The economic and environmental potential of electric cars within the Amsterdam Airport Corridor

A research commissioned by theGROUNDS – Schiphol Group

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PREFACE

Schiphol, May 2011

July 2010

"One thing, I am sure of. If I can choose, my graduation project should emphasize the subjects mobility, sustainability and innovation. Maybe I can conduct my research within the aviation industry to build on earlier experiences. Let´s find out." I start the Google search engine and enter the Dutch words: 'mobiliteit', 'duurzaamheid', 'innovatie' and 'luchthaven'.

May 2011

By that time I had never heard of theGROUNDS, nor the initiatives of Schiphol Group to increase the airport's sustainability. Airport activities – while being of major importance for a region's or county's economy and having countless interfaces and relationships with its environment that must be carefully maintained – are above all not environmentally sustainable, right?

Right, no doubt about it. But at that time my second hit on Google contained a news item at the website of my very own university stating the following (translated from Dutch): "At 10 May (2010) Schiphol Group launched 'theGROUNDS'; the platform and laboratory of Amsterdam Airport Schiphol where renowned companies and knowledge institutes jointly develop innovative solutions for a sustainable airport". Obviously, I knew immediately this was the place where I wanted to finish my student career.

Last year I found out that theGROUNDS' quest for airport sustainability is sincere. However, there is a continuous struggle to combine sustainability with the satisfaction of economical goals of Schiphol Group. Persistency is needed to realize progressive projects, as well as the belief in the potential of sustainability. For me it was a great honour to be able to contribute to the difficult quest. I hope that theGROUNDS will continue its initiatives related to the Airport City´s activities in its broadest sense, and that companies and governments are inspired by the projects exposed.

While Schiphol struggles to find balance between economic and environmental goals, the research exposed personal struggles as well, balancing business and academic relevance in my research. I was lucky to have empathic supervisors that – when necessary – helped me to find the right directions. I owe special thanks to Jan Anne Annema for his involvement, flexibility, patience and substantive comments. Furthermore, I want to thank Zofia Lukszo and Vincent Marchau for their time, interest and critical notes. I also want to thank Carijn Manders and Jonas van Stekelenburg for the opportunity to work on this interesting project and actually contribute to the airport's goals. And all my colleagues at theGROUNDS for the intimate and inspiring atmosphere, the perfect work-life balance, the wonderful experience. But most of all I want to thank those close to me, my family and friends, that dragged me through a turbulent period, with big ups and downs, as I know they will always do.

This report presents the results of a research project that is conducted as a thesis of the master program Systems Engineering, Policy Analysis and Management for graduating from Delft University of Technology (DUT). The research is commissioned by theGROUNDS – a department of Schiphol Group.

Let the vision inspire you,

Niels Nobel

EXECUTIVE SUMMARY

Introduction

Schiphol Group – airport operator – aims to position Amsterdam Airport Schiphol as Europe's preferred airport. One of the elements to achieve this is the minimization of negative impacts of airport operations, which also contributes to the continuous license to operate and grow. The emissions of greenhouse gases and air pollutants form an important aspect of the considered impact. Airplane movements, energy use and background concentrations contribute to 70% of the most important emissions in the airport area – CO_2 and NO_X. The remaining 30% is caused by traffic and transportation. Worldwide, electric cars are emerging as a promising alternative to reduce transport related emissions. Schiphol Group shares this interest. A supplementary point of interest for the airport operator is the strengthening of the coherence between and the attraction of the airport and nearby business centres; the area that is referred to as the Amsterdam Airport Corridor.

The research question that substantiates the interests of Schiphol Group is the following:

> *What is the economic and environmental potential of introducing electric cars within the Amsterdam Airport Corridor?*

To answer this question, this thesis presents the assessment of four different alternative projects to introduce electric cars in the Amsterdam Airport Corridor. The performance of electric cars, relative to mainstream diesel cars, is determined using the Net Present Value and emission rates. Uncertainties within the economic and environmental variables are covered using scenarios. Based on the results there is formulated a conclusion regarding the potential of electric cars in different alternative projects, and the best alternative to start their introduction. Furthermore, there are made recommendations about the future use of the results and underlying research methods.

Analysis description

To assess the potential of electric cars, they are compared with diesel cars in different project alternatives. The comparison is done on the basis financial and environmental performance, using the Net Present Value (NPV) and emission rates. As there are several important input factors that are subject to uncertainty, there is made use of scenarios to indicate the possible range of performance. Judging by the results the street taxi seems most interesting to start the small scale introduction of electric cars.

Project alternatives

There are four alternatives within the Amsterdam Airport Corridor that are considered suitable to start the introduction of electric cars: the street taxi, ordered taxi, rental car and semi-private taxi. The first three are currently commercially exploited. The semi-private taxi is a newly designed alternative that attempts to optimally take into account the technical limitations of the electric car and the specific mobility demand within the corridor. The focus on commercial transport services enables cooperation with central operators and fleet owners.

Economic and environmental performance

Currently, the exploitation of these transport services is mainly done using diesel cars. The potential of the electric car is assessed using its relative economic and environmental performance compared to diesel cars. An Excel spreadsheet model is used for quantitative calculations. Input for the financial analysis is partly based on background research on technology and market development. Specific input for the alternative projects is derived from expert interviews from Schiphol Group and transport service operators. The input for the calculation of emissions is based on literature research.

Net Present Value

The financial performance of electric and diesel cars is determined on the basis of the Net Present Value (NPV). The NPV calculation uses investment costs and operational income and expenses during the whole project period and returns the potential value of investment options. Relevant input variables are the technical and financial specifications of cars, batteries, chargers and infrastructure. Furthermore, for each project separately, there are made considerations about the locations within the corridor that must be served, weekly and daily operations schedules, operating costs and benefits, possible demand for electric transport services and the related number of cars for actual service provision.

Emission rates

The environmental performance is determined on the basis of CO_2, NO_X and PM_{10} emissions, which are considered most important for traffic and transportation. Total emission levels are a result of the emissions per kilometre and the yearly mileage of all the cars in a specific project. The latter relates to the possible service demand which is a result of the financial analysis. The emission per kilometre is a summation of central well-to-tank (WTT) and local tank-to-wheel (TTW) emissions. Literature seems to be certain about emissions from diesel cars, as well as local emissions of electric cars. However, there are made widely differing estimations for WTT CO_2 emissions related to electricity generation that is needed for electric car usage.

Uncertainties

Some of the input for the calculation of the NPV and emission rates is subject to uncertainty. The analysis uses scenarios for uncertain factors having high impact on the project's outcome. This way, insights are gained in the risks of investments; the possibility of negative impact under particular circumstances. Having these insights, more robust decisions can be made. There are distinguished three scenarios: an optimistic (+), neutral (0) and pessimistic (-) one.

For NPV calculations these scenarios differ in the demand for electric transport services and the related number of cars for which investments are needed. Second, technical and financial specifications are varied in their favourability for the electric car. The most important uncertainty in the calculation of emission rates is the CO_2 emission that relates to the generation of electricity that is needed for electric cars. The optimistic and pessimistic scenario cover the extreme emission rates presented in literature, while the neutral scenario returns an average level.

Results

The economic and environmental analyses indicate the NPV and emissions using either electric or diesel cars within the alternative projects. To obtain the potential of electric cars, its performance is compared to diesel cars, which returns the relative NPV and emissions. As indicated, the NPV reflects the financial performance of the whole project, while the emission rates are reflected per single year. Table 1 presents the results considering the neutral scenarios for the calculation of NPV and emissions.

Table 1: Relative performance of electric cars compared to diesel cars considering the neutral scenarios

	NPV (€ x1.000)	**CO_2** (ton/yr)	**NO_X** (kg/yr)	**PM_{10}** (kg/yr)
Street taxi	145	31	125	2,7
Ordered taxi	7	23	94	2,0
Rental car	-281	4	18	0,4
Semi-private taxi	-335	37	150	3,3

The table indicates that the NPV of the street taxi and ordered taxi alternative is higher when using electric cars. The electric semi-private taxi returns best emission rates, followed close by the street taxi. Electric rental cars perform worse than their diesel counterpart, both economically and environmentally.

To enable a clear visualization of the results in each scenario, the values indicating the potential of electric cars are made relative again, this time to each other. The reference points are the scores of the alternatives with the highest economic and environmental potential in the neutral scenarios. As indicated in Table 1, these are the street taxi for the NPV and the semi-private taxi for the emissions. Their maximums are set at 100 while the other scores are made relative to 100. By doing so, the alternatives can be easily plotted in a economic-environmental performance graph. Besides, it enables the use of one single score for the emission rates, because the relative difference between the alternative projects is the same for each type of emission.

Figure 1 shows the results in the neutral scenarios again, this time a bit clearer than in the above table. Where the electric street taxi and semi-private taxi perform best economically and environmentally (their maximums are set at 100), the electric rental car performs worst. The emissions of electric rental cars are lower than diesel cars, but the reduction realized is only 12% compared to electric semi-private taxis. The economic performance is worse than with diesel cars, and almost equals -200% compared to the electric street taxi.

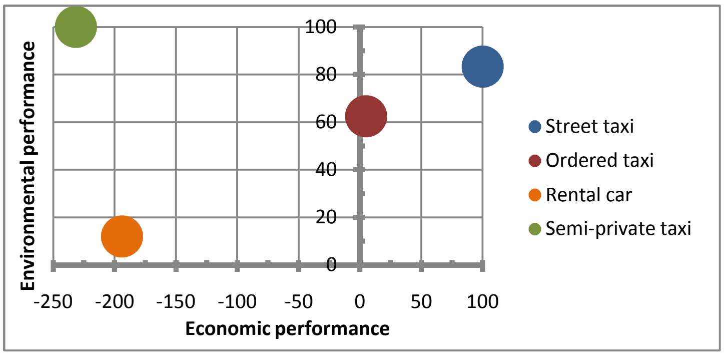

Figure 1: Graph of the relative performance of electric cars in the neutral scenario

Figure 2 visualizes the economic and environmental potential under different scenarios. An explanation is given below. Again, the performances are made relative to the maximums in the neutral scenarios. On the horizontal axis there are displayed three NPVs for each alternative relating to the three scenarios (indicated with the -, 0 and + symbols) that influence the economic potential of electric cars. Each NPV is accompanied by the range of potential emission reduction. The -, 0 and + symbols indicate the environmental potential in a neutral scenario. The upper limit of the emission range indicate the emission savings in an optimistic scenario, while the lower limits relate to the pessimistic scenario.

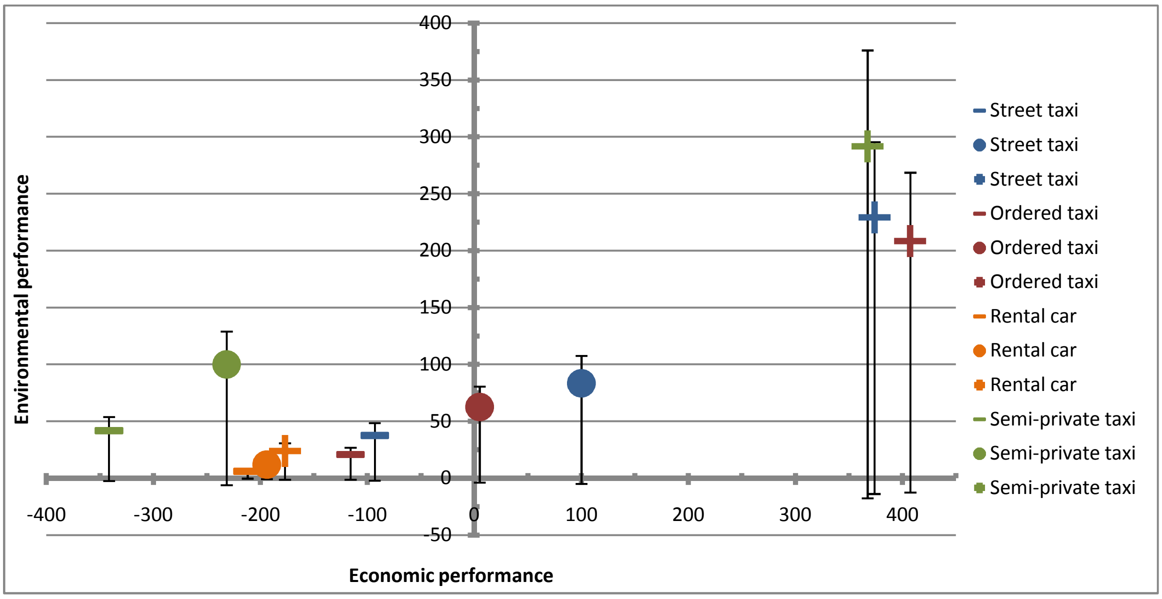

Figure 2: Graph of the relative performance of electric cars in different scenarios

Conclusions and recommendations

Interpretation results

Given the limitations and assumptions of the performed analysis, the above results indicate that an electric street taxi project has the highest economic potential, while a project with electric semi-private taxis scores best environmentally. The use of scenarios indicates the high impact of extreme assumptions for uncertain variables. In the pessimistic scenarios electric cars perform worse than diesel cars in each alternative, while the performance is outstanding in the optimistic scenarios.

Generally, high car mileages positively influence the financial potential. This can be explained by the big difference in kilometre costs for fuel and maintenance between diesel and electric cars. For the emission of NO_X and PM_{10} there are no scenarios used. In any scenario the reduction of these types of emissions is positive. There are used three scenarios for CO_2 emissions. In the pessimistic scenario the WTW emissions of CO_2 are higher for electric cars than for diesel cars, for which reason a negative score is returned. In future research of Schiphol Group for electrification of transport modes there should be paid attention to the factors that determine success; intensive use of the electric vehicle and clean electricity generation.

Dealing with uncertainties and risks

The analysis presents uncertainties and risks that need to be considered when investing in electric cars. Large setbacks by disappointing performance can be prevented by the gradual increase of project size. The large scale use of electric cars for transport services should only be pursued after a certain level of reliability is proven. Small scale projects, like the ones proposed, can be started now. While increasing knowledge on the performance of electric cars in a particular project, the presented analyses should be repeated to include this new knowledge and possible changes in the uncertainty of factors. This way it becomes clear how uncertainties develop and if new opportunities arise.

To be able to profit from rapid technology development, it is recommended to prevent technology dependency and carefully monitor possible improvements. Future projects require reconsideration of the available alternatives. Possible negative impacts must be acknowledged while contributing to their mitigation. Maximum adaptation and acceptance of new technologies and services must be achieved by intensive involvement of operators and customers. Their input should be used for continuous optimizations during the development phase but also after the start of operations.

Future opportunities and Schiphol Group's role

While it is recommended to continue to introduce electric cars in one of the promising alternative projects, its success will only lead to marginal emission reductions compared to the total emission in the Amsterdam Airport Corridor. However, indirectly, successful execution of projects can inspire new initiatives and boost the further introduction of electric vehicles.

For future projects Schiphol Group needs to carefully consider its role. Transport is not its core business. However, a guiding role fits well with the goals to further develop the Airport City, achieve environmental targets and become Europe's preferred airport.

Schiphol Group is also not unfamiliar with the guiding role. Its natural position within the regional and national political and economical environment attracts businesses and governments to cooperate. Schiphol Group should take its responsibility and align internal and external actors for optimal cooperation. Reference projects indicate that cooperation helps to decrease risks and increase success; knowledge and experience can be shared. Secondary benefits are achieved as increased cooperation helps to secure the licence to operate and grow. Initiatives of Schiphol Group in sustainable transport can have a positive drawback on the image of the airport. Jointly initiated projects of parties within the Amsterdam Airport Corridor can help to strengthen the brand of the airport region as a whole.

Part of the greater good

Electric cars are introduced for increased sustainability in traffic and transportation. However, when deciding on the division of investments and efforts, there must be balanced other goals as well. Accessibility of the airport is considered as important as sustainable transport. At a higher level, there is the goal for increased sustainability of the airport as a whole. There should also be attention for synergy between these goals that can improve the effectiveness of investments.

Future model use

Until the actual investment decision, new insights needs to be processes in the quantitative model and qualitative considerations. Reference projects should be followed as well as alternative technologies and the interests of relevant actors. Current uncertainties will fade, others will emerge. For robust decision making some needs to be considered, others can be taken for granted.

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1 INTRODUCTION

This introduction presents the origin of the research that is presented in this thesis. First, it provides the research background including the main research question. Next, the main problem owners are presented. Finally, the general structure of the report is outlined.

1.1 Research background

Schiphol Group takes its responsibility in fighting global climate problems and improving local air quality

In 2007 Schiphol Group presented the 'Schiphol Climate Plan'. This policy document discusses the company's intention to play a leading role in fighting global warming. By improving its own activities as well as by influencing and guiding business partners, Schiphol Group wants to decrease airport related CO_2 emissions by 30% in 2020 compared to 1990 (Schiphol Group, 2007) and prevent further growth in NO_X emission. This intention rises not only from the goal to be a responsible company, which is for instance formulated in the policy document 'Corporate Responsibility' (Schiphol Group, 2008). It is also believed that that a "green airport can be an interesting proposition for modern passengers" (Schiphol Group, 2007) and thus generates profit. At the Dutch Aviation Group Symposium on 25 November 2009, Schiphol Group presented a 'quality driven' strategy. This means that the airport does not necessarily need to be recognized as the biggest or cheapest of Europe. Instead, it wants to be 'Europe's preferred airport' (Rutten, 2009). The reduction of airport related emissions should contribute to this goal.

Traffic and transportation contributes substantially to airport related emissions

Airport related emissions have different sources. At Schiphol, 50% of the CO_2 emissions comes from airplane movements[1] and 30% relates to traffic and transportation on and around the airport. The final part finds its source in the use of electricity. An extensive overview of sources of CO_2 emissions can be found in Appendix A. The ratios for NO_X emissions are divided differently. 15% is caused by airplane movements and 30% relates to traffic and transportation. The remains can be attributed to background concentrations and the category 'other'[2] (Schiphol Group, 2009).

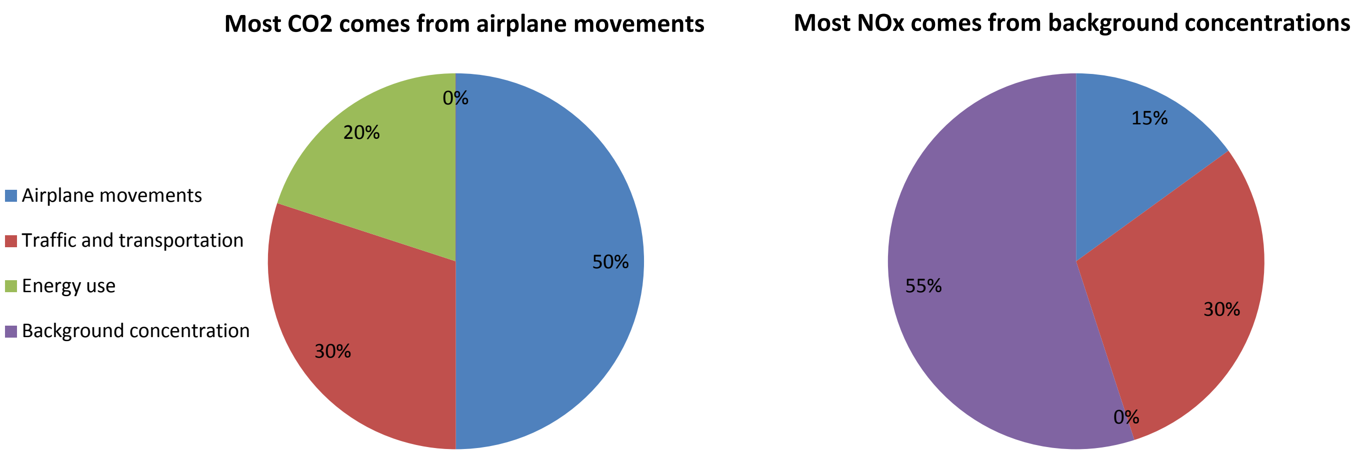

Figure 3: Sources of CO_2 and NO_X emissions at Schiphol

[1] Airplane movements include taxiing and the landing and take-off of airplanes. En route emissions are not part of this particular distribution (Schiphol Group, 2009).

[2] The background concentration of NOx can for instance be attributed to industrial activities in the airport surroundings. The category 'other' comprises for instance the use of Ground Power Units (GPUs) (Schiphol Group, 2009).

For each of the above mentioned sources, mitigating measures are formulated and initiated. As a substantial part of the airport related emissions are caused by activities within the field of traffic and transportation – 30% for both CO_2 and NO_X– a large part of these measures have to do with traffic and transportation. Projects within this field try to change the travelling behaviour of people going to Schiphol, extend infrastructure and public transport availability, think of new spatial and transport concepts and limit emissions at the source. An overview of traffic and transportation related measures is presented in Appendix B.

There is increased attention for the potential of electric cars to improve the airport's sustainability

An alternative that gets increased attention in the quest for improving the sustainability of airport related traffic and transportation is the use of electric cars. Electric engines are very efficient (Kendall, 2008), while local emissions are reduced to zero which substantially contributes to local air quality. Leading car manufacturers start large scale production of electric cars while national and local governments stimulate the use of electric vehicles[3]. These developments are carefully followed by Schiphol Group. The company already purchased 2 electric cars and a scooter that are available for its employees. Besides, by placing an order for 20 electric cars that will be used for daily operations at the airport, the company participates in a tender of DC-TEC (DC-TEC, 2010; Schiphol Group Corporate Affairs, 2010). Also other companies located at or in the surrounding of the airport are interested in the use of electric vehicles in general and electric cars in particular. Together with its partners Schiphol Group wants to investigate possibilities and the feasibility of the broad introduction of electric cars for airport related transportation and its potential contribution to reduced CO_2 and NO_X emissions.

The Amsterdam Airport Corridor is perfectly suitable to start the implementation of electric cars

Like Schiphol Group, private as well as public organizations start to undertake concrete actions to improve the sustainability of the airport region and the activities within. Also for others, traffic and transportation forms an important starting point for mitigating measures, while electric cars are increasingly seen as part of the solution. The municipality of Amsterdam heavily subsidizes the use of electric cars (Spier, 2009). Zuidas stimulates its employees to use public transport to travel to work; giving them the opportunity to use electric pool cars for customer visits (NUON, 2009). The shared interest in the potential of electric cars makes it interesting to cooperate in further research and development.

But shared interest is not the only reason to take into account Zuidas and Amsterdam in a research project concerning electric cars. Zuidas and Schiphol Group already have a partnership to alter traffic and transportation flows in order to increase the region's accessibility, while decrease the negative impact of traffic on the environment (Zuidas Amsterdam, 2010). The intensive traffic flows in the airport region form a major concern considering local air quality and CO_2 emissions (Rozema and Groenwold-Ferguson, 2010). However, if fundamental changes can be realized within these intensive traffic flows, the net improvements will be higher.

It is also believed that the international attractiveness of the region can be maintained or increased by emphasising the short distances and large integration between the airport, business districts and city centre. By presenting the region as one entity – the Amsterdam Airport Corridor – this should be done most effectively. Working together in achieving climate goals can strengthen the image of the corridor as a whole.

[3] By using the word vehicle the following definition is assumed: "any means of transport on land, *especially* on wheels, *e.g.* a car, bus, bicycle *etc"* (K Dictionaries, 2010). For this research a clear distinction has been made between vehicles and cars.

A research project is initiated to investigate feasible alternatives

This thesis elaborates on a study that is initiated by Schiphol Group to substantiate the interest in electric cars that the company shares with its environment. Succeeding the above introduction, the research question that forms the basis of this thesis is as follows:

> *What is the economic and environmental potential of introducing electric cars within the Amsterdam Airport Corridor?*

To answer this question, multiple alternative projects for the introduction of electric cars in the region are investigated. The main variables assessed are the impact of these alternatives on corporate finances and emissions. Relating these variables provides an indication of the most cost effective way to reduce emissions. Important input comprises information on the transport market in the corridor, the technology needed for electric cars, emissions related to transport and electricity generation and the possible organization of electric car operations. On this basis, analyses regarding the economic and environmental performance of different alternative projects can be done. This enables statements on the potential of electric cars in general and alternative applications in particular.

Electric vehicles are considered only part of the possible solution towards sustainable mobility

This research explores alternative projects for the introduction of electric cars that can contribute to the increased sustainability of transport in the Amsterdam Airport Corridor. There is presented argumentation for the particular focus on electric cars. It is however believed that the introduction of electric cars is only part of a complete transition to achieve Schiphol Group's goals for sustainability. Cars are only a single modality in a large transport market that causes emissions. In fact the exact drive train technology and modality focussed on is irrelevant. Likewise, transport is only one of the many activities that cause emissions at the airport and within the corridor. Achieving a sustainable airport requires attention for the improvement of all activities and technologies.

1.2 Problem owners

The study related to this thesis is initiated by *theGROUNDS*, a department of *Schiphol Group*, located at *Amsterdam Airport Schiphol*. The thesis is supported by *SIM* ('Samenwerking Innovatieve Mainport' or 'Innovative Mainport Alliance'). Schiphol Group can be considered the main stakeholder, represented by theGROUNDS. Below, for each of these four entities a short description is presented.

Schiphol Group

Schiphol Group is one of the leading airports worldwide. Schiphol Group perceives airports to be more than just a physical location that facilitates aircraft movements. Instead, the company aims at the development of Airport Cities. "An Airport City is a dynamic environment integrating and enhancing people and businesses, logistics and shopping, information and entertainment" (Schiphol Group, 2011a). Additional to aviation industry related activities, the airport provides offices, logistic services, a museum, library, casino and a golf course. Schiphol Group exploits the Airport City concept on a worldwide scale, for instance in Stockholm (Sweden), Jakarta (Indonesia), Guangzhou (China), Milan (Italy) and Hong Kong (Schiphol Group, 2011d). Furthermore, Schiphol Group is continuously working on expanding its international position through selective collaborations. Alliances are formed with other international airports, including John F. Kennedy Airport, New York (JFK), Brisbane International Airport (BNE), Reina Beatrix Aruba Airport (AuA) and Aéroports de Paris (ADP) (Schiphol Group, 2011e). Despite the worldwide business, the primary activity remains the operation of Amsterdam Airport Schiphol (AAS). AAS is an Airport City in its most advanced form, being a major example of the concept.

Schiphol Group focuses on four main business areas (Schiphol Group, 2011c). These areas cover the main activities within the Airport City of AAS: providing services and facilities to airlines, passengers and handling agents (Aviation), the operation of shops, car parks, marketing and advertising (Consumers), developing, managing and investing in properties on and around the airport location (Real Estate) and finally managing the interests in domestic and international Airports (Alliances & Participations).

Amsterdam Airport Schiphol

The most important activity of Schiphol Group is the exploitation of Amsterdam Airport Schiphol (AAS). AAS is Netherlands' main international airport. AAS is one of the oldest airports worldwide and ranked 5^{th} in Europe for the number of passengers. When Schiphol is mentioned in this report Amsterdam Airport Schiphol is meant. The executed research focuses on the Schiphol and its region; the Amsterdam Airport Corridor.

TheGROUNDS

TheGROUNDS is a department of Schiphol Group established in May 2010. It comprises a partnership with Imtech, Wageningen University and Research centre (WUR), Delft University of Technology (DUT) and the Dutch organization for applied scientific research (TNO). The main goal of theGROUNDS is to accelerate the development and introduction of sustainable airport innovations (Schiphol Group - theGROUNDS, 2010). Therefore, theGROUNDS established an incubator (theGROUNDS INCUBATOR), an area of 60 hectares to test innovations (the testingGROUNDS (Silvester et al., 2010)) and an innovation fund to financially support technical start-ups (Mainport Innovation Fund (Mainport Innovation Fund, 2011)). Furthermore, theGROUNDS initiates its own projects responding to needs and questions formulated within Schiphol Group. The study related to this thesis is initiated from that perspective; to encourage sustainable mobility and investigate the potential of electric cars to achieve this.

SIM

The 'Samenwerking Innovatieve Mainport' (SIM) or 'Innovative Mainport Alliance' comprises a cooperation between Schiphol Group, Koninklijke Luchtvaart Maatschappij (KLM), the National Aerospace Laboratory (NLR), the Dutch organization for applied scientific research (TNO) and Delft University of Technology (DUT). The SIM aims to position AAS as an innovative and leading European airport by providing new solutions for current and future issues. To achieve this, the SIM invites graduates to perform research while profiting from knowledge and experience from its partners (Samenwerking Innovatieve Mainport, 2010).

Responsibilities and arrangements

The research project is executed at theGROUNDS department. To maximize project relevance there has been close contact with departments and persons within Schiphol Group being relevant for the researched topic. Opportunities for other airports operated by Schiphol Group were not taken into account. So only the activities at Amsterdam Airport Schiphol and within its region – the Amsterdam Airport Corridor – were researched. Finally, SIM helped to secure the quality of the research and provided a database with completed research projects that was used for inspiration, relevant additional information and insights in the Schiphol environment.

1.3 Thesis outline

The following chapter contains the research description. In this chapter the problem that is introduction is this section is further described and delineated. These are followed by the main research goal and questions that must lead to an answer for the presented problems. Finally, the method that is used in this research is presented.

To be able to perform and present relevant analyses on the presented problem, there was done extensive background research. The most important retrieved information that is also influencing the presented research is summarized in Chapter 3 - Exploratory research. The chapter describes the possibilities to embed presented projects in the existing organization of Schiphol Group. Furthermore there are analyzed technical systems that are needed for the use of electric cars. And finally the market that must be penetrated is assessed for its potential to adapt electric transport services.

Chapter 4 presents the model that is used to substantiated further analyses. The required output is deducted from the general problem description. The necessary input as well as the calculations to achieve the required output follow logically from this.

