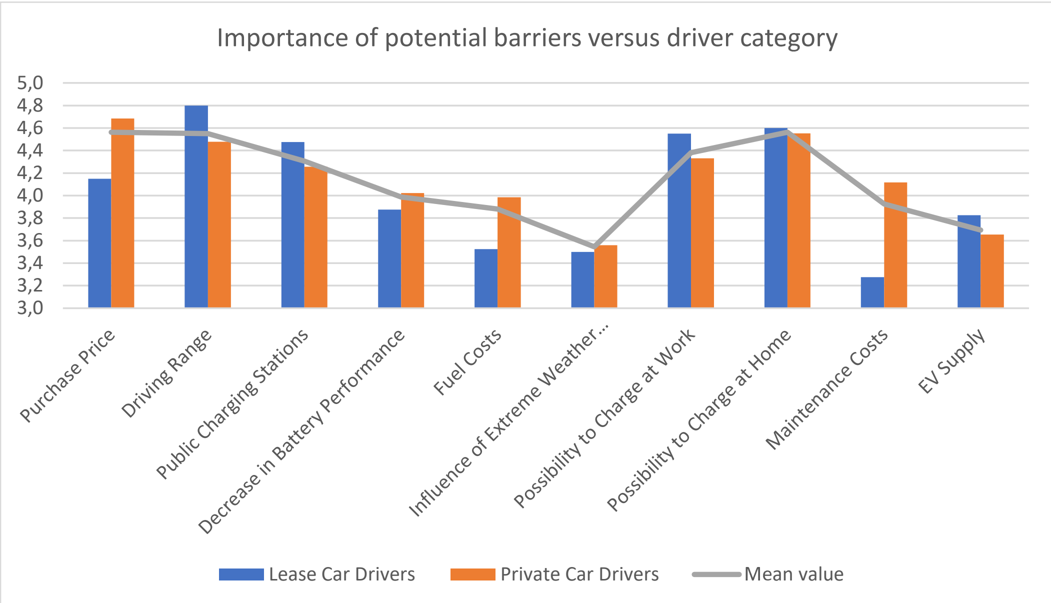


Figure I.1: Distribution of the importance of the potential barriers to the driver categories.

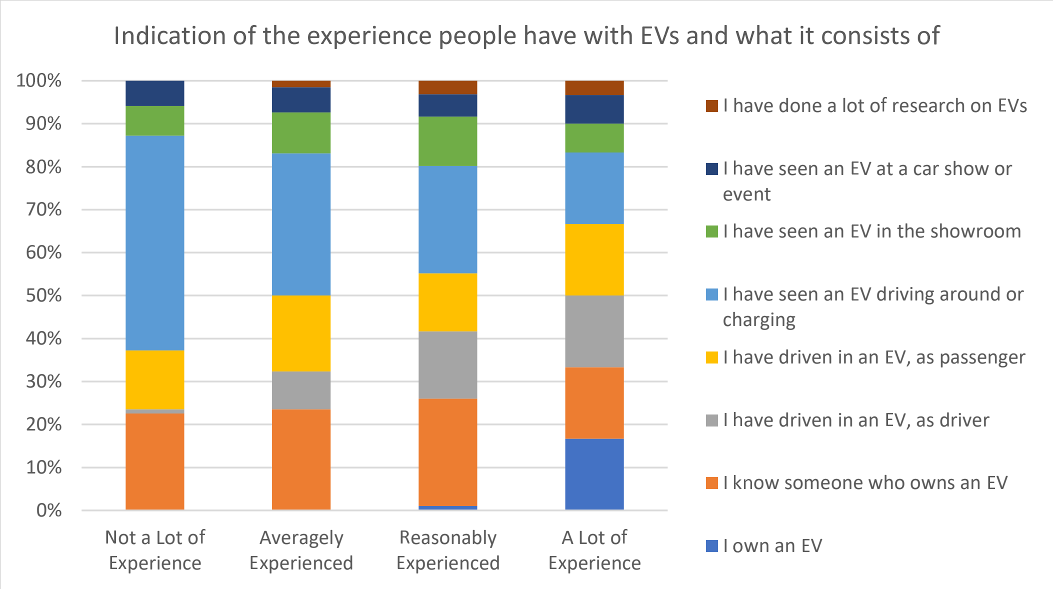


Figure I.2: Distribution of the experience respondents feel they have with EVs and what their experience consists of.

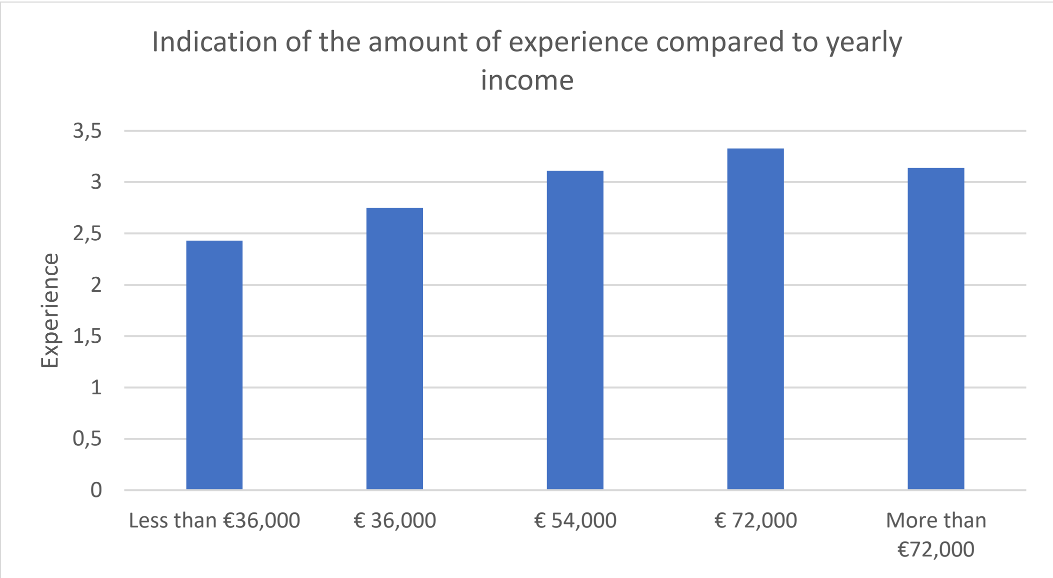


Figure I.3: Indication of the amount of experience respondents have compared to their yearly income.

Figure I.4: Indication on how the ratio is between position within the company and a certain income group.

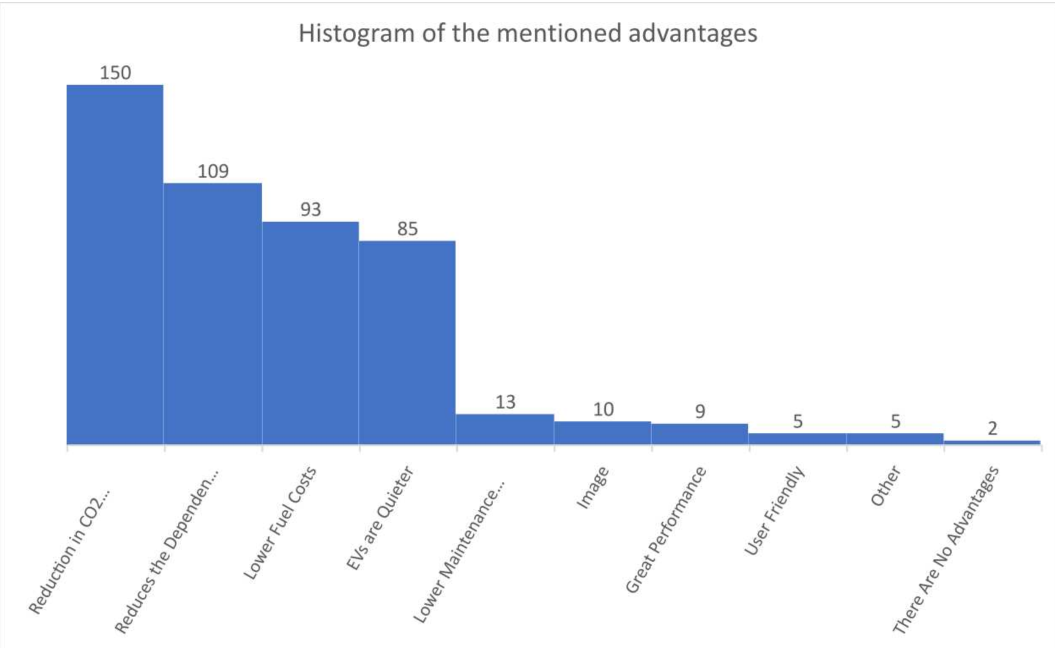


Figure I.5: Histogram indicating the amount of times a certain advantages is mentioned by the respondents

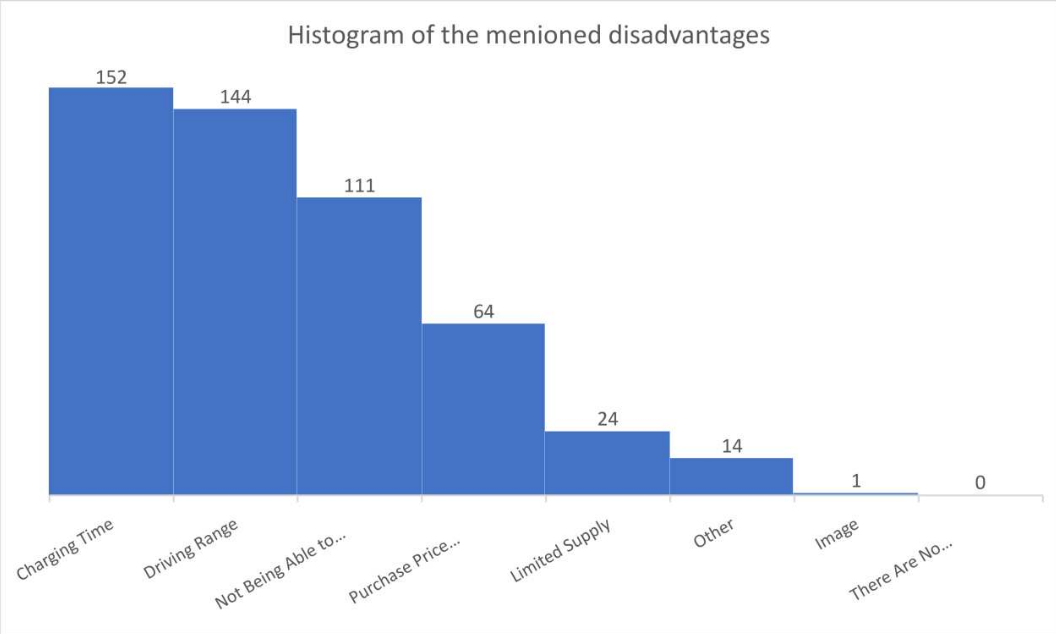


Figure I.6: Histogram indicating the amount of times a certain disadvantage is mentioned by the respondents.

