ANALYSIS OF (INTER)NATIONAL ELECTRIC VEHICLE PROJECTS

KEY FACTORS UNDERLYING SUCCESS AND FAILURE

Assignment: Evaluation Living lab Hybrid and Electric Vehicles

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List of Terms and Abbreviations

Term	Description
EV	Electric Vehicle
Co-EV	Commercial Electric Vehicle
BEV	(Full) Battery Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
Pa-EV	Passenger Electric Vehicle
PHEV	Plug in Hybrid Vehicle
WP	Working Package

List of Contents

1. Samenvatting

Voor u ligt een onderzoek naar de evaluatie van het programma 'Living lab Hybrid and Electric Vehicles' aangevuld met de laatste inzichten op basis van een studie naar (inter-)nationale EV-projecten en innovatieve ontwikkeling. Het doel van deze studie is om de impact factoren of belangrijke factoren te identificeren en te evalueren die samenhangen met de mate van aanvaarding van elektrische mobiliteit in zowel het personenvervoer (Pa-EV) en het zakelijk vervoer (Co-EV).

Om een antwoord op deze vraag te krijgen zijn de volgende activiteiten uitgevoerd:

- Het bepalen van de technische, financiële en sociale *Key Factors* die samenhangen met het succes of falen van EV-projecten in specifieke business cases;
- Literatuurstudie, interviews en bestudering van evaluaties van projecten;
- Vaststellen van eventueel verstorende elementen in de gevonden relatie tussen resultaten van het project en de belangrijkste factoren die successen of falen bepalen;
- Overzicht van belangrijke mondiale technologische ontwikkeling en nieuwe producten en hun betekenis voor de toekomst van elektrische auto's (bijvoorbeeld: efficiëntie van het opladen van batterijen of infrastructuur).

Voor deze studie zijn kwantitatieve en kwalitatieve onderzoeksmethoden toegepast. De kwantitatieve benadering wordt gebruikt om de Key-Factors te bepalen en van een relatief gewicht te voorzien. Zonder een relatief gewicht aan de factoren te koppelen is het immers onmogelijk om iets over hun relatieve invloed op succes of falen vast te stellen. Literatuuronderzoek en kwalitatieve methoden zijn toegepast op nationale en internationale studies en projecten. In combinatie is in het onderzoek een aantal Key Factors vastgesteld die een belangrijke invloed hebben op de acceptatie en het duurzaam gebruik van elektrische voertuigen voor privé gebruik en het zakelijke verkeer.

Algemene en specifieke conclusies

Algemeen De eerste algemene conclusie die wordt getrokken uit deze analyse van negen verschillende proefprojecten en andere nationale en internationale proefprojecten, is dat al de projecten moeilijk onderling zijn te vergelijken. Elk project heeft zijn eigen dynamiek en omstandigheden. Bijvoorbeeld, het voertuigtype, de methode van implementatie, timing en de project aanpak verschilde aanzienlijk per project. De meest in het oog springende verschillen hebben te maken met de verschillen in de productontwikkelingsfase van de voertuigen. Ten aanzien van de verschillende voertuig segmenten, wordt wel duidelijk dat een cruciaal verschil bestaat in de levenscyclus van de personenauto's (Pa-EV) en bedrijfsvoertuigen (Co-EV) met alle gevolgen voor de storingsgevoeligheid (''kinderziekten''), service en eisen met betrekking voor specifiek gebruik

Ondanks de verschillen zijn er ook overeenkomsten gevonden die leiden naar de volgende specifieke conclusies. Deze overeenkomsten worden gezien als belangrijke factoren die algemene betekenis hebben voor de praktische inzet van elektrische mobiliteit..

Specifiek Er is een duidelijke top drie Key-Factor ranking voor succes of falen. Waar nodig zijn deze factoren specifiek gemaakt voor personenauto's (Pa-EV) en bedrijfsvoertuigen (Co-EV).

Key-factoren die het succes van een proeftuin ondersteunen:

+ Impact & imago:	Een van de belangrijkste stimulerende factoren voor het gebruik van Pa-EV is het positieve imago en de impact op het milieu en de omgeving;
+ Opladen:	Zowel het normale laden als het snel-laden van het elektrisch voertuig wordt als eenvoudig beoordeeld en daarom beschouwd als positief;
+ Comfort:	Het gebruikscomfort van de elektrische auto wordt beschouwd als even of zelfs comfortabeler dan dat van een conventioneel voertuig.

Key-factoren die kunnen leiden tot het falen:

- TCO: Het belangrijkste nadeel voor EV is de hoge inkoopprijs in verhouding tot de totale cost of ownership (TCO). Zonder subsidies is de TCO nog steeds hoger dan die van conventionele voertuigen waardoor het als een dure activiteit wordt beschouwd om gebruik te maken van een elektrisch voertuig.
- Bereik: De angst dat het voertuig te weinig bereik heeft speelt nog immer parten in de afweging ten aanzien van de aanschaf – of gebruik - van een elektrische auto.
- Betrouwbaarheid: Veel pilots werkten met de eerste generatie EV, in sommige gevallen zelfs met prototypes. In menig project bleken de auto's onbetrouwbaar en de service infrastructuur beperkt. Voor de Pa-EV zijn inmiddels de tweede en derde generatie auto's op de markt waardoor deze punten van minder belang lijken te worden; voor de Co-EV is dit nog wel een punt van aandacht.

Discussie achteraf

De initiatiefnemers van de proeftuinen waren meestal pioniers van EV implementatie en ontwikkeling. In die zin is er veel van geleerd. De resultaten hebben bijgedragen aan het besef dat de moderne EV's een serieuze oplossing kan bieden voor de toenemende problemen veroorzaakt door conventionele voertuigen. Onze observatie achteraf is dat de huidige leidende positie van Nederland, de relatief hoge marktpenetratie van EV's en laadinfrastructuur deels te danken zijn aan de focus op proeftuinen.

De EV ontwikkelingen gaan snel maar zijn nog niet volledig ontwikkeld

De vraag is of EV proeftuinen na de bovenbeschreven pioniersfase nog steeds nodig zijn. Sinds de start van de eerste in 2011, zijn de meeste auto's sterk verbeterd en is de publieke oplaadinfrastructuur verbazingwekkend snel uitgerold. Vanuit historisch oogpunt gaan EV ontwikkelingen erg snel, maar tegelijkertijd is ze nog niet volledig ontwikkeld in termen van technologie en de markt potentieel. We zijn nog maar aan het begin van de ontwikkeling van de markt en dat is de reden dat proeftuinen zijn nog steeds nuttig en aantrekkelijk zijn.

Aanbevelingen voor vervolgstappen

1. Proeftuinen in verschillende product-marktcombinaties (PMC's)

Speciaal personenwagens, lichte bedrijfsvoertuigen en stadsbussen, zijn EV producten die al verder ontwikkeld en inmiddels via OEM fabrikanten verkrijgbaar zijn. Echter, de huidige hoge prijs kan nog steeds de aankoop belemmeren of het rendabel gebruik van deze voertuigen voor enkele jaren hinderen. Proeftuinen met deze nieuwe voertuigen en gericht op verschillende PMC's zouden waardevolle gebruikersinformatie opleveren die de acceptatie door de markt kan versnellen.

Voor zware bedrijfsvoertuigen (> 3,5 ton), de haven distributie voertuigen en bussen, is de potentiële EV markt nog steeds gebaseerd op ombouwproducten. Een proeftuin op dit gebied moet worden gericht op het optimaliseren en versnellen van het productieketen in een PMC, zodat verder ontwikkelde professionele OEM-producten op de markt komen. Daarnaast is in deze sector aanpassing van de logistieke keten erg belangrijk.

Harmonisatie van de nationale en vooral lokale subsidies en privileges zijn een punt van zorg. Decentralisatie van het beleid is goed, maar verschillende regelingen beperken de kritische massa in een PMC. Kritische massa is cruciaal voor de professionele productie, ontwikkeling en implementatie van EV's.

2. Proeftuinen moeten worden gekoppeld aan business plannen

Voor elk proefproject, moet vooraf worden bepaald hoe de technische, economische en juridische voorwaarden individueel zullen bijdragen tot een rendabele inzet. Onder deze business voorwaarde en risicoanalyse, moet de proeftuinbijdrage alleen betrekking hebben op de 'onrendabele top' tijdens de proefperiode. Het is ook van belang om de ontwikkeling na de experimentele periode te volgen.

2. Abstract

The following report is an evaluation of the 'Living lab Hybrid and Electric Vehicles' program, which is put in a broader perspective of (inter) national EV projects and development. The purpose of this study is to identify and evaluate the impact factors or Key Factors on the acceptance of electrical mobility in both passenger and business transport. Identification refers to the determination of key factors that play a role in, among others, acceptance, usage, participation and sustainable continuation of EV mobility in their particular economic and social environment. Evaluation refers to the relative weighting that can be contributed to the identified key factors.

To provide an answer to this question the following main activities were commenced:

- Determining technical, financial and social Key Factors underlying success or failure in specific business cases
- Literature study of the available interviews and usage experiences and assessing results
- Determining disturbing or noise-inducing elements in the relationship found between the outcome of the project and the key factors that underlie the successes
- Overview of important global technological and supporting products and their significance for electric cars (for example: efficiency of batteries or charging infrastructure).

For this study quantitative and qualitative research methods have been applied. The quantitative approach is used to study the Netherlands Enterprise Agency pilots by identifying the key *factors*. The data is fairly easy to categorize and analyze. As the key factors were identified, the next step in the process is to have their relative weighting determined. Without having a proper weighting system of the different key factors, it is impossible to conclude anything about their relative impact on success or failure. Furthermore, literature reviews were conducted on additional national and international studies. These reviews brought further refinement to the identified key factors.

General and specific conclusions

General The first general conclusion that is drawn from this analysis of nine different pilot projects and other national and international pilot projects is that such projects are difficult to compare one to one. Each project has had its own dynamics and circumstances. Vehicle type, deployment, timing and approach differed significantly per pilot.

This fact leads us to the following general conclusion that striking similarities have been found. These similarities are seen as Key Factors, which are apparently "generic" for the practical deployment of EVs. Looking at the different vehicles segments, led to the final general conclusion that there is a crucial difference in the development life cycle of the passenger cars (Pa-EV) and commercial vehicles (Co-EV). Although both are young, the Pa-EV is more mature than the Co-EV.

Specific There is a clear top three key-factor ranking underlying success or failure. Where necessary, these factors are broken down by passenger cars (Pa-EV) and commercial vehicles (Co-EV) and explained.

Key-factors that support success:

+ Impact & Image: One of the most significant benefits found for Pa-EV is its positive impact on end-users due to its contribution to a clean and green environment.

+ Charging: Normal and fast charging of the vehicle is regarded as an easy task and is therefore seen as positive.

+ Comfort: User comfort with EV is regarded as equally or more comfortable than conventional driving.

Key-factors that can lead to failure:
- TCO: The most significant drawback for EV is the high purchase price in relation to the total cost of ownership (TCO). Without subsidies TCO is still higher than for conventional vehicles making it less desirable to drive or use an electric vehicle.

- Range: Insufficient range is proposed as an often-found problem and could cause range anxiety by the end-user creating inefficient usage of the vehicle. Efforts should therefore be made to diminish this issue. In this respect, especially battery development has already delivered and is still expected to deliver more improvement in capacity, lifetime and price.

- Reliability: Many pilots worked with the first generation EV available on the market, even prototypes in some cases. Often, these vehicles were unreliable, while service was sometimes slow and poorly organized. For the Pa-EV the second and third generation is on the market now and these issues seem to have been solved.

Discussion in hindsight

The initiators of the pilots were typically pioneers of EV deployment and development. In that sense, a lot was learned. The results contributed to the awareness that modern EVs can offer a serious solution to the increasing problems caused by conventional vehicles. Our observation in hindsight is that the current leading position of the Netherlands, the relatively high market penetration of EVs and charging infrastructure are partly due to the substantial focus on pilots.

The EV developments are moving fast, but are still not fully developed

The question is whether or not EV pilots after the pioneer phase described above are still necessary. Since the start of the first pilot in 2011, most vehicles have greatly improved and the public charging infrastructure has been amazingly quickly rolled out. From a historical point of view, EV developments are going very fast but are at the same time not yet fully developed in terms of technology and market potential. We are only at the beginning of market development and that is why pilots are still useful and attractive.

Recommendations for next steps:

1. *Pilots in different product-market combinations (PMC's)*

Especially for passenger cars, light commercial vehicles and city buses, EV products that have undergone further development are commercially available today. However the current high price may still hinder the purchase or profitable use of these vehicles for some years. Pilots with these new vehicles and aimed at different PMC's would bring valuable user-information which can accelerate the market acceptance.

For particularly heavy commercial vehicles (> 3.5 tons), harbor-distribution vehicles and coaches, the potential EV market is still based on converted products. A pilot in this area should be focused on optimizing and accelerating the product manufacturing chain in a PMC, so that further developed professional OEM products will enter the market. In addition, customization of the logistics chain in the road transport sector is very important.

Harmonization of national and especially local grants and privileges are a concern. Decentralization of policy is good but different regulations are restricting the critical mass in a PMC, which is crucial for professional production development and deployment of the EVs.

2. *Pilots should be linked to business plans*

For each pilot project, it should be predetermined how technical, economic and legal conditions will individually contribute to a profitable deployment. Under this business precondition and a risk assessment, the pilot should only cover the 'financial gap' during the pilot period. It is also of importance to follow the evolution after the experimental period.

3. Introduction

The depletion of fossil fuels, increasing global CO_2 emissions and local air pollution are still growing concerns. Successful implementation of alternative, renewable energy sources and the electrification of the transport sector are essential for the transition to more energy efficient and clean mobility. Electric vehicles (EV) are expected to deliver a great contribution to the sustainability of automotive mobility.

Therefore, the Dutch government decided in 2010 to stimulate this form of road transport by a program called 'Living lab Hybrid and Electric Vehicles', formally in Dutch known as Proeftuinen Hybride en elektrisch rijden'. This program of nine different pilot projects emerged from the National Action Plan for Electric Driving [35].

This plan mentions three important reasons to pursue the electrification of road transport:

1 *Reinforcement of the Dutch Economy (a/o new employment, product development and knowledge)*
2 *Improvement of energy security (road transport is 32% of oil need, and stimulates renewable energy)*
3 *Support for the climate goals by the reduction of CO_2 and improved quality of live in cities by the reduction of pollution (N0x and fine dust) and noise*

In 2013, the pilot program 'Living lab Hybrid and Electric Vehicles' was evaluated mid-term [36]. In 2015 the last reports about pilot projects have been published. More or less in the same period there was also a program called 'Proeftuin innovatieve OV bussen' (Living lab innovative public transport busses). This is a separate program because it concerns public transport only. Seven pilot projects regarding efficient city buses, six of which were hybrid electric, were executed in this program. In addition, these pilots have been completed and the program has already been evaluated. The insights of that evaluation are, where relevant, incorporated in the report [37].

In the meantime, stimulated by tax incentives, the Dutch EV market is developing as one of the leading markets in the world. After Norway, the Netherlands has the highest sales penetration of EVs and to date more than 60,000 plug-in hybrid and full electric vehicles are on the Dutch roads. In addition, the changing infrastructure is a world-class example of interoperability and coverage. Recently, the Dutch Parliament approved a vision on sustainable energy for the whole transport sector. In this vision, electrification plays a leading role in automotive transport, beginning with light and medium weight vehicles but in the longer term including heavy vehicles.

The following report is an evaluation of the 'Living lab Hybrid and Electric Vehicles' program, which is put in a broader perspective of (inter) national EV projects and development. The goal is to determine the key factors underlying success and failure for future activities that support the electrification of road transport.

We wish you an 'electrifying' read.

Dutch-INCERT

3.1 Reading Guide

The document contains all the necessary building blocks for a proper evaluation. This reading guide is meant to signpost the process that led to the conclusions and recommendations and also enable the reader to efficiently choose the particular relevant chapters of interest.

Chapter 1 and 2 provide an abstract with the key findings, in English and Dutch respectively. Chapter 4 (Research assignment) gives the subject as well as the background and major reasons for conducting this study. In research methodology terms, both the ''WHAT'' and ''WHY'' questions are answered. Chapter 5 explains the research method in brief. For further details on this subject, the reader is referred to the appropriate appendix. For this evaluation, both quantitative and qualitative methods are used. In research methodology terms, the ''HOW'' question is addressed. Chapter 6 provides the initial weighted Key Factors that contributed to the results of the 9 Netherlands Enterprise Agency pilot projects. These Key Factors also provide the analytical framework for the continued and elaborated quantitative and qualitative evaluation in the following chapter. Chapter 7 deals with (inter)national electro-mobility projects for passenger and business transport that were not piloted by Netherlands Enterprise Agency. The main goal of this exercise is to explore new findings and perspectives on the results as found in chapter 6. Finally, in chapter 8, the main results of the evaluation are presented ending with a discussion and recommendations in Chapter 9 where the conclusions are drawn.

4. Research Assignment

In 2010, as one of the activities in the National Action Plan for Electric Driving, nine EV project pilots were launched in the Netherlands. Supervision was carried out by the Netherlands Enterprise Agency, who encourage Dutch entrepreneurs in sustainable, agrarian, innovative and international business.

These EV projects are subject to evaluation with the purpose to identify key factors determining success or failure for the introduction of electric mobility in different economic and social environments. In short, the goal and central question will be outlined, as well as the related sub questions (paragraph 4.1). The research questions are dealt with in the work packages (WP) as outlined in paragraph 4.2 to 4.4.

The following nine pilots were involved in the evaluation:

1. **'Elektrische Greenwheels auto's in de G4' – Collect Car (Greenwheels)**

   Twenty-five electric cars, and associated charging infrastructure, were deployed to test a possible introduction of electric vehicles in a car-sharing concept.

2. **'Prestige GreenCab'- Prestige GreenCab**

   Sixteen electric vehicles were deployed by Prestige GreenCab for passenger transport in a variety of sectors (i.e. taxi, school or hospital transport).

3. **'Rotterdam Test Elektrisch Rijden'- Stedin**

   In the city of Rotterdam 75 electric cars were deployed by grid operator Stedin, the municipality of Rotterdam and energy supplier Eneco, with the main focus on learning and monitoring. Pool cars for staff and passenger vehicles for municipal services were deployed and an appropriate infrastructure was implemented.

4. **'Elektrische vuilnisauto's bij Van Gansewinkel Groep'- Van Gansewinkel**

   Development of prototype electrical garbage collection vehicle. Final deployment of eight electric trucks in urban areas for the development of an economical business case of garbage collection, also considering the labor market, waste-to-energy and sustainable innovation.

5. **'Texel Gastvrij Elektrisch Vervoer - Opladen op Texel' - Stichting Urgenda**

   A total of 26 electric cars were purchased, with the goal to introduce electric mobility to the local population and to improve image of the island as holiday destination.

6. **'Elektropool Haaglanden'- Ontwikkelingsmaatschappij Den Haag**

   In The Hague, the consortium deployed eleven electric pool cars. Additionally, one electric van was deployed by a courier company.

7. **'Elektrische stedelijke bezorgservice' – Combipakt**

   Three electric trucks, which was less than the projected amount of 7 trucks, were deployed for urban distribution in the east of the Netherlands.

8. **Urban distribution with Hytrucks**

   In this project, eight medium to heavy electric trucks were deployed for urban distribution. Several different cargo companies joined the project, including food distribution and relocation services.

9. **Express delivery / Courier service 'Fijnmazige stadsdistributie/ pakket-bezorging'- UPS**

   Six electric trucks were used to deliver UPS parcels in the Amsterdam area.

4.1 Background, goal and central question

Conducting research requires a research design. This is the blueprint for how to conduct the evaluation. Selecting the appropriate design and working through and completing a well thought-out logical plan provides a strong foundation for achieving a successful and informative evaluation. To start a research project one of the first items to address is to answer the so-called WHAT and WHY of the research project. The ''WHAT'' is about the data that needs to be gathered to provide the right information for analysis and conclusion; the ''WHY'' provides the context or background and therefore refers to the goal or results to be achieved by the project. The WHY theme is therefore reflected in the background and goals while the WHAT theme is outlined in the central questions and sub-questions.

The purpose of this study is to identify and evaluate the impact factors on the acceptance of electric mobility in both passenger and business transport. Identification refers to the determination of key factors that play a role in, among others, acceptance, usage, participation and sustainable continuation of EV mobility in their particular economic and social environment. Evaluation refers to the relative weighting that can be ascribed to the identified key factors. Evaluation research is a form of applied research intended to have some real-world effect. It is for that reason that the outcome of this research project will provide practical recommendations for the implementation of EV projects.

Goal of the evaluation

> *"Determine the key drivers of success and failure in the pilot projects for electric mobility for different business cases and respective social and economic contexts"*

Central question of the evaluation

> *"What are the parameters of ''key success drivers'' that increase the feasibility and sustainability of new electric mobility projects for different business cases in relevant social and economic contexts?"*

If the goal is met and the central question is answered, then there will be a set of practical data available that basically provides the incentives and inhibitors for organizations that want to initiate electric mobility solutions in their business situation. To be more precise in the identification and evaluation of the key factors, the next sub questions are to be answered.

Sub question 1:

> *"How much are potential users of electric vehicles willing to pay extra for an electric vehicle?"*

Sub question 2:

> *"What is the best market or application for electric vehicles, taking costs and usage into account?"*

Sub question 3:

> *"What are the key factors that determine a growth, stop or decrease in participation in driving electric vehicles?"*

Sub question 4:

> *"What is the most appropriate economic scale for a project based on electric vehicles?"*

Sub question 5:

> *"How can we use the soft factors, for example image or positive stories, that influence the adoption of electric vehicles, to influence the market segments in a positive way?"*

With the research of the nine Netherlands Enterprise Agency projects, the central questions will be answered. The activities needed to answer the research questions focused on gathering experience of and insight into factors determining success or failure of the specific projects are divided and further explained in section 4.2.1 (WP1: determining the key factors). The evaluation of the factors is explained in section 4.2.2 (WP2: evaluation of the key factors). The results on the main questions of the assignment are elaborated upon in section 4.2.3 (WP3: main results, conclusion and recommendations).

4.2 Work packages

To answer the central question and sub-questions, the research has been divided in work packages (WP). In these WP key factors are determined in the nine projects (WP1), evaluation and further fine-tuning of these factors occurs in other national projects and international projects (WP2) and finally conclusions are drawn (WP3). In the following paragraphs the main activities in the WP are presented.

4.2.1 Determination of Key Factors in 9 Netherlands Enterprise Agency projects

The focus of WP 1 is to study the available technical, financial and social data delivered by the 9 EV pilots to identify key factors impacting acceptance and sustainable development of electrical mobility projects. The nine EV pilots are divided into two market segments ''Passenger Electric Vehicles'' (Pa-EV) and ''Commercial Electric Vehicles'' (Co-EV) as shown in Table 4.2.1.1.

Passenger transport – (Pa-EV)		**Cargo transport & urban distribution – (Co-EV)**	
1	Greenwheels – shared car concept	4	Electric garbage trucks by Van Gansewinkel
2	GreenCab – e-Cabs	7	Electric urban delivery by Combipakt
6	Elektropool Haaglanden	8	Electric urban delivery with Hytrucks
3	Rotterdam tests electric driving	9	Meshed urban distribution by UPS
5	Texel hospitable electric transport	3	Rotterdam tests electric driving
		5	Texel hospitable electric transport

Table 4.2.1. Overview of EV Pilots launched under the supervision of Netherlands Enterprise Agency.

The goal of these pilot projects was to gain experience of and insights into the factors influencing the acceptance and development of electric transport in the Netherlands. By evaluating these projects, recommendations regarding the preconditions are given to ensure the success of electric transport . Furthermore, the societal, technical and financial aspects of the experiences of the pilot projects ultimately need to indicate which changes are needed to create a level playing field for large-scale implementation of electric transport in the Netherlands, and possibly also for other countries.

The main question prompted by this specific goal is:

> *"Which key drivers of success and failure can be identified based on insights and experience from the pilot project, and what is their influence on the feasibility of EV business cases?"*

To provide an answer to this question the following main activities were commenced:

- Determining technical, financial and social key factors underlying success or failure in specific business cases.
- Literature study of the available interviews and usage experiences and assessing results, if possible with project management.
- Determining disturbing or noise-inducing elements in the relationship found between the outcome of the project and the key factors underlying success.
- Overview of important technological and supporting products and their significance for electric cars (for example: efficiency of batteries or charging infrastructures).

4.2.2 Evaluation and fine-tuning Key Factors in (inter)national EV projects

To evaluate, adapt and fine tune the initial key factors determined in the 9 projects (WP1), in WP2 additional national and international EV projects were studied. The outcome of this part of the study is (1) a weighted, quantitative score providing the relevance per Key Factor in general and (2) qualitative statements focusing on relevant contextual situations that need to be taken into account to fully understand the quantitative outcome. Part of the research activities in WP2 is a quick scan on the execution of business models other than applied in the 9 Netherlands Enterprise Agency pilots in WP1.

4.2.3 Conclusion and recommendations

In WP 3 a conclusion is drawn on the previous work packages to produce a report that is suitable for international dissemination. It will answer the main question and related sub questions.

5. Research Method

The research method determines HOW the research is conducted. For this research project quantitative and qualitative research methods have been applied. The quantitative approach is used to study the Netherlands Enterprise Agency pilots by identifying the key factors as determined in the 9 Netherlands Enterprise Agency pilot studies. The data is fairly easy to categorize and analyze. As the key factors were identified, the next step in the process is to have their relative weighting determined. Without having a proper weighting system of the different key factors, it is impossible to conclude anything about their relative impact on success or failure. Furthermore, literature reviews were conducted on international studies (WP 2). These reviews further refined the identified key factors. The qualitative approach is used in addition to the quantitative method for two reasons. The first reason is that due to the set-up, status of the project, executional power and timing, especially in business transport where it was impossible to compare the cases; interviewing was therefore the only way to collect relevant data. So interviews were held with people to find out their views and experiences. The method is very suitable for answering the 'WHY' and the 'HOW' questions and getting to the bottom of complex and case-specific issues. The interviews produced rich, insightful information on the cases. However, due to the lack of comparable data, it took a lot of time to collect all the data. The second reason for interviewing project owners and key opinion leaders is to double-check the appropriateness of the determined key factors and to make sure that all relevant topics were addressed in the project.

The key factors as determined in WP 1 have been used to evaluate the cases in WP 2 for as far the quantitative analysis was concerned, especially for passenger transport cases; the extra business transport evaluations in WP 2 were mainly done through interviewing (qualitative method) and relevant literature research. As already stated, the key factors that were found in WP 1 were further developed and fine-tuned through the extended evaluations of the cases in WP 2.

5.1 Method WP1 & WP2

Firstly, the scope of the different projects was assessed to provide a general direction in the method maintained in work package one.

Category	Project	Planned Deployment	Deployed
Pa-EV	Greenwheels	25 Pa-EVs	25 Pa-EVs
Pa-EV	GreenCab	18 Pa-EVs	16 Pa-EVs
Pa-EV	Elektropool Haaglanden	11 Pa-EVs + 1 Co-EV	11 Pa-EVs + 1 Co-EV
Co-EV	Garbage Van Gansewinkel	8 Co-EVs	8 Co-EVs
Co-EV	Distribution Combipakt	7 Co-EVs	3 Co-EV
Co-EV	Distribution Hytrucks	9 Co-EVs	8 Co-EVs
Co-EV	Distribution by UPS	6 Co-EVs	6 Co-EVs
Pa-EV + Co-EV	Rotterdam tests EV	75 Pa-EVs/Co-EVs	34 Pa-EVs + 41 Co-EVs
Pa-EV + Co-EV	Texel hospitable EV	26 Pa-EVs/Co-EVs	17 Pa-EVs + 9 Co-EVs

Table 5.1.1: Overview of projects with the number of EVs planned and actually deployed.

After an initial brief evaluation of the pilots, it appeared that a substantial variety in the set-up, stakeholders, types of vehicle, deployment and maturity was seen. Therefore, it was decided to split the evaluation into a quantitative and a qualitative research component.

5.1.1 Quantitative Method

In this subsection, the quantitative method is outlined, using the establishment of key factors and the formation of a score matrix.

Key Factors

Through an extensive literature search, using the research results available, thirteen (13) key factors were established that are responsible for a successful introduction of electric vehicles in the Dutch pilots. The factors were identified and then categorized by points of improvement and strengths. ”Points of improvement” were further developed to enable a smooth introduction of this type of transport. ”Strengths” are findings that already favor electric vehicles over conventional vehicles and could be further exploited.

