Validating Freight Electric Vehicles in Urban Europe

D3.2: Economics of EVs for City Logistics - Report

Work package: WP3 Analysis

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Glossary

BMC	Business Model Canvas
BSS	Binnenstadservice
CAN bus	Controller Area Network bus
CCC	Construction Consolidation Centre
CFV	Conventional Freight Vehicle
EAS	Engine After Treatment
EFV	Electric Freight Vehicle
EV	Electric Vehicle
GVW	Gross Vehicle Weight
HoReCa	Hotels Restaurants Cafe – (hotel and) catering (industry)
ICE	Internal Combustion Engine
OEM	Original Equipment Manufacturer
km	kilometres
kWh	Kilowatt-hour
TCO	Total Costs of Ownership
TRL	Technology Readiness Level
UCC	Urban Consolidation Centre

Executive summary

The aim of the deliverable on economics of electric vehicles for city logistics

FREVUE's deliverable 3.2 'Economics of EVs for City Logistics' aims at answering the question: what are the conditions to get a feasible / successful business case for electric freight vehicles (EFVs) in city logistics. This deliverable shows what logistics operators operationally and financially can expect when implementing EFVs and show authorities the existing barriers and opportunities for electrifying city logistics, by presenting:

- the operational experiences and lessons from using EFVs in real-life city logistics demonstrations (in chapter 2);
- the total cost of ownership comparisons between conventional and electric freight vehicles, as well as the barriers to switch from the CFV to the EFV based on the logistics operators value network (in chapter 3);
- the required changes in the logistics concepts to make EFVs fit city logistics better and the experiences with making these changes (in chapter 4); and
- the technical and economic possibilities for scaling-up (a few of) the electric city logistics operations as well as the exploration of the technical and economic possibilities for scaling-up the considered vehicle (weight) classes in a more generic context (in chapter 5).

Overall, this deliverable shows that city logistics operations can be performed by electric freight vehicles, but that at the time of writing the high vehicle purchasing costs are still a barrier for large scale utilisation of (especially large) EFVs for logistics operations.

Electric freight vehicles operating in city logistics

In FREVUE more than 15 companies demonstrate the use of electric freight vehicles in city logistics operations. Vehicles vary between small EFVs (small vans <3.5 tonnes), medium EFVs (between 3.5 and 7.5 tonnes), and large EFVs (rigid trucks >7.5 tonnes). These vehicles carry different goods, operate different routes and drive in different climates.

EFV routes are compared with the routes of the replaced CFVs, and the differences in kilometres, time and drops are shown. Next also the changes for a logistics operator are analysed when operating an EFV by a business model canvas comparison between the CFV and EFV situation.

A total of fifteen operators using over 60 EFVs in eight European cities has shown us that it is indeed possible to carry out at least part of the city logistics operations with EFVs, both technically as well as operationally. Both 'last mile' deliveries (e.g. from a consolidation centre to a city centre) by EFVs and replacement of entire trips formerly carried out by conventional vehicles have been tested and proven to be feasible in daily routines. The smaller EFVs in the demonstrations were used in a number of cases for last mile deliveries and led to changes in the logistics concept. Where they replaced CFVs, EFVs were planned more often on fixed trips/routes and did less ad hoc pick-ups and deliveries, due to the EFVs' range. For medium electric freight vehicles no major changes were made to the logistics concepts, but in some cases the EFV trips were of shorter distance than the CFV trips and the EFVs did relatively more deliveries and fewer pick-ups than CFVs. For the large electric freight vehicles it was very case-dependent whether or not changes were made to the logistics concept.

Changes in the logistics operator's network

Logistics operators who decide to procure an EFV or more EFVs face challenges as the value network in which they act requires several changes. The logistics operator needs to establish new relationships as especially large vehicles cannot be procured from OEMs and charging infrastructure is not as widely available as fuel stations. In other words, for a logistics operator to currently switch from the existing diesel-powered vehicles towards electric powered vehicles, requires more than just buying another vehicle, as the logistics operator has to explore many new and uncertain areas. Extra effort is required in procuring EFVs in comparison to CFVs, as well as overcome sceptics in a traditionally conservative sector. These extra elements can be (and indeed turned out to be) a barrier for operators in moving from CFVs to EFVs, in addition to sometimes unfavourable total cost of ownership for EFVs. The development that OEMs will start producing these vehicles will be removing one barrier in the transition from CFV- to EFV-dominated city logistics, as the operator can then use the regular maintenance network and buy the vehicles from familiar suppliers.

Total cost of ownership comparison between electric and conventional freight vehicles

The total cost of ownership (TCO) comparison between an EFV and a CFV is an important purchasing decision criterion for logistics operators. The TCO comparison results differ per vehicle type and usage. The TCO also depends on many other elements that can be country or even company specific.

For small electric freight vehicles, lighter than 3.5 tonnes, the TCO can be favourable for an EFV within about five years, in the case the vehicle drives 60 kilometres a day. The more kilometres the vehicle can be deployed on and the longer the (depreciation) period in which it operates, the larger the TCO advantage becomes for a small EFV. Small EFVs are already available from some OEMs, which reduce the purchase barrier even more.

For a medium sized electric freight vehicle, weighting between 3.5 and 7.5 tonnes, the TCO comparison shows that under specific circumstances a positive business case for using an EFV is, although challenging, possible. The more kilometres an EFV drives the more favourable the comparison, as kilometre costs are lower for an EFV (lower costs for electricity instead of diesel and lower maintenance costs). Specific circumstances, like the exemption for paying the congestion charge for EFVs, have a very positive effect on the business case for the EFV, whereas major grid investments for charging larger fleet sizes affect the business case negatively. Next, many uncertainties still exist around the residual value.

For the large EFVs, divided into small rigids and medium rigids in the TCO comparison, the TCO of a CFV is lower than that of an EFV. The purchase price for the individually retrofitted large electric freight vehicle is currently so much higher than for the OEMs' conventional truck that advantages due to lower operational costs do not result in a positive business case for the large EFV. Even a depreciation time of ten years, and a (purchase) subsidy do not currently allow for a cost-neutral business case for a logistics operator. Notice that driving the maximum number of kilometres the battery allows (about 180 kilometres a day) paired with a purchase subsidy can almost result in a cost-neutral business case.

Reorganizing logistics concepts for electric freight vehicles

For a larger scale transition towards electric freight vehicles, which is necessary to achieve essentially CO_2 free city logistics in major urban centres by 2030, the reorganisation of existing diesel based and diesel evolved logistics systems is necessary. Reorganising the existing logistics concepts, in which the city operations are decoupled from the kilometres driven outside the city, are necessary to use the potential of electric freight vehicles for city logistics.

There are different ways and forms to (re)organise city logistics in such a way that electric vehicles can be used for the last mile, such as the use of a dedicated hub by TransMission's Cargohoppers in Amsterdam, the use of an urban consolidation centre (Binnenstadservice in Rotterdam and as well as one in Stockholm), a cross docking centre (in Madrid), a decoupling point for swap bodies (in Rotterdam) and the setup of a construction consolidation centre. Such hubs allow for the transfer of goods somewhere near the city border from conventional vehicles to electric vehicles, so that the limited range of EFVs is not hindering city logistics operations. The examples discussed show that there is no easy proposition yet to convince existing logistics operators or shippers to use (or set-up) a zero emission alternative for city logistics operations..

Transition towards wide-scale electrification

A quantitative TCO-focussed analysis of upscaling the electric fleets for EFVs in the GVW categories 3.5t, 13t and 19t shows that at the time of writing the large EFVs are at least twice the price of their conventional counterparts, as the EFVs are retrofitted because no OEM offers a comparable EFV yet. To enable a large-scale transition towards full EFV fleets, the lower operational costs need to compensate the higher investment costs within the targeted depreciation period. With electric vehicles there is potential for lower maintenance costs as well. A first order approximation of the costs saving (per km) for an EFV compared with a CFV is provided by the following formula:

$$\mathrm{CostSavingPerKm} = \left(\frac{FuelPrice}{3.5} - ElectricityPrice\right)$$

This implies that there is only a cost saving potential in the case that the diesel price per litre is at least 3.5 times as expensive as the electricity costs per kWh, thereby presuming the depreciation costs for the charging equipment to be included in the kWh price.

Battery costs can be reduced by using a smaller battery. However to maintain the required daily mileage, fast charging then needs to be applied. Fast charging costs more than slow charging, which means that although the investment in the battery will decrease, the speed with which this smaller investment can be earned back will also be reduced. Where the battery price is the main price differentiator between the EFV and the CFV (as is expected with in-series produced EFVs), then reducing the battery size and (also) applying fast charging will decrease the earn back mileage. However if the price difference between the EFV and CFV is high and the battery price has less significance in this price difference (as is the case with CFVs that were converted into EFVs), then the reduction of the battery size in combination with applying fast charging might increase the earn back time.

At the current production scales for large EFVs (small series or even on a one-off basis) of companies converting CFVs to EFVs, the effect of volume on battery costs is limited.

Furthermore, these companies are confronted with labour intensive (reverse) engineering activities, and are therefore able to drive the production and maintenance costs significantly lower than the in-series produced vehicles.

Ultimately, a short-term market stagnation where transport companies are waiting for robust OEM products can be anticipated, given that they are faced with uncertainties on the purchase of higher priced products from conversion companies. This stagnation is not desirable, since there is a significant optimization potential by a combination of smart fleet planning and optimal charge regimes, as also seen from the partner scenario analyses. Here national or more localized legislation, and/or incentive programs, can play a significant role in encouraging the uptake of electric commercial vehicles in the next few years.

1. Introduction

1.1 Background and overview of FREVUE

As part of the FREVUE project, eight of Europe's largest cities, including six capitals, demonstrate that electric vehicles operating "last mile" freight movements in urban centres can offer significant and achievable decarbonisation of the European transport system.

The public-private partnership of FREVUE, which brings together 17 industry partners, nine public sector bodies and six research and networking organisations, jointly deploys demonstrators in Amsterdam, Lisbon, London, Madrid, Milan, Oslo, Rotterdam and Stockholm. The demonstrators have been designed to ensure FREVUE covers the breadth of urban freight applications that are common across Europe, including a wide range of:

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

By exposing over 80 electric vehicles to the day to day rigours of the urban logistics environment, the project aims to prove that the current generation of 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 with well-designed local policy.

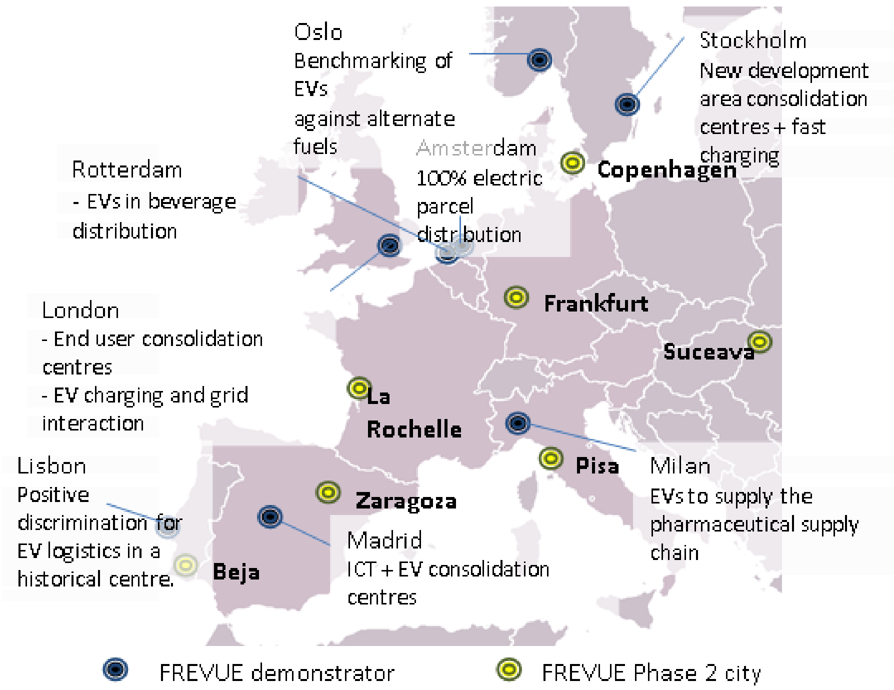

Figure 1: FREVUE demonstrator activities

The project demonstrates solutions to the barriers currently inhibiting uptake of EVs in the sector. Novel leasing and procurement models are explored to help mitigate the high capital cost penalty for EV purchase. The impact of a wide range of local policies on the overall ownership case for EVs in logistics applications is also tested.

The project includes leading European research institutions with expertise in transport policy, logistics and electric vehicle technologies. These institutions have designed and implemented a data capture protocol and subsequent assessment framework for the project. This ensures that the project creates a valuable European evidence base on the role of EVs in urban logistics. Partners will produce clear guidelines and recommendations targeted towards the key focus groups of this project: Freight operators and fleet managers, public authorities at the local and regional level, energy network operators, ICT and service providers, and vehicle manufacturers.

These guidelines and recommendations will feed into a targeted dissemination campaign to ensure that the results of the study reach an audience that will be able to act on the findings of the study and hence increase take-up of EVs in urban logistics. To complement this, FREVUE also created a network of "Phase 2" cities to directly share the lessons learned from the demonstrators. These cities are expected to be the first to expand the successful concepts developed by FREVUE.

1.2 Work package overview

The FREVUE project is broken down into five work packages, which are described below:

Figure 2: FREVUE work packages

WP1 – Assessment and ICT Framework: This work package defined the data protocols, data handling procedures and assessment framework for the demonstrators. This ensures that all required data is gathered and correctly communicated during the demonstrator operations. In addition, a review of state-of-the art logistics ensured that lessons from previous projects were taken into consideration during the planning phase for the demonstrators. Due to the dynamic and fast-changing situation around electro-mobility and urban logistics, it was agreed to update this state-of-the-art report in mid-2015 and in February 2017.

WP2 – Demonstrator trials: This package contains all aspects of the delivery of the demonstrators. Each trial has a local project manager responsible for day to day delivery of the project and the implementation of the data collection frameworks agreed in WP1. The trials follow a common structure across the eight trans-national demonstrators.

WP3 – Analysis: Data from the demonstrators is analysed and relevant conclusions for the logistics industry and policymakers are drawn including:

- Technical and economic performance of the demonstrators in FREVUE
- Environmental performance of the demonstrators (with respect to CO_2), and analysis of impacts for wider scale deployment (for air quality, congestion and the electricity grid)
- Social impact of the EV logistics applications and policies (e.g. curfew extension)
- Impact of the range of policies on the economic case for the logistics operators to deploy EVs
- Any safety issues arising during the demonstrators

WP4 – Dissemination: The dissemination activity is the key to the project and will target professionals in the logistics and ICT industries, energy network operators, vehicle manufacturers as well as policy makers with the potential to unlock further EV deployment in logistics. The task also includes direct "officer to officer" dissemination to the Phase 2 cities who have expressed interest in deploying similar programmes in the near future.

WP5 – Project coordination and management: This WP oversees the project overall and ensures efficient reporting to DG Move, that partners in the project are communicating effectively, that the project is progressing on schedule and that issues are identified at an early stage and dealt with promptly.

1.3 FREVUE deliverable 3.2– Economics of EVs for city logistics

1.31 Aim

This deliverable reports the economic analyses for the different FREVUE demonstrations. The main aim of this deliverable is to answer the question: what are the conditions to get a feasible / successful business case for electric freight vehicles (EFVs) in city logistics. Or in other words: this deliverable answers, from a logistics / operations perspective, the question: "What is necessary to make the transition from the current situation in which the majority or urban freight trips are undertaken by ICEs (internal combustion engines) to a zero emission situation in which electric freight vehicles are used?"

1.32 Target audience

The target audience for this deliverable are:

- the logistics operators (both transport companies and shippers) as these operators are responsible for the actual transport operations in cities. They have to be informed of the value of EFVs in city logistics operations by showing the actual results and experiences of real life usage and practical barriers in implementation of EFVs in daily operations.
- the (local) authorities as these are the main stakeholder group acting on the improvement of air quality and zero emissions, as well as the stakeholders that can – as will be clear from the results in this deliverable – influence the business case of EFVs by monetary (e.g. subsidies) and non-monetary (e.g. policy exemptions resulting in operational cost savings for operators) support.

This deliverable shows in detail what operators can expect when implementing EFVs in daily city logistics operations; for example new partnerships that are required, how operations change, what the effect is of charging time and infrastructure on the daily routines, what policy measures exemptions really make operations easier or less stressful for the driver, what is the expected change in costs (variable as well as fixed). Other aspects that are also relevant, for example on technical performance, are not the specific focus of this deliverable (see FREVUE, 2017), but how technical performance influences the business case, due to for example maintenance or limited action radius will be covered here.

1.33 Added value

This deliverable adds value to the field of e-mobility and city logistics. Although total cost of ownership (TCO) calculations do exits about different vehicles in city logistics, most of these studies are ex ante TCO calculations, and do not – or hardly – take empirical data in to account. D3.2's analysis is based on the actual results *and* experiences of the FREVUE demonstrations that take place in real life. The approach taken in this deliverable, i.e. the case study approach, allows for detailed information on real life experiences and lessons, which should fit the target audience of this deliverable very well.

1.4 Outline of this deliverable

This deliverable is set-up as follows: chapter 2 describes the actual FREVUE demonstrations on a case-by-case basis, where the logistics operators, the actors actually using a EFV are the point of focus. We use a business model canvas comparison to examine the differences in the cost-related areas (partners, activities, resources) and the revenues. The purpose of doing this for all cases is to be able to include case specific details and lessons.

Chapter 3 then generalizes from the individual FREVUE cases: we discuss the changes in an operator's value network (that includes the relevant stakeholders and changes) for three different vehicle types: small (<3.5t), medium (3.5-7.5t) and large (>7.5t). Based on these changes in the value network, barriers that operators face in practice when changing from using conventional freight vehicles to electric freight vehicles are highlighted. Next, the TCO comparisons for the three categories are presented.

The forth chapter looks at one specific detail of the business model changes from the FREVUE demonstrations: the logistics concept. Based on the different demonstrations we look at what the requirements are to use EFVs in case these are simply replacing ICEs or for those case where the logistics concept has to be adapted to fit EFVs' characteristics (like setting up a UCC to deal with limited range). The central question in this chapter is how logistics could be (re)organised in such a way that electric vehicles can be used in the last mile, also for trips where a CFV cannot simply be replaced by am EFV at a feasible business case. This chapter is based on experiences from FREVUE demonstrations as well.

After discussing the experiences from the current FREVUE demonstrations and demonstrators, the current barriers to switch from conventional vehicles to electric freight vehicles; TCO comparisons between CFVs and EFVs; and the necessity (and challenges) of reorganising the logistics concepts to better fit EFV characteristics; chapter 5 examines the transition towards wide-scale electrification for city logistics. What kind of barriers and challenges can be expected when scaling up the EFV fleets and how to deal with these challenges that we can expect in the next three to five years, is what this chapter goes into. Chapter 5 specifically focusses on: (1) the technical and economical possibilities for scaling-up (a few of) these demonstrators, and (2) exploring the technical and economical possibilities for scaling-up the considered vehicle (weight) classes in a more generic context.

2. FREVUE case descriptions – business model changes

2.1 Introduction

2.11 Set-up of case descriptions: using a business model canvas comparison

This chapter describes the FREVUE demonstration (situations before and after FREVUE, focusing on the description of operational activity) and the changes that were required for the actual implementation of EFVs in city logistics practice. The changes are reported in the format of the business model canvas (BMC).

To analyse which business aspects change due to the use of an EFV instead of a CFV, we look into the business model of the operator that actually runs the vehicles in the FREVUE demonstration. We compare the business model of the business as usual with the business model using the EFV(s) as in FREVUE demonstration. The business models are explored through the use of the Business Model Canvas by Osterwalder and Pigneur (2010) and the work that has been carried out within TURBLOG (2011), Deliverable 2: "Business Concepts and models for urban Logistics" and STRAIGSTOL (2014ab).

Following STRAIGHTSOL (2014a) "in order to describe an organisation's business model, Osterwalder and Pigneur propose a single reference model, which is known as The Business Model Canvas (see Figure 3). The model initially consisted of nine building blocks (i.e. partners, activities, resources, value proposition, customer relationships and segments, cost and revenues streams). In the Business Model Canvas an implicit assumption is made that the goal of an organisation is to generate revenue streams. However, when it comes to urban logistics, societal and environmental impacts are of great concern as well, for example, the reduction of pollution, noise, congestion and traffic accidents. When applying the business model canvas to urban logistic concepts it becomes clear that the model does not directly capture those externalities. For this reason, a 10th building block has been added to the model (TURBLOG, 2011). By defining the 10th building block Externalities, the Urban Logistics Business Model has been created. This tenth block can be considered the value proposition to the society. The 10 building blocks together make up a complete business model. The Business Model Canvas helps to map, discuss, design and invent new business models."

As shown in Figure 3 the Business Model Canvas is split up in ten blocks that can be grouped as follows:

- the customer-part (the right part including customer relationships, channels and customer segments) that results in revenue streams. This customer part on the right side of the model focuses on how value is being provided to the customer (through which channels and relationship models). The externalities-block contains the value proposition to relevant stakeholders in the urban logistics settings (for example residents), but it is often very difficult, if possible at all, to put monetary values on this proposition for the focal company. Based on what a customer is willing to pay for a service or product, a company can create revenue streams. The business model canvas shows that the three blocks at the right (i.e. customer segment, customer relationships and channels) together result in a revenue stream (which is in its turn a derivative of these three blocks).
- the organisational part (on the left side with the key partners, key activities and the key resources) that results in the cost structure. This part shows the elements that

are necessary to make, produce or offer the value proposition by means of certain key partners and key activities.

- the financial model*:* The financial model shows the financial arrangements between the different actors in the value network.
- The value proposition and the value proposition to society (i.e. the externalities block) show the value that a company offers to the customers and the society.

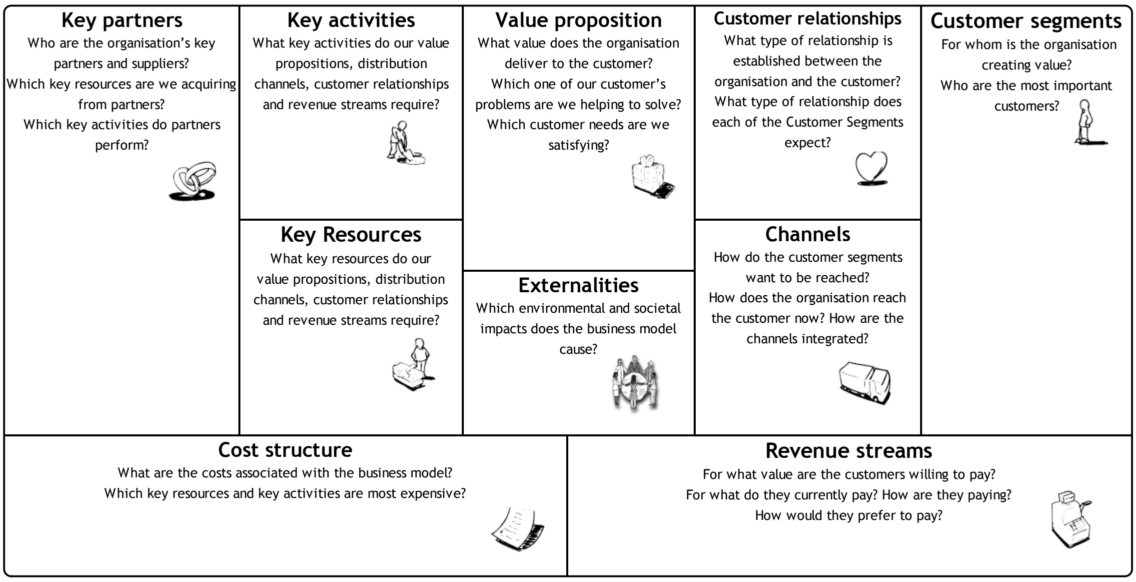

Figure 3: Urban Logistic Business Model Canvas

The structure of the Business Model Canvas helps to analyse and compare which part of the business changes when an operator is using an EFV instead of a CFV in its city logistics operations (which by the way are part of the logistics operators' key activities) and how this affects other parts and eventually what the effect of this change actually is on the value propositions, the cost and benefits of the operations. The BMC comparison is applied to each FREVUE demonstration, and allows us to analyse the full details of the changes the operator faces (and not 'just' the operations). This is done by answering a set of questions for each block, as shown in Figure 3. In the analysis, we primarily focus on the changes and associated consequences due to the use of EFVs in city logistics operations. We use the BMC comparison to make sure all relevant aspects that change, as well as all elements that do not change, are included.

A total of 69 vehicles from FREVUE demonstrations for which we received cost and operational data are included in the overall economic evaluation, out of a total number of 80 FREVUE vehicles. The markets for small, medium and large EFVs differ a lot in their procurement, costs and deployment characteristics. Therefore the cases are organized according to these three categories of vehicles in sections 2.2 (small EFVs), 2.3 (medium EFVs) and 2.4 (large EFVs). Each of these sections starts with an introduction presenting a summary of the characteristics of the cases.

Table 1 presents an overview of vehicles deployed in FREVUE, also indicating (1) whether the vehicle replaced a CFV or was added to the operation, (2) vehicle size, (3) the form of ownership and (4) whether there was additional deployment of an urban consolidation centre (UCC) in the demonstration.