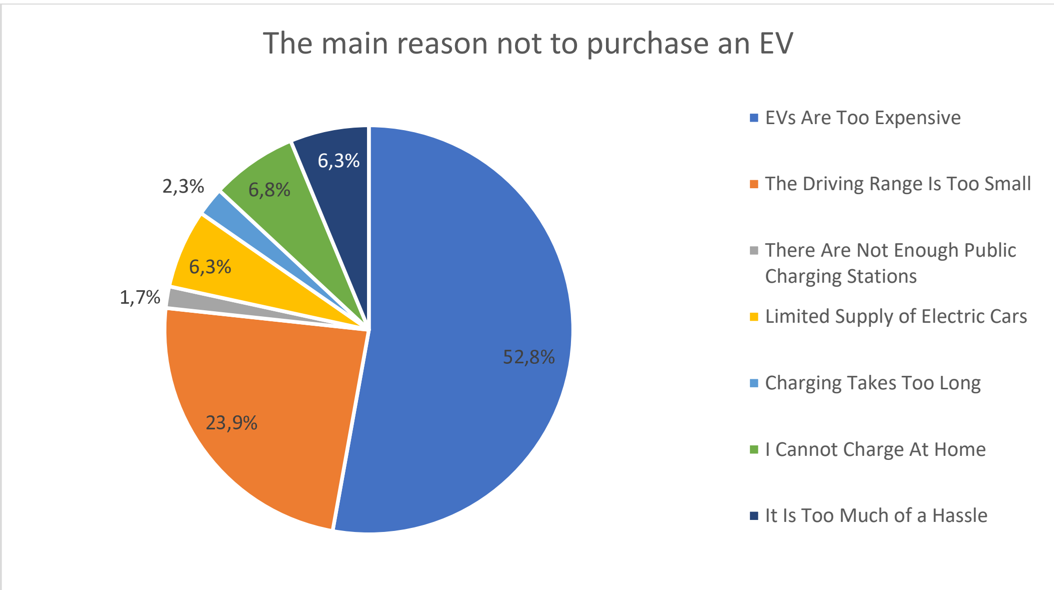


Figure I.7: Distribution of the main reason why respondents do not want to buy an EV.

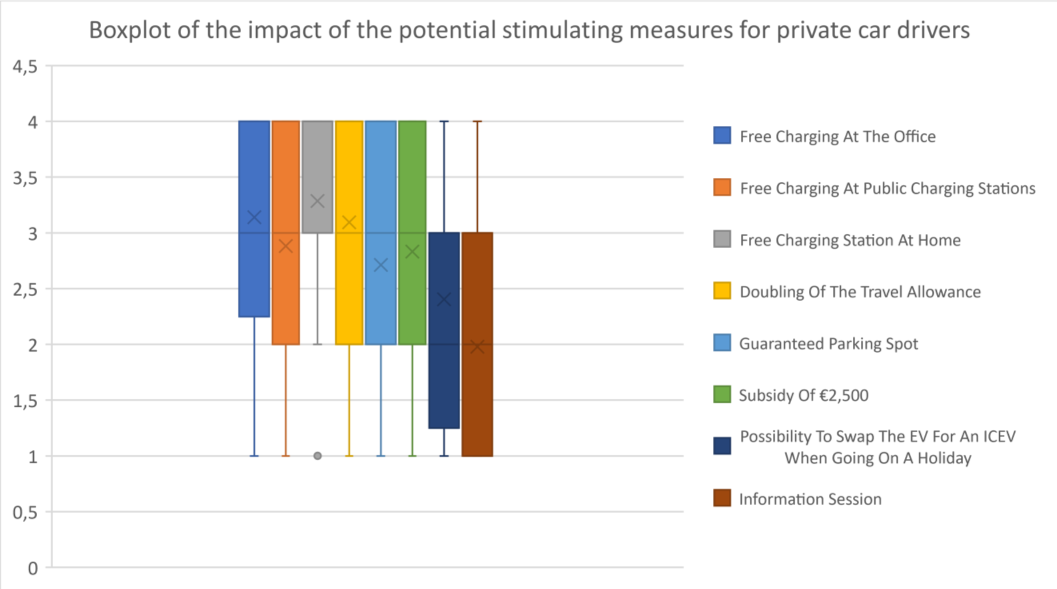


Figure I.8: Boxplot of the impact the potential stimulating measures have on the willingness of private car drivers to switch towards driving electrically. The X's indicate the average willingness (on a 4 point Likert scale).

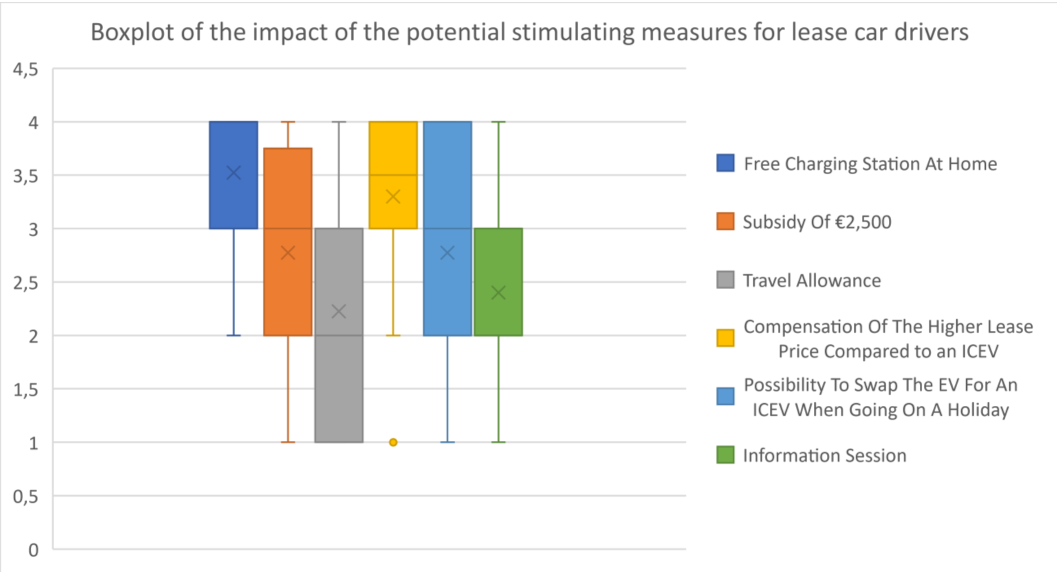


Figure I.9: Boxplot of the impact the potential stimulating measures have on the willingness of the lease car drivers to switch towards driving electrically. The X's indicate the average willingness (on a 4 point Likert scale).

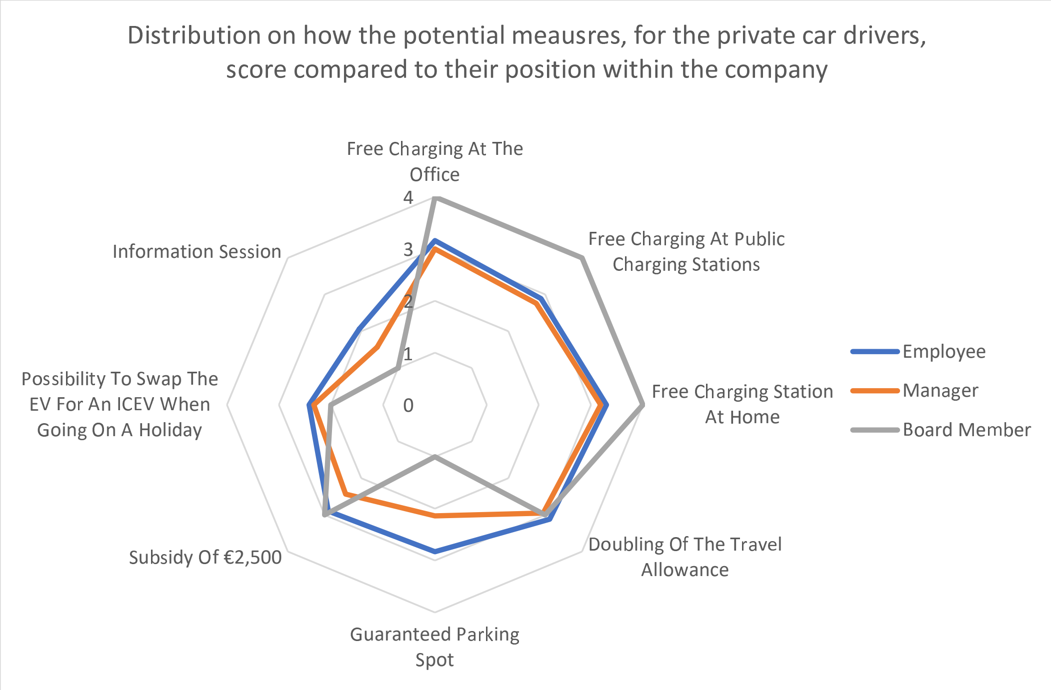


Figure I.10: Distribution on how the potential measures, for the private car drivers, score compared to the respondents' position within the company.