The next chapter discusses the results from the research. First, the project alternative are assessed qualitatively by analysing the generic input for each of the alternatives as well as the input that is specific for each of them. Finally the quantitative results are presented, indicating the performance of the alternative projects relative to each other.

The report finished with conclusions on the presented results and recommendations for further research within Schiphol Group. Besides, there is presented an elaborate reflection on the research performed leaving room for further improvements.

2 RESEARCH DESCRIPTION

The introductory chapter presented the research's origin and justification. This chapter discusses the framework of the research. The first paragraph elaborates on Schiphol Group's problems that motivate the research and the second paragraph presents the research delineation. These lead to the main research goal and questions. Finally, the method is provided to answer the questions and come to a solution to mitigate the problems experienced.

2.1 Problem description

The introduction of electric cars in the airport region can contribute to increased sustainability. By presenting the ideal and current contribution of the airport to its environment, as envisioned by Schiphol Group, there is given insight in the gap that is supposed to be bridged. The goals that are set by Schiphol Group, both for the company as a whole as for this particular project, should contribute to the decreased difference between the ideal and current situation.

Ideal situation

The ideal situation is the desired future state of the airport within its environment. While envisioning an ideal not likely to become reality, it forms a good starting point for comparison with the current situation, the definition of the gap and the formulation of goals.

In the ideal situation the existence of Schiphol has maximal positive contribution to its environment. Noise and pollution are reduced to zero, the region is perfectly accessible, and the airport provides economic prosperity to the airport region as well as the Netherlands as a whole. Local air quality easily meets the required European standards, while the contribution to global warming is reduced to zero as the airport operates CO_2 neutral. There is a strong license to operate and grow as negative impacts of the airport are hardly perceived.

Current situation

The current situation lies miles behind the sketched ideal situation. Currently negative impacts of the airport on its environment like polluting emissions, noise and deteriorating accessibility gain a lot of public attention. This is noticed even more due to the growing awareness of climate change and the need for corporate responsibility.

The airport's contribution to global climate issues and local impact passed the board room of Schiphol Group as well. To be competitive is not the only formulated goal anymore. Being responsible within the own environment is currently as important. Closing the airport is not an option; jobs created and the positive economic impulse on the local and national region can compensate the negative impact. However, Schiphol Group is urgently searching for alternatives to limit complaints and improve air quality, while constantly proving its significant economic contribution.

Securing the licence to operate and grow

While there is still a lot of disagreement about the main drivers for and consequences of climate change (Hulme, 2009), there seems consensus about the contributions of CO_2 and other greenhouse gasses to global warming (Gore, 2006). As the attention for related problems grow, an increasing number of companies formulate sustainable strategies. This is not only done to retain or improve the company's image; the global attention for sustainability enables these strategies to be profitable.

As sustainable strategies become a way to make profit, they can also drive competitiveness. AAS can only grow if it operates in balance with its direct environment. The limits for growth are determined on the basis of existing social and governmental support. Without support, the airport has no license to operate and grow. Schiphol Group has to make sure that the perceived advantages of the airport – economic benefits – are bigger than the perceived disadvantages – the negative impact on the local and global environment (Bours, 2007).

The gap to bridge

The ideal and current situation indicate that there is a large gap to bridge. In the ideal situation the airport should only contribute to its environment in a positive way, while its license to operate and grow is indisputable. The current situation sketches the negative impact that is imposed by airport operations related to emissions, noise and accessibility as well as the necessary efforts to secure operations and growth. The goals of Schiphol Group aim to improve the current situation and minimize the gap with the ideal one.

Schiphol Group´s goals

As explained, Schiphol Group aims at securing its license to operate and grow. The introductory section presented Schiphol Group´s goal to become Europe´s preferred airport. Both can be considered primary goals to achieve long term security of profitable airport operations. While having a different focus – on the airport's customers and its relation to the environment – there can be appointed overlap in related sub goals. The figure below visualizes the different goals and the related policy documents.

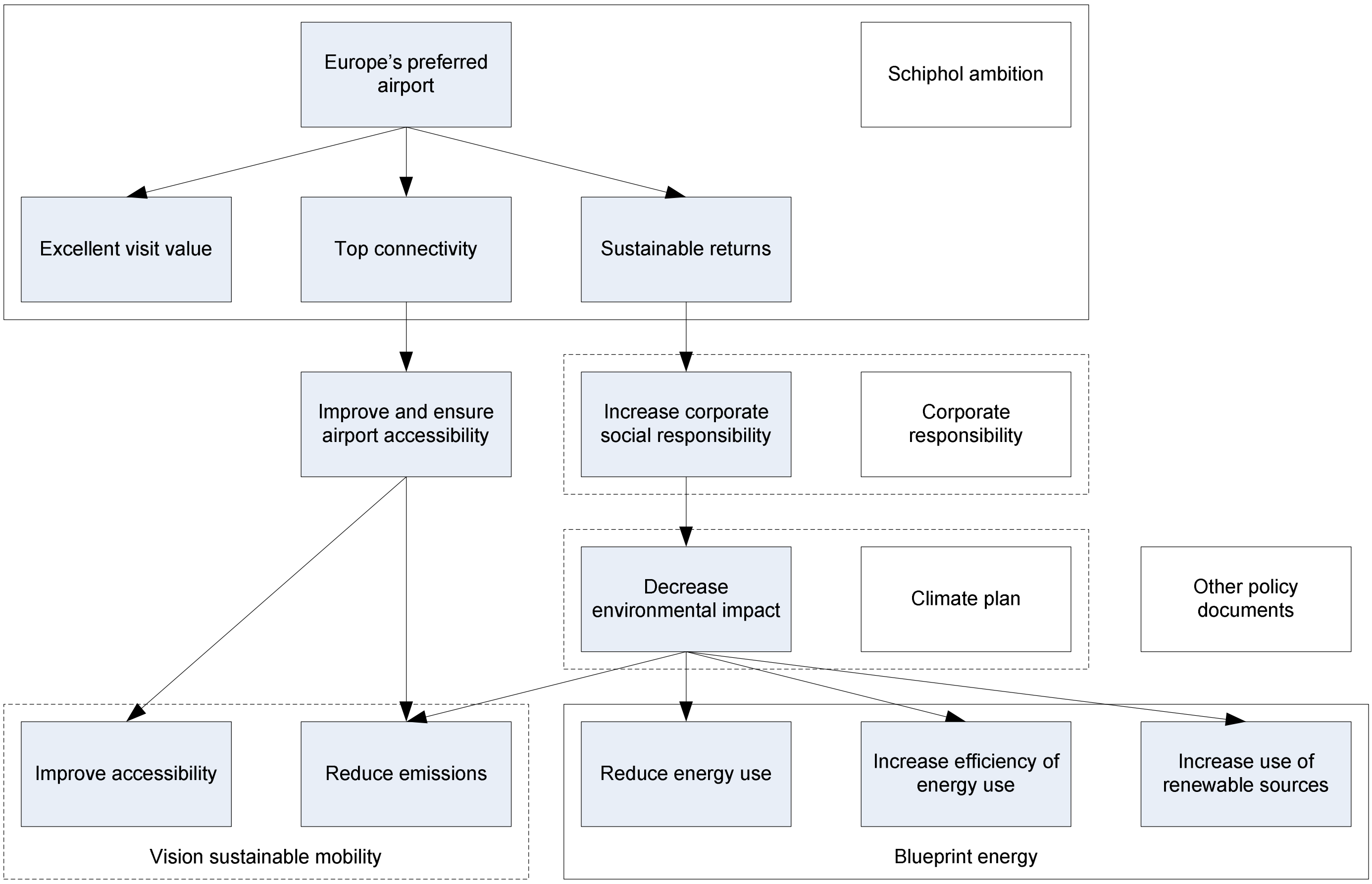

Figure 4: Overview of Schiphol Group's goals and related policy documents

The alternative projects presented in this research for the introduction of electric cars should contribute to the reduction of transport related emissions. Next to this research, there can be considered other projects to achieve reduced emissions in transport, as well as projects relating to the other goals at the operational level of the above figure.

Research problem

Schiphol Group sees a lot of possible alternatives to mitigate the effects of airport related transport on the ecological environment. Most of the alternatives are quite innovative, and not yet implemented on a large scale. Therefore the knowledge on these alternatives is limited. Besides, most alternatives involve relatively high investment costs. The risks involved with innovative transport alternatives make the Schiphol Group a bit reticent towards their introduction. To overcome this, there should be more knowledge on the actual effects of innovative transport alternatives, the costs involved and potential investment risks. The reticent attitude does also exist towards electric cars which should be overcome by increased knowledge from this research.

2.2 Project delineation

The initiated research project assesses the potential of electric cars to improve transport sustainability in the Amsterdam Airport Corridor. This implies research delineation on several fronts, which is elaborated in this paragraph.

Amsterdam Airport Corridor

First, the project scope is bounded geographically by only looking at the Amsterdam Airport Corridor (AAC); the area surrounding Schiphol and Zuidas (depicted in Figure 5). For Schiphol Group it is obviously most relevant to consider its direct region. Thereby, Schiphol and Zuidas are in a unique situation compared to other European cities, having the airport located within a 10 kilometre range of the city´s main business district.

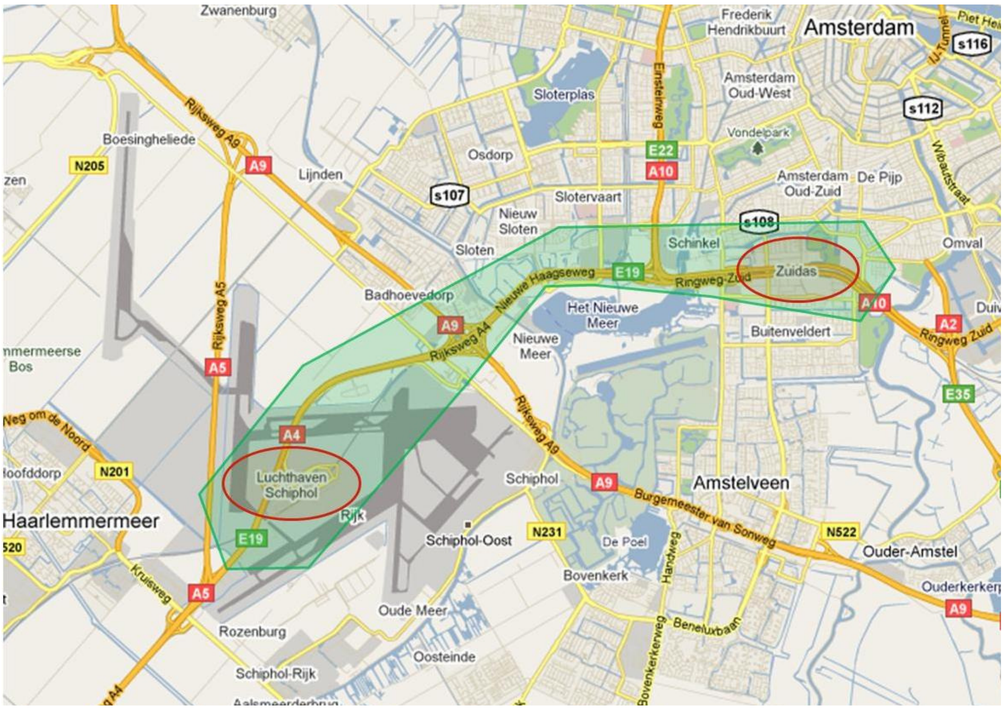

Figure 5: Visualization of the Amsterdam Airport Corridor

Schiphol and Zuidas already cooperate intensively to optimally profit from their proximity. However, despite the natural competitive edge, they recognize the importance of increasing cooperation to continuously keep ahead of other regions (Zuidas Amsterdam, 2010). Shared interests concern the accessibility of the AAC and necessary management of the huge traffic flows within it, both on road and rail (Ministry of Transport Public Works and Water Management, 2010a; Ministry of Transport Public Works and Water Management, 2010b). Also similar goals for improved sustainability – Zuidas aims for the European top 10 of sustainable urban areas in 2030 (Gemeente Amsterdam, 2010) – form a motivation for intensified cooperation.

Sustainability

The research is conducted at theGROUNDS, a relatively new department of Schiphol Group that is established to accelerate the development and introduction of sustainable airport innovations (Schiphol Group - theGROUNDS, 2010). In line with these goals and the transport related problem, theGROUNDS is looking for technical innovations that contribute to the reduction of emissions in the airport region. This implies the second point of delineation; the focus on the sustainability of transport alternatives. The emissions that are the subject of research are CO2 – an important greenhouse gas – and NO_X and PM_{10} – pollutants having considerable effect on local air quality and human health.

Electric cars

As most routes towards Schiphol, the corridor route can be traversed using different modalities. For each of the separate modalities there are alternatives to increase sustainability. Moreover, the sustainability of complete transport flows can be increased by giving preference to sustainable modes; the train or bike instead of the car. Also the modality focussed on in this research project – the electric car – is promoted in literature and practice as a promising alternative for increased sustainability in transport. Taking its perceived responsibility Schiphol Group wants to particularly investigate alternative uses of the electric car to improve the sustainability of transport that is directly and indirectly related to the airport's activities. The focus on electric cars form the third point of delineation.

Dimensions of sustainable transport

In practice sustainability is often linked to the environment. Contrary, literature identifies three different dimensions of sustainability (Glavic and Lukman, 2007; Nykvist and Whitmarsh, 2008). First, the economic dimension. Considering transport this comprises factors like accessibility, operation costs and economic benefits. The second dimension concerns the environment and includes the use of resources, emissions in air, soil and water and noise. Finally, the social dimension comprises factors like affordability, safety and health.

The environmental dimension of sustainability is of primarily importance for theGROUNDS and this research project.

Despite efforts to change people's modality choice, it is believed that cars will continue to be used. It is currently the most used modality and more sustainable modes are remain unsuitable for some because of low accessibility or high mobility needs. Schiphol Group believes that electric cars can be a good alternative for the remaining car trips within the airport corridor. As a consequence of the choice to investigate the potential of the electric car, public modes like the bus and train are excluded from the project scope. However, the potential of stimulating the use or improving these alternative modes is not underestimated. This definitely needs consideration in the overall efforts to improve transport sustainability.

The focus on electric cars does not only limit the modes that are researched but also the technology to improve sustainability. This implies a certain level of trust in electric drive trains, which seems a bit rash. Beggs (1981) performed a statistic demand forecast for electric cars and concluded, long before a serious large scale attempt for its introduction was made, that the lower operating costs of electric cars will not outweigh the disadvantageous of a limited range and long refuelling periods. In his historical analysis of electric and hybrid car development Høyer (2008) is only a bid less sceptic. His conclusion states that it still needs to demonstrated to what extend electric cars will gain more permanence this time.

However, next to these negative statements there should be placed the rapid technological development of electric mobility. Increasing efforts to eliminate barriers led to technology for fast charging (Epyon power, 2011a), quick battery change (Better Place, 2011a) and driving ranges of over 600 kilometres (Automobiel Managament, 2010). Governments and companies pronounce increasing belief in the potential of electric mobility. In 2011 the first full-fledged electric production cars were introduced in de market (Nissan, 2010); Amsterdam has subsidized the installation of 100 charging poles, and has released a public tender for another 1000 (Vink, 2010). Also the national government promotes the fast introduction of electric vehicles by stimulating the knowledge centralization and new initiatives in private-public partnerships like D-Incert (D-Incert, 2010), Formule E-team (Agentschap NL, 2011a) and the so called 'Proeftuinen' for hybrid en electric driving (Agentschap NL, 2011b). Represented by the Green Business Club (Businessclubsoftware BV, 2011) and theGROUNDS, Zuidas and Schiphol Group initiated the Mobility Lab; a forum that investigates alternatives to decrease and improve the sustainability of mobility in the Amsterdam Airport Corridor.

Project constraints

Economics

Schiphol Group is a commercial organization that is financially driven; it has to make profit. Individual projects that are executed within the company can normally not be unprofitable. In principal this is also the case for the research projects for the introduction of electric cars. TheGROUNDS aims for the realization of sustainable projects that are also profitable, as it is believed that only these projects can be successful on the long term. However, the financial demands are less strict than for normal projects or daily operations. The expected pay-back time can be a bit longer while there can be applied for subsidies to secure profitability at the start. Still, there must be an expectation for positive future returns. Normally, a project that only costs money will not be executed by Schiphol Group or theGROUNDS.

Project start and duration

Schiphol Group believes that electric vehicles can contribute to the realization of the environmental goals that are set for 2020. It wants to become familiar with related technology and possible applications on short term to be able to profit from the expected rapid developments. Therefore, it aims at project alternatives that can realized by early 2012.

Motivated by the rapid development of technology and the use of electric vehicles, the duration of the initial project alternative is limited by the economic depreciation period of related investments. This is further substantiated in Paragraph 5.3 where the general financial input is discussed.

Accessibility

Sustainability is not the only important transport related factor. Visualized in the overview of Schiphol Group's goals in paragraph 2.1Problem description, the quality of the airport´s connectivity relates to accessibility as well. Last years, Schiphol Group noticed an increase in travel times to the airport. This affects the airport's competitiveness; "declining accessibility has a negative effect on the labour, passenger, and cargo market" (Schiphol Group, 2009). Not only Schiphol is struggling with declining accessibility; like other urban regions, also the Randstad experiences problems with increasing demand for mobility (Ministry of Transport Public Works and Water Management, 2009).

The 'Vision Sustainable Mobility' (Schiphol Group, 2009) formulates a dual objective concerning transport around the airport: to guarantee and improve accessibility as well as to reduce polluting emissions. The policy document mainly focuses on landside mobility that directly affects accessibility and significantly contributes to airport related emissions (30% of CO_2 and NO_X emissions are caused by landside transport). While not integrated in this research project, the level of accessibility should not deteriorate as a consequence of new transport initiatives.

2.3 Research goal and questions

Research goal

This research should provide insights in the economic and environmental performance of electric cars to assess the potential of their introduction in the Amsterdam Airport Corridor. After analysing different alternatives it should become clear which transport service is suitable for the use of electric cars can and how they perform relative to mainstream cars. Besides, there should be provided insights in the uncertainties that relate to the analysis of the performances, as well as ways to deal with the consequential risks of the execution of projects.

Research questions

The main research question – as already presented in the introduction – is as follows:

> *What is the economic and environmental potential of introducing electric cars within the Amsterdam Airport Corridor?*

There are formulated three sub questions that dictate the explorative part of the research:

1. How can the introduction of electric cars be embedded in the organization of Schiphol Group?
2. What are the characterizations of the technical systems related to the use of electric cars?
3. What is the potential use of electric cars within the transport market in de corridor?

Based on the explorative research there are identified alternative projects for the introduction of electric cars. The following sub questions relate to these alternatives:

4. What is the financial impact of the alternative projects?
5. What is the effect of the alternative projects on transport related emissions in the corridor?
6. How can project related uncertainties and risks be mitigated?

2.4 General method

The presented research goal and questions indicate the factors of interest for Schiphol Group and the focus for the executed research. The research steps used to analyse alternative projects for the introduction of electric cars are depicted in the overview below.

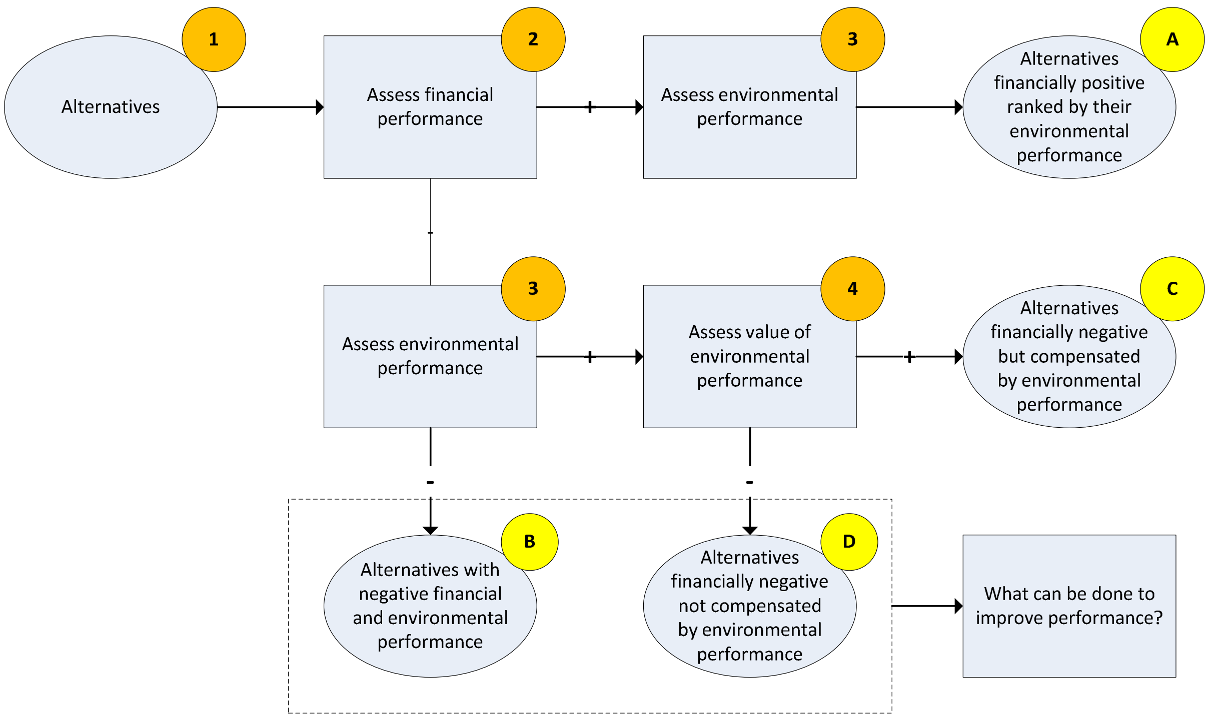

Figure 6: Analysis steps to assess the performance of alternative projects to introduce electric cars

The first part of the research analysis comprises a description of suitable alternatives, given the delineation presented. In the case of this project this means the formulation of four alternative projects for the introduction of electric cars that enable sustainable business travelling within the Amsterdam Airport Corridor, without deterioration of the airport´s accessibility and profitability.

In the second part of the analysis the economic potential of these alternative projects is assessed. The possible introduction of electric cars initiated or motivated by Schiphol Group, is a project for which an investment decision must be made. Schiphol Group is the problem owner and the first one to decide on the feasibility of alternative projects. Therefore, it is important to take the standards of this company as a starting point for the financial assessment of alternatives. Schiphol Group normally uses the Net Present Value calculation method to determine the financial performance of investments. This method, that is also commonly known and used in science, shapes the second part of the analysis.

For each of the alternative projects the NPV is calculated when using either electric or diesel cars. The potential of electric cars is obtained by comparing the financial performances of these options. The NPV calculations of the different alternatives lead to a distinction between two different groups: one group of alternatives in which the electric car performance positive, and another group in which a negative NPV is obtained compared to the diesel option. In a regular situation, Schiphol Group would stop the project analysis at this point and use the alternatives with the highest financial potential to execute a detailed business case. However, as explained in the introductory section and research description, for this project the reduction of emissions from traffic and transportation is at least as important as being profitable.

This additional goal requires the extension of the analysis with an assessment of the environmental potential of electric cars within the different alternatives. It also means that alternatives in which the electric car performance financially less than the diesel option are not necessarily unfeasible. So thirdly, both groups are assessed on their environmental potential. In other words, the emissions that can be reduced if the electric alternative would be introduced are calculated.

The environmental assessment enables a second subdivision, leaving four groups. The group of alternatives that have positive financial performance can be ranked according to their environmental performance. In the figure above, this group is labelled with an A. One part of the alternatives in the group that has negative financial performance are placed under label B. The alternatives within this group do not perform positive on both financial and environmental aspects. Normally, this is a group not to look at anymore. The other part of the alternatives in the group that has negative financial performance, have positive environmental performance. For this group of alternatives it is considered if the positive environmental performance can compensate the negative financial performance. If so, the alternatives are placed in category C, which is still interesting to take into consideration for possible investments. If environmental performance is positive, but not enough to compensate negative financial scores, the alternatives are placed under label D.

The figure below places the alternatives in a financial-environmental performance matrix. Roughly stated, the groups with label A and C are interesting for further analysis in a thorough business case in which more practical aspects are taken into account. For these alternatives the analysis shows that electric cars perform better than diesel cars, either economical, environmentally or both. If the number of remaining alternatives is too large, the alternatives can first be ranked after which the first few are taken for the further analysis. This is not necessary for this research, as there are only analysed four alternatives.

In Chapter 4 the exact model is described that is used for calculations concerning the NPV and emissions of the alternative projects.

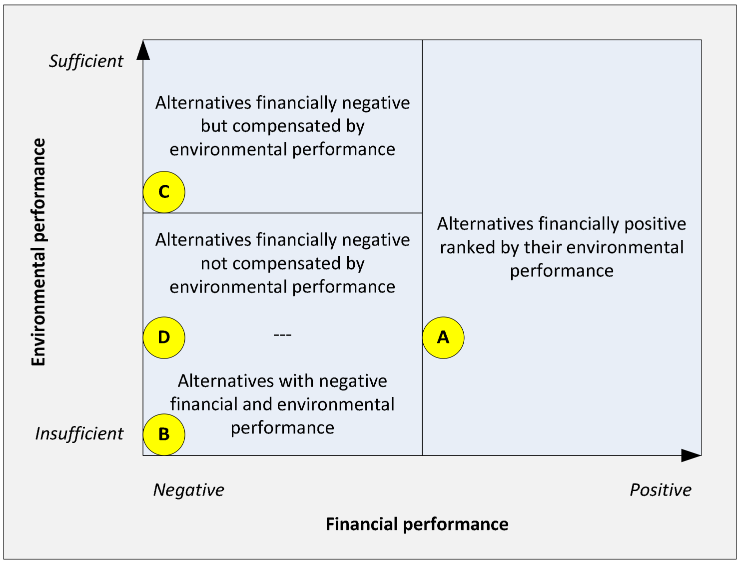

Figure 7: Matrix for the visualization of the alternatives' performance

3 EXPLORATORY RESEARCH

This chapter presents the results of exploratory research that is done during this project; information that gives necessary background for the introduction of electric cars in the Amsterdam Airport Corridor. First, the organizational embedding of the project is discussed. Schiphol Group has defined standard for the embedding of sustainability projects in the internal organization. These standards can best be followed, so it is interesting to assess where a project for the introduction of electric cars exactly fit the organization. The role of external stakeholders is also briefly discussed. Second, the technical systems that are needed to enable the use of electric cars are discussed. Related financial information and uncertainties are brought back in the financial analyses of the different projects. Finally, the market potential is assessed. Different from the actual financial analysis, this section uses a top-down approach to make estimations on the number of potential customers of the different alternative projects for the introduction of electric cars.

3.1 Organizational embedding

3.1.1 Levels of responsibility

As presented in the introductory section, Schiphol Group formulated a set of goals to reduce airport related emissions. In 2020, CO_2 emissions must be decreased by 30% relative to 1990. Besides, NO_X emissions caused by new activities must be neutralized by compensating measures (Schiphol Group, 2007). To define its responsibility for mitigating measures to reduce airport related emissions, Schiphol Group distinguishes between three levels: Control, Guide and Influence (Schiphol Group, 2007).

Control	This level comprises activities that can be managed directly by Schiphol Group and for which it is therefore directly responsible. Mitigating measures related to these activities can and must be taken by Schiphol Group.
Guide	Within this level activities are grouped that cannot be controlled directly by Schiphol Group, but for which it can guide its partners in the right direction. This can be done by means of contracts with suppliers and concessionaires that demand mitigating measures. Another option is the cooperation in activities that aim for emission reduction.
Influence	The level of influence contains activities that cannot be controlled by Schiphol Group. Through cooperation and awareness Schiphol Group can try to influence others to mitigate activities. Within this level there is made a distinction between airside and landside activities.

The figure below visualizes the different levels of responsibility and corresponding areas. The level of control contains the entity 'Amsterdam Airport Schiphol' (AAS). Schiphol Group consists of several divisions, as it also owns other airports. AAS refers to the division being responsible for activities at Schiphol. 'Location Schiphol Airport' refers to the geographical area that is owned by Schiphol Group. It can direct activities in this area by guiding responsible partners.

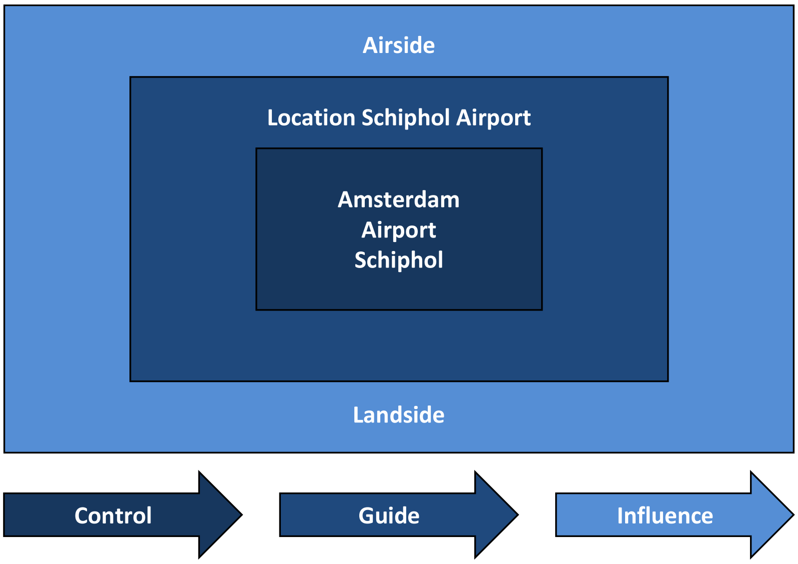

Figure 8: Different scopes for mitigating measures

To realize the set goals, Schiphol Group formulated and initiated various measures relating to the levels of responsibility visualized in the above figure. These are presented in Appendix B.