The markets for small, medium and large EFVs differ a lot in their procurement, costs and deployment characteristics. Therefore the cases are organized according to these three categories of vehicles in sections 2.2 (small EFVs), 2.3 (medium EFVs) and 2.4 (large EFVs). Each of these sections starts with an introduction presenting a summary of the characteristics of the cases.

Table 1 Overview of vehicles deployed in FREVUE

Country/company	**Replacement or additional vehicle(s)**		**Vehicle size**			**Ownership**			**UCC**	**Total EFV**
	Repl.	**Add.**	**<=3,5**	**>3,5 <=7,5**	**>7,5**	**Bought**	**Subcontract**	**Leased**		
PT: EMEL	5	6	11			5		6		11
PT: CTT	10		10			10 (vehicles)		10 (batteries)		10
NO: Bring	4		4				4			4
ES: SEUR		1	1				1			1
ES: TNT		1	1				1		1	1
ES: Leche		2	2				2		2	2
IT: Eurodifarm		1	1			1				1
NL: BSS	1		1			1				1
NL: TNT	7			7		7 (retrofit)				7
NL: UPS	4			4		4 (retrofit)				4
UK: UPS	16			16		16 (retrofit)				16
NL: Heineken	9				9		9 (retrofit)			9
NL: BREYTNER		1			1	1				1
UK: Clipper	1				1	1				1

2.12 Operations: data plotted in a box plot

The operational data of the demonstrators is represented in box plots. A box plot is a simple way to give an overview of the distribution of a data set. The distribution is characterized by five special values of the data set: the minimum, the first quartile (Q1), the median (Q2), the third quartile (Q3), and the maximum. The minimum and maximum are represented by a short horizontal line at the bottom and top of the box plot respectively. These values are connected to the box in the middle by a vertical line. The box itself is bounded by both the first and the third quartile. This implies that 50% of the values in the data set are contained inside the box. The red horizontal line inside the box represents the median value. Note that this value is different from the average value (the mean). The advantage of the median value compared to the mean value is the fact that the median is less sensitive to extreme values. So in case of measurement errors or other outliers, the median is not influenced by the size of these outliers, but only by the number of extreme values on one of both sides. In case of outliers, the small horizontal line at the bottom and the top do not represent the exact minimum and maximum. These lines represent the minimum and maximum value after removing all outliers. There are different ways to define outliers; in this case the interquartile range is used. The interquartile range (IQR) is the difference between the first and the third quartile: IQR = Q3-Q1. All values lower than Q1 - 1.5 x IQR and all values higher than Q3 + 1.5 x IQR are defined as outliers. So the vertical lines on both sides of the box have a length of at most 1.5 x IQR. In this case outliers are not shown in the box plots.

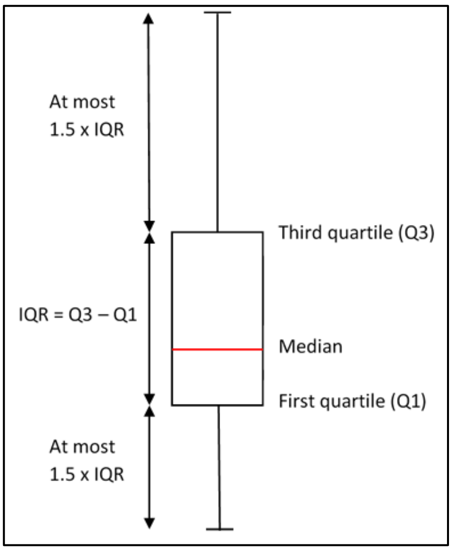

Figure 4: Box plot example

2.2 Small electric vehicles in city logistics operations

2.21 Introduction and general outcomes

There are eight cases in which logistics companies use small EFVs in their operations in the FREVUE demonstrations. The cases mainly concern postal and parcel operations, in which either CFVs are replaced by EFVs or EFVs are added to the operations. Typical EFVs used are the Renault Kangoo Z.E. and Nissan E-NV 200. In two cases the EFVs are introduced for the 'last mile' deliveries (e.g. from a consolidation centre to a city centre), in the other cases they replace longer part of the trips. In most cases there was a change in the logistics concept because of the limitations in range of the EFVs. The EFVs were used for specific trips that were suitable for them. In comparison to CFVs the EFVs drive more fixed trips/routes and do less ad hoc pick-ups and deliveries. The tests and demonstrations of the EFVs show that it is possible to carry out at least part of the city logistics operations by an EFV. Disadvantages mentioned are the limited capacity and range of the EFVs used, and the need to recharge. EFVs that offer more in this respect come with a higher price. Companies would welcome more information about the EFVs available in the market to be able to make a better choice. When looking at the costs and resources, the most important ones are the purchase or lease of the EFVs, required infrastructure (if any) and operating costs (fuel vs. electricity). Sometimes there are tax reductions for EFVs compared to CFVs. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

2.22 EMEL in Lisbon

Demonstration description

EMEL is Lisbon's municipal parking company, fully owned by the Municipal Council. Its main role is to manage the public on-street parking throughout the City of Lisbon, and it does so through (1) collecting money from on-street parking meters, which is the organisation's main activity, (2) maintenance operations of parking meters, and (3) internal postal services.

Figure 5: EMEL's EFVs operating in FREVUE

In FREVUE EMEL first replaced five conventional vehicles (Renault Kangoo) with five EFVs (Renault Kangoo ZE), as shown in Figure 5. Later in the project - and based on the positive experience made – EMEL leased six additional EFVs. Associated to this lease are services such as insurance, maintenance and vehicle replacement. The EFVs have a higher payload than the conventional vehicles, see Table 2. The EFVs are mostly charged at night at the EMEL operational centre, located in the centre of Lisbon. Additional charging stations were bought by EMEL. If necessary, a nation-wide charging network exists in Portugal, which can be used.

Table 2 Overview of vehicle characteristics EMEL

Vehicle/Parameter	**EFV**	**ICE**
Model	Renault Kangoo ZE	Renault Kangoo
Payload (kg)	650	439
Type of vehicle	Light duty	Light duty
Gross vehicle weight (kg)	2175	1918
Maximum loading capacity(m3)	3	3

Changes in business model

Partners, activities, resources: With regard to the activities, the EFVs can be used for two out of the three main activities at EMEL: maintenance operations of parking meters and internal postal services. However, only the newest EFVs can be used for EMEL's main activity – collecting money from on-street parking meters as an alarm system is necessary and only the newest vehicles have that installed. Because charging takes place during the night, there is no problem of vehicles that cannot be used for daily operations. Parking meter maintenance trips do not have specific routes defined by EMEL due to the type of work involved. For this activity EFVs are deployed for on average 60 kilometres per day and four kilometres between the stops. No operational changes were made in comparison to the ICE vehicles.

We have looked at the operations in more detail. Figure 6 and Figure 7 show boxplots presenting information on the trips driven by CFVs and EFVs. These figures show that the trips driven by an EFV were shorter in distance and in duration and show a larger variety. In line with this, fewer stops were made than in trips performed by the CFVs. These differences could be caused by the fact that not all EFVs collect money from parking meters during their trips, so their trips are of a different nature than the average trips carried out by CFVs.

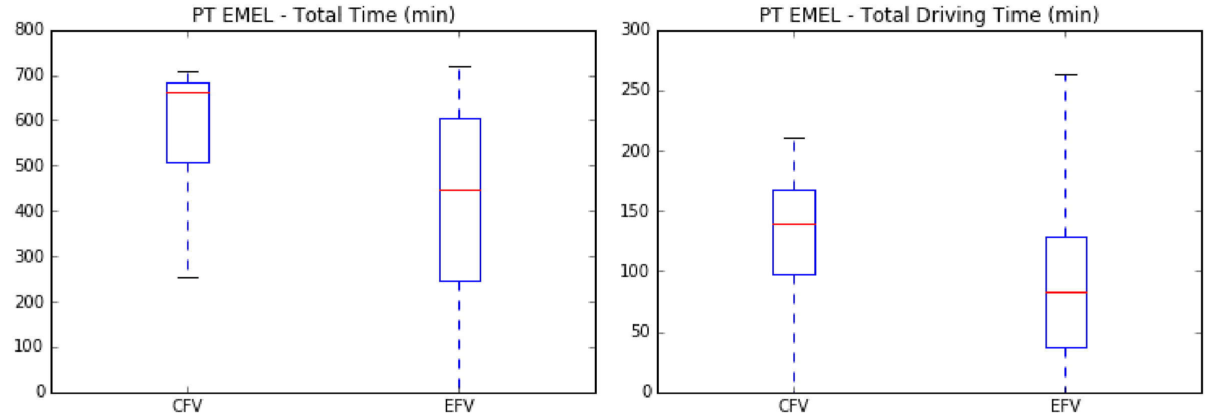

Figure 6: Boxplots of the total time and total driving time per day for EMEL in Lisbon[1]

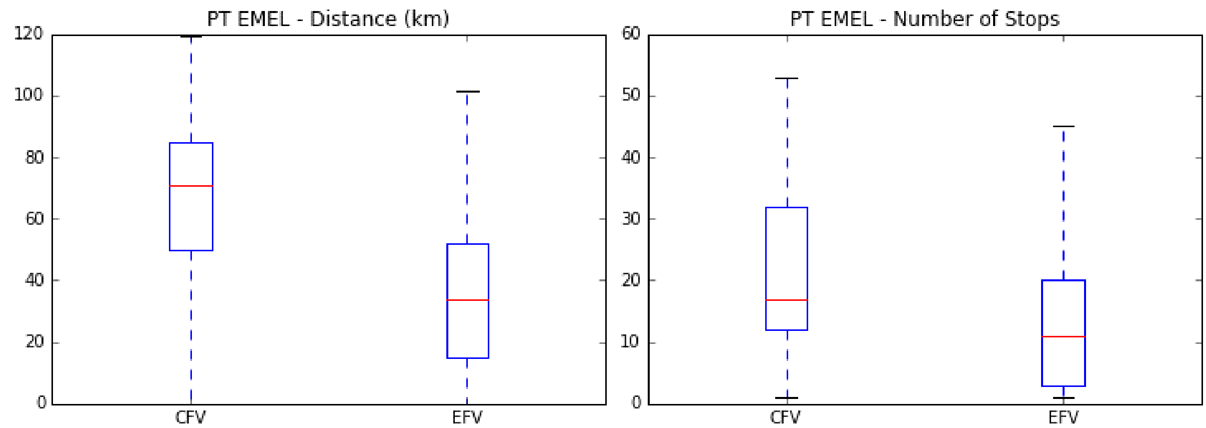

Figure 7: Boxplots of the distance driven and number of stops made per day for EMEL in Lisbon

With regard to resources, there is a change in fuel costs because of the change to EFVs. Additional charging stations were bought and installed at EMEL's premises. In addition, costs were involved in the managing of the purchase and leasing of the EFVs. Finally, the use of the EFVs led to higher insurance costs, probably due to the fact that the value of the cars is higher. The use of EFVs also led to savings. The fuel costs, maintenance costs, and vehicle repair costs are lower when using an EFV than when using a CFV.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

[1] Box plots in Figure 6 and Figure 7 are based on 81 observations for ICEs and 941 observations for EFVs; the EFV data are corrected for outliers (especially in driving time, in about 10% of the observations the driving time continued counting more than one day).

Value proposition: There are no changes in the value proposition of EMEL. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Investment costs for purchasing and leasing the EFVs (-)
- Purchase of charging equipment (-)
- Lower fuel costs (+)
- Lower maintenance costs (+)
- Lower repair costs (+)
- Higher insurance costs (-)

In the revenue structure there are no changes (0). A non-monetary revenue stream is that the company is more sustainable.

Conclusion and discussion

The EMEL demonstrator shows that:

- EMEL's activities can be carried out with the EFVs, only collecting money cannot be done by all EFVs as this requires additional changes to the operating vehicle (not directly related to the electric drive line).
- There are no particular changes, just the 'regular' ones (investment costs for purchasing the EFVs and lower fuel costs are the most important ones).
- The EFVs make shorter trips with fewer stops, but variation is larger than for CFVs.

2.23 CTT in Lisbon

Demonstration description

Correios de Portugal, S.A. (CTT) is the national postal service of Portugal, processing more than six million postal items on a daily basis, distributed in more than 5.6 million domiciles by 5,840 postmen and 6,295 postal delivery routes. Over the lifetime of the FREVUE project the profile of the CTT operation itself has changed. In 2015 two previously independent operations – mail (post and small parcels) and express mail (large parcels and express) – were partially integrated. This resulted in an increased need for higher payload vehicles transporting mail and express mail items together. Typically, mail delivery and collection between the CTT distribution centres and Lisbon city centre is organised along two time shifts:

- Morning delivery from 08:00-13:00
- Afternoon mail collection from 14:00-18:00

Conventional vehicles are used both in the early morning and in the afternoon shifts, performing sometimes two or more services a day.

In FREVUE CTT introduced ten EFVs into their fleet, replacing the following conventional vehicles:

- 5 Peugeot Partners were replaced by 5 Renault Kangoo ZE Maxi
- 1 Peugeot Partner and 4 Renault Kangoo were replaced by 5 Renault Kangoo ZE (see also Figure 8).

The EFVs have a higher payload than the conventional vehicles, see Table 3.

Figure 8: CTT's EFVs operating in FREVUE

Table 3 Overview of vehicle characteristics CTT

Vehicle/Parameter	**EFV**	**EFV**	**ICE**	**ICE**
Model	Renault Kangoo ZE	Renault Kangoo ZE Maxi	Peugeot Partner	Renault Kangoo
Payload (kg)	650	650	558	439
Type of vehicle	Light duty vehicle	Light duty vehicle	Light duty vehicle	Light duty vehicle
Gross vehicle weight (kg)	2126	2239	2130	1918
Maximum loading capacity (m3)	3	4	4	3

The vehicles were purchased by CTT and the batteries are leased. The vehicles are charged during the night on the premises of the Postal Distribution Centres. For this, charging equipment was bought in the form of cables and sockets; this solution was opted for because it is not subject to a market consultation (a procedure that would take some time to conclude), thus avoiding delays in the vehicle reception by the users.

Changes in business model

Partners, activities, resources: With regard to the activities, CTT has analysed the circuits in Lisbon's downtown area taking into account the type of vehicle used (considering only the type envisaged in the project) and distances driven. Routes from three distribution centres to the city centre were considered. This resulted in ten routes being identified as suitable for EFV operation. After the merge of mail and express mail operations, the required vehicle payload increased, and routes where EFVs are deployed were reconsidered. EFVs were mostly deployed on shorter routes, reducing the average distance for an EFV-roundtrip to

23-51 km/day (where the average distance of a CFV trip was up to 65 km/day). This was a choice of CTT to divide the shorter routes to the EFVs, the range of the vehicles allowed also assignment to the longer routes.

Over three weeks in October and November 2014, CTT monitored operations of two conventional and two electric vehicles performing deliveries from two mail distributions centres:

- SAD distribution centre in Lisbon’s outskirts
- CDP1200 Lisbon downtown distribution centre

Figure 9 and Figure 10 show boxplots presenting information from the monitoring. There were only small changes for the roundtrips (trips leaving from and returning to the distribution centre) comparing EFVs and CFVs. The median total time for trips was about the same for EFVs and CFVs, but with a larger variation for CFVs. The median total driving time was larger for EFVs. The median number of stops was comparable for EFVs and CFVs, but there was a larger variation in number of stops for CFVs. This explains the differences in total (driving) time. The average distance travelled per day for the EFVs was around 23 km for SAD and 51 km for CDP1200. Other results (not shown in the boxplots) are as follows. For CDP1200 less roundtrips were made with EFVs (-15%) and the average distance per roundtrip was longer (+8%). The pattern over the day (with a clear reduction in kilometres travelled during ‘lunch’) stayed the same. A low average speed of 14 km/h was observed with both vehicle types, typical for urban centres.

An exact comparison is not possible, as the routes changed during the project. What the figures do show is that the EFV can perform similar operations as the CFVs did before the FREVUE project.

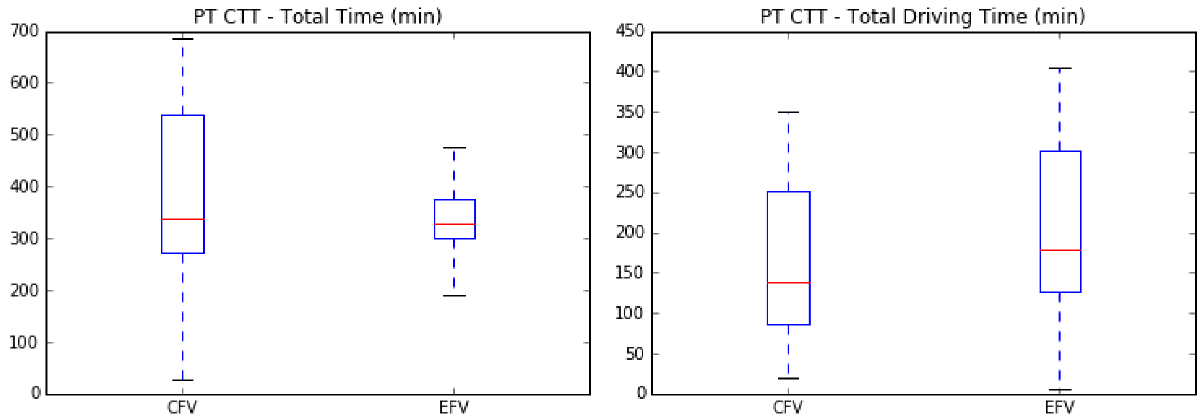

Figure 9: Boxplots of the total time and total driving time per day for CTT in Lisbon[2]

[2] Figures based on dataset sampling 58 trips of CFVs and 286 EFVs trips; test trips of EFVs or trips where time was two days were removed from the data set (about 10% of the observations)

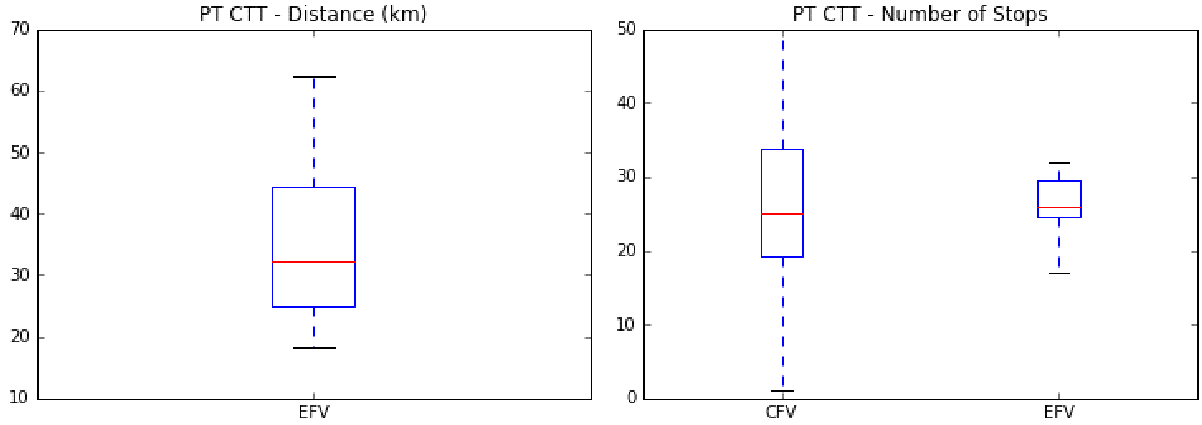

Figure 10: Boxplots of the distance driven and number of stops made per day for CTT in Lisbon

New activities for CTT were the training of drivers and fleet owners, and the charging of the EFVs at the Postal Distribution Centres. The average recharging duration is between 2.1 and 5.6 hours, with starting times at the end of the day or at night. No charging is needed during the day.

With regard to the resources, there is a (positive) change in fuel costs because of the change to EFVs. Only charging equipment had to be purchased at the start.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of CTT. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Investment costs for purchasing the EFVs, including training of drivers and fleet managers (-)
- Purchase of charging equipment (-)
- Lower fuel costs (+)
- Lower insurance costs (+)
- No circulation tax (+)
- No change in operating costs (0)
- Free parking for EFVs in Lisbon, but CTT did not pay parking fees for CFV vehicles, as the vehicles did not park but were loading and unloading in the operations in Lisbon (0)

So far there have been no technical problems with the EFVs, so there is no insight yet into the maintenance and repair costs. Depreciation of the EFVs is six years, compared to four years for the ICEs. This has to do with a difference between the buying/leasing structures.

In the revenue structure there are no changes (0). A non-monetary revenue stream is that the company is more sustainable.

Conclusion and discussion

- All activities that were selected in FREVUE can be carried out with the EFVs; there are changes in the type of trips (shorter distance, lower average speed).
- There are no particular changes, just the ‘regular’ ones (investment costs for purchasing the EFVs and lower fuel costs are the most important ones).

2.24 Bring in Oslo

Demonstration description

Bring is supplier of post and logistics services in the business market, and owned by Posten Norge AS. Bring owns a network consisting of 41 warehouses throughout the Nordic region and 45 company-operated terminals. All Bring drivers are employed through a franchise agreement. Therefore Bring does not own any vehicles and participating transporters have purchased their own EFVs (as part of a larger EFV procurement order by Norwegian post). Nearly 10,000 vehicles are in daily usage for Bring. Bring Express is the subsidiary that offers courier and express services, locally, nationally and internationally.

Figure 11: Bring’s EFVs operating in FREVUE

Prior to FREVUE, Bring used bicycles for distributing post and packages within the ring road 2 (the inner circle of Oslo’s city centre), and diesel vehicles outside this area. Under FREVUE, Bring Express replaced four diesel vehicles (VW Transporter) operating outside of ring road 2 but within ring road 3, with EFVs (Peugeot Partner), see Figure 11. The vehicles have the same loading capacity but the maximum payload of the EFVs is much lower, see Table 4. The participating transporters have purchased their own EFVs (within a larger EFVs procurement order by Norwegian post).

Table 4 Overview of vehicle characteristics Bring

Vehicle/Parameter	EFV	ICE
Model	Peugeot Partner	VW Transporter
Payload (kg)	636	1000
Type of vehicle	Light commercial vehicle	Light commercial vehicle
Gross vehicle weight (kg)	2225	3000
Maximum loading capacity (m3)	3.5	3.5

Changes in business model

Partners, activities, resources: The logistics concept for the EFVs is different than that for the ICEs. With conventional vehicles almost all deliveries and pick-ups are ad hoc, with no week being exactly the same (this makes the before scenario difficult to define and direct comparison between Bring's EFVs and CFVs operations not possible). With the introduction of EFVs the choice was made to develop fixed routes as this would help to avoid range issues. When planning an EFV routine, charging locations for the vehicle have to be taken into account. This leads to tighter vehicle routines for the electric vehicles. Most of the goods carried by Bring Express either originate or arrive within the demonstrator's geographical area. The logistics concept for EFVs in Bring is as follows: in the morning deliveries are made and in the afternoon pick-ups are done.

Basically, the route starts at the driver's home, to the post office to pick up the load, to the customers in Oslo city centre for deliveries, then doing pick-ups, to the post office to unload, and back home. The normal working day of the EFVs is split into two shifts: the morning shift from 7.30-11.00 and the afternoon shift from 13.30-16.00 with fast charging in between, if necessary. All vehicles can drive on average range of 200 to 220 km per day. Fixed routes help to avoid range issues. The vehicle is charged at night at the driver's home. Four different postal offices are used forming four different routes for EFVs.

For each fixed EFV route Bring subcontractors receive a certain amount of money (the exact price they get per day depends on the weight and volume of the parcels and the number of zones that it has to be transported to). There are no fixed prices for the CFV. EFV subcontractors can still do ad hoc deliveries and pick-ups, but that depends on the vehicle and the driver. This model reduces uncertainty for drivers on their income and is also more beneficial for Bring, as drivers with fixed routes deliver up to 10% more parcels per day (based on data from two drivers). EFV drivers all have reported an increase in their income, due to expenses being lower than with previous diesel vehicles (electricity is cheaper than expenses on diesel) and an increase in the number of parcels delivered. Subcontractors are paying these expenses themselves.

At some public (fast) charging points there are queues during rush hour, especially during the winter. This results in long waiting times to charge the vehicle, with drivers often waiting more than an hour to get access to the chargers. This results in a time loss of up to 1-1.5 hours per day and also loss of money for drivers and Bring Express. In 2016 two new fast charging stations were installed in Oslo and Bring EFV operators get advantages (financially and time-wise – charging time of 30 minutes) when using these stations. The supplier of the fast chargers has modified a new pre-booking software, by giving priority to FREVUE Bring EFVs at the two fast charging stations. Drivers of other vehicles are given a notice when a Bring vehicle is approaching and the outlets will automatically be closed for other vehicles on one charger for Bring. Furthermore, Bring is given a 40% charging discount during the FREVUE project lifetime.

In Figure 12 are the boxplots for the electric vehicles given with respect to the total time and distance of their trips. The median distance is almost 100 kilometres, while the median duration is over five hours. The total time includes the stopping time at the different delivery and pick-up locations. Figure 12 does not provide a comparison between CFVs and EFVs, as no data on comparable CFV operations were available (due to the described change in operations). The number of delivered and collected packages (and the corresponding number of stops) was not available in combination with other trip data. Bring reported making approximately 70 deliveries per EFV trip.