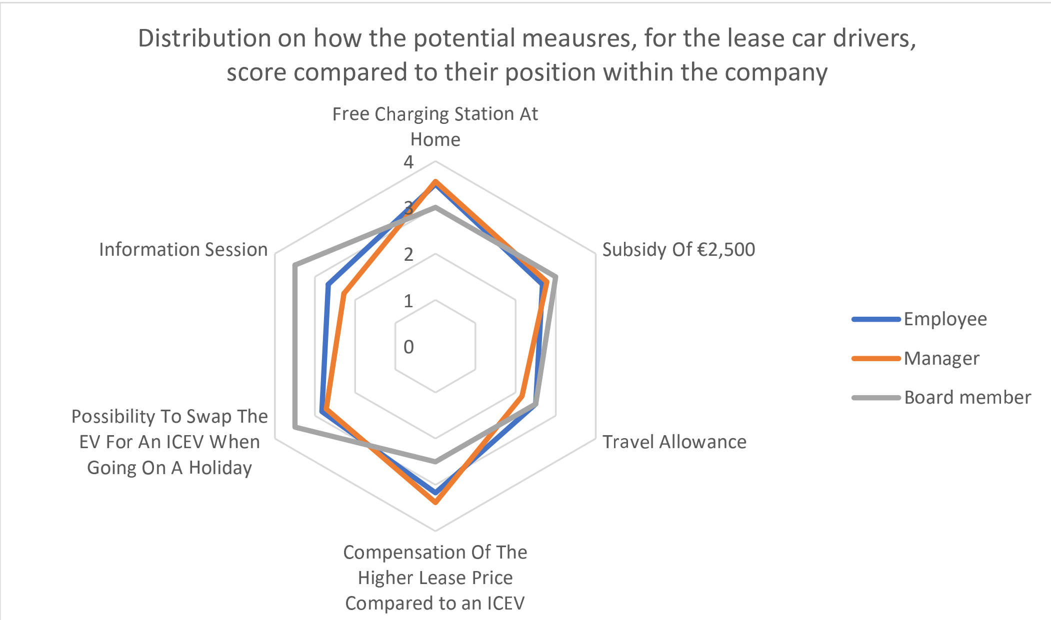


Figure I.11: Distribution on how the potential measures, for the lease car drivers, score compared to the respondents' position within the company.

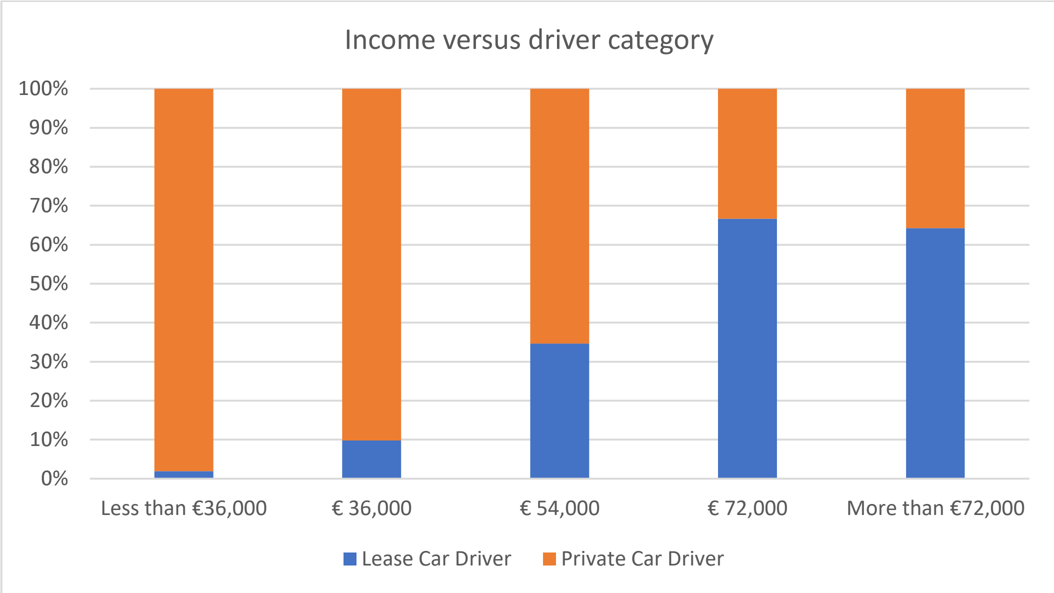


Figure I.12: Distribution of driver category over the yearly income of the respondents.

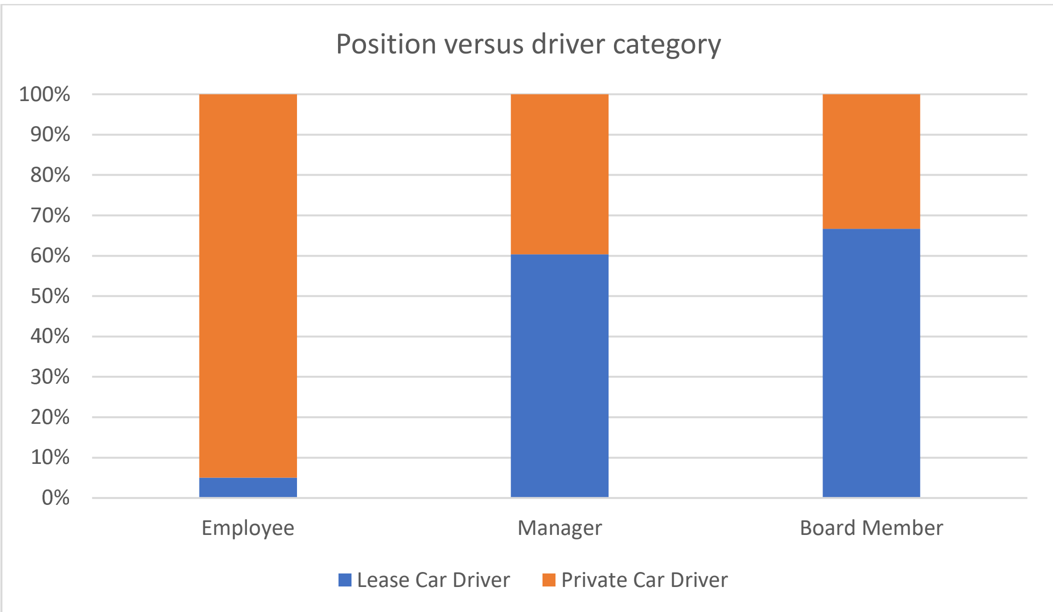


Figure I.13: Distribution of driver category over the position within the company.

I.2 Tables

Table I.1: Overview of available EVs and their price and driving range [56].

Car Type	Costs	Driving Range*
Volkswagen e-UP! Gen 2	€22,000	350 km / 225 km
Skoda CitigoE-iV	€22,000	350 km / 225 km
SEAT eMii	€22,000	350 km / 225 km
Sono Motors Sion	€25,500	320 km / 250 km
Volkswagen ID.3	€30,000	400 km / 300 km
Hyundai IONIQ Electric	€33,995	280 km / 200 km
Opel Corsa-e	€34,999	450 km / 310 km
Hyundai KONA Electric (39 kWh)	€35,000	420 km / 260 km
Pugeot e-208 Allure	€36,250	450 km / 310 km
Nissan Leaf	€38,940	380 km / 250 km
Hyundai KONA Electric (64 kWh)	€39,195	520 km / 405 km

*The first value indicates the driving range in a control environment. The second indicated real-life driving range.

I.3 Open-Ended Question

Below the answers to the question: Do you have any suggestions on how TUI can stimulate her employees to transition towards EVs?

I.3.1 Private Car Drivers

- Nee
- nee
- Lease auto aanbieden
- Nee
- nope
- Neen
- Hoewel we allemaal met het milieu bezig zijn blijft de kostenpost voor nu de grootste overweging. Ik ben bereid iets extra te betalen maar dit zou niet veel moeten zijn. Het blijft een noodzakelijk goed voor mij en geen imago ding. Daarom blijft de kosten baten overweging belangrijk.
- nee
- nee
- Zorgen voor (Privatelease) auto tegen zeer lage prijzen. Ook aanbod in (midden) grote MPV
- nee
- Mogelijkheid tot leasen ipv reiskostenvergoeding
- Betere voorlichting en duidelijker inzichtelijk maken wat de echte CO2 vermindering is en welke impact dat heeft op het klimaat. Persoonlijk ben ik ergens sceptisch over elektrische autos in die zin dat de elektriciteit ook opgewekt moet worden en het de vraag is of dat of een groene manier gebeurt of niet. Daarom zou het mij persoonlijk helpen als er in plaats van elektrische autos zijn beter voor het milieu wat specifiekere feiten worden gegeven die aangeven bij het rijden van x aantal km per jaar in een elektrische auto wat de CO2 vermindering is over het gehele proces (incl. de bron van elektriciteit).
- Misschien kan TUI gratis proefauto's ter beschikking stellen
- Nee