3.1.2 Principles for mitigating measures

The identified measures to reduce emissions are based on four different principles: 1) Reduction, 2) Efficiency, 3) Sustainability and 4) Compensation. The figure below describes these principles and visualizes a logical sequence for the execution of measures.

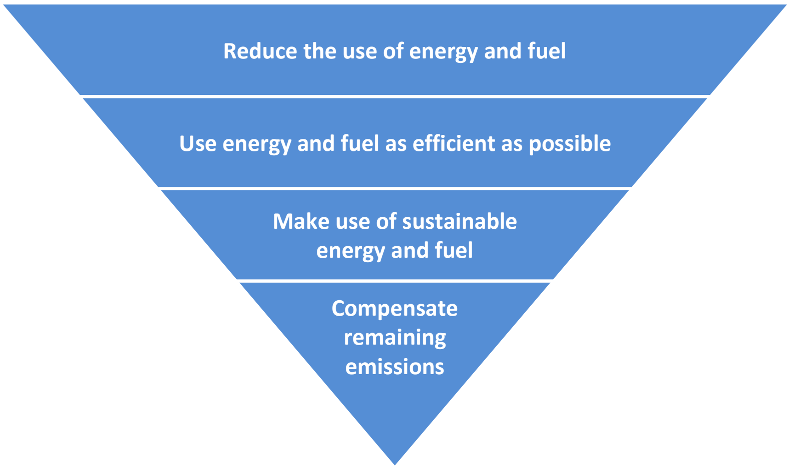

Figure 9: Possible basic principles for mitigating measures

First there are measures to reduce the need for energy and fuel usage. After the need is reduced improvements can be realized by using necessary energy and fuel as efficient as possible. For the remaining demand, the third principle promotes the use of sustainable energy and fuel. The emissions that are generated after implementing mitigating measures relating to the first three principles should be compensated in order to realize emission neutrality. In Appendix B different measures to improve the sustainability of mobility as well as the principle that they pursue are presented.

3.1.3 Stakeholder management

There are many stakeholders that must be taken into account for this research project, both internally and externally. It is very important to keep all stakeholders informed. Internal stakeholders possess important knowledge about the possibilities for implementing new transport alternatives. They will have to make decisions on new projects. By informing internal stakeholders on a regular basis, they have the opportunity to give input to the project. If they do not feel involved, there will be a risk that they will step out of the project.

External stakeholders are very important to gain extra knowledge on the latest developments around electric cars. They can provide indication on technical feasibility of alternatives and the costs associated with their implementation. Because technologies and services concerning electric cars are relatively innovative, most knowledge must be gained within R&D departments of organizations and in pilot projects. Having good contact with the external parties gives the opportunity to share this information.

An overview of stakeholders is presented in Appendix E.

3.2 Technical systems

3.2.1 Electric cars

The public opinion of electric vehicles in general and electric cars in particular is increasingly positive the last years. Sometimes the impression is given that electric propulsion in cars is a new innovative technological application; however this is far from true.

Historical context

In 1886, Karl Benz invented the modern automobile powered by an internal combustion engine (Eckermann, 2001). For the following decades, steam-, electric-, and gasoline-powered vehicles competed to become most dominant. Sovacool (2009) mentions various factors that lead to the preference of gasoline cars after 1910. First, the gasoline powered combustion engine outperformed the electric engine, as it improved much faster at the same time. This also had to do with the energy density of patrol being 300 times greater than that of the earliest used lead-acid batteries (Duke et al., 2009). Second, the price for a gasoline car could easily compete with prices paid for electric driving, and continuously decreased. This trend became even stronger when Henry Ford decided that it was a bigger challenge to standardize the complex gasoline engine and the manufacturing process; a remarkable choice as he worked intensively with Thomas Edison[4] and was much more familiar with electric technology. Companies concerned with the development of the gasoline car worked together to organize auto shows, test drives, advertising campaigns, automobile insurance and instalment financing. On the contrary, the industry around the electric variant failed to develop standards for batteries and charging infrastructure. The third group of reasons that gasoline became more successful then electric propulsion were more of a political nature. Gasoline companies bought tram and train companies to replace electric vehicles for diesel busses or even retire the public service to increase car dependency. Besides, the First World War gave an impulse to the production of gasoline powered vehicles and their export to Europe, after which the 'Great Depression' (the financial crises between 1929 and 1937) accelerated the bankruptcy of smaller (thus more vulnerable) car manufactures and increased the power of the Big Three (Ford, Daimler Chrysler, and General Motors). The fourth and final reason for gasoline dominance had to do with social status. EVs were easier to operate and therefore preferred by women, giving the cars a feminine image. The gasoline car was technically seen much more complex, but became associated with mobility, individualism and progress.

Today, lessons can be learned from the past development of car technology. To increase the chances of success, technical limitations must be overcome, life-time cots must be lower than competing technologies, com-

[4] Thomas Edison set up the first research lab for the purpose of constant technological innovation and improvement. This lab, located in Menlo Park, New Jersey, had an important focus on electro technology (Edison Memorial Tower Corporation, 2009)

panies concerned with electric driving must work together intensively to speed-up developments while securing a positive image of the electric car.

Potential of electric car variants

Considering the historical context, the electric car is not a new innovation, but a technique being reintroduced. This does not mean that electric propulsion has not developed over time. For instance in industry, electric propulsion forms a very important element. A quick scan through possible applications for mobile energy supply systems of Conductix Wampfler[5] shows alternatives for instance for container cranes, monorail systems, automated guided vehicles, people movers, mining equipment and tunnel drilling machines (Conductix-Wampfler, 2011a).

As conditions for the car industry changed rapidly the last decades, the chances that electric cars will outperform combustion alternatives for specific alternative forms of use are increasing. In comparison to the early 20th century, also the electric passenger car is more likely to succeed during these days.

In an elaborate report on the 'end of the oil age' Kendall (2008) describes – on behalf of the World Wildlife Fund (WWF) – five key factors on which energy analysts have come to an agreement that they will 'fundamentally alter the energy landscape in the coming years'. First the global energy demand is rising due to upcoming economies like China and India. Second, the supply of energy is hardly able to keep in pace with this demand. As production of energy increases and resources are used even faster, the limit of capacity is near. And as sources are exhausted the concentration of fossil fuels lies in the hand of fewer and fewer countries. Finally the increased use of fossil fuels also increases the negative environmental impact.

The changes in the energy landscape will also affect the automobile industry. So called peak oil puts a pressure on the production and use of traditional combustion engines in cars. It drives car producers to use fuel more efficient, or to look for feasible alternatives. This is also stimulated through stricter environmental regulation.

So why then choose for the electrification of cars? First of all, the last years there have been made major technological improvements in electric drive trains and supporting technology. Second, with alternatives for more efficient combustion engines the dependency of oil would remain. Third, early investments in the development of new technology can lead to substantial economical benefits as companies can evolve and profit from the successful introduction of electric cars. Fourth, environmental issues, especially on a local scale, demand for drive trains that are (potentially) more efficient and do not emit polluting gasses. The final reason why electric alternatives tend to succeed has to do with the consumer awareness that is currently far more aimed at sustainable alternatives than years before.

Types of electric drive trains

Thomas (2009) published a study on drive train alternatives in a carbon-constrained world. The electric engine forms an important alternative in order to achieve goals concerning the decrease of greenhouse gas emissions. The following electric variants are distinguished:

- BEV (Battery Electric Vehicle): depends completely on the electric grid for all its energy
- HEV (Hybrid Electric Vehicle): a vehicle with both an internal combustion engine and electric traction motor (in the variants gasoline or ethanol). By constant combustion of either gasoline or ethanol the battery that drives the electric engine is powered very efficient. If extra power is needed, the combustion engine can be used.
- PHEV (Plug-in Hybrid Electric Vehicle): the same as above, with the possibility to charge the battery directly from the grid. This enables electric driving without the need for combusting gasoline or ethanol.
- FCEV (Fuel Cell Electric Vehicle): a fuel cell constantly powers the battery that is used for the electric motor. The vehicle depends completely on hydrogen to recharge the fuel cell.
- PFCEV (Plug-in Fuel Cell Electric Vehicle): the same as above, however this vehicle can be fuelled with both hydrogen and electricity.

The main interest for this research is the BEV.

[5] "Conductix Wampfler is the world's leading supplier of mobile energy supply and data transmission systems" (Conductix-Wampfler, 2011b).

Actual use

On the background of the drive train's history, the successful use of electric propulsion in several industrial fields and the current favourable conditions for alternative cars being more environmental friendly, it is not surprising that there have been made some concrete steps towards the broad introduction of electric cars.

Only recently, electric or hybrid vehicles were rarely seen on the road. There were only available conversion kits for the real fanatics. The Toyota Prius in 1997 was the first step towards the full electric drive train as it introduced combined electric and combustion (hybrid) motor technology. Since then, more car manufacturers started producing hybrids and electric cars. In the Netherlands, currently 1 in 200 cars is a hybrid and this amount is growing rapidly (almost 170% from 2009 to 2010) (see also the overview of RDW/CBS in Appendix C (2011)). The full electric car, which is the subject of this research, has not started its serious introduction on the market yet.

At the end of 2010, 263 electric cars were driving in the Netherlands. These were all either cars for a particular niche market (for instance the Tesla Roadster (Tesla Motors, 2011) – a quite expensive sports car – and the Tazzari ZERO (Tazzari Zero, 2010) – a small city car with a top speed of only 80 km/h) or converted cars (like the VW Golf and the Citroën C1). However, this year (2011) the first large scale fabric-built electric cars are introduced in the Netherlands. This has started with the Mitsubishi iMiEV, the Citroen C ZERO and the Peugeot iOn (a result from the cooperation between PSA Peugeot Citroen and Mitsubishi) and the Nissan LEAF. Next year, other models will be introduced. It can be expected that the growth of the number of available cars and improved technology, research and development will push the prices for electric vehicles down.

For this project it is important to evaluate the usefulness of these cars for certain purposes. Therefore some factors like speed, range and sizes are important. An overview of the specifications of the Mitsubishi iMiEV and the Nissan LEAF is presented below. These models were chosen because of their availability and their usefulness in general markets instead of niche markets.

Table 2: Electric car specifications (The New Motion, 2010a)

	Mitsubishi iMiEV	Nissan Leaf
Car investment	€ 32.830	€ 32.839
Lease price	€ 653	€ 725
Lease price Amsterdam	€ 482	€ 635
Top speed	130 km/h	145 km/h
Range	120-130 km	160 km
Normal charging time	7 hours	8 hours
Fast charging time (80%)	30 minutes	30 minutes
Global introduction	July 2009	Dec 2010
Netherlands introduction	Q1 2011	Q3 2011

The models currently available are within the A and C segment. In comparison, the electric variant implies some limitations. This must be taken into account when assessing the usefulness of the alternatives for certain applications.

Speed-up introduction of electric cars

To speed up the market introduction of electric passenger cars certain barriers need to be overcome. This already became clear from the presented historical context; mistakes made in the early 20th century must not be made again. Farla (2010) give several barriers for the transition towards the use of hybrid cars, that can be extended to electric cars. First of all, there are technical barriers that have to do with the availability of different types of electric cars, battery performance and communication towards the public to manage expectations. Second, barriers regarding the physical infrastructure enabling electric driving need to be overcome. The charging infrastructure needs to be widely unfold and more knowledge is needed about balancing the electricity load curve for plug-in vehicles and its effect on the electric grid. Finally, some institutional barriers need to be challenged. There is needed a favourable taxing scheme whereas the uncertainty about well-to-wheel emissions and lifecycle environment benefit needs clear answers. The electric car industry will have to compete with well established and strongly cooperating companies in the car and oil industry. Therefore, extra attention to overcome the barriers is essential.

3.2.2 Battery technology

The first fabric-built car with an electric engine (actually a hybrid engine) was the Toyota Prius. This car used nickel based batteries, which have relatively low power and energy capacity (Silvester et al., 2010). Batteries currently used in electric vehicles are mostly Lithium-ion batteries. The lithium technology is also used in laptops and cell phones. These batteries are considered the best rechargeable batteries on the market; with theoretical specific energy around 400-500 Wh/kg (Peled et al., 2010) (currently the practical range is between 60 and 150 Wh/kg (Bossche et al., 2006). Electric cars currently available need 0.11-0.16 kWh/km (hetkanWel.nl, 2010). Because battery packs cannot become too heavy, the cars have a range between 100 and 200 kilometre.

For the near future, Lithium-ion technology shows most promising characteristics for battery usage. However, technology for car usage is still in its infancy. Besides, it is still very expansive (Hacker et al., 2009).

An upcoming battery technology (referred to as the 'holy grail') is lithium-air. General Motors is for instance working on batteries based on lithium-air (Rahim, 2010) and also IBM started investments in battery research, specifically the Li-air variant (Bourzac, 2009). The theoretical specific energy of the Li-air battery is 5,200 Wh/kg (Peled et al., 2010).

Lithium reserves

If the number of electric cars will grow the next decades, the dependency of oil becomes less. However, for the production of the required batteries large amounts of lithium is needed. This raises new questions; which countries own the most important sources for lithium (on which the world becomes dependent), is this a problem from a political perspective, and what is the amount of available lithium.

The information below gives an answer to these questions. For lithium production a distinction is made between lithium resources and reserves. Resources indicate the amount of lithium that is known to be present in the different countries. The reserves indicate the amount of lithium that can be economically extracted from the resources. Both can change over time. By investigating soils new resources might be found. It can be assumed, that with an increased demand for lithium, the number of resources found will increase. By economical and technological development, and of course due to the actual mining process, the amount of reserves fluctuates (U.S. Geological Survey, 2011). The table below indicates the countries in which lithium is produced and their resources and reserves, for both 1996 and 2010. The differences between these years indicate the fluctuation in resources and reserves.

Table 3: Global lithium production, reserves and resources (U.S. Geological Survey, 1996; U.S. Geological Survey, 2011)

	1995			2010		
Country	Production (tons)	Reserves (tons)	Resources (tons)	Production (tons)	Reserves (tons)	Resources (tons)
Argentina	8	NA	NA	2.900	850.000	2.600.000
Australia	1.800	370.000	NA	8.500	580.000	630.000
Bolivia	0	0	NA	-	-	9.000.000
Brazil	32	910	NA	180	64.000	1.000.000
Canada	650	180.000	NA	0	0	360.000
Chile	2.100	1.300.000	NA	8.800	7.500.000	7.500.000
China	320	NA	NA	4.500	3.500.000	5.400.000
Congo	-	-	NA	0	0	1.000.000
Namibia	40	NA	NA	-	-	-
Portugal	180	NA	NA	0	10.000	-
Russia	800	NA	NA	-	-	-
Serbia	-	-	NA	0	0	1.000.000
United States	W	340.000	760.000	W	38.000	4.000.000
Zaire	0	0	NA	-	-	-
Zimbabwe	350	23.000	NA	470	23.000	-
'Other countries'			12.000.000	NA	NA	NA
World total (reference)	6.300	2.200.000		25.300	13.000.000	33.000.000
World total (check)	6.280	2.213.910	12.760.000	25.350	12.565.000	32.490.000

W: Withheld to avoid disclosing company proprietary data
NA: Not available
-: Not included in the reference

As can be seen in the overview above the spreading of resources is quiet diverse. Like in the current situation with oil, there is no specific global region on which the production of lithium will become depended (although there are many resources in Latin America and relatively few in Western countries). Also because of the abundance of lithium (and the expected increase in resources as the demand for the material increases) it is not expected that there will be high dependency on certain countries. The overview also indicates that the amount of lithium will be sufficient for coming decades. In 1996, Will already predicted that the world reserves at that time would be sufficient to produce batteries for passengers cars the coming 50 years (Will, 1996).

3.2.3 Battery charging

To charge a battery direct current (DC or 'gelijkstroom') is needed. The grid provides altering current (AC or 'wisselstroom'). The battery charger is a device that converts the current to make it possible to recharge the battery. The charger can operate in two modes. The first mode enables energy delivery from the grid to the vehicle (G2V); the other mode enables energy delivery from the battery to the grid (V2G). When the battery is charged, overcharging and overheating must be prevented as this can damage the battery or even cause safety issues (Silvester et al., 2010).

State-of-the-art

The battery charger that is needed can be placed on-board the vehicle or of-board. The charger needs to communicate with the battery to provide optimal charging and prevent overcharging or heating. Charging can be done conductive (wired) or inductive (by means of a magnetic field). Conductive charging can be offered both on-board and of-board. If the battery charger is on-board, it can only be of limited size and weight, thereby limiting the power output and making it particularly (or only) suitable for slow charging. Of-board chargers are not bounded in size and weight. Charging times are then limited by the ability of the battery to accommodate the charging energy. Inductive charging makes use of high frequency AC power to be transferred by magnetically to the electric car.

Charging infrastructure

To charge the batteries following the possible alternative ways, slow chargers, semi-fast chargers and fast chargers are developed. A quite new development in the charging of electric road is the use of inductive charging techniques. This technique enables the elimination of charging infrastructure that uses space in the visible urban environment. Besides, there is no need to physically plug the car for charging (Silvester et al., 2010). It must be mentioned that with current battery technology the charging rate can best be kept between 20% and 80%.

The different varieties of chargers enable the full charging of regular batteries between 15 to 30 minutes (fast charging) (Epyon power, 2011a) and 6-8 hours (slow charging).

Fast charging

There are only few companies that offer qualitative fast charging technology that complies to international standards and can be used for most newly introduced electric cars. Epyon Power is a Netherlands based company that operates worldwide to develop and introduce fast charging solutions. First, a fast charging base station is needed to convert high voltage power from the net to lower voltage power that is suitable for the charging of cars. Fast charging requires relative high investments for adaptations on the grid and for the charging equipment itself. However, a fast charging base station can charge a maximum of four cars simultaneously in 15 to 30 minutes. As battery and charging technology improves, fast charging is fast becoming an interesting alternative for gasoline fuelling.

Battery switching

Together with Nissan and Renault, Better Place is developing another alternative for battery charging; the switching alternative. Utilizing this alternative requires cars that are equipped with batteries that can be taken out in battery switching stations. These switching stations enable battery switching within 75 seconds. A fully charged battery is placed in the car and the replaced battery is stocked at the switching station, charged, and checked for any irregularities. The switching technology requires the ownership of batteries to be arranged in a lease construction (Better Place, 2011b; Renault, 2011).

Figure 10: Visualization of Better Place's battery switch station

Inductive charging

Inductive charging provides an alternative for charging poles and switching stations. Technology currently available enables wireless charging with the main benefit that no visible and space taking infrastructure is needed (Eisenstein and Brooks, 2011). It also enables flexible charging at places where vehicles are temporary waiting; ideal for taxi's and busses. In Utrecht there was great success with a pilot project that research inductive charging for public buses (Bolier, 2010). In Italy and New Zealand buses using inductive charging techniques are already operational for years (Prins, 2010; Shelley, 2009). Like electric cars, the inductive charging technique is not a new innovation; it just finds a new application in road transport. In industry inductive powering is commonly used, as can also be seen from the project of Conductix-Wampfler (Conductix-Wampfler, 2011b).

3.2.4 Electric infrastructure (grid)

Estimates show that electric vehicles can potentially generate 12%-13% of the energy demand during peak hours in the future. This means that it is an important factor during grid design processes. The impact can be even larger on a local scale, specifically at places where a lot cars demand energy at the same time (for instance office buildings) (Silvester et al., 2010). Siemens argues that there are no new power plants needed to power the electric vehicles, and that these can actually be used to flatten the peaks in electricity production. The large scale introduction of electric vehicles can also boost the installed capacity of sustainable energy production as it provides storage for the energy production that is still quite unpredictable (Barkenbus, 2009; Siemens, 2010).

Depending on the demands from the charger, the grid needs to be adapted. Fast charging demands between 180 and 400 kVA (Silvester et al., 2010). However, systems for 55 kVA are also available (Epyon power, 2011b). ProRail investigates the possibilities to use its high voltage grid that is currently also used to power trains. This is perfectly suitable for fast charging and available at train stations where the density of traffic is higher and the alternatives for electrification more interesting.

3.3 Market potential

Schiphol Group is continuously researching the passenger flows to the airport, for which it interviews passengers at a daily rate. Only passengers that are departing from Schiphol are interviewed, as Schiphol Group does not want to bother people that have just landed.

Due to the extensive research, lots of information is available about the size the passenger flows, their origin, the transport mode they use for pre-transportation, travel motives, travel times, and much more. Within the software database of the responsible department it is also possible to perform specific analyses on the available data. This enables the answering of questions like: how much business travellers with Amsterdam as their origin come to Schiphol by taxi? To make estimations on the market potential of researched alternatives, it is important to have an idea of these kinds of numbers.

It must be noticed that passengers at Schiphol are not the only group that generates traffic. Even more important is the commuter traffic, as approximately 65.000 people work at the airport. These workers generate more traffic than the passengers that travel to and from the airport. However, for this research the commuting traffic is left out of scope.

Another traffic flow is generated by Schiphol Group's car fleet and the fleets from other companies operating at the airport. Schiphol Group already invested in 4 electric cars to improve sustainability of operations and the car fleet that is available for subscription by the employees. Besides, it participates in a tender procedure do obtain 20 extra electric cars for own activities (DC-TEC, 2010; Schiphol Group, 2011f).

The continuous research provides a possible starting point to estimate the market potential of new transport services. This can be considered a top down and approach. It is also possible to estimate the market potential by reviewing the possible use of services by individual business passengers or by companies. Researching the passenger flow as a whole gives good estimations of possible market penetration. Researching individuals or smaller and specific flows (e.g. the flow to a certain company) can give better indications of the actual chances that the service will be used.

Within this research the continuous research is thoroughly analysed, while only a limited number of companies and individuals is asked for their interest in the envisioned services.

3.3.1 Total number of passengers

The graph below shows the total number of passengers at Schiphol Airport from 1986 till 2020. The data is coming from the continuous research from Schiphol Group and the trend analyses that are made internally. For the years after 2010 it concerns assumed numbers. A growing future trend in the number of passengers is expected. This is in line with the expected growth of global air traffic (Eurocontrol, 2011). Major dips in the growth pattern can be found after the attack on the Twin Towers in New York on 11 September 2001, and the global economic crises that started in 2007. The air traffic industry managed to recover quite quickly after the latter crunch. While the expectations were quite pessimistic in 2009, the numbers of 2010 turned out to be better than expected. For this reason, also the expectations of 2011 were adjusted.

The quick recovering of the airline industry is also reflected in positive numbers for the tourism industry (World Tourism Organization, 2011). Consequently the profitability in airline industry in 2010 was above the levels from before the crisis, although the margins were very low (IATA, 2010; Willems, 2010). In Europe the recovering was a bit lower, due to heavy winter weather, the ash cloud and strikes (Henderson, 2010). Tax measures in Europe can lead to a further staying behind of the European industry in comparison to other continents (Koster, 2010).

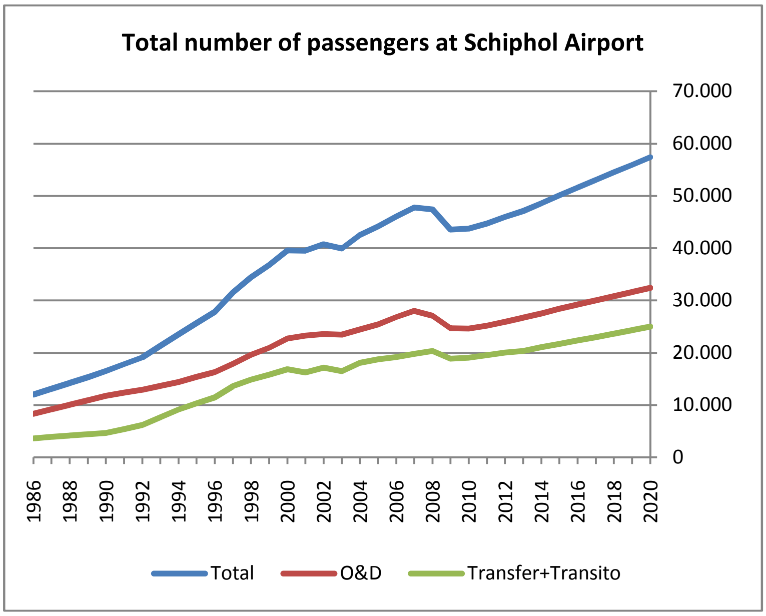

Figure 11: Historical and expected development of the total number of passengers at Schiphol

The numbers in the above figure are a sum of the transfer passengers at Schiphol and the so called O&D passengers. The first group are passengers that use Schiphol Airport as a hub, most of the time leaving the airport property. The latter group is of main interesting for this research. The O&D passengers have their origin or destination outside of the airport terminal and will therefore need another modality to start or continue their trip.

3.3.2 Motives passengers

Schiphol Group distinguishes between four different travel motives for their passengers: Dutch business, Dutch non-business, foreign business and foreign non-business. The graph below indicates the motives for O&D travellers at Schiphol. The figure indicates that the fraction of business passengers has decreased over the last 20 years.

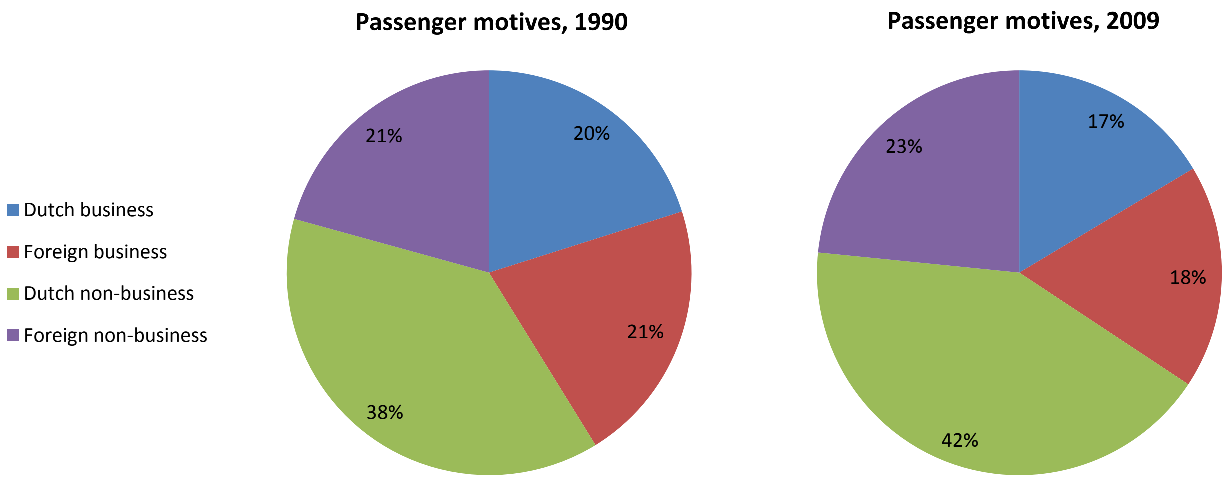

Figure 12: Motives for O&D passengers in 1990 and 2009

However, in line with the growth of the total amount of passengers, the absolute amount of business travellers is also increasing. Despite the declining trend in the fraction of business passengers last decades, the proportions of 2010 are assumed for making future predictions.

The figure below shows the predicted actual number of O&D passengers, divided over the four different motive groups. The number of business passengers (Dutch business and foreign business) travelling to and from the airport is expected to grow from almost 8,5 million in 2010 to more than 11 million in 2020.

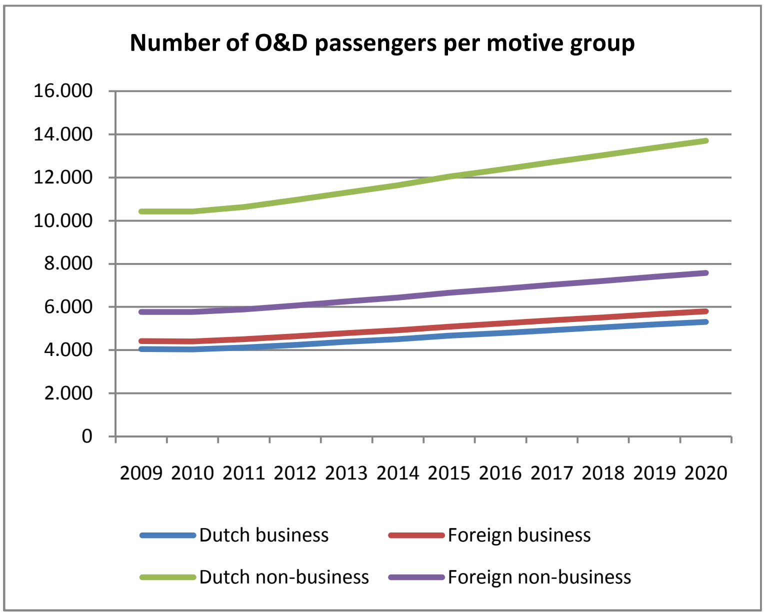

Figure 13: Forecast of the number of O&D passengers within each motive group

3.3.3 Transport modes O&D passengers

Different modalities are used to travel from and to the airport. Depending on the travel motive, the choice for certain modalities differs. It must be notified that the percentages below only account for people travelling to the airport. This has to do with the earlier fact that for the continuous research only departing passengers are interviewed. If indications are needed for the flow travelling from the airport to a certain destination, the fractions are simply copied. It is however very likely that the fractions will differ for the opposite flow. For this research, both qualitative argumentation and expert opinions are used to review the fractions used.