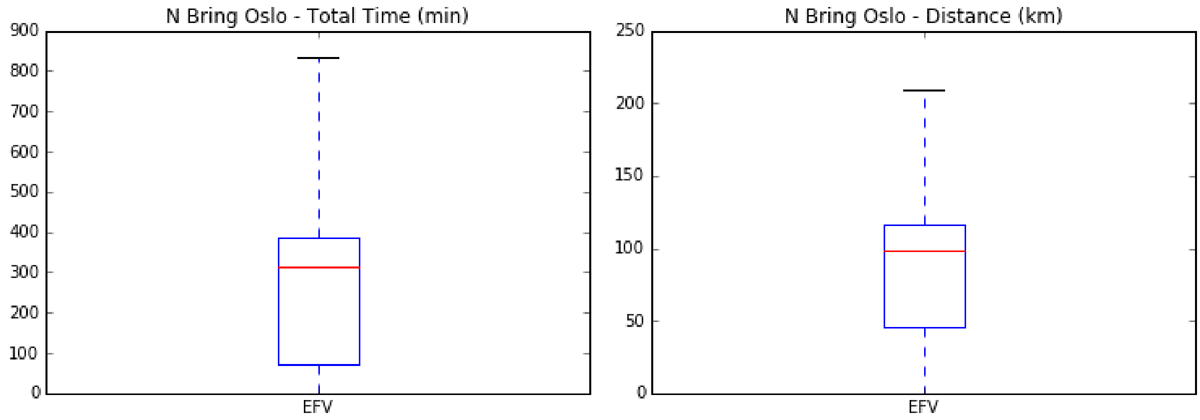

Figure 12: Boxplots of the total time and distance driven per day for Bring in Oslo[3]

One vehicle broke down in late 2015 and was replaced with another identical Peugeot Partner on the same day. Bring did experience technical issues with three out of the four vehicles.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of BRING. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: No serious changes have been made to the cost structure of Bring, since the subcontractors own their own vehicles and purchased the EFVs themselves, and the price they receive for the operations is for an EFV comparable to the conventional vehicle. Also no specific investments were made for charging infrastructure, since public charging poles are used and/or charging is done at home.

Also in the revenue structure of Bring there are no changes. A non-monetary revenue stream is that the company is more sustainable.

The cost structure for drivers has changed. They purchased an EFV (which is more expensive than a conventional vehicle) by themselves and pay for charging instead of for conventional fuels (which means a reduction of costs). They have now the opportunity to gain a higher income because they can deliver more parcels than before because of the fixed routes they are on. They also can profit from government policies that are in favour of EFVs, such as not having to pay any tax (car, road) or tolls, being permitted to use public transport lanes and free parking in the city.

Conclusion and discussion

All costs, risks, etc. are for drivers rather than for the company. The cost structure for Bring does not change, only the logistics concept (fixed routes). It is not known what the implications for the future are if they want to deploy more EFVs. For example, will they

[3] Figures based on data of more than 1500 trips made by EFVs (data corrected for outliers)

always have a certain share of conventional vehicles for the ad-hoc deliveries (that are out of reach due to the range limitations of the EFVs)?

2.25 SEUR in Madrid

Demonstration description

SEUR is a Spanish parcel company; its main business in Madrid is parcel deliveries and collection. In FREVUE, SEUR extended its vehicle fleet park with one EFV: a Renault Kangoo Z.E. The capacity of this EFV is smaller than the capacity of the conventional vehicles used in the city centre (Mercedes Sprinter/Ford Transit); the payload is halved and the maximum loading capacity is 30-40% of that of the conventional vehicles, see Table 5. Later SEUR added a Nissan e-NV 200 to its fleet, operating in Madrid's city centre (see Figure 13); this vehicle has not been analysed in this report.

Figure 13: SEUR's EFV operating in FREVUE

The EFV was a promotional offer by Renault and as a result there were no purchasing costs for SEUR except for the charging infrastructure. In its daily operations SEUR uses subcontractors for many of its deliveries, but for the EFV a driver was hired.

Table 5 Overview of vehicle characteristics SEUR

Vehicle/Parameter	**EFV**	**ICE**	**ICE**
Model	Renault Kangoo Z.E.	Mercedes Sprinter	Ford Transit
Payload (kg)	650	1290	1350
Type of vehicle	Light	Light	Light
Gross vehicle weight (kg)	1426	2150	2210
Maximum loading capacity(m3)	3	7.5	9.6

Changes in business model

Partners, activities, resources: Due to the fact that the capacity of the EFV is smaller than the capacity of the conventional vehicle previously used in the city centre, the delivery route was reorganised and only for part of the roundtrips in the city centre the conventional vehicle was replaced by the EFV. The conventional vehicle continued performing roundtrips but not in the central area of Madrid. Therefore, there was no full vehicle replacement, but only replacement of part of the roundtrips and both EFVs and ICEs continued the work in the Madrid city centre.

During demonstration SEUR did not use the UCC provided by Madrid municipality. SEUR operated from its own depot which is very well located for deliveries in the city centre of Madrid and situated in close proximity to the FREVUE UCC (the SEUR depot is between the UCC and the city centre). The EFV recharged every day at the SEUR depot.

Logistics trip characteristics of the EFV are as follows: the EFV was used for trips with small parcels in the central area of Madrid during the day between 9:00 and 18:00 and drove 50-100 km per day (see also Figure 14).

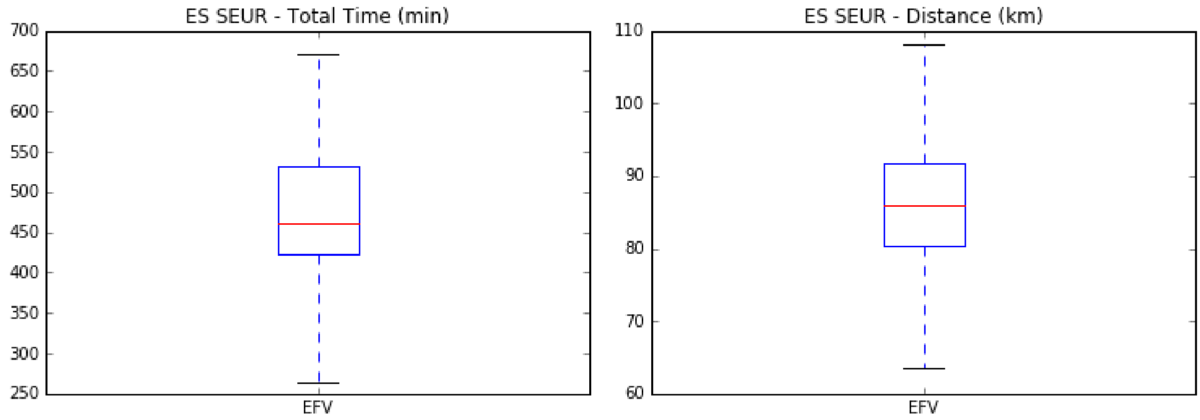

Figure 14: Boxplots of the total time and distance driven per day for SEUR in Madrid[4]

Besides the addition of the EFV, no other operations were changed. Although there are options to receive access to some restricted areas for EFVs, we did not find data supporting advantages from that (but no direct comparison to the routes before was possible, due to additional trips that were planned for the EFV); this also applied to the extended time windows that are available for EFVs.

With regard to the resources, there are additional costs because there is an additional vehicle and additional driver. Plus charging equipment was bought and installed. As this demonstration was set up as a demonstration of the suitability of the electric vehicle, it does not allow to compare economically to the before situation.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of SEUR. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure this demonstration reported the following changes; an increase in costs due to:

- Purchase and instalment of charging station (-)
- Hiring extra driver (-)
- Costs for additional vehicle (electricity, insurance, etc.) (-)
- Administration costs for starting up the operation (-)

[4] Due to capacity constraints for the EFV in comparison to the CFVs no direct comparison between the trips made by these vehicles is possible. The boxplots in this figure are based on 236 data points (data corrected for outliers).

In the revenue structure SEUR also reports changes, since extra parcel deliveries are possible because of the additional vehicle. Again, as this demonstration was set-up as a demonstration and test for using an electric freight vehicle in city logistics operations, a good TCO analysis is not feasible based on the available data (e.g. no costs for the vehicle).

Conclusion and discussion

The test and demonstrations of the SEUR vehicle shows that it is possible to carry out at least part of SEUR's city logistics operations by an EFV, which is also supported by the addition of a Nissan e-NV200 during the lifetime of FREVUE. SEUR learned the following lessons:

- Changes were required to the logistics concept to match it with the characteristics of the EFV
- There was no need to use the municipality's UCC, as SEUR's own depot was ideally located
- Some remarks from SEUR:
    - They would like to have EFVs with higher load capacity, because in the current situation they will need to increase the total number of vehicles and drivers.
    - The main disadvantages of EFVs are less autonomy and a need to recharge every day.
    - Companies need to have more information on EFVs that are available on the market to be able to choose types of EFVs with the same 'productivity' as the conventional vehicles they are using now.

2.26 TNT in Madrid

Case description

TNT is an international parcel company. Its main business in downtown Madrid is parcel deliveries and pick-up with two small trucks of 3.5 tonnes (Ford Transit and Nissan Cabstar); one vehicle from the national depot located in the south of Madrid, and one vehicle from the international depot located at Madrid international airport in Barajas.

In FREVUE, TNT extended its vehicle fleet park with one EFV: Renault Kangoo Z.E. The capacity of this EFV is smaller than the capacity of the conventional vehicles used in the city centre; the payload is 50-70% and the maximum loading capacity is 15-33% of that of the conventional vehicles, see Table 6.

The EFV was a free promotional offer by Renault, so there were no purchasing costs.

Table 6 Overview of vehicle characteristics TNT

Vehicle/Parameter	EFV	ICE	ICE
Model	Renault Kangoo Z.E.	Ford Transit	Nissan Cabstar
Payload (kg)	650	900	1200
Type of vehicle	Light duty vehicle	Van	Box Van
Gross vehicle weight (kg)	1426	1500	3500
Maximum loading capacity (m3)	3	9	20

Changes in business model

Partners, activities, resources: In the FREVUE demonstrator, deliveries and pick-up of small parcels are no longer performed by the conventional trucks. The conventional trucks from the national and international depots first go to the UCC provided by the Madrid authorities (in the old market), where small parcels are unloaded. The conventional trucks then continue their trip to the city centre, but only with larger loads (e.g. pallets). The small parcels are then being delivered from the UCC to the Madrid city centre by a subcontractor using the EFV. The EFV also performs pick-ups and by the end of the day returns to the UCC, where picked up parcels are loaded to the larger conventional trucks and transported back to the TNT depots. To summarize, there was no vehicle replacement during the FREVUE demonstrator, but one additional EFV was added to the TNT fleet and replaced part of the roundtrips performed by the ICEs in the city centre of Madrid.

The main advantage of the UCC is that it is much closer to the city centre of Madrid than the TNT depots, so that the EFV saves kilometres. The UCC is about 6 to 7 km to the delivery area and the depots are 25 km, so this saves about 36 km a day. The operational time of the EFV is 20 minutes more than for the conventional vehicles, due to the extra loading and unloading time in the consolidation centre. The EFV drives about 50-100 km per day.

See

Figure **15** and Figure 16 for boxplots on the EFV trips. Median total time is 538 minutes (9 hours) and median distance per trip is 44 km.

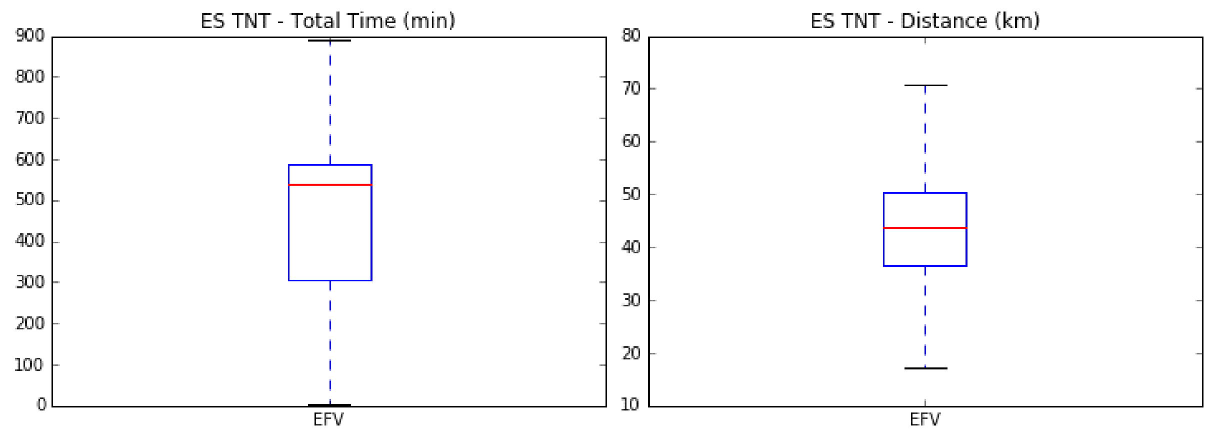

Figure 15: Boxplots of the total time and distance driven per day for TNT in Madrid[5]

[5] Figures based on 208 data points (data corrected for outliers). There are no data for the CFVs.

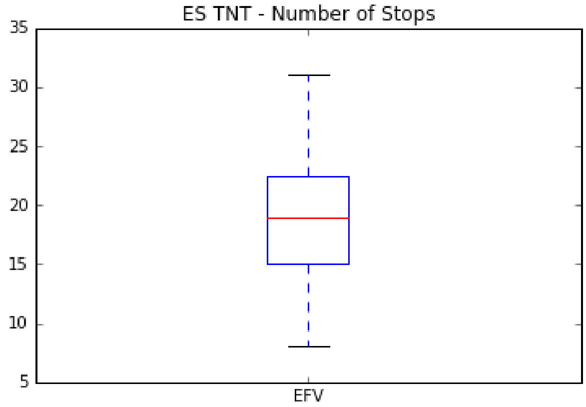

Figure 16: Boxplot of the number of stops made per day for TNT in Madrid

Vehicles are usually charged at the TNT facility. Another new activity was the training of drivers to get the maximum performance out of the EFVs.

With regard to the resources, there are costs for the use of the UCC and charging equipment was bought and installed.

There is a change in partners since the UCC is a new partner.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships, except that the usage of EFV has improved the image of the company.

Value proposition: There are no changes in the value proposition of TNT. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Purchase and instalment of charging station (-)
- Costs for additional vehicle (subcontractor) (-)
- Costs for using the UCC (facilities only) (-)
- Lower conventional fuel costs (+)
- No local taxes for EFVs (+)

In the revenue structure there are changes, since extra parcel delivery is possible because of the additional vehicle (+).

Conclusion and discussion

- Changes are made to the logistics trip characteristics; the EFVs are used for last mile delivery only
- Use is being made of the UCC
- Autonomy is the most important issue currently:
    - Due to limited autonomy EFV cannot yet cover the full distance between TNT own depots and full delivery area;
    - Due to weight restrictions EFV are only transporting small parcels and not the pallets.

2.27 Pascual in Madrid

Case description

Leche Pascual is a Spanish dairy producer and distributor. Its main business in the city centre of Madrid is the delivery of food and beverage products (to e.g. commerce, bars and restaurants) with vans and trucks.

In FREVUE, Leche extended its vehicle fleet park by two subcontracted EFVs: IVECO Ecodaily and Mercedes Vito E-cell. The capacity of these EFVs is smaller than the capacity of the conventional vehicles used in the city centre, see Table 7.

Table 7 Overview of vehicle characteristics Leche

Vehicle/Parameter	EFV	EFV	ICE
Model	IVECO Ecodaily	Mercedes Vito E-cell	Various
Payload (kg)	2100	850	3500-8000
Type of vehicle	Light duty vehicle	Light duty vehicle	Conventional vans and trucks
Gross vehicle weight (kg)	3300	2200	6000-12000
Maximum loading capacity (m3)	8	3.5	Various

Changes in business model

Partners, activities, resources: In the FREVUE demonstrator, trips that were performed in the city centre by conventional vehicles were replaced by the EFVs. Leche Pascual has specific requirements as they deliver food and other perishable items which need to be refrigerated. This logistics process is described below:

- The 12t ICE trucks, carrying 6t of food products in cold ambient temperature, arrive at the UCC at 05:30
- After receiving the goods, the two EFVs are loaded, delivering from 08:00-11:00 to those businesses located within the Low Emission Zone (35 clients, the type of customer is traditional retail and the hospitality sector)
- From 11:30 both EFVs come back to the UCC for a new load of goods in order to make a second and final delivery. The minimum daily amount delivered by the EFVs is six tonnes
- The ICE trucks then return to the UCC in the evening to collect cold perishable returned products

The EFVs replaced some, but not all, roundtrips in the city centre. The operational time of the EFVs is longer due to the necessity of additional loading and unloading at the UCC.

The payload of the EFVs is considerably lower than the payload of the conventional trucks used. As the UCC is situated close to Leche Pascual customers, the company was able to compensate for the lower payload of the EFVs by carrying out more trips, using therefore several trips to deliver the same amount of goods in terms of kilograms.

See Figure 17 and Figure 18 for boxplots on the EFV trips. The median distance per trip is 30 km, the median total time about 6.5 hours and the median number of stops 16. In the boxplots only the combined trip characteristics of the two different vehicles could be visualised.

With regard to the resources, there are costs for the use of the UCC and charging equipment that was bought and installed. Vehicles can charge at the Leche Pascual location.

The most important advantages are saving emissions and reducing the carbon footprint.

There is a change in partners since the UCC is a new partner.

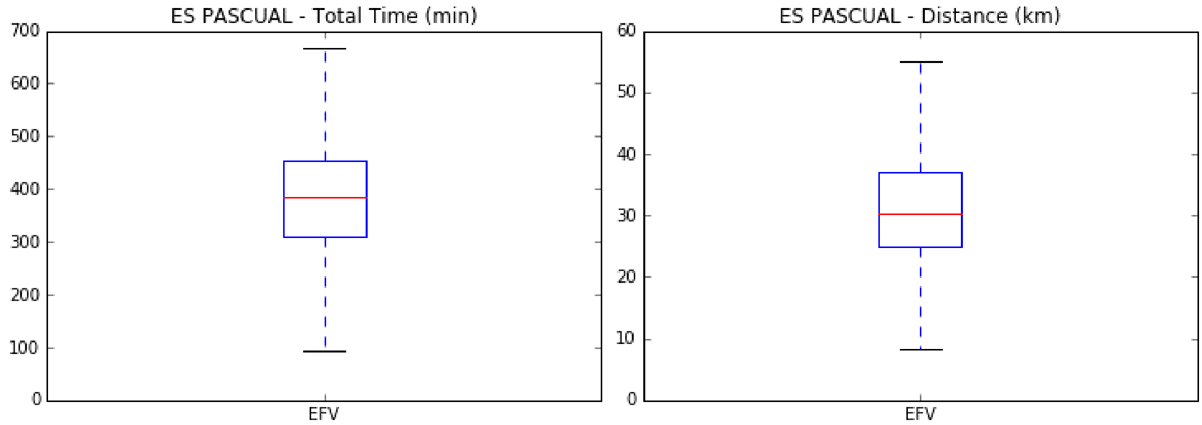

Figure 17: Boxplots of the total time and distance driven per day for Leche Pascual in Madrid[6]

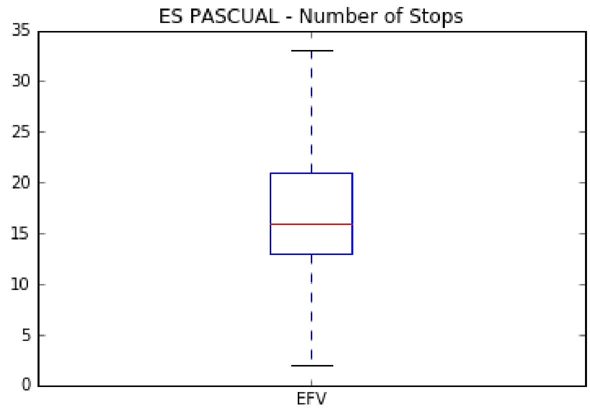

Figure 18: Boxplot of the number of stops made per day for Leche Pascual in Madrid

Customer, channel and relationship: Delivery is associated with the customer, therefore delivering with EFVs supports any certification that the client wants to get (such as ISO or EMMAS). Also, the usage of EFVs has improved the image of the company.

Value proposition: There are no changes in the value proposition of Leche. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

[6] The figures are based on 470 data points (data corrected for outliers). There are no data for the CFVs.

- Costs for renting two additional vehicles, including insurance and tax costs (-)
- Purchase and instalment of charging station (-)
- Costs for using the UCC (facilities only) (-)
- Lower conventional fuel costs, costs for energy: in total lower fuel costs (+)
- No local taxes for EFVs (+)
- Free parking for EFVs on the street (0)

Conclusion and discussion

- Changes are made to the logistics trip characteristics
- Use is being made of the UCC
- Autonomy and higher payload are the most important issues currently
- Wishes for the local government are:
    - Total freedom of access and timetables for EFVs
    - Driving in currently unauthorized areas, bus lanes or multiple user lanes
    - Free parking on the streets, and in public car parks
    - Granting the necessary infrastructure for charging vehicles
    - Using an EFV should be a criterion in tender of the local government.
- Leche Pascual is more interested in EFVs with a higher payload and better autonomy, as this is necessary in order to overcome a lack of the UCC that they may face in the future or in order to use the EFVs on other routes, where there is no UCC available. A disadvantage of this type of EFV is the very high price.

2.28 Eurodifarm in Milan

Case description

Eurodifarm (part of DHL) is an Italian logistics company specializing in the distribution of temperature controlled pharmaceutical, diagnostic and biomedical products to pharmacies, hospitals, third party distributors, nursing homes and patients. Its distribution centre is located in Casalmaiocco, 22.5 km from the city centre of Milan.

Trends of more restrictions for ICE vehicles in the centres of Italian cities made Eurodifarm want to be prepared for the use of EFVs in the near future. Therefore Eurodifarm trials a small EFV (Nissan e-NV 200) in the FREVUE demonstration in Milan to get experience with the implementation of EFVs. The demonstration focuses on the delivery of pharmaceuticals to pharmacies located within the Congestion Zone (known as Area C) inner ring in the “Area Bastioni” in Milan. Eurodifarm operates the EFV in the demonstration and the ICE in the business as usual situation; for some of the roundtrips the conventional vehicles are replaced by the EFV. While the payload is higher, the loading capacity of the EFV is much smaller than of the conventional vehicles used, see Table 8.

Table 8 Overview of vehicle characteristics Eurodifarm

Vehicle/Parameter	EFV	ICE
Model	Nissan e-NV 200	IVECO
Payload (kg)	695	650
Type of vehicle	Light duty vehicle	Light duty vehicle
Gross vehicle weight (kg)	1480	3500
Maximum loading capacity(m3)	4.2	16

The Eurodifarm consolidation centre (CC) located in Casalmaiocco serves a wider area than central Milan. In fact, in Casalmaiocco goods arrive from several pharmaceutical industries from all over Italy where vehicles are reloaded, optimizing their load capacity. However, it only optimises deliveries from a single carrier (Eurodifarm) rather than several ones and its distance from the city centre (22.5 km) means that deliveries to the city centre cannot be classified as 'last mile'. Inside the CC a special EFV area has been reserved for logistics operations related to delivering pharmaceutical goods from the CC to pharmacies located inside Area C. The CC has been provided with a stall for parking and a wallbox charging station with two plugs, one for charging the vehicle, the other for charging the box for the temperature controlled goods transportation (+2/+8° C).

Changes in business model

Partners, activities, resources: In the before situation, Eurodifarm handled all deliveries of pharmaceutical products in Area C by two ICE vehicles with a loading capacity of 16 m3 each. The new Nissan e-NV 200 has a loading capacity of 3 m3 with a refrigerator of 1.3 m3 included to deliver cooled pharmaceutical products. For the refrigerator a separate second battery is used in the vehicle.

The EFV is deployed for the delivery of pharmaceutical products in "Area C", the Milan congestion charge zone, between 07:00 and 16:00 (upon the request of the pharmacists). The EFV delivers three times a week. The vehicle does one roundtrip a day in the morning (because of the traffic situation it is not possible to make two round trips in the morning). The roundtrip differs according to the traffic situation and logistics rationalization. One round trip is about 70-75 km. The EFV can drive on the battery around 130 km, and after the roundtrip the EFV is being charged in the depot. The EFV does not cover the same route as the ICE ones. The deliveries of large parcels for Area C that do not fit into the EFV because of size are still distributed with an ICE vehicle. The EFV now serves on average approximately 17% of all pharmaceutical deliveries in Area C.

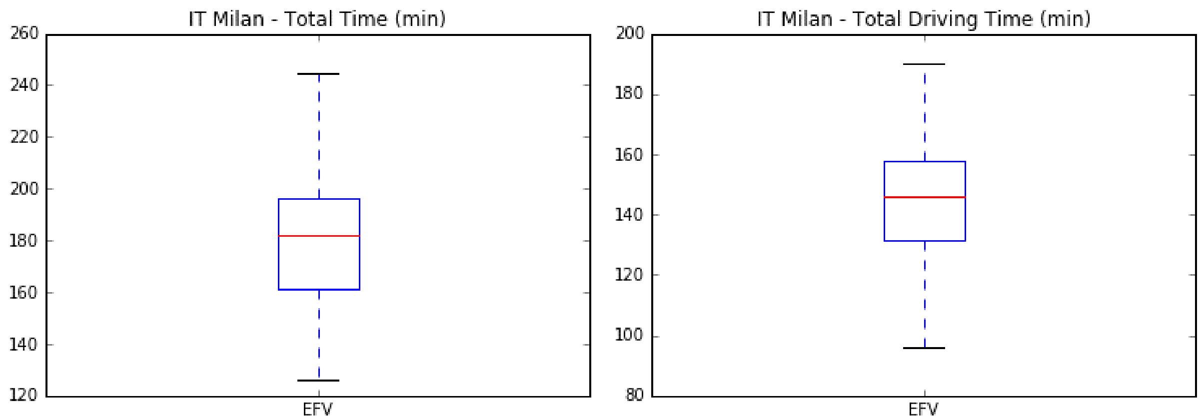

Figure 19: Boxplots of the total time and total driving time per day for Eurodifarm in Milan[7]

The boxplots in Figure 19 and Figure 20 show information on the EFV trips (data for CFVs were not available). The median total time per trip is about 3 hours and the median total

[7] The figures are based on 87 data points (data corrected for outliers). There are no data for the CFVs.

driving time about 2.5 hours. The median distance per trip is 63 km and the median number of stops about 7.