Categorization of Key Factors

Each of the thirteen key factors were sub-divided in one of the following categories: social, technological or financial. Due to the relatively broad categorization and scope, it is possible that key factors overlap. The factors and categories are shown in Figure 5.1.1.

A)

Strenghts	Social	Tech	Financial
Charging		1	1
Comfort	1		
Financial			1
Image	1		
PEE	1	1	1
Range	1	1	1

Points of improvement	Social	Tech	Financial
Charging		1	1
Comfort	1		
Cust. Req.		1	1
Financial			1
Range	1	1	1
Regulations	1		1
Reliability		1	1
Service	1		1
Suppliers	1		1
Technology		1	

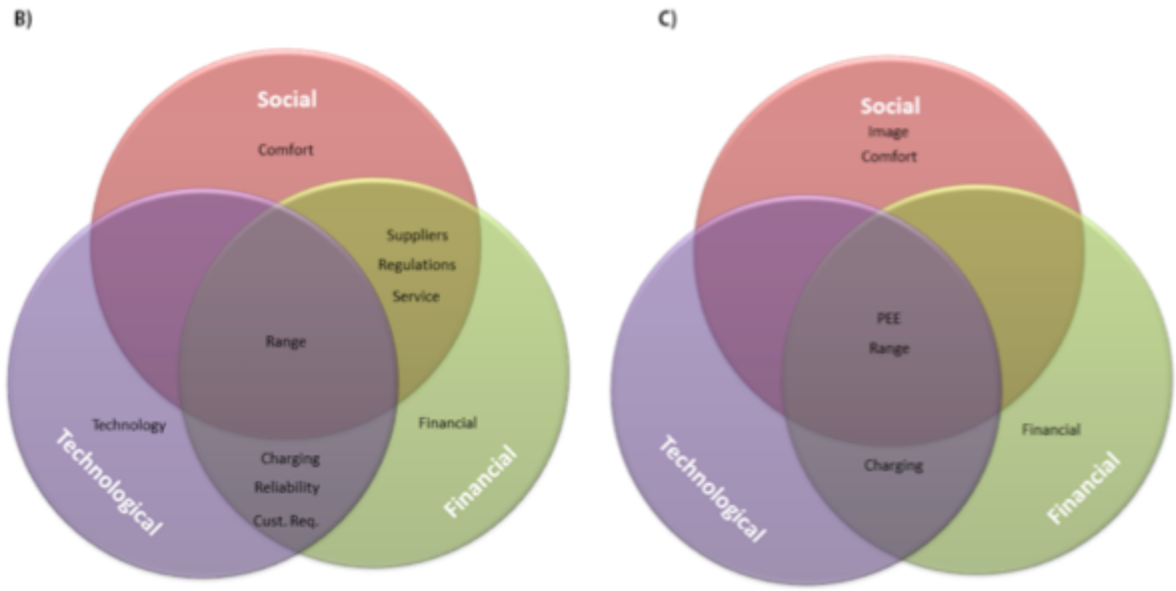

Figure 5.1.1 Categorized factors, left for Passenger EV and right Business EV.

Score matrix

To quantify the results of the individual projects a score matrix is introduced. The score matrix is based on the method of multi-criteria analysis (MCA) [1]. MCA uses multiple decision factors and a specific ranking to help structure decision making. In other words, it can be used to determine the importance or relative weighting of factors in (decision) processes.

The score matrix determines the occurrence and impact of factors per project. The overall scope, as shown in table 5.1.1, shows that large and small projects are considered so a weighting (*W-factor)* is assigned to every project. Using the occurrence, impact and previously introduced W-factor, a score can be computed per project and thus for all the projects. The specific parameters that can be influenced are elaborated upon below.

W-factor The weighting factor addresses the weighting that is given to each project. It is based both on the size (scale: 1-4) and the measurement quality (scale: 1-3) of the pilot. In these scales, the importance of size of the projects is emphasized additionally by the introduction of an extra scale point. The final weighting factor is calculated as an average of the size and measurement quality scale, thus resulting in a W-factor ranging from 1 to 3.5. This W-factor is used to calculate the score per key factor, by the multiplication of the W-factor, occurrence and impact, which is elaborated upon below.

Occurrence, impact & score In the score matrix, projects are shown vertically and key factors horizontally. Per key factor, two inputs can be set: occurrence (Occ in figure) and impact (Imp in figure). To start off, occurrence is simply a logical operator which is 1 when the key factor plays any role in the project, and is 0 if the factor does not play a role. The other input is the impact. On a scale of 1-3 the effect that this weakness or strength has on the project can be scored. The score (Sco in figure) category is a multiplication of the impact and the W-factor of the specific project, generating a higher score for more sophisticated and larger projects. In the output matrices described later, this score will be referred to as impact, since it is in essence a weighted version of the impact. Importantly, occurrence is also displayed over all of the projects (vertically) as a percentage, indicating the extent to which a certain key factor plays a role in pilots. For the impact score, the average of the non-zero values is generated in the vertical direction, providing a mean impact score for each key factor.

Figure 5.1.2 shows an example of the scoring in the score matrix. It can be seen that “Rotterdam Tests Elektrisch Rijden” receives a high W-Factor due to a large size and measurement quality. The two factors “Range” and “Reliability”, which occurred and had a very high impact according to the pilot evaluation, are shown. This results in a score of 10.5, due to the high impact and high w-factor, thus significantly affecting the final score of “4.9” for the “Range” key factor.

Points of improvement										
					Range			Reliability		
Project	Type	Size	Meas. Qual.	W-factor	Occ	Imp	Sco	Occ	Imp	Sco
Cityshopper	Cargo EV	1	2	1 1/2	1	3	4,5	1	3	4 1/2
Elektrisch Bezorgen	Cargo EV	1	1	1 1/2	0	0	0	0	0	0
Elektrisch Vuilnisauto	Cargo EV	1	1	1	1	2	2	1	3	3
Elektropool Haaglanden	Passenger EV	1	3	2	1	2	4	0	0	0
Fijnmazige stadsdistributie	Cargo EV	1	1	1	1	2	2	0	0	0
Greencab	Passenger EV	2	3	2 1/2	1	3	7,5	0	0	0
Greenwheels	Passenger EV	3	1	2	1	2	4	0	0	0
Rotterdam Test	Both	4	3	3 1/2	1	3	10,5	0	0	0
Texel Gastvrij	Both	3	2	2 1/2	1	2	5	0	0	0
Total					89%		4,9	22%		3,8

Figure 5.1.2 Example of score per pilot

5.1.2 Qualitative Method

Research Method

In addition to the quantitative method (MCA), the pilots were also individually evaluated in terms of qualitative aspects like planning, management and execution in relation to the expected results.

The following activities were performed:

1. Provision of criteria for the evaluation of projects along various evaluations studies
2. Brief evaluation of project plans and submitted project results
3. Final adoption of the criteria according to the model as outlined in figure 5.1.2..

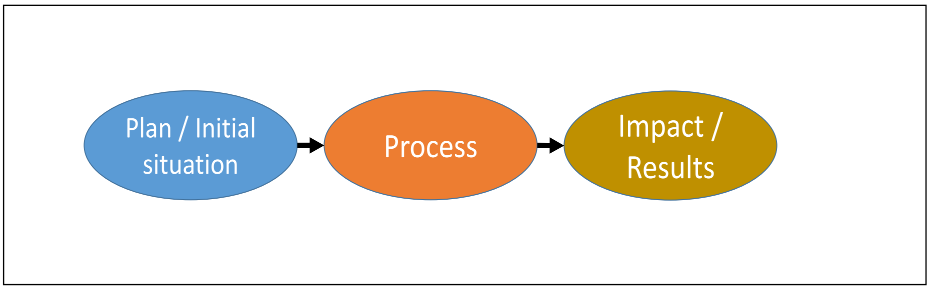

Figure 5.1.2. Model for analyzing projects

In table 5.1.2, some examples of criteria are mentioned. For the complete list of criteria we refer to appendix A1.2. Topics of qualitative attention are listed below. For example, regarding the plan questions were asked to check whether the set-up of a pilot was according to the original plan in terms of number of cars, people involved, stakeholder participation, etc. This kind of qualitative information, must be taken into account when the quantitative data is interpreted.

Criteria	Examples sub criteria
Plan	Scope, objective, stakeholders, type of deployment, size of project
Process	Target group, criteria for monitoring, unforeseen events
	Technology, infrastructural circumstances
	Existing laws and regulations, infrastructural conditions
Results	Relevance, reliability, business case

Table 5.1.1 Criteria for evaluation WP1

1. In-depth evaluation of the submitted reports
2. Additional interviews and check with stakeholders in case of ambiguities
3. Scoring the project plans, process and results
4. Conclusions

5.1.3 Concluding remarks: Method

To complete the score matrix, the results of the qualitative method provide guidance in weighting of the different pilots affecting quantitative key factor scores. Small pilots with low measurement quality, for example due to faulty equipment and adverse influence of stakeholders, receive a lower W-factor than large pilots with a high measurement quality. In this way, the final key factor score matrix provides results of higher quality. The scoring of the actual W-factor has already been discussed in section 5.2.1

The results of WP1, which are presented later in this report, clearly show that there are differences in market maturity for Pa-EV and Co-EV. Therefore, the evaluation and verification of factors is performed separately for the different markets to prevent results being influenced by other market situations that do not exist for one of the segments. In WP2 the results of WP1 are validated by the assessment of (inter)national EV projects, not including the Netherlands Enterprise Agency pilots. More detailed information is found in Appendix A.1.

6. Results WP2: Determination of Key Factors in 9 RVO.nl projects

In this chapter the evaluation and verification of factors is performed separately. The overall quantitative study of the factors is presented in 6.1, whereas the results of the individual qualitative assessment of the projects are shown in 6.2.

6.1 Quantitative Analysis

The quantitative analysis is performed according to the method described in chapter 5.1. Key factors are established and scored using the qualitative analysis, which results in a score matrix that can be used to draw conclusions on the impact and influence of specific key factors per market sector.

6.1.1 Key Factors

The key factors that have been established can be found in Appendix A.2.

6.2.2 Conclusion: Quantitative Analysis

For electric transport to become a success there are several requirements that can serve as a basis. These requirements are based on previous analyses performed in this report. Because there is a significant difference between Pa-EV and Co-EV, requirements are given for both types.

Pa-EV

There are key factors that are perceived as stimulating and key factors that have a negative impact on the outcome of the pilots. Firstly, the most significant benefit found for EV is its positive impact on end-users due to its contribution to a clean and green environment. Advertising this could therefore further stimulate the use of EV. Secondly, charging the vehicle is regarded as an easy task and is therefore seen as positive. This point should also be stressed in EV campaigning. Finally, EV user comfort should be considered as comfortable as or more comfortable than conventional driving.

On the negative side, the first key factor impacting Pa-EV is total cost of ownership, the most significant drawback. It is still higher than for conventional vehicles making it less desirable to drive an electric car. Costs should therefore be lowered to at least the level of conventional vehicles. Secondly, insufficient range is proposed as an often-found problem and could cause range anxiety among end-users, thereby creating inefficient use of the vehicle. Efforts should therefore be made to diminish this issue.

Co-EV

The first most significant beneficial key factor found for EV regarding Co-EV is the publicity generated for the respective businesses when using EV. Companies are seen as innovative and environmentally aware and this produces positive publicity. Secondly, it was largely acknowledged that costs can be reduced by substituting conventional vehicles with EVs, if daily demands of all vehicles are correctly assessed .

On the negative side, the first key factor is the limited range. This restriction often limits deployability for the company. The range is also excessively influenced by poor driving style . Secondly, the total cost of ownership, as is also the case for Pa-EV, exceeds the costs for conventional vehicles and should be addressed. A third negative key factor is reliability. The reliability of a Co-EV is an unknown quantity due it being a first generation vehicle on the market. For obvious reasons, reliability is an important asset in commercial, professional use of (E-)vehicles.

6.2 Qualitative Analysis

In view of the variety in size, set-up, type of vehicle and timetable, the projects were also analyzed on an individual basis.

6.2.1 Findings

In this paragraph we present a summary of our findings of the analysis of the individual projects in WP1.

Process

- In the Pa-EVs GreenCab project they started with Mitsubishi iMiEVs but these cars did meet the required range. Therefore, for the remaining vehicles they changed to the better performing Nissan Leaf. The monitoring give a less accurate picture of the latest technological developments.

  In Co-EVs only converted vehicles are deployed. Co-EVs above 3.5 tons are converted new diesel vehicles, produced on demand by so called EV vehicle rebuilders. This labor-intensive and small-scale conversion activity leads to an extremely high production cost, which comes on top of the vehicle price. Moreover, converted or retrofitted EV vehicles are produced with limited quality experience and hardly any established after sales network.

- Earlier pilots were faced with limited availability of charging points. This was considerably better at the end of the evaluation period.

- Co-EVs. At the start, there was a considerable delay in delivery of the vehicles because of technical start-up problems, especially pilot nr 7 *Combipakt* that was faced with technical teething problems. Pilot number 8, *Peter Appel*, was considerably delayed and made a restart as Hy-Trucks (coordinator Boudesteijn) Another point that had a negative influence was the underperformance of vehicles. Apart from that, the transporters were faced with frequent downtime periods. This was mainly caused by insufficient service. Good service is essential for adoption in a market in its infancy. It goes without saying that these facts have considerably affected the results and the attitude of drivers and their managers.

- Electricity and gas companies were able to adequately supply electricity through the charging points. The scale of the projects has not led to grid distortions.

Results

- A broad consortium composition provides more detailed results. In the pilot 'Rotterdam Test Elektrisch Rijden' stakeholders with different backgrounds participated resulting in a broader view. Additionally, the results were analyzed by an independent party.

- Project results are difficult to generalize because of:
  - Great diversity in deployment and type of vehicles.
  - Time: some projects ended in 2012, others in 2015
  - Difference in the availability of a charging infrastructure. At the start in 2012, the availability of charging points appeared to be a bottleneck. In 2014, this bottleneck appeared to be improved considerably. See table 6.2.1 on next page.

Public and private charging points by year end	31.12.2012	31.08.2015
Standard charging points		
Public (24/7 publicly accessible)	2,782	7,065
Semi-public (limited public access)	829	8,677
Private charging points	18,000*	28,000*
Fast Charging points		
Public and semi-public	*63*	*389*

Table 6.2.1 Number of charging points in the Netherlands

* Based on estimates. Source RVO.nl

- The results per category show that the development stages of the segments differ considerably.
  - The segment of passenger cars and then especially the PHEVs is not faced with range limitations and is hardly faced with technical teething problems. When comparing the results of the BEVs with the results of PHEVs one may conclude that the market of PHEVs is beginning to outgrow the infant stage in terms of market development.
  - The market of Co-EVs is facing teething problems from a technological point of view and is still positioned in the infant stage.

- Significant influence of the following factors on energy consumption. These particular qualitative statements apply to all pilots and projects studied.
  - High proportion of the batteries in the total weight of the vehicle has a negative effect on energy consumption / range and payload of commercial vehicles.
  - Conditioned / Non-conditioned. Cooling and or freezing facilities in the vehicles have a considerable impact on the range of BEVs, and a reason why result of each type of deployment should be considered separately from each other.
  - Summer / winter. Use of air conditioning in the summer and especially heating in the winter has a considerable influence on the range.
  - Behavior of individual drivers. Driving style (driving at high speed and rate of acceleration) and attitude toward charging in addition to refueling create big differences, especially in passenger plug-in hybrid vehicles (PHEV).
  - TCOs / business cases are hardly provided. Our impression is that profitable TCOs are only viable with a substantial grant and tax facilities.

Additionally, we would like to mention that in the interviews we learned that with respect to submitting data regarding further experiences, no arrangements were made for the period after the pilot. The knowledge and experience acquired in the period after project closure, which could give good input for future projects, will therefore be lost.

6.3 Concluding Analysis

Using the qualitative and, the start of, the quantitative analysis, the concluding analysis can be performed. The concluding analysis uses results of the qualitative analysis to score the pilots and key factors on weighting, impact and thus influence.

From this score matrix per pilot, a score matrix per key factor can now be calculated, which will be presented in table format in the coming paragraphs. Results for electric vehicles in general will be shown first, followed by Pa-EV and then Co-EV. Per section, the following order will be followed: key factors will first be displayed ordered by the percentage of occurrence in all the different trials. Following this, sorting will be on standardized impact (scale 1-10) and standardized influence (scale 1-10). Impact in this case is the input from the Score field, as described above. Influence is simply the product of occurrence and impact and provides a powerful instrument to assess the factors that are most likely to hinder or favor EV introduction.

6.3.1 Conclusion: Key Factor Score

The key factor score is presented in table 6.4.2, for the combination of Co-EV and Pa-EV. The detailed results, which also include separate results for Co-EV and Pa-EV, are shown in Appendix A.2.3.

Key factors ordered by occurrence					
Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Range	100%	4.9	4.9	7.1	10.0
Financial	75%	6.3	4.7	8.9	9.5
Charging	63%	3.8	2.4	5.4	4.8
Suppliers	63%	3.6	2.3	5.1	4.6
Regulations	63%	3.2	2.0	4.6	4.1
Technology	38%	7.0	2.6	10.0	5.3
Comfort	38%	4.8	1.8	6.9	3.7
Customer Requirements	38%	4.5	1.7	6.4	3.4
Reliability	25%	3.8	0.9	5.4	1.9
Service	13%	4.5	0.6	6.4	1.1

Figure 6.4.2: Example of key factors (points of improvements) ordered by Occurrence for CO-EV and PA-EV.

Remarks Co-EV and Pa-EV

When looking at the points of improvement table that is sorted by influence, two factors clearly stand out. First of all range scores highest in the standardized product column, which is largely due to the high occurrence. While the factor financial has the highest impact, it is less present (75%) and therefore comes in second place when looking at the product score (9.5). Remarkably, technology scores highest in the impact category, but its influence is far lower than financial or range, since it is only mentioned as a possibility for improvement in a few pilots, influenced mostly in the Co-EV area.

For the strengths, comfort and image are most important. For comfort, this is mostly due to the high score in impact. For Image, this stems from a high occurrence combined with a reasonably high impact.

Remarks Pa-EV

When judging the specific points of improvement for Pa-EV, financial and range stand out, the former scoring highest on occurrence and impact. While range is also a weakness in all of the projects, its impact is slightly lower and it therefore comes behind financial.

For the strengths, both image and charging have the largest impact, closely followed by comfort. Surprisingly, all factors are present in only 33% of the pilots.

Remarks Co-EV

When judging the specific points of improvement for Co-EV, it can be observed that there are now many more factors with a high score than compared to Pa-EV. Range is the factor with the most influence, followed by financial and reliability, which in their turn are followed closely by suppliers and customer requirements. Remarkably, technology and service both have a high impact, but have little influence due to their low occurrence.

As for strengths, both image and financial score highest. Again all the factors are present in only 33% of the projects.

Apart from the factors, it was found that Co-EV and Pa-EV are in different stages of Product Life Cycle (PLC). The commercial vehicles are still faced with teething problems with the medium and heavier vehicles especially still in a predevelopment stage. In addition, the wide variation in the deployment and payloads for these type of vehicle requires a segmentation and focus on niches like moving services, city distribution and additional public transport.

In view of the different stages in development, the research was divided into Pa-EV and Co-EV for WP2.

7. Results WP2: Evaluation and fine-tuning key factors in (inter)national EV projects

In this chapter, the results for WP2 are presented. The initial key factors from WP1 have been further evaluated and fine-tuned based on the analysis of the WP2 projects. The initial score matrix as developed in WP1 is updated with the findings of WP2. As a result, a definite score matrix is established. In Appendix A4 analysis and findings are outlined in more detail.

7.1 Passenger Transport (Pa-EV)

Due to market maturity passenger transport is considered separately from cargo transport. Therefore, the quantitative method can be continued in order to further evaluate key factors.

7.1.1 Key factor assessment

During the interviews, with parties involved in Pa-EV project management and software development, all the factors presented to companies and pilots were found to be of importance. However, not every factor is considered equally crucial [38][39]. The following factors were found to be a much-discussed topic in pilots and companies:

- Range
- Financial
- Charging
- Regulations
- Image or Positive External Effects

This is an indicator of importance to pilots and companies. Therefore, these key factors were assessed in further detail in the interviews and will be assessed in the following sections.

Range

In WP1, the range key factor occurred in every project and the impact was measured to be a little below average. It is, however, a much-discussed topic in the transport sector. Often, the driving range of electric cars in the low volume, personal transport sector is assumed to be much lower than the actual driving range [11]. Consumers, drivers and fleet managers are often simply not informed of the current state of the art in the electric driving range. In the near future, the average driving range [30] of an electric car will be somewhere near 275 kilometers, which is more than half of the average driving range of a conventional car [30]. Business drivers need about half of the average driving range to make their average day trips [29]. Therefore, even the most demanding users should be satisfied with the range of an EV, even when the worst-case scenario arises that there are no charging possibilities halfway or at the initial destination. Taxi drivers and companies sometimes experience the limited range as a problem, although urban-based projects seem to be able to cope with the limitation. It requires some additional planning, but companies like Schiphol Taxis and Taxi Electric show that it is possible to provide an efficient service to customers [4].

Results

It can be concluded that the range of an electric car is already, or nearly, sufficient for most Pa-EV users. Since battery technology will continue to improve, the focus should probably lie on educating potential EV users and fleet managers given that knowledge is seriously lacking in these areas [17].

Financial
In WP1, the financial key factor is considered to be important due to its high influence and impact.

According to research, fleet managers are not sure about whether they are able to design or determine a successful business model using EVs [17]. Almost all firms that consider introducing EVs into their fleet state this as a downside. Some firms are, however, prepared to pay somewhat extra for the introduction of EVs. It seems that fleet managers are prepared to test the new vehicles at an acceptable higher price. Fleet managers also seem to consider their public image by investing in sustainability.

Results
The price of an EV is determined to be influenced heavily by the price of the battery pack. Developments in the battery area, as mentioned in section 7.1.2, will also influence the financial key factor. Although current prices will stay the norm while increasing range, lower priced EVs will be introduced as well. These lower priced EVs will probably offer the same range as today, so a wider variation of options is presented when choosing a specific EV that fits in a certain business model. For further details on battery developments, see section 7.3.

Charging
Charging an electric car is an important daily activity in order to profit from a maximum range. This is supported by measurements performed by *Green eMotion*. The actual charging happens at charging stations and at different speeds depending on both the docking station and type of EV. However, some charging stations are able to return 80% of the original charge in just 30 minutes, while others take 4-5 hours to return the charge to an acceptable level.

Results
In the future faster charging will be possible, which is crucial (see previous paragraphs) to the somewhat inadequate charging key factor. The impact of the charging factor may very well be greater than the actual range if charging times are reduced to a matter of minutes. Rapid charging at every 200 kms would probably be very acceptable for most of the drivers when taking this speed and comfort into consideration. When installing new charging stations it is important that the compatibility of the infrastructure complies with future energy demands, or can at least be upgraded with little effort.

Furthermore, new applications, such as inductive charging, will provide charging possibilities at locations where an actual charging station with a cable is inconvenient. An example for inductive charging is shown in figure 7.1.2.6. This would open up applications for usage in taxi lanes and bus stops.

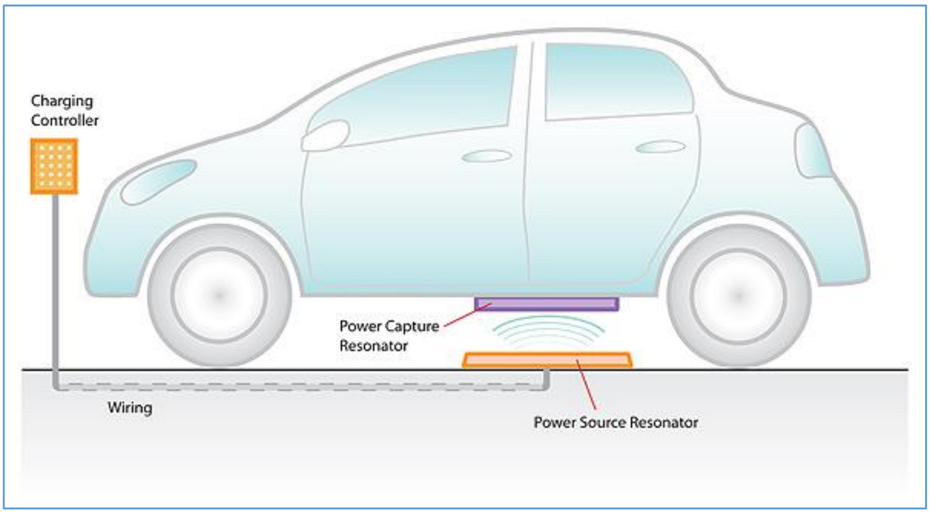

Figure 7.1.2.6: Example of an inductive charging application

Regulations

The introduction of many major technological innovations that want to make use of public space requires supporting legislation in order to facilitate consumer and business adoption. Therefore, supporting regulations are considered as a relevant key factor in the adoption of EVs.

Results

The future of regulations in the EV landscape, especially those that have a financial impact, are difficult to predict.

There are, however, two trends visible. Firstly the lobby from mobility interests groups continues, the ANWB [8], de BOVAG, Natuur & Milieu, RAI Vereniging and the Vereniging voor Nederlandse Autoleasemaatschappijen, have succesfully supported initiatives to increase financial support for BEVs, whilst conventional vehicles and PHEVs are taxed in higher levels [9]. Apart from this, they seem to support the benefits already in place for electric vehicles. The government should, and probably will, exploit this positive development.

Secondly, the government remains ambitious with respect to EVs [7], which may see the Dutch government introducing more supporting legislation in the near future.

Editorial Note: It should be mentioned that the Netherlands has been and is internationally seen as very EV-friendly due to financial tax incentives for lease and business vehicles. On pages 136-138 of the recent report ‘Overcoming Barriers to Deployment of Plug-in Electric Vehicles’ of the US National Research Council there is a detailed overview of the different financial incentives of counties. The Netherlands is mentioned as ‘a hot market for BEV’ thanks to the tax incentives, although pilots are not mentioned. In contrast, ‘Germany does not offer customer incentives and is instead relying on a demonstration program’. It is known this has not yet led to a high adoption of EVs in neighboring Germany. This poses the question of whether pilots are enough to kick off the EV consumer market.

Image or Positive External Effects

The most important opportunities for businesses to provide, and thus for other businesses and consumers to profit from, are in the area of system and data management. EV data can be accessed easily, making it possible to develop numerous *Internet of Things* applications, which can help in smart fleet management and route planning. This is already being exploited by companies like Viriciti [3], reducing the impact of the weaker factors of EV by introducing these applications.
The area of system and data management is already heavily exploited by Tesla, which makes the car even more attractive. The car is often considered an *iPad on wheels* [4], introducing elegant and easy-to-use in-car information and entertainment systems, and applications in order to control the car from a smartphone. This functionality has not been implemented at this scale in conventional consumer cars and therefore adds (a lot of) value to EVs at low costs for the manufacturer.

The electronic driveline and possibilities concerning (control of the) electronic system and data management also open new doors for the safe operation of the car, allowing automatic braking in emergencies and various warning systems. Although not always novelty innovations, such innovations will be easier to implement in all electric cars in the future.

Another positive opportunity introduced by EVs is that it is probably the best possible option to drastically reduce emissions in city centers, which is a proven method to increase quality of life and life expectancy.

Future Outlook

The future opportunities in EVs are almost limitless; the biggest opportunities probably lie in the area of driverless cars, energy storage and grid stabilization, and the energy-producing car.

Score Matrix Optimization

The score matrix is optimized using the results that the validation of the key factors rendered. This is done by considering the validation as a virtual pilot that has a high W-Factor (double of 3.5 = 7). This results in a new score matrix which can provide some guidance in establishing the importance of the key factors, considering that the new results are still influenced by the pilots considered in WP 1.

The results ordered by influence are shown in Figure 7.1.2.10, the rest of the results are shown in Appendix A.3.1.