By using research data from 2008, an indication could be given about the number of passengers that will use for instance taxi or train. The table below shows the fractions that are used for future projections.

Table 4: Transport modes used by different O&D passengers in 2008

Data from 2008		Business		Non-business	
	Total	**Dutch**	**Foreign**	**Dutch**	**Foreign**
Taken by car	13,7%	18,8%	8,5%	32,0%	9,3%
Car parked during trip	1,9%	12,0%	0,2%	4,1%	0,2%
Rental car	1,8%	0,3%	4,0%	0,1%	1,2%
Taxi/taxi bus	23,6%	25,2%	33,2%	17,0%	19,1%
Train	47,6%	40,3%	38,9%	41,3%	57,9%
KLM-bus/hotel bus	4,4%	0,5%	7,4%	1,3%	4,1%
Charter bus	2,5%	0,6%	2,0%	0,3%	4,0%
Scheduled bus	2,9%	1,5%	2,3%	3,6%	3,3%
Walking	1,3%	0,7%	3,1%	0,3%	0,5%
Other	0,3%	0,1%	0,4%	0,0%	0,4%
Total	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**

It can be seen that almost half of the total passengers takes the train to travel to the airport, but it is more often used by non-business travellers then by business travellers. The latter group will easier make use of a taxi and in the case of Dutch business passengers 12% parks its car at the airport.

This research assesses the potential of electric cars within the Amsterdam Airport Corridor. So, of main interest are the modes that are operated by cars; trains and buses can initially be left out of scope. Within the AAC business centres are important activity centres. It is also seen that cars form an important mode for business travellers (almost 50% of business travellers coming to the airport takes the car).

A final delineation is made on the basis of the possibilities to influence choice for modalities and improving the sustainability of modes used. Schiphol Group does not want to interfere in the choice of the airport's passengers; the customer cannot be hindered in making its own choices. Schiphol Group does however want to work together with companies operating at the airport to improve the sustainability of transport modes. These starting points lead for instance to subtle measures for passengers driving their own car, providing them the alternative to fuel with electricity or bio-fuels. Employees at the airport are actively stimulated to use sustainable travel modes. Companies operating at the airport are stimulated most actively, for instance by including contract agreements about polluting emissions. As Schiphol Group wants to achieve quick wins in improving the sustainability of transportation, it is chosen to focus on the modalities that can be influenced most. This concerns the rental cars and the different taxi products.

To conclude; this research delineates on the geographical region of the Amsterdam Airport Corridor and business travellers within that use rental cars and taxis to travel to and from the airport.

3.3.4 Individual adaptation

A substantial part of the passengers at Schiphol indicates that sustainability is important for choosing an airport to travel from (Schiphol Media, 2010). This number can be used as an indication of the adaptation of green services by the individual passenger.

3.3.5 Company adaptation

The research comprises the clarification of decision factors for individual passengers. Companies will make different choices when sustainability is considered. This distinction must be taken into account when assessing the possible adoption rate of new sustainable services.

It is assumed that companies take into account other factors when evaluating the possible switch to sustainable travel alternatives. For instance travel costs, time, comfort, the availability of transportation and easiness to arrange it. For instance, a business person at Zuidas can easily take the train (every 5-10 minutes a train is departing from Amsterdam Zuidas to Schiphol station. The travel time is only 6 minutes). However, because of the type of companies at Zuidas (banking, accounting) it is also possible that these persons prefer the taxi, especially when they are foreigners. A business person that travels to or from Riekerpolder will have more difficulties to reach the airport (he can take a bus every 15-30 minutes, which has longer travel time – 20min – or he must take a bus-metro combination, which he can do almost every 5-10 minutes, but this will take him 30 minutes travelling and one time switching of transport mode). However, the type of workers at the companies located at Riekerpolder might be more likely to use public transport.

Depending on the above qualitative assessment estimations can be made for the likelihood of business passengers using alternative modes to travel to the airport.

4 MODEL DESCRIPTION

This chapter describes the model that is used to generate the required output that enables the answering of the research questions. The starting point for the model is the need to be able to compare alternative projects for the introduction of electric cars. There are needed calculations to assess the financial impact of different alternatives and the effect on the emission levels around the airport. The quantitative nature of these factors justify the use of an Microsoft Excel spreadsheet to substantiate the model. The model distinguishes between the performance of electric and diesel cars within the different alternatives. This enables the assessment the performance of electric cars within a certain alternative project, relative to its diesel counterpart. Besides, results from the different alternatives can be compared to find the project with the highest potency.

4.1 Net Present Value

Calculation input

For the calculation of the Net Present Value of the different alternatives the following input is necessary:

Accounting rules of Schiphol Group

Schiphol Group is the problem owner for this research and the entity deciding on the continuation of the project and necessary investments. Making sure the financial results are useful for Schiphol Group, the NPV calculation is made using the company's accounting rules. On this basis the starting year of the project, the project period, tax rates, discount rate and depreciation periods are determined.

Investments

The different alternatives require different investments. For each alternative at least investments in electric cars, chargers and electric infrastructure to enable charging need to be made. The necessary level of investments is determined on the basis of desk research, expert interviews and proposals by possible suppliers. For investments that are uncertain differing input is used within three different scenarios.[6] The investments are listed in the Excel spreadsheet and form input for the first year of the NPV calculation. Investments are also depreciated over a certain depreciation period according to the accounting rules of Schiphol Group. Depreciation costs are input in each year of the NPV calculation.

Operating costs

Depending on the alternative service concepts certain operating costs need to be taken into account. These are determined the same way as the investments. Again, for uncertain expenses differing input within different scenarios is used. The operating costs are listed for the whole duration of the project.

Revenues

Revenues are the result of an income rate for operations and the amount of 'saleable items'. In the case of the taxi alternatives this item is a trip between the customers' pick-up and drop-off point. In the case of the rental car the saleable item is the rental period of a car. An additional variable item is the distance that is travelled.

The calculation of the revenues is less straightforward then the other input groups, subject to larger uncertainty while having high impact on the NPV. Therefore, the potential revenues are validated an extra time. Next to the regular data collection by means of expert interviews and desk research, there is made a revenue calculation on the basis of the Schiphol Traffic and Transportation database. This database contains a wide range of information about numbers people travelling to Schiphol, their origin and the modalities used. Data can be found for past years and future expectations on a wide range of relevant details of passenger flows are based

[6] The scenarios that are used are further substantiated in Chapter 5.

on this database. It can give an indication for the number of people travelling by taxi or rental car between the airport and the city of Amsterdam. The numbers are used to validate and further substantiate the indication that are given by expert on the expected trips and rented day for the intended services.

Potential revenues form an important input for the NPV calculation and influence the results in each year. Because of its importance on the model output and the uncertainty in which potential revenues are covered, the input is distinguishes within the different scenarios.

NPV calculation steps

As indicated, a Microsoft Excel spreadsheet is used for the NPV calculations of the alternative projects to introduce electric cars in the Amsterdam Airport Corridor. The overview in Figure 15 gives insights in the calculations that result in the NPVs of the project alternatives. The calculations follow the standard rules NPV. The overview only shows the calculations made in the first year of the project. The other years use exactly the same formulas. The NPV is calculated for a project duration of five years. This is the period in which most investments are depreciated. It is assumed that no intermediate investments are necessary.

Profit and loss	**Year 1**
Revenues	A
Operating costs	B
EBITDA	**Z = A-B**
Depreciation	C
EBIT	**Y = Z-C**
Tax	X = Y*K
Net profit/loss	**W = Y-X**

Cash flow analysis	**Year 1**
EBIT	**Y = Z-C**
Tax	X
Net profit/loss	**W**
Depreciation	C
Investment	D
Cash flow	**W+C-E**

NPV	**Year 1**
Discount rate	L
Discount factor	V = 1/(1+L)^(Year n)
PV	W*V
Total NPV in Year 1	**U = SOM(PV(year 1-5))**

A	Revenues
B	Operating costs
C	Depreciation
D	Investments
K	Tax rate
L	Discount rate
U	NPV
V	Discount factor
W	Cash flow
X	Tax
Y	EBIT
Z	EBITDA

Figure 14: Calculation steps for the NPV

Profit and loss

First, the net profit and loss is calculated. Therefore, the total sum of operating costs (B) are subtracted from the total sum of operating revenues (A). Then, the depreciation costs (C) are subtracted which leaves the Earnings Before Interest and Taxes (EBIT=Y). Depreciation costs are the result of the investments made in the first year and the depreciation period that is used for the different investments. Tax (X) is levied on the EBIT leaving the net profit or loss (W). The presented profit and loss calculation is a summary of the profit and loss statement that gives information of the company's ability to generate profit by revenue increases and cost reduction.

Cash flow analysis

For the cash flow analysis the depreciation is added to the net profit and loss again, as the depreciation is only an accounting measure that should not influence the cash flow in a certain year. Next, the investment costs are deducted which results in a the cash flow. The cash flow can be used to calculate the Internal Rate of Return (IRR). Like the NPV, the IRR is a value that can be used to measure and compare the profitability of possible investments. It represents the discount rate that would lead to a Net Present Value equal to 0 (zero). A high discount rate (and IRR) means that investors can receive higher returns on their investments. The IRR is not displayed in the above overview of calculations.

Net Present Value

The Net Present Value (NPV) is the sum of Present Values (PV) for each of the project years. To calculate the PV, the cash flow of each year is multiplied with the discount factor for the same year. The discount factor can be calculated in the following formula, using the discount rate (r) and the project year for which the calculation (T) is made:

$$Discount\ Factor\ (T) = \frac{1}{(1+r)^T}$$

This formula results in a – as years continue – decreasing discount factor, which forms the essence of the NPV. Because of the decreasing discount factor depending on the time, the cash flows of future years contribute less to the NPV; the value of a project investment.

NPV comparison

The Net Present Value is calculated for four different alternatives. For each alternative the performance of the electric car is compared to the performance of its diesel counterpart. Important input variables that are subject to uncertainty are covered by variations in three different scenarios. This leads to a total of 24 NPV that are – together with the calculation of emissions and a qualitative analysis – for the assessment of the project alternatives.

4.2 Emissions

The introduction of electric options for the four alternatives have – next to the financial consequence – an environmental effect through the reduction of emissions. This also covers the primary reason to investigate electric alternatives for transport modes at the airport.

Researched emissions

There is a broad range of emissions that can be considered. In research related to transport emissions there is made a distinction between greenhouse gases (GHG) and air pollutants. The first group is of global concern because of its potential effect on global climate change. The latter group has a negative effect on the health of humans and vegetation, visibility and structural and building materials through corrosion (Fang et al., 2002). The Kyoto Protocol mentions the following six GHG: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 (Kerkhof et al., 2008). GHG emitted as a result of traffic and transportation are CO_2, CH_4, N_2O and HFCs (EPA, 2005). NO_X and PM_{10}, as well as VOCs, $PM_{2.5}$, CO, SO_2 and PAHs are categorized as air pollutants that are caused by traffic and transportation (Fang et al., 2002; Huo et al., 2009).

Not all of these emissions are researched. For the speed and profundity of the analysis, it is chosen to take into account the emissions that were subject to earlier researches and are generally considered most important. These emissions are CO_2, NO_X and PM_{10}.

Most studies on CO_2 emissions of passenger cars consider the CO_2 equivalent of all GHG. The CO_2 equivalent is a value used to compare various GHG on the basis of their global warming potential (GWP) (EPA, 2011). On the basis of the GWP it is estimated that the contribution of CO_2 to global warming is almost 95 percent of the total GHG emitted (EPA, 2005). While only CO_2 is considered in this study, it is important to understand that there are other emissions with comparable effects. However, since it is concluded that their impact is much lower – at least when looking at the current range of emissions of passenger cars – it is considered acceptable to exclude them from research.

The emission standards for passenger cars laid down by the European Commission restrict the emissions of CO, HC, NO_X and PM as these are considered harmful to human health (European Commission regulation, 2009). Emission goals of Schiphol Group focus on CO_2 and NO_X (Schiphol Group, 2009).

Calculation steps

For this research the output of interest is formed by the total emissions of CO_2, NO_X and PM_{10} over a project period of 1 year. For each of these three emission forms, the total emission over a year can be calculated by multiplying total mileage with the emissions per kilometre. The first is a result of the NPV calculation, in which the number of cars used in a project and the average distance per car are calculated. For the emission per kilometre there is made a distinction between the Well-to-Tank (WTT) and the Tank-to-Wheel (TTW) emissions. Their summation returns the total emissions per kilometre; the Well-to-Wheel (WTW) emissions. The overview in Figure 15 summarizes these calculations.

WTW emissions per kilometre	
WTT emissions	D
TTW emissions	E
WTW emissions	**C = D+E**

Total emissions per year	
Total mileage	B
WTW emissions	C
Total emissions	**A = B*C**

Figure 15: Calculation steps for total emissions

It must be recognized that for GHG it does not matter where the pollution takes place; the harmful effect on global climate is equal for locally and centrally emitted gases. However, for air pollutants the damage is higher when emitted in densely populated areas. This is taken into account when qualitatively assessing the performance of the different alternatives.

The WTT and TTW emissions are calculated differently for the electric and diesel option.

WTW emissions of electric cars

Since the electric car is just about to be introduced on a larger scale, there is quite some difference in which the emissions from electric cars are calculated. At the beginning of the current 'hype' a lot of the proponents of electric mobility only emphasized the local emissions that were reduced to zero. Of course this is a very important feature of the electric option; it reduces local emission problems. But for fair comparison the whole chain of power generation and related emissions needs to be assessed.

For the electric option, the TTW emissions are set to zero for all types, as there are no tailpipe emissions. It must however be mentioned that some of the PM emissions that are caused by passenger cars find their origin in the wear and tear of tires and brakes. This part can even be higher than the part caused by the combustion process (Huo et al., 2009). Where it is good to have a notion about this, it is not taken into further consideration, because this part of the emission is the same for diesel and electric cars. Another type of emission that is independent of combustion processes is related to the car's air conditioning. Because of the slow leakage from hoses and seals, HFCs are emitted (Wallington et al., 2008). Also this emission is not taken into consideration as it is equal for both options.

The WTT emissions per kilometre are harder to determine. For the electric car the WTT emissions are depending on the amount of energy that is used for driving and the emissions caused to produce this energy. The first depends on the energy efficiency of the car, the efficiency of charging and possible losses of energy in infrastructure. The efficiency of the car, which is most important here, is normally provided by the car manufacturer in the car specifications. However, it turns out that for instance driving patterns, weather conditions and reduced battery performance have significant effects on the car's efficiency rate. The certainty of the average energy use for driving will increase as the number of electric cars rise.

The calculation of the emissions caused by energy production for electric driving is even more complex. Most research base this number on the current generation mix of a particular country (Huo et al., 2009; Thiel et al., 2010; Torchio and Santarelli, 2010) and the associated emissions. However, as indicated by Verzijlbergh (2011) not only the generation mix, but also the moment of charging, the installed wind generation capacity and trading prices for CO_2 are of importance here. It is also recognized that most research focus on the emissions per kilometre. In order to get to this result different assumptions on the emissions for energy production and car's energy efficiency were made (Huo et al., 2009; Thiel et al., 2010; Torchio and Santarelli, 2010; Vliet et al., 2011). For these reasons interpreting earlier research must be done very carefully, taking into account the large uncertainty that surrounds the emissions for electric driving.

WTW emissions diesel car

Calculation on the emissions of diesel and gasoline cars are much older. The emission levels presented by earlier research can be considered less uncertain or sensitive for assumptions. There is also not much difference found in the presented results of other research. The WTT emission of diesel cars is generally 25 g/km (Thiel et al., 2010; Torchio and Santarelli, 2010; Vliet et al., 2011). The slight difference that is shown for the total emissions is the result of the fact that some research assesses the CO_2 equivalent of all GHG (Torchio and Santarelli, 2010; Vliet et al., 2011), while others only take into account the CO_2 emission (Thiel et al., 2010).

The calculation of the TTW emissions from diesel cars is quite straightforward, as they depend on the average fuel used by the car. This is reflected in the specifics of the car manufacturer, that bases the fuel consumption in the ECE 15 and EUDC test cycles. The EURO 5 norms set by the European Commission regulate the TTW emissions for car production (European Commission regulation, 2009). These norms are taken into account for this research.

5 RESULTS

This chapter presents the results of the analysis performed. First, there is further elaborated on the alternative projects, indicating the transport services that is aimed for and the scenarios used to analyse their performance. Second, the generic input that is used within the analysis of all of these alternatives is presented. There is distinguished between input for the qualitative, the financial and the emission analysis. Then, the specific input for each of the alternatives is presented. By processing the data in the calculation models that are presented in the last chapter, the quantitative results can be retrieved.

5.1 Alternative projects

5.1.1 Transport services

The alternatives that are analysed fit the delineation that is presented earlier in this report. It concerns car based alternative projects within the Amsterdam Airport Corridor that are suitable for the transport of business passengers to and from the airport. The modalities that are currently used at the airport and fit this delineation are the street taxi, ordered taxi and rental car.

Within the research the feasibility to use the electric car for the above purposes is assessed. Therefore, the financial and environmental performances are quantitatively calculated following the model presented in Chapter 4. These performances are compared to the performance of the mainstream diesel car that can be used for the particular transport services. It is important to mention that the assumptions concerning the implementation of the electric option are leading. The mainstream option does therefore not necessarily reflect the current situation, but a slightly differing variant that fits the used delineation.

Next to the quantitative calculation, a qualitative analysis is done to assess the level of fit of the electric option of the alternatives within the airport environment. This comprises for instance the service level for business passengers and the contribution to overall accessibility of the airport.

On the basis of interviews and the exploratory research presented in Chapter 3 it is concluded that electric cars cannot fulfil the need for all of the users of the above travel modes. For instance, a person that wants to take a taxi to travel to Belgium or Germany from Schiphol, will have to be disappointed when he asks the driver of an electric taxi. A fourth new-designed service is introduced as an alternative to the traditional modes already in place. This alternative tries to optimally take into account the needs of business passengers when they travel in the region as well as the limitations of electric cars. The new service is labelled the 'semi-private taxi'. Also for this alternative mode both the electric option and the diesel option are analysed.

Electric and diesel option

For each alternative there is made a comparison between electric and diesel cars. In the case of the introduction of electric cars, there is made an investment in a number of cars to realize the required operations. To enable the successful introduction of the electric option several adaptations on infrastructure and organization are needed as well.

The second option considers the case where there is not invested in electric cars, but in mainstream diesel cars that realize comparable services.

After comparing the electric and diesel options, there can be concluded on the potential of electric cars within each alternative.

The number of alternatives researched sums up to four:

- Street taxi
- Ordered taxi
- Rental car
- Semi-private taxi

On the basis of interviews with internal and external experts and stakeholders involved, as well as broad desk research, calculations are made about the possible performance of these four alternatives. For each alternative the financial as well as the environmental performance is assessed.

5.1.2 Scenarios

Factors used for the quantitative calculation are sometimes very uncertain. First, an important uncertainty lies within the level of take up of electric transport services. This is influenced by different factors that can increase or decrease the attractiveness of the electric option. The level of take up is an important element in the analysis as it influences the revenues from the transport services. By using scenarios on the factors that indirectly influence these revenues, the effect on the financial performance, the NPV, can be indicated. Another important uncertainty relates to the emission levels that are caused by the use of electric cars. Also the values related to this factor is changed in the different scenarios.

The scenarios that are used to cover uncertainty in the most important input reflect a neutral situation, and the plausible extremes (positive and negative) for the development of important input factors. The scenarios are labelled as follow:

- Pessimistic scenario
- Neutral scenario
- Optimistic scenario

Three scenarios

The introduction of electric cars comes with a number of uncertainties. This is partly because of the fact that it comprises an innovative product. Schiphol Group and its partners do not have much experience with the electric option. Besides, there are not a lot of comparable projects realized that can function as an example. Consequently, part of the input must be based on common sense and assumptions. The second reason for uncertainty finds its source in the innovative nature of the technology and its application. As the number of electric car manufacturers grow and produced number increase together with the interest of potential buyers, there can be realized quick technology improvements and cost reductions. However, this optimistic future will remain uncertain until the electric car gains a substantial market share, which must be considered far from a given.

To overcome the uncertainty involved with the comparison of the mainstream and electric option, the alternatives are analysed in three different scenarios. The first scenario reflects neutral assumptions. The input used in this scenario is based on average information currently available and the expectations of experts on the development of these factors. The other two scenarios reflect plausible extremes of the environment in which the alternatives will have to evolve. The most important factor on which these extremes are based is the level of development and acceptance of the electric car. In the scenario that is labelled 'pessimistic world' higher level external factors inhibit the fast introduction of the electric option. This translates for instance in relative high investments in cars and charging infrastructure and limited interest from potential customers in the sustainable option. Meanwhile, the mainstream option remains a very interesting alternative for customers, hampering the necessity for more sustainable alternatives. In the scenario labelled 'optimistic world' these factors make a 180 degree turn, as they positively stimulate the introduction of the electric option.

Schiphol Group has the ambition to introduce electric cars within one of the presented alternatives in the beginning of 2012. As the time span until the moment of introduction is relatively short, the differences in input are not too large, at least not for investments. More uncertain is the level of acceptance of the electric car and operational costs. Considering the environmental performance, differences are primarily based on uncertainty around the level of innovation (and thereby lighter batteries and more efficient electric engines) of next batches of electric cars and the development of the emissions of the mainstream alternative.

5.2 Generic input

Customers

Within the boundaries laid down earlier in this report the target group is chosen. Customers can come across the new service as an individual, which is for instance the case when looking for a taxi at Schiphol Plaza. The other possibility is top down, when companies subscribe to the electric taxi service and make sure they decrease foot print by promoting the service with their employees and make it a preferred taxi-supplier. The second option is stimulated by promoting the service at companies and make them aware of the possibility to subscribe.

Primary service locations

The starting point for the service design is the appointment of locations that will be served. Within the Amsterdam Airport Corridor a number of locations were searched. These locations are not setting a limitations for the offered taxi service. They form a starting point for the search for customers, and an indication for these customers where they can travel with the electric taxi. It can be imagined that there will be a taxi at each of these locations that can be used by customers within a certain range of these points. However, it would be smart to limit the service within certain boundaries, as this is necessary for operating the service properly. The figure below shows two circles with a 10 kilometre radius around the Schiphol arrival passage and Zuidas. These can be considered the rough contours of the Amsterdam Airport Corridor.

Figure 16: Range of 10 kilometre around Schiphol – Arrival Passage and Amsterdam – Zuidas, WTC

Within the marked area above 13 locations are appointed that have the potential to generate an interesting demand for the electric vehicle. These are the following locations:

1. Schiphol – Arrival Passage
2. Schiphol – Centre
3. Schiphol – Rijk
4. Schiphol – East
5. Hoofddorp
6. Amsterdam West – Riekerpolder
7. Amsterdam West – World Fashion Centre
8. Amsterdam West – Teleport
9. Amsterdam – Zuidas, WTC
10. Amsterdam – RAI
11. Amsterdam Oost – Omval
12. Amsterdam - Zuidoost
13. Amstelveen

The above locations are marked in the map below. For orientation there are drawn circles around Schiphol arrival passage and Zuidas again, this time with a radius of 5 kilometres.

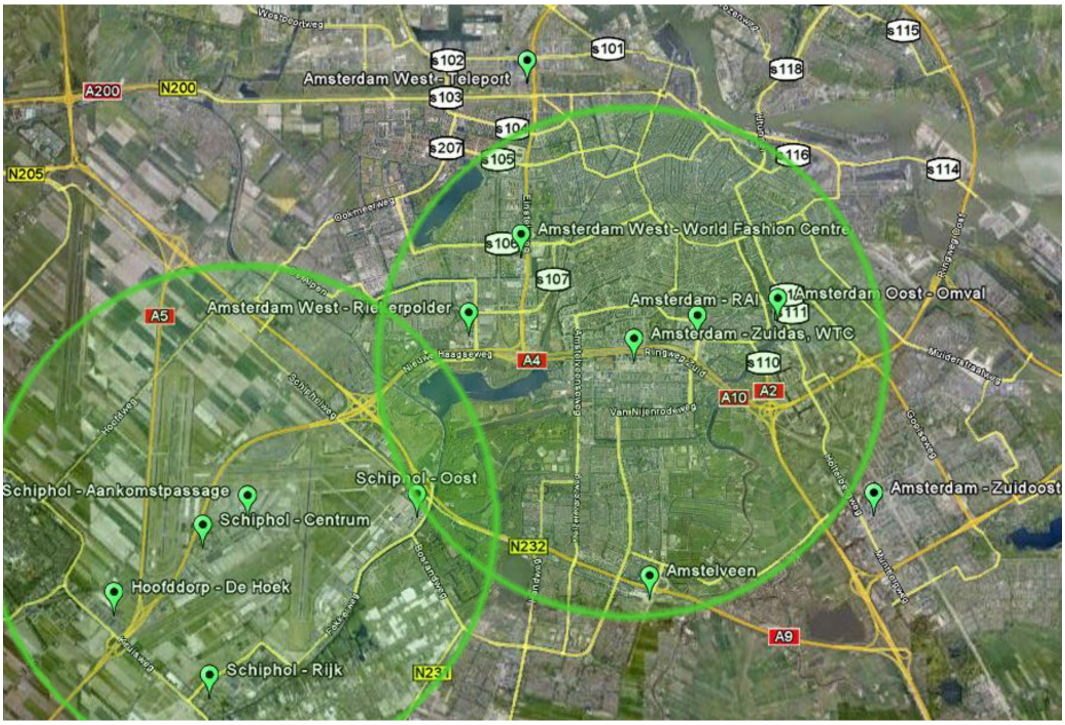

Figure 17: Range of 5 kilometre around Schiphol – Arrival Passage and Amsterdam – Zuidas, WTC

It can be seen that the area is perfectly suitable for the use of electric cars that have limited range, since these 13 busy activity centres are located very close to each other. Having the short trips makes that the intervals between trips are smaller, giving the driver the opportunity to charge the car at a more regular base. Thereby, it is easier to prevent that the car is running out of power.

Risk reduction

The introduction and use of electric cars in this stage comes with a number of risks. The electric cars are not widely used yet, certainly not as taxis, and technology is still developing very rapidly. The risks are even higher, because in this case a new service is proposed. When limiting the initial investments, the potential damage after failure of the service concept or the use of electric cars can be limited. Besides, it is important to offer proper service levels to the users of the service. A lacking service level with a new service can increase the chance for overall failure and will also damage the reputation of electric cars in general.

The risks are limited by limiting the number of locations to the ones that have highest potential for trip generations towards the airport. The locations are chosen on the basis of two criteria; accessibility and activity. It is chosen to focus on the primary axis of the Amsterdam Airport Corridor (the A4 highway) and the busiest locations around this axis. Thereby the number of locations is limited to the following 6:

1. Hoofddorp
2. Schiphol – Arrival Passage
3. Amsterdam West – Riekerpolder
4. Amsterdam – Zuidas, WTC
5. Amsterdam – RAI
6. Amsterdam Oost – Omval

The above presented locations form the starting point for the services, however depending on the exact service concept the exact locations can differ.

Electric cars

The car that is initially assigned for the use as taxi is the Nissan LEAF. This is currently the only full-electric car that does not differ too much from the standards laid down for taxis at Schiphol. It must be recognized that the standard of the Nissan LEAF is different from the currently used Mercedes and Audi limos. However, the Nissan LEAF is currently the only suitable factory build car. It is important to monitor the availability of the LEAF because the first badges produced are already assigned to certain customers. However, if ordered in time, the delivery time is not expected to form a problem.

Possible alternatives currently suitable for taxi purposes must be found in refit centres, where cars with combustion engines are converted into electric cars. However, because these cars are refitted by another party then the original car manufacturer, there are some issues with guarantees. Besides, these cars are much more expensive, sometimes more than twice the original price paid for the car with combustion engine. If such a car might be an option, there is for instance the London cab in a electrical edition available at All Green Vehicles in Oosterhout. The purchase price is quite a bit more than the Nissan LEAF, but the travel distance is far more which can reduce investments for charging infrastructure. With small adaptations this car is also suitable for induction charging, which can highly reduce the impact of the installation of charging infrastructure on the build public area.

In 2011 and 2012 more fabric build electric cars are expected to be introduced in Europe. Schiphol airport can be an interesting environment for car manufacturers to promote their new cars. If the airport is planning the use of electric cars, it has a relative high chance to obtain cars from one of the first batches produced.

Depending on the exact service concept and the uptake of the electric services, there is decided on the number of cars that is used.

A decision must be made about the number of cars that are bought the first year. Investments in charging infrastructure are taking a large part of the total investment. If more taxis are operational, the costs for infrastructure will be less per car. However, there is a risk of using too much cars the first year. The technology-service combination has not proven itself yet. Besides, the number of persons that will use the service is very important for its success, however one of the most uncertain ones (despite thorough market analysis).

In the base case it is suggested to start with a small batch of cars, to minimize investment risks. This batch must be large enough to provide a proper taxi service between the appointed locations and large enough to obtain relevant data. If the electric taxi service turns out to be a success, it is relatively easy to upscale the service area and intensity. This also provides the opportunity to use other (better suitable) cars in a later stage. The loss on high infrastructure investments can partly be overcome by sharing the chargers with other users. For instance for the own car fleet of Schiphol Group chargers are installed. Also Microsoft, a large company at Schiphol Centre, wants to have chargers in its parking. This gives opportunities to share investments in the first years of relative expensive operations.

Another possibility is that another party is investing in infrastructure and charges for the use of it. This way, high investments can be prevented for this single project, where the supplier of charging infrastructure can easily make charging available for multiple parties. Within Schiphol Group, the Utility Service department will construct and maintain charging infrastructure. They will also invest in it. This department can charge higher costs than normal for transportation of electricity within its own grid to earn back its investments.