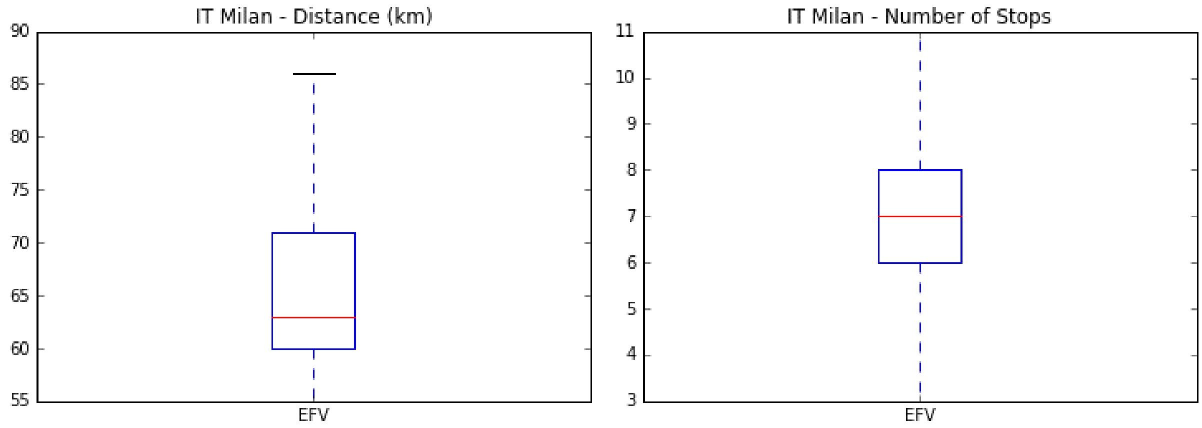

Figure 20: Boxplots of the distance driven and number of stops made per day for Eurodifarm in Milan

With regard to the resources, charging equipment was bought and installed.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships, except that the usage of EFV has improved the image of the company.

Value proposition: There are no changes in the value proposition of Eurodifarm. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Costs for additional vehicle (-)
- Purchase and instalment of charging station (-)
- Lower conventional fuel costs (+), costs for energy (-), in total lower fuel costs
- Free entering of the congestion charge area (+)
- Lower taxes (+)
- Lower insurance costs (as a result of special Italian regulation) (+)

Conclusion and discussion

- Changes are made to the logistics trip characteristics
- There were problems with buying the vehicles (Italy has very restrictive laws for the circulation of foreign vehicles)

2.29 Binnenstadservice in Rotterdam

Case description

Binnenstadservice is a small UCC in the centre of Rotterdam. It is operated by Roadrunner Couriers, who are the owner of the fleet and the premises. Roadrunner already used an EFV (Citroen Berlingo) for the Binnenstadservice tasks, and additionally it has conventional vehicles (15) and bicycle couriers. Consolidated goods are delivered to participating retailers. To minimize the amount of empty kilometres, disposable materials, plastic and empty pallets are collected at the delivery addresses in order to be recycled at Binnenstadservice.

FREVUE co-financed a second EFV to be deployed in the UCCs daily operation. The city of Rotterdam procured a Nissan e-NV 200 to lease to the Binnenstadservice which replaces a VW Caddy. Although the Nissan is clearly newer and more advanced than the older Berlingo, the action radius did not really increase dramatically (Berlingo: about 80-100 km, Nissan: about 150 km). See Table 9 for the vehicle characteristics.

Table 9 Overview of vehicle characteristics Binnenstadservice

Vehicle/Parameter	**EFV**	**ICE**
Model	Nissan e-NV 200	VW Caddy
Payload (kg)	650	750
Type of vehicle	Light duty vehicle	Light duty vehicle
Gross vehicle weight (kg)	2220	2200
Maximum loading capacity(m3)	4	3.2

Changes in business model

Partners, activities, resources: The EFV is used for a standard route delivering the internal post for a large shipper, with a route starting at the depot, serving several delivery points in Rotterdam and returning to the depot. The shift is from 8:15-11:00 and covers approximately 65 km. In the afternoon the EFV is used for ad hoc deliveries and pickups in the Rotterdam area, driving on average 45-50 km. The charging of the vehicle is performed at night, during the low peak hours. No extra investment was necessary for the charging of the vehicle (charging is done at a regular 220V charge point).

Overall, there are no major changes in operations. The only constraint for planning is the limitation of the EFV range. Combined with the occasional limitation of the planning capacity at the office (in time), the action radius limits the options for the planner. Therefore it is easier to plan ad hoc pickups and deliveries (after the fixed round) with conventional vehicles. In case more capacity is available at the office (in time) it is possible to make a precise planning so that the EFV is used as much as possible; however if there are many deliveries and not so much planning capacity is available, it easier to appoint ad hoc jobs to one of the conventional VW Caddies running in the city of Rotterdam.

There are no remarks with regard to the resources.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships, except that the usage of an additional EFV has improved the image of the company.

Value proposition: There are no changes in the value proposition of Binnenstadservice. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Vehicle costs (-)
- Lower fuel costs (+)
- No road tax (+)
- Higher insurance costs (-)
- No infrastructure costs (0)

There is no information available yet about maintenance costs. The residual value of the EFV is probably lower. Depreciation time of the EFV is longer.

Conclusion and discussion

- No major changes in operations
- Constraints are the limitations of the EFV and limitations in planning capacity

2.210 Conclusions small electric vehicles

A total of 31 small electric vehicles were used in 8 different cases. The smaller EFVs in the demonstrations were used in a number of cases for last mile deliveries and led to changes in the logistics concept. Where they replaced ICE vehicles, they drove more fixed trips/routes and did less ad hoc pick-ups and deliveries.

<table>
<tr>
<td rowspan="2">Key Partners

• Closer co-operation with cities via UCC (0)
• Fewer knowledgeable service men available for maintenance (-)</td>
<td>Key Activities

• Vehicle charging time (-)
• EFVs more difficult to plan due to range (-)
• Possible advantages due to policy exemptions/privileges (+)</td>
<td>Value Proposition

Limited changes: most customers want low emission deliveries, but willingness to pay is very limited at this moment (0)</td>
<td>Customer Relationships

No changes</td>
<td rowspan="2">Customer Segments

Customers including zero emission criterions in the procurement (+), although hardly used –at this moment – in practice</td>
</tr>
<tr>
<td>Key Resources

• Ownership of the vehicles: fewer lease options (0)
• Fuel costs vs. electricity (+)
• Procurement cost (-)</td>
<td>Value proposition for society

• Reduction of emissions (+)
• Less noise nuisance (+)</td>
<td>Channels

No changes</td>
</tr>
<tr>
<td colspan="2">Cost Structure

• Investment costs: cost in purchase or lease of the vehicle (-)
• Operating costs (0) or in case of exemptions (+) or in case of UCC use or additional vehicle/driver (-)
• Training of drivers (-)
• Less fuel costs; less maintenance costs (+)</td>
<td colspan="3">Revenue Streams

• No changes (0), except if: subsidy for the vehicle purchase (+), or for charging point purchase (+), zero emission in procurement (+), tax reductions (+)
• Non-monetary revenue stream: more sustainable</td>
</tr>
</table>

Figure 21: Business model canvas (BMC) for operators using EFVs – changes positive (+) neutral (0) or negative (-) compared to CFV situation

Slowly more different types of these kind of vehicles come onto the market. However, companies would welcome more information about the EFVs available in the market to be able to make a better choice. Disadvantages mentioned are the limited capacity and range of the EFVs used, and the need to recharge. When looking at the costs and resources, the most important ones are the purchase or lease of the EFVs, required infrastructure (if any) and operating costs (fuel vs. electricity). Sometimes there are tax reductions for EFVs compared to CFVs. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance (see also Figure 21).

2.3 Medium size electric vehicles in city logistics operations

2.31 Introduction and general outcomes

There are three cases in which logistics companies use medium sized EFVs in their operations in the FREVUE demonstrations. The cases concern TNT (Rotterdam and Amsterdam) and UPS (Rotterdam and London), in which ICEs are replaced by EFVs (retrofitted). The EFVs are introduced to replace part of the trips, and no serious changes are made to the logistics concepts. However, in some cases the trips the EFVs make have a slightly shorter distance than the trips the CFVs make. For one case the number of deliveries and pick-ups was analysed, and the EFVs showed a high number of deliveries and low number of pick-ups, and for CFVs it was the other way around. An explanation for this could be that the EFVs are less flexible for picking up packages due to their range limitation. There is also less flexibility when using the EFVs when it comes to charging; operations have to be planned around the charging times. When looking at the costs and resources, the most important ones are the retrofitting of the vehicles, required charging infrastructure, training of drivers (if any) and operating costs (fuel vs. electricity). In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

2.32 TNT in Rotterdam and Amsterdam

Case description

TNT Express provides a wide range of express services to businesses and consumers around the world.

Within FREVUE seven retrofitted EFVs of originally 3.5t were implemented in Rotterdam (4 vehicles) and Amsterdam (3 vehicles), replacing conventional vehicles. See Table 10 for the characteristics of the vehicles. The transition of ICEs to EFVs involved a decrease of 629 kilograms in payload. The vehicles were purchased, whereas normally TNT leases vehicles.

Table 10 Overview of vehicle characteristics TNT in Rotterdam and Amsterdam

Vehicle/Parameter	EFV	ICE
Model	Fiat Ducato	Mercedes Sprinter
Payload (kg)	821	1450
Type of vehicle	Light duty vehicle	Light duty vehicle
Gross vehicle weight (kg)	4250	1950
Maximum loading capacity (m3)	13	13

Changes in business model

Partners, activities, resources: The EFVs drive from TNT depots to the city centre and replace the routes previously made by conventional vehicles. TNT did not have to make any serious changes to the logistics concept. The charging of vehicles takes place at night at the TNT depot.

In Figure 22 the total time (time from leaving the depot to returning to the depot) and total driving time per trip are displayed. While the total times are nearly identical for both types of vehicles with an average of around 8 hours (although there are more outliers to longer total times for EFVs), the total driving time differs by an hour: about 7 hours for conventional vehicles versus 6 hours for EFVs, and the range is much larger for EFVs than for conventional vehicles. In Figure 23 the distance driven and number of stops made per trip are displayed. These boxplots might explain the lower driving time for the EFVs, since the median of the distance driven by EFVs is 24 kilometres less than the median distance driven by CFVs. The number of stops is comparable.

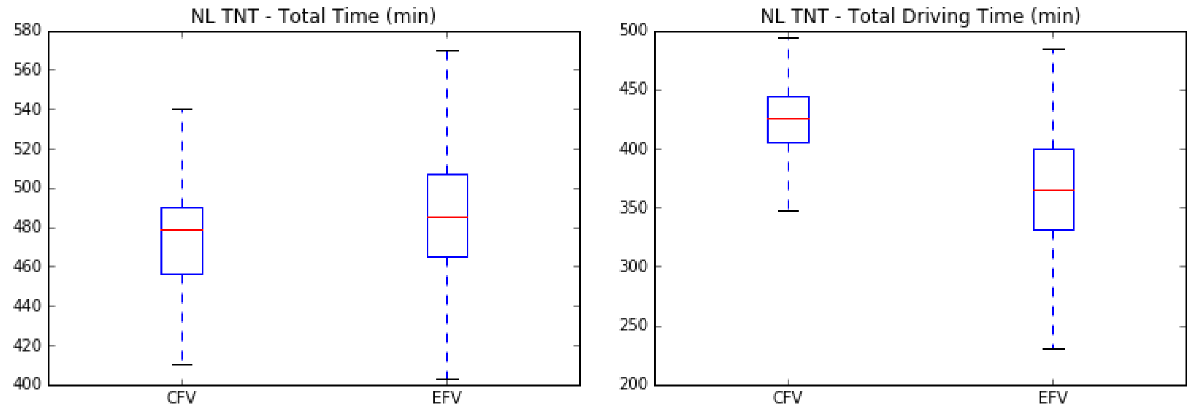

Figure 22: Boxplots of the total time and total driving time per day for TNT in NL[8]

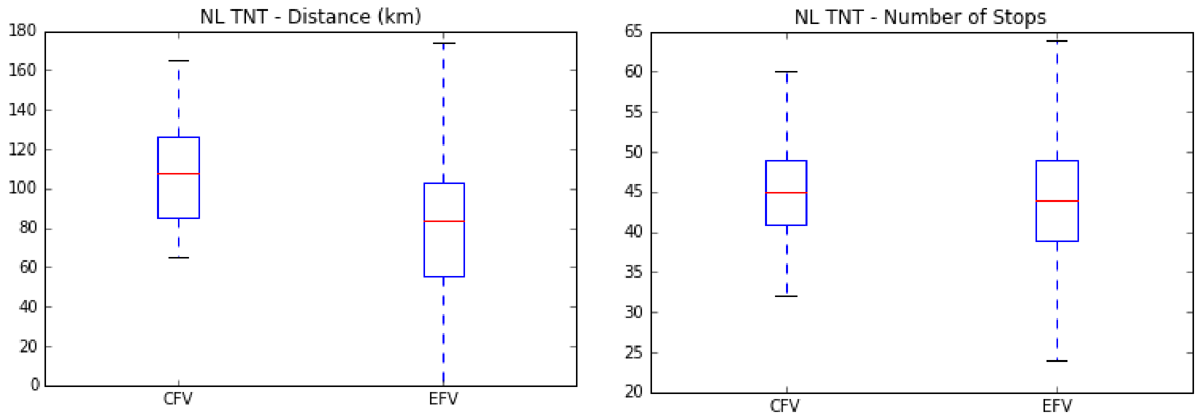

Figure 23: Boxplots of the distance driven and number of stops made per day for TNT in NL

With regard to resources, the use of EFVs led to a reduction in fuel costs (electricity is less expensive) and the receipt of a subsidy. However, extra investments had to be made for the EFVs such as the purchase of charging equipment, the purchase of more expensive telematics, and the additional training costs of drivers.

[8] Box plots in figures are based on 139 observations for ICEs and 696 observations for EFVs. Data are corrected for outliers.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of TNT. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Purchase and instalment of charging station (0/-) (no serious extra investments had to be made)
- Vehicle costs (-)
- Telematics purchase (-)
- Lower fuel costs (+)
- Subsidy (+)
- Costs for training of drivers (-)

Because the EFVs are purchased and not leased, there are depreciation costs instead of leasing costs. It is quite likely that TNT gets privileges in both Rotterdam and Amsterdam for their EFV operations, but what these privileges exactly are is not known yet. In Amsterdam the government has taken complementary policy measures to make the use of EVs more attractive (in addition to subsidies). Those "privileges" for EVs are "exemptions" on traffic codes/regulations/rules, such as parking on sidewalks to load/unload, driving into roads that are only for pedestrians, etc.

Conclusion and discussion

No change to operations, the EFVs replace CFVs routes. However, trips with EFVs usually have a slightly shorter distance than trips made with CFVs.

2.33 UPS in Rotterdam

Case description

UPS is a global logistics company. The roundtrips that they perform are typically of short distance and contain many stops. The delivery areas of UPS Rotterdam is Rotterdam and its surroundings. In FREVUE, UPS Rotterdam deployed four retrofitted EFVs for operations. These electric vehicles have 540 kilogram less payload than the conventional vehicles that they replace, see Table 11 for an overview of the vehicle characteristics.

Table 11 Overview of vehicle characteristics UPS in Rotterdam

Vehicle/Parameter	**EFV**	**ICE**
Model	P80E Mercedes T2	Mercedes Vario 813d
Payload (kg)	3450	3990
Type of vehicle	Medium duty	Medium duty
Gross vehicle weight (kg)	7490	7490
Maximum loading capacity (m3)	24	24

Changes in business model

Partners, activities, resources: UPS Rotterdam had one requirement for their participation: it should be possible to replace the existing roundtrips. This requirement is met, they do replace existing roundtrips for the ICEs and each roundtrip is less than 75 kilometres, so they do not exceed the daily range of the EFVs. The routes involved are for urban distribution and the average daily distance covered by each vehicle is 42.7 kilometres.

In Figure 24 the total time (including stopping time) and the distance of each trip is presented in several boxplots. It can be concluded that the use of EFV did not lead to major changes regarding the total time and distance of the trips. This is consistent with the fact that the EFVs are deployed on the same routes as the ICEs were. In Figure 25 the number of stops and packages involved per trip are displayed. The median number of stops and packages involved in a trip is slightly higher for the EFV trips than for the ICE trips. These totals are split up into delivery and pickup stops in Figure 26, and into delivered and picked up packages in Figure 27. For trips performed by the ICEs, few packages were delivered and many packages were picked up, but this is the other way around for the trips performed by the EFVs. An explanation for this could be that the EFVs are less flexible for picking up packages due to their range limitations.

A challenge with the EFVs is that at UPS the vehicles have very tight routines (washing and fuelling, loading and unloading). With ICEs this routine is easy and fast and with EFVs there is less flexibility. The EFVs are charged during the night, and they have to be planned at a charging location where they should be for eight hours. Operations at the depot have to be planned around the charging of the vehicle.

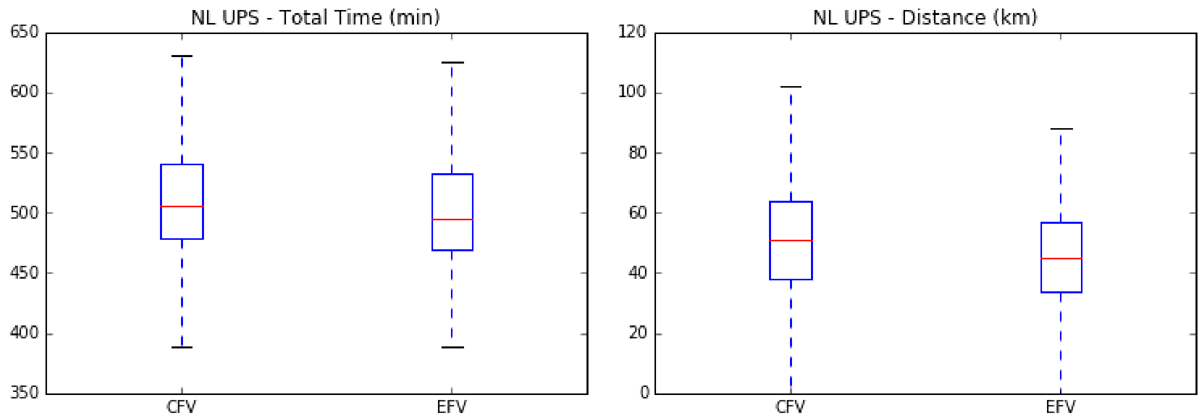

Figure 24: Boxplots of the total time and distance driven per day for UPS in Rotterdam[9]

[9] Box plots are based on 2476 observations for ICEs and 2035 observations for EFVs. Data are corrected for outliers.

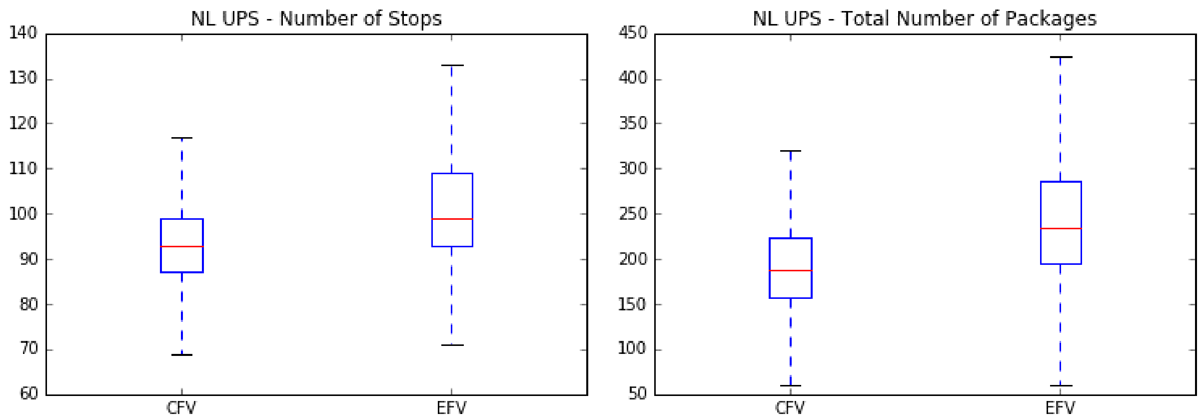

Figure 25: Boxplots of the number of stops made and packages involved per day for UPS in Rotterdam

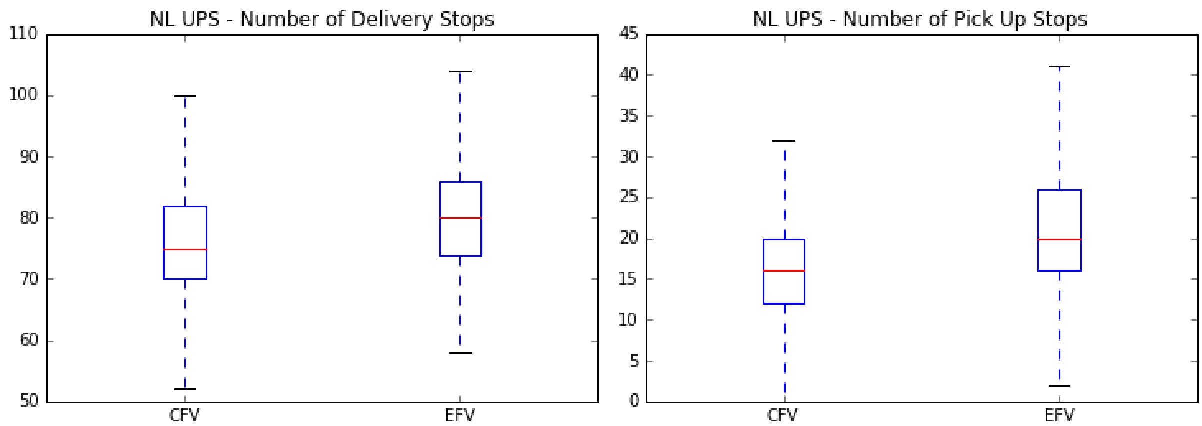

Figure 26: Boxplots of the number of delivery and pick up stops made per day for UPS in Rotterdam

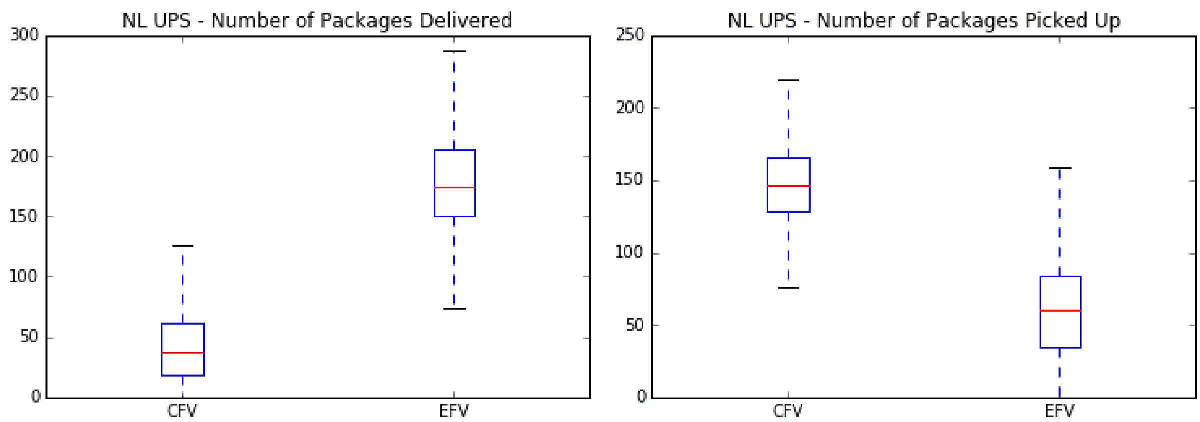

Figure 27: Boxplots of the number of packages delivered and picked up per day for UPS in Rotterdam

With regard to resources, the use of EFVs led to additional expenses for UPS Rotterdam. The retrofit costs are higher than the ICE purchase price, and an upgrade and adaptation of the grid capacity was required. The latter is the case because typically in UPS buildings electric power consumption is low during the day and high during the night (due to sorting parcels, i.e. the belt system). Charging EVs comes on a top of this, and in Rotterdam there is an actual power constraint in the building. The benefit of using EFVs is that the electricity costs are lower than the fuel costs of the ICEs.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of UPS. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Upgrade and adaptation of the grid capacity (-)
- Vehicle costs (retrofitting) (-)
- Lower fuel costs (+)

Whether there are changes to the maintenance costs is not known yet due to the short time the EFVs are running at the moment. It is expected that they will be lower as there are less mechanical components.