Key factors ordered by influence (standardized)

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Financial	100%	10.1	10.1	9.4	10.0
Range	100%	9.1	9.1	8.5	9.0
Charging	75%	8.5	6.4	7.9	6.3
Regulations	50%	10.8	5.4	10.0	5.3
Suppliers	50%	4.5	2.3	4.2	2.2
Technology	25%	6.0	1.5	5.6	1.5
Comfort	25%	5.0	1.3	4.7	1.2

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	50%	9.5	4.8	10.0	10.0
Comfort	50%	9.0	4.5	9.5	9.5
PEE	50%	8.3	4.1	8.7	8.7
Charging	25%	5.0	1.3	5.3	2.6

Figure 7.1.2.10: Table of final key factor assessment (PA-EV) ranked by influence

Remarks new result

In terms of the points of improvement, the most important key factors are:

- Financial
- Range
- Charging
- Regulations

The specific impact or influence changes the ranking of the key factors, although all the key factors are of significance in considering new EV projects or pilots. The same is true for strength key factors, in particular the opportunities that have been discussed in the previous subsection, being lower emissions and other opportunities that present themselves.

7.2 Business Transport (Co-EV)

Since the start of the Living lab Hybrid and Electric Vehicles in 2012 a lot of things have changed. Teething problems have merely been solved. The Hy-trucks introduced in 2014 performed much better than the trucks in 2012.

Despite technical progress, the market for commercial vehicles is still in a development stage. This can be concluded from the fact that international projects like Frevue are halfway and will be finalized in 2017. The commercial vehicles on the road are still converted vehicles. Only service vans (N1) developed by OEMs have been integrated.

Total costs of ownership (TCO)

The TCO is still the dominant factor for fleet managers [40]. It is hardly possible to get a viable TCO or an acceptable payback period [41]. This is due to the following:

- The initial costs compared to ICE vehicles are 1.5 for N1 to 4 times higher for N3 trucks
- The battery costs take a very high share in the production cost.
  - The vehicles of 3.5T and heavier are converted vehicles, leading to high production cost.
  - The energy density of batteries compares unfavorably to diesel or gasoline; the additional battery weight leads to a loss of income due to of a smaller payload.

Role of stakeholders

Stakeholders play an important role in the adoption of commercial vehicles. The majority of companies are interested in sustainability but are hardly prepared to pay a higher price for sustainable transport. Some companies would like to take the lead in sustainable transport. They are participating in subsidized projects like Frevue and know how to use sustainability in their marketing. The majority has a big fleet and a few zero emission vehicles would have little impact on their company results.
The transport industry is still very skeptical about electric powertrains. They are used to very reliable diesel trucks, the costs for diesel are relatively low and diesel is a one fit for all solution. Even when a compelling economic case exists, fleet operators will need to be confident that the vehicle can accomplish the mission and be all round deployable, in contrast with electric powered vehicles that can only be deployed for a specific task [42]. Perhaps the most critical challenge affecting fleet adoption of electric drive technology will be fleet adopters’ impressions like:

- Uncertainty about which technology will come out on top for specific situations
- The perception of route predictability
- Range anxiety, charging infrastructure and time of charging
- Support and guarantees of suppliers plus grants and leasing possibilities
- Overall deployability of a vehicle.

Because of the gap in TCO for zero-emission vehicles versus the ICE vehicles, the role of the government is essential. Clean air goals are the main driver. Grants and privileges are instruments that can be of help for the companies that would lead the way to sustainability. Cities are different and a decentralized policy is appropriate. The negative point is that the differences between cities will not help to reach scale and it is difficult for entrepreneurs to cope with these differences. Even with grants and privileges, the gap in TCO between zero-emission and ICE vehicles can hardly be bridged.

The majority of commercial vehicles is leased. In view of the lack of experience in electric cars, leasing companies are reluctant to take high risks, which means relatively high lease rates.

Urban transport

If we look at the type of transport - long distance versus regional or urban - it is obvious that in urban areas (especially city centers and harbors) the opportunity for battery-powered vehicles is higher than for longer distance transport.
It is generally expected that in future city distribution will increasingly occur via transshipment points outside the city. However, urban distribution is very fragmented and many logistic flows do not allow transshipment. The following segments can be distinguished:

- Delivery of goods (business and home);
- Service transport and construction and demolition traffic;
- Shopping trips made by private households;
- Reverse logistics for waste removal and for returns management;
- Service vans, e.g. for maintenance and e-commerce deliveries

Developments in bus transport
Trucks for distribution are considered as a different industry segment with different customer requirements and suppliers. Since there are also some similarities we have looked into the developments of this segment. Bus transport differs considerably in distances, size and local infrastructure. Designs are much more modular and OEMs are working together with partners like Siemens and ABB, and have a lot of support from local governments. Tenders are more and more based on long-term partnerships, which is an important criterion since the extra investments in zero emission have a long payback time. Appendix A 4.2 page 34 and 35 and Appendix A 5.2.5, pages 48 to 54 contains a detailed report on recent developments in this industry.

7.3 Battery technology development

Several studies give a similar picture on battery price trends. In 2010 the cost per kWh was between $600 and $1000, whereas in 2015 prices per kWh of $300 and $400 are mentioned [43]. For the near future a further decrease in costs is expected. For 2022 a price of $125 is foreseen, and for 2022 even a price of $100 per kWh. The U.S. Department of Energy (DOE) has set a target of $150 per kWh for battery electric vehicles to become broadly competitive and see widespread market adoption [44] [45]. Further details in appendix A 4.3.

8. Main results: Overview per Research Question for Pa-EV and Co-EV

The main results are presented by answering the research (sub) questions.

8.1 Passenger transport (Pa-EV)

Since answers differ for Pa-EV and Co-EV, they are answered separately, starting with Pa-EV.

8.1.1 Sub question 1

"How much are potential users of electric vehicles willing to pay extra for an electric vehicle?"

Firstly, the validation of the key factor *Financial* has shown that an electric car does not necessarily have to cost more than a conventional vehicle. Therefore, it is not necessary to pay more for an ordinary electric car that has essentially the same functionality as a conventional car.

However, it does not mean that companies are ready to pay a higher price for an electric vehicle. It is very well possible companies acquire EVs like the Tesla Model S because of novelty features that can help creating a business model around the driving experience and for the fact that the car is essentially a gadget or perceived to be a luxury good. The exact price that consumers are willing to pay extra depends on the extra features added or added luxury, although simplicity in usage and general comfort has its own price.

Although the total cost of ownership of an EV is mostly lower that the TCO of a conventional vehicle, consumers seem to think that the TCO is actually higher. More than half of the interviewees at least have their doubts that an electric car is cheaper [11]. This proves that consumer education is needed, as well as more proof that electric-powered driving does not need to be more expensive, when considering a TCO with governmental incentives, than driving conventional cars.

Fleet managers indicate that the most common reason for currently adopting electric vehicles into their fleet is to test the new technology, to reduce emissions and to improve their public image.

8.1.2 Sub question 2

"What is the best market or application for electric vehicles, taking costs and usage into account?"

The question is best answered by considering several key factors. When taking costs and usage into account, the *financial* key factor is obviously important. Due to the high purchasing costs and relatively low operational cost of electric vehicles, it is important that the vehicle is used enough to render a lower TCO than for a competing class. This demands an effective usage strategy where the amount of vehicles needed is minimized and the vehicle uptime is maximized. Novelty strategies are needed here; there are examples of EVs that are used during the day by the employees of a specific company while in the evening the cars are for public use.

When maximization of use is central to the successes in electric vehicle, the result will be that the *charging* and *range* key factors will play an important role. Range can compensate for charging less often or less long. However, being able to charge as often as possible will be a key success factor in an EV pilot. Research has shown that projects that maintain a central charging strategy, in which minimum charging is possible in 30 minutes, seem to be most successful. Now after applying this charging strategy, the *range* of the chosen electric vehicle should still be able to comply with daily demand. Therefore, daily range needs to be matched to the market or application where the electric vehicle is used. This means that the EV should be able to cover daily demand in terms of range without exhausting the complete battery in order to comply with daily outliers or range anxiety.

Additional benefits can be found in the *Regulations* and *Image and Positive External Effects* key factors. First, regulatory benefits should be exploited by EV projects as much as possible. This may be through financial benefits, including subsidy or favorable loans, provided by the municipality or government, lowering the TCO. Regulations can also play a role in market niche that is partly controlled by the government by procurements. Some governmental mobility procurements offer extra benefits for EV applications. Second, benefits of the *Image/PEE* key factor can help when the application or market operates in public areas by the improvement of company or area image. Furthermore, numerous internet of things applications can be used in electric vehicles, allowing for novel smart connected mobility concepts.

Combining and using all or some of recommendations will result in the following applications and markets:

- Mobility in highly urbanized environments
- Consumer mobility
- Public transport in cities
- Car sharing in cities
- (Elite) Taxi companies that focus on short rides
- Pupil (school) transportation
- Daily transportation for the elderly or disabled

8.1.3 Sub question 3

”What are the key factors that determine a growth, a stop or a decrease in participation in driving electric vehicles?”

The key factors that play a role in electric vehicles have already been established and include the following considerations on:

- Range
- Charging
- Financial
- Regulation
- Image and Positive External Effects
- Comfort

Most of the key factors have been extensively evaluated in Chapter 7.1. General conclusions can be drawn on the growth, stop and decrease:

Growth
Key factors involved: Range, Charging, Financial, Regulations, Image/PEE
Key factors not involved: [-] .

Range
The average driving range of electric vehicles in the near future has been underestimated. Already a considerable amount of an average fleet can be replaced by EVs, as long as the daily and annual kilometers are assessed. Sometimes, the maximum daily range, without extra recharging, will not be sufficient. Increasing range of EVs will stimulate the adoption rate. Furthermore, business models should be developed which facilitate driving beyond the maximum range. This can be achieved by the introduction of rapid charging or provided in low-cost or free conventional car rental.

Charging
The realization and marketing of an extensive charging network should be accelerated, in order to facilitate charging for users of EVs. Furthermore, new business models should be developed for charging stations, since very few companies have entered the EV-charging market in the segment of actual local and on the road service. On a smaller scale; pilots, projects and companies considering business models that allow frequent and/or longer charging have the best chances of succeeding in the market.

Financial
With the right business model, it is possible to realize a lower TCO for EVs than for a conventional car due to lower operational costs. It is approaching the point where average daily business usage in terms of kilometers driven already results in lower TCOs. A significant amount of a vehicle fleet can be substituted for EVs by range as well as by operational costs. When more kilometers are driven, the differences in TCO rise, so it is very important that business models allow large distances and efficient and intelligent charging strategies. In the near future, it might also be possible to reassess redundancy strategies, due to the improved reliability of EVs since they contain fewer moving parts.

Regulations
A more uniform policy on EVs may stimulate the adoption on a larger geographic scale than currently; companies complain about different policies in different cities and are hesitant to expand. In highly urbanized environments EVs thrive, but it is currently a barrier to consumers to invest in their own or shared charging stations in the public domain. Key public (economic) areas can be used to show the state of the art of EVs and internationally promote the Netherlands. The government should consider leading by example in the area of EVs.

Image/Positive External Effects
The promotion of a green image through the usage of EVs is relatively easy to implement. Furthermore, electric vehicles are a superior platform for novelty Internet of Things (IoT) applications in business models. As an example, autonomous car projects are mostly focused on electric cars and new innovations are possible in safety through IoT applications.

Stop or decrease
Key factors involved: Range, Charging, Financial, Regulations
Key factors not involved: Image/PEE.

Range
A stop or decrease in the adoption of electric vehicles may result if the range of EVs is not improved. Business models that rely primarily on old EV models have a high chance of failure due to the low range as well as reliability issues. Furthermore, the sale of EVs to consumers or introduction to company staff that do not meet the average daily range requirements will probably fail.

Charging
The need for an extensive charging network should not be underestimated in order to be able to actively battle range anxiety. Furthermore, the introduction of multiple charging subscription, and thus the lack of having a main, easy, checkout method, will hinder the adoption of EVs. Paying should be as easy as, or maybe even easier than, filling up the tank with gas.

Financial
Business models that use EVs only to market them as green vehicles that reduce emissions are bound to fail. Research has shown that only a small percentage of consumers is ready to pay for reduced emissions, when they do not really have to. Additionally, it seems that a lot of consumers and companies are not aware of subsidy possibilities.

Regulations
Research questions the stimulation of plug-in hybrid cars, due to higher emissions when driven too much without charging. Continued heterogeneously distributed legislation on EVs slows growth, since companies have to overcome extra obstacles to expansion.

8.1.4 Sub question 4

"What is the most economic scale for a project based on electric vehicles?"

Defining one exact general economic scale is practically impossible, although it is possible to assess scaling through a few key factors:

Range and Charging
Firstly, the limited range and recharging should be considered when scaling a project. This is achieved by the determination of daily area that needs to be covered and matching this with a specific EV. A specific strategy needs to be developed in order to maximize the options on usage thus driving a maximum amount of kilometers using the EV. Two strategies are possible in operating and thus scaling:

- Frequent charging; keeping battery level generally high
- Infrequent charging; reducing battery level as much as possible during the day

Frequent charging
It is important that the EV is able to charge relatively fast and is mostly scheduled for short to medium distance journeys in order to accommodate for infrequent longer journeys. This would result in a drop in the battery level for longer journeys only, ensuring that the EV reaches the end of the day. This would be most applicable to taxi business models.

Infrequent charging
When charging infrequently the journeys should generally be as long as possible in order to realize optimum mileage. This would result in large drops in the battery level, after which the battery is fully charged again and the EV drives another long journey. This would be most applicable for business models that drive during specific times of the time (elderly or disabled transport).

Financial
The most economic scale in terms of the financial key factor is reached when the total amount of kilometers for an EV is maximized, resulting in a lower TCO for the same amount of kilometers with a conventional car. An EV is increasingly profitable when usage is higher due to lower maintenance and fuel costs. Therefore, EV uptime is crucial and new initiatives like in-fleet car sharing could be researched for application purposes. Given the higher reliability of EVs, fleet redundancy strategies can be reassessed to reduce the amount of vehicles in a fleet.

Regulations
Effective regulations to promote the adoption of EVs should positively affect all economic scales of projects. The scale should, however, be exactly matched to different types of EVs. It may be lucrative to provide extra benefits to BEVs and FCEV, whilst reduced benefits are provided for PHEVs.

Image/PEE/Opportunities
Although past key factors can already be applied at very small scales, this factor is the most defining in terms of scale. A few examples are:

Emissions
In order to reduce emissions huge economic scales are necessary, beyond the current scope of this report. EVs are, however, the number one candidates to reduce CO_2 and other harmful gasses in city centers.

Internet of Things Applications
Currently the industry lacks a standard for tracking cars in car sharing or renting applications. This means that projects need to develop their own hardware and software to comply with current expectations on the consumer side. This development of own hardware and software requires some scale in a project, although specific numbers are hard to present since each project has its specific needs. Ambitions in this specific area are, however, probably easier to realize with EVs since the basic electrical infrastructure and sensors are already provided throughout the car.

Image
Fleet managers consider EVs in order to improve their image. Visibility is everything in these cases and is more dependent on marketing than reaching a scale by the amount of EVs used.

8.1.5 Sub question 5

”How can we use the soft factors, for example image or positive stories, that influence the adoption of electric vehicles, to influence the market segments in a positive way?"

The soft factors, which are mostly described by Image/PEE, offer only limited possibilities in terms of positive influence. Although consumers appreciate sustainable efforts by companies, they are only prepared to pay for these efforts to a limited extent .

Communication on EV novelties is, however, important. It is questionable whether current residents of city centers (want to) know that low-emission zones bring higher quality of life in the longer term. It is possible that local authorities are hesitant in communicating the effect of harmful emissions since the solution is not completely within reach yet.

Positive stories can contribute to higher adoption, or can at least contribute to the start of testing with EVs, since fleet managers do not want to lag behind other companies. It has already been established that the government can accelerate adoption by leading by example. This can be achieved by stimulating local governments to successfully adopt electrical vehicles where possible. Another possibility is in restarting a few successful pilots as a proof concept. These efforts can translate into positive stories, possibly triggering consumers and companies to rethink their stand on electric vehicles.

Apart from hearing about EV pilots consumer education should receive additional attention, as research shows that current consumers do not know about:

- Reasons to buy an electric vehicle
- Reasons not to buy an electric vehicle
- State of the art of EVs
- Ambitions that the Netherlands has for EV and why (eg. noise and air pollution reduction)

It is still believed that EVs are impractical due to low range, that charging takes too long and that they are unreliable and unsafe. These misperceptions probably hinder sales and should be countered to stimulate adoption.

8.2 Commercial vehicles (Co-EV)

For commercial electric vehicles, the following answers to the key questions were found.

8.2.1 Sub question 1

"How much are potential users of electric vehicles willing to pay extra for an electric vehicle?"

The market for transport is fragmented and very competitive. Transport companies have limited room for financing innovations. Initial innovations should come from the OEMs, but they are for the time very much focused on vehicles for long distance haulage, where diesel, dual fuel / LNG has the most potential for the period up to 2025.

From interviews and studies of Frost & Sullivan in 2011 and Innovam 2014, it can be concluded that a viable / positive TCO is the determining factor in market for commercial vehicles.

The majority of business cases are set up by entrepreneurs that have a bigger fleet, whereby alternative ICE vehicles are available in cases of problems and the impact of extra costs for EV are limited on their total budget. Apart from that, the majority of Co-EVs participated in a subsidized project and extra grants and privileges were obtained.

The high initial investment ratio is the main reason for the much higher TCO of battery-powered commercial vehicles. None of the interviewed parties was able to obtain a viable TCO, without grants, tax advantages and /or privileges.

City Buses are a separate business case. Due to pilots Innovative Busses [37] and the Green Deal Zero Emission Bus some concession rules have already been adapted to accommodate electric buses by 2025. The longer concession period up to 12 years and the demand for zero emission makes introduction possible today. OEMs also started to offer electric buses on a commercial basis. However, this is because of the high technology price not yet the case for Hydrogen Electric Buses.

8.2.2 Sub question 2

"What is the best market or application for electric vehicles, taking costs and usage into account?"

The observation from several studies and our interviews is that the general applicability of affordable clean drivelines is still far away and future expectation varies by type of transport. It is expected that until 2025 alternative powertrains play hardly a meaningful role in the segment of heavy trucks (N3). This is less true for the market of light commercial vehicles like vans and service vehicles in urban areas (N1), where speed is relatively low and sufficient charging points are available. Light commercial vehicles (<3.5 tons) are more likely to be electric in the near future.

In general, one can conclude that battery driven powertrains are very clean but not suitable for heavy loads in combination with long distances and are even very expensive. The energy density of batteries is very low in relation to fossil fuels. The longer the range the more battery capacity in the vehicle (weight) and the lower the pay load, which is an essential criterion for the majority of the transports.

The technical limitation and high price for batteries limits the possibilities for BEV to niches in urban areas, whereby local governmental grants and privileges are a prerequisite. For the time being, Co-EVs are only promising where favorable conditions (especially limited range) apply: urban areas and in segments like

- City Buses
- Moving (limited kilometers per day and charging overnight)

- City distribution for the hospitality industry
- Parcels / Express delivery
- Service vans / Pool cars / Shared company car
- Additional public transport (disabled & infirmed people)

It is generally expected that city distribution in future will increasingly occur via transshipment points outside the city. However, urban distribution is very fragmented and many logistic flows do not allow transshipment so a big share of retail shipments cannot be handled via transshipment centers, because of size, time and cost. For this type of transport customized or niche Co-EVs should be developed, if zero emission is an issue. For BEV city distribution it could be helpful for bigger shipments if fast charging is available during discharging.

8.2.3 Sub question 3

"What are the key factors that determine a growth, a stop or a decrease in participation in driving electric vehicles?"

According to the interviews, desk research and literature the following factors have a considerable impact on the participation of Co-EVs.

- Lack of scale on the supply side

  At the moment there are no OEM cargo vehicles commercially available; all Cargo-BEVs (Trucks with battery powered drive train) are converted from ICE based vehicles, involving

    - Cost for conversion
    - Cost for batteries
    - Limited scale of production
    - Relative expensive components for the battery-powered driveline

- Initial investment is a clear bottleneck for transport companies

  Apart from the aforementioned viability of TCO, the initial high investment costs are a bottleneck for growth. It is understood that the lack of scale and limited Co-BEV options will result in a high initial investment.

- Overall deployability is a basic requirement of transporters

  For operational reasons entrepreneurs find it important that their vehicles can be deployed all round. Apart from the operational effect, this of course relates to their TCO.

  1. Technical Support and guarantees by suppliers are a basic requirement for transporters

  The majority of entrepreneurs with BEVs faced imperfections in the technique during deployment, mainly due to the development stage of these types of vehicle. Repairs were not resolved in time because of lack of experienced service personnel, leading to unmotivated management and drivers involved.

  2. Harmonization of governmental support (grants and privileges)

  Apart from the aforementioned grants, privileges and tax facilities, it is important that the governmental support instruments are harmonized. For entrepreneurs who work on a larger scale it forms an obstacle to deploy more Co-EVs.

  3. Other factors

- Other factors such as a charging infrastructure play a less important role compared to passenger cars. Fast charging can support the feasibility of some concepts like retail distribution (charging during discharging cargo) and service vans.
- Commercial vehicles are merely leased, so leasing possibilities for BEV are an important condition. In that case, the risk attitude of leasing companies is an issue.

A big leap forward can be achieved if electric designed trucks are produced by OEMs, as is already happening with city buses. Besides, it may be a good idea to give extra attention and support to the real pioneers in the whole supply chain. Representative interest groups will generally defend the interests of the average member and will also be inclined to take stragglers into account. More focus on the leaders / initiators could be of interest for accelerating innovation.

8.2.4 Sub question 4

”What is the most economic scale for a project based on electric vehicles?”

As explained earlier, urban areas have biggest potential for exploiting Co-EV but it is important to differentiate by type of transport. The load factor and range for a van (N1) can hardly be compared with a mover N2 or N3 or a garbage truck (N 3) with a vehicle for conditioned food transport (N2 or N3). Since the medium (N2) and heavy trucks (N3) are for the time being in a pre-development stage, the technology should first be improved before product launches can take place on a larger scale. As suggested above, the cost for batteries, apart from the range, are the main bottlenecks for adoption, also in the N1 category type vans. The battery technology is improving year on year, but it will take approximately 5 years before the TCO of Co-EV will be on a break-even basis compared with ICE vehicles. In figure 8.2.4.1 below, we indicate where the focus of stimulation per category should lie: on TCO viability for the lighter commercial vehicles and on innovation of the technology for the heavier trucks.

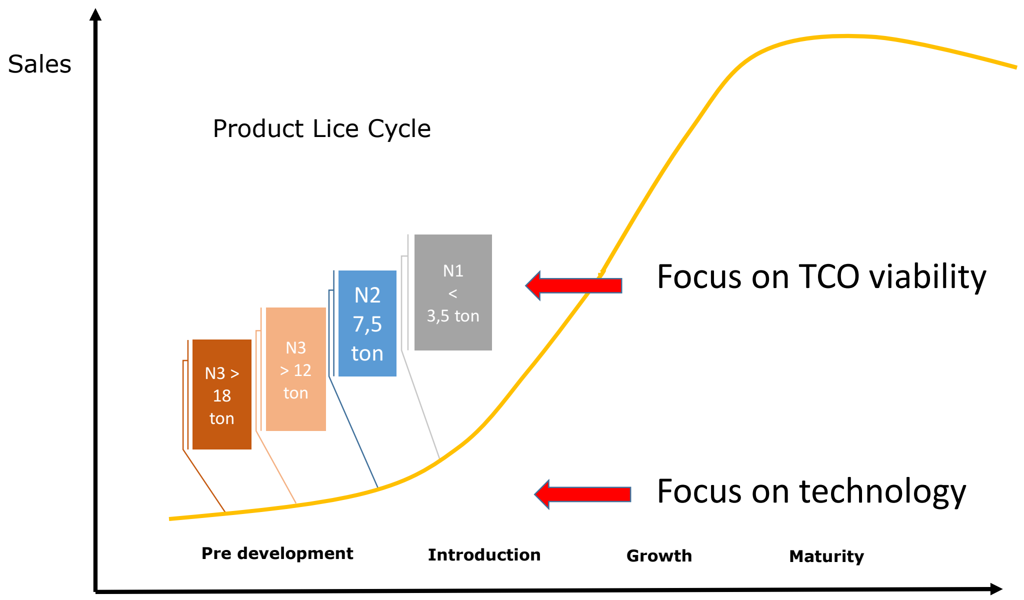

Figure 8.2.4.1 Focus of stimulation per commercial vehicle category

When we look at this global classification in figure 8.2.4.1 and link it to possible measures then we get table 8.2.4.2 (next page).

Category	Focus	Possible measures
N1	TCO viability --> Market growth / scale	• Fiscal arrangements • Grants and privileges depending on deployment • Purchase N1 for public services like service cars, vans for transport WMO / disability (e.g. Nissan NV 200).
N2.	Scaling up	• Guarantees, financial funds • Stimulating cooperation and sharing of knowledge • Grants and privileges depending on deployment
N3	Innovation of technology	• Stimulating innovation by grants • Stimulating cooperation and sharing of knowledge

Table 8.2.4.2 Basic idea for differentiated stimulation on commercial vehicles

As soon as the basic powertrain technology is improved, further specialization can be based on movers and trucks that supply supermarkets.

In fact, city buses can set an example for good conditions for the introduction of Co-EV as a whole. Although the detail of every bus order is different, scale is achieved by larger and longer ‘green’ concessions with specific emission requirements. This also attracts OEMs to get involved and to speed up commercial development. The infrastructure is made smart, which needs the involvement of charging and electricity suppliers and, last but not least, the local government. Also ways of new financing and operational models are introduced in this segment. And very important, there is a dedicated open source TCO tool, which makes the dialog about the innovation decision more transparent for all stakeholders.

8.2.5 Sub question 5

”How can we use the soft factors, for example image of positive stories, that influence the adoption of electric vehicles to influence the market segments in a positive way?"

Transporters/operators

Perhaps the most critical challenge concerning soft factors is the perception of the majority of transporters or public transport operators. They are very satisfied with the present technology that supports their demand for all round operability. Apart from that, they are able to meet government requirements for the coming period and they are relatively short-term orientated with no expectation that battery powered drivelines will be a reality for long distance transport before 2030. Their attitude is supported by the general opinion on

- Uncertainty about which technology will come out on top for specific situations
- Limited availability of OEM vehicles with all-round deployability.
- The perception of route predictability
- Range anxiety, limited charging infrastructure and time of charging
- Lack of support and guarantees of suppliers plus grants and leasing possibilities

Even when a compelling economic case exists, fleet operators will need to be confident that the vehicle can accomplish its mission.

Principals, shippers

Companies are keen on sustainability but this strongly depends on the ability to be a distinctive and competitive market player. The harder the competition, the less the willingness to proceed with procurement of sustainable investments.

Some entrepreneurs look more to the future developments and want to lead the way, despite the financial disadvantages. In most situations, they have a larger fleet and the impact of one or a few EVs on the total is limited. Others prefer to wait until

- The technology is further developed
- There is more clarity on the dominant technology
- It is enforced by market demand
- The costs are lower.

There is no concrete evidence that investments in sustainability improve the image accordingly, but some entrepreneurs are willing to assign the last 5 to 10% of their investment to improve their image.

The introduction should start with OEM manufactured vehicles in N1 category followed by N2 and N3, with a focus on early adopters under transporters and principals. Striking examples of projects with a differentiated communication that is targeted to specific groups should play a role in the further adoption together with training of drivers.

9. Conclusion and Recommendations

This analysis will, as the title suggests, address conclusions about the key factors underlying success and failure in the implementation of electric vehicles, key factors found during the execution of the pilot projects and which are put into the perspective of recent technical and market developments.

General conclusions

The first general conclusion that is drawn from this analysis of nine different pilot projects and other national and international pilot projects is that **such projects are difficult to compare one to one**. Each project has had its own dynamics and circumstances. Vehicle type, deployment, timing and approach differed significantly per pilot.

This fact leads us to the following general conclusion that, despite the great differences**, striking similarities have also been found**. These **similarities are seen as key factors**, which are apparently "generic" for the practical deployment of EVs. This, together with the interviews with the project stakeholders and information of other experimental pilots, **provided additional insights for the further successful market development**.

Looking at the different vehicle segments led to the final general conclusion that **there is a crucial difference in the development life cycle of the passenger vehicles (Pa-EV) and commercial vehicles (Co-EV)**. Although both are at an early stage, the Pa-EV is more mature than the Co-EV. In both markets the technical development speed is extremely fast. This difference in life cycle and the high speed of technical development of EV should be taken into account when further assessing the EV market development.