Electric switch cars for taxi services

One of the main obstacles that has to be overcome when taxi services are offered with electric cars, is the limited range in combination with time-consuming charging. Most part of the operational expenses are attributable to personnel expenses. If the introduction of electric taxi means that the fuelling time (or in this charging time) increases a lot, the taxi service will not be profitable anymore. A solution that is suitable until battery performance increases is to make use of switch cars. An extra car in the pool of taxis enables fast switching of an ‘empty’ car by a full one. This can be planned smart in a way that there is always a charged car available. Given a fast charging period of 30 minutes, the switching of five cars in direct succession takes 3 hours. If the switching takes place in front of the buffer at Schiphol, it hardly takes any extra time. If necessary the switching cycle can be repeated more times a day. It is imaginable that charging takes place during brakes of the drivers and outside rush hours. This would decrease the need for a switch car, however not having one when necessary is a risk too high. The possibility to have a fully charged car without having to wait, will also saves expensive driver costs.

Scheduling operations

In consultation with taxi companies there is made a decision on the days and hours that the electric taxi will be operational. There is a big difference here between drivers that have purchased their own car and drivers that are employed by a company. This first is willing to work very long days and is happy with every trip available. The latter earns a certain wage per hour paid by the company. This driver earns a bit less per trip, but has better working conditions and less risk. For the company it is not interesting to let its drivers be operational during quiet hours. Because the costs of driving electric this point is reached even earlier.

On the basis of information about travel peaks of business people a decision was made to limit the hours that the electric taxi service is available.

Below this information is provided:

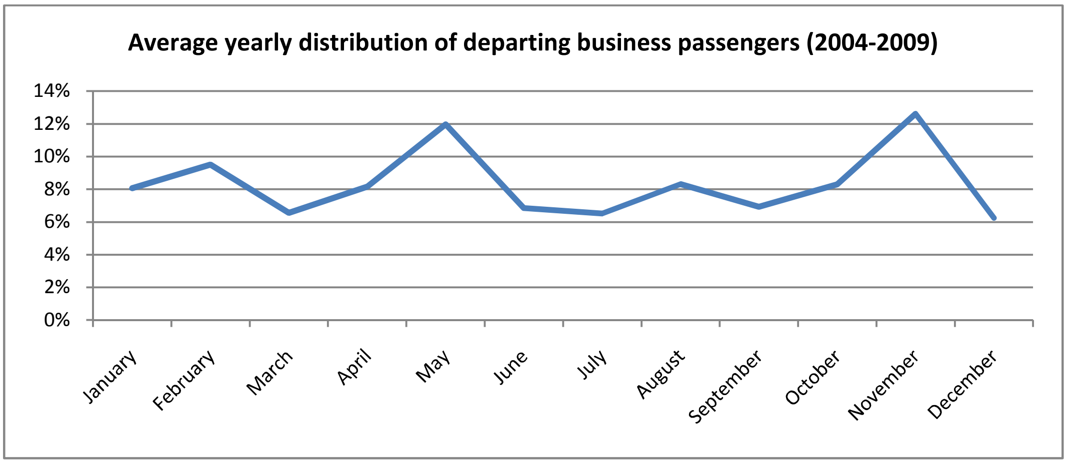

Figure 18: Average yearly distribution of departing business passengers at Schiphol between 2004 and 2009

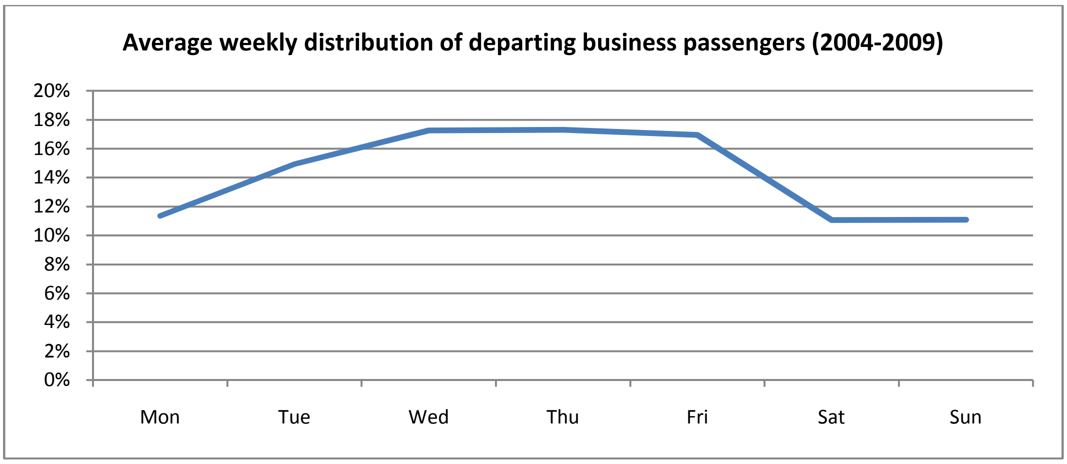

Figure 19: Average weekly distribution of departing business passengers at Schiphol between 2004 and 2009

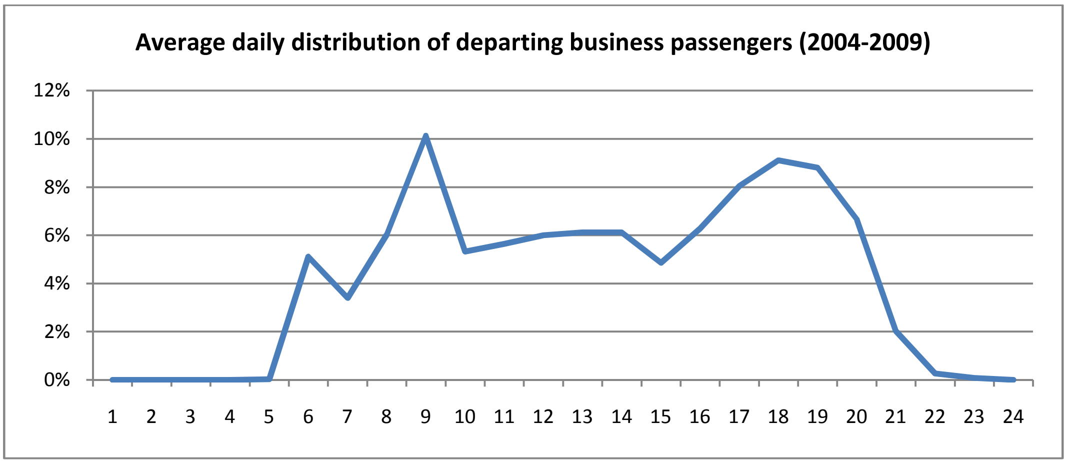

Figure 20: Average daily distribution of departing business passengers at Schiphol between 2004 and 2009

The above graphs are based on average data over the period 2004-2009. There are no large shifts throughout these years, so it can be expected that these divisions are relatively stable. The distributions for departing passengers can be copied for arriving passengers without major shift but taking into account a delay of 1-2 hours, assuming that business passengers travelling daily to Schiphol do not travel very long distances.

This data give an indication of the possible distribution of taxi trips from and to the airport. As there are hardly any business passengers leaving the airport during the night between 10pm and 6am it can be expected that the trip demand from this group is also negligible. For the electric taxi service the period between 6am and 9pm seems most interesting. The taxi companies confirmed this with their expectation that operations would be interesting between 7am and 7pm.

The graph showing the weekly distribution shows that demand during the mid-week is the highest, questioning the necessity to offer services in the weekend. Because labour costs are also higher during weekends, it seems relevant to limit services to the mid-weeks.

The yearly distribution is taken out of consideration, as people working for the taxi companies cannot be taken out of circulation for periods of months. However, if possible it would be good to take the differences between months into account (the differences are sometimes 100%), for instance by planning holidays around the months that are less busy.

As an input for the business case, an operation of 12 hours per day and 5 days a week is used.

Trip details

When using electric cars currently available for taxi operations the main limitations would be the distance travelled. For this reason the number of locations was limited to 6, all within a close range of the Schiphol Airport and Zuidas. The only source of income will be the fee paid by taxi customers. The starting point is that the electric taxi service is price competitive with the alternative; taxi's with combustion engines. However, this is considered not the most important factor since the customers aimed for are business travellers.

To make an estimation of the average income per trip, the distances between the proposed locations were taken together with the price paid if a normal taxi would be taken. Below an overview of the distances between the appointed data is provided. The second table provides an indication of the price for taxi trips between these locations, if a normal street taxi would be taken. The regular starting tariff for these taxis is €7,5. For this price the first two kilometres are free of charge. Starting from 2 kilometres, the price per kilometre is €2,2. So to calculate the regular prices the following formula is used: "starting tariff + (distance – free distance) x kilometre price". This equals €7,5 + (distance – 2km) x €2,2.

Table 5: Distances between primary services locations

(km)	1	2	3	4	5	6
1 Hoofddorp		6	13	16	18	22
2 Schiphol - Arrival Passage	6		9	14	14	17
3 Amsterdam West - Riekerpolder	13	9		5	7	11
4 Amsterdam - Zuidas, WTC	16	14	5		3	5
5 Amsterdam - RAI	18	14	7	3		3
6 Amsterdam Oost - Omval	22	17	11	5	3	

Table 6: Prices for regular taxi trips between primary locations

(€)	1	2	3	4	5	6
1 Hoofddorp		17	31	38	42	51
2 Schiphol - Arrival Passage	17		22	34	33	41
3 Amsterdam West - Riekerpolder	31	22		15	19	27
4 Amsterdam - Zuidas, WTC	38	34	15		11	14
5 Amsterdam - RAI	42	33	19	11		9
6 Amsterdam Oost - Omval	51	41	27	14	9	

As explained the prices above give an indication of the maximum costs for a taxi trip between the locations of interest. For the new service it is important to offer comparable tariffs. However, this is not necessary. If contracts are closed with certain companies, the taxi service does not fall under the governmental regulation for street taxis. The average costs for a trip in the above overview is €26,90. In the base case scenario a tariff of €25,- is used. It is expected that this will be more, assuming that there are more trips from Schiphol to other locations then for instance between Amsterdam – RAI and Amsterdam – Omval. It is important to have a good impression of the average income per trip, since this highly influence the outcome of the business case.

Other data related to trips are the trip distance and the number of passengers that are transported per hour by each taxi. The average distance per trip can be based on the first table above, however it must be taken into account that the taxi will have to drive to the exact location of the passenger. Given the limited number of locations and taxis, the taxi companies propose a system where taxis circulate between the different locations. To achieve the highest possible occupation rate for the taxis, it is important to minimize the time that there are no taxis available at the different locations. For instance, if a taxi drives a certain passenger from Schiphol to Zuidas, arriving there 14 minutes later, and nothing else happens there are two inefficiencies. First, there is no taxi at Schiphol. Second, there are two taxis at Zuidas waiting. To prevent this, the taxi companies suggest a system of circulation. If the taxi leaves Schiphol heading to Zuidas, the taxi waiting at Riekerpolder can go to Schiphol and the taxi at Zuidas can go to Riekerpolder which takes 8 minutes. In the meanwhile the taxi from Zuidas can go to Riekerpolder in 10 minutes. After the taxi from Schiphol arrives at Zuidas, all locations are occupied again. With a small number of electric taxis it cannot be prevented that potential customers are not able to take the electric alternative. However, with the circulation system the chance for picking up customers is maximized.

There are numerous ways to increase the chances for picking up customers. An easy alternative would be to indicate the waiting time at the different locations. However, the customer must be physically present at the location which is not necessarily the case. A more advanced way would be to introduce a telephone application that communicates with the reservation system of the taxi company. If a regular customer indicates he wants a taxi immediately, it can be indicated on the basis of his location, the location of the taxi's and their occupation, how long it will take for a taxi to arrive. Then he can indicate if he wants to wait for this. The availability can be increased if taxis can be ordered by the same application.

For the number of expected passengers per hour, an expectation of the taxi companies is used based on their experience for passenger transportation within the Amsterdam Airport Corridor. It is very hard to assess the accuracy of this estimation. On the one hand, the electric car is surrounded with uncertainty for its users. People are not familiar with the car and are maybe anxious to step into an electric taxi. On the other hand many companies and individuals indicated that they would prefer and promote the use of the electric car if available. It is imaginable that the use will be lower than 1,2 passengers per hour. However, if the electric taxi can make use of preferred locations and companies and individuals start to trust the technology, the use might be much higher.

5.3 Finances

Parts of the input for the assessment of the alternatives is generic and is taken as input for all alternatives. This concerns some accounting variables and certain operational costs. The most important are stated in the table below.

Table 7: Generic input for the assessment of financial performance

Accounting	
Start year	2012
Tax	25%
Debt	60%
Equity	40%
Debt interest rate	6%
Equity discount rate	15%
WACC	8,7%
Depreciation periods	
(Electric) vehicles (yr)	5
Slow charging systems (yr)	5
Fast charging systems (yr)	5
Electric infrastructure (yr)	20
Operational costs	
Electricity costs (€/kWh)	0,10
Tire replacement (€/km)	0,025

The above input counts for all alternatives, both options within and the three scenarios in which the alternatives are assessed. There are also input factors that are the same for the different alternatives, but differ within the three scenarios. This input comprises the acceptance of alternatives (where higher acceptance of the electric alternative relates to a higher number of introduced cars), uncertain operational costs and investments in charging infrastructure. The table below gives an overview of the input used. Some numbers need some explanation. First of all the number of purchased vehicles differs over the different scenarios. As the rate of acceptance the of electric is highest in the optimistic scenario, the number of cars that can be operated is higher as well. It is important to take this into account as the investments necessary can be divided over a larger number of cars while the total emissions reduced increase. The number of purchased mainstream vehicles changes as well, however slightly different than in the electric option. More electric cars are needed to acquire the same level of service as they will have to charge somewhere during the day. Based on indicative calculations, common sense and consultation of fleet owners it is estimated that for every 5 mainstream cars 6 electric cars are needed to acquire the same level of availability.

While costs for tires are set the same for every alternative and scenario (see the last table), the general maintenance cost differ for the electric and mainstream option. About the first there are some experiences and expectations available. However, technology is evolving rapidly while the exact maintenance costs are relative uncertain due to low current use of electric cars. This is different for mainstream cars, for which the maintenance costs are based on long term experience and trend lines do not show great changes. Another input factor for the electric car that is uncertain is its electricity use per kilometre. Also for this factor estimation and expectations are set, however the uncertainty is high enough to vary input over the three scenarios.

The final input factors that are the same for the different alternative but vary over the scenarios are about investments in chargers and charging infrastructure. While the demand for slow chargers rises rapidly (at least as fast as the introduction of new electric cars) production costs drop and competition increases. For this reason, there are relative high differences over the scenarios for the investment in slow chargers. The same counts for the possible adaptation of existing grid and the connection of the chargers to this network. What is also important here, is the fact that Schiphol Group own the electric grid and can also perform (parts of) the necessary work itself. Fast charging systems demand much higher investments for purchasing and work on infrastructure. However, competition is much lower and less saturated. The expected cost reductions within the set time frame are considered negligible. However, the different alternatives and scenarios require different charging systems. The three systems presented are differing for the configuration of the base station and the number of chargers that are connected (or can be connected) to the station.

Table 8: Semi-generic input for the assessment of financial performance

Electric cars	Pessimistic	Neutral	Optimistic
Purchases (#)	6	12	24
General maintenance (€/km)	0,015	0,012	0,010
Electricity use (kWh/km)	0,23	0,21	0,19
Diesel cars			
Purchases (#)	5	10	20
General maintenance (€/km)	0,025	0,025	0,025
Slow chargers			
Slow chargers costs (€/charger)	3.750	3.250	2.750
Infra slow chargers (€/charger)	2.000	1.500	1.000
Fast chargers			
System 1 (€)	67.950	67.950	67.950
System 2 (€)	109.100	109.100	109.100
System 3 (€)	117.550	117.550	117.550
Infra fast chargers (€/base)	160.000	135.000	110.000

5.4 Emissions

Energy efficiency of electric driving

To compare the different emission performance of electric and diesel cars, a standard measurement is needed. Looking at specification of diesel cars, emissions are expressed as grams per kilometre. This is also the case with the emission restrictions laid down by the European government. In contrast, electric cars have no emissions, at least not from their tailpipe. The 'fuel' use of electric cars is expressed as Wh/km. However, the production of the necessary electricity caused emissions as well, which is most of the times expressed as g/kWh (or at least the electricity production in GWh and the related emissions in ton are known). To compare different sources of emissions with each other it is important to use the same measurement. Most related research studies convert the emissions to g/km, which seems rather logic as the comparison between traditional cars has always been done on this basis, while EURO norms also require the expression of emission in this measurement.

For the diesel option the required measurement will not form any problem since all research done complies to this already. However, for calculations on electric vehicles, some assumptions are made to prevent analyses to become too complex.

Emissions caused by electric driving do not relate to the driving itself but to the production of electricity that is needed. As stated, this research requires emissions to be expressed as a result of the distance travelled (g/km). The emissions from electricity production are expressed as a result of the amount of electricity produced (g/MJ, ton/GWh or g/kWh). For the transition of this expression to the required one (so g/kWh → g/km) there is needed information on the energy efficiency of electric driving. So how much energy is needed to travel a certain distance (kWh/km). This is not only depending on the energy efficiency of the electric drive train, but also on the efficiency of charging and electricity transportation. But also on driving patterns, car weight, battery cycle efficiency and corrosion (Vliet et al., 2011).

The difficulty in calculating the full cycle's efficiency, lies mainly in the fact that performances are not known yet. Besides, battery and charging technology are evolving very rapidly. Even the car's energy efficiency specified by the car manufacturer seems subject to uncertain external factors like wind and temperature.

Because of this uncertainty, it is chosen to use some scenarios for energy efficiency. The table below shows which input is used an which values are used for the scenarios.

Table 9: Energy efficiency of electric cars

Energy use (Wh/km)	Pessimistic	Neutral	Optimistic
		150	
	162	127	92
Used for scenarios	**190**	**170**	**150**

From the financial business case follows that the electric car that will be used falls within the category of the Nissan LEAF. The specifications of this car, but also of the comparable Renault FLEUNCE C.E., indicate a car efficiency of 150 Wh/km. Vliet (Vliet et al., 2011) gave a medium efficiency of 127 Wh/km and added an deviation of 35 Wh/km. Both can be considered typical Tank-to-Wheel efficiencies that did not include efficiency of charging and electricity transportation.

Because literature does not provide adequate information on the full cycle efficiency of electric driving, there are made some assumptions. The uncertainty about this factor is reflected in three scenarios. The optimistic scenario takes the car efficiency as specified by the car manufacturer. This assumes that charging and transportation efficiencies are 100% and that the manufacturer made right estimations about the average car efficiency.

The following scenarios each add 20 Wh/km to this starting point. There is no strong foundation for the choice of these steps, except that the pessimistic scenario of 190 Wh/km leaves room for the worse case of Vliet (Vliet et al., 2011) and an added margin for charging and transportation losses.

The presented scenarios for energy efficiency form an input for calculations regarding CO_2 emissions. For the calculation concerning NO_X and PM_{10} emissions, there are not made scenarios. These calculations therefore make use of the 'neutral' scenario of 170 Wh/km.

Mileage

As indicated above, the comparisons in this research are based on the emissions per travelled distance (g/km). In order to gain the total emission that are caused by a project, this measurement needs to be multiplied by the estimation on the kilometres travelled within a certain project. This factor follows from the financial business case and differs for the different alternative-scenario combinations. For fair comparison, no distinction is made between the mileage of the electric and diesel option. However, the spreadsheet used contains the option to do so.

The table below shows the mileage for each alternative-scenario combination. This is a result of the calculations made in the financial business case and depends among other on the number of cars and the intensity of their use. The more optimistic scenarios assume higher acceptance and consequential use of the electric option, which leads to increased mileage.

Table 10: Mileages of the different alternative-scenario combinations

(km)	Pessimistic	Neutral	Optimistic
Street taxi	275.400	612.000	1.683.000
Ordered taxi	153.000	459.000	1.530.000
Rental car	43.800	87.600	175.200
Semi-private taxi	306.000	734.400	2.142.000

The above presented mileage is input for the calculations of CO_2, NO_X and PM_{10} emissions.

5.4.1 CO_2 variables

Diesel option

This section presents the considerations that were made to calculate the WTT and TTW CO_2 emissions of both the diesel and the electric car.

For the diesel car a starting point was found in the CO_2 regulation that is laid down by the European government. This regulation limits the TTW CO_2 emission of passenger cars at 130 g/km. Literature presents almost the same level of 131 g/km (Vliet et al., 2011). Of course there will be cars that reach lower CO_2 emissions. However, at least for the taxi alternatives, there will be used luxury and heavy cars that are not expected to perform much better than the imposed norms.

In case of diesel cars, the WTT emissions are a result of fuel production and transportation (Huo et al., 2009). Also about these emissions, literature is quite consentient. Vliet (Vliet et al., 2011) gives the number of 25 g/km and deviations of 5 g/km. Torchio (Torchio and Santarelli, 2010) supports the median estimation.

It is not surprisingly that there is much consensus on the CO_2 emissions of diesel cars. Drive train and fuel production technology can be considered mature and undergo only small improvements. Besides, research to CO_2 emissions is very extensive as it is the most important GHG.

Because there is high consensus about the WTT and TTW CO_2 emissions, it is decided not to take into account any uncertainty in the form of scenarios for these factors.

Table 11: WTW CO_2 emission of diesel cars

CO_2-emission (g/km)	Neutral
Well-to-Tank	25
Tank-to-Wheel	130
Well-to-Wheel	155

Electric option

Contrary to the diesel option, there is considerable disagreement about the WTT and TTW CO_2 emission of the electric car. This is not surprising. However existing as long as combustion versions, the electric car has only just drawn the attention of the big audience. This helped to increase research on the effects of large introduction of the electric car. But it also stimulated technological innovations for which reason the car's performance is rapidly improving. Because there is less consensus about the electric car's performance and because technology is developing rapidly, this research takes into account different input for the calculation of CO_2 emissions.

But first start with the part that is certain; the TTW emissions. Since the electric car does not make use of any combustion process there are no tail pipe emissions. Literature obviously confirms with this (Thiel et al., 2010; Torchio and Santarelli, 2010).

Deciding on the WTT CO_2 emissions of the electric car is a bit more complex. Multiple studies assess the energy mix of a specific region. Thiel (2010) for instance takes assesses the energy mix of the EU-27 and comes to an emission of 123,9 g/MJ which compares to 446,0 g/kWh. However, for this research the Netherlands electricity generation mix is of importance. Using the same sources as Thiel it was calculated that the Netherlands generation mix results in 612,5 g CO_2/kWh. This is more than the EU mix, mainly because of the relatively low amount of nuclear energy produced.

Despite the fact that the method of using the energy mix for the calculation of the WTT CO_2 production is frequently used, there is also critique on this method. Verzijlbergh and Lukszo (2011) stated that the generation mix is only one factor among three others that influences the emissions. Also the moment of charging, CO_2 trading costs and the installed capacity of wind energy contribute to this number. Verzijlbergh and Lukszo (2011) estimated the emission to be between 400 and 1400 g/kWh.

Given the inconsistent method of calculation and the wide range of estimations, it is chosen to use three scenarios for the WTT CO_2 emissions. The values presented by Verzijlbergh and Lukszo (2011) are thereby taken as plausible extremes. The calculation on the basis of the method of Thiel (2010) is used as a neutral value.

The above findings are summarized in the table below.

Table 12: WTW CO_2 emission of the production of electricity for the electric car within different scenarios

CO_2-emission (g/kWh)	**Pessimistic**	**Neutral**	**Optimistic**
Well-to-Tank	1.400	612	400
Tank-to-Wheel	0	0	0
Well-to-Wheel	1.400	612	400

At the beginning of this section there were presented scenarios on the energy efficiency of the electric car. It was clarified way this was also be used for CO_2 calculations. So there are two variable on which to base the CO_2 emission per distance travelled (g/km). The table combines the values of both the energy efficiency and the WTW CO_2 emission. The first scenarios only vary the energy efficiency of electric car driving. The second group of scenarios only varies the WTT CO_2 emissions on the basis of the above findings. The later combines both pessimistic and optimistic cases. The scenarios that arise take for both uncertain factors the extreme scenarios. The neutral scenarios are all the same. There were formed by the neutral scenarios of energy efficiency and WTT emission.

Table 13: WTW CO_2 emission per kilometre of electric cars in different scenarios

	Energy efficiency			**WTT emissions**			**Enery efficiency & WTT emissions**		
CO_2-emission (g/km)	**Pessimistic**	**Neutral**	**Optimistic**	**Pessimistic**	**Neutral**	**Optimistic**	**Pessimistic**	**Neutral**	**Optimistic**
Well-to-Tank	116	104	92	238	104	68	266	104	60
Tank-to-Wheel	0	0	0	0	0	0	0	0	0
Well-to-Wheel	116	104	92	238	104	68	266	104	60

After the calculation of the CO_2 emissions of the electric car, there can be made a comparison with the data on diesel emissions. The WTW emissions of the above table were subtracted from the diesel related emissions that were presented in Table 11. The results of this calculation are presented in the figure below. It can be seen that the uncertainty around WTT CO_2 emissions has a higher impact than the uncertainty around energy efficiency. If the pessimistic scenario is considered, there are not even CO_2 savings possible by the electric car introduction.

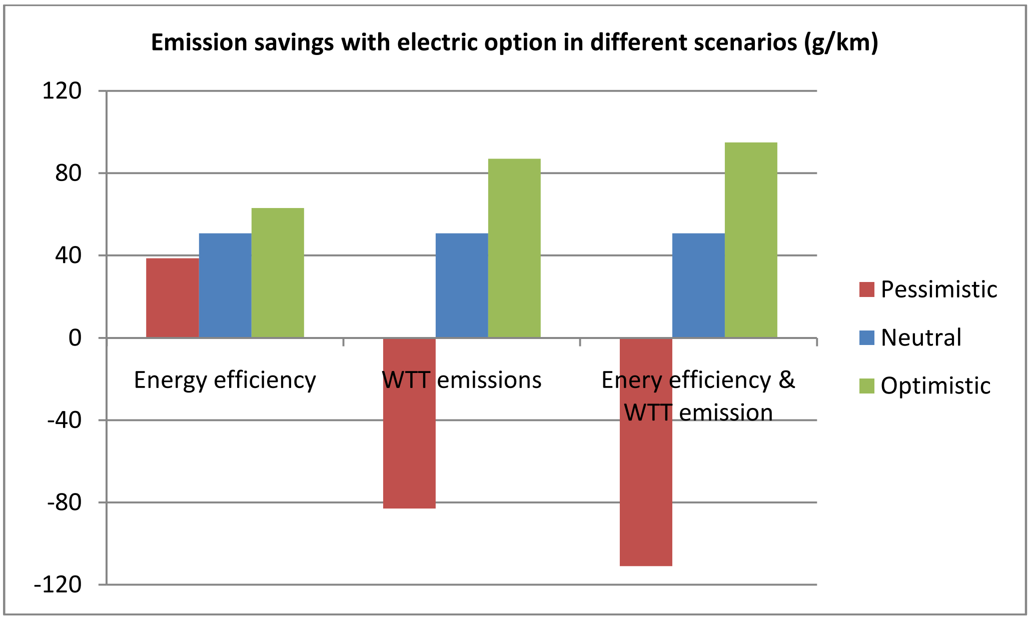

Figure 21: Relative CO_2 emission savings of electric cars in different scenarios

5.4.2 NO_X variables

As indicated before, for global effects it does not matter where CO_2 emissions occur. Since the main effect of concern of NO_X is about local air quality and human health, it is important to consider the location of the NO_X emissions. NO_X also has a greenhouse effect however this is not taken into account for this research.

As is presented below, for diesel cars is this the location where they drive, trough the combustion of diesel. The electric option does not have any tailpipe emissions. However, there can be NO_X emissions through energy production that must be taken into account, depending on the energy source and the location.

Amsterdam has a large coal and gas fired power plant located in the Harbour area relatively close to the city centre. For fair comparison with the diesel option, this research assumes that all energy for the electric vehicles comes from this plant (Hemwegcentrale, NUON). The emission per kilometre will be compared to literature resources.

Diesel option

In the supply chain of diesel, there are NO_X emissions during the recovery and transportation of feedstock (crude oil), the production and transportation of the actual fuel. Moreover, when the diesel is combusted in the car there are NO_X tailpipe emissions (Huo et al., 2009). The emission of primary interest is the tailpipe emissions as this takes place in densely populated areas (at least in the case of the cars travelling within the AAC). This research distinguishes between the Well-to-Tank and Tank-to-Wheel emissions. The latter is purely related to the tailpipe emissions. When interpreting the results it is fair to consider the locations of the Well-to-Tank emissions to be able to evaluate their effect on human health.

HUO (Huo et al., 2009) calculates the tailpipe emissions to be 0,17 g/mile equal to 0,106. For WTT emissions he calculates 0,08 g/mile which resembles 0,05 g/km. This is however for the USA situation.

Torchio (Torchio and Santarelli, 2010) gives different estimation when researching the European situation. For the tailpipe emissions he takes 0,18 g/km and for the WTT emissions 0,064 g/km; both a bit higher than the USA case.

The final number considered is the EURO norm for diesel engines. This European norm states that tailpipe emissions (TTW) cannot be higher than 0,18 g/km; not surprisingly the same as presented by Torchio.