Conclusion and discussion

- No change to operations; EFVs take over part of the round trips previously made by ICEs
- The characteristics of the EFVs trips are different from the ones ICEs make: EFVs deliver more packages and pick up less packages than ICEs

2.34 UPS in London

Case description

Prior to FREVUE UPS operated 179 package cars from their Kentish Town depot in London, of which 18 were Modec EFVs. The FREVUE activity of UPS London included the conversion and deployment of 16 EFVs in their central London operations as well as the update of grid capacity and relevant infrastructure to accommodate the new vehicles. The retrofit (for each vehicle the powertrain was changed and the vehicle was refurbished) and introduction of the vehicles was performed in two stages. Ten vehicles have been operational since September 2014 and the remaining six since September 2015. Until the full upgrade of infrastructure and grid capacity, the first ten EFVs were operating in shifts with the 18 Modec vehicles which were already deployed.

The electric vehicles have 540 kilogram less payload than the conventional vehicles that they replace, see

Table 12 for an overview of the vehicle characteristics.

Table 12 Overview of vehicle characteristics UPS in London

Vehicle/Parameter	EFV	ICE
Model	P80E Mercedes T2	Mercedes Vario 813d
Payload (kg)	3450	3990
Type of vehicle	Medium duty	Medium duty
Gross vehicle weight (kg)	7490	7490
Maximum loading capacity(m3)	24	24

Changes in business model

Partners, activities, resources: The roundtrips performed by EFVs are exactly the same ones that conventional vehicles were performing before FREVUE. On average the UPS vehicles are driving 20 to 70 km/day which fits perfectly with the EFV range (120 km). As these are retrofit vehicles, the body of the vehicle does not change so the loading/unloading routine remains the same. In Figure 28 a boxplot is given for the distances driven per trip for the EFVs (the median is slightly below 30 km).

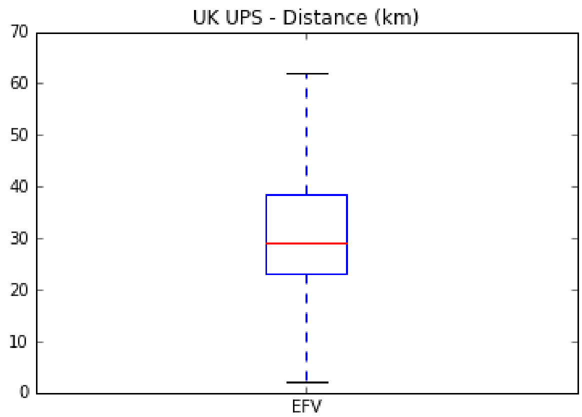

Figure 28: Boxplot of the distance driven per day for UPS in London[10]

The introduction of EFVs required the following operational changes:

- The power network had to be upgraded to also facilitate the charge of EFVs overnight. Usually in UPS buildings electric power consumption is low during the day and is high during the night due to the sorting activities (e.g. belt system). Charging of the EFVs came on a top of this and network upgrade was performed, resulting in a grid capacity and charging points that can accommodate 68 EFVs in total.
- EFVs have a tighter operational routine than ICEs and are less flexible in their routine (washing, charging, loading and unloading). EFVs have to be planned at their locations for at least eight hours of idle time necessary for charging. Operations at the depot for EFVs need to planned around charging of the vehicle.
- There is about one minute benefit in checking an EFV vehicle before departing for a trip; an EFV driver only needs to make sure that the vehicle is fully charged, while an

[10] Box plots are based on 5287 observations for EFVs. Data are corrected for outliers.

ICE driver needs to check fuel, the level of water, and the main components of the engine.

- The use of EFVs led to additional expenses for UPS London. The retrofit costs are higher than the ICE purchase prices. UPS London also had to upgrade their grid capacity and they had to invest in additional training of their drivers. The benefits of using EFVs are the lower costs for electricity compared to fuel, the reduction in maintenance costs, and an exemption from the congestion charge.

For conversion of the vehicles UPS is looking at the fleet which will be depreciated in UPS UK and depending on the age of the vehicle they take a decision on conversion. It takes on average two weeks to convert one vehicle.

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of UPS. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Upgrade and adaptation of the grid capacity (-)
- Vehicle costs (retrofitting) (-)
- Lower fuel costs (+)
- Lower maintenance costs (+)
- Lower taxation (+)
- No congestion charge (+)
- Training of drivers (-)

Conclusion and discussion

- No change to operations; EFVs take over part of the round trips previously made by ICEs
- Tighter operational routine due to charging time

2.35 Conclusions medium electric vehicles

A total of 27 medium electric vehicles were used in 3 different cases. These vehicles were all retrofitted. It is still difficult to find these kind of vehicles available at OEMs. No major changes were made to the logistics concepts, but in some cases the EFV trips were of shorter distance than the CFV trips and the EFVs did relatively more deliveries and fewer pick-ups than CFVs.

When looking at the costs and resources, the most important ones are the retrofitting of the vehicles, required charging infrastructure, training of drivers (if any) and operating costs (fuel vs. electricity). In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance (see Figure 29)

.

<table>
<tr>
<td rowspan="3">Key Partners
New OEMs and dealers for EFVs are usually smaller and less professional than for ICEs (-)
Fewer knowledgeable service men available for maintenance (-)</td>
<td>Key Activities
Vehicle charging time (-)
EFVs more difficult to plan due to range (-)
Possible advantages due to policy exemptions/privileges (+)</td>
<td rowspan="2">Value Proposition
Limited changes: most customers want low emission deliveries, but willingness to pay is very limited at this moment (0)</td>
<td>Customer Relationships
No changes</td>
<td rowspan="3">Customer Segments
Customers including zero emission criterions in the procurement (+), although hardly used –at this moment – in practice</td>
</tr>
<tr>
<td rowspan="2">Key Resources
Ownership of the vehicles: fewer lease options (0)
Fuel costs vs. electricity (+)
Procurement cost (-)
Charging infrastructure required (-)</td>
<td rowspan="2">Channels
No changes</td>
</tr>
<tr>
<td>Value proposition for society
Reduction of emissions (+)
Less noise nuisance (+)</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Investment costs: cost in purchase or lease of the vehicle; cost in purchase of charging point, grid adaptations and telematics (-)
Operating costs (0) or in case of exemptions (+)
Training of drivers (-)
Less fuel costs; less maintenance costs (+)</td>
<td colspan="2">Revenue Streams
No changes (0), except if: subsidy for the vehicle purchase (+), or for charging point purchase (+), zero emission in procurement (+), tax reductions (+)
Non-monetary revenue stream: more sustainable</td>
</tr>
</table>

Figure 29: Business model canvas (BMC) for operators using EFVs – changes positive (+) neutral (0) or negative (-) compared to CFV situation

2.4 Large electric vehicles in city logistics operations

2.41 Introduction and general outcomes

There are four cases in which logistics companies use large sized EFVs in their operations in the FREVUE demonstrations. The cases concern Heineken (Rotterdam and Amsterdam), BREYTNER (Rotterdam) and Clipper (London). BREYTNER – a company that uses electric vehicles only – is a different to the other companies. For the FREVUE case it uses the concept of swap bodies for last mile deliveries, to serve one of their customers. Clipper purchased a new EFV which was not used in daily operations due to changed market conditions. Heineken made no serious changes to their logistics concept. For Heineken a comparison was made between trip characteristics; in Rotterdam the only change was that the EFVs transported less kilograms (because of the lower payload), in Amsterdam there was more variance in (driving) time and number of stops for the EFVs compared to the CFVs. When looking at the costs and resources for the cases with large sized EFVs, most important ones are the retrofitting of the vehicles (in the case of Heineken), purchase of new vehicles (Clipper and BREYTNER), required charging infrastructure / battery pack, training of drivers, operating costs (fuel vs. electricity) and possible subsidies. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

2.42 Heineken in Rotterdam

Case description

Heineken is a beer brewing company, one of the three largest breweries in the world and the largest brewer in the Netherlands. The delivery area of Heineken Rotterdam is displayed in Figure 30. Heineken has a distribution centre on the outskirts of Rotterdam.

Figure 30: Heineken UDC Rotterdam location and delivery area

As part of the FREVUE project Heineken deployed one retrofitted 19t EFV in Rotterdam, which lead to a loading capacity reduction of 730 kilograms, see Table 13 for the vehicle characteristics. The EFV replaces an ICE. Heineken uses a subcontractor for the delivery processes which has bought the specified vehicle.

Table 13 Overview of vehicle characteristics Heineken in Rotterdam

Vehicle/Parameter	EFV	ICE
Model	Emoss	DAF
Payload (kg)	7500	8230
Type of vehicle	Heavy duty vehicle	Heavy duty vehicle
Gross vehicle weight (kg)	19000	19000
Maximum loading capacity (m3)	38	38

Changes in business model

Partners, activities, resources: Heineken Rotterdam did not have to change their existing logistics concepts, since the EFV replaces a CFV and takes over its trips. The 19t truck in Rotterdam operates almost exclusively (99%) in the city centre, drives an average of 60 km per day and has an average drop count of between 13-17 deliveries per day. The vehicle is charged overnight at the depot; extra investments in charging infrastructure were made. The truck also has equipment on the truck for extra quick loading; in this way the truck can be charged in four hours.

Using an EFV has both advantages and disadvantages for Heineken Rotterdam. On the one hand, the EFV saves costs on fuel and is supported through subsidies. On the other hand, using an EFV costs money because of investments in charging infrastructure, higher insurance costs, training costs, and a lower estimated residual value. An EFV also requires a different maintenance contract than an ICE.

From Figure 31 and Figure 32 it can be concluded that the trip characteristics ((driving) time, distance, number of stops per day) remained nearly identical. It can be observed that while the median duration of a trip is around eight hours for both vehicles, the median driving time is only 108 minutes for an ICE and 120 minutes for an EFV, implying that during the trip six hours are spent on other activities such as loading and unloading of freight at the delivery stops. From Figure 33 it can be concluded that the EFV transports less kilograms per day than the ICE; this is in line with the fact that the EFV has a lower payload.

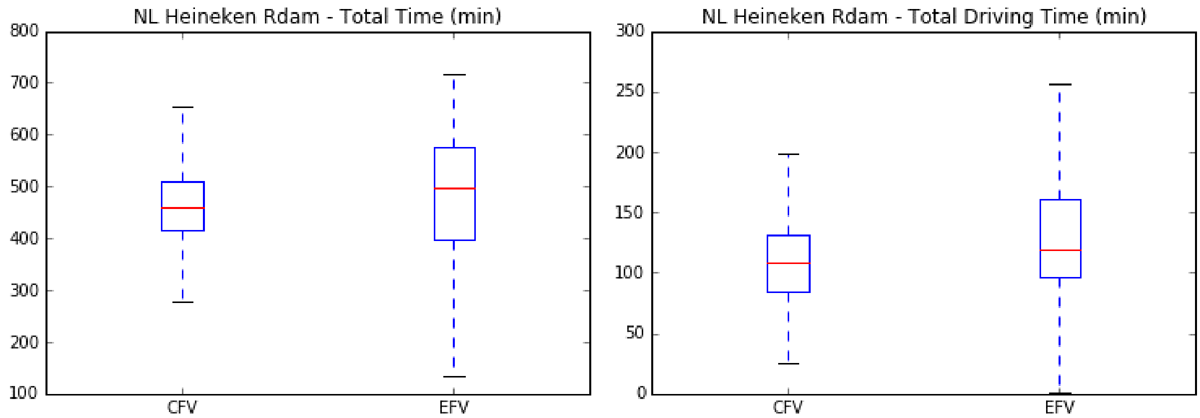

Figure 31: Boxplots of the total time and total driving time per day for Heineken in Rotterdam[11]

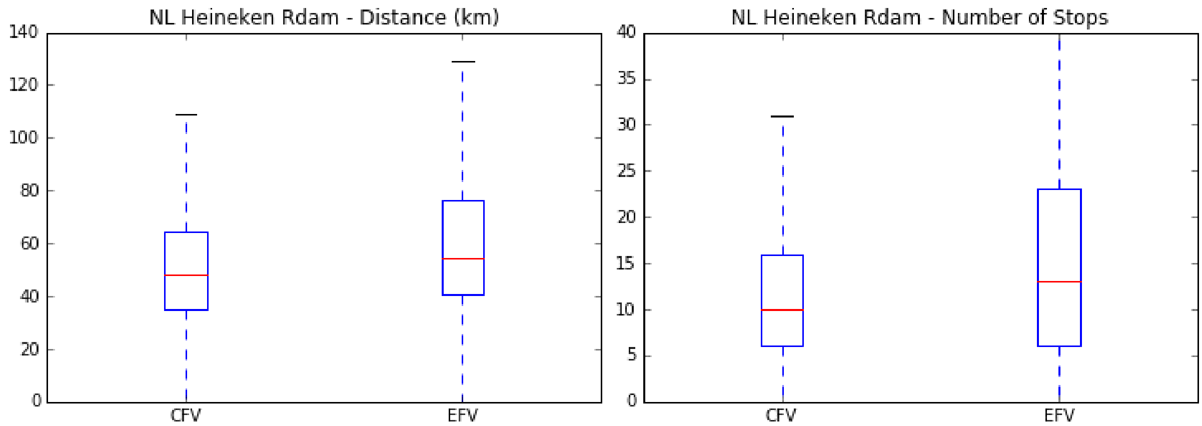

Figure 32: Boxplots of the distance driven and the number of stops made per day for Heineken in Rotterdam

[11] Box plots in figures are based on 663 observations for ICEs and 1626 observations for EFVs. Data are corrected for outliers.

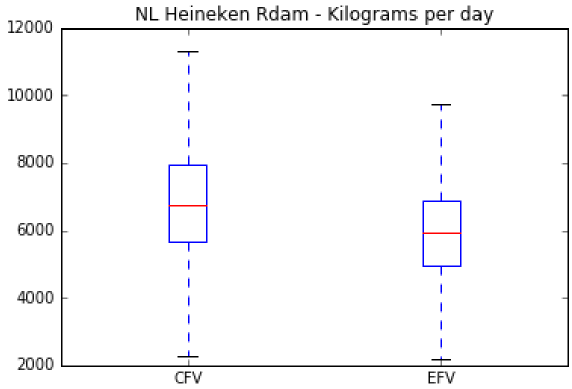

Figure 33: Boxplot of the kilograms transported per day for Heineken in Rotterdam

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of Heineken. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Charging infrastructure (-)
- Vehicle costs (retrofitting) (-)
- Lower fuel costs (+)
- Subsidy (+)
- Change in maintenance costs (?)
- Lower estimated residual value (-)
- Higher insurance costs (-)
- Training of drivers (-)

Conclusion and discussion

There is no real change in operations, the only issue is that the EFV has a lower payload capacity so it transports less kilograms per day than the ICE.

2.43 Heineken in Amsterdam

Case description

The delivery area of Heineken Amsterdam is displayed in Figure 34. Heineken has a distribution centre on the outskirts of Amsterdam.

Figure 34: Heineken UDC Amsterdam location and delivery area

As part of the FREVUE project Heineken deployed one retrofitted 12t EFVs in Amsterdam, which lead to a loading capacity reduction of 1810 kilograms, see Table 14 for the vehicle characteristics. In a later stage, seven additional 13t EFVs where purchased for Heineken Amsterdam. Heineken uses subcontractors for the delivery processes and these have bought the specified vehicle.

Table 14 Overview of vehicle characteristics Heineken in Amsterdam

Vehicle/Parameter	EFV (1)	EFV (7)	ICE
Model	Ginaf	Ginaf	DAF
Payload (kg)	4000	5045	5810
Type of vehicle	Heavy duty vehicle	Heavy duty vehicle	Heavy duty vehicle
Gross vehicle weight (kg)	12000	13000	11990
Maximum loading capacity(m3)	25	25	25

Changes in business model

Partners, activities, resources: Heineken Amsterdam did not have to change their existing logistics concepts, since the EFVs have taken over roundtrips that were previously performed by ICEs. The 12t truck in Amsterdam operates in the city centre only and drives on average 60 km per day. Each vehicle operates two routes per day, one in the morning and one in the afternoon. A specific loading pole had to be installed at the depot. The trucks themselves also have equipment on the truck for extra quick loading; in this way the truck can be charged in four hours. The trucks benefit from heavy regeneration so that the batteries are still at about 50% at the end of the day.

Using an EFV has both advantages and disadvantages. On the one hand, the EFV saves costs on fuel and is supported by subsidies. On the other hand, using an EFV costs money because of the installation of a loading pole, investments in charging infrastructure, higher insurance cost, and training costs. An EFV also requires a different maintenance contract than an ICE.

The boxplots showing trip characteristics (per day) are given in Figure 35, Figure 36 and Figure 37. The medians of total time per day performed by ICVs and EFVs are close to each other, but there is much more variation for EFVs. The same holds for the driving time per day (which excludes the loading and unloading time at delivery stops). The median distance driven and number of stops per day of the EFVs are lower than the medians of the ICEs. The kilograms transported per day by each truck are comparable for EFVs and ICEs. All figures combined we can conclude that per stop, more kilograms are loaded/unloaded by EFVs than by ICEs. The variation in number of stops and (therefore) variation in total (driving) time is much larger for EFVs than for ICEs.

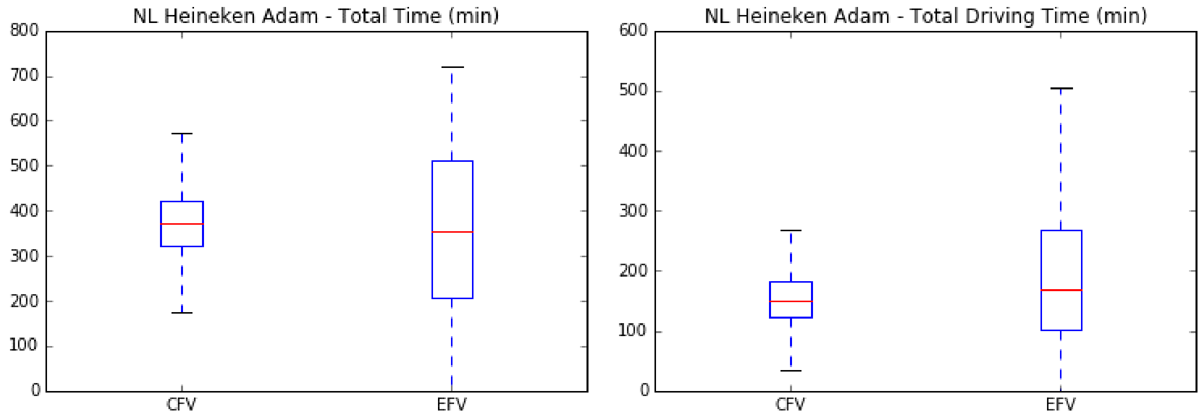

Figure 35: Boxplots of the total time and the total driving time per day for Heineken in Amsterdam [12]

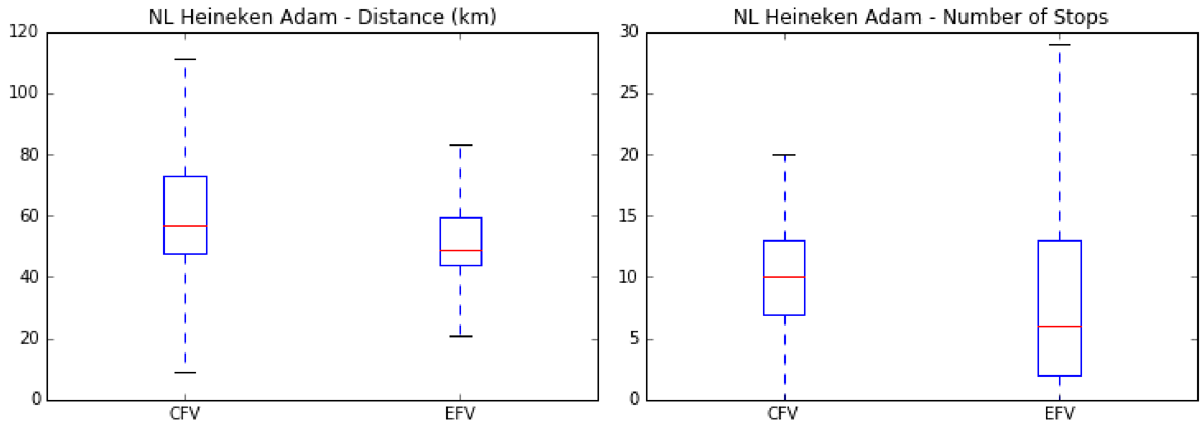

Figure 36: Boxplots of the distance driven and number of stops made per day for Heineken in Amsterdam

[12] Box plots in figures are based on 2341 observations for ICEs and 1586 observations for EFVs. Data are corrected for outliers.

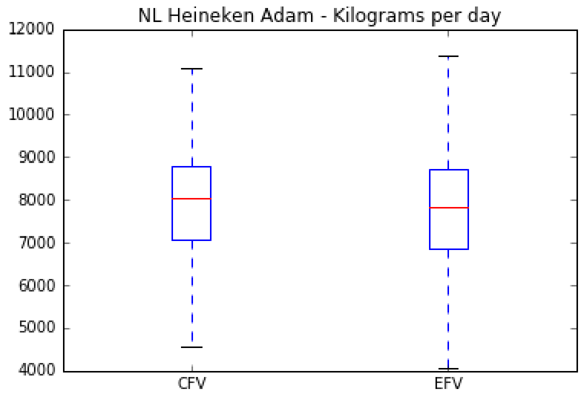

Figure 37: Boxplot of kilograms transported per day for Heineken in Amsterdam

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

Value proposition: There are no changes in the value proposition of Heineken. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Vehicle costs (retrofitting) (-)
- Installation loading pole (-)
- Investment in charging infrastructure (-)
- Lower fuel costs (+)
- Subsidy (+)
- Change in maintenance costs (?)
- Higher insurance costs (-)
- Training of drivers (-)

Conclusion and discussion

For Heineken in Amsterdam, there is no real change in operations. When we look at trip characteristics, the EFVs show more variance in (driving) time and number of stops than the CFVs. The amount of kilograms transported is about the same.

2.44 BREYTNER in Rotterdam

Case description

BREYTNER provides logistics services for all parties with goods intended for central Rotterdam. The 'first mile' is done by other parties with their (conventional) vehicles, after which BREYTNER transports the swap bodies with 19t EFVs into the city centre. No additional equipment is needed to attach and detach the swap body to/from the truck, so it is possible to leave the container at the hub for a while. Swapping takes five to ten minutes and goes faster with increasing experience of the driver. BREYTNER provides services for both entering and leaving the city. The process is also suitable for freight flows starting further away from town. The range of the trucks is sufficient to operate in central Rotterdam for a full day.

BREYTNER currently operates two electric EMOSS trucks on a MAN chassis, with a range of 200-250 kilometres and a 200 kWh battery. One of these trucks is deployed for a customer in the fashion business and this truck is used as a case for FREVUE.

Changes in business model

Partners, activities, resources: BREYTNER did not have to change their logistic concepts, since they already operated with electric vehicles only. For the fashion customer the process is as follows. Early in the morning (before 6:00) conventional trucks bring two swap bodies to the south hub and two swap bodies to the north hub. Around 7:00 the electric truck picks up a swap body from the south hub and leaves it at a store of the chain on the South bank (city centre) during the day. Then it gets the second swap body from the south hub and leaves it at a store on the North bank (city centre) during the day. The EFV continues to the north hub and makes a round trip passing three stores of the chain. Around 11:30 the driver is back at the north hub to swap the bodies and makes another roundtrip passing three other stores of the chain. In the afternoon the EFV picks up the two swap bodies in the city centre one by one and brings them back to the south hub. Between 16:00 and 17:00 the route is finished.

The EFV for FREVUE drives the same route for this customer each day. The length of this route is about 165 kilometres, which means that the range is never a problem. The vehicle is charged overnight and this requires about 4.5 to 5 hours. In Figure 38 it is shown that the median total time per day is 662 minutes (about 11 hours) and the median distance is 173 km per day.

Charging infrastructure is very expensive and there are currently no public fast charging possibilities. At the moment it is cheaper to use bigger batteries. BREYTNER has installed two charging poles from which they can receive data on the charging process.

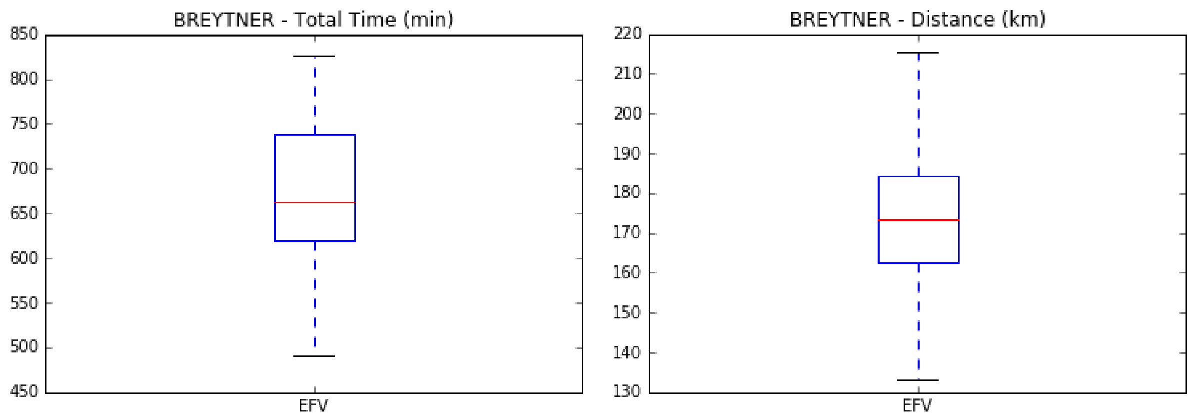

Figure 38: Boxplots of the total time and distance driven per day for BREYTNER in Rotterdam[13]

Customer, channel and relationship: There are no changes with regard to customers, channels and relationships.