Specific conclusions

From the final reports of the pilots, **the technical, social and financial key factors have been analyzed and reviewed**. Additional Information from interviews and other pilot projects have resulted in deeper and broader insights behind the key factors, generating a top three of key factors underlying success or failure. Where necessary these factors are broken down for passenger cars (Pa-EV) and commercial vehicles (Co-EV), and explained.

Key factors that support success:

+ Impact & Image: One of the most significant benefits found for Pa-EV is the positive impact on end-users due to its **contribution to a clean and green environment**. Advertising this could therefore further stimulate the use of EV. Moreover, one of the most significant benefits found for Co-EV is the publicity generated for the business involved when using EV. Companies are seen as innovative and environmentally aware and this creates positive publicity.

+ Charging: Normal and fast charging the vehicle is regarded as an easy task and is therefore seen as positive. This point should also be stressed when campaigning for EV. In most pilot cases private or dedicated charging was used since the public charging infrastructure was still under development. **Finding a nearby free charger has since significantly improved.** And last, but not least, the interoperability of the Dutch public charging is very convenient for the user and is seen as a world-leading example. Inductive charging has the potential to make charging even more user friendly.

+ Comfort: User comfort with EV is considered as comfortable as or more comfortable than conventional driving. **Low noise, direct torque, smooth acceleration and one pedal drive regenerative braking are seen as unique selling points for EVs and provide excellent driving quality in modern traffic.** Initial problems with the user-interfaces and the quality with heating, ventilation and air-conditioning in the first generation vehicles have been solved in the later vehicles. The flipside of the lower noise production is that EVs are not ‘heard’ by pedestrians and bicyclist. However, more experienced EV drivers seem to be well aware of this problem and anticipate by careful driving. In addition, special pedestrian sounds or pedestrian friendly horns are added to modern EV’s.

Key-factors that can lead to failure:

- TCO: The most significant drawback for EV is the high purchasing price in relation to the total cost of ownership (TCO). Without subsidies, **the TCO is still higher than for conventional vehicles making it less desirable to drive or use an electric vehicle**. The TCO should therefore at least be lowered to the level of conventional vehicles. In general, the TCO of Co-EVs still exceeds the costs for conventional vehicles and should be addressed. An important reason for the high TCO of Co-EVs above 3.5 tons is that they are converted new diesel vehicles produced on demand by so called EV vehicle rebuilders. This labor-intensive and small-scale conversion activity leads to extremely high production costs on top of the vehicle price. Some studies indicate that there are positive TCOs to be achieved if more realistic ‘market’ prices for the vehicles are calculated. For the short term, cost reduction could be achieved by retrofitting the conventional vehicles the company already has. But more significant for this sector is for OEMs to develop affordable series produced vehicles with state-of-the-art service.

- Range: Insufficient range is proposed as an often-found problem and could cause range anxiety for the end-user and create inefficient vehicle usage. Efforts should therefore be made to diminish this issue. In this respect, battery development especially has already delivered and is still expected to deliver more improvement in capacity, lifetime and price. **A range of 250 to 500 km seems be the standard for new Pa-EVs.** Also for Co-EV one of the most significant drawbacks can be the limited range. In theory it results in limited deployability or flexibility for the company. However, in most commercial applications that were tested in the pilots this could be dealt with by planned or fixed-duty/driving cycles. **Due to the relatively heavy specific weight of the batteries, a good match between useful range based on the drive-cycle and the net payload is important for a positive TCO of Co-EVs.**

- Reliability: Many drivers worked with the first generation EV available on the market, in some cases even prototypes. Often, these vehicles were unreliable, while service was sometimes slow and poorly organized. For the Pa-EV the second and third generation now being on the market, these issues seem to have been solved. OEMs are offering 8 to 10 years warranty on batteries. Recent user-statistics show that OEM produced EVs are reliable and cheap to maintain. This is not yet the case with Co-EV which have so far been converted or retrofitted EV vehicles, produced in small series, with limited quality experience and hardly no established after-sales network. **In addition to TCO, reliability and accountability are regarded as very imported in the commercial transport sector, making or breaking the business.**

Finally, in 2010 the Dutch government decided to stimulate electrification of road transport by a program called ‘Living lab Hybrid and Electric Vehicles’. In this framework the following observations and recommendations are formulated.

Observations and recommendations

The nine pilot projects, which were implemented from 2011 to 2015, were analyzed with the aim to determine key factors underlying success and failure. The analysis was not limited to just the technical outcome of the nine pilots but also considered the environmental factors, the process and the organization. In addition, the nine pilot projects are related to other pilots and developments in the field of EVs in the Netherlands and abroad. Based on and in addition to the analysis of the (inter)national electric vehicle project, we have been asked to formulate the following recommendations about 'lessons learned and next steps' regarding EV pilots.

In hindsight

Looking back, we concluded that the pilots were very diverse in EV technology (particularly in terms of the phase in the product development life cycle), objectives, design and implementation. The initiators were typically pioneers of EV deployment and development. In that sense, a lot was learned. The results contributed to the awareness that modern EVs can offer a serious solution to the increasing problems caused by conventional vehicles. Our observation is that the current leading position of the Netherlands, the relatively high market penetration of EVs and charging infrastructure are partly due to the substantial focus on pilots.

Despite the fact that the results of the pilots were not always positive, they have acted as guiding projects in which the strengths and weaknesses of development and deployment of EV including the charging infrastructure clearly emerged. More than once, the pioneers or others could build on lessons learned from the experiences gathered by the pilots. Due to the great diversity and different circumstances, it was difficult to come to general conclusions. But thanks to the diversity it has become clear that EV deployment is still no simple 'one size fits all' solution. Short-term opportunities occur mainly as cleverly chosen and specifically facilitated mobility or transport solutions. In addition, in some pilot projects it became clear that EVs provide new economic opportunities in both the development of products, applications and services for the Netherlands. The latter is the case, for example, for Spijkstaal with the Ecotruck, e-Traction and VDL with the Citea Electric, the several electric distribution trucks and the leading business around the charging infrastructure, which would probably not have been developed or have emerged without pilots.

The EV developments are moving fast, but are still not fully developed

The question is whether or not EV pilots after the pioneer phase described above are still necessary. Several pilot projects, which were completed only one or two years ago, seem already outdated by reality. Since the start of the first pilot in 2011, most vehicles have greatly improved and the public charging infrastructure has been amazingly quickly rolled out. Some pilots were not followed up because of negative experiences but similar concepts in other situations have been proven successful, such Car2Go and Taxi-e.

From a historical point of view, EV developments are going very fast but are at the same time not yet fully developed in terms of technology and market potential. We are only at the beginning of market development and that is why pilots are still useful and attractive. The latter is confirmed by the different Green Deals, which are partly built as a result of the pioneering pilot phase. Examples are: Zero Emission Bus, Green Deal Public Charging Infrastructure and Zero Emission City Distribution). And there are other EV projects that deserve similar support. However, these should be placed within a framework of advancing EV development.

Next steps

The following is to be recommended for next steps:

1. *Pilots in different product-market combinations*

Especially for passenger cars, light commercial vehicles and city buses, EV products that have undergone further development are commercially available today. Because products made in series production from "Original Equipment Manufacturers" (OEMs) are still relatively few and the development is new, the current price is relatively high. This may still hinder the purchase or profitable use of these vehicles for some years. Pilots with these new vehicles and aimed for use as taxi, rental cars, service vehicles, delivery vehicles or even selected private car owners, for example, would bring valuable user-information which can accelerate the market acceptance. By reducing the financial risk in a pilot, the viability of the broader use of these EVs can be determined in the relatively short term. This presumes, of course, a good exchange for sufficient and structured information on such a scale that serves the public interest.

For particularly heavy commercial vehicles (> 3.5 tons), harbor-distribution vehicles and coaches, the potential EV market is still based on converted products. Therefore, these product-market combinations contain two major uncertainties; uncertain product delivery / service and uncertain earnings. Often, it is possible to calculate that the Total Cost of Ownership at reasonable product prices and high reliability could pay off. However, due to the inefficient conversion supply chain these vehicles are disproportionately expensive, which makes commercial application far from feasible. A pilot in this area should be focused on optimizing and accelerating the product manufacturing chain, so that further developed professional OEM products will enter the market. In addition, customization of the logistics chain in the road transport sector is very important. It goes without saying that, in exchange for this product development support, added value for the Dutch economy is an important factor.

Finally, the harmonization of national and especially local grants and privileges are a concern. Decentralization of policy is good but different regulations are restricting the critical mass, which is crucial for professional production development and deployment of the EVs.

2. *Pilots should be linked to business plans*

For each pilot project, it should be predetermined how technical, economic and legal conditions will individually contribute to the development of a profitable deployment. Under this business precondition and a risk assessment, the pilot should only cover the 'financial gap' during the pilot period. During the pilot, it should be examined how and under what conditions planning remains feasible. A restart after the experimental pilot period should be a basic condition unless it can be proven that the goal cannot be achieved within a reasonable period in respect of the expected price development and technological progress. It is also of importance to follow the evolution after the experimental period. A good example is the follow-up pilot with the e-Busz for the RET at Rotterdam. The business initiators and government are again involved, but now in the more challenging context of a Zero Emission Bus. The extended pilot is till 2019 and only covers ‘the extra’ cost to achieve the goal: an exploitable zero emission bus fleet.

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A.1 Appendix on Research Method

A1.1 Appendix on Pa-EV - Passenger cars

The research method for PA-EV is presented in the following subsections.

Overview workflow

A schematic overview of the workflow is shown in figure 5.2.1, please note that the amount of interviews and literature study is higher than the combined number of three.

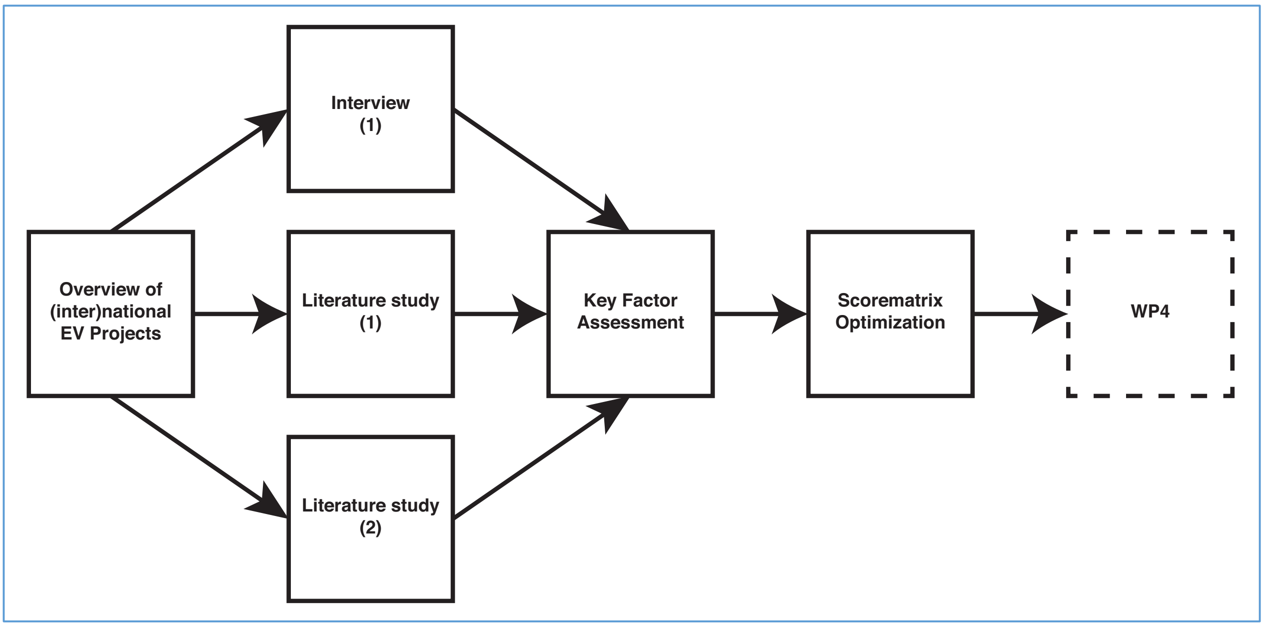


Figure 5.3.1: Schematic overview of workflow used.

Below, the specific steps to be taken are discussed in chronological order of the schematic overview.

Overview EV projects

Firstly, a database, with contact data, is built to accommodate a vast amount of EV projects, both national as international. Projects with similar business models were included as well. Including more projects and companies does increase the validity of the overall findings. Although new business models are not excluded, already in the method designing phase it was concluded that hardly any new business models have been developed. It is, therefore, assumed that successful companies and projects contributed directly to the results of this investigation. Therefore the focus was as much as possible on successful companies and projects.

Secondly, the companies and projects in the database were categorized to prevent recommendations and findings of a certain personal transport sector niche wrongly influencing other sectors. Based on initial exploration and discussion with key stakeholders, it is expected that the personal transport sector will contain the following two niches or subsectors:

- Low volume personal transport
  - Private Transport (including car sharing)
  - Taxi transport
  - Other low volume personal transport
- Higher volume personal transport
  - Public transport
  - Special transport (e.g. transport of disabled people)
  - Other higher volume personal transport

In general, the two niches or subsectors are considered in this report while the subdivision of the subsectors received attention where appropriate.

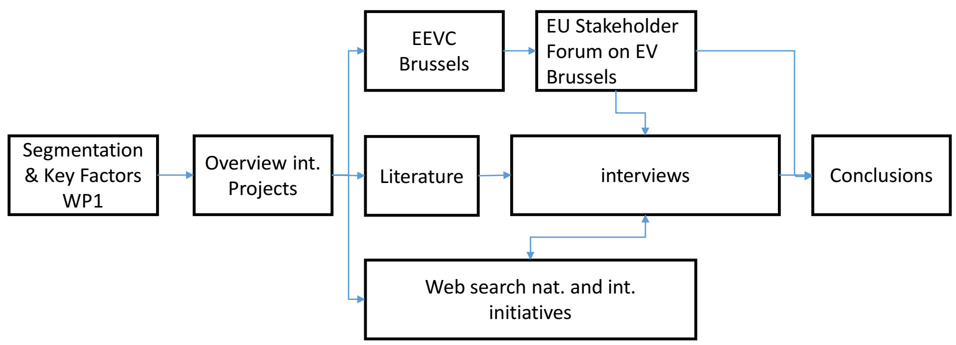
Interviews
Having the database, the companies and project (owners) were approached by writing them a recommendation letter (marked with approval by prof. dr. ir. M. Steinbuch) stating the intentions of the research. After contact was established, the list of questions was shared to prepare the interviewee for the questions in advance. The interviews were done by phone or on site. The transcripts of the interviews were formalized and used in the 'Key factor assessment phase', prior to the MCA (WP 1).

Literature and web research
In addition to the interviews, additional literature and web research was undertaken, with articles studied that were submitted to academic journals or to conferences. Web research and documentation study were the most important sources of information for (inter)national pilots which were not in WP 1.

Key factor assessment
The key factors were assessed using the results of the interviews and literature and web research. New factors came into play if the interviews or written research revealed them, or if further validation of existing, preliminary factors was facilitated. In the assessment per key factor, the current and predicted future state of the art – current and future incentives that have an impact on electric mobility - was considered. Per determined key factor (WP 1) it was important to check the occurrence and impact in new projects and companies (WP 2 / WP 3). This knowledge optimized the ultimate score matrix. The prediction of the future state of the art was concluded by assessing corresponding key factors in recent articles and other relevant literature.

Score matrix optimization
Using the key factor assessment the current score matrix was created, which resulted in the establishment of a new validated score matrix. It is expected that a successful project will have addressed all those key factors, thus the focus for new projects should be on the use, implementation or avoidance of these key factors.

A1.1.2 Appendix on Co-EV - Commercial vehicles WP2/3
As mentioned in the project analysis of WP1 we have found a great diversity in operating conditions, development stage of applied technology between passenger cars and commercial vehicles. Apart from that, it appeared that even in commercial vehicles the spread in load weight, type of deployment and range is considerable. Especially the medium and heavy vehicles are in a predevelopment stage, whereby the purchase was based on grants and extra privileges. New viable innovative business cases are not developed yet. Therefore, we concentrated further research on this category. To answer the central and sub-questions, we followed the following steps and methods for WP 2, 3 and 4.



EEVC = European Battery, Hybrid and Fuel Cell Electric Vehicle Congress, December 2014.

EU = European Electro mobility Stakeholder Forum February 2015, co-organized by three European projects: cars (Green eMotion), urban buses (ZeEUS, coordinated by UITP) and freight (FREVUE).

Figure 5.2.2 Schematic overview of workflow used.

in WP 2-3.the criteria for commercial vehicles were divided into the following four categories as shown in Table 5.2.2.

	Category	Criteria
1	Development of powertrains, types of transport and supply chain	Technology , Range, Reliability
2	Customer requirements	Range, Charging, Fleet, Regulations (Law / grants / privileges), Financial (TCO & investment ratio, Reliability, Service, Image
3	Other stakeholders	Fleet, Financial, Charging, Image, Regulations (Law / grants / privileges)
4	Battery technology	Range, Financial

Table 5.2.2 Categories and criteria

In view of the variety in commercial vehicles for cargo we have used the following categories. Table 5.2.2.

Vehicle class	Gross vehicle weight	Field of application
Van (N!)	Below 3.5 t 	Service and delivery vehicle
Light truck (N2)	3.5 – 7.5 t 	Short haul
Medium truck (N2)	7.5 – 12 t 	Medium short haul
Heavy truck (N3)	Above 12 t 	Motor tractor in articulated train construction traffic
Road tractor (N3)	Usually up to 40 - 44 t	Long distance haul

Table 5.2.2 Categories of commercial vehicles

A.2 Appendix on Results: Analysis of Pilots Netherlands Enterprise Agency (WP1)

A.2.1 Quantitative Analysis

Key Factor Assessment

Strengths

Range
This factor includes benefits that have to do with the range of EV.

PA-EV + CO-EV: When matched correctly some companies have seen that 50% of their fleet can be replaced by EVs when taking range into consideration.

PA-EV: Firstly, shortcomings in range can be overcome by making use of range extenders. These options might not be 100% electric, but are mentioned as a positive factor in the use of electric vehicles. Also, some situations might not require extensive range (for instance on the island of Texel).

Comfort

This factor includes the comfort benefits that arise from EV.

CO-EV+PA-EV: The feeling of safety is equal to conventional vehicles, which contributes to a comfortable feeling. Reduced Noise levels are regarded as comfortable.

PA-EV: Electrical driving is regarded as very comfortable, in one study even more so than conventional driving. Additionally, EV featured better acceleration than expected.

CO-EV: The reduced noise level is the main advantage encountered in CO-EV trails.

Financial

This factor includes the financial benefits that arise from EV.

CO-EV: Refurbishment of conventional vehicles has shown to enable cost reductions.

PA-EV: Driving is regarded as very affordable, but this is in part due to subsidies.

Image

This factor includes benefits that stem from EV that have a positive impact on image of end-users.

CO-EV: The positive factor image consists of the enhanced green image and publicity for the business involved.

PA-EV: Owners of electric vehicles get a lot of attention and questions. Additionally, electric cars are regarded as ‘cool’ cars. Finally, it serves as good publicity for companies that own EV fleets.

Charging

This factor includes benefits that are associated with charging.

PA-EV + CO-EV: Users consider charging an easy task.

PA-EV: Charging docks are easy to find using internet and smartphones. Moreover, the number of loading docks is growing and so is the infrastructure.

Positive External Effects (PEE)

This factor includes the spin-off effects from EV.

CO-EV+PA-EV: The emission of harmful gases is diminished and there is potential for further strong reduction.

CO-EV: As a positive external effect, green ecosystems are growing around electric vehicles. Their introduction has also led to more knowledge in the field of niche electric vehicles in (garbage collecting). Additionally, compliments were heard for the low level of noise.

PA-EV: Causes the growth, or even creation, of regulation and policy on the subject of EV.

Points of improvement

Charging

This factor includes all problems that are involved in charging the electric vehicle (EV) at the charging dock. This can range from physical operations to technical complications.

CO-EV+PA-EV: Differences in technical requirements between different net operators. Moreover, procedures governing the connection of charging docks to the network are not standard. Additionally, a shortage of charging poles and inexperience on the matter of charging causes problems. Not all charging docks are accessible with the ‘nationale oplaadpas’.

CO-EV: One of the problems associated with charging is the inability of vehicles, or charging docks, to support fast charging.

Comfort

This factor includes all problems that are involved in dealing with and driving in an electric vehicle.

PA-EV: Discomfort involving lifting charging cables because there is no automatic roll-up system. Additionally, comfort of cars is reported to be lower than in conventional transport.

Customer requirements

This factor includes mandatory requirements for the end-user that are made more difficult or cannot be met by electric vehicles.

CO-EV+PA-EV: The logistics involved are more difficult for EV, due to the changing driving range.

CO-EV: Lack of loading capacity (weight), which impairs the deployability of the vehicles.

Financial

This factor includes all the direct financial disadvantages of electric vehicles.

CO-EV+ PA-EV: Plug-in hybrids that are not being charged are potentially less efficient. Furthermore, high purchasing costs make the total cost of ownership higher than for conventional vehicles.

CO-EV: The financial factor first of all includes the uncertainty of residual value, and lifespan of vehicles. Additionally, if deployability is very low due to technical constraints, this strongly affects financial coverage. Furthermore, batteries have to be depreciated quickly. Lastly, electric vehicles do not yet offer sufficient competition to conventional transport due to the limited amount of subsidies.

PA-EV: To begin with, high costs are involved with connection to the existing power network. Also the purchase cost of cars is higher. In some cases, no profitable business case is yet possible due to the shortage in range.

Range

This factor includes the disadvantages of the limited range associated with EV.

CO-EV + PA-EV: Due to limited range of EVs, the user and vehicle should be matched according to range needed. When not matched correctly a situation is likely that the user does not use the EV at all.

CO-EV: The range factor in all cases has to do with a shortcoming in action radius. The direct consequence is limited deployability of vehicles. Deployability of CO-EVs is mostly restricted to environmental zones in traffic-dense city centers. The range decreases particularly in cold weather.

PA-EV: The drivable distance is limited and thereby the convenience of use. The range decreases particularly in cold weather and strong winds. Furthermore, people show the tendency to travel shorter distances, which is disadvantageous for taxi companies, for instance. Additionally, this type of personal transport requires a minimum amount of kilometers for a profitable business case, which cannot be reached at the moment.

Regulations

This factor includes problems with legal regulations, set by local or national government..

CO-EV+PA-EV: Much legal hassle is involved in the request of permits and the placing of charging docks. Additionally, there is currently no possibility to fine regular cars that park at EV charging points. Furthermore, no uniform parking policy exists in the different municipalities. Also, obtaining permits involves a lot of legal difficulty. Lastly, subsidies now work in a way that might not be solely beneficial to EV. For instance, hybrid owners that do not use the hybrid functionality benefit from the 0% addition regulation.

CO-EV: Firstly, through the introduction of batteries the vehicle weight may rise over a threshold that causes problems like a mandatory type of drivers license or the obligatory installation of a tachograph. Additionally, sudden changes in regulations, due to the early state of the EV life, may result in mandatory inspections or changes to vehicles, causing additional costs and downtime.

Reliability

This factor includes problems that regard the reliability of electric vehicles.

CO-EV: Reliability includes the extent to which owners can be sure that they can deploy their vehicles. It therefore includes downtime.

Service

This factor includes problems that have to do with maintenance of EV.

CO-EV: No existing service network, no local dealer, no spare parts in stock.

Suppliers

This factor includes problems with suppliers of EV.

CO-EV: At the time of the project reviews, there was a very limited amount of suppliers, which increases risk and reduces choice, as well as little competition. Also the suppliers are relatively small and therefore susceptible to problems like sudden bankruptcy. A final, persistent, problem is the long delivery times.

PA-EV: At the time of the reviews there was a very limited amount of vehicles to choose from.

Technology

This factor includes general technical problems that occur in dealing with EV.

CO-EV: A lot of small technical problems which lead to more downtime and high service costs. Furthermore, batteries have to be depreciated quickly because the battery capacity quickly deteriorates.

A.2.2 Qualitative part: Project analysis

Plan/initial situation

Plan/initial situation	1	2	3	4	5	6	7	8	9	Mean
	GW	GC	RE	GA	TE	HL	CP	HT	UPS	score
Clear purpose and target group?	5	5	5	4	5	3	5	3	5	**4.4**
Defining research - type of transport - magnitude and duration.	3	3	5	4	4	2	1	5	5	**3.6**
Which stakeholders are involved?	4	3	5	2	5	3	2	5	1	**3.3**
What is their position, importance and influence?	4	3	5	2	4	2	4	4		**3.5**
Principles / assumptions / definitions?	3	3		3	4	3	3	4	4	**3.4**
Implicit assumptions -> how explicit?	4		4				2			**3.3**
Research period - when and duration?	2 / 6 2011 – early 2013 ??	1 / 8 2011 – mid 2013	4 / 2012-3 2013	11. 2010 – mid 2013 ?	5 2011 – 3 / 2013	4 2012 – 6/2013	19-4 till 17-8-2010 + short period later	End 2013 ? Till ?	28.11.13 – 7.3.14	
1=low, 5 = high							**Total mean score**	**3.6**		

Process

Process	1	2	3	4	5	6	7	8	9	Mean
	GW	GC	RE	GA	TE	HL	CP	AH	UPS	score
Target group / research object in line with plan?	3	3	5	1	4	4	2	5	5	**3.4**
Circumstances re. existing laws. Infrastructural conditions	3	4	4	2	3	4	2	4	4	**3.3**
Collaboration - researchers with research object vs. client (s) vs. external parties. Were the right people / parties promptly involved in the project?	5	3	5	1	4	4	3	5	5	**3.9**
Technique (s)	3	2	3	4	4	3	0	4	4	**3.0**
Available resources sufficient? Financial. Knowledge. Experience. Communication. From whom?	4	2	5	4	4	3	2	3	5	**3.6**
Methods - current. this corresponds with the question? - Expensive? - Sample size? Data processing?	4	2	5	0	4	4	1	5	3	**3.1**
What criteria are applied and how has monitoring taken place?	5	2	5	0	5	4	2	5	2	**3.3**
Consulted external sources? Role. number and quality?	1		1		3	3		4	1	**1.3**
Were there any unexpected events? How to deal with this?	2	3	3	0	4	5	2	4	3	**3.3**

1=low. 5 = high

Impact/results

Impact / results	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean**
	GW	**GC**	**RE**	**GA**	**TE**	**HL**	**CP**	**AH**	**UPS**	**score**
Desired outcome achieved? Degree of answering research purpose or goal	2	3	5	1	5	4	3	5	5	**3.7**
Desired outcome useful?	4	4	4	1	4	1	2	5	5	**3.3**
Assessment. The translation to result or reality? Weighting factors?	3	4	5	1	4	1	4	5	5	**3.9**
Business case made? Assumptions. € payback. technique (s)	4	2	1	1	5	2	3	5	4	**2.9**
State of the art?	4	2	3	2	3	3	3	5	5	**3.3**
Reliable / Valid? - Substantiation?	4	2	4	1	4	4	2	4	4	**3.2**
Desired result achieved? Degree of answering research purpose or goal. desired result useful?	2	1	4	4	3	2	1	5	4	**2.9**
1=low. 5 = high							**Total mean score**	**3.3**		

Impact / results

Main Conclusions Per Project
Most important findings that formed the basis for the assessment

Passenger transport (Pa-EV)

Pa-EV / Greenwheels / Shared cars

- Period: Feb. / June 2011 - early 2013
- Concrete figures are available, business case not feasible
- Peugeot iOn, purchase 3x as expensive as 107, 15% fewer reservations, 66% less mileage than gasoline cars.
- Peugeot iOn uses 44% more energy than anticipated
- Electric cars have not ensured an (expected) increase in Greenwheels Customers.
- Free Parking hardly motivating
- Final conclusion: feasible in 2-4 years, but Greenwheels stopped offering EV!
- Compare with Car-to-Go concept!

Pa-EV / GreenCAB Electric taxis

- Period: Start Jan / Aug 2011 - Mid 2013
- Scheduled 18 cars - Realization 16 cars
- OEM suppliers were not ready in 2011
- iMiev: 80km radius, Nissan Leaf: 125km. Desired to be profitable: 320km
- The deployment of Essent is described as "very disappointing". A green energy contract has been agreed.
- Concrete figures are available, business case not feasible
- Inadequate launching customers → scale not met
- Mercedes give taxis an extremely high discount on the purchase! Influence BPM?
- Daytime charge also costs the driver time and money
- People in wheelchairs were barred (limited space for the battery)
- Infrastructure costs much higher than budgeted
- Operational Director was meanwhile appointed but not budgeted for.