As presented, the numbers between European and USA research differ a bit, however not enough to doubt the results presented by Torchio, also because half of this result resembles the EURO norm. So for further calculations on NO_X emissions from diesel, the following emission levels are taken into account:

Table 14: WTW NO_X emission of a diesel cars

NO_X-emission (g/km)	**Neutral**
Well-to-Tank	0,064
Tank-to-Wheel	0,18
Well-to-Wheel	0,244

Electric option

Where the Tank-to-Wheel NO_X emission is not hard to determine – 0 g/km (Torchio and Santarelli, 2010) – the WTT emission are a bit more complex. As stated in the introduction, it seems interesting to work with the data from the Hemwegcentrale of NUON, located just a bit west of the city of Amsterdam. The electricity is produced by coal and gas combustion, which causes central NO_X emissions. If this would be the case in an area with low population it would not be of much concern. However, given the range to Amsterdam and the common west winds in the Netherlands, it is assumed that the NO_X from the power plant causes effects equal to tailpipe emissions.

In 2010 the Hemwegcentrale produced 4.640 GWh of electricity. The corresponding NO_X emission was 1.157 ton (NUON, 2010). These numbers equal 0,234 g NO_X/kWh. For the calculation of the emission per kilometre, the energy efficiency – previously introduced at the beginning of this section [check] – is taken. As explained [check] it is chosen not to work with different scenarios of the energy efficiency in the case of NO_X emissions, but to take the value of the neutral scenario: 170 Wh/km. If done so, the NO_X emissions caused by energy production in the Hemwegcentrale equals 0,04 g/km. It must be mentioned that this calculation did not took into account the recovery and transportation of coal and gas.

To investigate the validity of this number, two other literature resources were investigated. First the research of Huo (Huo et al., 2009) is used again. Huo presents two numbers: the USA and the California average NO_X emission. These resemble 0,24 and 0,14 g/mile or 0,15 and 0,09 g/km (these numbers only include combustion processes and no feedstock recovery processes. However, it is still considerably higher than calculated by means of the production and emission of the Hemwegcentrale.

The second source used is Torchio (Torchio and Santarelli, 2010). He investigated numbers for the European market and presents the NO_X emissions to equal 0,171 g/MJ. This compares 0,616 g/kWh. The next step he takes is to calculate the emission per kilometre. However, to do so he used a car efficiency of 308 Wh/km, which is almost twice the number assumed for this research. This results in a very high NO_X emission of 0,19 g/km. It does not become clear where this difference comes from. It is chosen to stick to the own number assumed (170 Wh/km). If this number is used in the same calculation the outcome is 0,104 g/km.

Also this value is higher than calculated only with the data of the Hemwegcentrale. Still, the calculation on the basis of the data of the power plant are considered most valuable, as these emissions definitely effect local air quality.

The table below summarizes the numbers:

Table 15: WTW NO_X emission of electric cars

NO_X-emission (g/km)	**Neutral**
Well-to-Tank	0,040
Tank-to-Wheel	0,0
Well-to-Wheel	0,040

5.4.3 PM_{10} variables

The analysis on PM_{10} emissions closely resembles the one on NO_X emissions.

Diesel option

For the WTT emission there is made use of the same resource as for NO_X emissions; Torchio (2010). He indicates the WTT emissions to be 0,002 gram per kilometre. The used TTW emission relate to the European standard of 0,005 gram per kilometre. The table below summarizes this numbers.

Table 16: WTW PM_{10} emission of diesel cars

PM_{10}-emission (g/km)	Neutral
Well-to-Tank	0,002
Tank-to-Wheel	0,005
Well-to-Wheel	0,007

Electric option

Like the TTW NO_X emission of electric cars, the TTW PM_{10} emissions are equal to zero. For the WTT emission there is made use of the same reasoning as above. Following the above calculations returns 0,0026 gram per kilometre for the generation of electricity for electric cars.

Table 17: WTW PM_{10} emission of electric cars

PM_{10}-emission (g/km)	Neutral
Well-to-Tank	0,0026
Tank-to-Wheel	0,0
Well-to-Wheel	0,0026

5.5 Specific input

This paragraph describes the specific input for the quantitative financial analysis for each of the alternatives. Different input is chosen for the electric and mainstream option and within the different scenarios, depending on the service concept of the particular alternative modalities.

5.5.1 Street taxi

Concept description

The street taxi is the most used taxi product at Schiphol. In the past, there were many problems with the street taxi at the airport. TCA, the biggest taxi company in the Amsterdam region, literally fought against the allowance of other companies at the airport after the liberalization of the taxi market in 2000. Finally new entrants had to be accepted, but the internal organization of TCA became a mess which lead to the dismissal of the whole board in 2006. When the tender procedure for the taxi's at the airport started in 2008, TCA already lost a lot of the trust from Schiphol Group. In the end they did not won the tender as they scored less on the criteria organization, quality and corporate responsibility. Parts of the taxi concession are tendered to BIOS-groep, Connexxion and Willemsen de Koning in 2009 for a period of minimal 3 years and 2 options for the continuation of a year.

The figures below show the way the street taxi transportation is currently organized. The first figure gives an overview of the street taxi buffer zone. This zone is used by the concessionaries to assemble the taxi's before they can drive in front of the terminal. The red and blue taxis are normal taxis (sedan type) from the concessionaries; the green and white cars are small passenger busses from the concessionaries. The black cars are so called free riders that are not working for a taxi-company. Together with the concessionaries the free riders can take a number of spots in the taxi lane. They also function as a backup when the taxi companies do not have cars waiting in the buffer zone.

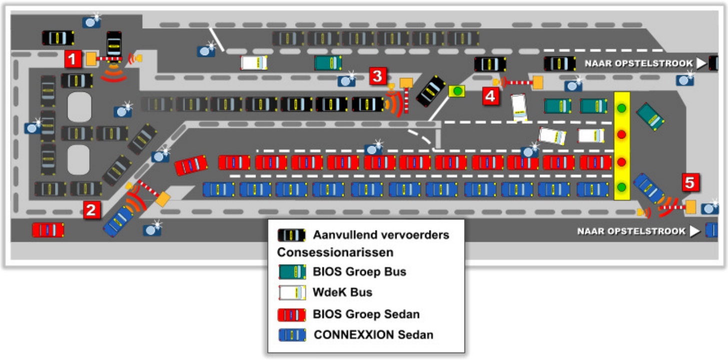

Figure 22: Street taxi buffer zone at Schiphol

After a taxi leaves the buffer zone, it enters the taxi lane at the airport arrival terminal. The concession provides divides the 14 spots available over the different concessionaries: 4 spots for both BIOS-groep and Connexxion, 4 spots for the free riders, and 1 spot each for the taxi busses of BIOS-groep and Willem de Koning. If one of these taxis leaves the taxi lane, a green light is shown to the same type of taxi that is waiting in the buffer zone. If the particular taxi is not present in the buffer, a free rider can take its position.

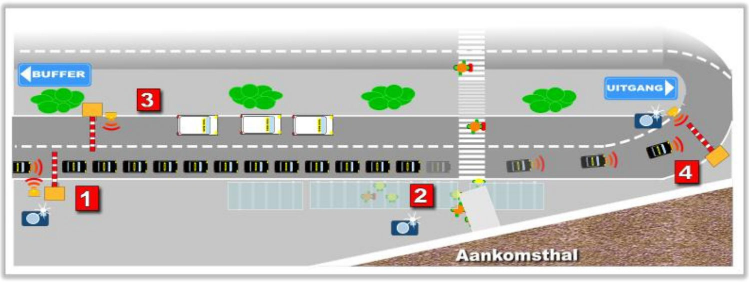

Figure 23: Taxi lane at the Schiphol – Arrival Passage; the first lane is for street taxis

As explained, this situation will remain at least until the end of the concession period. Without any irregularities, this will be 2015. Until the end of the concession period, it is normally not possible to offer competing taxi products, unless the current concessionaries agree. So if the electric car will be used as a street taxi, it will have to adapt to the current situation. This means that it cannot have a specific place at the taxi lane in front of the arrival terminal. However, if the electric taxi is driven by one of the concessionaries, this company can arrange itself that the electric taxi will get priority in the taxi buffer. This way the maximum occupancy of the electric taxi can be achieved, making the investments more interesting and having higher positive environmental impact.

So the electric taxi will fully emerge in the process currently at place. However, it will have to be clear to potential customers that they have to do with an electric car, and the limitations this entails. When fully charged the taxi can only drive 100-140 kilometres before plugged into a charger again. It is somehow undesirable that there are offered different taxi products at the taxi lane and it needs to be really clear how these are differentiated.

Specific input variables

The described concept of the electric street taxi entails specific input for the calculation of the financial performance. The calculation of the environmental performance follows directly from the generic input presented earlier in this chapter. The input important for financials is presented in the overview below.

Table 18: Specific input for the comparison of diesel and electric street taxis

	Pessimistic		Neutral		Optimistic	
	Diesel	Electric	Diesel	Electric	Diesel	Electric
Purchase price (€/vehicle)	40.000	33.000	40.000	31.000	40.000	29.000
Trips per taxi (#/hr)	0,9	0,9	1	1	1,1	1,1
Average distance per trip (km)	20	20	20	20	20	20
Trip income (€/trip)	45,00	45,00	45,00	45,00	45,00	45,00
Gross labour costs (€/hr)	18,8	18,8	18,8	18,8	18,8	18,8
Overhead (%)	25,0%	25,0%	22,5%	22,5%	20,0%	20,0%
Fast charger base stations (#)	0	1	0	1	0	1
Fast chargers per base station (#)	0	1	0	1	0	2
Output points total (#)	0	2	0	2	0	4

The first factor that differs for the different scenarios is the purchase price of cars. At least, for the electric version. The purchase price of the mainstream option will be like in the current situation. The internal department enforces minimal service levels for the car and its driver in the concession. For this reason there are only large limousines (e.g. Mercedes, Audi) used as a street taxi at the airport. However, Schiphol is considering to depart from these demands if it is about an electric car (or other non-emitting alternatives). The analysis thus takes different type of cars. Where the electric option is expensive for its type, it is still less expensive than the mainstream alternative. Besides the price for the electric car is quite uncertain, even within the short time frame before the start of the project. This uncertainty is taken into account.

For two reasons the trips per taxi can be different for electric taxis than for the mainstream option. First, the electric car will get priority in the buffer zone to increase environmental impact and have a higher rate of return for the relative high investments. On the other hand potential customers can doubt if they want to make use of an electric taxi because they are unfamiliar. This latter argument can also work the other way around, and drive customers to use the electric car. Because this is a bit uncertain, this factor varies over the different scenarios.

The average distance per trip is set equal for the different options and scenarios. The additional service must improve the sustainability, accessibility and coherence within the Amsterdam Airport Corridor. These numbers take this as a starting point. In the case of the street taxi it is imaginable that some of the mainstream taxis have their destination outside the Amsterdam region. However, if the travel distance increases the number of trips will decrease, which levels this effect more or less.

The taxi drivers are working for a taxi company and get paid per hour. This will not change over the different options and scenarios.

For the estimation of costs for planning and supervising activities the taxi companies use a percentage of the wages for taxi drivers and the depreciation costs of cars. This method is rather rough, as it is not clear how a more expensive car drives the overhead costs. However, for this research a better estimation was not achievable. Besides, the taxi companies have the experience and do not use such an estimation for nothing. It was indicated that for overhead a percentage between 20 and 25 of the wages and car depreciation was taken. The uncertainty around this number is integrated in the scenarios.

To enable guaranteed fast charging possibilities of the switch cars, one charging output is needed for every 5 cars. For street taxis it is assumed that a fast charging station near the buffer entrance is sufficient for smooth operations. The type and number of base stations and chargers is adapted to the number of cars.

5.5.2 Ordered taxi

Concept description

The ordered taxi is a different concept than the street taxi. Considering trips from the airport to a destination within the airport region, the ordered taxi service enables the arrangement of a taxi prior to the arrival at the airport. This can be useful for passengers that want to make sure there is a taxi available, prevent waiting in the line or have specific demands for the taxi they take (for instance high end limousine services or wheel chair suitability). The ordered at the airport is called the Schiphol Travel Taxi. This can be arranged at the Schiphol Transfer Assistance Desk, online or at the airport. The passenger can decide himself at which company he wants to order a taxi, however this company needs to be subscribed as a Schiphol Travel Taxi. After a taxi is ordered, it is scheduled and (if ordered in time) readily available after the arrival of the passenger. The taxi that is picking up the passengers wait at a designated area in Schiphol North, and after the passenger checks in at the Schiphol Transfer Assistance Desk the taxi is given a signal. Within several minutes it can drive in front of the arrival terminal at the designated lane (lane three in the figure below).

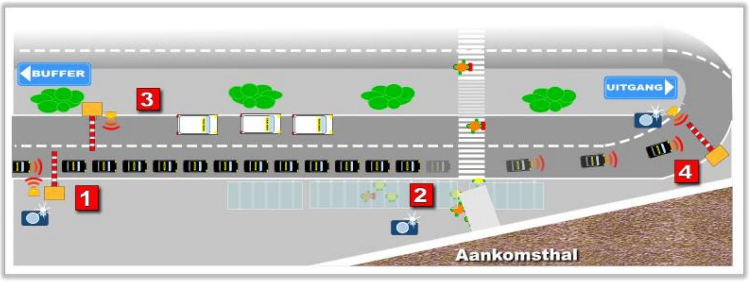

Figure 24: Taxi lane at the Schiphol – Arrival Passage; the second lane is for ordered taxis

The ordered taxi is most of the times a bit more expensive then the street taxi. This is also due to the fact that ordered taxis (different then street taxis) are not legally enforced a particular tariff. The price agreement is set by the passenger and the taxi company of its choice.

As a means to increase accessibility within the Amsterdam Airport Corridor the ordered taxi can be promoted towards the intended users, business passengers. Because the ordered taxi is not limited to regulations set out in a concession, the alternative can be actively promoted and adapted to the needs of its users. There can for instance be made agreements with companies in the corridor about the use of the ordered taxi by their employees and visitors.

The electric option can be fully integrated in the current operations of the ordered taxi. However, at some points in the process it differs a bit from the mainstream alternative. In the promotion it needs to be clear that there is an electric option. Companies can be informed how the use of the electric taxi can decrease their environmental footprint, but they also need to be informed about the range limitations of the electric option. Its needs to be clear that the electric option focuses on the trips between the airport and certain business areas in its region.

Specific input variables

The described concept of the electric ordered taxi entails specific input for the calculation of the financial performance. The calculation of the environmental performance follows directly from the generic input presented earlier in this chapter. The input that is important for financials is presented in the overview below.

Table 19: Specific input for the comparison of diesel and electric ordered taxis

	Pessimistic		Neutral		Optimistic	
	Diesel	Electric	Diesel	Electric	Diesel	Electric
Purchase price (€/vehicle)	40.000	33.000	40.000	31.000	40.000	29.000
Trips per taxi (#/hr)	0,5	0,5	0,75	0,75	1	1
Average distance per trip (km)	20	20	20	20	20	20
Trip income (€/trip)	55,00	55,00	55,00	55,00	55,00	55,00
Gross labour costs (€/hr)	18,8	18,8	18,8	18,8	18,8	18,8
Overhead (%)	25,0%	25,0%	22,5%	22,5%	20,0%	20,0%
Fast charger base stations (#)	0	1	0	1	0	1
Fast chargers per base station (#)	0	1	0	1	0	2
Output points total (#)	0	2	0	2	0	4

The purchase price for the cars is set with using the same starting points as with the street taxi. For the electric option the most advanced passenger car within the sedan segment is chosen. Currently this is the Nissan LEAF. The purchase price at the moment of the project start is uncertain (and different for each scenario) because every new batch of electric cars performs better for a lower price and the competition is only increasing. The price for the mainstream (diesel) option is fixed. There are no big uncertainties here. It is also higher than the electric option. If a diesel car from the same type of the electric car would be introduced as an alternative for comparable prices and service, it cannot differentiate itself for which reason it will not stand out above the normal luxury taxis. This is different for the electric version that differentiate on sustainability and for which no luxury (normal) passenger car is available yet.

The trips per hour are much lower than with the street taxi. This has to do with the service concept. An ordered taxi will have to be available the moment the passenger arrives at the terminal. A margin will be taken to make sure this is the case. The waiting time before the trip will therefore be higher. This is also the case when the ordered taxi is picking up somebody at one of the locations in the airport region for transportation to the airport. Because the waiting time is very uncertain, there are taken bigger differences within the different scenarios.

The average distance per trip is the same as in the case of the street taxi and relates to the locations presented in the general results. In contrary the trip income is fairly higher for the reason explained in the concept description of the ordered taxi. This price is not legally limited and can be agreed on between the taxi company and the passenger. Because competition is less then with the street taxi and the waiting time is generally higher, the average trip price will be higher than with the street taxi.

The gross labour costs are the same as with the street taxi as well as the overhead that is fairly uncertain and will become less while scenarios become more favourable. It is assumed that only one fast charging base station is needed, and one charging output for every 5 cars. Different from the street taxi the ordered taxi does not need switch cars for the electric option. Because cars have longer waiting times before picking up passengers, there will be sufficient charging time available.

5.5.3 Rental car

Concept description

The rental car is a bit of an outlier within the set of researched alternatives. However, it earns attention because of the fact that it is one of the car based modalities used by business passengers to travel to and from the airport. Different then the taxi based alternatives, the rental car is driven by the passengers itself.

At the airport many car rental companies. Rental cars can be reserved before the flight arrival, or arranged hereafter. In both cases the passenger needs to go to the company desks located in the arrival terminal. Following the car can be picked up in front of the arrival terminal. The cars are maintained and stored at a different location on the airport. Before, the rental the car is brought from this location to the pickup location in front of the terminal. After use the car is brought to the remote location for necessary cleaning, maintenance and storage. Some of the rental companies located at the airport have dependences at other locations within the Amsterdam Airport Corridor as well. This simplifies the exchange of cars between different locations, which can be interesting for certain passengers.

The use of electric car for rental services can fit well within this process. However, it must be made clear to the potential customer that the car has certain limitations as it comes to range. The electric car can be actively promoted on websites of the rental company, the airport and airlines to the customers that planned short travel distances. Like the mainstream electric car, the rental is especially suitable for passengers that plan more trips then just the pre- and post transport to and from the airport. For instance to visit some touristic locations during the stay that are not sufficiently accessible with public transport or taxis. Especially when a business passenger plans to stay at locations that have charging facilities (like the Dorint Hotel at the airport or the Okura hotel in the city centre of Amsterdam) an electric car can be interesting.

Specific input variables

The described concept of the electric rental car entails specific input for the calculation of the financial performance. The calculation of the environmental performance follows directly from the generic input presented earlier in this chapter. The input important for financials is presented in the overview below.

Table 20: Specific input for the comparison of diesel and electric rental cars

	Pessimistic		Neutral		Optimistic	
	Diesel	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**
Purchase price (€/vehicle)	22.500	33.000	22.500	31.000	22.500	29.000
Fraction rented days (%)	60%	60%	60%	60%	60%	60%
Average distance (km/day)	40	40	40	40	40	40
Average rental price (€/day)	50	50	50	50	50	50
Gross labour costs (€/hr)	0	0	0	0	0	0
Overhead (%)	25,0%	25,0%	22,5%	22,5%	20,0%	20,0%
Fast charger base stations (#)	0	1	0	1	0	1
Fast chargers per base station (#)	0	1	0	1	0	1
Output points total (#)	0	2	0	2	0	2

As explained, the rental car alternative differs on several factors from the three taxi alternatives. The biggest difference lies in the fact that passengers do not pay per trip, but per day they rent the car. This means the some of the input of the quantitative analysis is different. This can be seen in the above table.

However, the first factor – the purchase price – is the same. Again, the specification of the best available car is used for the electric option. Different from the taxi alternatives, the purchase price of the mainstream alternative is lower. Where there are set minimum demands for the cars used as a street taxi and the ordered taxi must compete with luxury cars, the rental is available in different types. It is expected that passengers that want to rent a big luxury car will not choose for the electric option that is of a smaller type. However, the passengers choosing the same type of car anyway, will probably be interested in the electric version. So the comparable purchase price for the mainstream electric car is lower.

For the taxi alternatives the number of trips per hour is taken as a starting point to calculate the use of the alternatives. For the rental alternative, the fraction of rented days is used. It is uncertain how well the electric version will be rented. For this reason the different scenarios use different percentages for the fraction of rented days.

As the electric rental is used for transportation over short distances the travel distance per day is fairly low, especially compared to the taxi alternatives. For the mainstream alternative the same distances are taken to enable fair comparison. The average rental price per day is depending on the distances travelled and the type of car rented. This factor is therefore fixed for the different scenarios.

Labour costs are set to zero as no driver is required for the rental car. The overhead percentage is the same percentage as with taxi alternatives, however the absolute overhead costs are much lower as these are calculated as a fraction of the labour costs and the car depreciation costs of which the first is set to zero.

For the number of chargers needed different starting points are taken as well compared to the taxi alternatives. The rental company cannot provide charging alternatives during the rental period, so the passenger relies on public chargers made available at the airport or in the region. However, for fast re-rental the rental company will need a fast charger at the remote location to enable charging during cleaning and possible quick maintenance. If there would not be a fast charger available there is a risk that the car cannot be rented shortly after return which involves loss of income.

Other factors that are not presented in the table but are fairly different from the taxi alternatives are the following:

- There are no costs involved with the refit of purchased car to make them suitable for taxi services. For the taxi alternatives €5.000,- is accounted for this cost factor.
- The taxi alternatives are only positively exploitable during the day and outside the holidays. Despite the fact that the car is available during holidays and weekends, it is not operational because the operational costs of a driver cannot be earned back. This is different for the rental car that is always available and for which operational costs are always equal. The rental car is therefore available 365 days a year.

5.5.4 Semi-private taxi

Limitations within existing alternatives

The first three alternatives presented the integration of electric cars within existing transport services; the street taxi, ordered taxi and rental car. These services are currently arranged in a certain predictable way. High comfort standards are pursued and all potential passengers can be served whether they want to travel to Amsterdam's city centre or to Paris. People know what they can demand and the service they can expect. Integrating electric cars in the fleet that is used to offer the service, entails some limitations, both for the passenger as for the operating company. The passenger cannot just go everywhere because of range limitations. The operator will have to take into account the different characteristics of electric cars, for instance because they need to be 'refuelled' more frequently than the alternative mainstream option.

In the cases of the street taxi there are actually offered two different services under one label. The electric transport for short distances and the 'normal' transport option for all distances. The alternatives of the ordered taxi and rental car can better cope with these differences, as the used car can be directly adjusted to the need of the customer. However, these alternatives show low user rates making them less interesting for emission reduction and promotion goals.

Because of the limitations for both the passenger and the operator or to reach the set goals, the question raises if there is not another alternative that better fit the requirements set by Schiphol Group its partners and can better cope with the limitations of the electric car. In the end, the offered service must reduce emissions for the trips of business passengers within a region of limited proportions; the Amsterdam Airport Corridor. Given the characteristics of the electric car, it must be perfectly suitable for this purpose.

Concept description

The latter alternative concerns an alternative that aims at the perfect integration of transport needs within the Amsterdam Airport Corridor and the possible achievements of the electric car. Schiphol group aims at the reduction of emissions by traffic and transportation. The electric car is considered an interesting option to do so, but it entails range limitations and not every car type is available in an electric version. Schiphol considers deviating minimal demands for travel comfort if it concerns sustainable alternatives. Companies in the airport want to limit their environmental footprint and are interested in sustainable travel alternatives. These considerations form the starting point for the new concept.

A new taxi service concept is offered, exclusively or particularly aiming at the transportation of business passengers over distances within the Amsterdam Airport Corridor. The primary locations that the service aims at are set on beforehand. Locations that are not appointed, will not be served. This must be clear for potential customers. At the different locations a special taxi stand is established that is easily recognized and enables communication with (potential) customers, for instance about costs, waiting time and travel time. Customers can order the taxi (provided that they are located in the designated area) or get on board at one of the taxi stand located at the busiest business centres in the Amsterdam Airport Corridor. Both at the airport and at a central location in Amsterdam there are placed fast charging facilities where switch taxis are available for drivers that need a charged car.

Promotion of the new service especially aims at companies located at the airport and in the corridor that generate a lot of car trips to the airport through one of the traditional transport services. There must be established direct communication between the companies and the planning office of the company that operates the semi-private taxis. If a clear estimation is available about the number and moments of trips that are generated, better planning is possible reducing costs. Besides, companies can be assured available cars at the moment needed. The number of (operational) cars can be adjusted to the number of subscribed companies and the demand for trips within the corridor they foresee. Because of this nature the service is labelled as semi-private taxi. However, if available taxis can also be used by people that are not subscribed.

Specific input variables

The described concept of the electric semi-private taxi entails specific input for the calculation of the financial performance. The calculation of the environmental performance follows directly from the generic input presented earlier in this chapter. The input important for financials is presented in the overview below.

Table 21: Specific input for the comparison of diesel and electric semi-private taxis

	Pessimistic		Neutral		Optimistic	
	Diesel	Electric	Diesel	Electric	Diesel	Electric
Purchase price (€/vehicle)	40.000	33.000	40.000	31.000	40.000	29.000
Trips per taxi (#/hr)	1	1	1,2	1,2	1,4	1,4
Average distance per trip (km)	20	20	20	20	20	20
Trip income (€/trip)	45,00	45,00	45,00	45,00	45,00	45,00
Gross labour costs (€/hr)	18,8	18,8	18,8	18,8	18,8	18,8
Overhead (%)	25,0%	25,0%	22,5%	22,5%	20,0%	20,0%
Fast charger base stations (#)	0	2	0	2	0	2
Fast chargers per base station (#)	0	1	0	1	0	2
Output points total (#)	0	4	0	4	0	8

For this alternative it is harder to decide on the type of car to compare the electric option with. However, if looking from the perspective of the potential customer – the companies located near the airport – taking a normal car from the same type of the electric version would probably not be an option. The electric car distinguishes itself because of its sustainable character, not because of the luxury offered. If sustainability is not an alternative, business passengers are expected to just make use of the normal luxury option. Again, this is the reason the purchase price of the mainstream car is higher than the electric version.

As explained, the semi-private taxi service aims at companies that subscribe themselves and estimate the number of trips they need throughout the day, week, month and year. This enables optimal planning and for the fixed demand. During quiet moments the taxi can be offered to other customers that call the taxi at the given locations. At these locations, the semi-private taxi must have its dedicated taxi stand to make it distinguishable from alternatives. More people will then be attracted to the sustainable alternative for short distances. For these reasons the occupancy rate is expected to be higher than with normal street taxis. However, because of the innovative character of the service there is also quiet some uncertainty around this number, for which reason the differences between the scenarios are quiet large.

Average distance per trip is the same compared to the street taxi and order taxi alternatives. Trip income resembles the street taxi alternative because the character of the service resembles most to this alternative. Gross labour costs are set the same as in the other taxi alternatives.

There are needed more fast chargers then in the other alternatives. The gravity point of the street taxi and order taxi service will be around the airport, as all trips are from or to the airport. In the case of the semi-private taxi the gravity point is located more towards the city as there will also be trips between the different business locations around the city. This requires a charging point near the city as well as well as switch cars located at this point.

5.6 Comparison of alternatives

For each combination between alternative, scenario and option the presented input leads to the following results:

- Financial performance; NPV
- CO_2 performance
- NO_X performance
- PM_{10} performance

The different alternatives are assessed and compares on the bases of their performance on these points. Thereby, this section aims at the completion of the different assessments steps that were presented in the method section.

5.6.1 Financial performance

NPV

Table 22 gives an overview of the Net Present Values of the electric and diesel options for each alternative and subject to the different scenarios. The colour spectrum from green to red indicates the performance of the different alternatives. The following considerations can be made:

- Obviously the optimistic scenario show the best results, for both the electric and the diesel option. For the project period of 5 years, the taxi alternatives show a NPV of 4,3 up to 7,5 million Euros.
- The street taxi is the only alternative that give positive NPVs, for each scenario and option.
- From a financial point of view the rental car alternative does not perform very well.

Table 22: Financial performance of the electric and diesel options in alternative projects

			NPV (x1.000)
Street taxi	-	Electric	275
		Diesel	410
	0	Electric	1.384
		Diesel	1.239
	+	Electric	4.881
		Diesel	4.340
Ordered taxi	-	Electric	-299
		Diesel	-131
	0	Electric	998
		Diesel	991
	+	Electric	6.264
		Diesel	5.675
Rental car	-	Electric	-269
		Diesel	38
	0	Electric	-202
		Diesel	78
	+	Electric	-93
		Diesel	164
Semi-private taxi	-	Electric	-9
		Diesel	485
	0	Electric	1.518
		Diesel	1.853
	+	Electric	7.525
		Diesel	6.993

While the above results show the performance of each option separately, most interesting for Schiphol Group is the relative financial performance of the electric option compared to its diesel counterpart. The figure below gives for each alternative-scenario combination, the difference between the NPV of the diesel and the electric option. The numbers are a direct result of the summation of the NPVs shown in the above table. A negative number indicates that the electric option performs less than the diesel option.