[13] Box plots in figures are based on 51 observations. Data are corrected for outliers.

Value proposition: There are no changes in the value proposition of BREYTNER. In the value proposition for society there is no change because BREYTNER was already using electric vehicles only.

Cost structure and revenue streams: Since BREYTNER already operated with electric vehicles only, there are not that many changes, except for the purchase of the new EFV.

Conclusion and discussion

Since BREYTNER already operated with electric vehicles they did not have to change their logistic concepts. In the FREVUE case they serve the fashion customer with a new EFV, using the concept of swap bodies.

2.45 Clipper in London

Case description

Clipper Logistics ltd is a third-party logistics provider, one of the UK's leading logistics providers, expert in retail and high-value goods.

Within FREVUE, additionally to the 12t Smith EFV that Clipper already had, they bought another 10t Smith Newton EFV with 500 kilogram less loading capacity than the ICE it replaced. See Table 15 for the vehicle characteristics. For the Clipper case there are unfortunately not much data available, so the description here is shorter than for the other cases.

Table 15 Overview of vehicle characteristics Clipper in London

Vehicle/Parameter	EFV	ICE
Model	Smith Newton	Iveco Eurocargo
Payload (kg)	3000	3500
Type of vehicle	Large duty vehicle	Large duty vehicle
Gross vehicle weight (kg)	10000	7500
Maximum loading capacity (m3)	13.2	14

Changes in business model

Partners, activities, resources: Both EFVs are used for operations in the inner London area (Regent Street and surrounding areas). The consolidation centre operated by Clipper is about 50 kilometres from the city centre. At the time of purchase, the new EFV was designed and used for a specific customer and the required roundtrip for this customer, which was characterised by a small operational area in central London with a large number of drops. A small battery pack was enough at the time, despite a relatively limited range. Later the battery pack was enlarged for a new customer but since the contract with that client has terminated, the EFV has not been in daily operation as the range is now too short to complete a return trip to central London plus the required distances within the city centre. No additional charging equipment had to be bought as the EFV had its own dedicated charging point already.

Customer, channel and relationship: There are no changes with regard to channels and relationships.

Value proposition: There are no changes in the value proposition of Clipper. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance.

Cost structure and revenue streams: In the cost structure there are the following changes:

- Vehicle purchase costs and additional investments in battery pack (-)
- Lower fuel costs (+)
- Tax benefit (+)
- Higher driver and insurance costs (-)

Conclusion and discussion

The EFV of Clipper has not been in daily operation due to external factors.

2.46 Conclusions large electric vehicles

A total of 11 large electric vehicles were used in three different cases. Also for this category of vehicles, the lack of availability on the market is a problem. It was case-dependent whether or not changes were made to the logistics concept. When looking at the costs and resources for the cases with large sized EFVs, most important ones are the retrofitting or purchase of the vehicles, required charging infrastructure / battery pack, training of drivers, operating costs (fuel vs. electricity), insurance costs and possible subsidies. In the value proposition for society there is a positive change because of a reduction of emissions and a reduction in noise nuisance (see Figure 39).

<table>
<tr>
<td rowspan="2">Key Partners

• New OEMs and dealers for EFVs are usually smaller and less professional than for ICEs (-)
• Fewer knowledgeable service men available for maintenance (-)</td>
<td>Key Activities

• Vehicle charging time (-)
• EFVs more difficult to plan due to range (-)
• Possible advantages due to policy exemptions/privileges (+)</td>
<td>Value Proposition

Limited changes: most customers want low emission deliveries, but willingness to pay is very limited at this moment (0)</td>
<td>Customer Relationships

No changes</td>
<td rowspan="2">Customer Segments

Customers including zero emission criterions in the procurement (+), although hardly used –at this moment – in practice</td>
</tr>
<tr>
<td>Key Resources

• Fuel costs vs. electricity (+)
• Procurement cost (-)
• Charging infrastructure required (-)</td>
<td>Value proposition for society

• Reduction of emissions (+)
• Less noise nuisance (+)</td>
<td>Channels

No changes</td>
</tr>
<tr>
<td colspan="2">Cost Structure

• Investment costs: cost in purchase of the vehicle; cost in purchase of charging point (-)
• Operating costs (0) or in case of exemptions (+)
• Training of drivers (-)
• Less fuel costs; less maintenance costs (+)</td>
<td colspan="3">Revenue Streams

• No changes (0), except if: subsidy for the vehicle purchase (+), or for charging point purchase (+), zero emission in procurement (+), tax reductions (+)
• Non-monetary revenue stream: more sustainable</td>
</tr>
</table>

Figure 39: Business model canvas (BMC) for operators using large EFVs – changes positive (+) neutral (0) or negative (-) compared to CFV situation

2.5 Conclusions: experiences and changes in city logistics operations

A total of fifteen cases in seven European cities where electric freight vehicles have been tested and demonstrated has shown us that it is very well possible to carry out at least part of the city logistics operations with EFVs. Both 'last mile' deliveries (e.g. from a consolidation centre to a city centre) by EFVs and replacement of entire trips formerly carried out by conventional vehicles have been tested and proven. The smaller EFVs in the demonstrations were used in a number of cases for last mile deliveries and led to changes in the logistics concept. Where they replaced ICE vehicles, they drove more fixed trips/routes and did less ad hoc pick-ups and deliveries. For the cases with medium electric freight vehicles no major changes were made to the logistics concepts, but in some cases the EFV trips were of shorter distance than the CFV trips and the EFVs did relatively more deliveries and fewer pick-ups than CFVs. For the cases with large electric freight vehicles it was very case-dependent whether or not changes were made to the logistics concept.

For all vehicle types there is a reduction of flexibility (because of range limitations and charging times) when it comes to the use of EFVs. However, the experiences in FREVUE show that with some adaptations to the operations, using EFVs in city logistics operations is well possible. This is especially the case when a company has such large volumes to deliver that it can also operate one or more ICE vehicles next to the deliveries with EFVs. In that case, the routes can be planned in a way that they best fit the positive characteristics of both the EFV and the ICE vehicles.

<table>
<tr>
<td rowspan="2">Key Partners
Closer co-operation with cities via UCC and energy networks (0)
New OEMs and dealers for EFVs are usually smaller and less professional than for ICEs (-)
Fewer knowledgeable service men available for maintenance (-)</td>
<td>Key Activities
Vehicle charging time (-)
EFVs more difficult to plan due to range (-)
Possible advantages due to policy exemptions/privileges (+)</td>
<td>Value Proposition
Limited changes: most customers want low emission deliveries, but willingness to pay is very limited at this moment (0)</td>
<td>Customer Relationships
No changes</td>
<td rowspan="2">Customer Segments
Customers including zero emission criterions in the procurement (+), although hardly used –at this moment – in practice</td>
</tr>
<tr>
<td>Key Resources
Ownership of the vehicles: fewer lease options (0)
Fuel costs vs. electricity (+)
Procurement cost (-)
Charging infrastructure required (-)</td>
<td>Value proposition for society
Reduction of emissions (+)
Less noise nuisance (+)</td>
<td>Channels
No changes</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Investment costs: cost in purchase or lease of the vehicle; cost in purchase of charging point and telematics (-)

Operating costs (0) or in case of exemptions (+)

Training of drivers (-)

Less fuel costs; less maintenance costs (+)</td>
<td colspan="2">Revenue Streams
No changes (0), except if:
subsidy for the vehicle purchase (+), or for charging point purchase (+), zero emission in procurement (+), tax reductions (+)
Non-monetary revenue stream: more sustainable</td>
</tr>
</table>

Figure 40: Business model canvas (BMC) for operators using EFVs – changes positive (+) neutral (0) or negative (-) compared to CFV situation

Figure 40 shows a fully filled in BMC that summarizes the main changes based on the experiences from FREVUE demonstrations. Note that not all items mentioned in the BMC are relevant for each case.

3. Changes in the value network

3.1 Introduction: EFVs in city logistics

This chapter discusses three archetypes of value networks in which a logistics operator normally performs its city logistics operations. We discern these archetypes based on vehicle type:

- small commercial vehicles (corresponding to vehicle category N1 'Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes'),
- medium commercial vehicles (corresponding to vehicle category N2 'Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes'), and
- large vehicles (corresponding to vehicle category N3 'Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes'). Note that the group of N3 vehicles varies from rigid trucks (like the ones used in FREVUE by Heineken and BREYTNER) to tractor-trailer combinations.

The actor network, as well as the typical operations – including the transported weight, volume, number of stops and kilometres per trip varies between these three archetypes. This applies to the current situation in which conventional vehicles are used for city logistics operations, as well as for the case in which EFVs are used. The business case for these three categories is quite different, as is the related availability of produced vehicles. Based on the demonstrations' data and demonstrations' experiences we discuss the value networks for these three archetypes, as well as the total costs of ownership (TCO) for the logistics operator. Based on these archetypes we discuss the opportunities and barriers for a transition from diesel-powered city logistics operations (as the majority currently is) towards an electrified (i.e. zero emission[14]) city logistics from an operational and economic point of view, as the logistics operator is the actor who actually is investing in an electric freight vehicle.

This chapter is based on data and experiences provided by the FREVUE operators in interviews and reports. All analyses in this chapter are anonymized as was agreed on with respect to costs data in the project. The data for the medium sized and the large electric freight vehicles includes also inputs from companies that were not FREVUE partners (however, under the condition that their inputs would be anonymised). As a result, the TCOs and experiences mentioned in this chapter are based on two additional companies operating medium sized vehicles, and three other companies operating or in the process of procuring (or not) a large electric freight vehicle, and therefore for medium and large vehicles this chapter is not solely based on the four demonstrating companies that were described in sections 2.3 and 2.4.

[14] Obviously, electrifying the city logistics fleet does not automatically mean a zero emission city logistics system. This depends on the question how electricity is generated (i.e. the energy mix of the country in which the EFVs operate). However, this is out of scope for this study. We acknowledge the difference between tank-to-wheel emissions and well-to-wheel emissions, but in this deliverable we assume EFVs to be zero emission vehicles.

3.2 The city logistics playing field: transition requires new relationships

Logistics operations take place within in a context as (freight) transport is a derived demand. Therefore, we do not consider the logistics operator – and it's TCO – in isolation, but we first discuss the city logistics playing field and the relevant operational and economic issues in the case the city logistics system would make a transition. This deliverable does not aim at discussing city logistics actors, their stakes and relationships, as there are many other studies and reports going into these details; therefore we refer to for example CIVITAS Policy Note (2015). In this deliverable our focus is on the changes a logistics operator currently faces in its value network (i.e. an economic perspective) in the case an operator decides to switch to electric freight vehicles. We first shortly discuss the required changes in the network (from the operator's perspective) in case the operator decides to use EFVs instead of CFVs for its city logistics operations.

Figure 41 shows the value network around a logistics operator doing city logistics operations in the current situation in which diesel vehicles are used (based on TNO, 2015).

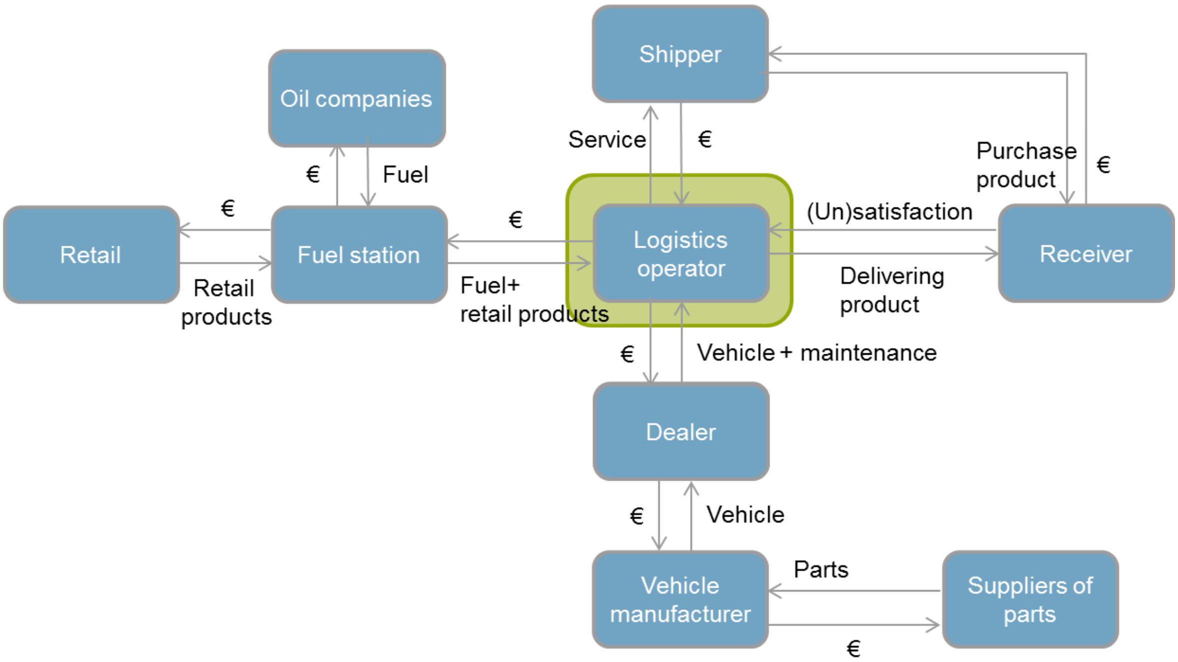

Figure 41. Value network from logistics operator's point of view (current situation, mainly ICE-vehicle operated city logistics)

The upper right part shows how the logistics is established, following the supply chain of goods: basically goods need to be transported from a shipper to a receiver. Usually in urban freight transport, the shipper hires (for-hire transport) a logistics operator or does it itself (own-transport) that carries the goods from the shipper to the receiver. The receiver pays the shipper for the products (or services) acquired, including – often implicitly – the transport to its premises. The shipper pays the logistics operator, and there is often no transactional relationship between the receiver and the operator.

In order to provide the transport service, the logistics operators require rolling stock, i.e. vehicles[15]. The lower right corner in Figure 41 shows that in the current city logistics situation, the logistics operators lease or buy vehicles from often existing relations with a leasing company or at a (local) vehicle dealer. Even if the relationship between the operator and the vehicle supplier (leasing company / dealer) does not exists, the vehicle supplier is a well-established economic entity that sells / leases a well-tested and mature product. The vehicle supplier procures the ICE vehicle from a vehicle manufacturer (i.e. an OEM), that produces the vehicles on a large scale and has – very often – a very agile production process, where suppliers of parts are fully integrated (and available).

Figure 41's left side shows another industry where the logistics operator procures materials. Large operators often have fuel stations at their depots to fuel their ICE vehicles, whereas smaller operators use the largely available network of commercial fuel stations. Large oil companies (and retail companies) supply these fuel stations and the density of these stations is high. Figure 41 only shows the transaction network from the logistics operators point of view, as well as the economic stakes of other related industries (i.e. automotive and oil) in the current situation. The area – for example a dense city centre, the existing policy regime, or other contextual factors determining the boundaries for a logistics operator to perform its city logistics operations are not included here (and are discussed in more detail in FREVUE Deliverable 3.5 'Policies, procurement mechanisms and governance').

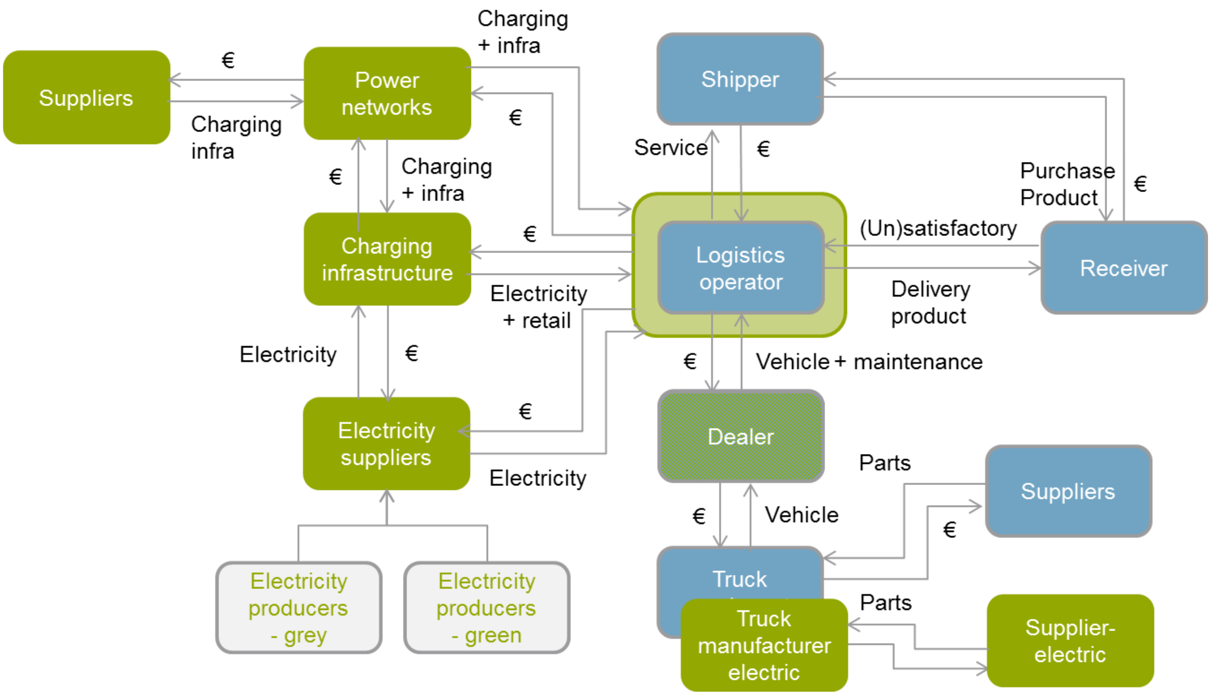

Figure 42. Value network from logistics operator's point of view (new situation, EFV operated city logistics)

Now, in order to change the existing – mainly diesel power situation - Figure 42 shows a similar value network, but now for the logistics operator that uses an EFV. The green boxes show actor-relations that change due to the use of another vehicle by the logistics operator.

[15] Or other modalities or means, like bikes or light electric freight vehicles (see for example: LEVV Logic, 2017) focusing on electric or electric supported vehicles smaller than the N1 van; these vehicles are out of this study's scope.

Starting again in the upper right corner of the figure, i.e. the logistics organisation, the most striking is that nothing changed here. The relationships and transactions between shipper, receiver and logistics operator are the same as they were in the existing (diesel-powered) situation. This corresponds to the outcomes from the several business model descriptions of various FREVUE demonstrations described in chapter 2. The majority[16] of shippers is not currently willing to pay extra for zero emission deliveries. This situation is the same for receivers. So in the logistics settings nothing changes; except for the logistics operator that operates an EFV. The direct results for the operator were already discussed in chapter 2's business model canvases. This chapter discusses the changes for the logistics operator in more detail based on a TCO analysis.

In the logistics relations (currently, and in general) nothing changes, in the transition from CFV to EFV. However, as Figure 42 shows, almost all other relationships change for the operator, which makes a smooth transition quite difficult. To start with Figure 42's lower right corner: no longer is the logistics operator able to buy or lease the vehicle from its normal dealer or leasing company, as the availability of electric vehicles is – as of early 2017 - still limited (especially for larger vehicles, N2 and N3). For the larger vehicles no OEM products and associated services are available at the moment. Notice that this situation is changing as more OEMs have announced to introduce large electric vans and trucks to the market[17]. Besides better availability of the electric freight vehicles (although not yet the case for rigid trucks or larger vehicles) and the expected decrease in costs if these vehicles are mass-produced, the main advantage for the logistics operator is that it can buy or lease the products via their regular relations and under the – for them – familiar conditions and services. As for the current large electric freight vehicles, that are often retrofitted vehicles, the operators face two serious differences in comparison to the conventional vehicle situation (again, especially for the larger electric freight vehicles, as for the smallest vans OEM produced vehicles are available – although not so much as conventional), which can form a barrier for the operators in procuring an EFV or increasing the number of EFVs in their fleet[18]:

- Although the retrofitting companies that are producing the electric drivelines in the electric freight vehicles do a good job and technical performance is often appreciated, there are differences in comparison to the mass-produced conventional vehicles – which follows directly from the difference in a high mature and further developed ICE truck / large van as well as the production process, in comparison to manually converted electric trucks[19];
    - Initial issues in CAN bus communications, as this is custom-made work per retrofitted vehicle; in the first weeks of operations some issues often arise (although the vehicle is tested by the manufacturer); note that these are initial starting issues that, once fixed, usually do not occur anymore;

[16] There are examples of shippers that do pay more for electric freight transport, but that is a vast minority (see for example Heineken in FREVUE, or Gucci's deal with TNT (see FREVUE, 2015)).
[17] For example, Mercedes e-Sprinter (2019, 2020), Volkswagen e-Crafter (2017), or the announcement of the first small series of Mercedes eTrucks (Electrek, 2017); which is promising, but at the moment (Q1, 2017) not yet available.
[18] Chapter 5 goes into the question on what barriers operators are confronted with in case the operators want to increase the number of EFVs in their vehicle fleet.
[19] Compare a TRL for EFVs that is demonstration in operational environment to a full mature product and market of the CFVs.

    - Down-times and production lead times are considerable longer (weeks or months for production), whereas for conventional vehicles this is done in hours.
- Risks and financing issues:
    - It is difficult to finance large electric freight vehicles via commercial banks, as these vehicles are considered innovative and the risks are considered too high, partly due to the yet unanswered question what the second -hand (residual) value will be.
    - Many retrofitting companies are relatively small and are not able to guarantee EFV's technical performance in time (e.g. battery lifetime) in a similar integral way as it is done for ICE vans and trucks. Therefore the logistics operator is confronted by either higher risks itself, or by additional costs in buying these risks off (whereas this is integral part of the mature ICE vehicle costs).

These issues currently are – even if there is a business case / positive TCO – a barrier for many operators. Uncertainty, unknown relations and situation and potential risks, as well as the extra effort and time required to familiarise with this situation, are not or hardly addressed in TCO comparisons, but constitute an important reason for operators not to invest in EFVs at this point.

Finally, Figure 42's left part shows another new relationship for the logistics operator that starts operating an electric freight vehicle, i.e. no longer can it use the easily accessible fuel station network. The operator needs to have charging infrastructure for its electric freight vehicles. This also requires the EFV's logistics operator to do things it would not normally do when buying a conventional vehicle. The major differences a logistics operator faces after procuring an EFV, besides typical EFV-characteristics such as limited range and long periods of charging (see chapter 2, where the specific changes for logistics operators are discussed in the BMCs), concern charging infrastructure and electricity grid infrastructure.

First of all, there is no extensive charging infrastructure available, especially for medium-sized and large electric trucks. Most commercial vehicles are charged overnight at the depot, which means the operators have to invest in charging infrastructure. Notice that this is often the preferred option for an operator, as it enables the operator to plan the EFV trips without extra constraints concerning charging and time, except for the vehicle range. Currently, public fast chargers are, even if available, not that often used by the logistics operators as it requires extra planning constraints. Next, there is the risk that the commercial vehicle has to wait for another vehicle at the charger (see also the Bring demonstration in FREVUE), which results in potential issues for the rest of its roundtrip (i.e. late deliveries and / or missed time slots). Next to the additional costs for charging infrastructure, this again is often a new knowledge domain for the operator, which requires the investment of time and which could be – due to time or unfamiliarity – an extra barrier for an operator to start using EFVs.

Finally, another major challenge for the operator could occur in the case that the electric freight vehicle fleet grows. Many EFV investments at this moment are only to demonstrate and learn from the EFVs, and are limited to a single or a few EFVs in a diesel dominated fleet. If, however, an operator aims at investing in a larger EFV fleet, the operator runs the risk that the power grid is not sufficient to charge the entire electric fleet (as was the case for UPS in London, see FREVUE, 2016). This implies, that after overcoming all the extra challenges (see difference between Figure 41 and Figure 42) to make the transition towards using an electric vehicle in city logistics, one major new area rises for the operator. As the UPS example showed, this issue – although it is an issue from another part of the value network, i.e. the power networks, - is also made into an issue for the operator.

In other words, for a logistics operator – at this moment – to switch from the existing diesel-powered vehicles towards electric powered vehicles, requires more than just buying another vehicle. It requires new relationships and time investments in areas that normally only ask for a limited effort from the operator, which can be (and actually turned out to be indeed) a barrier for operators in moving from CFVs to EFVs. Therefore – apart from the costs (that are discussed in the next section 'Total costs of ownership') – the development that OEMs will start producing these vehicles will be removing one barrier in the transition from CFV-dominated city logistics to EFV- dominated city logistics.

3.3 Total costs of ownership

Apart from the barriers in the value network, one of the most important indicators in the purchase decision for operators is the TCO (total costs of ownership) comparison between a CFV and an EFV. As the previous section showed, this is not the only criterion for an operator to buy or test an EFV, as many other elements change and require effort and attention. However, if there is no prospect of a lower TCO for an EFV in time than for a CFV, it is not expected that many operators will purchase these vehicles. So, as was also experienced during the procurement decisions for some of the EFVs in FREVUE, a similar TCO (including subsidies) for an EFV is often considered as minimum requirement, considering all other uncertainties the operator faces.