- Buiten de onredelijke verwachting het verschil t.o.v. een gelijkwaardige benzineauto bij te dragen, nee.
- voor mij zijn het puur de kosten.
- Volledig vergoeden, maar dat is natuurlijk niet realistisch. Ik denk dat het meerendeel van de werknemers het geld gewoon niet heeft.
- Het is nog te vroeg om te verwachten dat iedereen over kan stappen op elektrisch. Kijk naar denemarken waar elektrisch rijden heel populair is maar er en bij lange na niet genoeg oplaad punten zijn. nu ook de huizen prijzen heel hoog zijn zullen zeker de jongere generatie prioriteiten stellen.
- Juist door onderzoek aantonen dat electrische voertuigen op dit moment NIET milieuvriendelijker zijn dan (actieve)hybride-benzine voertuigen en je het beste een ondersteuning als bedrijf kunt bieden om alle werknemers de mogelijk te voorzien in een auto met als bouwjaar na 2016 (waar heel veel nieuwe 3 cilinder benzine motoren in zijn gepresenteerd, die een enorme efficientie hebben). Ondanks de nul-uitstoot van elektrische voertuigen weegt het nog steeds niet op met de uitstoot van centrales die energie opwekken. Daarbij verschuift het probleem zich alleen maar doordat het afbreken van batterijen in de toekomst (als de auto's op zijn) voor heel veel milieuproblemen zal zorgen.
- Aanschafprijs verlagen
- geen
- Subsidie geven omdat in basis de aanschaf van een elektrische auto al duurder is dan de aanschaf van een benzine auto
- Misschien kan TUI een collectief lease contract sluiten waar medewerkers gebruik van kunnen maken waarbij het lease bedrag van het salaris wordt ingehouden, met de daarbij horende belasting voordelen.
- Nope
- Ik rijd vaak grote afstanden en probeer dit op n dag te plannen. Ik zou hier dan nog meer extra tijd voor moeten vrijmaken. Gezien de files etc. op dit moment niet wenselijk. Ik zou misschien voor een hybride kunnen kiezen, zodat je minder afhankelijk bent van opladen. Bijtelling is niet aantrekkelijk om dit te gaan doen met alle ongemakken van dien.
- Hogere instap vergoeding dan 2.250 euro ,of iedereen de mogelijkheid geven voor een electrische leaseauto voor woon-werk verkeer
- Salarisverhoging f elektrische auto van de zaak ;-)
- Nee geen suggesties

- Medewerkers stimuleren de auto te laten staan en gebruik te maken van (elektrische) fiets.
- Deze vraag zou ik bij een autodealer neerleggen, zij zijn daar verder in hun kennis
- Als er berhaupt de mogelijkheid is, stap ik over.
- duurzaamheid
- Lease mogelijkheden
- Geweldig dat je hier mee bezig bent. Heb hier zelf ook al eens over nagedacht. Zelf heb ik alle piloten onder mij. Hoe gaaf zou het zijn als TUI een soort private lease constructie heeft waarbij TUI een deel van de kosten draagt. Bv drie soorten autos waar je uit kunt kiezen afh van je eigen wensen en de afstand waar je woont. Gratis thuis oplaadpaal. Onderweg (alleen in NL) op schiphol en op kantoor gratis opladen. TUI draagt daarbij ook mee in de maandelijkse kosten en hoeveel is afh van of er wel of niet een TUI logo (extra korting maar wat een reclame ineens in het land) op de auto komt. Natuurlijk vervalt dan de maandelijkse kilometer vergoeding die er nu is. Dit geldt alleen voor piloten en cabin in vast dienstverband. Andere bedrijven (Bv Eneco) hebben al zon constructie. Als klap om de vuurpijl zou je een collectieve regeling kunnen treffen met een zonne of windpark. Dus dat we eigen TUI zonnepark maken waar personeelsleden aan meedoen. Oftewel zij stappen over naar die energiemaatschappij. Of een regeling voor goedkopere zonnepanelen of iemands dak. Je ziet ik heb wel wat ideen maar of die echt voerbaar zijn? Dat hangt af van wat het mag kosten van TUI. En of het belastingtechnisch kan. Wel zou ik bij een regeling ook inbouwen dat er in de toekomst ook voor waterstof autos gekozen kan worden want persoonlijk voel ik daar meer voor. Alleen is dat nog niet echt grootschalig. Daarnaast zouden alle bedrijfs autos (incl lease) zoveel mogelijk electrisch moeten zijn. Succes met dit alles en ik ben een groot voorstander!
- Zelf ben ik in een kleiner benzine auto gaan rijden voor woon/werk verkeer. Ik zou het liefst dit met een elektrisch voertuig naar het werk toe komen, maar dit is voor particulieren niet te betalen. Als TUI haar medewerkers, welke niet over een lease auto beschikken wilt stimuleren elektrisch te rijden kan een stimulans zijn: 1. Gratis opladen op het werk 2. (grote) korting op aanschaf auto 3. Lease constructie voor medewerkers 4. verschil maken in reiskosten electrisch / benzine
- Salarisverhoging ;)
- Gratis auto of reclame auto dus voordelige auto
- Nee, ik vind dit een slecht plan en zou dit bij de OR aanvechten. Voor veel medewerkers die geen keus hebben en met de auto naar werk moeten, is er nu al geen plek op de parkeerplaats en is de kilometervergoeding niet toereikend. Dit zie ik graag eerst opgelost.

- Iedere medewerker de mogelijkheid geven voor een lease auto. Zelf een nieuwe auto aanschaffen is duur en lang niet iedereen heeft de financile mogelijkheid. Iedereen zou de kans moeten krijgen om een lease auto voor een elektrische auto aan te schaffen. Dit is financieel gezien veel gunstiger en wellicht voor een hoop medewerkers een mogelijkheid om dan wel elektrisch te rijden.
- Nee
- Mijn reden om op brandstof te rijden is op dit moment vanwege de marktwerking rond elektrische auto's en de nu nog hoge prijs. Mijn huidige auto heb ik als jonge occasion (3 jaar oud) gekocht en in dit segment zijn nog relatief weinig occasions, de occasions die er wel zijn hebben al snel een 30% hogere prijs. Ik rij op dit moment 600 km per week. Met mijn huidige auto sta ik 1x per 1,5 week 3 minuutjes bij de pomp en ik kan weer 900km rijden. Dat vind ik makkelijker dan mij druk te maken over het vinden van een laadpaal. TUI kan hier in zekere zin alleen wat aan veranderen als ik een lease-auto zou krijgen, maar dat is geen haalbare kaart.
- nee
- Iedereen de optie geven om een elektrische auto van de zaak te kunnen kiezen (met eigen bijdrage).
- Nee
- mogelijkheid tot lease, ook voor medewerkers
- nee
- elektrische leaseauto beschikbaar stellen of meer km vergoeding bij elektrisch rijden
- De mogelijkheid aanbieden.
- Mogelijkehden onderzoeken op het geven van belastingvoordeel via de werkkostenregeling. Bijdrage van TUI bij de aanschaf.
- nee. Je kan mensen niet verplichten tot de aanschaf van een dure electrische auto. Mits voordelig lease contracten aanbieden
- Lease aanbieden
- Geen leaseauto's meer aangezien leaseauto's erg veel privekilometers maken, meer dan een eigen auto. Of verplicht elektrische leaseauto's.
- Nee
- Voorlichting geven over de voordelen.
- Nee

- het gaat om de afstand die je kan afleggen met elektrische auto, die is niet zo heel groot. dat los je als TUI niet echt op (op dit moment is aanbod zoals het is). meer hybride aanbod in de lease regeling zou helpen
- nee
- Concrete samenwerking met een dealer
- aanbieden van lease auto (als onderdeel van salaris)
- Ik mis de keuze voor de (elektrische) fiets of het OV. Geen auto levert de meeste CO2 besparing op . Iedereen een elektrische leaseauto aanbieden (op kosten van TUI) zal zeker helpen.
- meer informatie geven over de voordelen van elektrisch rijden.
- Het is de aanschaf wat mij het meeste weerhoudt. Of dit nu voor een elektrische of niet-elektrische auto zou zijn.
- Door bedrijfsautos elektrisch te maken zodat medewerkers hier aan kunnen wennen.
- Aanbieden als leaseauto, met name voor medewerkers die op dit moment geen recht hebben op een leaseauto.
- Ik denk dat de aanschaf van een elektrische auto veel geld kost. Daarnaast is de reiskostenvergoeding zeer minimaal, als je 80km op een dag rijdt, moet je geld bijleggen aan benzinekosten om op je werk te komen. Wanneer er andere mogelijkheden zijn om het milieu te stimuleren moet de drempel eenvoudig zijn om over te stappen en gegarandeerde voordelen. (Trein biedt geen voordelen voor Ammerzoden - gebonden aan tijden - trein missen en krasbus is weg, kom je niet snel op je werk..).
- Deze autos beschikbaar stellen voor haar medewerkers wellicht in lease vorm
- Elektrische TUI auto, gelijk reclame en goedkoop voor de medewerkers.
- Subsidie regeling introduceren
- nee
- Nee
- nee
- Ook open staan voor hybride - kost ook minder brandstof, meestal betaalbaarder en kunnen verder rijden.
- Nee
- meer lease auto's
- Leaseauto beschikbaar stellen voor iedereen die electrisch wil rijden.