Elektropool Haaglanden

- Period: April 2012 - June 2013
- Total of 12 EV's.
  - 8 shared EVs + 3 individual driver EVs (8 PU (iMiEV C-Zero, Peugeot iOn, Nissan Leaf + 3 Hybrid Ampera)
  - 1 EV van for Courier work (Renault Kangoo EV)
- Remote monitoring and driver research
- Strong focus on charging behavior
- No insight into sub segments
- No information on business case or TCO
- "Car sharing in the area Koningskade-Raamweg" has not got off the ground.
- Many obstacles (including change of partners and not getting financing because the subsidy fund was empty).

Passenger transport & Cargo transport & urban distribution - Pa-EV/Co-EV

Pa-EV & Co-EV Rotterdam

- Period: April 2012 to March 2013
- 75 EVs for service technicians and pool cars
- Stedin, Eneco and municipality Rotterdam driving forces
- Goal: Testing grid load and clean air
- Segments: Distinction between segments like (PHEV (hybrid) and (B)EV not easy to establish
- External reporting: many monitoring data on e.g. ranges and charging behavior
- Business cases / TCO made
- Purchase costs too high, lower consumption no compensation
- Large range differences between cars
- Hybrid frequency of EV charging depends on attitude of driver
- Winter: consumption at 0° C is 40% higher than at 15° C
- Driving style: power consumption is 30-40% less than for an inefficient style
- Potential: full EV at the municipality much higher (60%) than Stedin (18%) and Eneco (27%)

Texel Hospitable EV

- Period: Start in May 2011 - March 2013
- 26/24 drivers in 13 different cars
- Hybrid and electric
- Relatively small island (20x8km on average), generally short distances
- Wide consortium
- Goal: image improvement: EV-island
- Segments: no detailed info
- Technical problems limited monitoring
- Initial legal, financial, organizational barriers largely solved
- Intend follow-up with sequel project " Sustainable Texel Electric "

Cargo transport & urban distribution - Co-EV

Co-EV / Combipakt

- Goal: 7 cars - City distribution - Albert Hein
- 1 Smith & Newton 19-4 to 17-8-2010, successor Renault Maxity did not meet the requirements and any other potential candidate Modec went bankrupt in the course of 2011
- AGV (importer Smith & Newton) went bankrupt in 2012. In spite of that Smith & Newton is back in operation
- Insufficient power of batteries at Smith & Newton → no journeys on very cold winter days
- Necessary fast loading in combination with AC technique was not possible and is likely to affect degeneration of batteries
- Impact on motivation of participants including drivers
- Project completed by the end of 2012 - Report dated 18-7-2013
- Measurement results proved unreliable - Protocol, supplier, knowledge
- Albert.nl and DPD want to experiment further, but are not prepared to pay a higher price
- Meanwhile Combipakt is still experimenting with 3 trucks from Smith & Newton
- Still lack of mechanics who have EV knowledge → too many downtime losses
- Still not a suitable supplier available. Potential supplier: OEM supplier in Istanbul.

UPS Courier

- Internal problems at initial participant Duncker → Project taken over by UPS
- 6 vehicles
- Period 28/11/13 - 7.3.14
- EFA-S (Mercedes Chassis), 90kW, 61kWh battery, 80km, relatively light cars and easy to build
- After a period of teething problems concerning reliability, it became comparable with diesel at the end of the period
- Positive operation - subsidy included - mild winter

Gansewinkel – Garbage

- Goal of 8 trucks achieved
- Spijkstaal - project started in 2008 with a grant from the RCI (Rotterdam Climate Initiative)
- Period 11.2010 - mid-2013? (First car November 2010, July 2012 last car)
- Influence reorganization on project?
- Unclear reporting
- Bottlenecks
    - Limited range solved with heavier batteries in newer cars
    - Not all round operational
    - Fault sensitivity improved during project period
- Subsidy seems to be used as a start-up grant
- Separate study: TCO Binkie appears cheaper than diesel variant, but this is not reported
- Spijkstaal continues further pilots with Binkie

Hytrucks – Finalized after initial WP1 formation

- Initially, Smith & Newton, Renault Maxity did not meet the specs → Hytrucks
- Extra delay due to bankruptcy supplier components Hy-Trucks
- Project finished as last project: 6th car was put into operation in July 2014
- The perfect tuning of the necessary electronics proved problematic, now appears to be resolved.
- Adaptations needed per electric truck depending on application.
- Local charging facilities have to be created (63A charging dock)
- Longer service times due to absence of a dealer network
- Range in urban environment seems to be large enough
- Marketing/Image opportunities for participants are large.

Participants

- 2Switch, Arnhem – Shop in used products for a second life - Project with people with distance from the labor market – Pick-up and delivery of goods in urban areas - Hytruck C12E-120 (12 ton GVW)
- Vroegop-Windig, Amsterdam. Wholesale in vegetables and fruit, fine distribution with cooling - Hytruck C12E-160 (12 ton GVW)
- Peter Apel Transport, Middenmeer, Food service supplies combined with cooling and freezing = Sligro. Hytruck 12 ton GVW Range 170 km, dependent on the intensity of the electric cooling. of course). The 63 Amp plug in Amsterdam: In four hours, the battery pack is fully charged again.
- Aad de Wit, Castricum, removals. End 2013-4 Hytruck C12E-200 (12 ton GVW).
- Deudekom, IJmuiden, removals, Hytruck C16E-160 (16 ton GVW) for moves into urban areas. The city of Amsterdam facilitated this with a grant
- Boudesteijn Movers B.V, Verwijk - Hytruck C16E-200 (16 ton GVW)
- G. van der Heijden Distributie B.V. - Heineken beer - catering in Rotterdam – 2013, Hytruck C18E-160 (18 ton GVW)

- De Rooij transport, 't Goy (Houten) - zero-emission urban distribution, Hytruck C18E-200 (18 ton GVW). Delivered in July 2014. Battery Package 200kWh - the perfect adjustment of the necessary electronics proved problematic

The monitoring results of this project were finalized in January 2015.

A.2.3 Concluding Analysis

The occurrence shows the percentage of pilots in which the key factor was mentioned in similar fashion. The impact is the average score the key factor rendered in the score matrix, as described in Chapter 5.2.1. Since the average score does not include projects that have not described a certain factor, influence is introduced. This is a final multiplication of the occurrence and the impact, resulting in a score that considers both occurrence and impact (or importance) of a factor.

The standardized impact and influence assigns the highest score the value of 10 and scales the other results accordingly, resulting in a standardized score from 0-10.

The results can be interpreted as follows. The impact shows how important a factor is in the respective pilots where it occurred. Therefore, the impact shows how important a factor is compared to other factors, considering that they all occur in a pilot. The influence shows a more averaged impact to general EV pilots, regardless of whether the factors will occur or not. Thus, in order to draw conclusions, both impact and influence should be considered.

Key Factors (CO-EV + PA-EV combined)

Key factors ordered by occurrence

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Range	100%	4.9	4.9	7.1	10.0
Financial	75%	6.3	4.7	8.9	9.5
Charging	63%	3.8	2.4	5.4	4.8
Suppliers	63%	3.6	2.3	5.1	4.6
Regulations	63%	3.2	2.0	4.6	4.1
Technology	38%	7.0	2.6	10.0	5.3
Comfort	38%	4.8	1.8	6.9	3.7
Customer Requirements	38%	4.5	1.7	6.4	3.4
Reliability	25%	3.8	0.9	5.4	1.9
Service	13%	4.5	0.6	6.4	1.1

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	50%	4.5	2.3	6.9	9.2
PEE	50%	3.6	1.8	5.6	7.4
Comfort	38%	6.5	2.4	10.0	10.0
Charging	38%	4.8	1.8	7.4	7.4
Range	25%	6.5	1.6	10.0	6.7
Financial	25%	2.3	0.6	3.5	2.3

Key factors ordered by score (standardized)

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Technology	38%	7.0	2.6	10.0	5.3
Financial	75%	6.3	4.7	8.9	9.5
Range	100%	4.9	4.9	7.1	10.0
Comfort	38%	4.8	1.8	6.9	3.7
Customer Requirements	38%	4.5	1.7	6.4	3.4
Service	13%	4.5	0.6	6.4	1.1
Charging	63%	3.8	2.4	5.4	4.8
Reliability	25%	3.8	0.9	5.4	1.9
Suppliers	63%	3.6	2.3	5.1	4.6
Regulations	63%	3.2	2.0	4.6	4.1

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Comfort	38%	6.5	2.4	10.0	10.0
Range	25%	6.5	1.6	10.0	6.7
Charging	38%	4.8	1.8	7.4	7.4
Image	50%	4.5	2.3	6.9	9.2
PEE	50%	3.6	1.8	5.6	7.4
Financial	25%	2.3	0.6	3.5	2.3

Key factors ordered by influence (standardized)					
Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Range	100%	4.9	4.9	7.1	10.0
Financial	75%	6.3	4.7	8.9	9.5
Technology	38%	7.0	2.6	10.0	5.3
Charging	63%	3.8	2.4	5.4	4.8
Suppliers	63%	3.6	2.3	5.1	4.6
Regulations	63%	3.2	2.0	4.6	4.1
Comfort	38%	4.8	1.8	6.9	3.7
Customer Requirements	38%	4.5	1.7	6.4	3.4
Reliability	25%	3.8	0.9	5.4	1.9
Service	13%	4.5	0.6	6.4	1.1

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Comfort	38%	6.5	2.4	10.0	10.0
Image	50%	4.5	2.3	6.9	9.2
PEE	50%	3.6	1.8	5.6	7.4
Charging	38%	4.8	1.8	7.4	7.4
Range	25%	6.5	1.6	10.0	6.7
Financial	25%	2.3	0.6	3.5	2.3

Remarks Pa-EV + Co-EV

When looking at the points of improvement table which is sorted by influence, two factors clearly stand out. First of all **range** scores highest in the standardized product column, which is in great part due to the high occurrence. While the factor **financial** has the highest impact, it is less present (75%) and therefore comes second when looking at the product score (9.5). Remarkably, technology scores highest in the impact category, but its influence is far lower than financial or range, since it is present in only 38% of the cases.

For the strengths, **comfort** and **image** are most important. For comfort this is mostly due to the high score in impact. For Image, this stems from a high occurrence combined with a reasonably high impact.

Key Factors Pa-EV

Key factors ordered by occurrence

Points of improvement	*Occurrence*	*Impact*	*Influence*	*Stand. Impact*	*Stand. Influence*
Range	100%	5.2	5.2	7.9	7.9
Financial	100%	6.5	6.5	10.0	10.0
Charging	67%	4.0	2.7	6.2	4.1
Suppliers	67%	4.5	3.0	6.9	4.6
Technology	33%	6.0	2.0	9.2	3.1
Regulations	33%	4.0	1.3	6.2	2.1
Comfort	33%	5.0	1.7	7.7	2.6

Strengths	*Occurrence*	*Impact*	*Influence*	*Stand. Impact*	*Stand. Influence*
Comfort	33%	4.0	1.3	8.0	8.0
Image	33%	5.0	1.7	10.0	10.0
PEE	33%	2.5	0.8	5.0	5.0
Charging	33%	5.0	1.7	10.0	10.0

Key factors ordered by score (standardized)

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Financial	100%	6.5	6.5	10.0	10.0
Technology	33%	6.0	2.0	9.2	3.1
Range	100%	5.2	5.2	7.9	7.9
Comfort	33%	5.0	1.7	7.7	2.6
Suppliers	67%	4.5	3.0	6.9	4.6
Charging	67%	4.0	2.7	6.2	4.1
Regulations	33%	4.0	1.3	6.2	2.1

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	33%	5.0	1.7	10.0	10.0
Charging	33%	5.0	1.7	10.0	10.0
Comfort	33%	4.0	1.3	8.0	8.0
PEE	33%	2.5	0.8	5.0	5.0

Key factors ordered by influence (standardized)

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Financial	100%	6.5	6.5	10.0	10.0
Range	100%	5.2	5.2	7.9	7.9
Suppliers	67%	4.5	3.0	6.9	4.6
Charging	67%	4.0	2.7	6.2	4.1
Technology	33%	6.0	2.0	9.2	3.1
Comfort	33%	5.0	1.7	7.7	2.6
Regulations	33%	4.0	1.3	6.2	2.1

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	33%	5.0	1.7	10.0	10.0
Charging	33%	5.0	1.7	10.0	10.0
Comfort	33%	4.0	1.3	8.0	8.0
PEE	33%	2.5	0.8	5.0	5.0

Remarks Pa-EV

When judging the points of improvement specific to PA-EV, **financial** and **range** stand out. Financial comes out on top since it scores both highest on occurrence and impact. While range is also a weakness in all of the projects, its impact is slightly lower and is therefore second.

For the strengths, both **image** and **charging** come first, closely followed by **comfort**. Surprisingly, all factors are present in only 33% of the pilots.

Key Factors Co-EV

Key factors ordered by occurrence

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Range	100%	2.8	2.8	6.3	10.0
Financial	67%	3.8	2.5	8.3	8.8
Reliability	67%	3.8	2.5	8.3	8.8
Suppliers	67%	3.3	2.2	7.2	7.6
Customer Requirements	67%	3.3	2.2	7.2	7.6
Regulations	67%	1.8	1.2	3.9	4.1
Technology	33%	4.5	1.5	10.0	5.3
Service	33%	4.5	1.5	10.0	5.3
Charging	33%	1.5	0.5	3.3	1.8

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	33%	2.0	0.7	10.0	10.0
Financial	33%	2.0	0.7	10.0	10.0
PEE	33%	1.0	0.3	5.0	5.0

Key factors ordered by score (standardized)					
Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Technology	33%	4.5	1.5	10.0	5.3
Service	33%	4.5	1.5	10.0	5.3
Financial	67%	3.8	2.5	8.3	8.8
Reliability	67%	3.8	2.5	8.3	8.8
Suppliers	67%	3.3	2.2	7.2	7.6
Customer Requirements	67%	3.3	2.2	7.2	7.6
Range	100%	2.8	2.8	6.3	10.0
Regulations	67%	1.8	1.2	3.9	4.1
Charging	33%	1.5	0.5	3.3	1.8

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	33%	2.0	0.7	10.0	10.0
Financial	33%	2.0	0.7	10.0	10.0
PEE	33%	1.0	0.3	5.0	5.0

Key factors ordered by influence (standardized)

Points of improvement	*Occurrence*	*Impact*	*Influence*	*Stand. Impact*	*Stand. Influence*
Range	100%	2.8	2.8	6.3	10.0
Financial	67%	3.8	2.5	8.3	8.8
Reliability	67%	3.8	2.5	8.3	8.8
Suppliers	67%	3.3	2.2	7.2	7.6
Customer Requirements	67%	3.3	2.2	7.2	7.6
Technology	33%	4.5	1.5	10.0	5.3
Service	33%	4.5	1.5	10.0	5.3
Regulations	67%	1.8	1.2	3.9	4.1
Charging	33%	1.5	0.5	3.3	1.8

Strengths	*Occurrence*	*Impact*	*Influence*	*Stand. Impact*	*Stand. Influence*
Image	33%	2.0	0.7	10.0	10.0
Financial	33%	2.0	0.7	10.0	10.0
PEE	33%	1.0	0.3	5.0	5.0

Remarks Co-EV

When judging the points of improvement specific to CO-EV, it can be observed that there are now many more factors with a high score, as compared to PA-EV. **Range** is the factor with the most influence, followed by **financial** and **reliability**, which in their turn are followed closely by **suppliers** and **customer requirements**. Remarkably, technology and service both have a high impact, but have little influence due to their low occurrence.

As for strengths, both **image** and **financial** score highest. Again all the factors are present in only 33% of the projects.

A.3 Appendix on Results Analysis (Inter)national Projects (WP2/WP3)

A.3.1 Results Key Factor Assessment

Key factors ordered by occurrence

Points of improvement	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	**Stand. Influence**
Financial	100%	10.1	10.1	9.4	10.0
Range	100%	9.1	9.1	8.5	9.0
Charging	75%	8.5	6.4	7.9	6.3
Regulations	50%	10.8	5.4	10.0	5.3
Suppliers	50%	4.5	2.3	4.2	2.2
Technology	25%	6.0	1.5	5.6	1.5
Comfort	25%	5.0	1.3	4.7	1.2

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	50%	9.5	4.8	10.0	10.0
Comfort	50%	9.0	4.5	9.5	9.5
PEE	50%	8.3	4.1	8.7	8.7
Charging	25%	5.0	1.3	5.3	2.6

Key factors ordered by impact (standardized)					
Points of improvement	***Occurrence***	***Impact***	***Influence***	**Stand. Impact**	**Stand. Influence**
Regulations	50%	10.8	5.4	10.0	5.3
Financial	100%	10.1	10.1	9.4	10.0
Range	100%	9.1	9.1	8.5	9.0
Charging	75%	8.5	6.4	7.9	6.3
Technology	25%	6.0	1.5	5.6	1.5
Comfort	25%	5.0	1.3	4.7	1.2
Suppliers	50%	4.5	2.3	4.2	2.2

Strengths	***Occurrence***	***Impact***	***Influence***	***Stand. Impact***	***Stand. Influence***
Image	50%	9.5	4.8	10.0	10.0
Comfort	50%	9.0	4.5	9.5	9.5
PEE	50%	8.3	4.1	8.7	8.7
Charging	25%	5.0	1.3	5.3	2.6

A.4 Appendix on Results: International Projects

A.4.1 Appendix on Passenger transport

A.4.1.1 Range

It should be noted here that in both cases the business case was also adapted to the use of EVs. Taxi Electric is a call-up taxi service that only offers door-to-door service. Therefore, the range can be planned for every trip. Additionally, there are extra vehicles to cope with the charging time and taxi drivers are independently scheduled from the vehicles. At Schiphol, several companies can only operate by concession aimed at minimal or zero emissions. Moreover, they use advanced monitoring applications to increase the range up to 25% by smart planning [3]. Probably urban-based taxi pilots and companies are able to profit more from technologies like rapid charging, which provides relatively fast recharging up to a certain level. These superchargers can provide up to 80% re-generation of charge, in 30 minutes [31]. When recharges are planned in a smart way, these could be scheduled during a break of specific taxi drivers. Rural taxi companies and pilots may see more difficulties with the range, since longer distances have to be travelled [4]. Therefore, rural areas could aim at intermodal transport projects, which incorporate different means of transport, including public transport and a variety of small and large EVs, as in the ENEVATE project in Germany.

Future outlook

Since the evaluation of the first pilots, it is already noticeable that the average range of electrical vehicles has increased. The range of EVs is very reliant on the prices of batteries and the energy density. Both are predicted to change in favorable direction. Figure 7.1.2 shows the cost predictions for batteries over time. Notice that on average the costs are predicted to be half of 2015 by the year 2020. This would imply the same prices with double the amount of installed batteries and potentially double the range. Battery development is at least expected to not hinder electrification of small to medium sized vehicles [34].

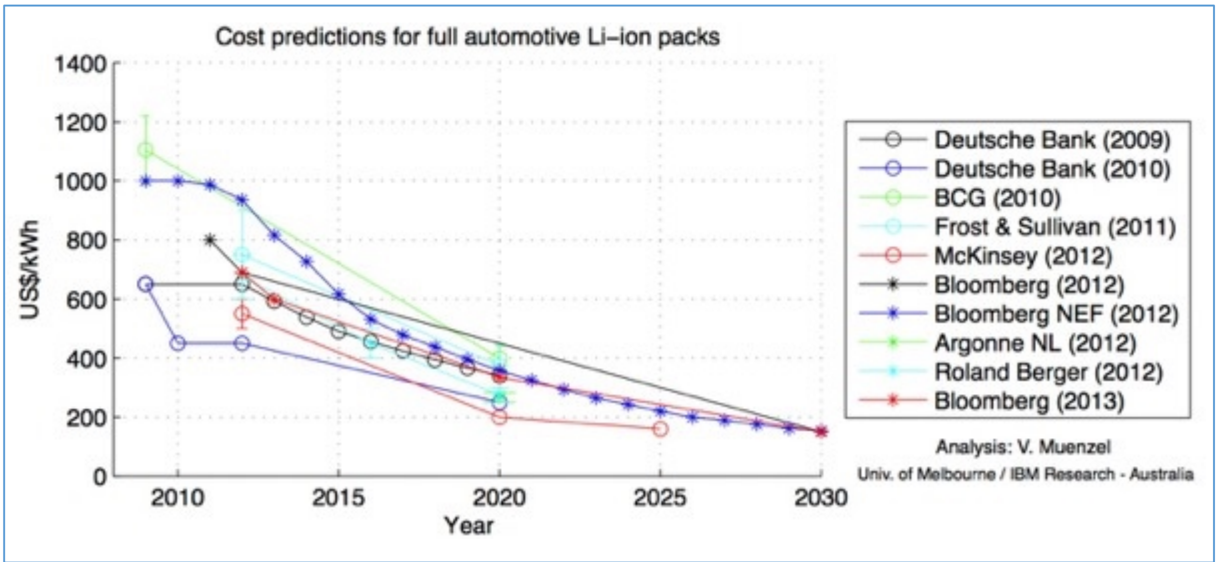
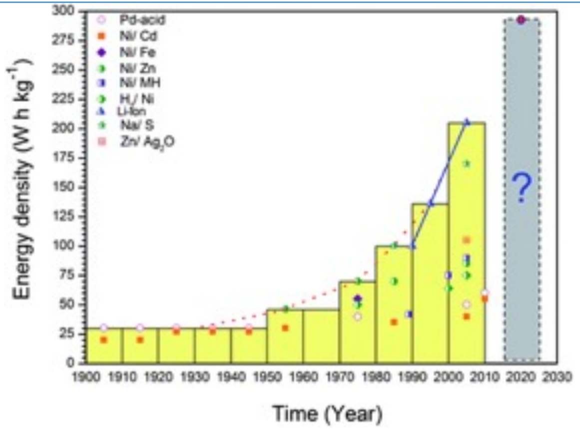
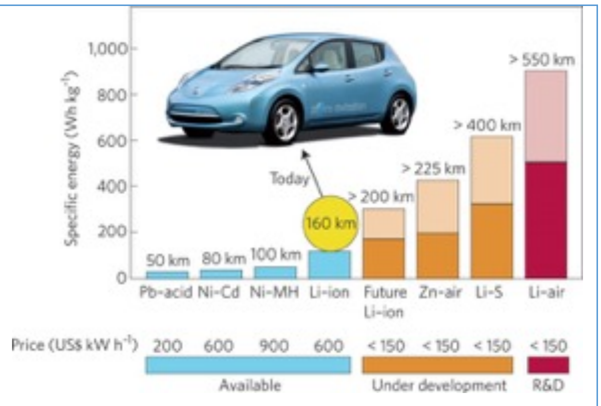


Figure 7.1.2: Cost predictions for full automotive Li-ion packs

In figure 7.1.2.2a the energy density of batteries in Wh/kg is shown over time. Although the accuracy of figure 7.1.2.2a is debatable, the fact that energy density is increasing should be apparent. The increase of energy density decreases the weight of future electric vehicles, resulting in increased range. In Figure 7.1.2.2b the expected future energy density and driving range is shown by the introduction of new battery techniques.



(a) Energy density of batteries in Wh/kg over time



(b) Energy density versus future development battery types and driving range

Figure 7.1.2.2 Energy density over time

A4.1.2 ***Financial***

As shown in Figure 7.1.2.3, fleet managers believe the total cost of ownership is a problem with EVs.

Textual categories	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6	Firm 7	Firm 8	Firm 9	Firm 10	Firm 11	Firm 12	Firm 13	Firm 14
Total ownership cost	−1	−1	−1	−2	−2	+3		−1		−1			−1	−1
Fixed routes				+1						+1				+1
Central refueling				+1			+2		+1					+1
First mover advantage								+3				+3	+3	+3
Lower env. impact		+2	+2	+2		+2	+1	+1	+2			+1	+1	+3
Govt. regulation				+3	+2									
Govt. grant	+2	+1	+1		+1		+1	+1			+1		+1	
Test new technologies		+3	+1	+3	+3	+3				+1	+1	+3	+3	+3
Improve public image	+1		+1	+1		+1	+1			+2		+1		

Legend
+ Positive factor (greater numerical value indicates increased emphasis)
− Negative factor (greater numerical value indicates increased emphasis)

Figure 7.1.2.3: Fleet managers' adoption influencing categories

The question is, however, whether the TCO of an electric vehicle, in personal transportation, is still higher compared to a conventional vehicle. Figure 7.1.2.4 seems to suggest that the TCO of a Nissan Leaf is lower than a comparable conventional vehicle, due to the reduction in fueling costs [27].

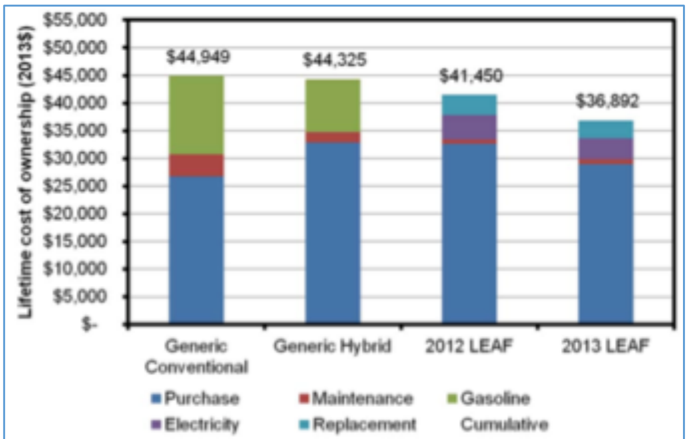


Figure 7.1.2.4: TCO of Nissan Leaf

Figure 7.1.2.5 shows that 36 percent of the interviewees believe that the TCO of an EV is lower than a conventional car. This is in contradiction to the reality, as the price of a Nissan LEAF, shown in Figure 9, has dropped. With these models the TCO alone might result in more viable business models. However, it should be noted that with older EV models range and reliability concerns return. Therefore, it can be assumed that, currently, a lower TCO in the personal transportation sector can only be reached when enough kilometers are driven while maintaining a central charging strategy [27]. In order to reach a high amount of kilometers several projects have found specific solutions, as in ENEVATE 2.0 by means of car sharing in Limburg [32]. The car share program in Limburg utilizes EVs during daytime as corporate cars, while releasing them in evenings and weekends to citizens, maximizing kilometers and minimizing the amount of cars in the area.

Figure 7.1.2.5: Attitude towards and assessment of electric cars - EU level [11]

A4.1.3 Charging

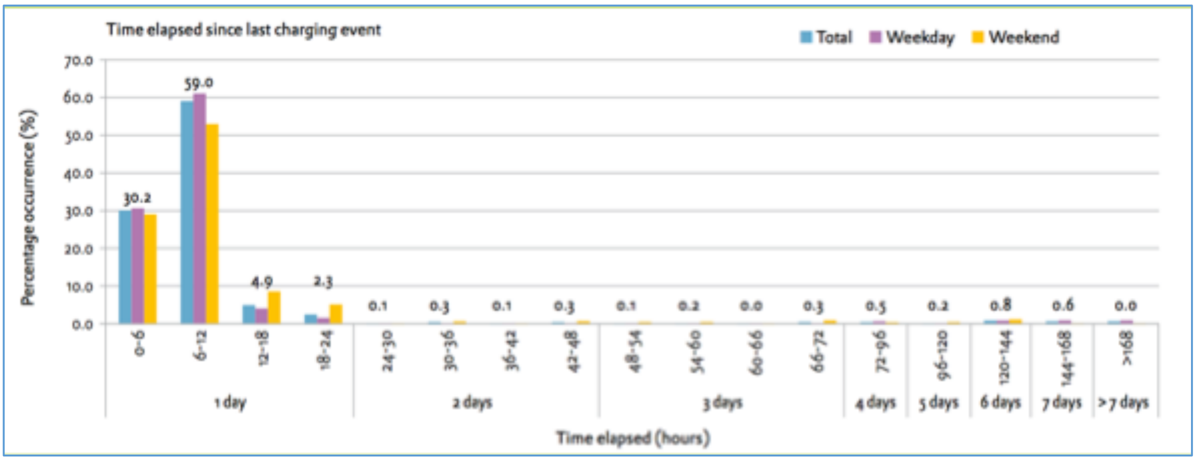


Figure 7.1.2.5: Time elapsed since last charging event [13].