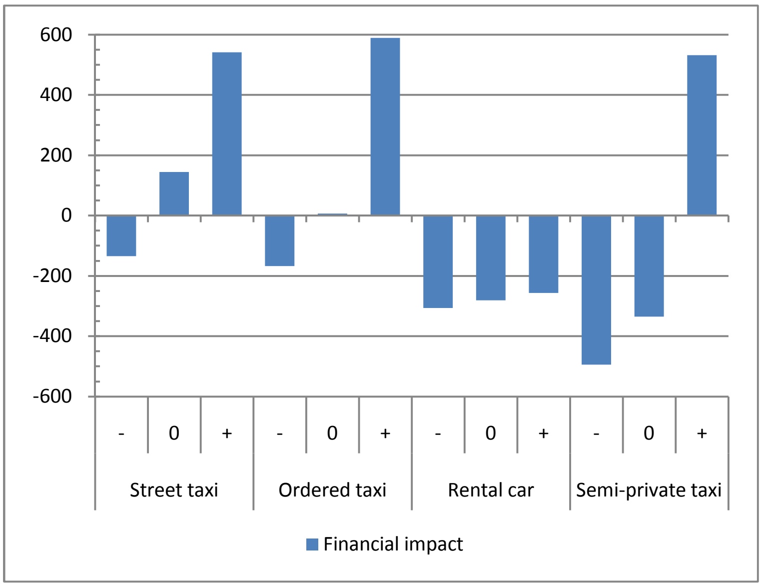

Figure 25: Relative financial impact of the introduction of electric cars

The above figure gives already better insights in the financial performance of the electric option relative to its diesel counterpart option for the different alternatives. The following considerations can be made:

- In most cases the electric option has a worse financial result then the corresponding diesel option.
- The street taxi is the only alternative for which the electric option has a substantial higher NPV than the diesel option.
- From a financial point of view the electric option does not seem to be an interesting one for the use as rental car.

The above figures indicate that a positive NPV of an electric car project does not necessarily mean that the project is interesting from a financial point of view. If the corresponding diesel option performs even better, the net result of introducing electric cars will be negative.

It must also be concluded that there is no alternative that shows positive results for the electric option in each scenario. Looking at the different assessment steps, it must be concluded that there are no alternatives that end up in group A.

This does not mean that there might not be interesting alternatives for the introduction of electric cars. After all, the financial performance is not the only point of interest for Schiphol Group.

5.6.2 CO_2 performance

As discussed in the section for generic input there are composed three different scenarios that are applied on three different sets of uncertain factors for the calculation of CO_2 emissions. To limit the data set of the final results, only the most extreme results from this scenario analysis are taken into further consideration.

The table below has the following input:

- The total amount of kilometres driven per year, for both options in each alternative-scenario combination.
- The CO_2 emissions for the electric option in three different scenarios. As explained in the generic input section, the pessimistic scenario shows disappointing energy efficiency and Well-to-Tank emissions. For the optimistic scenario the values of these factors turn out much better. Finally, the neutral scenario shows medium performances.
- The CO_2 emissions for the diesel option. As explained in the generic input section, there are not used different scenarios for the diesel option, since there is shown quite some certainty on this value.

Multiplying these inputs results in the total CO_2 emissions for both the electric and diesel option in each alternative-scenario combination.

Table 23: CO_2 emissions of the electric and diesel options in alternative projects

CO_2 (ton)			-	0	+
Street taxi	-	Electric	73	29	17
		Diesel	43	43	43
	0	Electric	163	64	37
		Diesel	95	95	95
	+	Electric	448	175	101
		Diesel	261	261	261
Ordered taxi	-	Electric	41	16	9
		Diesel	24	24	24
	0	Electric	122	48	28
		Diesel	71	71	71
	+	Electric	407	159	92
		Diesel	237	237	237
Rental car	-	Electric	12	5	3
		Diesel	7	7	7
	0	Electric	23	9	5
		Diesel	14	14	14
	+	Electric	47	18	11
		Diesel	27	27	27
Semi-private taxi	-	Electric	81	32	18
		Diesel	47	47	47
	0	Electric	195	76	44
		Diesel	114	114	114
	+	Electric	570	223	129
		Diesel	332	332	332

Better insight in the above numbers is gained when the relative performance of the electric option, compared to the diesel variant, is taken. The table below shows these differences. A negative number indicates that the CO_2 emissions from the electric option are higher compared to the diesel option.

Table 24: Relative impact on CO_2 emissions by the introduction of electric cars

CO_2 (ton)		-	0	+
Street taxi	-	-31	14	26
	0	-68	31	58
	+	-187	86	160
Ordered taxi	-	-17	8	15
	0	-51	23	44
	+	-170	78	145
Rental car	-	-5	2	4
	0	-10	4	8
	+	-19	9	17
Semi-private taxi	-	-34	16	29
	0	-82	37	70
	+	-238	109	203

The following considerations can be made from the above table:

- The above table combines two sets of scenarios. The first are the scenarios also used to calculate the NPVs. This set of scenarios is referred to as the business case scenarios and is presented in the rows of the above table. It effects the yearly mileage by the cars of the specific alternative. The other set takes into account uncertainties concerning CO_2 emissions. This set of scenarios is referred to as the emission scenarios and is presented in the columns of the above table. This set effects the CO_2 emission per kilometre. As explained in the generic input section, both sets contain a pessimistic and an optimistic scenario, as well as a neutral one in between.

- The electric alternative is not always a cleaner one. In the possible emission scenario where both energy efficiency and Well-to-Wheel emissions are disappointing, the electric option performs worse in all cases.
- The electric option performs better in all cases of the neutral and optimistic emissions scenario.
- The business case scenarios determine the number of kilometres driven. The optimistic scenarios have higher kilometre inputs. This intensifies the effect of the emission scenarios and thereby increases the differences.

5.6.3 NO_X performance

For both option in each alternative-scenario combination the total NO_X emission for a project period of one year are calculated. The input is a bit different compared to the CO_2 emissions. As explained in the generic input there were no scenarios used for the calculation of NO_X. The estimations on NO_X found in literature show less uncertainty, however it must also be mentioned that there is far less research done on NO_X (and PM_{10}) emissions compared to CO_2.

Another difference compared to the CO_2 calculation, lies in the source of the emissions. As explained [check], for the negative climate effects of CO_2 it does not matter where the gas is emitted. In contrary, the damage of air pollution caused by NO_X higher in densely populated areas (at least for the damage on humans). Therefore, NO_X emitted by a diesel car in the city centre is of greater concern then NO_X emitted by a coal plant for electricity production (at least when this coal plant is not situated in a densely populated area).

The input used in the table below is the distance travelled as well as the WTT and TTW emissions of both the electric and diesel car in the different business case scenarios.

Table 25: NO_X emissions of the electric and diesel options in alternative projects

NO_X (kg)			WTT	TTW	WTW
Street taxi	-	Electric	11	0	11
		Diesel	18	50	67
	0	Electric	24	0	24
		Diesel	39	110	149
	+	Electric	67	0	67
		Diesel	108	303	411
Ordered taxi	-	Electric	6	0	6
		Diesel	10	28	37
	0	Electric	18	0	18
		Diesel	29	83	112
	+	Electric	61	0	61
		Diesel	98	275	373
Rental car	-	Electric	2	0	2
		Diesel	3	8	11
	0	Electric	4	0	4
		Diesel	6	16	21
	+	Electric	7	0	7
		Diesel	11	32	43
Semi-private taxi	-	Electric	12	0	12
		Diesel	20	55	75
	0	Electric	29	0	29
		Diesel	47	132	179
	+	Electric	86	0	86
		Diesel	137	386	523

A better understanding on the possible effect of the introduction of electric cars is gained when the relative emissions compared to the diesel option are presented. This is done in the table below. A positive number indicates the amount of NO_X that is reduced by introducing electric cars for the specific alternatives.

Table 26: Relative impact on NO_X emissions by the introduction of electric cars

NO_X (kg)		WTT	TTW	WTW
	-	7	50	56
Street taxi	0	15	110	125
	+	40	303	343
	-	4	28	31
Ordered taxi	0	11	83	94
	+	37	275	312
	-	1	8	9
Rental car	0	2	16	18
	+	4	32	36
	-	7	55	62
Semi-private taxi	0	18	132	150
	+	51	386	437

The following considerations can be made about the comparison between NO_X emissions of electric and diesel cars:

- In all cases the electric option performs better than the diesel option.
- The biggest differences are found in the Tank-to-Wheel emissions. This is not surprising, as the electric car has not tailpipe emissions.
- Logically, there is a positive effect of the number of the distance that is travelled. This increases the positive effect of electric cars.

5.6.4 PM_{10} performance

The analysis of PM_{10} emissions completely resembles the NO_X analysis. Also in the case of PM_{10}, emissions in urban areas have higher consequences for human health then the emissions in rural areas.

The table below gives the overview of the PM_{10} emissions of both options (Well-to-Tank, Tank-to-Wheel and Well-to-Wheel) in each alternative-scenario combination. Like NO_X, there are no tailpipe emissions from electric cars.

Table 27: PM_{10} emissions of the electric and diesel options in alternative projects

PM_{10} (g)			WTT	TTW	WTW
Street taxi	-	Electric	702	0	702
		Diesel	551	1.377	1.928
	0	Electric	1.561	0	1.561
		Diesel	1.224	3.060	4.284
	+	Electric	4.292	0	4.292
		Diesel	3.366	8.415	11.781
Ordered taxi	-	Electric	390	0	390
		Diesel	306	765	1.071
	0	Electric	1.170	0	1.170
		Diesel	918	2.295	3.213
	+	Electric	3.902	0	3.902
		Diesel	3.060	7.650	10.710
Rental car	-	Electric	112	0	112
		Diesel	88	219	307
	0	Electric	223	0	223
		Diesel	175	438	613
	+	Electric	447	0	447
		Diesel	350	876	1.226
Semi-private taxi	-	Electric	780	0	780
		Diesel	612	1.530	2.142
	0	Electric	1.873	0	1.873
		Diesel	1.469	3.672	5.141
	+	Electric	5.462	0	5.462
		Diesel	4.284	10.710	14.994

The table below presented the differences in PM_{10} performance between the electric and diesel car. A negative number indicates that the electric cars performs worse.

Table 28: Relative impact on PM_{10} emissions by the introduction of electric cars

PM_{10} (g)		WTT	TTW	WTW
Street taxi	-	-151	1.377	1.226
	0	-337	3.060	2.723
	+	-926	8.415	7.489
Ordered taxi	-	-84	765	681
	0	-252	2.295	2.043
	+	-842	7.650	6.809
Rental car	-	-24	219	195
	0	-48	438	390
	+	-96	876	780
Semi-private taxi	-	-168	1.530	1.362
	0	-404	3.672	3.268
	+	-1.178	10.710	9.532

The following considerations can be made on the basis of the table above:

- Electricity generation for electric cars caused more PM_{10} emissions than fuel production and transportation. This results in worse WTT PM_{10} performance.
- The TTW performance of electric cars is much better.
- Again, effects are increased by mileage numbers that differ for the different business case scenarios.
- In all cases, the total PM_{10} emissions of electric cars is less compared to its diesel counterpart.

5.6.5 Overview and interpretation of results

The results presented in the previous paragraphs are summarized in the table below. Looking closely at the numbers clarifies the different performance of the electric car in the alternative projects.

Table 29: Overview of the relative economic and environmental performance of electric cars compared to diesel cars

		NPV	**CO_2** (ton)			**NO_x** (kg)			**PM_{10}** (g)		
		(x1.000)	-	0	+	WTT	TTW	WTW	WTT	TTW	WTW
	-	-135	-31	14	26	7	50	56	-151	1.377	1.226
Street taxi	0	145	-68	31	58	15	110	125	-337	3.060	2.723
	+	541	-187	86	160	40	303	343	-926	8.415	7.489
	-	-167	-17	8	15	4	28	31	-84	765	681
Ordered taxi	0	7	-51	23	44	11	83	94	-252	2.295	2.043
	+	589	-170	78	145	37	275	312	-842	7.650	6.809
	-	-307	-5	2	4	1	8	9	-24	219	195
Rental car	0	-281	-10	4	8	2	16	18	-48	438	390
	+	-256	-19	9	17	4	32	36	-96	876	780
	-	-494	-34	16	29	7	55	62	-168	1.530	1.362
Semi-private taxi	0	-335	-82	37	70	18	132	150	-404	3.672	3.268
	+	531	-238	109	203	51	386	437	-1.178	10.710	9.532

However, the table is quite hard to interpret. To improve the clarity of the results, the table has been simplified in a single figure that returns the relative performance of the alternative projects compared to each other. The first figure below only presents the relative performance within the neutral scenario. The street taxi performs highest on economics, for which reason the alternative is placed at 100 on the horizontal axis. The other alternatives are placed on the horizontal axis, depending on their economical performance relative to the street taxi. It can be seen that the NPV of the rental is almost two times as high as the street taxi, however on the negative side of the axis. This procedure is repeated for the environmental performance, for which the semi-private taxi has the highest score. This way the alternatives are plotted in a economic-environmental performance diagram, like explained in method description in Paragraph 2.3.

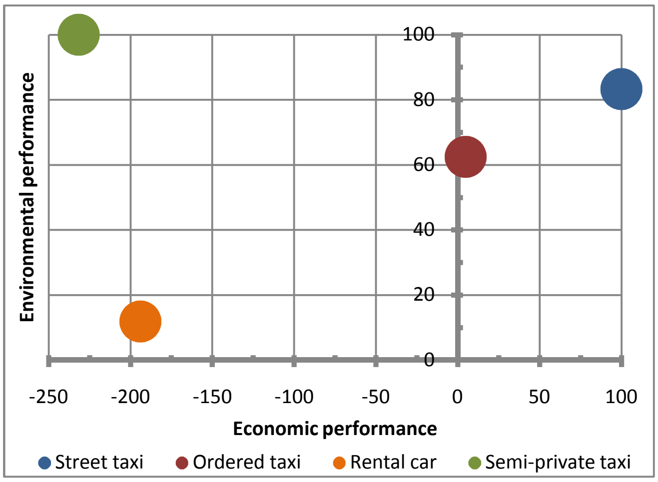

Figure 26: Graph of the relative performance of electric cars in the neutral scenario

The figure becomes more interesting as the other scenarios, both for the economic and environmental performance, are added. This is done in the figure below. For each project alternative there are plotted three scenarios on the horizontal axis, displaying the different NPVs that are returned from the assumptions within these scenarios. The environmental performance relates to the calculation of the NPV, and the range of uncertainty becomes bigger as the economic scenario becomes more optimistic. The range for environmental performance is presented using a range bar between the plausible extremes that are expressed in the optimistic and pessimistic scenarios for emissions.

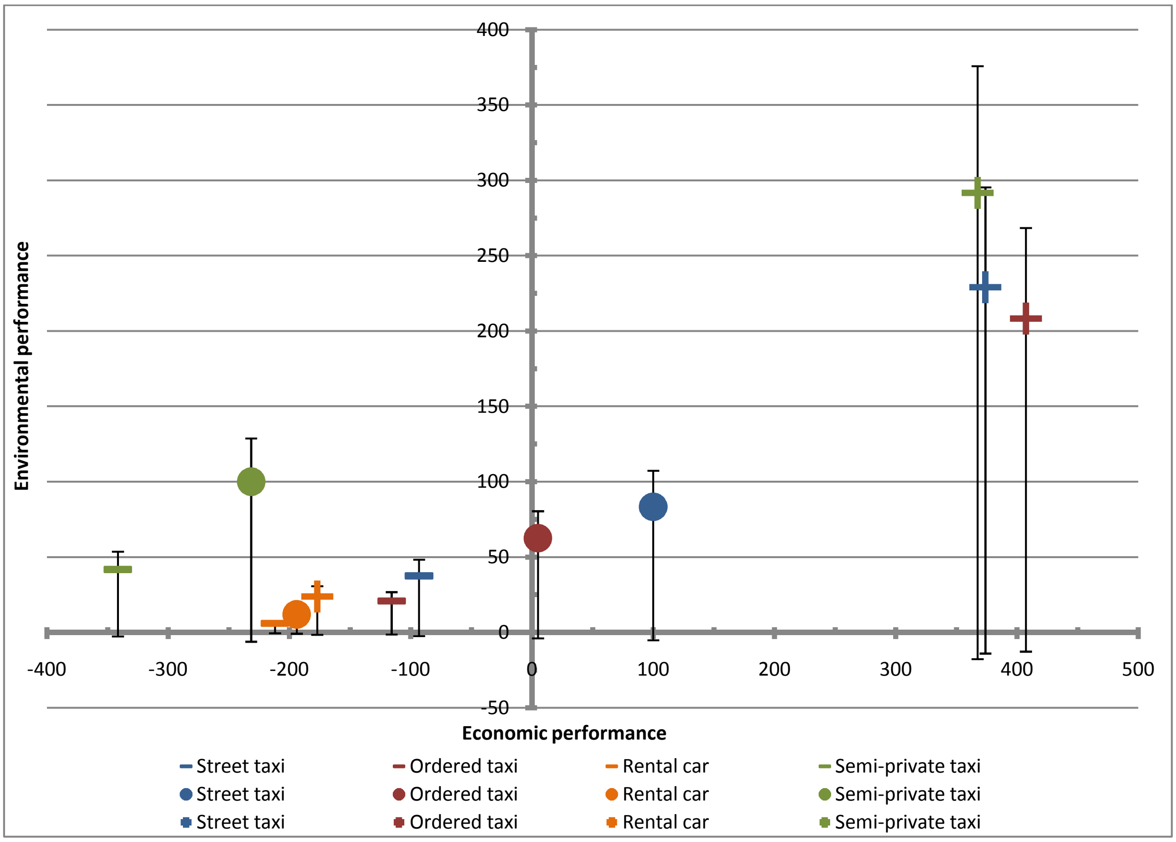

Figure 27: Graph of the relative performance of electric cars in different scenarios

The above figure indicates high impact of the uncertainties that are expressed in the different scenarios.

6 CONCLUSIONS AND RECOMMENDATIONS

Interpretation of results

At the start of the research project there were set expectations about the performance of electric cars relative to diesel cars. The hypothesis stated that their introduction would contribute to the reduction of transport related emissions. Contrary, due to the innovative character of electric cars and related high investments, the financial performance was expected to be negative. The presented results contradict both expectations. First, it is indicated that within certain plausible scenarios, transport services that make use of electric cars can be more profitable compared to the use of diesel cars. On the other hand, the electricity generation needed to power the cars can actually lead to higher CO_2 emissions compared to mainstream diesel cars.

The results enable the answering of the main research question; "what is the economic and environmental potential of introducing electric cars within the Amsterdam Airport Corridor?" Providing the given limitations and assumptions within the analyses, the comparison between electric and diesel cars indicate that the introduction of electric cars in the Amsterdam Airport Corridor can potentially lead to significant emission reductions while being financially interesting. The project alternative aiming for the electrification of street taxis has the highest potential. Its environmental score is just below the – at this point best scoring – semi-private taxi while a positive NPV is far more likely. The electric rental car project is the least interesting on both fronts.

It also became clear that these results are subject to multiple uncertainties. The main conclusions can only be adopted in combination with the necessary explanations about these uncertainties and the related risks.

Financial performance

The financial results are different for the scenarios, the alternative projects and the drive train technology options. Obviously, the optimistic scenarios generate better results than the pessimistic ones. The differences between the alternative projects are partly caused by differing requirements and related investments for the service concepts. However, the main differences are caused by the expected amount of 'saleable products'; taxi trips or rented days. The differences between the electric and diesel cars are a result of differing costs. Fixed investment costs are higher for the electric option, while operational costs – primarily depending on the travelled distance – are lower. At a certain point the positive impact of low operational costs compensates the negative impact of high investments. Above this point the NPV of the electric option is higher compared to the use of diesel cars. When Schiphol Group or other organizations search for financially sound alternatives for transport electrification, it can be recommended to focus on alternatives with intensive operations.

Environmental performance

CO_2

The uncertainty about actual changes in CO_2 emissions, caused by the increased use of electric cars, motivated the use of scenarios for CO_2 calculations. The optimistic and neutral scenario return positive results, however there is a plausible chance that electric cars cause higher CO_2 levels on a WTW level.

Changing emissions caused by the generation of extra electricity needed for electric cars, depend on variables like the current energy mix, moment of charging, wind capacity installed and costs for CO_2 certificates. Providing that the relation between these factors and the factual change in emissions is known, the emission effect of using electric cars can be partly influenced. If the national and European governments decide to stimulate the uptake of electric cars, they can maximize related environmental benefits by steering the factors in the optimal direction. At a company level Schiphol Group can contribute to this as well. There are already initiated project for sustainable electricity generation within the airport region. Synergy could be achieved when this is combined with the introduction of electric cars. However, this requires the use of smart grids. Schiphol Group can consider extra research to investigate necessary investments and efforts that enable to profit from synergy effects. Likewise, Schiphol Group can stimulate users of electric cars to charge at certain moments. However, restrictions or guidelines cannot be imposed to all types of users. For instance for the transport services described in this research, it would be very costly if charging is not possible at a certain moment.

Air pollutants

It is clear that the Amsterdam Airport Corridor will profit from the elimination of pollution after the introduction of electric cars. However, it is uncertain what the damaging effect of the pollution from electricity generation will be. Governments can maximize the positive effects by limiting polluting electricity generation in populated areas. The possible contribution of Schiphol Group compares to the CO_2 case. While there are no uncertainties taken into account for the emissions of air pollutant, it is expected that electric cars have a positive effect on damaging air pollution in any scenario.

Relative impact

The researched alternatives only have a marginal potential impact on the total emissions within the airport region. As the share of traffic and transportation is only 30% and the researched projects only cover a very small part of this sector, the airport will not suddenly become sustainable. Therefore, this should also not be the current target of Schiphol Group; the main contribution of initiated projects lies in the contribution to increased knowledge and experience which can be helpful to achieve higher goals for sustainable transportation during the coming years.

Schiphol Group's role

Schiphol Group formulated progressive goals concerning the sustainability of the airport and related transport. Consequentially, multiple projects are initiated – mainly small scale – while the interest in the potential of electric cars to achieve these goals arose. However, at some point the airport operator will have to seriously consider its role in the uptake of sustainable transport. Normally, its primary focus is on the aviation industry which demands safety and reliability. From this perspective it would be more logical to act more conservative and only utilize transport alternatives that have been subject to continuous development and proved themselves over a longer period and in different environments.

However, the nature of Schiphol Group – the company that aims to operate Europe's most preferred airport and fully eploit the advantages of its own invention; the Airport City – fits a progressive attitude and the adaptation and execution of innovative and entrepreneurial projects. Assuming that Schiphol Group wants to have a guiding role in the improvement of transport sustainability, it will have to increase related knowledge. Also, the internal organization will have to be adjusted to fit this role. Departments that need to cooperate to enable related projects need to be involved and aligned. Furthermore, relevant external stakeholders should be tempted to share knowledge and contribute to (successful) project realization.

Opposite to the guiding role, Schiphol Group can decide to outsource knowledge development and the formation of coalitions related to transport sustainability. Innovations would then only be introduced after their potential is proven.

Schiphol Group is not unfamiliar with the guiding role. The company and the airport in general form a central point within the governmental and business environment, both regional and national. This entails an exemplary function, also as it comes to the integration of electric cars in daily businesses. Companies in the airport region, municipalities and the provincial government are eager to cooperate to introduce electric cars and increase knowledge. By this means, projects at the airport can also stimulate and accelerate the general introduction of electric cars in the Netherlands. However, currently there seems to be doubt about the role of the airport and the involvement and alignment of internal departments. It seems wise to carefully consider – at a high level in the organization – Schiphol Group's role in the uptake of sustainable transport alternatives in general. After this, the internal organization can be constructively aligned to match the intended role.

Cooperation

But cooperation can be interesting for more reasons. First, it can help to reduce financial risks if high investments (for instance for chargers and the electric grid) and potential loss of margins are shared. Furthermore, cooperation effectuates the sharing of knowledge and experience while it reduces the distance between suppliers and users of electric car services. Realizing projects through partnerships within the Amsterdam Airport Corridor can strengthen the region´s brand. And finally, constructive cooperation with governments helps to secure the airport´s license to operate and grow.

Given the central role of the airport and its operator, it is recommended that cooperative structures and potential advantages are actively pursued. Attention should be given to arrangements for project ownership, sharing of costs and benefits and the utilization of project elements. If cooperation can be achieved at a higher level it is conceivable that even the electrification of rental cars becomes a feasible alternative.

Dealing with uncertainties and risks

The research presents different uncertainties and consequential risks that relate to possible investments in electric cars. It is important to acknowledge these uncertainties and risks and build in systems to optimally deal with them.

Technology independency

In this regard it seems unwise to rely too much on a single technical solution for sustainable transport. If projects are gradually extended in size and number there can be benefited from learning effects. Therefore, it is important to keep track of technology improvements. Each separate project requires the reconsideration of the latest available technical alternatives while there must be left possibilities for their implementation. This may for instance also result in the re-introduction of diesel technology – not inconceivable given the fact that also this technology is rapidly improving.

High investments entail high risks and are therefore not recommended. Maintaining a gradual uptake of innovative technology until it has fully proven itself can prevent large setbacks. This does not mean that there cannot be made challenging choices. Decisions should be properly argued while admitting possible negative consequences. Meanwhile, Schiphol Group can co-investigate improvements and take its responsibility where possible. Concerning the latter, there can for instance be thought of local sustainable energy production to power electric cars and the recycling of used batteries. If choices are properly argued, reliable fall back options are available and there are no strong thresholds to turn back decisions, the damage of choices that turn out badly can be minimized.

Involvement of service providers and customers

Schiphol Group is not a transport service company. After the possible execution of a project, close contact with the service providers and their customers is necessary to be able to take into account practical experiences, complaints and recommendations for improvements. Service providers should to be actively involved in the designing phase of services and continuous improvement processes of products and services. This way the adaptation and acceptance of new technologies and services can be maximized.

Part of the greater good

Schiphol Group wants to become Europe´s preferred airport while it retains its license to operate and growth. Sustainability – in its broadest sense – is only part of necessary pathways to achieve this. The 'visit value' of the airport as well as 'top connectivity' contribute in a similar way to the highest goal. Emissions related to traffic and transportation are only one concern within the environmental aspect of sustainability issues at the airport. The research presents four principles for mitigating measures. Electric cars relate to the second type of measure: 'use energy and fuel as efficient as possible'. However, there are also alternative projects that relate to reduced use of energy and fuel, the use of sustainable energy and fuel and measures to compensate remaining emissions.

Initially the use of electric cars only marginally contribute to the greater good of sustainability and the airport's preference. In the first place electric car projects will have to be weighed against alternatives for sustainable transportation and energy production. In its turn, the set of sustainability improvements will have to be weighed against other improvements that influence the preference of the airport. Internal decisions on the balancing of the total set of projects relate to the effectiveness of alternatives on the realization of the highest goals of Schiphol Group and on possible pressure from external parties. Thereby, it is important to keep track of developments on all fronts, and spread the risks of investments by diversifying the set of measures. There can also be looked for opportunities to combine projects and profit from synergy effects. In combination with smart grids electric cars can for instance contribute to the feasibility of sustainable local energy production. This type of energy production is quite erratic. If the energy is stored in the car's batteries, it can be evenly delivered to the grid. Electric cars parked at the airport can also help to secure the energy delivery during peak demands.

Future model use

The Excel models used for the analysis of the alternatives can be adopted by Schiphol Group for future use. The effects of the use of electric cars are estimated on the basis of information currently available. It is made clear that results are subject to uncertainties, which lead to investment risks. A continuation of research at Schiphol Group on the alternatives for the introduction of the electric drive train will lead to increased knowledge and a decrease of uncertainties and risks. Also other projects and research in knowledge institutes can be used as a reference for the projects at the airport. To integrate new insights in the calculation models, continuous adaptations are needed. These can concern factor values and relations. It is also possible that uncertainties fade and related scenarios can be left out of the analysis. Likewise, new dependencies can pop up, leading to inclusion of new scenarios if covered with uncertainty.

There are also multiple known uncertainties that are not taken into account. For instance the development of transport demand, both for flights as for transport to and from the airport. This demand can decrease, but there can also occur shifts in the modality mix away from car usage. High investments in car based transport services can form a risk. These risks are not too high in the proposed projects as the number of cars invested in are relatively low. Also, investments in the car itself are not too risky, as depreciation periods of these cars are quiet short. But for substantial investments in chargers and infrastructure, high level uncertainties that impact the charging demand should be considered.

Another uncertainty left out is the value of CO_2 certificates. Currently, these are quite low, having minimal impact on the presented calculations. But the values can increase as concerns of CO_2 emissions grow. Besides, there can be introduced a market for other transport related emissions.

Robust decisions require continuous assessment of the values used for the input factors of the quantitative model and the inclusion of scenarios to deal with present uncertainties.

7 REFLECTION

Applicability of the used method

The methods used to assess the financial and environmental performance of projects are generally applicable, both within Schiphol Group and other companies. However, for every project there are needed reconsiderations of the assumptions done. There must for instances be decided which uncertainties need to be included in the analysis, and which ones can be left out. Furthermore, there can be made efforts to monetize qualitative advantages – for instance the reduction of emissions – and include them in the financial assessment. This requires that

Additional uncertainties and risks

The analysis only took into account a limited number of uncertainties. The group of uncertain factors and related risks that are not taken into account can be divided into three groups: technical specifications, acceptance and knowledge and innovation. These groups of uncertainties are considered to be interrelated. First, the exact specification and performance of technical systems are uncertain. Related risks are for instance disappointing reliability, range, charging times and grid integration. Second, the electric car is an innovative product. Technology and knowledge develop rapidly. Technology currently used can become obsolete quickly and in the medium term electric drive train technology can be outclasses by other sustainable technology. Intensified research can reveal new insights on the negative impact of the use of electric cars and underlying supply chains. Third, the acceptance of electric cars in general and for specific transport services is uncertain. As there is no experience with the use of cars within services proposed in this research, it is unclear if an adequate service level can be provided. There is a risk of rejection by both service providers and potential customers. This can also occur at a higher level if public opinion turns against electric cars or when the transport market and customer needs change.

This research only roughly studied the uncertain factors to formulate possible scenarios. It is expected that these scenarios provided enough possibilities to assess the impact of uncertainties on the alternative's potential within the conducted research. However, when larger projects are initiated, it might be useful to perform a more substantial scenario analysis. This would also leave room for the inclusion of other uncertainties, like the ones presented above.