- Voordelig lease tarieven regelen
- Waarom wordt er niet gedacht over openbaar vervoer? Een nieuwe auto aanschaffen lijkt me voor een groot deel van de medewerkers niet van toepassing.
- Nee
- Nee
- Meer voorlichting om medewerkers bewust te maken van de voordelen en de noodzaak. Wat mijzelf betreft heb ik niet meer stimulans nodig. Ik zie de voordelen en begrijp de noodzaak. Financieel gezien kan ik me de aanschaf van een elektrische auto echter niet veroorloven.
- Lease auto alleen maar elektrisch
- Dit is een auto enquete en gaat voorbij aan fietsers en OV gebruikers
- Voor mij is het niet rendabel om met de auto te komen, aangezien ik met openbaar vervoer meer voordelen heb, via TUI. Verder denk ik dat het alleen rendabel is voor hoger management en directie vanwege de kosten. De gemiddelde werknemer kan geen elektrische auto betalen.
- Introduceren van een lease regeling
- nee
- Nee
- helaas niet.
- nee
- Met mijn salaris kan ik helaas geen elektrische auto aanschaffen.
- nee
- Nee
- het aanschaffen voordeliger maken voor werknemers, of meer te werken met een autopool (gratis auto van de zaak maar wel op voorwaarde dat je met 4 collega's naar kantoor gaat in 1 auto)
- nee
- Gn
- opzetten van TUI Privat Lease electric voor TUI medewerkers
- Meer laadpalen op de parkeerplaats en gegarandeerde plek

- Nee
- Gereduceerd Leaseplan (ook gebruikte auto's) aanbieden zoals bij Fietsplan
- nee
- Mogelijkheid tot leasen.
- Door alleen electrische auto's aan te bieden in het lease aanbod en als pool auto
- Mijn auto rijd nog goed dus vervang hem nog niet. Bij vervanging zou ik kijken naar de aanschafprijs versus een benzine auto. Mocht hier verschil in zitten, dan ga ik voor de goedkoopste optie
- Voorwaarde zijn vaak belangrijkst
- Voor medewerkers die door overplaatsing verder weg wonen ipv extra reiskosten zo'n regeling van bonus 2500 maar dan veel hoger aan te bieden
- Op dit moment heb ik geen budget voor een andere (elektrische) auto. Indien ik dit wel had zou het goed zijn dat TUI een eenmalige bijdrage levert voor de aanschaf maar ook een bijdrage aan het verkrijgen van een (eigen) oplaadplaats bij of vlakbij huis. Ik denk dat dit in de stad met portiekwoningen/ flats lastiger is dan bij een rijtjes-/vrijstaandhuis waar je altijd plek voor de deur hebt.
- De aanschafprijs van een elektrische auto is hoog voor particulieren. Zijn er opties om dit zakelijk aan te bieden in een lease contract?
- geen suggesties
- nee
- Niet overstappen naar elektrische auto - kies voor waterstof- dat is de toekomst
- Nee
- Nee
- Nee.
- Hogere reiskosten vergoeding.
- Gegarandeerd een parkeerplek met oplaadpunt in garage
- Nee niet direct
- nee
- nee geen suggestie
- Belastingvoordeel
- nee

I.3.2 Lease Car Drivers

- nee
- optie to share a car
- Het kan voor mij persoonlijk alleen werken als de auto mid-size is met een range van minimaal 500KM en 100% laadmogelijkheid op alle BENELUX locaties
- Nee
- thuiswerken
- Duidelijk onderzoek naar oplaadmogelijkheden buitenland, daar ik mijn leaseauto gebruik voor inkoopreizen naar oa. Itali
- Investering contrato
- Door de lease via het werk aan te bieden tegen aantrekkelijkere prijzen.
- Neem ook de mogelijkheid voor een auto op waterstof mee.
- Auto moet minimaal 400km kunnen rijden anders geen optie
- Als je bewust kiest voor een hybride auto die een hogere catalogusprijs heeft zoals in mijn geval dan ook korting geven of laten vervallen van de eigen bijdrage. De bijtelling is afhankelijk van de cat prijs dus daar kun je niets aan doen
- Ik heb bewust gekozen voor een hybride leasauto, ook al is die duurder (bijtelling) dan een andere. Ik zou wel zelf een laadpaal moeten betalen thuis. Daarin zou ik wel een tegemoetkoming willen; het is immers ook in het belang van TUI, want veel lagere brandstofkosten. De installatie van een laadpaal kosten meer dan €1000,-
- heb al voor een hybride gekozen
- Flexibiliteit in de regeling, als je een hogere eigen bijdrage wilt betalen voor een grotere/luxere/elektrische auto (om wat voor reden dan ook) dan moet dit kunnen, zeker als je er ook prive mee rijdt en dit de enige auto is. Ander idee is mogelijkheid om binnen het huidige, lopende contract toch over te kunnen stappen naar elektrisch. Dat als je zuiniger/milieuvriendelijker wilt rijden dit ook 'direct' mogelijk. Verder alles prima geregeld qua lease!
- Ik krijg er volgende week eentje
- Geen
- pro aktief een aanbieding doen als lease contract verloopt
- Meer keuze in aanbod

- de aanschaf van de nu beschikbare modellen en de levertijd van deze auto's ligt op 1,5 jaar.....
- Meer keuze, extras, zorgen voor een grote range in accuduur indien mogelijk
- autoplan net als het fietsplan
- ik denk dat vooral de kosten bepalend zijn, meer dan de CO2 uittoot
- Nee
- Op het moment dat een leasecontract afloopt gelijk de voordelen/nadelen doorlopen wat de keuze voor een elektrische auto zou opleveren voor iedereen persoonlijk
- Meer informatie geven over elektrische auto's en daarnaast moeten er auto's beschikbaar komen waar je meer km's mee kan rijden, zonder tussentijds op te laden.
- Beter leasevoorwaarden waarbij de mogelijkheid een grote(re) middenklasse auto met meer actieradius te rijden mogelijk wordt.
- Keuze type auto elektrisch moet in zelfde categorie mogelijk/beschikbaar zijn als benzine/diesel; daarbij moet de auto voldoende actieradius hebben voor lange afstandsritten (zakelijk)
- Meer laadpalen beschikbaar stellen op het werk maar ook een thuis, elektrische lease auto financieel aantrekkelijker maken.
- Leasecontracten eerder kunnen omzetten dan de huidige termijn/afloopdatum
- nee
- Op alle locaties meer oplaadpunten installeren. En meest vervuilende auto's niet meer aanbieden.
- Actief informeren, mn over aantal km dat gereden kan worden en mogelijkheden voor oplaadpalen
- Mogelijkheid om huidige leaseauto in te ruilen zonder boete clausules van de lease maatschappij. Ik zou graag overstappen.
- Niet zo zeer mbt stimuleren van een elek. auto, maar wel door uitstoot te reduceren: thuis werken meer stimuleren.Voor mij is het gebruik van de lease auto vooral voor zakelijke reizen binnen Europa en dan is het belangrijkste dat je 800-1000 km op een dag kunt afleggen, met 'korte' tankbeurten en de huidige elek. auto's kunnen dat nog niet bieden.
- meer aanbod/voorlichting
- Nee

Appendix J

Extra Matlab Plots

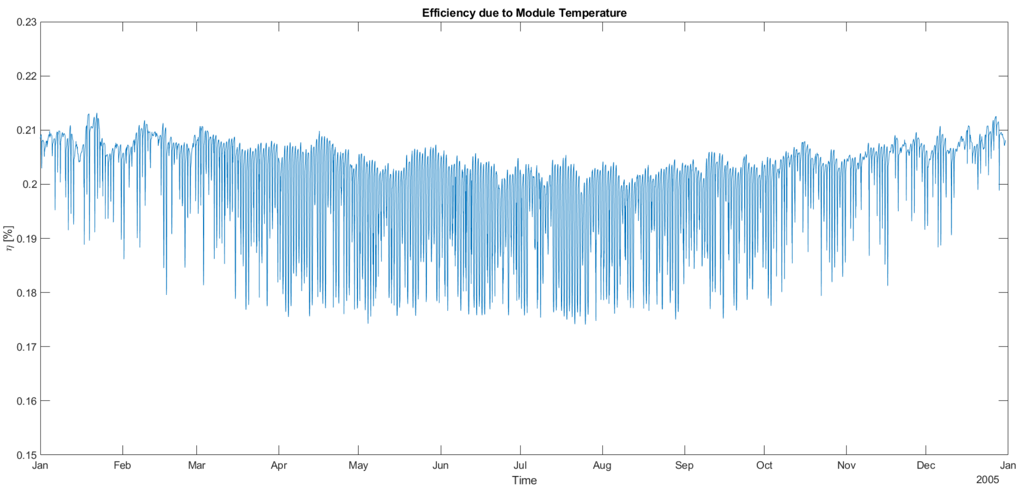


Figure J.1: Efficiency of the module, over an entire year, due to the temperature of the module.

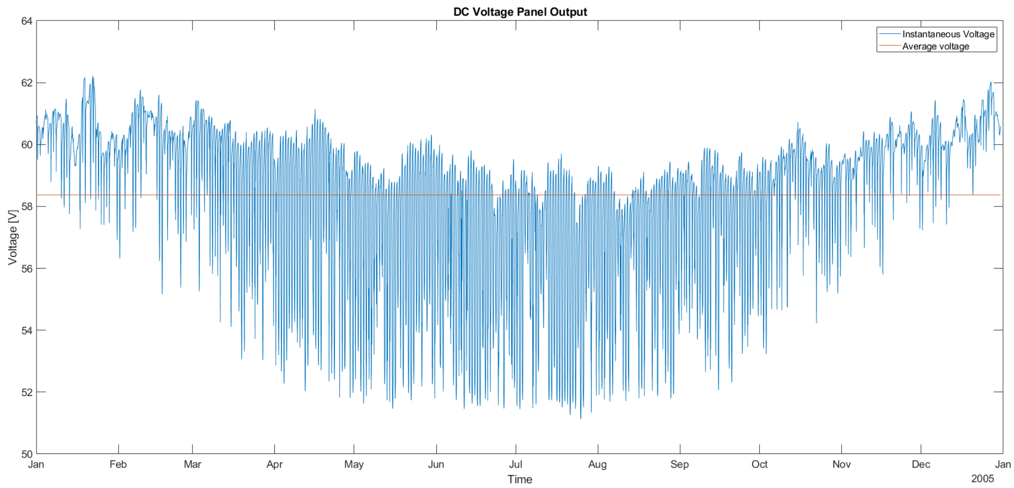


Figure J.2: Output voltage of a panel, over an entire year, due to temperature effects.

Appendix K

Solar Panel - Datasheet

Panasonic

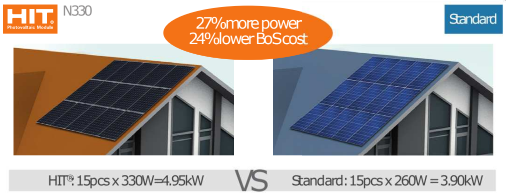
Photovoltaic module HIT®
VBHN330SJ47/ VBHN325SJ47

N 330
N 325

HIT® Photovoltaic Module

19.7% module efficiency

Enables reaching a higher output and lower specif c installation and balance-of-system costs than with the same number of standard 60-cell modules.