Lebau et al. (2015, p. 553) explain the rationality of a TCO comparison between CFVs and EFVs: "Owning and operating a vehicle is associated with costs that occur at different moments in time. To compare these costs across time, the TCO methodology uses the financial formula of the present discounted value. This way, the present value of every cost can be summed to obtain the full cost of one alternative. The TCO is defined as "a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier" (Ellram, 1995, p. 4)".

Several researchers actually compare the TCOs of light electric and conventional commercial vehicles; see for example Ajanovic and Haas (2016), Lebau et al. (2015), Lee et al. (2013) and Taefi (2016). TCO calculations and comparisons are used for better understanding of the life time costs of electric compared to conventional freight vehicles in research as well as in procurement decisions of operators. Next to these contributions, several TCO comparison-tools[20] are also presented at seminars, webtools, etc. One main lesson from discussions between practitioners and researchers is that none of the tools describes the situation for different operators. Examples are differences in purchase prices operators pay (for conventional vehicles) depending on among other things the purchasing power, which determines the comparison. This also applies to the estimates for elements such as the residual value of the electric vehicle, the deterioration of the battery (and estimated replacement costs), difference in maintenance between CFV and EFV. It is widely supported that EFVs' maintenance costs will be (or are) lower than CFVs', as there are fewer moving parts. However, as the experience with EFVs does not cover a long time span and the technology readiness level (TRL) of the currently operating EFVs is lower than that

[20] The majority of these tools focusses on comparison for passenger vehicles though.

of the CFVs (the EFVs are still developing), it is difficult to make accurate estimates for these costs in advance that are correct according to all practitioners.

The TCO comparison we present in this deliverable aims at addressing some of these issues, by using actual data of operators in FREVUE, completed with data that other operators were willing to share (in order to guarantee that the presented TCO comparisons cannot be reduced to one operator or manufacturer as agreed with the operators sharing their data). The TCO comparisons we present are calculated under the following assumptions and conditions:

- Maintenance: we take the costs for maintenance as paid by the operator. Most often, operators pay a fixed amount per year for maintenance (i.e. a service contract), which reduces their risks. Therefore, we cannot compare the actual differences in maintenance (as incidents are not registered in this way – but we do compare the actual costs for maintenance paid by the operators).
- Tax advantages: in different European countries and cities different incentives are used to promote EFVs; we use the average advantages based on received operators data. For example in the Netherlands tax relief schemes for environmentally friendly investment reduces the operators purchasing costs[21], whereas for other areas there are exemptions from road or circulation tax (see for example Norway and the United Kingdom).
- Energy costs – fuel costs: obviously, energy costs and fuel prices vary in time; next, energy prices also vary per operator, depending for example if an operator is an industrial consumer or not (see also for example: Eurostat, 2017). Again we follow the averaged data that the operators shared with us in the calculations.
  Fuel prices, costs for electricity and expected (future) costs for batteries change in time (see chapter 5 for further elaboration). Again, in our TCO comparison we use the data received form FREVUE's operators. As we generalize TCO calculations to vehicle type, we use average prices (per vehicle type) for electricity and for fuel, as these vary from less than 0.04 € / kWh in down peak periods to over 0.15 € / kWh. Prices at charging stations are often much higher. Similarly, we base our fuel prices on the costs provided by the operators.
- Residual value: the variance between what operators estimate the residual value will be is quite high. As the uncertainty on the EFV's residual is high, some operators use no residual value in their TCO calculations to be on the safe-side. We follow this, but we also vary the residual value by assuming the CFV residual value as used by the operators and estimate a residual value for the battery of 20%.
- Battery warranty: again the uncertainty is high. Manufacturers provide different warranties, for example to 2000 cycles or 5 years / 150,000 kilometres, or guaranteed upgrades of a battery – if necessary – after eight years. In the TCO calculations we assume no need for a new battery, but warranty-costs as paid by the operators are included. As the batteries in most FREVUE demonstrated vehicles are currently over dimensioned for the trips made, the estimate is that it can be used for a longer period even if performance goes down in time; but we do not have data on that from FREVUE demonstrators to show this (or show the opposite) – as the project has not covered a long enough period (see for more information FREVUE, 2017).

[21] http://www.rvo.nl/sites/default/files/2014/02/MIA%20and%20Vamil.pdf

- Grid investment: FREVUE (2016) shows “UPS then discovered that at their depot in London it was not possible to charge all their electric freight vehicles simultaneously. The vehicles need to be charged in the late evening when returning from their routes, a time when the depot’s sorting machines also run and electricity consumption is at its peak”. In the TCO calculations we show one example of the impact of the costs for upgrading the grid; note that these costs will appear for other operators in case of a transition towards larger EFV fleets (but do not yet occur in most demonstrations, as only a few vehicles are charged simultaneously).
- Charging infrastructure: for the charging infrastructure we use the data as was provided by the operators.
- Vehicle purchase price: for both the purchase price of the CFV and the EFV we base our TCO on the actual prices paid by the operators; note that these prices (can) differ from the prices mentioned in the catalogues; as e.g. negotiations between operators and dealers, as well as order-sizes do influence the actual purchase price. Notice that the purchase prices that we used are based on vehicles procured in FREVUE; this implies that current prices could be different, as many vehicles have been running in FREVUE for more than two years.
- Driver costs: we did not include costs for the vehicle’s driver, as similar drivers are driving the CFVs and the EFVs; so adding labour costs to the TCO comparison does not add value. The operators stated that there are no serious changes in drivers’ time spent (due to for example the fact that the driver does not need to fuel the CFV but put the EFV in a charger) and no difference at all in the driver’s costs for the operator.

The aim of the TCO comparison we provide is to show on the one hand the sensitivity towards changes in currently uncertain events, as well as to see what elements can be used to influence the TCO. A (on the longer term) positive TCO for an EFV is for many operators a requirement, in order to make the decision to use EFVs.

3.31 Economics for a logistics operator with a small EFV

The small sized electric vehicles in FREVUE are used for various types of urban logistics activities, varying from parcel deliveries and pick-ups, medicines, general cargo, and maintenance operations of parking meters. The market for conventional vans is dominated by relatively low-cost products, as there is no market for luxurious vans (in contrast to passenger cars and trucks). Therefore, the comparatively expensive electric van has to compete with a value-for-money vehicle. For this segment OEM-produced vehicles are available and used (in contrast to the other vehicle segments discussed later), i.e. Nissan eNV200 and Renault Kangoo ZE.

We used the data from FREVUE partners (see section 2.2 for more information) for the TCO comparison in this category. The data in the presented TCO calculations do not represent one operator and are based on averages from the different FREVUE operators. The results are generalized to one TCO comparison (which means for example that some country specific elements are not included anymore, or company specific characteristics are left out);

for prices, we use averages, e.g. for fuel we use € 1.10 per litre constant for the next decade and for electricity we use 0.03 €/km[22].

Figure 43 to Figure 45 show the TCO comparison for the small sized vehicle. Figure 43 shows that the total cost of ownership decreases per year for both the electric freight vehicle and the conventional vehicle. The graph shows the yearly total costs given a certain life time on the horizontal axis. For example, the TCO of an EFV excluding subsidy with a lifetime of 8 years is approximately € 5000 per year, so € 40000 in total. Without subsidy, there is a break-even point at about four years (with subsidy even earlier) assuming the vehicle drives 60 kilometres per day. Figure 44 shows the subdivision of cost elements in five years' time (i.e. Figure 44 shows the cross-section depicted by the red line in Figure 43 and Figure 45 the cross-section depicted by the yellow line).

Notice that Figure 43 (and following similar figures) shows the TCO development in costs per year, which explains the decreasing trend. The cumulative costs obviously increase as can be observed from the increase in TCO from Figure 44 compared to Figure 45. Figure 43 shows the TCO *per* year, which means it shows the TCO divided by the number of years a transport company operates a vehicle (which is depicted by the number of years at the *x*-axis) of the figure.

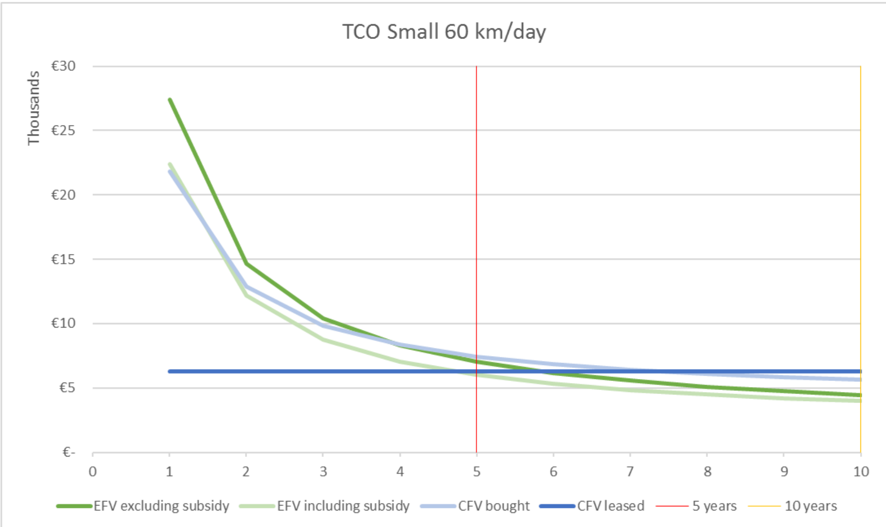

Figure 43. Development of yearly TCO per year-operated small sized vehicle (average 60 km / day)

The vehicle price is by far the largest cost-driver for an EFV, but does not differ that much from the purchasing price for CFVs. Since operating costs are lower (fuel vs. electricity and maintenance) for an EFV and investments for charging infrastructure are in this category relatively low, there is a break-even point quite early. Note that, although from a TCO point of view the EFV performs quite well, operationally it still has some limitations (in for example range), which can be a barrier for large-scale uptake.

Maintenance costs are relatively high in the TCO comparison for small vehicles; the values we received from partners varied considerable for maintenance contracts and repair costs. This is striking for the TCO comparison for small vehicles, as the vehicle procurement costs are – in comparison to the medium and large trucks – relatively small and therefore the

[22] Data on performance characteristics of the vehicles are provided in FREVUE Deliverable 3.1 Technical Suitability of EVs for Logistics – Report.

maintenance and repair costs take a relatively large share in the TCO for small vehicles. We use a weighted average for maintenance costs based on the partners' inputs in the TCO comparison.

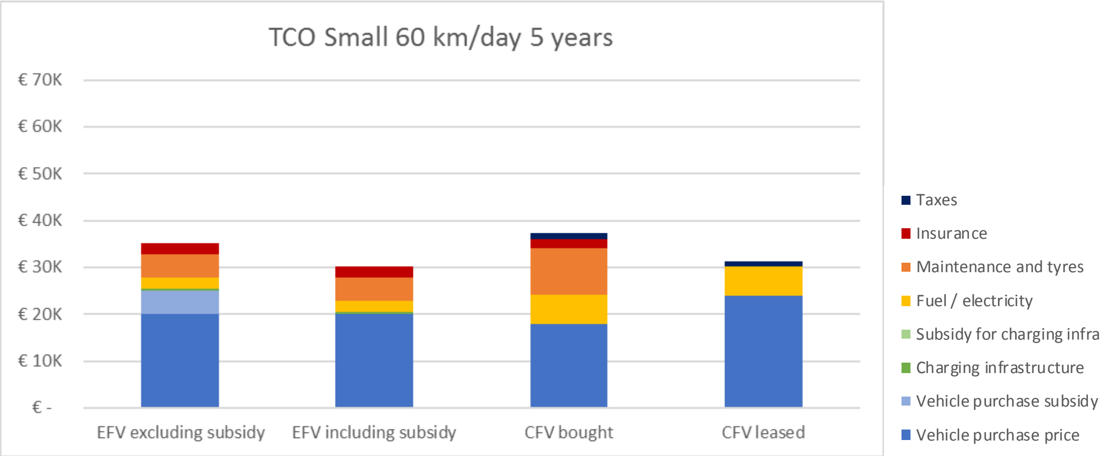

Figure 44. TCO small sized vehicle (5-year cross-section - 60 km / day)

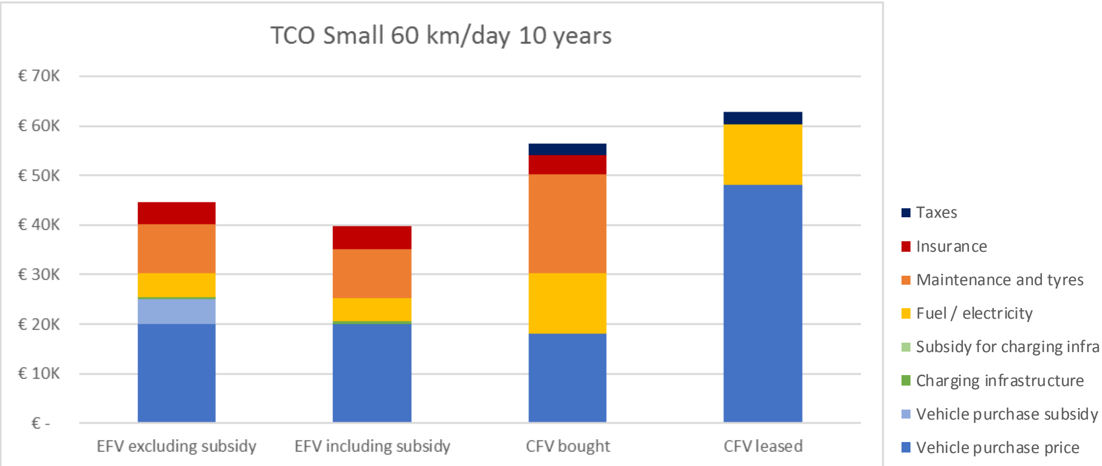

Figure 45. TCO small sized vehicle (10-year cross-section - 60 km / day)

As can be derived from the TCO comparison after 5 years (Figure 44) the TCO for using a small EFV are lower than for using a CFV, even without subsidy. This also explains why some of the partners (e.g. EMEL and CTT) are increasing their electric freight vehicle fleet. Note, that for some operators the relatively limited range is the main reason for still investing in CFVs rather than introducing more EFVs in their fleet (see for example Binnenstadservice). The TCO over a period of 10 years is really favourable for the EFV (Figure 45), but the demonstrations in FREVUE did not last long enough to show if a time-period of 10 years is also technically feasible. As these small EFVs are available from OEMs, some of the hurdles mentioned in section 3 do not apply to this vehicle category, which makes the transition to use small EFVs instead of small CFV relatively easy.

Several elements are not included in Figure 43 to Figure 45. The following figures show the effects on the TCO in case of changes in the average number of kilometres per day (Figure 46 - Figure 48). The TCO comparison can be even more positive in case the EFVs travel more than 60 kilometres a day. Figure 46 to Figure 48 are similar to Figure 43 to Figure 45 but the average distance driven is increased from about 60 km per day (like Eurodifarm) to about 90 kilometres per day (like for example SEUR did in FREVUE). As the operational costs for EFVs are lower than for CFVs', the TCO comparison shows that the TCO is even more favourable for the EFV, as operating costs per kilometre (fuel (CFV) versus electricity (EFV)) make up a part of the total costs of owning the vehicles.

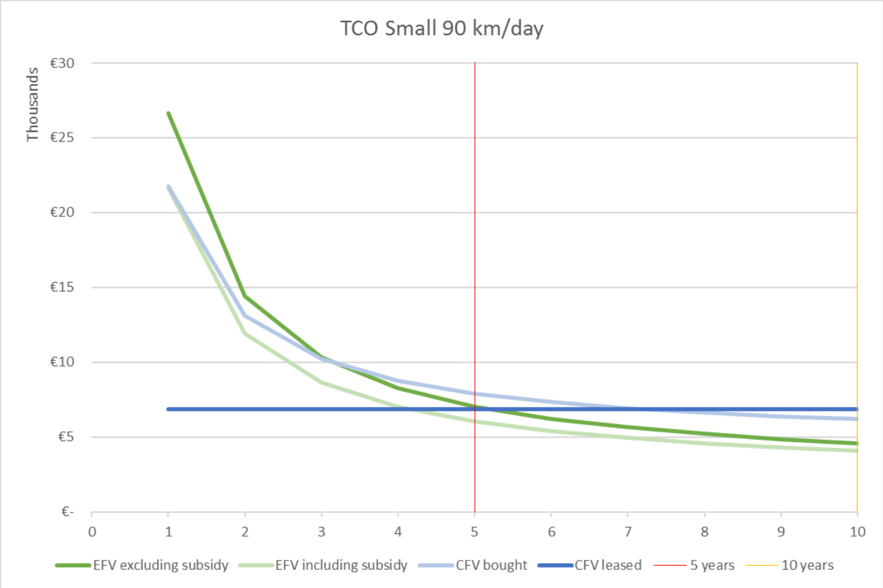

Figure 46. Development of yearly TCO per year-operated small sized vehicle (average 90 km / day)

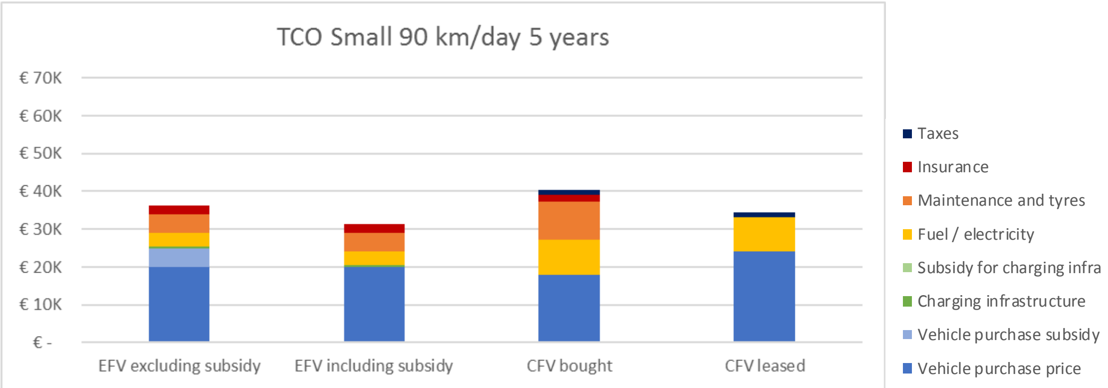

Figure 47. TCO small sized vehicle (5-year cross-section – 90 km / day)

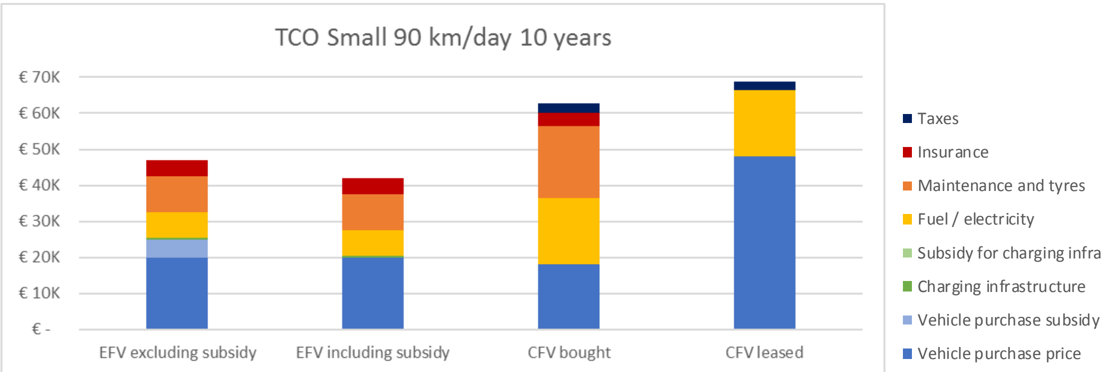

Figure 48. TCO small sized vehicle (10-year cross-section – 90 km / day)

However, the figures in section 2.2 show that most demonstrators use the small EFVs for a limited number of kilometres a day, so we also made a TCO comparison for the case an EFV driven on average 30 kilometres per day (comparable to EMEL and CTT in FREVUE), as Figure 49 shows. Even with this relatively low number of kilometres travelled per day (and therefore relatively low operating advantages for the EFV), Figure 49 shows that without subsidy the TCO break-even point for an EFV is around 5 years compared to buying a CFV and around six years compared to leasing a CFV. For this TCO comparison we do not show similar cost breakdowns (after 5 years and 10 years), but these can be derived from Figure 49.

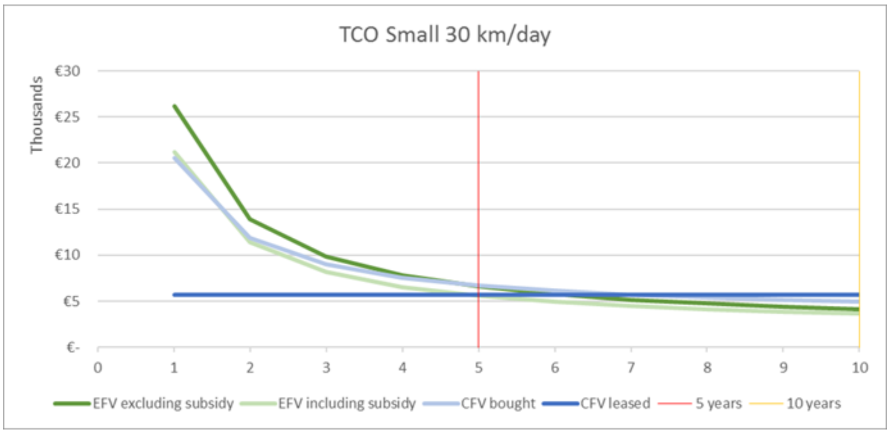

Figure 49. Development of yearly TCO per year-operated small sized vehicle (average 30 km / day)

3.32 Economics for a logistics operator with a medium EFV

The medium sized electric vehicles in FREVUE are used for parcel deliveries and pick-ups. The market for conventional vans is dominated by relatively low costs products, as there is no market for luxurious vans (in contrast to passenger cars and trucks). Therefore, the relative expensive electric van has to compete with a value for money vehicle.

Next to the data we received from UPS in London and Rotterdam and TNT in Amsterdam and Rotterdam, we included another (anonymous) case with similar trips, vehicles and operations. The data in the presented TCO do not represent one operator and are based on all three cases and generalized to this one TCO comparison (which means for example that some country specific elements are not included anymore, or company specific characteristics are left out); for prices we use averages. E.g. for fuel we use € 1.10 per litre constant for the next decade and for electricity we use 0.08 €/kWh[23].

Figure 50 to Figure 52 show the TCO comparison for the medium sized vehicle. Figure 50 shows that the total cost of ownership significantly decreases per year for the electric freight vehicle in comparison to the conventional, and even without subsidy eventually breaks even with the comparable CFV after about 10 years of ownership. The steep slope in the first years of the EFV graph (compared to the CFV graph) can be explained by the relatively high investment costs (i.e. purchase price and charging infrastructure) for EFVs. For a longer life time (on the horizontal axis), these investment costs are spread out over more years, which decreases the yearly costs that are shown in Figure 50. Figure 51 shows the subdivision of cost elements in five years' time (i.e. Figure 51 shows the cross-section depicted by the red line in Figure 50 and Figure 52 the cross-section depicted by the yellow line).

[23] Data on performance characteristics of the vehicles are provided in FREVUE Deliverable 3.1 Technical Suitability of EVs for Logistics – Report.

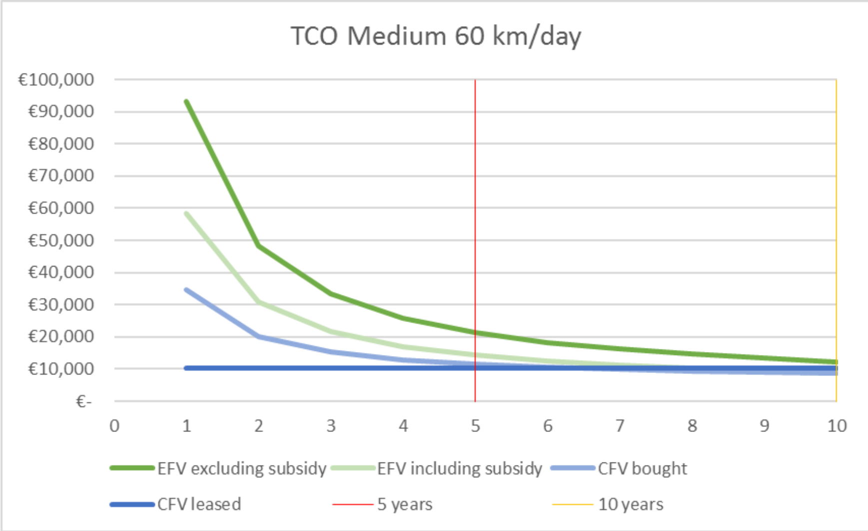

Figure 50. Development of yearly TCO per year-operated medium sized vehicle (average 60 km / day)

From data provided by the operators we learned that insurance costs for the majority of the EFVs are higher. Insurances are a fixed percentage of the vehicle price, and as the EFV purchase price is higher, this implies the insurance costs are higher as well. The vehicle price is by far the largest cost-driver for an EFV, the required charging infrastructure and other variable costs are much lower. The parcel operators normally depreciate their vehicles over approximately five years; therefore we show the 5-year period TCO comparison. However, as the EFV purchasing costs are much higher than the CFV, a longer depreciation time would be an option and therefore we also look at a 10-year life time (assuming the battery can last that long).