Schiphol Group´s role and responsibility

Reflecting on the role of Schiphol Group, there are needed careful considerations about the level of inclusion of internal and external actors. Besides, Schiphol Group should consider for which emissions it wants to take responsibility. It is arguable that it only takes into account the local emissions resulting from transport around the airport. However, the requires the ignorance of emissions related to electricity generation, which seems unwise as well.

Paving the way for new initiatives

There are great opportunities for governmental organizations to pave the way for businesses like Schiphol Group and make it easier to initiate projects related to sustainable transport. Currently, there is high uncertainty about general factors like emissions from electricity generation. Companies can be supported by the provision of clear information on costs and emissions of different alternatives for the introduction of sustainable transport, as well as practical reference projects. Science and governments can help to decrease uncertainties.

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APPENDICES

Appendix A Sources of CO_2 emissions at Schiphol

The table below gives an elaborate overview of different sources for CO_2 emissions at Schiphol. If known, the table indicates the tonnes of CO_2 emission for each of these sources. Besides, if know and relevant, the amount of travel kilometres that is causing the emissions is provided. Finally, for most sources it is presented which projects are formulated within Schiphol Group to reduce the emissions. The table is based on an overview that is composed and managed by Ed Koelemeijer, internal expert of Schiphol Group and manager of the programs 'water' and 'sustainable mobility'.

Table 30: Overview of sources of CO_2 emissions at Schiphol and related mitigating alternatives

Source of CO_2 emissions	CO_2 emission (tonnes)	Kilometres (x1.000)	Leading Projects
Control	**138.686**		
Electricity use AAS	103.724		
Gas use AAS	28.088		
Green energy	-1.226		
Fleet AAS Cars Airside busses	2.745		- CO_2 neutral car fleet including snow fleet and fire cars (electric/bio fuels) - CO_2 neutral bus (electric/bio fuels)
Commuting traffic from workers at Schiphol Group Train Car Motor Scooter	4.214	 7.020 19.970 1.053 1.053	- Tele working - Establish Smart Working Centres - Arrange electric charging alternatives - Agreement municipality of Amsterdam: 10% reduction total car kilometres and an extra 10% reduction during rush hours - Introduction sustainable gross/net cafeteria model - Flexible Mobility pas - Car pooling - Private car plan - ECO_2 parking - Flexible employee transport - Project Pay4Use
Lease cars Schiphol Group	634		CO_2 neutral lease cars
Declared car kilometres Schiphol Group employees	45		
Fire department	452		Fire department trainings
Business trips Schiphol Group per plane	662	1.790	Policy business trips (distance, teleconferencing, train)
Compensation through KLM and Climate Neutral Group	-652		
Freight traffic			Trucks suppliers Schiphol Group
			Organization distribution centre (expedition, transport in small electric trucks)

Source of CO_2 emissions	CO_2 emission (tonnes)	Kilometres (x1.000)	Leading Projects
Guide	**303.752**		
Electricity use third parties	84.641		
Gas use third parties	33.433		
Traffic airside third parties	27.692		Set conditions for vehicles at airside by means of the ecology platform
Commuting traffic from workers at Schiphol Airport Train Car Motor Scooter	106.773	 177.886 506.056 26.683 26.683	- Flexible Mobility pas - Flexible employee transport - Project Pay4Use - Car pooling - ECO_2 parking - Arrange electric charging alternatives - Multi fuel gas station - Agreement State: Schiphol is a pilot environment for new mobility concepts like electric car driving
Use of GPU	45.900		

Schiphol Sternet	3.111		
Schiphol Zuidtangent	2.108		
Connexxion			
NS			- Primary train infra: SAAL project (SPL, Adam, Almere, Lelystad) - Optimizing timetables and product development
Infrastructure at Schiphol Airport			
Infrastructure around Schiphol Airport			- High Quality Public Transport East - Public transport infrastructure - Infrastructure road network
Taxi's			Sustainable taxi's (electric/bio fuels)
Waste transport	94		
Freight traffic			Trucks suppliers concessionaries and tenants

Source of CO_2 emissions	**CO_2 emission (tonnes)**	**Kilometres (x1.000)**	**Leading Projects**
Influence	**822.980**		
LTO cycle	617.000		Landing procedure
Mobility OD passengers	177.169		- CO_2 neutral parking - Discourage drop off and pick up - Travel advice to Schiphol including CO_2 advise - ECO_2 parking travellers - Arrange electric charging alternatives
Freight traffic	18.606	26.280	- Freight traffic for aviation - Amsterdam Connecting trade
Others	10.205		

Appendix B Traffic and transportation related measures of Schiphol Group

The overview below shows measures that are formulated by Schiphol Group to reduce CO_2 emissions related to traffic and transportation on and around Schiphol. The measures are retrieved from Schiphol Group's policy document 'Vision Sustainable Mobility' (Schiphol Group, 2009). There is made a distinction between four different categories:

1. Travel behaviour
2. Infrastructure and public transport availability
3. Spatial and transport concepts
4. Source measures

For each measure it is indicated which principle for mitigation is followed[7], what the level of responsibility for Schiphol Group is[8], and in which term the project should be realized.

Table 31: Overview of traffic and transportation related at Schiphol (Schiphol Group, 2009)

		Measure	Mitigation principle	Level of responsibility[9]	Term
Travel behaviour	1	Flexible and home working	Reduction	C/G/I	<5 years
	2	Differentiate parking costs and communicate this	Reduction	C/G/I	<5 years
	3	Stimulate self parking instead of bring and pick-up	Reduction	C/G/I	<5 years
	4	Introduce mobility budget	Reduction	C/G/I	<5 years
	5	Give financial incentives to avoid rush hours	Reduction	C/G/I	<5 years
	6	Stimulate carpooling	Reduction	C/G/I	<5 years
	7	Offer multimodal subscriptions	Reduction	C/G/I	<5 years
	8	NS Business card along with lease car	Reduction	C/G/I	<5 years
	9	Sign agreement for accessibility	Reduction	C/G/I	<5 years
Infrastructure and public transport availability	10	Expand Zuidtangent network	Reduction	G/I	<10 years
	11	Expand Sternet network in 15-30 km zone	Reduction	G/I	<10 years
	12	Improve connection between public transport infra and road infra		G/I	>10 years
	13	Improve connection between public transport modes		G/I	>10 years
	14	Deltalijn: upgrade existing rail connection to the east	Reduction	G/I	>10 years
	15	Divert A9 at Badhoevedorp		G/I	>10 years
	16	Parallel road system next to A4		G/I	>10 years
Spatial and transport concepts	17	Transfer City	Reduction	C	<10 years
	18	Transport City			
	19	Connect work locations within the Airport Corridor			
	20	Regional rail track North Wing	Reduction	G/I	>10 years
	21	Front ports	Reduction	G/I	>10 years
Source measures	22	ABC policy lease cars	Sustainability	C/G/I	<5 years
	23	Establish low emission zone	Sustainability	C	<5 years
	24	Lower maximum speed at A4	Efficiency	G/I	<5 years
	25	Use bio fuels	Sustainability	C/G/I	<5 years
	26	Electrify platform traffic	Sustainability	C	<5 years
	27	Increase sustainability public transport kilometres	Sustainability	C/G/I	<5 years

[7] Principles for mitigation are reduction, efficiency, sustainability and compensation. More information about these principles is provided in Chapter 3.

[8] Schiphol Group distinguishes between three levels to define its responsibility for mitigating measures: control, guide and influence. More information on these levels is provided in Chapter 3.

[9] C=Control, G=Guide, I=Influence

Appendix C Passenger cars classified by fuel type and reference class

The overview below presents the distribution of passenger cars in the Netherlands. There is made a distinction between 7 different fuel types. For each fuel type the number of cars owned by natural and legal persons is given. The table indicates the development from 2007 to 2010. The number of hybrid cars shows an increase. There is also a growing amount of full electric cars, however still in very small numbers.

Table 32: Overview of passenger cars in the Netherlands classified by fuel type and reference class (RDW/CBS, 2011)

		2010	2009	2008	2007
Gasoline	Natural person	5.655.001	5.582.083	5.489.592	5.411.962
	Legal person	415.431	429.862	415.689	398.836
	Total	6.070.432	6.011.945	5.905.281	5.810.798
Diesel	Natural person	874.115	831.920	818.891	786.336
	Legal person	415.429	445.208	432.191	397.964
	Total	1.289.544	1.277.128	1.251.082	1.184.300
Lpg	Natural person	203.772	208.352	202.523	204.039
	Legal person	18.365	21.202	21.543	23.252
	Total	222.137	229.554	224.066	227.291
Hybrid	Natural person	15.972	10.937	7.710	5.398
	Legal person	23.350	12.307	3.492	2.201
	Total	39.322	23.244	11.202	7.599
Cng	Natural person	108	57	29	17
	Legal person	434	259	149	90
	Total	542	316	178	107
Full electric	Natural person	139	104	66	50
	Legal person	124	39	27	31
	Total	263	143	93	81
Other	Natural person	62	1	1	2
	Legal person	51	-	-	-
	Total	113	1	1	2
Total	Natural person	6.749.169	6.633.454	6.518.812	6.407.804
	Legal person	873.184	908.877	873.091	822.374
	Total	7.622.353	7.542.331	7.391.903	7.230.178

Appendix D Electric car availability

The overview in Appendix C indicates that the number of electric cars is currently very low. However, while the number of introduced car models is increasing and the required charging infrastructure becomes better accessible, it is expected that the uptake will increase. The national government aims for 200.000 battery electric cars in 2020, which is 2-3% of the total car fleet in the Netherlands.

Currently, electric cars can be acquired in two ways: at a refit centre or via a full service providers. At refit centres, original cars (with a gasoline or diesel engine) are converted to an electric car. This is a costly procedure, getting more interesting as the number of converted cars increase.

Electric cars from original car manufacturers are not yet available at central car dealer. Currently the cars from for instance Nissan and Renault are made available through third parties offering full services: a lease car, charging alternatives, maintenance, guarantees, et cetera.

Through these supply channels several cars are already available, while there are multiple expected models. The electric car that resembles the usual cars most is the Nissan LEAF. For this reason, its specifications are used for this research. The overview below presents the present supply channels and available electric car models.

Table 33: Overview of electric car dealers and available models

Refit centres	
All Green Vehicles (AGV)	www.allgreenvehicles.nl. Electric car manufacturer and refit of several models. Distributor of Toyota Prius Plug in and electric TukTuk. Multiple dealers throughout the country.
Electric Cars Europe (ECE)	www.ececars.nl. Refit of VW Golf, Lotus Elise and Citroen E-C1.

Full service providers	
The New Motion	www.thenewmotion.nl
Mister Green	www.mistergreen.nl

Introduced models	
Tesla Roadster	www.teslamotors.com/roadster
Think City	www.thinkev.com
Tazzari	www.tazzari-zero.com
Nissan LEAF	www.nissan.nl/leaf
Mitsubishi iMiEV	www.mitsubishi-motors.com/special/ev
Peugeot iOn	www.peugeot.nl/minisite/ion/5-deurs
Citroen C-ZERO	www.c-zero.citroen.com

Expected electric car models	
Fisker Karma	www.fiskerautomotive.com
Renault ZE Kangoo	www.renault-ze.com
Renault ZE Fluence	www.renault-ze.com
Tesla Model S	www.teslamotors.com/models
BYD F3DM	www.byd.com/showroom.php?car=f3dm

Hybrids and electric cars with a range extender	
Toyota Prius Plug-In Hybrid	www.toyota.nl/cars/new_cars/prius/index.aspx
Opel Ampera	www.opel.nl/ampera

Appendix E Stakeholders

This appendix gives an overview of the companies that were involved in the research project. The first table, Table 34, gives an overview of the stakeholders that were involved and consulted the most. The next Appendix also indicates the experts from these companies that were contacted.

Following,

Table 35 presents a broader set of external stakeholders. All are important players in the region of Schiphol as it comes to electric mobility. During the research project there were moments of contact with representatives of the mentioned companies, however at a lower level.

In both tables there is made a distinction between different stakeholder groups. The division is made for reasons of clarity, there are no related consequences. However, it is important to mention that the cooperative and contractual structures existing with the concessionaries should carefully be taken into account. There are certain legal agreements that cannot be ignored.

The stakeholders are divided over the following groups:

- Fleet owners
- Suppliers
- Knowledge institutes and service providers
- Potential users

The second table adds the governments that are involved.

The presented stakeholders can be of importance during further research or initiatives of Schiphol Group in the field of electric mobility in general or electric cars in particular. As indicated earlier in the main document, co-operative structures can increase the feasibility of electric mobility. Schiphol Group needs to consider the companies it wants to work with and to which extend cooperation should be realized.

Table 34: Stakeholders that are closely involved in the research project

Fleet owners	
For this research there has been close contact with experts of Connexxion, BIOS-groep, TCA and Avis Budget Group to discuss the possibilities of electric car introduction within the markets related to these companies. These companies are labeled the fleet owners. Effective changes are more likely to be realized cooperating with large fleet owners, as opposed to individual car owners (which needed to encourage rigorous improvements in commuting traffic).	
Connexxion	*Company description* Connexxion is a public transport company owned by Trandev; one of the biggest private passenger transport companies in Europe operating on a global scale (Transdev, 2007). Connexxion provides public transport services on city and regional levels by bus, tram, train and shared taxi. The company also operates private transport services like taxi services, ambulance operations and group tours. Finally the company operates public transport by boat (Connexxion, 2011). *Project involvement* Connexxion is one of the two concessionaries at Schiphol to operate the street taxi services. The company also operates the Schiphol Travel Taxi (Schiphol Group, 2011g) that is a joint initiative of both Connexxion and Schiphol Group. Being a concessionary, Connexxion is one of the first parties to discuss possibilities to improve the sustainability of the taxi products at Schiphol.
BIOS-groep	*Company description* BIOS-groep is a provider of particularly passenger transport services, but since its concession at Schiphol it also operates street taxi services. BIOS-groep is one of the bigger passenger transport companies in the Netherlands. *Project involvement* Together with Connexxion, BIOS-groep operates the street taxi service at Schiphol as it holds the concession since

	2009. Like Connexxion, BIOS-groep is one of the parties to discuss the possibilities to improve the sustainability of the taxi products at the airport.
Prestige Taxicentrale and Prestige Green-Cab	*Company description* Prestige Taxicentrale is a passenger transport company with its basis in Utrecht. It is one of the first taxi companies aiming for a complete 'green' car fleet. The company operates a series of cars on biogas and just launched the operation of the first electric taxis in the Netherlands. This project is done in a big consortium involving companies from the whole chain of electric car operations (from grid operators and energy suppliers to governmental organizations and car manufacturers). The electric car service is labelled Prestige GreenCab. *Project involvement* The introduction of the GreenCab service forms a good example of collaboration between the right commercial and governmental parties to realize the successful use of electric cars. The project evolvement should be followed carefully as it gives useful references for projects at the airport.
TCA	*Company description* TCA is the biggest taxi company in the Netherlands (TCA, 2010); a reason in itself to contact the company to get an idea of developments in the taxi market. Bas Vos – former director of TCA (Berkeljon, 2006) and currently, among others, chairman of the supervisory board of Corio N.V. (Reuters, 2011) – is planning the introduction of a series of electric London Cabs to drive in Amsterdam under the name of TCA (Bom, 2011; Pedro, 2009). The first electric taxi cab is planned to start operations in April 2011. *Project involvement* As TCA is not a concessionary at Schiphol and does not have full electric cars operational so far, their involvement in this research project is rather small. However, the developments regarding this alternative should be carefully followed.
Avis Budget Group	*Company description* The Avis Budget Group operates two of the most recognized brands in the global vehicle rental industry; Avis and Budget (Avis Budget Group, 2011). Avis was founded in 1946 by Warren Avis Willow Run in Detroit and therewith the first car rental operation located at an airport (Avis, 2011). In 2001 and 2002 the original companies of Avis and Budget were bought by Cendant Corporation – a provider of business and consumer services, primarily within Real Estate and travel industries – but in 2006 Cendant splits into four businesses of which one the Avis Budget Group. Having multiple offices the Avis Budget Group is widely spread throughout the Netherlands. Both subsidiaries also operate services at Schiphol Airport, next to Europcar, Hertz, National Car Rental and Sixt (Schiphol Group, 2011b). *Project involvement* Like the taxi companies, it is very relevant to consult the rental companies to have an idea on their intentions to improve the sustainability of the car fleet. Consultations during this research project made clear that Avis Budget Group is very interested in close cooperation to evaluate the introduction of electric cars as rentals.

Suppliers	
Within the group of suppliers, the companies that provide certain infrastructure to operate new services are placed. There can be made a distinction between car manufacturers, suppliers of electrical infrastructure and electricity (incl. battery producers) and service companies providing new services for electric car drivers. This research did not involve companies from the total range. The most important ones being involved are mentioned below.	
Epyon	*Company description* Epyon is leading company in Europe in the development and production of electric vehicle fast charging systems (Epyon power, 2011a). The company develops, markets and sells battery-charging products and services for optimized fast charging of electrical vehicle batteries. Epyon operates on a world wide scale. *Project involvement* Schiphol Group already has close contact with Epyon about the possible delivery of fast charging systems. The information retrieved from the company is used as data for this research. The products of Epyon are taken into account while evaluating charging alternatives.
Imtech	*Company description* Imtech is a globally operating technological expert. The company offers services within the entire chain of technology development; from consultancy and design, to implementation, maintenance and management (Imtech,

	2011). *Project involvement* Imtech is a partner of theGROUNDS and therewith an important source for technical expertise and applications. Concerning electric vehicles their main focus is on the development of charging infrastructure and smart grids. Imtech is partner of the 'Smart Energy Collective', the biggest cooperative initiative for the development of smart energy services and grids (Stenus, 2010).
Siemens	*Company description* "Siemens is a global market leader with innovative solutions for energy, industry and healthcare and the most comprehensive environmental portfolio worldwide" (Siemens, 2011). Siemens believes the future is 'electro mobility'. The company researches smart grid solutions to fuel electric cars and make use of the energy storage potential in electric vehicles. The company believes that no new power plants are needed as the storage capacity of electric cars can be used to flatten peak energy demands (Siemens, 2010). *Project involvement* It is believed that most knowledge on new innovations can be found at research and development departments of leading companies. This information becomes (partly) available as Siemens is very willing to cooperate on multiple levels of research.
ProRail	*Company description* ProRail is responsible for the construction, maintenance, management and safety of the rail network in the Netherlands. The company is constantly working on the optimization of the rail network contributing to the accessibility of the Netherlands (ProRail, 2011). Part of the rail infrastructure comprises the masts and contact lines that 'fuel' trains during their trip. The high voltage electric infrastructure of ProRail is an important asset. It can be used to power vehicles other then trains that are present at the railway stations. The overcapacity on the electrical grid during night and between peak hours can be used to charge bikes and scooters in bicycle parking facilities at the stations, electric cars at P+R sites and taxis and busses arriving and departing the station (OV Magazine, 2010). *Project involvement* The presence of ProRail at Schiphol station and their initiatives in charging electric vehicles make it an interesting player to talk with. ProRail did a pilot with Connexxion at Utrecht CS to charge a bus with induction technique (Bolier, 2010) and worked together with Conductix Wampfler to improve inductive charging infrastructure. This company has technical expertise in the field of Inductive Power Transfer (IPT) (Conductix-Wampfler, 2011c), a technology that can be interesting to follow for solutions at Schiphol.

Knowledge institutes and service providers	
Within the market of electric vehicles there are arising multiple initiatives relating to the development and collection of knowledge. During this research project, there has been specific contact with D-Incert (an innovation centre from the three technical universities in the Netherlands), APPM (a consultant with – among others – a focus on electric cars) and The New Motion (a provider of a wide range of services related to electric cars).	
D-Incert	*Company description* The Dutch Innovation Centre for Electric Road Transport has been founded in 2008 by 3TU, HRo (Rotterdam) and HAN (Arnhem/Nijmegen). Since then several strategic innovation partners joined the network organization. D-Incert aims to connect, scientific research, technological innovation and education regarding the transition to electric road transport in the Netherlands. *Project involvement* Stephan van Dijk, PhD and Program manager at D-Incert is closely involved at theGROUNDS and the Mainport Innovation Fund representing the TU Delft. He is able to evaluate the technical parts of the research, and gave information on the latest developments at D-Incert. Besides, there has been a joint research between TU Delft and theGROUNDS about a scenario for the integration of electric mobility into the built environment at Schiphol Airport (Silvester et al., 2010).
APPM	*Company description* APPM is a management consultant focussing on the spatial development of cities and countryside, mobility and accessibility and sustainability (APPM, 2011a). For several municipalities APPM performed research and executed projects in order to come to balance decisions and/or the implementation of electric mobility infrastructure (APPM, 2011b).

	Project involvement APPM is already involved in several different projects at Schiphol. Also for electric mobility they feel there are opportunities, as the airport forms an interesting experimental project environment with a lot of exposure. The knowledge of APPM in the field of electric mobility and their hand-on mentality form interesting assets for the-GROUNDS and Schiphol Group.
The New Motion	*Company description* The New Motion is a Mobility Service Provider in the field of electric mobility that offers products and services aiming for sustainable mobility. It offers a platform for (potential) users of electric cars to share knowledge and experience (The New Motion, 2010). The New Motion started project in Amsterdam but already spread out to the rest of the Netherlands. The company is a subsidiary of Tendris (Tendris, 2011). *Project involvement* The New Motion is broadly integrated in initiatives concerning electric mobility in the Netherlands. There is a lot of practical knowledge available at the company, which aims to approach electric cars as a business opportunity and an attractive product for young and conscious people. At most events that were visited The New Motion was present and there were many informal contact moments.

Potential users	
While a sustainable alternative for existing transport services is developed, it is important to actively involve the projected user to reach maximal potential of the service. Current activities around sustainable mobility lack this involvement, making projects incoherent and ineffective (Smeets, 2009). By using Schiphol Group's research and available literature, a user profile could be developed. Furthermore, there was contact with companies within the Amsterdam Airport Corridor. A company can be considered a group of users, however this group will make different consideration compared to an individual. The most important company that was involved is ABN AMRO.	
ABN AMRO	*Company description* The current entity ABN AMRO Bank N.V. is a judicial merger between ABM AMRO Bank N.V. and Fortis Bank Nederland. The bank combination offers three business units: Personal Banking, Private Banking and Commercial & Merchant Banking (ABN AMRO, 2011). Within the business unit Special Projects, ABN AMRO is enlarging its knowledge about a diverse set of subjects among which sustainable mobility and electric cars. Sander Schuurman is Vice President Special Projects and focuses on the promotion of electric vehicles, in particular at Zuidas. ABN AMRO already operates two electric vehicles, and currently a car sharing project is being realized for more companies at Zuidas. *Project involvement* Sander Schuurman is the first man of ABN AMRO if it concerns electric mobility. He did a presentation on the car sharing project at Zuidas during the PEM (RAI Vereniging, 2011) meeting at the Ecomobiel fair in Rotterdam. As described in the main text, the relation with Zuidas is very important for Schiphol Group, so contact was made with ABN AMRO to work together on plans concerning electric mobility.

Table 35: External stakeholders

Fleet owners		
Connexxion	Taxi services	Concessionary of the street taxi
BIOS-groep	Taxi services	Concessionary of the street taxi
Prestige Taxi	Taxi services	Electric taxi project in Utrecht
Bas Vos		Former director TCA, introduces electric London cabs in Amsterdam
Avis Budget Group	Car rental	

Suppliers

Renault-Nissan	Electric cars	Nissan LEAF, Renault ZE series
CT&T	Electric cars	Small electric city cars, Korean company
ECE	Car refit	VW Golf, Citroen e-C1, Lotus Elise
AGV	Car refit	Toyota Prius Plug-In, Spirra
Epyon	Chargers	Fast charging technology
E-lixer	Chargers	
Imtech	Infrastructure	Contact: Wiebe Emsbroek. One of the partners of theGROUNDS.
Siemens	Infrastructure	Contacts: Jaap Bolhuis, Jan Langedijk. Interested in cooperation to realize Smart Grids.
Schneider Electric	Infrastructure	
Essent	Electricity	
De Meerlanden	Green energy	Energy production from waste incineration
Better Place	All-round	Represented by DHV in the Netherlands. Developed battery switch stations and chargers. Globally active.

Knowledge institutes and service providers		
APPM	Consultant	Contacts: Tim van Beek, Floris de Groot, Mark van Kerkhof
DC-TEC	Business cooperation	Dutch Consortium for the Tender of Electric Cars
DOET	Industry association	Dutch Organization for Electric Transport
RAI	Industry association	Association for car industry
D-Incert	University cooperation	Dutch Innovation Centre for Electric Road Transport
TU Delft	Knowledge and service	Contact: Stephan van Dijk. One of the partners of theGROUNDS.
Mister Green	Knowledge and service	
The New Motion	Knowledge and service	Full range service for electric driving.
REGGS	Consultant	Contact: Jop Timmers. Creative company having ideas on electric mobility and the future personalization of cars and private transport services. Involved in the Professional Passionates Rally
Goudappel Coffeng	Consultant	Data on transport movements in the corridor. Useful to verify data of Schiphol Group's continuous passenger research.
Syntens	Consultant	Contact: Vincent Wouters. Organized an electric mobility event in cooperation with TNO.

Potential users		
HMS Host	G5 Schiphol Group	
ABN AMRO	G5 Corridor	Contacts: Annemarie van Doorn (Smart Work Centres), Sander Schuurman (Electric Mobility)
ING	G5 Corridor	Contact: Dirk Jan van Swaay
IBM	G5 Corridor	
Dorint Hotel	Hotel company	Located at Schiphol Oost. Operates hotel bus from Schiphol Plaza. Installed several chargers at hotel. Contact via Denise Pronk (Schiphol Group).
Okura Hotel	Hotel company	Located in the centre of Amsterdam. Operates hotel bus from Schiphol Plaza. Contact via Denise Pronk (Schiphol Group).

Governments

Municipality of Amsterdam Amsterdam Electric Dienst Zuidas Amsterdam	Local Government Project program Municipal department	Eric van den Burg – Alderman of Amsterdam
Municipality of Haarlemmermeer	Local Government	Schiphol is located in the municipality of Haarlemmermeer
Province of North-Holland	Provincial Government	Schiphol is located in the province of North-Holland
Formule E-team	Government	Supporting organization to bring together different companies related to electric mobility and speed up processes. www.nlmilieuenleefomgeving.nl/formuleeteam

Appendix F Internal expert interviews

Internal experts Schiphol Group

Within Schiphol Group several persons were identified as being relevant to interview for this research. Their relevance has different origins: the knowledge of the person, its responsibilities and experience at the airport or its decision-making authority within Schiphol Group. First of all, the interviews were set up to gain insights in the roles and relations that have to do with projects concerning sustainable mobility in general or electric mobility in particular. Second, information could be retrieved from projects that were already executed at Schiphol Group and relate more or less to this research. This prevented overlap between different projects and exposed interesting insights and knowledge gaps. Finally, via the person interviewed interesting contacts within and outside the organization were identified and used to strengthen the basis for this research even more. In the end a good impression on the most important responsibilities and supporting departments could be formulated. Below an overview of the interviewees is provided. For each person its department and function is indicated, as well as the date of the first interviews. In most cases there were multiple follow-up meetings:

Table 36: Interviewed experts of Schiphol Group

Name	Department	Function	Date
Peter van den Brink	Analysis, Development and Innovation	Senior Advisor	19 October 2010
Maarten de Groof	Board of Directors	Chief Commercial Officer	14 October 2010
Corine den Hamer	Real Estate Development	Development Manager	13 October 2010
Roel Huinink	Parking and Mobility Services	Senior Manager	12 October 2010
Ferry Jongkind	Traffic and Transportation	Product Manager Taxis	30 September 2010
Ed Koelemeijer	Asset Management	Program Manager Sustainable Mobility	18 October 2010
Sjoerd de Lange	Traffic and Transportation	Advisor Airport Development and Innovation	20 October 2010
Hans Martens	Market Research and Intelligence	Manager Market Research	12 October 2010
Birgit Otto	Asset Management	Director	2 November 2010
Olaf van Reeden	Traffic and Transportation	Manager Accessibility	25 October 2010
Maurits Schaafsma	Airport Development	Senior Advisor	18 October 2010
Joost Wagemakers	Airport Development	Senior Advisor	12 October 2010
Richard Versteegh	Asset Management	Manager Energy and Environment	NA

Appendix G Electric mobility events

During the period of the research project there were multiple relevant events that were attended to gain extra information and deepen the knowledge on the topic. An overview of these events is given below:

Table 37: Attended events during research period

Name	Location	Date
Mobility Lab	ABN AMRO – Zuidas Amsterdam	26 August 2010
Amsterdam Duurzaam	Westergas Fabriek – Amsterdam	17 September 2010
Ecomobiel Beurs	Van Nelle fabriek – Rotterdam	21 September 2010
Elsevier Technologiedebat: De elektrische auto	Campus Den Haag	27 September 201
Electric Mobility Lab	TheGROUNDS – Schiphol	16 November 2010
Prestige GreenCab Launching event	Utrecht	19 January 2011

For the purpose of the research, there was organized one event – the Electric Mobility Lab – at theGROUNDS on 16 November 2011. From each of the stakeholder groups (Appendix E) there were invited multiple representatives. The initiatives of Schiphol Group concerning electric mobility were presented as well as the initial findings of this research project. Furthermore, there were given presentations on electric mobility related projects by experts from Siemens, ABN AMRO, Prestige GreenCab and the municipality of Amsterdam. After the presentations there was held a workshop in small groups on different topics relevant for this research.