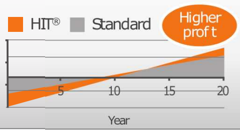


100% Panasonic, 100% HIT®

Proudly featuring Panasonic's original invention, the heterojunction solar cell. With over 1 billion cells produced commercially over 18 years, 25 years after the breakthrough in the development and looking back to over 40 years of experience in solar, Panasonic really of ers you a 25-year guarantee you can trust.

More energy, higher prof t!

Helping you reach a higher f nal prof t with your PV system!



Measured in Nagano (Japan) 2012

330W/325W

High Ef ciency + High Performance at High Temperatures = High Power Generation

QUALITY PROVEN 4 WAYS

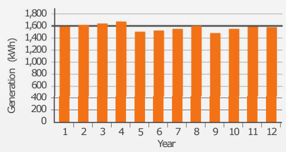
1 Guaranteed by Panasonic

- IEC and over 20 Panasonic internal tests
- Vertically integrated own manufacturing (wafer, cell and module)

3 Less degradation on the f eld

12 years actual data prove a reliable and stable performance.

Installation:	March 2004
Location:	Gloucestershire, UK
Model:	HIP-180BE
System size:	1.80 kWp
Tilt:	40 deg.
Direction:	South-West



2 Record low claim rate

Less than 0.0044% failure rate after more than 10 years experience in Europe (as of January 2019)

4 3rd party verif ed

- Lifecycle testing (Long-Term-Sequential-Test) by TÜV Rheinland (tested on VBHN240SE10)
- PID-free (tested by Fraunhofer Institute)

HIT® is a registered trademark of Panasonic Group.

Panasonic Eco Solutions Europe
Panasonic Electric Works Europe AG

www.eu-solar.panasonic.net

EN

Electrical and Mechanical Characteristics N330/N325

HIT® Photovoltaic Module

Electrical data (at STC)

	VBHN330SJ47	VBHN325SJ47
Max. power (Pmax) [W]	330	325
Max. power voltage (Vmp) [V]	58.0	57,6
Max. power current (Imp) [A]	5.70	5,65
Open circuit voltage (Voc) [V]	69.7	69,6
Short circuit current (Isc) [A]	6.07	6,03
Max. over current rating [A]	15	15
Power tolerance [%] *	+10/-0	+10/-0
Max. system voltage [V]	1000	1000
Solar panel ef ciency [%]	19.7	19,4

Note: Standard Test Conditions: Air mass 1.5; Irradiance = 1000W/m²; cell temp. 25°C
* Maximum power at delivery.

Temperature characteristics

Temperature (NOCT) [°C]	44.0	44.0
Temp. coef cient of Pmax [%/°C]	-0.258	-0.258
Temp. coef cient of Voc [V/°C]	-0.164	-0.164
Temp. coef cient of Isc [mA/°C]	3.34	3.32

At NOCT (Normal Operating Conditions)

Max. power (Pmax) [W]	251.9	249.3
Max. power voltage (Vmp) [V]	56.3	56.1
Max. power current (Imp) [A]	4.54	4.52
Open circuit voltage (Voc) [V]	65.8	65.9
Short circuit current (Isc) [A]	4.89	4.88

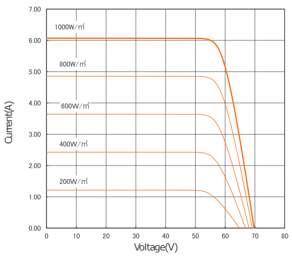
Note: Normal Operating Cell Temp.: Air mass 1.5; Irradiance = 800W/m²; Air temperature 20°C; wind speed 1 m/s

At low irradiance (20%)

Max. power (Pmax) [W]	63.5	62.3
Max. power voltage (Vmp) [V]	57.0	56.4
Max. power current (Imp) [A]	1.12	1.11
Open circuit voltage (Voc) [V]	65.6	65.3
Short circuit current (Isc) [A]	1.22	1.21

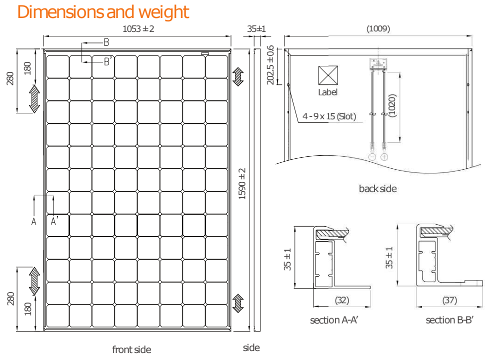
Note: Low irradiance: Air mass 1.5; Irradiance = 200W/m²; cell temp. = 25°C

Dependence on irradiance



Reference data for model VBHN330SJ47 (Cell temperature: 25°C)

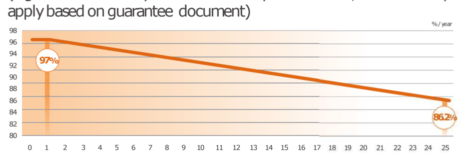
Dimensions and weight



weight: 18.5kg
weight/m²: 11.3 kg/m²
unit: mm
snow and wind load: 2400 Pa

Guarantee

Power output: 25 years linear
(1st year 97 % from 2nd year -0.45 %/year, in 25th year 86.2%)
Product workmanship: 25 years
(registration necessary on www.eu-solar.panasonic.net, otherwise 15 years apply based on guarantee document)



Materials

Cell material: 5 inch photovoltaic cells
Glass material: AR coated tempered glass
Frame materials: Black anodized aluminium
Connectors type: SMK

Certif cates

CLASS UNO
By TÜV Rheinland
UNI 8457
UNI 9174
UNI 9177

IEC61215
IEC61730-1
IEC61730-2

RoHS COMPLIANT
Electrical Protection Class II
CE

Please consult your local dealer for more information

⚠ CAUTION! Please read the installation manual carefully before using the products.

Used electrical and electronic products must not be mixed with general household waste. For proper treatment, recovery and recycling of old products, please take them to applicable collection points in accordance with your national legislation.

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Panasonic

03/2019

Appendix L

Sunny Tripower Inverter - Datasheet

Sunny Tripower 15000TL / 20000TL / 25000TL

efficient
- Maximum efficiency of 98.4%

Safe
- DC surge arrester (SPD type II) can be integrated

Flexible
- DC input voltage of up to 1000 V
- Multistring capability for optimum system design
- Optional display

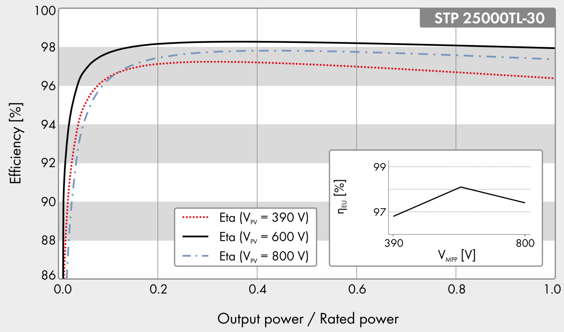
innovative
- Cutting-edge grid management functions with Integrated Plant Control
- Reactive power available 24/7 (Q on Demand 24/7)

Sunny Tripower 15000TL / 20000TL / 25000TL

The versatile specialist for large-scale commercial plants and solar power plants

The Sunny Tripower is the ideal inverter for large-scale commercial and industrial plants. Not only does it deliver extraordinary high yields with an efficiency of 98.4%, but it also offers enormous design flexibility and compatibility with many PV modules thanks to its multistring capabilities and wide input voltage range.
The future is now: the Sunny Tripower comes with cutting-edge grid management functions such as Integrated Plant Control, which allows the inverter to regulate reactive power at the point of common coupling. Separate controllers are no longer needed, lowering system costs. Another new feature—reactive power provision on demand (Q on Demand 24/7).

efficiency Curve



Accessory


RS485 interface
DM-485CB-10


Power Control Module
PWCMOD-10


DC surge arrester Typ II,
inputs A and B
DCSPD KIT3-10


Multifunction relay
MFR01-10

● Standard features ○ Optional features — Not available
Data at nominal conditions
Status: October 2017