In private personal transport applications, only seven percent of the customers find an extensive network of charging stations irrelevant in purchasing an EV [11]. That means that this is an important factor in buying an electric car and is a potential threat to market development, when knowledge about actual range is scarce among consumers. The misperceptions in range means that customers expect to charge once or more during a journey, which puts extra emphasis on this key factor.

In interviews, most expert respondents believe that the existing charging infrastructure is the biggest problem in the current EV landscape [4]. The roll-out rate of new (public) charging stations is decreasing, which hinders the development of new consumers but also drivers and companies involved in car sharing or taxi business (for the occasional public charge).

It should be noted that current maximum refueling speed for EVs is much lower than for conventional vehicles. When recharging is possible in matters of minutes, the somewhat limited range factor on longer trips decreases drastically in influence. If charging is cheaper and refueling only takes one or two magnitudes in time more than conventional refueling, consumers will probably quickly become much less hesitant.

A public charging grid is not necessary for drivers and businesses that maintain a preferably frequent central charging strategy. These drivers and businesses return their fleet, after a job has been completed, to a central location. In this central location charging can take place. Business models that are built upon this principle seem to be more profitable [17]. Interesting in this respect is the difference between the pilot of *Greenwheels* and the well-received electric *Car2Go* service in Amsterdam. The business concept of *Car2Go* for Amsterdam is pure electric. This means that the customer is clearly informed about what he or she gets. And the other crucial difference is that *Car2Go* uses the public charging infrastructure and has no reserved parking places. This means that no investment was needed in that, which was beneficial for Car2Go and the charging pole operators since the occupation increased. And last, but not least, Car2Go introduces smart incentives for the user to re-charge the cars. The Director of Mercedes-Benz Netherlands claims that although this is a new concept it is nearly profitable already.

In addition, business models that rely on transportation during focused times of the day, such as transportation commissioned by schools or the transportation of elderly and disabled people could potentially benefit from EVs. These business models may also apply the central charging strategy in order to serve customers, for example, during the morning and afternoon. During the rest of the time, the vehicle can be charged at relatively low speeds using the most basic and thus cheapest charging stations available.

A.4.1.4 Regulations

In interviews with pilots and pilot evaluation literature, local regulations are found to be lacking for several reasons. Firstly, there is limited permission to place private charging stations in public spaces and, if permitted, multiple and different procedures are enforced by local authorities [4]. Due to limited range and longer charging times, EVs are currently most applicable to highly urbanized areas, where the average dwelling space per capita is assumed lower than in rural areas. Therefore, this living space is efficiently used by outside car parking, most of the time in a public space instead of in a garage or private space. Given this, charging accommodation should be provided. EV users charge daily, as shown in figure 7.1.2.6, therefore, they will need the security that charging stations are available on daily basis. If a private charging station on private property is not possible, the following options exist:

- Large availability of public charging stations, thus consumers do not need to worry about a charging station being available or not.
- Having a personal charging station available in a public space.

Currently, both options seem to cause problems. Local authorities are reducing the rollout rate of public charging stations and there are simply not enough public charging stations in the Netherlands to allay the concerns of consumers. The second option is not possible either, since private investments in public spaces are often not allowed. Authorities will probably have to change their stance on private investments in public spaces that facilitate the steps that the government wants to take in the field of electric vehicles. Previous problems seem to arise mostly in urban areas, where public and private space is limited. The eMAP project notices that a shift in focus towards suburban areas could alleviate these problems, since charging at home is easier and areas around shopping centers can more easily accommodate charging docks [33].

Furthermore, different cities apply different legislation on having charging stations. Although stimulation in key areas can accelerate the adoption of EVs, it could just as well create unequal playing fields on a national level. At least having the same measures of stimulation throughout the

Netherlands would provide consumers and businesses with a clearer idea of the possibilities and restrictions in the legal area of EV. Having general rules on building charging docks in the Netherlands could accommodate more companies developing national business models on charging infrastructure, improving the conditions for charging and thus range. Having general legislation on reduced emission zones in certain cities could also speed up the adoption of cleaner and thus electric cars. Although the EU is already very ambitious regarding general emissions, as shown in figure 7.1.2.7, stricter regulation could be introduced to all city centers.

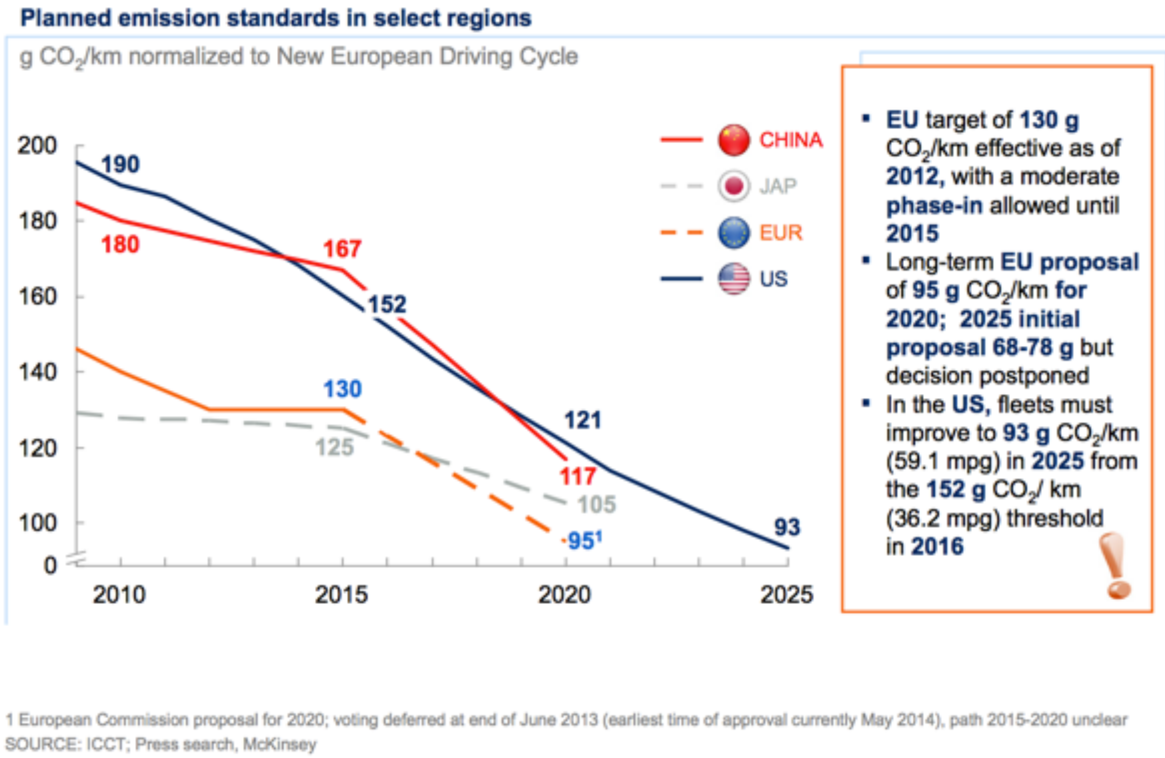


Figure 7.1.2.7 Planned emission standards in select regions [15].

The national legislation already in place is found to be ineffective when taken into account that plug-in hybrids are also subsidized. Research shows, already in WP 1, that PHEV are not charged enough and often only bought for the fiscal benefits. Since normal EVs have evolved in range, it should be considered to reduce the amount of benefits when buying a PHEV, also taking into account that the wrong usage of PHEVs can be more harmful in terms of CO_2 emissions than conventional cars.

Apart from national legislation aimed at stimulating the adoption of EV, national and local authorities should examine the possibilities of increasing the adoption rate of EVs in their own fleet. The government could not only lead by example, but also be a suitable candidate in terms of the requirements it sets for its fleet. The expansion of the fleet and charging points for government purposes can be realized by carefully designed public procurements, which can be used to provide stimulation in specific areas of the EV world.

Last but not least, semi-public procurements for public transport and private transport in, for example, Schiphol can focus more on providing a push in the direction of EV. The procurement procedure of Schiphol has been very effective in the introduction of electric vehicles, mostly by produced by Tesla. This shows that a push in the right direction, by awarding companies that come up with cleaner EV transport solutions in procurements, actually works. Additionally, Schiphol can be considered as a key location, which can be used to promote the Netherlands as an EV country and can be used as a proof of concept at the same time. In these cases, the results of the project can be considered as a winner in all terrains.

A.4.1.5 Image or Positive External Effects

In WP1, the factor appeared as important in the positive appeal that an EV can bring to companies and projects. During the interviews and literature study performed, the two key factors image and positive external effects were perceived to be the same. Therefore, the key factors are described together in this subsection, focusing more on the positive opportunities that EVs bring. The positive opportunities that come with EVs are perceived to be one of the key strengths in the transition to electric mobility [2] [3]. These opportunities are also recognized by McKinsey, as shown in figure 7.1.2.8.

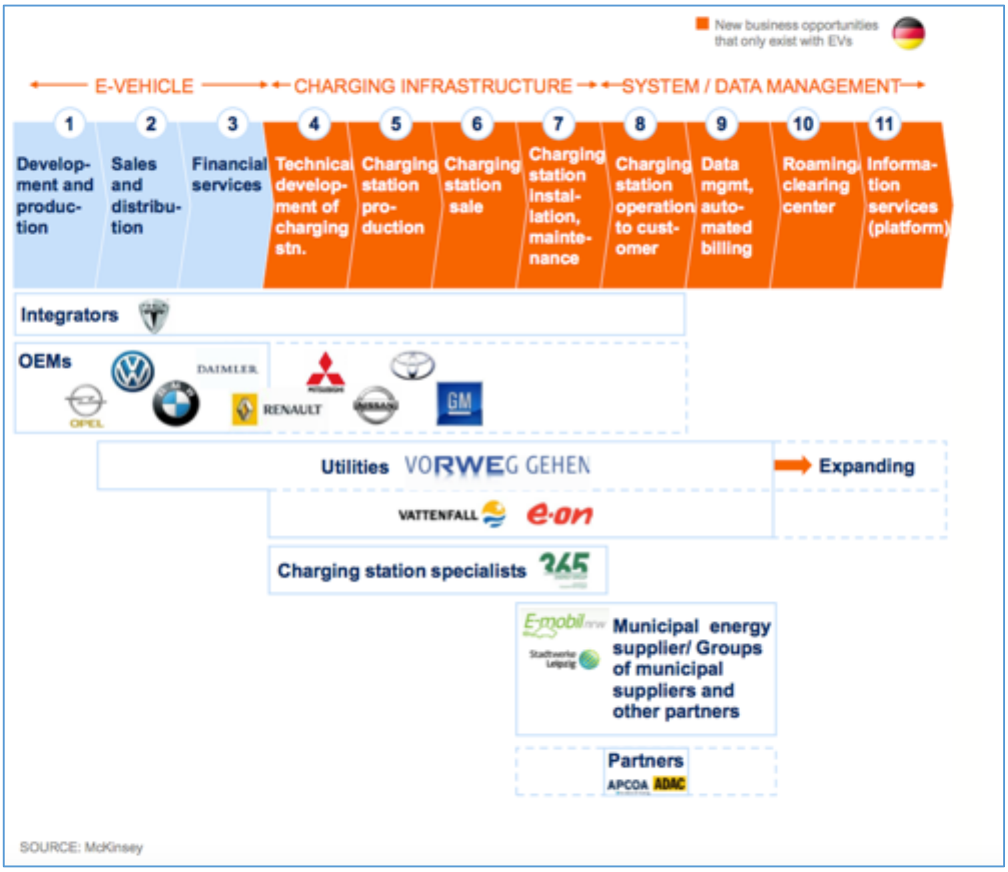


Figure 7.1.2.8: New business opportunities that only exist with EVs [15].

The driverless car will probably be electric, due to large adaptations that have to be made to the current model of cars we know[28] and due to the fact of electric cars are cheaper when driven enough on an annual basis. The driverless car introduces the possibility to cope with all the negative factors using well-designed software, rapidly opening doors for EVs.

If the shift from centralized to local generation of energy is continued, electric vehicles could play an integral role in the energy grid. Firstly, an electric car could be charged at different speeds when not in use, opening doors in the storage of excess energy during off-peak hours. An electric car could also play a role in storing excess energy generated by solar cells or micro combined heat and power generation units, such as fuel cells, when local demand is low. Last but not least, the car could even generate energy, as the car Stella designed and produced by Solar Team Eindhoven shows. Stella uses solar cells, as shown in figure 7.1.2.9, to charge the batteries during operation, but can also provide energy to the grid when parked in the sun. Previous opportunities have the potential to reduce the impact of the financial factor, making EVs more affordable over its lifetime.

Figure 7.1.2.9: Electric vehicle (Stella by Solar Team TU/e Eindhoven) supported by solar cells.

A.4.2 Appendix on Co-EV (WP2/WP3)

A.4.2.1 International Projects on Co-EV

For commercial vehicles, we have made a list of EV-projects. In the Netherlands, there are no new pilots on commercial vehicles, but a few parties are participating in three European projects: FREVUE, ZeEUS and Green eMotion.

These projects cover all of the key modes of electrified transport and will gather results by live demonstrations. The central goal is to provide stakeholders and decision makers with all of the key information and results to help implement the wide scale adoption of electro mobility. The focus of these projects as follows:

- Green eMotion is mainly on passenger cars but contains some information on commercial vehicles.
- ZeEUS on City buses
- Frevue on commercial vehicles.

The status of these projects were presented at the EEVC-2014, Brussels, 2nd to 5th December 2014. On the 3rd European Electromobility Stakeholder Forum 25 and 26 February 2015 in Brussels the results of Green eMotion, were presented. We briefly describe the status and key results here.

Green eMotion

Launch: 2011 – February 2015

After four years, Green eMotion ended in February 2015. The project defined and demonstrated a European framework for electro-mobility that connects all stakeholders for a seamless, cost-efficient and interoperable electro-mobility ecosystem. Starting in 2011, the project developed prototypes to connect the islands of electro-mobility existing at the time. An overarching ICT architecture was defined and standards, especially for ICT interfaces, were set. New business models for a public charging infrastructure was analyzed and ways shown for its optimized integration into the grid. Within ten demo regions and two replication regions, Green eMotion demonstrated that the project findings really work in practice and support the establishment of an electro-mobility environment from scratch. The following points are relevant for commercial vehicles: urban distribution and the impact on the grid.

Urban freight distribution network

It is very important to understand the specific needs of different supply chains in urban areas. The goods distribution is different in every case: there are different needs such as weight, delivery times, refrigerated vehicles, etc. Among the key features to deploy the urban freight electric vehicles would be: planning and organization of the urban freight distribution network, the creation of green logistic centers and loading and unloading charging areas, access to controlled zones with small electric freight vehicles, the application of the new ICT technologies for the management and control of urban freight distribution, reduction in the mobility taxes or purchase taxes for freight electric vehicles and incentives for Zero Emission & Zero Noise delivery in urban areas.

Impact of charging on grid

In respect of the impact of charging on the grid, the key message of the Green e-Motion study is that because of electricity unbundling, different electricity businesses (generation, transmission, distribution and retail) are involved. Independent business actors are running all these activities. Therefore, charge management (incl. smart charging) needs to be a coordinated process among these actors and cannot be identified under an unique regulation.

Charging
The Green eMotion analysis of the business models for public charging infrastructure revealed that public charging is a difficult business case today. The results lead to the conclusion that the business case of public charging as a standalone business can only be profitable within such mid-term business scenarios such as highly frequented charging stations. Hence, the charging stations need to be located at points of interest, so that people are willing to pay for the usage, and usage time must be short enough to allow for several charging events per day. An option to improve the business case of public charging is the combination of different businesses. Examples are advertising, parking in a parking lot, or to use charging to attract people for other services like shopping, cinema, food & drink etc.

FREVUE
Launch: December 2013 – End date 2017

FREVUE (Freight Electric Vehicles in Urban Europe) will demonstrate to industry, consumers and policy makers, how electric freight vehicles can provide a solution to many of these problems.

127 Electric freight vehicles will be exposed to the day to day rigors of the urban logistics environment and prove that the current generation of large electric vans and trucks can offer a viable alternative to diesel vehicles; particularly when combined with state-of-the-art urban logistics applications, innovative logistics management software and well-designed local policy.

Co-funded by the EU Seventh Framework Programme (FP7), the demonstration projects will occur in Amsterdam, Lisbon, London, Madrid, Milan, Oslo, Rotterdam and Stockholm.

The demonstration projects have been designed to ensure the range of conditions that are common across Europe are covered, including:

- Goods deliveries (including food, waste, pharmaceuticals, packages and construction goods)
- Novel logistics systems and associated ICT (with a focus on consolidation centers which minimize trips in urban centers)
- Vehicle types (from small car-derived vans to large 18 ton goods vehicles)
- Climates (from Northern to Southern Europe)
- Diverse political and regulatory settings that exist within Europe

The final objective will be to encourage the exploitation of the results through a targeted dissemination campaign aimed at decision makers across the logistics industry and associated policy makers and regulators.

Heineken and UPS, which participated in the Netherlands Enterprise Agency pilots, are also participating in the Frevue project. TNT has just announced in June 2015 that it will join the FREVUE project and deploy seven new 3.5-ton e-Ducato vehicles for its operations in and around Amsterdam and Rotterdam. TNT makes also use of certain privileges such as exemptions from parking bans and access to closed areas outside loading and unloading times. These plans fit in well with the Green Deal Zero Emission of the City of Rotterdam. TNT's electric fleet in the Netherlands is at the moment nine in total.

Figure 7.2.1.1 Electric Ducato for TNT

The eDucato vehicles are converted Fiat Ducatos supplied by BD Auto in Alphen aan den Rijn.

The project is nearly halfway and final results will be published in 2017.

ZeEUS
Zero Emission Urban Bus System

ZeEUS
Launch: 2014 – End: 2017

UITP (International Association of Public Transport, a non-profit international association for sustainable mobility) coordinates a consortium of 40 partners to work on the 42-month demonstration project ZeEUS aiming at extending the fully electric solution to a wider part of the urban bus network. Developing electric vehicles of large capacity and creating an infrastructure able to provide the required charging energy will facilitate the market uptake of electric buses in Europe. ZeEUS covers innovative electric bus solutions with different electric powertrain systems to be demonstrated in eight cities: Barcelona, Bonn, Cagliari, Glasgow, London, Münster, Plzen and Stockholm. ZeEUS' analyses will allow developing guidelines and tools to support stakeholders in efficiently introducing electrified bus systems in European cities

Up to May 2015 there are not yet interim results published. In the stakeholder forum in Brussels on 25 and 26 February, 2015 the project set-up was presented. One could conclude that the variety in deployment and operating conditions between the participating cities differ very much and that one overall solution is not realistic. The involvement of OEMs is clearly visible and together with the big number of cities and their plans it can be expected that scale will have a positive effect on the purchase prices for city buses. An advantage of buses over Co-EVs is that the battery capacity can be limited because of shorter ranges, fixed routes and more time for charging.

VDL Bus & Coach

VDL Bus & Coach from Valkenswaard is taking part in the ZeEUS project through a project in the German city of Münster. Münster is a medium-sized city, has 300,000 inhabitants and is ideal for a pilot project with an electric fast-charging battery-powered bus, which seats about 85 passengers. On the two ends of the line are quick chargers. The bus depot has an additional fast charging station. The fully electric Citea Electric has a modular design whereby bus companies can choose from a variety of electric drives and battery packages. This means that the most ideal and optimum combination for each area of operation can be assembled. The VDL battery electric bus Citea Electric uses the unique e-Traction in-wheel motor technology further developed from the Dutch pilot project NEMS with the e-Busz in Rotterdam.

Figure 7.2.1.2 VDL Electric Citea with in wheel motors for Stadtwerke Münster - ZeEUS project

A.4.2.2 Development of powertrains, types of transport, and supply chain

Powertrains developments

The development stage of the electric powered driveline compared to ICE and other alternative powertrains will be discussed in this paragraph. In this report, we focus on Co-EV. Nevertheless, we will briefly deal with the alternatives in relation to the type of transport.

Alternative powertrains

Basically, the term “alternative” means any kind of powertrain solution for commercial vehicles different to that widely used ICE powertrains: in conjunction with efficiency improvements of new transmission designs, electrification and/or hybridization of the powertrain, or its components, as well as alternative fuels like CNG or vegetable oil fuels. However, in terms of technology, every application has its own specific challenges as the operation modes are so different, and there are pros and cons for each technology.

Uncertainty about winning technology

Apart from the strong focus on TCO in commercial vehicles, the attitude is very traditional, which is based on really good arguments. Present diesel technology performs. Diesel engines in commercial vehicles are very reliable and durable. With commercial vehicle engines, European users expect an engine life until first overhaul of 1.2 million km (750,000 mi) in a HD long haul truck, and up to 800,000 km (500,000 mi) in MD trucks.[xii] Diesel is a single fit for all products, whereas alternative powertrains only perform in specific tasks and require huge investment in a charging infrastructure.

A complicating factor is that there is a great diversity in operational circumstances, whereby one energy technology is not suitable to meet the requirements under all operating conditions.

Types of transport and technology - Diverse conditions of use

In a survey in 2009 an overview of the deployment opportunities for EV for cargo was given. A study of Innovam in 2014 still refers to this research and considers the results as accurate.

Hybrid and Electric MCV, HCV, Transit and Other Bus Market: Electric Commercial Vehicle Suitability, (Americas and EMEA) 2009			
GCW / GVW 1* (ton)	Load Capacity (ton)	Typical Application	Pure Electric Attractiveness
3.5	1.5	Urban distribution	✔ ✔ ✔
7.5	4	Urban distribution	✔ ✔
12	7.2	Urban distribution	✔
18	11	Inter Urban distribution	✗
26	17	Long distance	✗✗
40	25	Long distance	✗✗✗

Table 7.2.2.1: Types of transport and expectations for electrification of commercial vehicles

In the aforementioned study of Innovam, an energy source type prediction is made [xiii] that produces the following table (per transport type).

Type of transport	Future energy source expectations
Long-distance transport	• Conventional diesel technology will long be the standard. LNG is the best alternative. • Around 2030 is a trend reversal to hydrogen. Biodiesel and Bio-LNG continue to increase in proportion to replace diesel.
Regional transport	• Truck Dealers see solutions especially in diesel, hybrid and an LNG propulsion. LNG as a dual fuel as well as LNG only.
Urban distribution	• Up to 2030 use of alternative drive systems can already be made. Especially LNG, CNG and hybrid powertrains ant to some extent BEVs are suitable for 'last-mile' distribution. • Around 2030 a breakthrough into hydrogen and electricity occurs. The climate objectives of the EU within the stipulated timeframe are not feasible without this trend change.

Table 7.2.2.2 Division in type of transport

The observation that the general applicability of clean powertrains is still far away and future expectation varies by type of transport. Until 2025, alternative powertrains play hardly a meaningful role in the segment of heavy trucks (N3). This is less true for the market of light commercial vehicles like vans and service vehicles in urban areas (N1), where speed is relatively low and sufficient charging points are available.

Around 2030 a breakthrough for hydrogen and electric propulsion systems is expected[xiv]. Light commercial vehicles (<3.5 tons) are more likely to be electric in the near future [xv]. As mentioned earlier, WP1 revealed that the N2 and N3 vehicles in the pilots were all converted vehicles. For Co-EV city distribution it could be helpful for bigger shipments if fast charging is available during unloading of shipments.

Supply chain

Development stage of Co-EV

A small survey among large truck manufacturers has taught us that there are no commercially ready N2 and N3 vehicles available yet. We had the impression that R&D efforts barely focus on battery-powered trucks, and hardly at all on hydrogen-powered vehicles. The vehicles that have been deployed up to now are merely converted ICE vehicles. Generally speaking, one can say that there is a considerable difference in the stage of the product development cycle for the three categories of commercial vehicles. N1 (vans and small trucks) is already in the introduction stage whereas the other two categories are still in a pre-development stage.

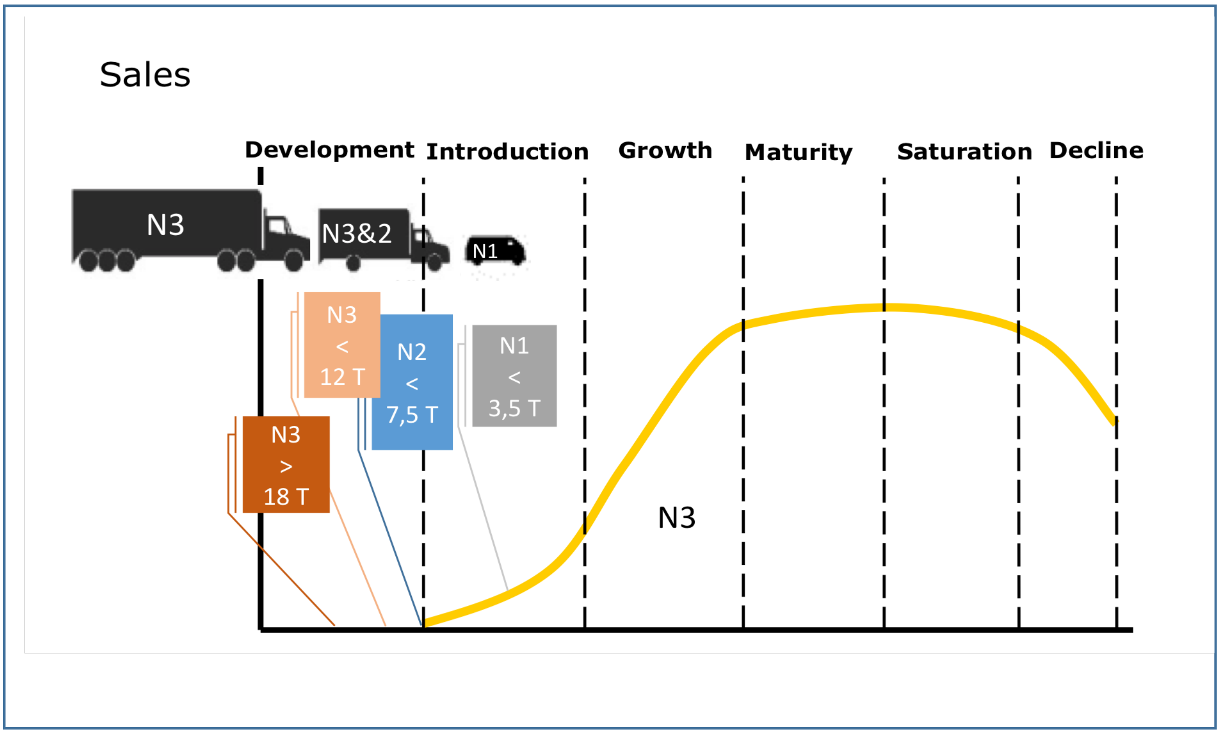


Figure 7.2.2:1: Product life Cycle and development stage per Co-EV category

Lack of scale on the supply side

Although attention to the electrification of the driveline is greatly increased, small-scale initiatives currently characterize the market best. There are currently no fully developed electric cargo vehicles available and there is lack of mass production. Sales in the Netherlands are very dependent on government procurement and grants.

The supply chain for electric drive technology is still very fragmented and not comparable with the supply chain for mainstream automotive technology. The current N2 (MD) and N3 (HD) trucks are converted fossil-fuel trucks assembled by so-called conversion companies. These conversion companies purchase the necessary components from various sources. The knowledge of the individual components lies with suppliers. Specific knowledge about combining the various components is hardly exchanged. The suppliers of components are reluctant to exchange specific knowledge since they are afraid of losing their competitive advantage. The individual development and lack of knowledge exchange are the main cause of teething problems. Solving these technical problems is often time-consuming [xvi].

Meanwhile, there is already a clear improvement in the quality and reliability of electric-powered trucks, but further optimization is required and the scale especially is important to achieve better cost. A big leap forward can be achieved if electric designed trucks are produced by OEMs.

It seems that supporting the real pioneers in the whole supply chain is necessary. Interest groups, who represent the industry, will generally defend the interests of the average member and are also inclined to take stragglers into account. This is not in the interest of accelerating innovation. It could be a good idea to keep eye on the pioneers in addition to the interest groups.

Urban areas have biggest potential for exploiting Co-EV

The analysis of the future development of the transport and logistics sector showed that e-commerce and other remote sales are rising rapidly each year in many European countries. It is the fastest growing part of the home shopping market and is expected to grow rapidly in the coming years, with e-Sales in retail business in Europe estimated to reach 24% of global retail sales by 2020, which will be four to five times its share in 2014. This trend will dramatically affect the last kilometer delivery process. Today, the average costs for logistics amount for 10 to 15% of the costs of finished goods [xvii].