Technical Data	Sunny Tripower 20000TL	Sunny Tripower 25000TL
input (DC)		
Max. generator power	36000 Wp	45000 Wp
DC rated power	20440 W	25550 W
Max. input voltage	1000 V	1000 V
MPP voltage range / rated input voltage	320 V to 800 V / 600 V	390 V to 800 V / 600 V
Min. input voltage / start input voltage	150 V / 188 V	150 V / 188 V
Max. input current input A / input B	33 A / 33 A	33 A / 33 A
Number of independent MPP inputs / strings per MPP input	2 / A:3; B:3	2 / A:3; B:3
output (AC)		
Rated power (at 230 V, 50 Hz)	20000 W	25000 W
Max. AC apparent power	20000 VA	25000 VA
AC nominal voltage	3 / N / PE; 220 V / 380 V 3 / N / PE; 230 V / 400 V 3 / N / PE; 240 V / 415 V	
AC voltage range	180 V to 280 V	
AC grid frequency / range	50 Hz / 44 Hz to 55 Hz 60 Hz / 54 Hz to 65 Hz	
Rated power frequency / rated grid voltage	50 Hz / 230 V	
Max. output current / Rated output current	29 A / 29 A	36.2 A / 36.2 A
Power factor at rated power / Adjustable displacement power factor	1 / 0 overexcited to 0 underexcited	
THD	≤3%	
Feed-in phases / connection phases	3 / 3	
Efficiency		
Max. efficiency / European Efficiency	98.4%/ 98.0%	98.3%/ 98.1%
protective devices		
DC-side disconnection device	●	
Ground fault monitoring / grid monitoring	● / ●	
DC surge arrester (Type II) can be integrated	○	
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / —	
All-pole sensitive residual-current monitoring unit	●	
Protection class (according to IEC 62109-1) / overvoltage category (according to IEC 62109-1)	I / AC: III; DC: II	
General data		
Dimensions (W / H / D)	661 / 682 / 264 mm (26.0 / 26.9 / 10.4 inch)	
Weight	61 kg (134.48 lb)	
Operating temperature range	−25 °C to +60 °C (−13 °F to +140 °F)	
Noise emission (typical)	51 dB(A)	
Self-consumption (at night)	1 W	
Topology / cooling concept	Transformerless / Opticool	
Degree of protection (as per IEC 60529)	IP65	
Climatic category (according to IEC 60721-3-4)	4K4H	
Maximum permissible value for relative humidity (non-condensing)	100%	
Features / function / Accessories		
DC connection / AC connection	SUNCLIX / spring-cage terminal	
Display	○	
Interface: RS485, Speedwire/Webconnect	○ / ●	
Data interface: SMA Modbus / SunSpec Modbus	● / ●	
Multifunction relay / Power Control Module	○ / ○	
OptiTrac Global Peak / Integrated Plant Control / Q on Demand 24/7	● / ● / ●	
Off-Grid capable / SMA Fuel Save Controller compatible	● / ●	
Guarantee: 5 / 10 / 15 / 20 years	● / ○ / ○ / ○	
Certificates and permits (more available on request) * Does not apply to all national appendices of EN 50438	ANRE 30, AS 4777, BDEW 2008, C10/11:2012, CE, CEI 0-16, CEI 0-21, DEWA 2.0, EN 50438:2013*, G59/3, IEC 60068-2-x, IEC 61727, IEC 62109-1/2, IEC 62116, MEA 2013, NBR 16149, NEN EN 50438, NRS 097-2-1, PEA 2013, PPC, RD 1699/413, RD 661/2007, Res. n°7:2013, SI4777, TOR D4, TR 3.2.2, UTE C15-712-1, VDE 0126-1-1, VDE-AR-N 4105, VFR 2014	
Type designation	STP 20000TL-30	STP 25000TL-30

Appendix M

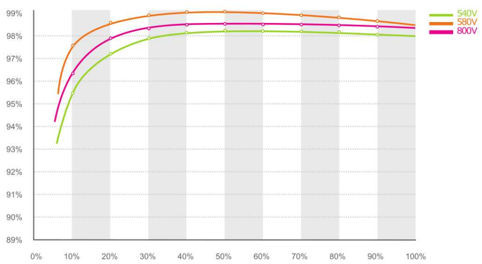
Growatt Inverter - Datasheet

Growatt 30000TL3-S/33000TL3-S/ 40000TL3-NS/50000TL3-S

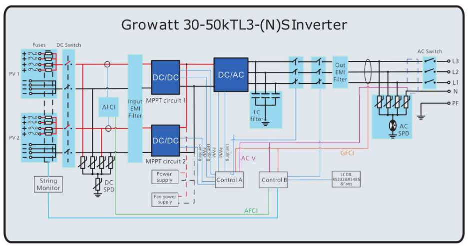
Leading - edge Technology

- Maximum efficiency of 99%
- Multi MPP controller and MTL string
- 8 strings intelligent monitoring and Fuse protection
- Internal DC switch and Transformerless
- Type II surge arresters for both DC and AC
- Anti-PID for PV module
- Optional AFCI function
- Supporting AC power supply
- Compact design and easy installation
- Comprehensive warranty program

Growatt 50000TL3-S efficiency



Growatt 30-50kTL3-(N)S topology



GROWATT NEW ENERGY TECHNOLOGY Co.,LTD
A: No.28 Guangmming Road, Longteng Community, Shiyan, Baoan District, Shenzhen, P.R.China.
T: +86 755 2747 1900 F: +86 755 2749 1460 E: info@ginverter.com

Datasheet	Growatt 30000TL3-S	Growatt 33000TL3-S	Growatt 40000TL3-NS	Growatt 50000TL3-S
Input Data				
Max recommended PV Power (for module STC)	37500W	41250W	50000W	60000W
Max DC voltage	1000V	1000V	1000V	1000V
Start Voltage	250V	250V	250V	250V
PV voltage range	200V - 1000V	200V - 1000V	200V - 1000V	200V - 1000V
Nominal voltage	580V	580V	580V	695V
Full load MPP voltage range	450V - 800V	450V - 800V	540V - 800V	645V - 850V
Max. input current	34A/34A	38A / 38A	38A / 38A	38A / 38A
Max. input current per string	12A	12A	12A	12A
Number of MPP trackers / strings per MPP tracker	2/4	2/4	2/4	2/4
Output (AC)				
Rated AC output power	30kW	33kW	40kW	48kW
Max. AC apparent power	33.3kVA	36.6kVA	44.4kVA	53.3kVA
Max. output current	48.3A	53A	64.5A	64.5A
AC nominal voltage	230V/400V	230V/400V	230V/400V	277V/480V
AC grid frequency	50/60Hz	50/60Hz	50/60Hz	50/60Hz
Power factor	0.8 leading - 0.8 lagging	0.8 leading - 0.8 lagging	0.8 leading - 0.8 lagging	0.8 leading - 0.8 lagging
THDi	<3%	<3%	<3%	<3%
AC grid connection type	3W+N+PE	3W+N+PE	3W+N+PE	3W+N+PE/3W+PE
Efficiency				
Max.efficiency	98.9%	98.9%	99%	99%
Euro - eta	98.4%	98.4%	98.5%	98.5%
MPPT efficiency	99.5%	99.5%	99.5%	99.5%
Protection Devices				
DC reverse polarity protection	yes	yes	yes	yes
DC Switch for each MPPT	yes	yes	yes	yes
DC Surge protection	Class II	Class II	Class II	Class II
Ground fault monitoring	yes	yes	yes	yes
Output short circuit protection	yes	yes	yes	yes
AC Surge protection	Class II	Class II	Class II	Class II
String Fuse protection	yes	yes	yes	yes
String fault monitoring	yes	yes	yes	yes
Anti-PID protection	yes	yes	yes	yes
AFCI protection	opt	opt	opt	opt
General Data				
Dimensions (W / H / D)	470/754/270 mm	470/754/270 mm	470/754/270 mm	470/754/270 mm
Weight	48kg	48kg	48kg	48kg
Operating temperature range	-25 ℃ ... +60 ℃ (with derating above45℃)	-25 ℃ ... +60 ℃ (with derating above45℃)	-25 ℃ ... +60 ℃ (with derating above45℃)	-25 ℃ ... +60 ℃ (with derating above45℃)
Noise emission (typical)	≤50 dB(A)	≤50 dB(A)	≤50 dB(A)	≤50 dB(A)
Self-Consumption (night)	<1W	<1W	<1W	<1W
Topology	Transformerless	Transformerless	Transformerless	Transformerless
Cooling concept	Smart cooling	Smart cooling	Smart cooling	Smart cooling
Environmental Protection Rating	IP65	IP65	IP65	IP65
Altitude	4000m without derating	4000m without derating	4000m without derating	4000m without derating
Relative Humidity	0~100%	0~100%	0~100%	0~100%
Features				
Display	Graphic LCD	Graphic LCD	Graphic LCD	Graphic LCD
Interfaces: RS232/RS485/WiFi/LAN/GPRS	yes / yes / opt / opt / opt	yes / yes / opt / opt / opt	yes / yes / opt / opt / opt	yes / yes / opt / opt / opt
Warranty:5 years / 10 years	yes / opt	yes / opt	yes / opt	yes / opt

Certificates and Approvals

CE, IEC 62109-1/2, IEC 61727, IEC 62116, VDE 0126-1-1, Greece, VFR 2014, CEI 0-21, CEI 0-16, VDE-AR-N4105, EN50438, G59/3, AS 4777, PEA, IEC 60529, IEC 60068, IEC 61683,

Appendix N

Questionnaire

Onderzoek naar motivatie voor elektrisch rijden

Let op: In dit onderzoek verwijst de term elektrische auto's alleen naar de volledig elektrische auto's. De hybrides vallen dus niet onder deze term in dit onderzoek.

*Vereist

1. **Hoe bekend ben je met elektrische auto's?** *
   Markeer slechts één ovaal.

   - ( ) Veel ervaring
   - ( ) Redelijk bekend
   - ( ) Gemiddeld
   - ( ) Niet heel erg bekend
   - ( ) Niet *Ga naar vraag 3.*

Ga naar vraag 3.

Ervaring

2. **Welke van de volgende beweringen zijn van toepassing op jouw ervaring met elektrische auto's? (meerdere antwoorden mogelijk)** *
   Vink alle toepasselijke opties aan.

   - [ ] Ik heb zelf een elektrische auto
   - [ ] Ik ken iemand die een elektrische auto heeft
   - [ ] Ik heb in een elektrische auto gereden, als bestuurder
   - [ ] Ik heb in een elektrische auto gereden, als bijrijder
   - [ ] Ik heb wel eens een elektrische auto zien rijden of opladen
   - [ ] Ik heb een elektrische auto gezien in de showroom
   - [ ] Ik heb een elektrische auto gezien bij een autoshow of event
   - [ ] Ik heb veel onderzoek gedaan naar elektrische auto's

Ga naar vraag 3.

Mening over elektrisch rijden

3. **Wat denk je dat de voordelen zijn van elektrisch rijden? (maximaal 3 antwoorden mogelijk)** *

Vink alle toepasselijke opties aan.

- [ ] Minder CO2 uitstoot
- [ ] Verlaagt de afhankelijkheid van brandstoffen zoals diesel & benzine
- [ ] Lagere brandstofkosten
- [ ] Goedkoper in onderhoud
- [ ] Gebruiksvriendelijk
- [ ] Levert goede prestaties
- [ ] Imago
- [ ] Elektrische auto's zijn stiller
- [ ] Ik denk niet dat er voordelen zijn
- [ ] Anders: ____________________

4. **Wat denk je dat de nadelen zijn van elektrisch rijden? (maximaal 3 antwoorden mogelijk)** *

Vink alle toepasselijke opties aan.

- [ ] Oplaadtijd
- [ ] Aanschafprijs van een nieuwe elektrische auto t.o.v. benzine & diesel voertuigen
- [ ] Beperkt aanbod
- [ ] Afstand die gereden kan worden op één accu
- [ ] Oplaad mogelijkheden
- [ ] Niet thuis kunnen opladen
- [ ] Imago
- [ ] Ik denk niet dat er nadelen zijn
- [ ] Anders: ____________________

5. **Geef bij elk van de onderstaande potentiële barrières aan hoe belangrijk deze is voor jou** *
Markeer slechts één ovaal per rij.

	Heel belangrijk	Belangrijk	Neutraal	Niet belangrijk	Helemaal niet belangrijk
Aanschafprijs van het voertuig	◯	◯	◯	◯	◯
Aantal kilometer dat kan worden gereden op één volle accu	◯	◯	◯	◯	◯
Aantal publieke oplaadpunten	◯	◯	◯	◯	◯
Afname in batterijprestaties over de tijd	◯	◯	◯	◯	◯
Brandstofkosten	◯	◯	◯	◯	◯
Invloed van bepaalde (externe) weersomstandigheden op de prestaties van het voertuig	◯	◯	◯	◯	◯
Mogelijkheid om op te laden op het werk	◯	◯	◯	◯	◯
Mogelijkheid om thuis op te laden	◯	◯	◯	◯	◯
Onderhoudskosten	◯	◯	◯	◯	◯
Type voertuig dat gekozen kan worden	◯	◯	◯	◯	◯

Over jou

6. **Op welk niveau ben je werkzaam bij TUI?** *
Markeer slechts één ovaal.

- ◯ Directie
- ◯ Leidinggevend
- ◯ Medewerker

7. **Wat is je bruto jaarinkomen ongeveer?** *
Markeer slechts één ovaal.

- ◯ Minder dan modaal (<€36.000)
- ◯ Modaal (€36.000)
- ◯ 1.5 keer modaal (€54.000)
- ◯ 2 keer modaal (€72.000)
- ◯ Meer dan 2 keer modaal (>€72.000)
- ◯ Wil ik niet zeggen

8. **In wat voor auto rijd je nu? (wanneer je beschikt over meerdere auto's kies dan degene waarmee je de meeste kilometers rijdt)** *
Markeer slechts één ovaal.

- Benzine
- Diesel
- Elektrisch
- Hybride
- Waterstof

9. **Onder welke categorie val je?** *
Markeer slechts één ovaal.

- Ik kom met mijn eigen auto *Ga naar vraag 10.*
- Ik ben lease rijder *Ga naar vraag 14.*

Eigen auto

Bij de volgende twee vragen gaan we ervan uit dat je nu een nieuwe auto gaat aanschaffen.
Let op: Het gaat hier om nieuwe auto's, dus een tweedehands auto valt hier niet onder

10. **Als je nu een nieuwe auto zou aanschaffen, wat voor type auto zou je dan kiezen?** *
Markeer slechts één ovaal.

- Cabriolet
- Hatchback
- MPV
- Pick-up
- Stationwagen
- SUV
- Sportauto

11. **Als je nu een nieuwe auto zou kopen, wat verwacht je dan uit te geven aan de nieuwe auto? (aanschafprijs)** *
Markeer slechts één ovaal.

- Minder dan €10.000
- €10.000 - €15.000
- €15.000 - €20.000
- €20.000 - €25.000
- €25.000 - €30.000
- €30.000 - €35.000
- €35.000 - €40.000
- €40.000 - €45.000
- €45.000 - €50.000
- Meer dan €50.000
- Meer dan €75.000
- Meer dan €100.000

Als bedrijf is TUI erg gemotiveerd om een positieve impact te hebben op de maatschappij en daarom ziet TUI graag dat haar medewerkers zich op een meer duurzame manier verplaatsen van huis naar werk.

12. **Geef bij elk van de onderstaande opties aan hoeveel invloed deze zouden hebben op de beslissing om voor een elektrische auto te kiezen als jouw volgende auto.** *

Markeer slechts één ovaal per rij.

	Heel veel invloed	Veel invloed	Een beetje invloed	Geen invloed
Gratis opladen op werk	◯	◯	◯	◯
Gratis opladen (onderweg)	◯	◯	◯	◯
Gratis eigen laadpaal thuis	◯	◯	◯	◯
Dubbele kilometervergoeding t.o.v. de huidige vergoeding	◯	◯	◯	◯
Gegarandeerde toegang tot een parkeerplaats bij een van de hoofdkantoren	◯	◯	◯	◯
Eenmalige (geld) bijdragen tot €2.500	◯	◯	◯	◯
Mogelijkheid om de elektrische auto in te ruilen voor een benzine auto voor bijvoorbeeld een autovakantie	◯	◯	◯	◯
Voorlichting krijgen over elektrische auto's	◯	◯	◯	◯

13. **Heb je zelf nog een suggestie over hoe TUI haar medewerkers meer zou kunnen stimuleren om over te stappen naar een elektrische auto?** *

Ga naar vraag 21.

Lease auto

14. **Hoelang geleden ben je je huidige leaseovereenkomst aangegaan?** *

Markeer slechts één ovaal.

- ◯ Minder dan een halfjaar geleden
- ◯ Minder dan een jaar geleden
- ◯ Minder dan twee jaar geleden
- ◯ Meer dan twee jaar geleden *Ga naar vraag 16.*

Ga naar vraag 21.

Verdieping auto keuze

15. **Waarom heb je bij het aangaan van uw huidige leaseovereenkomst niet gekozen voor een elektrische auto?** *
Markeer slechts één ovaal.

- Ik heb wel voor een elektrische auto gekozen
- Ik heb de optie niet gekregen om te kiezen voor een elektrische auto
- Ik weet te weinig over elektrische auto's
- Ik vind een elektrische auto te veel gedoe
- Anders: ______________________

Nieuwe lease auto

Bij de volgende drie vragen gaan we ervan uit dat jouw huidige leaseovereenkomst binnenkort afloopt en dat je nu een nieuwe auto mag uitzoeken.

16. **Wat voor type auto zou je dan kiezen?** *
Markeer slechts één ovaal.

- Hatchback
- MPV
- Stationwagen
- SUV
- Pick-up

17. **Hoeveel ben je dan bereid om maximaal per maand te betalen aan bijtelling?** *
Markeer slechts één ovaal.

- Tot €100
- Tot €200
- Tot €300
- Tot €400
- Meer dan €400
- Anders: ______________________

18. **Hoeveel zou je maximaal bereid zijn om extra te betalen (bovenop de bijtelling) voor het leasen van een elektrische auto?** *
Let op: Het gaat hier dan om het bedrag dat je extra per maand extra moet betalen wanneer je een auto kiest waarvan de kosten hoger zijn dan behorende bij jouw functiegroep
Markeer slechts één ovaal.

- Tot €50
- Tot €100
- Tot €150
- Tot €200
- Tot €250
- Tot €300
- Meer dan €300

Als bedrijf is TUI erg gemotiveerd om een positieve impact te hebben op de maatschappij en daarom ziet TUI graag dat haar

medewerkers zich op een meer duurzame manier verplaatsen van huis naar werk, maar ook privé en zakelijk.

19. **Geef bij elk van de onderstaande opties aan hoeveel invloed deze zouden hebben op de beslissing om over te stappen op een (volledig) elektrische lease auto.** *

Markeer slechts één ovaal per rij.

	Heel veel invloed	Veel invloed	Een beetje invloed	Geen invloed
Gratis laadpaal thuis	◯	◯	◯	◯
Eenmalige (geld) bijdragen (tot €2.500)	◯	◯	◯	◯
Kilometervergoeding gelijk aan die voor niet lease rijders (9-13 cent/km)	◯	◯	◯	◯
Compensatie in het meer te betalen bedrag t.o.v. een reguliere auto	◯	◯	◯	◯
Mogelijkheid om de elektrische auto te ruilen voor een benzine auto voor bijvoorbeeld een autovakantie	◯	◯	◯	◯
Voorlichting krijgen over elektrische auto's	◯	◯	◯	◯

20. **Heb je zelf nog een suggestie over hoe TUI haar medewerkers meer zou kunnen stimuleren om te kiezen voor een elektrische lease auto?** *

Slot

21. **Eerder heb je al aangegeven wat je denkt dat de belangrijkste nadelen zijn van elektrisch rijden, maar welke van de onderstaande factoren is jou (op dit moment) dé reden om geen elektrische auto aan te schaffen?** *

Markeer slechts één ovaal.

- ◯ Het is te duur
- ◯ Ik kan niet ver genoeg rijden op één accu
- ◯ Ik kan onderweg nergens opladen
- ◯ De auto die ik zou willen, daar is (nog) geen elektrische uitvoering van
- ◯ Opladen duurt te lang
- ◯ Ik kan thuis niet opladen
- ◯ Ik vind het te veel gedoe/ Het is te ingewikkeld

22. **Verwacht u binnen nu en 2 jaar een elektrische auto aan te schaffen?** *

Markeer slechts één ovaal.

- Ja
- Nee, ik wacht tot TUI met gunstige voorwaarden komt
- Nee, ik wacht tot ze goedkoper worden
- Nee, ik blijf het te veel gedoe vinden en stap liever helemaal niet over op een elektrische auto

Einde

Dit was de laatste vraag van de enquête, heel erg bedankt voor je bijdrage!
Mocht je geïnteresseerd zijn in de resultaten of nog vragen hebben na aanleiding van de enquête, stuur dan een mailtje naar xenia.wesdijk@tui.nl