If we look at the type of transport - long versus regional or urban - It is obvious that in urban areas (especially city centers and harbors) the opportunity for battery-powered vehicles is higher than for longer distance transport.

It is generally expected that city distribution will increasingly occur in future via transshipment points outside the city. However, urban distribution is very fragmented and many logistic flows do not allow transshipment. The following segments can be distinguished [xviii].

- Delivery of goods (business and home);
- Service transport and construction and demolition traffic;
- Shopping trips made by private households;
- Reverse logistics for waste removal and for returns management;
- Service vans, e.g. for maintenance and e-commerce deliveries.

A.4.2.3 Customer requirements

Transport sector perceptions

Perhaps the most critical challenge affecting fleet adoption of electric drive technology will be fleet adopters' impressions like

- Uncertainty about which technology will come out on top for specific situations
- The perception of route predictability
- Range anxiety, charging infrastructure and charging time
- Support and guarantees of suppliers plus grants and leasing possibilities
- Overall deployability of a vehicle.

Even when a compelling economic case exists, fleet operators will need to be confident that the vehicle can accomplish the mission and is deployable all round.

For participating companies, the size of its own fleet plays an important role in absorbing any outages. In a bigger fleet the risks or the impact of higher cost are limited. The knowledge and expertise in the sales channel on how to solve problems or how to compensate uncovered costs by grants is limited.

The drivers are a not inconsiderable group, with influence on the general opinion and behavior concerning energy consumption. Their perception is very black or white. A small group of EV drivers is really committed to driving as economically as possible. A large proportion of the drivers consider EV as 'fake' vehicles. Discussions with Roteb Lease reveals that the image of EVs varies considerably and depends especially on the functionality. People look quite condescendingly at the "Binkie" garbage truck, while the Volvo Hybrid is seen as complete vehicle. A large group of the Volvo drivers sees it as a challenge to drive this car as efficiently as possible. Among a certain group of drivers, electric driving has a positive effect, provided the car is as functional as a conventional car [xix]. The impression is however, that the general attitude in favor of EV driving is growing, but more positive information on cases and training how to drive an EV is still required. First insights on barriers, possibilities and changes for electric freight vehicles in city logistics:

- Technical performance
- Economics
- Operational performance
- Environmental performance
- Social and attitudinal impact

- Policy

In interviews, TCO was the main issue after poor technical performance and limited all round deployability [xx] [xxi] [xxii].

A viable / positive TCO is the determining factor in the market for commercial vehicles.

The TCO consists of a vehicle purchase price, its maintenance and fuel costs, and the infrastructure costs over the lifespan of the vehicle. Sometimes, insurance and financing costs are also included. The consideration of the total cost of ownership (TCO) is very important for logistics providers. Current market conditions force entrepreneurs, especially in the heavy trucks (N3) and road tractor market (N3), to focus more and more on a viable TCO. Many Dutch transporters have lost the battle to international transportation providers from Eastern European countries [xxiii]. At cost, they cannot compete. Therefore, we see two developments in the Dutch transport:

- Carriers who want to remain active internationally in whole or in part have brought their fleet (partially) under other flags.
- The number of carriers focusing on national distribution is increasing. This creates a surplus of suppliers in the Dutch distribution market, putting sales and aftersales margins of truck companies under constant pressure.

A study of Frost & Sullivan in 2011 substantiates this claim on the importance of TCO as purchase criterion. In figure 7.2.3.1 is shown that among 63% of the customers the TCO plays a major, decisive role in the customers purchase decision because commercial vehicles are pure capital goods that are used for industrial purposes (transport of goods and passengers).

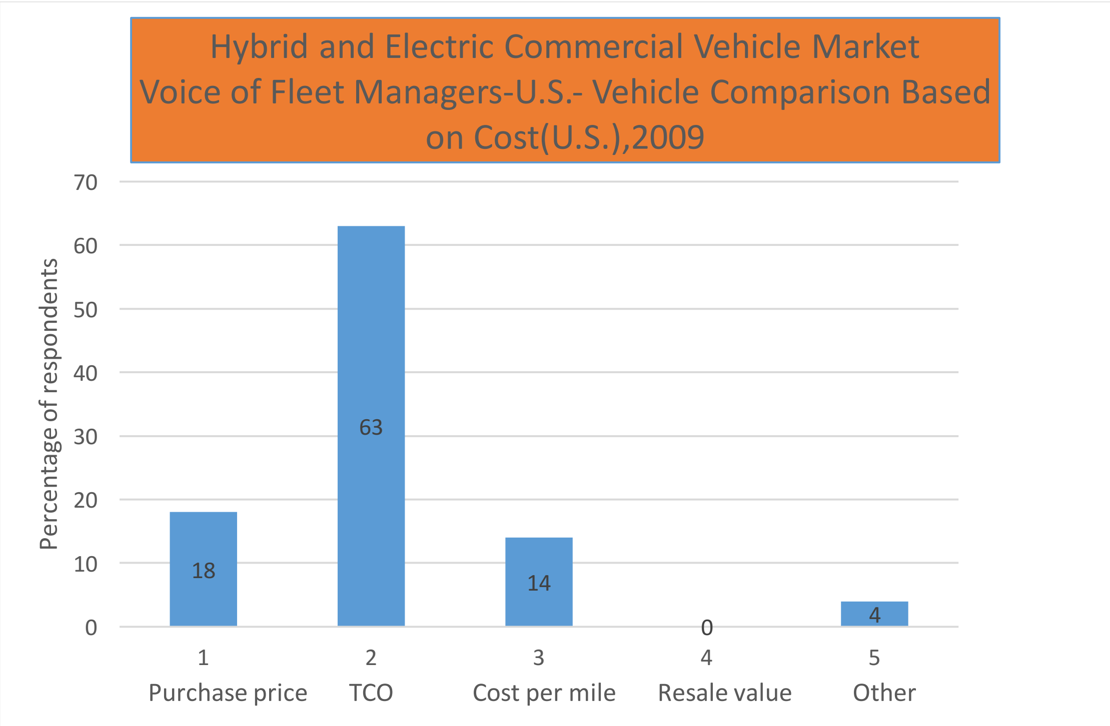


Figure 7.2.3.1 Purchase criteria on cost, based on 80 interviews with fleet managers. Frost & Sullivan 2011

The payback period is another criterion that appears to be important. The majority of fleet managers declare an amortization period of three to four years in which they expect to recover the purchase price of a hybrid EV. See figure 7.2.3.2.

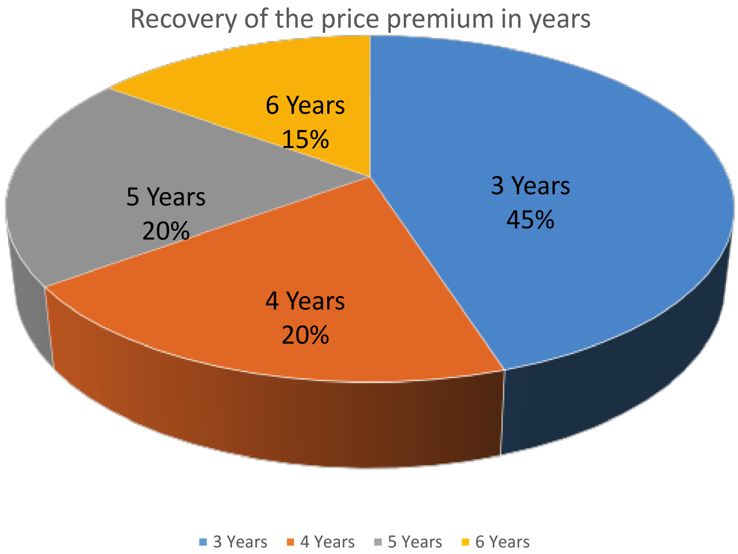


Figure 7.2.3.2 Hybrid truck payback considerations

In addition, the willingness of fleet managers to pay higher prices for alterative and clean energy is limited. 75% of the fleet managers considers 10 to 14% extra as maximum. See figure 7.2.3.3.

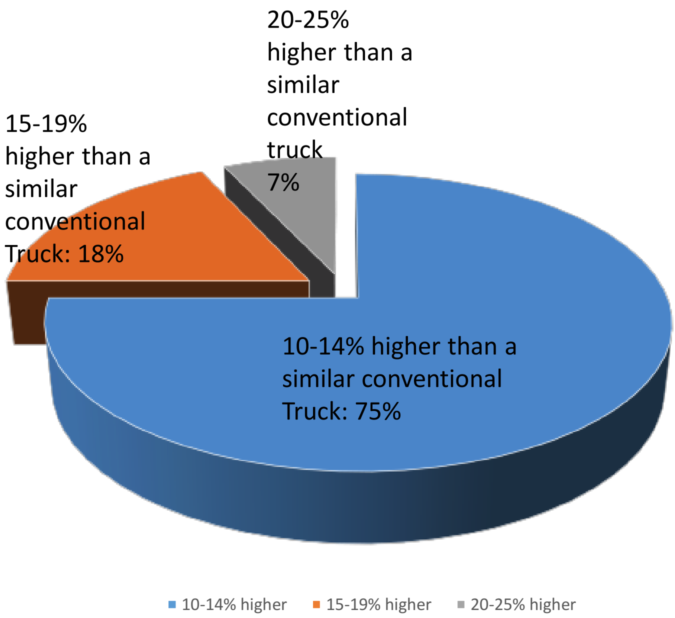


Figure 7.2.3.3 Maximum price that managers are willing to pay for hybrid -EV over diesel trucks

Based on the above research results and our interviews with the participants, it can be summarized that a viable TCO is the main criterion. In addition, for hybrid and EV-truck affordability and payback considerations fleet managers in U.S. are most comfortable with a price premium of 10-14 percent and a payback period of 3 to 4 years [xxiv,].

It is of course important to look for future TCO developments in terms of fossil and alternative energy sources. According to a survey of INNOVAM in 2014, the TCO rises to 2030 in all situations / scenarios [xxv].

- TCO of diesel-powered vehicles (reference scenario) will increase up to 2030 due to price increases of fossil fuels and additional taxes.
- The TCO of vehicles with alternative propulsion systems such as biofuel, EV and hydrogen (the other scenarios) will rise because of the need to recover R&D costs

- A higher purchase price for entrepreneurs will have to be recouped by lower operating costs. Therefore, TCO has become an important tool in monitoring the exploitation.

So far, we have discussed the medium and heavy trucks and the importance of a viable TCO. Even in vans, which are integrally designed by OEMs, the TCO appears to be much higher than for ICE versions.

Van N1 - Citroën Berlingo

Early 2015 a group of students from the University of Applied Science Rotterdam has made a TCO model for randomly chosen cars. In this case, the TCO model was filled with data of the Citroën Berlingo. Some specific aspects are taken into account by calculating the differentiation point between petrol, diesel and electric cars. For example, driving behavior, different seasons in the year, temperature and fiscal conditions. Based on the three types of driving behavior, the students made three different scenarios for the Citroën Berlingo. The three types of driving behavior are as follows:

1. Sportive
2. Normal
3. Defensive

Each of the scenarios gives another differentiation point. For example, the normal driver needs to drive 70,000 km in an electric car to exceed the costs of driving the same number of km in a diesel version. The majority of service vehicles will not meet this distance by far. For medium and heavy trucks as converted vehicles, the TCO will work out to be much more negative.

Transporters can hardly pass on costs of the higher TCO associated with alternative powertrains to clients

In the aforementioned study of INNOVAM it is also stated that the danger of a lock-in lies in wait here. Nobody wants to price himself out of the market, allowing innovations to keep pace with the competition. Another point that is blocking innovation is the reluctance of principals to pay higher prices for transport. Therefore, the chain – principal --> transporter --> truck dealer - blocks faster deployment of alternative vehicles on the road [xxvi],

Although the rapport of the Amsterdam Roundtable Foundation of April 2014 merely deals with passenger cars, it is also mentioned that the TCO is a main purchase issue. Currently, estimates for the difference in the TCO of EV compared to ICE passenger vehicles vary widely, from €5,000 to €20,000 per vehicle (for annual mileage of 20,000 km and a retention period of four years), depending on powertrain type, model, and country, as well as fuel price and other variables [xxvii].

Ratio of initial investments for the different categories

Let us give some background on the high difference in initial investments. During interviews with market parties, we learned that a few years ago DAF and Volvo developed a hybrid truck on a small scale. However, DAF and Volvo withdrew this product from the market due to a lack of demand. Reason: excessive costs. This policy probably says something about the difference between the potential and actual demand [xxviii].

Since there are no OEM cargo vehicles commercially available at the moment, all Co-EVs are converted from ICE based vehicles. The diesel engine is dismantled and the removed diesel engine retains only a small part of its original value even if unused. The same applies to motor management and other systems. The heavier the vehicle the more complex and the less experience. The components on Co-EV are made on a small scale. Given the limited experience, the number of teething problems is relatively large.

As learnt in WP1 a further breakdown per segment is necessary since the deployment within each category can differ considerably. This means that deployment for Co-EVs is limited to urban areas and limited ranges. For example, the load factor and range for a mover can hardly be compared with a garbage truck or a vehicle for conditioned food transport. The technical limitation and high price for batteries limits the possibilities for Co-EV to niches in urban areas, whereby local governmental grants and privileges are required.

Other factors such as charging infrastructure play a less important role compared to passenger cars. Commercial vehicles are merely leased so leasing possibilities for Co-EVs are an important condition. In that case, the risk attitude of leasing companies is an issue. However, cost competitiveness with ICE on a TCO basis is most critical for large-scale adoption of EVs. TCO reduction is contingent on the further evolution of battery pack costs, the path of which remains unclear.

From interviews with transporters, we learned that the perceived pressure on deploying EVs seems to be low due to the combination of the "low" requirements in environmental zones. Requirements with Euro 6 and LNG are already fulfilled so EV is not necessary. Besides the conversion cost to alternative duo fuels are significantly lower than EV. General applicability of one type of clean drivetrain is still far away and future expectation varies by type of transport [xxix] [xxx].

Initial investment ratio of Co-EV is a clear bottleneck

As mentioned before the N2 and N3 Co-EVs in the pilots were all converted vehicles. It is understood that the conversion of the vehicle greatly increases costs. One can say that the heavier the Co-EV is, the higher the initial investment ratio versus an ICE based powertrain is.

In the aforementioned study on the TCO for the Citroen Berlingo, the purchase price of a fully electric vehicle is about double the price of an ICE version. In the interviews with transporters, we learned that the high initial investment ratio is the main reason for the much higher TCO of battery-powered commercial vehicles. None of the interviewed parties was able to obtain a viable TCO, without grants, tax advantages and /or privileges. The general conclusion is that a big difference exists between the categories N1-N3 [xxxi] [xxxii] [xxxiii]. This implies that the heavier the truck is, the higher the initial cost for investments are. The initial investments grow from 1.5 for a van to 4 for an 18 tons Co-EV. See figure 7.2.3.5

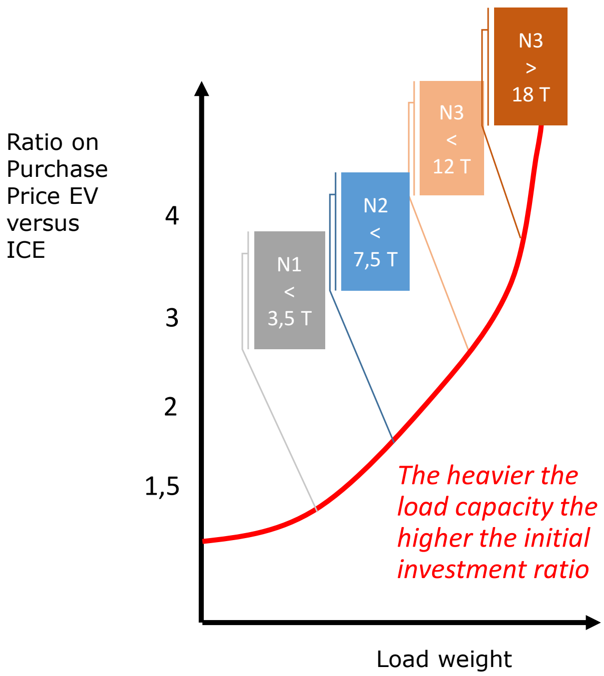


Figure 7.2.3.5: Investment ratio Co-EVs for cargo versus ICE powered vehicles

For vans in the N1 category one can broadly take a ratio of 1.5, whereas for an 18 ton N3 truck the ration amounts to roughly 4. These differences can be explained as follows. Vans in the N1 category are OEM built, whereas N2 and N3 are converted vehicles. The heavier the load, the heavier the required battery capacity and, accordingly, the lower payload.

The higher purchase price cannot be recouped by low maintenance cost and lower energy cost per km, especially not in urban areas where driving distances are relatively short. Outside the urban area or at regional transport level the price and weight of the battery would affect the payload capacity too much as well as the purchase price for the truck. For the longer routes, Hybrid versions or Fuel cell vehicles are solutions with better prospects.

Bottlenecks experienced during operation

Down time / service / teething trouble
The majority of entrepreneurs with Co-EVs is faced with imperfections in the technique during deployment. Repairs were not resolved in time, because of lack of experienced service personnel. This has led to the demotivation of management and drivers involved [xxxiv].

In commercial vehicles the payload is important, so apart from the purchase price of Co-EVs the intention is to save as much as possible on battery weight. The limited battery capacity implies that this has to be charged frequently. More fast charging points can be a solution.

Fast charging is not always an ideal solution. For example, for taxis, where the vehicle is taken over by the next driver, there is no time available to charge. In fact, charging time is perceived as potential loss of operational deployment.

A.4.2.4 Stakeholders

Principals, shippers
More and more companies are keen on sustainability but this depends strongly on the ability to be distinctive and competitive in the market. The harder the competition, the less the willingness to proceed with the procurement of sustainable investments.

Some entrepreneurs look more to the future developments and want to lead the way, despite financial disadvantages. In most situations, they have a larger fleet and the impact of one or a limited number of EVs on the total is limited. Others prefer to wait until

- The technology is further developed
- There is more clarity on the dominating technology
- It is enforced by market demand
- The costs are lower.

We could not find concrete evidence that investments in sustainability improve the image accordingly, but some entrepreneurs are willing to assign the last 5 to 10% of their investment to improvement of their image.

Government

Policies on air quality in urban areas
Clean air and health issues are increasingly a driver for zero emission transport. In some urban areas, the norms for air quality (especially NO2 and PM10) as defined in European legislation have not yet been met. Although the air quality situation has improved, the situation in big cities is still not acceptable. Similarly, in Rotterdam where life expectancy is 1.5 years shorter, it is generally believed that poor air quality adversely contributes to this [xxxv].

In 2015, TNO has reported that commercial vehicles, including busses, are responsible for 72% of NOx emitted in Dutch citie, although their share in mileage is only 15%. [xxxvi].

Economic growth is usually associated with higher emissions. This implies that environmental requirements could slow down economic growth. However, driving on hydrogen fuel cells, batteries or renewable gas can make an important contribution to the decoupling between mobility development / economic growth and environmental effect (CO_2, air quality, noise).

Environmental zones

More cities are initiating environmental zones since it is clear that the most polluting cars will have an impact on air quality. Besides, environmental zones can help entrepreneurs to invest in sustainable vehicles since these will create a competitive environment with a level playing field. However, closing the inner cities to medium and heavy traffic could, at the same time, lead to a kind of monopoly. Only a few big companies are likely to be able to make the required investments. In fact, the transport sector is characterized by a large number of small enterprises with limited financial resources. Closing the city to ICE vehicles would disrupt the market.

As we learned in our interviews with (potential) EV-participants, a well-balanced approach by governments on the closing the inner cities to polluting cars and meeting clean air goals is required. Apart from the effect on possible competitive disruption, the logistics flows are very diverse and time for adoption of new logistics concepts takes time.

Grants/Tax benefits

In the discussions we had with some entrepreneurs we discussed their business cases for commercial vehicles. From these discussions we found the following:

8 Grants/subsidies are essential to achieve a profitable business case. The heavier the truck the higher the grant should be.
9 Tax benefits are necessary to get a feasible business case. It is important that governments maintain a long-term policy and those policies are aligned on national and local level as in the provinces Overijssel, Gelderland and city region Haaglanden where subsidies have been initiated for clean trucks [xxxvii]. However, there are major differences between the provinces when we look at the grant, the conditions imposed and the duration of the grant. There are also substantial differences in subsidy policy between for example Rotterdam and Amsterdam [xxxviii] [xxxix].
10 For entrepreneurs there are enough uncertainties in the field of technology and market developments. Uncertainty about subsidies, taxes or privileges increases the perceived risks and may form an additional barrier to purchasing electric vehicles.
11 Tax benefits are concentrated on the business to business market and are promoting possession rather than usage/clean driving
12 For entrepreneurs it is difficult to cope with differences in grants and regulations. Uniformity is key to reaching enough economies of scale.

Charging points

Overnight charging with a standard charging cable is the basic principle for charging. Sufficient charging points should be in line with market demand and will reduce range anxiety. Fast charging can help the business case to get around and will contribute to reduction of range anxiety and potential long waste of time. Therefore, fast charging should get a higher share. Fast charging points are four times the price of a standard charging point. For some applications like taxis and city buses inductive charging can be an option in the future.

Concession duration public transport

Duration of the period for which the concession / tender is issued is a factor that can help to promote sustainable transport. The relatively high initial investment for EVs can be spread over more years and be recouped through lower maintenance and running costs of electric powered vehicles. The ZEB foundation has built a TCO model for transportation upon four pillars: vehicle, energy and energy infrastructure, business models and societal effect. In their model, ZEB mentions 12-15 years as a reasonable concession period since also the cist for charging infrastructure have to be paid off [xl]. The longer concession periods have recently been applied.

Financing companies

The majority of commercial vehicles is leased.

Lease

In view of the lack of experience in electric cars leasing companies are reluctant the take high risks, which means relatively high lease rates. The main reasons for this behavior is due to the following

- Leasing companies currently calculate a low resale value due to ignorance
- The lack of volume in EV makes it not so very attractive for financial Institutions
- The battery has value and that value should be visible in the chain, which is not the case
- At the moment there is limited proof available that the maintenance cost of EV is indeed lower than for ICE based vehicles.

Guarantees of suppliers, validated TCO models as well as proof of residual value could help create more competitive lease rates.

Energy companies

Implications for the grid

It is evident that electric cars are coming into vogue, at least in the short-term; the energy companies probably will not have major difficulties absorbing them into the system. Therefore, the impact of EVs on the power infrastructure and electricity demand today remains manageable.

It is also clear that they may have profound implications for the power grid in the longer term, based on behavioral issues, tariff policies, emerging technology and economics. Bringing a fleet of EVs or PHEVs into a small charging space will bring an unusually high burden to those areas and may require upgrades to local utility distribution networks. In particular, transformers serving charging facilities may be insufficiently robust to support the simultaneous charging of multiple vehicles. Utilities will need access to information and regulatory support to deal with these and other issues. Proactive consideration of the potential impact of upscaling and the role of EVs in emerging smart grids may result in potential savings for energy companies and grid operators [xli].

During the pilot periods there was reported a lack of charging locations. At present, there are sufficient charging locations in the Netherlands and it seems that the energy companies are sufficiently concerned with future developments. Entrepreneurs have mentioned us that fair costs of electricity are important for the viability of their TCO [xlii] [xliii] [xliv].

A.4.2.5 Development of powertrains of City Buses

A number of European OEM bus manufacturers has picked up sustainability as a strategic theme. The advantage of buses in relation to trucks is that manufacturers can build on the experience with trolley buses. Another advantage of buses over trucks is that buses are manufactured as a whole, while medium and heavy truck manufacturers produce the tractor and not the trailer.

Known energy carriers within city buses are: diesel, CNG, LNG, Biogas, Biodiesel and Electric (hydrogen fuel cell or battery – plug in hybrid and full electric). In this study, we focus on electric powertrains versus diesel. Diesel buses are highly autonomous and interchangeable, whereas electric buses must be seen as a part of a smart city system. To introduce electric buses, several actors have to be brought together in public-private partnerships: state and public transport authorities, municipalities, bus operators, utilities, technology companies and research institutes.

In China, a few large players already produce electric buses on a large scale. The approach to innovation in China is radically different from the Netherlands. In China, they settle for low quality and one learns by doing, while in the Netherlands and in western European countries an almost perfect product is developed before it is offered to the market.

Charging infrastructure

The optimal technology is very depending on the local situation end new developments on charging. It is understood that the charging infrastructure requires huge investments, long depreciation periods and support by the government.

A.4.2.6 Customer requirements

The city buses market differs from the medium and heavy truck market in terms of the following

- Contrary to trucks, buses are delivered by OEMs as integrated concept.
- Existing experience from trolley buses, predictable routing and regaining energy by frequent stops

Type bus transport	Specific deployment
Urban transport	Urban or suburban services
	Express bus services, Bus rapid transit (BRT)
	Park and ride bus services
	Feeder bus services
Long distance transport	National (Between villages and cities, Rail replacement bus services)
	International
Specialist services	Shuttle buses
	Additional public transport

Table 7.2.6.1: Division of types of bus transport

In view of battery weight and mileage urban areas and specialist services appears to be the most interesting segments for electrification with batteries. City buses have very predictable routes and need to stop regularly, every 3 miles (4.8 km), allowing opportunities for quick recharging.

The demand for city buses is dominated by local governments. Municipalities describe through transport concession the obligations regarding the frequency, punctuality, cleanliness and social safety on the relevant routes Bus operators like Arriva, Syntus and Connexion bid on concessions and deploy the bus transport for the duration of the concession according to the prescribed obligations. The longer the concession period the better the bus operators can introduce newer and cleaner technologies, because they can recoup the higher initial costs by lower maintenance cost and lower energy consumption over a longer period..

TCO

Although the costs of public transport are important, the additional costs for Co-EV buses play less of a role here than for trucks. For municipalities it is important to achieve the air pollution goals. By improving the sustainability of public transport, (local) governments can catch up on clean air targets and thereby gain budget scope, if necessary.

The bus itself is only 1/3 of the total cost, including overhead. On the other hand, the installation of the charging infrastructure is normally included in the investment. This underpins longer concession periods and other types of financing.

TCO model as web application
Calculating all cost components (such as investments, grants, financing and operating expenses) for the TCO and the cash flow for buses is very complex. The Stichting Zero Emission busvervoer (Foundation Zero Emission Bus transport) has started a project for a web application to calculate the TCO for bus transport. The application allows the user to make scenarios for different projects [xlv].

New types of financing
To make these substantial investments in electrification profitable, a different type of financing could help. Apart from a longer concession period, a different way of financing the bus than at present could help to come to a viable TCO.

One of the solutions that the stichting Zero Emission Busvervoer (Foundation Zero Emission Bus transport) is exploring is the service provider model. In this model there is a break-up in the carriage (supplied by the transport company) and in the power supply of this transport (through a service provider). The service provider determines, in consultation with the grantor and the carrier which technology and energy infrastructure is used [xlvi]. This different way of financing equipment and energy supply should be possible within the system of transport concessions. It should be tailored to each region. This requires research into the design of concessions.

Successful trial (Proeftuin Innovatieve Bussen 2008-2014)
From 2008 until 2014, seven trials with innovative buses were performed. These pilot projects were supported by the Dutch Ministry of Infrastructure and Environment to achieve experience with energy saving buses in the practice of public transport operators. The general evaluation was done in 2014 in the report 'Vernieuwing openbaarvervoer per bus beleidsevaluatie pilotprojecten' [xlvii]. The buses were divided into two categories: Prototypes 'alpha' and Pre-production 'beta'. The 'beta' buses which were used for two pilots in Zuid-Holland and Rotterdam with new 'mild' hybrid electric commercial buses from OEMs. They were bought by the public transport operators as part of their bus fleet and are all still in commercial service to date. The other pilot project used 'alpha' buses, which were dedicated built prototypes. One used a biogas bus but the rest of the projects used plug-in hybrid, range extended or hydrogen electric buses for the trials. All these pilot projects gave a boost to the innovation and a clear notion that clean and energy-saving buses are feasible. However, in many respects the technology was not mature yet and the concessions procedure was not ready. This changed by the following Green Deal of Zero Emission Bus that demands all new city buses to be emission free in 2025.

In Rotterdam, two prototype city buses called the e-Busz have been running since 2011 on line 46 of the operator RET. These buses are based on the VDL Citea model and have been converted by e-Traction to range extended electric buses. A diesel generator supplies electricity in the event that the batteries become depleted. The goal of the trial in Rotterdam was to test the range of electric vehicles under different situations plus the reliability, employability in regular service and user experiences. The electric range (up to 4 hours' drive) of the e-Busz is made possible by two specially built wheel hub motors. These motors appeared to be much more efficient than diesel or hybrid engines. A study of the HR in 2014 has shown that in a base case scenario the TCO of the e-Busz driven, as a fully electric bus, was already positive in comparison with the conventional diesel city bus [xlviii]. See table 7.2.6.2.

Electric City Bus		**Base Case**	**Conventional City Bus**	
Unit	Total Cost	Price difference	Total Cost	Unit
Total cost e-bus	€ 785,275.63	€ 95,369.51-	€ 880,645.13	Total cost bus
Per km	€ 1.19	€ 0.14-	€ 1.33	Per km

Table 7.2.6.2 TCO comparison of the e-Busz and conventional diesel bus

Although the pilot project was finished, the project partners decided to continue the deployment of the bus in the daily service but using fast charging instead of the diesel-generator to achieve the Zero Emission Bus target by 2019. The trail project with the prototype e-Busz indirectly also led to the development the VDL Citea Electric equipped with motors located in the rear wheels, and to the series-production of these in-wheel motors.

Scale

Scale can easily be reached if demand of the various cities in Europe is bundled which would lead to more competition and more R&D. The higher scale will lead to further reduction on cost of purchasing.

A.4.2.7 Stakeholders

Green Deal

In 2012 the Ministry of Infrastructure and Environment in the Netherlands signed a Green Deal with the Stichting Zero Emission busvervoer (Foundation Zero Emission Bus transport) and local governments. The Green Deal aims to include zero emissions as a requirement in all public bus concessions during the period of 2015-2025. Since 2015, the concessions for the purchase of expensive emission-free buses may be extended to 12 to 15 years, provided it concerns an innovative infrastructure.

Deployment of fully electric city buses

Schiphol Airport, Netherlands

Schiphol deploys 35 electric buses. In 2014, 35 electric BYD buses started operating at Amsterdam Airport Schiphol to transport travelers from aircraft to the gates. Each bus has its own charging point at the airport. The BYD ebus can drive for 250 km even in heavy city traffic after one full charge. The bus can be charges in 5 hours.

Figure 7.2.7.1 Electric bus on Schiphol airport

European cities

Several cities like Vienna and Hamburg have started to take fully electric city buses into operation. On 2.3.2015, Transport for London (TfL) has announced that Arriva (part of Deutsche Bahn) has been awarded the contract to operate one route in London, which will become the first route in London to be operated entirely by electric buses. In the meantime Arriva is currently in talks with bus manufacturers with a view to adding a further seven electric buses [xlix].

Amsterdam: all electric buses

As the first Dutch municipality, the city of Amsterdam has chosen the complete replacement of buses by renewable ones. Out of a total of 200 buses 40 diesel buses will be replaced by electric versions in the next two years. By 2025, the entire fleet will be electric. "With this plan, we say goodbye to symbols and pilots or small-scale projects. We decided just to do it, there is no need to experiment with five buses, but a full rollout," says Abdeluheb Choho (D66), alderman for the sustainability of Amsterdam. According to VDL, a leading bus manufacturer in the Netherlands, the cost per kilometer for electric bus will be approximately equal to the cost of diesel buses within four to five years. Apart from the city buses, the ferries over the IJ between the city center and northern Amsterdam will also be powered by green electricity [l].

OEMs on city buses

Several manufacturers of city buses are actively developing and improving electric buses. We give three examples.

BYD

According to BYD, 3,500 electric buses have already been delivered and there are orders for another 4,000 buses. Apart from the standard electric buses for Schiphol, BYD is delivering the first electric double-decker in the world to London. This double-decker will be operational from October 2015.

VDL

In 2013 VDL Bus & Coach BV, Valkenswaard, the Netherlands launched the Citea Electric, a modular design with various electric drive systems.

- Large battery, charged via a plug-in connection, is most suitable for use over longer distances without interim recharging. However, this does limit the number of passengers.
- Relatively small battery to be combined with various quick-charging methods, such as induction, trolley or plug-in.
- Range extender for covering distances of more than 200 km on a single charge. Adding a range extender has no consequences for the number of passengers or the comfort. A big advantage is that investment in infrastructure is kept to a minimum. As energy storage, a fuel cell or diesel generator can be chosen.

The Citea Electric can be equipped with wheel hub motors, which are located in the rear wheels.

Figure 7.2.7.2 Citea SLFA Electric of VDL

Volvo

Since 2012, Volvo Group and Siemens have been working together within the field of electro-mobility. They have signed a global agreement regarding supply of complete electrified bus systems to cities. Volvo Buses will supply electric-hybrid buses and full-electric buses and Siemens will supply and install high-power charging stations (charging power of up to 450 kW) for the electric vehicles.

Under the flag of ElectriCity Gothenburg Volvo fully electric buses will operate on route 55 in Gothenburg from the end of 2015. This is a result of a cooperative venture between the research fraternity, industry and city planners. The goal is to demonstrate and evaluate next-generation sustainable public transport [li]. See also the cooperation with Volvo with ABB for charging on the go at the stops in figure 7.2.7.3.

Figure 7.2.7.3 Collaboration between Volvo and ABB for charging on the go.

Technology for charging city buses

On the technology side, many steps have been taken, for example, for charging buses. There are several possibilities. An important factor appears to be that charging systems are developed in cooperation with suppliers of buses, local government and suppliers of the charging systems. Here are a few examples.

Volvo and Siemens

Volvo Buses and Siemens have already delivered a complete city mobility solution consisting of three Volvo electric hybrid buses and four charging stations to the German city of Hamburg, where the buses operate on the citys new Innovation route. The charging infrastructure supplied by Siemens includes the charging station, auxiliary equipment, cabling, civil works, installation, commissioning and maintenance.

A one-year field test in Gothenburg, Sweden, has shown that the Volvo Electric Hybrid bus enables the reduction of fuel consumption and carbon dioxide by up to 75%, compared with Euro 6 diesel buses. Total energy consumption is reduced by 60%. The Volvo 7900 Electric Hybrid bus runs in electric mode on average 70% of the route, silent and emission-free. Charging at end stations takes up to 6 minutes [lii].

Schunk Bahn- und Industrietechnik - VDL Citea

VDL participates in the ZeEUS project for the city of Münster in Germany. For this project, the new Citea SLFA Electric of VDL (see figure 7.2.7.2) is fitted with a fast charge system using a pantograph made by Schunk Bahn- und Industrietechnik GmbH in Wettenberg, Germany. The charging power is 250 kW and charging time is around 5-10 minutes. The batteries are fully charged at night.

ABB and Volvo

ABB, Switzerland a leading power and automation group, and Volvo agreed on a partnership in 2014 to co-develop and commercialize electric and hybrid buses with open standards-based direct current (DC) fast charging systems.

The cooperation creates a citywide standardized charging system for electric and electric hybrid buses that can charge buses quickly through an automatic rooftop connection system at bus stops or through cabled charging systems overnight.

Figure 7.2.8 Volvo electric-hybrid bus

The first joint project for Luxembourg's public transportation system is planned for 2015 with 12 Volvo Electric Hybrid buses operated by Sales-Lentz.

Double-deckers wireless charging

In London, many of the double-deckers will run for 19 to 20 hours per day. Batteries will weigh too much and require too much space. One alternative way is to charge the buses wirelessly. When the bus gets to a terminus, it can be parked over an induction pad, which will transfer power to the bus, at the rate of about 10kW every five minutes. The bus will have to be parked fairly accurately over an induction coil in the ground, which will match with one installed on the underside of the bus.

London is not the only city investigating the technology. In Milton Keynes, some bus stops are already fitted with inductive charging technology. In addition, South Korea is testing a system that also uses inductive charging for vehicles on the move. A similar initiative has been started in Utrecht, the Netherlands.

A.4.3 Energy resources: batteries and fuel cells

In this appendix, the results are discussed. Firstly, the results from international European projects are evaluated. Secondly, web research was done for the relevant business cases and recent developments followed by interviews at the various stakeholders.

A.4.3.1 Battery Technology

Batteries: The key cost driver in the EV TCO equation is the expensive battery pack, but the situation is improving.

Current challenges facing EVs include its high price tag, mainly caused by the high cost of batteries and by its range limitations, long charging times, and a limited but vastly improving charging infrastructure.

The most cost-intensive component in current-generation electric drive vehicles is the battery. Battery costs associated with the first commercially available electric drive vehicles will result in a substantial overall cost premium.

Current battery technology is descending the cost curve as volumes increase, but under some fleet applications, it may be difficult to realize a return on investment in a reasonable time. Ultimately, fleet operators may be more willing than personal-use consumers to consider multiyear paybacks but they will still want to see returns relatively quickly. See also Question 1 on TCO.

Low energy density brings a high weight. Weight that is carried and extra weight by the battery has a significant impact on TCO since battery weight is responsible for a lower payload.

There is some information published on passenger car models and the cost for batteries. One example is Tesla. Some estimates in the media have placed the cost around $400 per kWh, or $34,000 for the Tesla S 85 kWh version while others estimate the costs are well below $200 per kWh. In an interview with Barron's online, Tesla CEO Elon Musk claimed that improvements would bring the cost of the Model S battery to $10,000-$12,000, below $200 per kWh[liii]. An interesting analysis at Green Car Reports estimated Tesla's cost conservatively at $171 per kWh with prices collapsing [liv].

As already stated, batteries take up a huge part of the purchasing value so the long-term potential of the EV depends on innovations that will significantly reduce the cost of batteries. According to the latest IEA report on EVs, battery prices were around $485/kWh on average in 2012 [lv].

In a study of Miller in 2010, numerous estimates of both current and projected costs for EV and PHEV batteries have been published [lvi] The estimated cost of EV battery packs from the various studies is shown in Table 7.3.1.

Source	EV Battery Cost		
	2010	Estimate 2015	Estimate 2020
Argonne National Lab			150-200
Advanced Automotive Batteries		500-700	375-500
Boston Consulting	990-1220		360-440
Deutsche Bank	650		325
Electrification Coalition	600	550	225
Pike Research	940	470	

Table 7.3.1 EV battery cost estimates

Many of these are based on unpublished quotes from various battery manufacturers, and vary widely. Despite the differences in estimates of current costs, the expectations for future cost reductions are more consistent, with costs expected to drop by 50 percent or more between 2010 and 2020. Independent cost modeling studies, based on materials inputs and manufacturing requirements, yield cost estimates that are in good agreement for PHEV battery costs [lvii].

In an analysis by UC Davis of the University of California, they looked at the EV battery price forecasts from various influential consulting firms [lviii] (Figure 7.3.1).

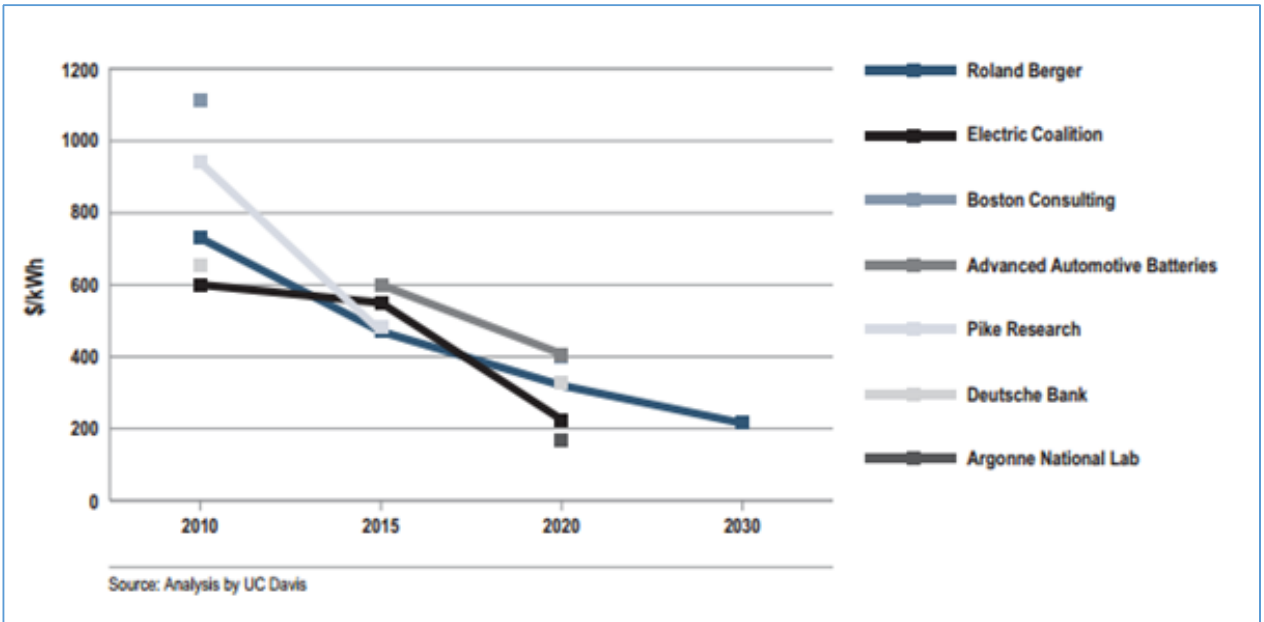


Figure 7.3.1 Forecast on price in $ per kWh by various consulting firms

According to these projections, they expect to see competitive battery pack prices around the year 2020, assuming a relatively low oil price of $70/barrel for WTI crude. If oil prices were to rise above this level, it would accelerate the expected date which EV and ICE reach pricing parity.

Longer warranty periods

Tesla has meanwhile increased the drive unit warranty to 8 years, matching that of the battery pack. The 85 kWh Model S, has an 8-year infinite mile guarantee on both the battery pack and drive unit. There is also no limit on the number of owners during the warranty period [lix]. It is to be expected that other manufacturers will follow this example. Longer guarantee periods for batteries will also have a positive effect on the risk assessments of leasing companies and thus have a positive effect on leasing rates.

Future developments

Although the passenger car industry is still somewhat reticent regarding EV, more news is gradually emerging about future developments in the field of EVs. Dr Heinz-Jakob Neusser head of powertrain development of VW AG spoke at the WRC in Strasbourg in October 2014 and told media outlets that the plug-in hybrid (PHEV) technology currently employed is merely a stop-gap on the way to all-electric mobility. “We have more energy density in the batteries [than before], and in 2015-16 will come the next step which means we come from 25-28 ampere hours (Ah) energy density to 36-37Ah. Now we are actually working on the next step to around 60Ah with research which will come from a completely new electro-chemical chemistry inside the batteries, and this will come at the beginning of the next decade.”

When discussing the VW e-Golf dr. Neusser said: “I expect the next generation in 2015-17 will increase to around 300 km [186 miles] and the following step will be around 500-600 km [310-372 miles],” He also indicated that the 500-600 kilometer (310- to 373-mile) electric cars will be launched by 2020 [lx].

In the meantime, huge investments are being made in the manufacturing of batteries. One example is the investment of Tesla with partner Panasonic. Tesla announced in 2014 that they will be constructing the world’s largest lithium-ion battery factory in Nevada, named the Gigafactory.[lxi] Planned production at the Gigafactory of battery cells by 2020 will exceed the entire industry’s production in 2013. Tesla estimates that cost per kWh will be reduced by over 30%. The Gigafactory will also have facilities for recycling batteries.

The smaller, safer cells allowed Tesla more flexibility in arranging the battery pack enabling them to create the large slab that covers the undercarriage rather than bulky batteries that eat into interior space [lxii].

In 2015, Björn Nykvist and Måns Nilsson made a comparison of the various studies on the development on the cost for batteries [lxiii]. In figure 7.2.10 below it is indicated that the cost in US$ per kWh could gradually fall to around US$230 per kWh in 2017–2018. This is significantly lower than what is otherwise recognized in peer-reviewed literature, and on par with the most optimistic future estimate among analysts outside academia (by McKinsey), which stated in 2012 that US$200 per kWh can be reached in 2020, and US$160 per kWh in 2025 [lxiv]. From US$230 per kWh, costs need to fall a further third to reach US$150 per kWh, at which Co-EVs are commonly understood as becoming cost competitive with internal combustion vehicles [lxv]. If costs reach as low as US$150 per kWh this means that electric vehicles will probably move beyond niche applications and begin to penetrate the market widely, leading to a potential paradigm shift in vehicle technology.

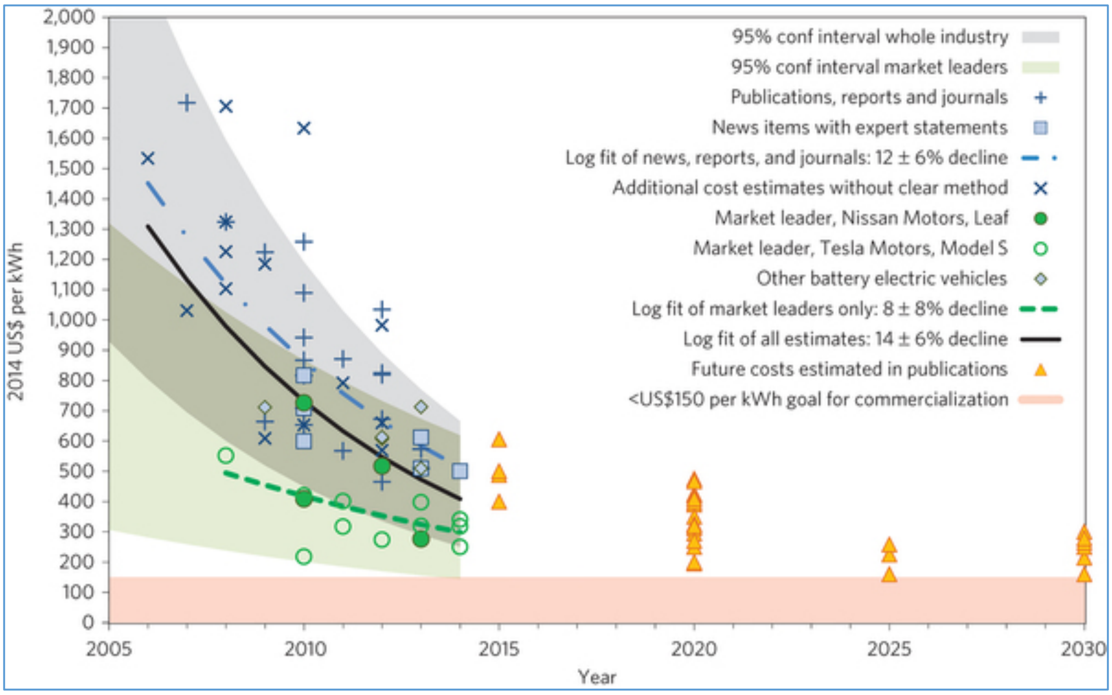


Figure 7.3.2 Overview on development of battery cost according to various studies

At the EVs 28 in Korea, Tien Q. Duong was one of the keynote speakers. Tien is a Senior Technical Advisor and Manager of the Batteries for Advanced Transportation Technologies (BATT) Program (http://batt.lbl.gov/). The focus of the BATT program is conducting research and development of next generation battery technology for automotive applications. During his lecture, he mentioned the following goals:

- 2022 US$ 125 per kWh based on lithium
- 2025 US$ 100 per kWh based on lithium metal.

These goals go somewhat beyond LG predictions, but the general trend is that the cost will decrease considerably.

If we take the US$ 150 per kWh as the turning point, it implies that up to around 2020 grants and support for electric vehicles will be required from governments. Ideally, government subsidies and privileges should keep pace with the reduction in the cost of batteries.

The main demand for batteries is in the Pa-EV sector, but one can expect that the market for commercial vehicles will also benefit from the innovations in battery technology. For Co-EVs the involvement of OEMs is required, whereby in the first instance the focus should be paid to the integrated development of the battery-powered driveline.

In view of the uncertainty about which technology will come out on top and the fact that there is not one technology that suits all situations, OEMs may choose for a long-term powertrain portfolio that includes Co-EV powertrains for small vehicles in urban areas and long-range vans powered by FCEVs.

Battery Residual Value

Today, estimating the residual value of used large-format automotive batteries is an educated guess at best. Early test data suggests that lithium-ion batteries may still possess 70 to 80 percent of their ability to store energy when they are no longer fit for automotive use. But this needs to be borne out by practical experience [lxvi].

Car manufactures are also starting projects for increasing the second life value of batteries. The lithium-ion batteries for BMW are designed to last longer than the car itself. The German manufacturer is now examining with the "Second Life Batteries" project opportunities to recycle the high-voltage battery. Together with energy company Vattenfall the BMW Group is cooperating on environmentally friendly manufacturing and recycling. After their life cycle in an EV, the batteries still have a storage capacity of about 80 percent. In an electric car this is no longer sufficient, but as stationary units, they can last for many years. In Berlin, BMW test vehicles with used batteries, charged by solar energy [lxvii].

In the Netherlands, a project has been started on the reuse of batteries. The plan is to offer households and businesses throughout the Netherlands an affordable form of energy storage. Over the next few years, thousands of these batteries are set to become available. The project will also contribute to the sustainability objectives of specific areas, businesses and organizations such as the island fort of Pampus. An additional advantage of this reuse is that by storing energy in households, less energy overall will have to be transported. Less energy will be lost and the grid will be less burdened, leading to lower demand for investments in the grid system [lxviii].

The roles of European Economic Community (EEC) and national governments are crucial. Governments can play an important role in encouraging and facilitating these innovations.

New developments on battery technology

Research on aluminum-ion batteries is not new but a sticking point to a commercial product has always been finding suitable materials for the anode and cathode that maintain their performance over repeated charge and discharge cycles.

On the battery front, Stanford researchers recently developed a new aluminum-ion battery that promises to deliver a number of improvements over the lithium-ion battery packs [lxix]. Not only is Stanford's battery technology less prone to exploding, but it can also reach a full charge in just about a minutes time. The prototype aluminum-ion battery of Stanford is extremely durable; it can endure a greater number of charge/recharge cycles than today's lithium-ion batteries. "We accidentally discovered that a simple solution is to use graphite," said Stanford Professor Dai Hongjie.

The result is a battery that can survive 7,500 charging cycles without losing performance. That is well over the roughly 100 cycles that other prototype aluminum-ion batteries can last at present and more than the typical 1,000 cycles from current lithium-ion batteries, according to the university. A drawback is that the energy density is too low. The aluminum-ion battery developed by Stanford has an energy density of 40 watts per kilogram compared to between 100 and 260 watts per kilogram for lithium ion. Although Stanford is positive on improving the energy density it is also justified to be critical. The past 20 years there have been many articles about "amazing battery breakthroughs" and many appeared not to have been commercially viable.

A.4.3.2 ***Fuel cell / Hydrogen***

Like electricity, hydrogen is an energy carrier and not an energy source. Normally it is made through a chemical process (e/g from natural gas), electro-chemically (e/g from water via electrolysis) or it is a waste gas (e/g from PVC production). Via a Fuel Cell (FC), hydrogen can be converted in electricity and water on board the EV. Also comparable with electricity is that when hydrogen is made from clean renewable sources (e/g wind, sun or hydropower), EVs can be operated zero emission from well to wheel. This relatively old FC technology is developing fast since its relatively affordable, safe and reproducible Proton exchange membrane (PEM) Fuel Cell has been on the market. However, hydrogen-electric powertrains in vehicles always are less energy-efficient than battery electric powertrains, though still more efficient that Internal Combustion Engines based powertrains. As ballpark figure BEV have an average practical ‘plug to wheel’ efficiency of about 80%, FCEV about 50% and ICE about 20% [lxx].

Still, there is a reason that FCEVs have a chance in the future auto-mobility. Filling a hydrogen tank is more or less comparable with LNG and can be done fast. From a weight perspective, hydrogen has the highest energy density of all fuels and energy carriers. So large ranges or 24/7 operations can be achieved easily. As rule of the thumb for a Pa-EV 1 kg hydrogen is needed for 100km for a heavy bus or truck Co-EV this will be about 5 to 10 kg. The big advantage of modern FCEV is that the FC is used as a range extender in addition to a relatively small battery pack. The FC range extender can also be small since it only supplies the average energy needed to drive the distance while the battery pack delivers the peak acceleration and brake-regeneration power [lxxi]. This means that increased range does not call for a bigger FC, but only a bigger tank, which is relatively cheap. At a certain range this can make FCEVs more affordable than BEVs, which need extra expensive and heavy batteries to increase the range. For this reason, VDL claims that for the large range buses it is better to build an FCEV than a BEV, since the latter will be a battery on wheels [lxxii].

Pilots with FCEV, both for passenger and commercial vehicles, have proven that the technology can be reliable and practical. The Honda FXC Clarity has now been in use in California for five years and has achieved very high customer satisfaction. Amsterdam tested two generations of FCEV buses from Mercedes and VDL-APTS that lived up to the expectations but were too expensive without subsidy. The price of the FCEV and of the hydrogen is still a cost killer. However, it is expected that the PEM FC technology will reduce in price by about 50% till 2020, as shown in Figure 7.3.3, and the current price of hydrogen of €10/kg at, for instance, the filling station at Rhoon can drop significantly. Industry experts expect that €2-3/kg is achievable. In the meantime, Toyota and Hyundai put their cards on a new FCEV rather than BEV or PHEV.

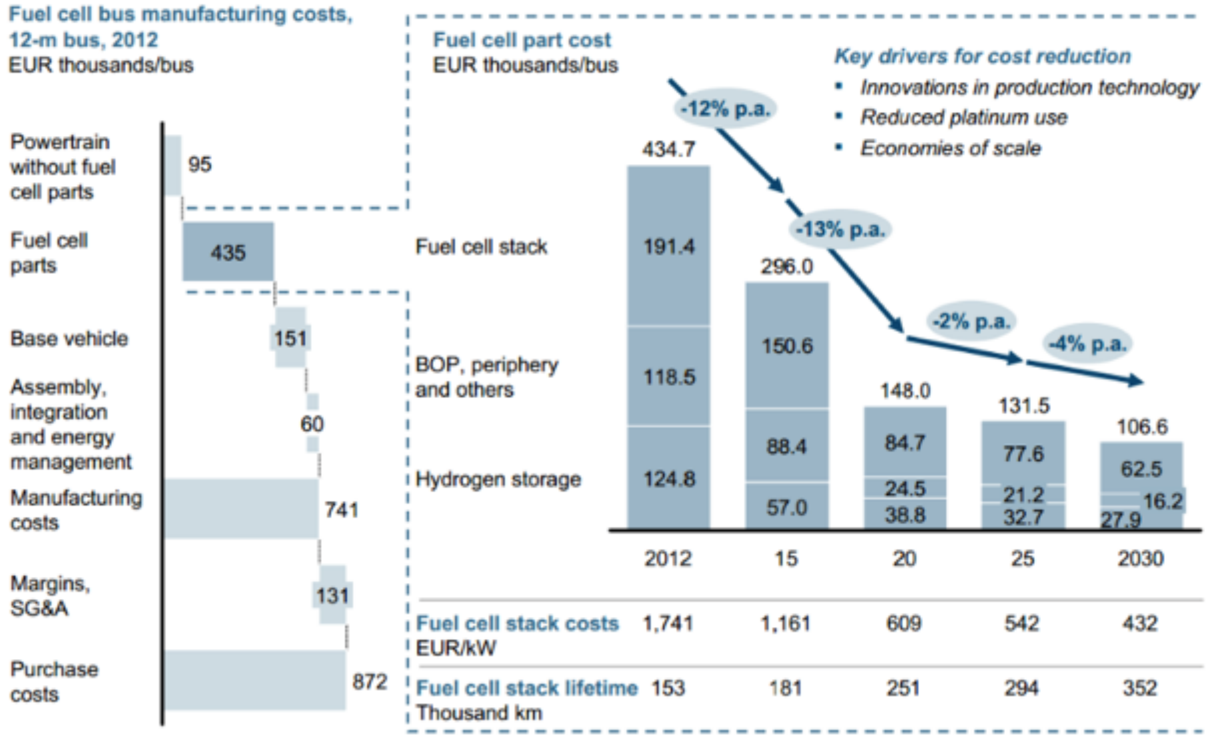


Figure 7.3.3: Development of fuel cell part costs until 2030 / Source FCH JU, Urban Buses: Alternative Powertrains for Europe, 2012

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