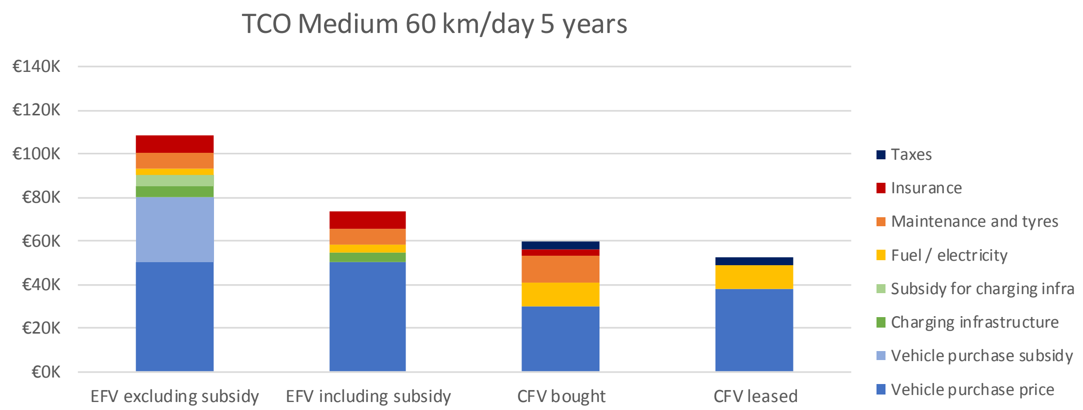

Figure 51. TCO medium sized vehicle (5-year cross-section - 60 km / day)

Several elements are not included in Figure 50 to Figure 52; which make the TCO for the EFV quite a challenge for an operator. The following figures show the effects on the TCO in case of changes in the average number of kilometres per day (Figure 53 to Figure 55); in case of congestion charge (and the exemption for EFVs, see Figure 56 and Figure 57); in case of reducing costs by decreasing it with an estimated residual value (see Figure 58 and Figure 59); and in case of extra investments in the electricity grid (Figure 60).

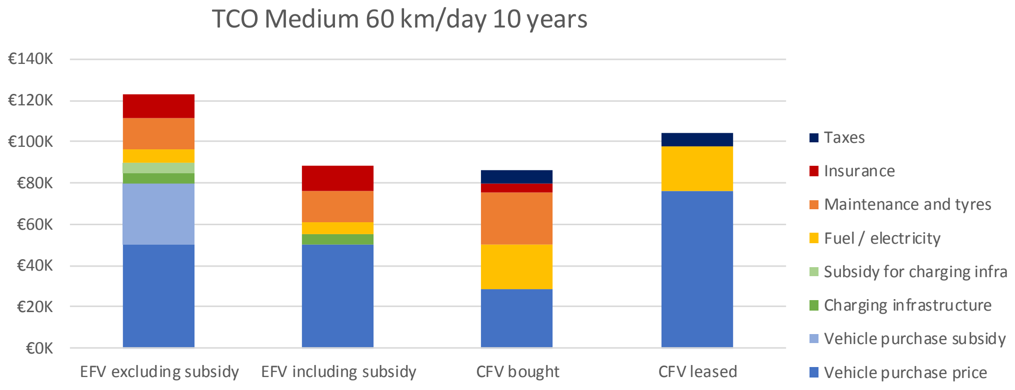

Figure 52. TCO medium sized vehicle (10-year cross-section - 60 km / day)

Figure 53 to Figure 55 are similar to Figure 50 and Figure 52 but the average distance driven is doubled (from about 60 km/ day, like UPS does in Rotterdam) to about 120 kilometres / day (like some of the TNT vehicles did in FREVUE). As the operational costs for EFVs are lower than the CFVs', the TCO comparison shows that the difference is smaller between the CFV and EFV. However, fuel (CFV) and electricity (EFV) make up for only a limited part of the total costs of owning the vehicles, so although the EFV's TCO comes closer to the CFV's TCO, currently there is no positive TCO situation yet for the medium sized electric freight vehicle, without subsidy in ten years. However, with subsidy a positive business case for an EFV is possible after six years.

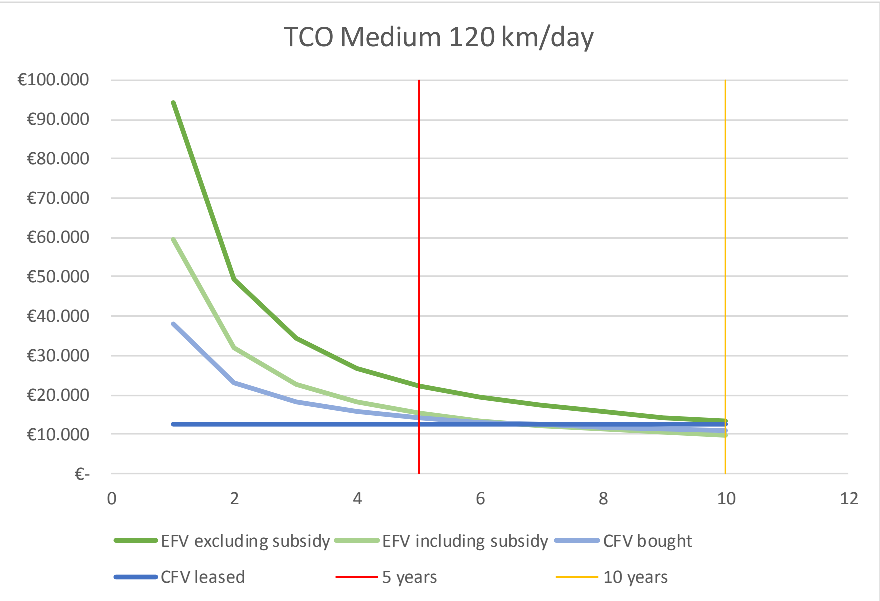

Figure 53. Development of yearly TCO per year-operated medium sized vehicle (average 120 km / day)

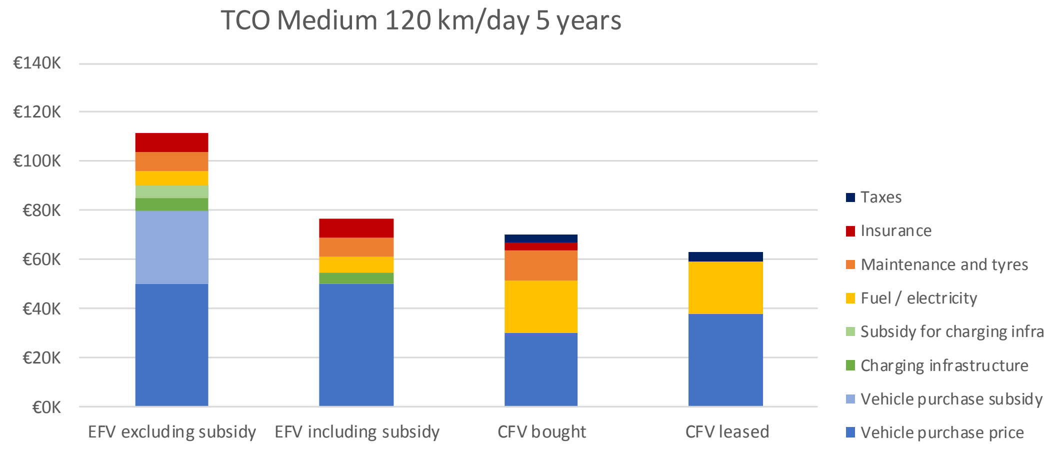

Figure 54. TCO medium sized vehicle (5-year cross-section - 120 km / day)

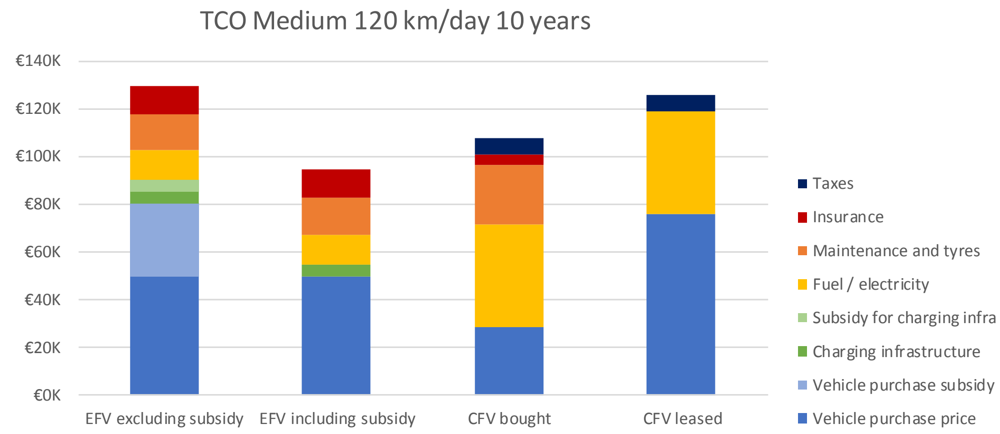

Figure 55. TCO medium sized vehicle (10-year cross-section - 120 km / day)

In the operations, see also chapter 2, we looked at the effects of supporting policies for EFVs. Although we learned from operators that policy exemptions were appreciated, we were not able to find the effects on operational performance based on the trip data as exact comparisons between CFV and EFV trips were not possible due to changing circumstances in e.g. number of drops and pick-ups in time (in Amsterdam, see for more information FREVUE, 2016b).

Congestion charging, like in London, and the exemption from the charge for electric freight vehicles can clearly support the business case for an EFV. Figure 56 and Figure 57 show the impact on the TCO comparison for operating an EFV and a CFV in a congestion-charged area. The total costs for the CFV increase considerable, due to the charge (see grey box in Figure 56 and Figure 57). These figures show that – for a time period of 10 years – the TCO is more or less similar when doing on average 60 km roundtrips per day, and positive for a vehicle making 120 km roundtrips. The congestion charge – or specifically the exemption for EFVs – contributes to the positive business case for EFVs in city logistics.

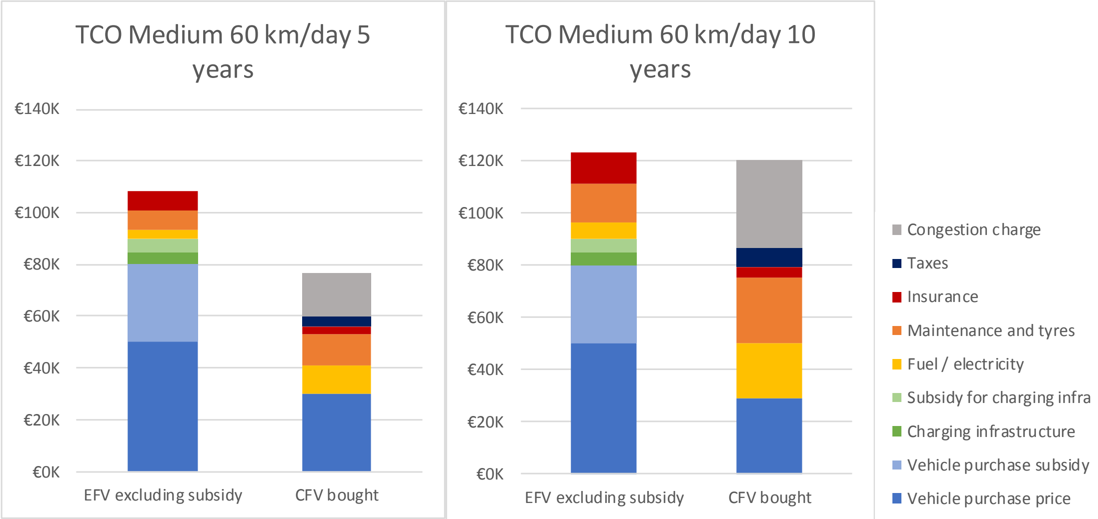

Figure 56. TCO medium sized vehicle (including congestion charge - 60 km / day)

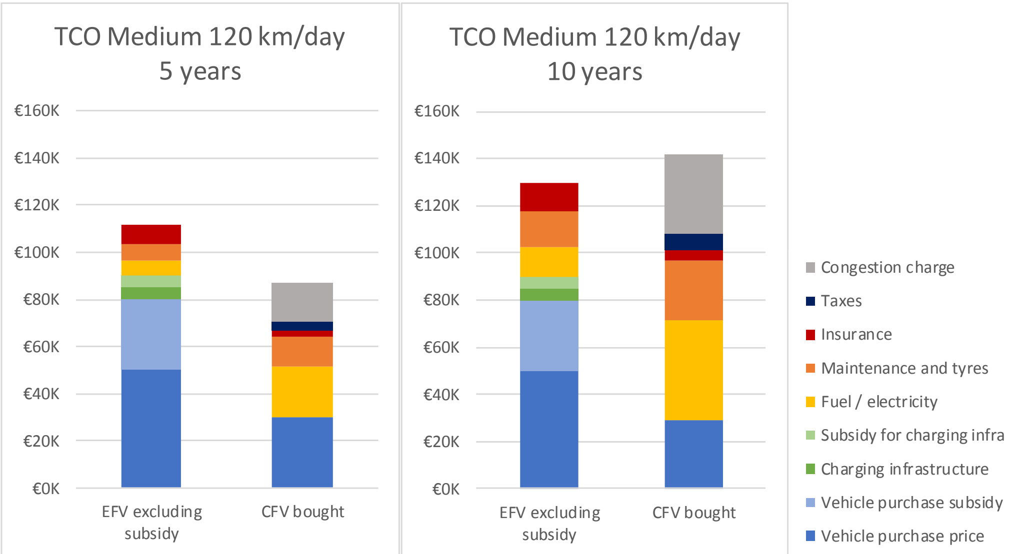

Figure 57. TCO medium sized vehicle (including congestion charge - 120 km / day)

Another element that we did not yet include in the TCO comparison is the residual value of the EFV (nor of the CFV). What the residual value of an EFV will be is one of the main uncertainties operators currently face. What the second-hand market will be for EFVs or for the battery in the EFV is at this moment not known. Notice that especially for the medium-sized vehicle segment there is normally a good second hand market and the average life of vans is quite high in comparison to other commercial vehicle types; see for example TNO, 2017.

Figure 58 and Figure 59 show what happens to the TCOs of the CFV and EFV in case we estimate a residual value for the vehicle and the battery. Especially if the second-hand battery can be used commercially the TCO for the EFV improves considerably. However, at the moment most operators estimate the residual value to be zero, to be on the safe side in their calculations and to make sure they are not confronted with negative results at the end of the EFV's operations time. Coming years will show what the residual value will be and how this influences the TCO.

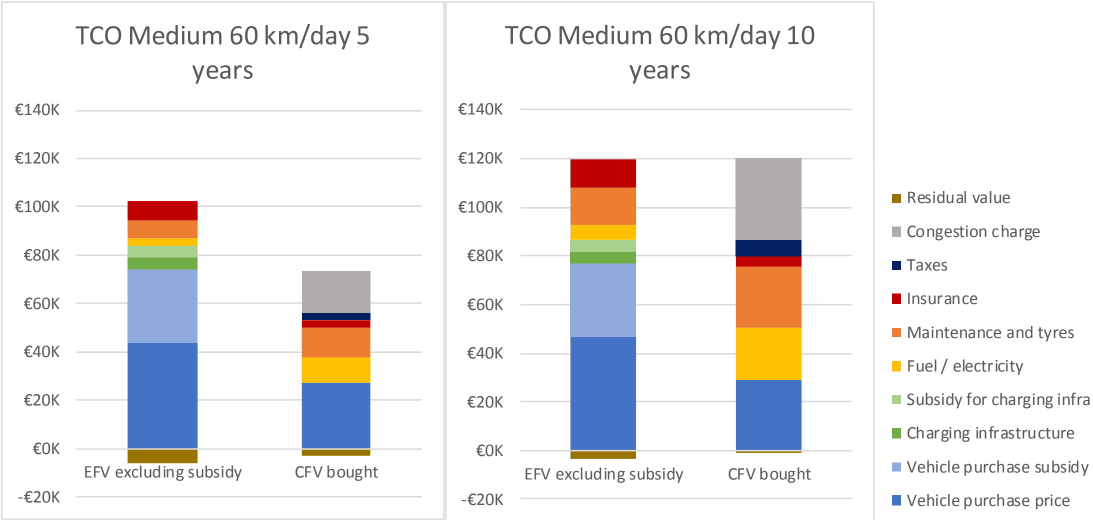

Figure 58. TCO medium sized vehicle (including estimated residual value- 60 km / day)

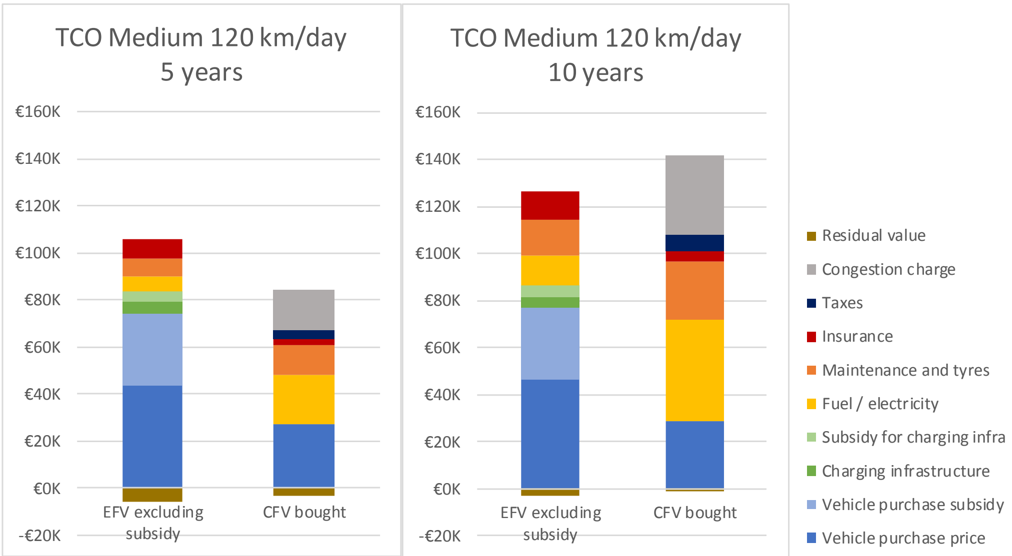

Figure 59. TCO medium sized vehicle (including estimated residual value - 120 km / day)

After presenting elements that can positively influence the business case for medium sized electric freight vehicles (in Figure 56 to Figure 59), reflection towards potential risks negatively influencing the business case is also required.

First of all, all TCO comparisons are computed under the assumption that the EFV's batteries do not deteriorate too much, and that these batteries can be used for five or even ten years without replacement. In the case this is not feasible, the EFVs' TCO increases with the costs of an extra battery, and is not going to be comparable to the CFV's TCO at all.

Another uncertainty lies in the development of fuel prices as well. Obviously the business case for an EFV profits from an increase in the costs for operating a CFV. As the TCO figures show, fuel costs form a considerable part of the total costs for a CFV. Therefore these (unpredictable) developments do influence the TCO comparison, but are difficult to include in the procurement decision of an EFV.

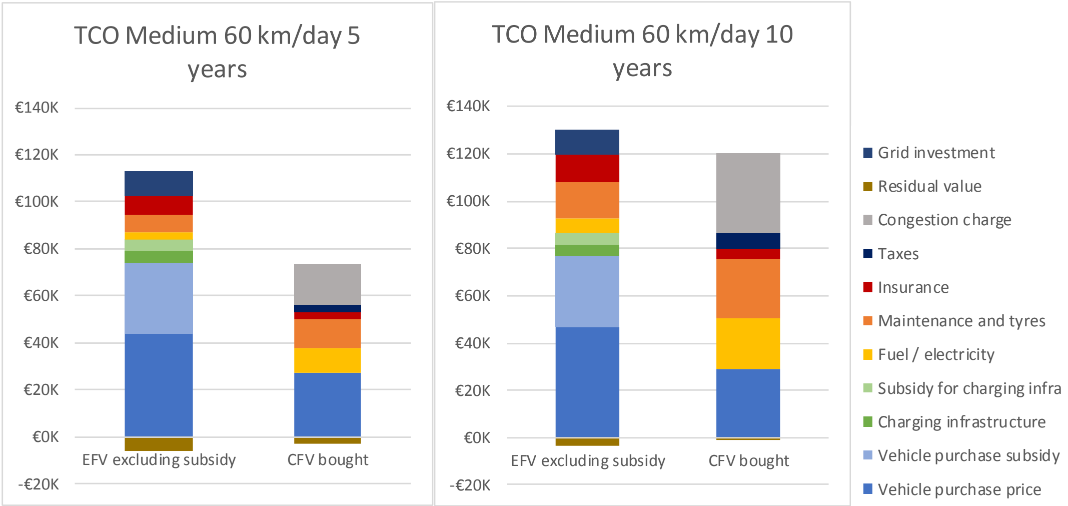

Figure 60. TCO medium sized vehicle (including grid investments - 60 km / day)

Finally, Figure 60 shows an estimate of the extra costs for upgrading the grid, like UPS had to do in London (see FREVUE, 2016). The calculations shown in Figure 60 can be much worse, as we now spread the additional investment over the 68 EFVs that could be charged. However, in case no 68 extra vehicles would be used to divide the investment over, but 'just' 17 – which is more realistic and in line with what happened in the UPS demonstration in London – the grid investment block in Figure 60 would be four times as big. As Figure 60 shows, this extra investment can – like the right figure in the 10-year case – make the difference between finding a feasible business case or not.

In conclusion we can say that for the medium size electric freight vehicle the TCO is in most cases currently worse than for a comparable CFV. However, the TCO comparisons do show that with financial support (as in some cases currently exists) from subsidies, or from projects (like FREVUE), or other financial incentives (such as the exemption of London's congestion charge) there can be a comparable TCO around five years. Next, many uncertainties still exist around the residual value. The current generation of EFVs are tested and demonstrated in daily city logistics operations, but not yet long enough to say more about the actual residual value at the end of life, or the actual deterioration (or not) of the batteries. As long as battery lifetimes cannot be guaranteed, in most procurement decisions (i.e. TCO calculations by operators) the operator calculates with a smaller depreciation period than the 10 years we used in this TCO comparison. Finally, the TCO calculations show that increasing the number of kilometres driven does have a positive impact on the EFV's TCO. In the end, the TCO depends – next to the number of kilometres – on the cost advantages due to lower costs for operating per kilometre with an electric vehicle than with a conventional vehicle. These cost advantages come from lower costs per kilometre (diesel versus electricity) and lower maintenance costs. For the electricity versus fuel costs we did not make a future price projection in this analysis, but used current data from the operators. See Chapter 5 for a more elaborate analysis on electricity and fuel price projections, and how this influences the TCO. For maintenance, we assumed the costs are lower due to a limited number of moving parts in the EV-driveline; however, we do not have data supporting that (nor the opposite):

- the vehicles' lifetime in the project is too short for that;
- the reported EFV issues (initial communication issues with CAN bus and drive line) have to do with fact that the EFV is not an OEM product (in comparison to an CFV), but retrofitted;
- most operators have a contract for maintenance which is either part of the producer's warranty or a fixed costs maintenance agreement; so no specific data on maintenance issues is collected.

3.33 Economics for a logistics operator with a large EFV

The large sized electric vehicles in FREVUE are used for HoReCa and fashion retail deliveries and pick-ups, see section 2.4. OEMs do not yet produce large EFVs but these are currently retrofitted vehicles. In addition to the data we received from Heineken and BREYTNER in Amsterdam and Rotterdam, we included other (anonymous) cases with similar types of trips, vehicles and operations. This is mostly data of vehicles that are being procured, as there is still a limited number of large electric trucks operational that can provide representative data. The data in the presented TCO do not represent one operator and are based on at least three cases. The presented TCO comparison shows generalized cases for large vehicles (which means for example that some country specific elements are not included anymore, or company specific characteristics are left out); for prices, we use averages.

Within this category we distinguish between small rigid vehicles (12ton and 13ton vehicles) and medium rigid vehicles (18ton and 19ton vehicles). We present two different TCO comparisons for the large EFVs, i.e. a TCO comparison for 12ton/13ton trucks (i.e. small rigids) and a TCO comparison for 18ton/19ton trucks (i.e. medium rigids), although the break-down in costs is comparable for these rigids. For fuel, we use € 1.10 per litre constant for the next decade and for electricity we use 0.08 €/km[24]. The purchase price for large EFVs is much higher than the price for comparable CFVs. From the data provided by the operators we learned that insurance costs for the majority of the EFVs are higher. Insurances are a fixed percentage of the vehicle price, and as the EFV purchase price is higher, this implies the insurance costs are higher as well. The vehicle price is by far the largest cost-driver for an EFV, the required charging infrastructure and other variable costs are much lower. The maintenance costs are estimated to be lower for the EFVs than for the CFVs (as explained in 3.2). Note that the initial issues that were reported with the retrofitted vehicles (see also 3) are not explicitly taken into account here, as these costs were not specified in detail due to the fact that these were on the account of the retrofitting company and part of the service costs. However, vehicles that do not operate also lead to an increase in costs for the logistics operator. After the initial teething issues experienced during the first few months, the large EFVs were reliable and operated as expected (see also 2.4).

A vehicle depreciation time of about 5 years is not unusual in logistics; therefore we show the 5-year period TCO comparison. However, as the large EFV purchasing costs are much higher than for the comparable CFV, a longer depreciation time would be an option and therefore we also look at a 10-year life time (assuming the EFV's batteries can last that long – chapter 5 deals more specifically with the lifetime of batteries).

[24] Data on performance characteristics of the vehicles (such as the kWh/km) are provided in FREVUE Deliverable 3.1 Technical Suitability of EVs for Logistics – Report.

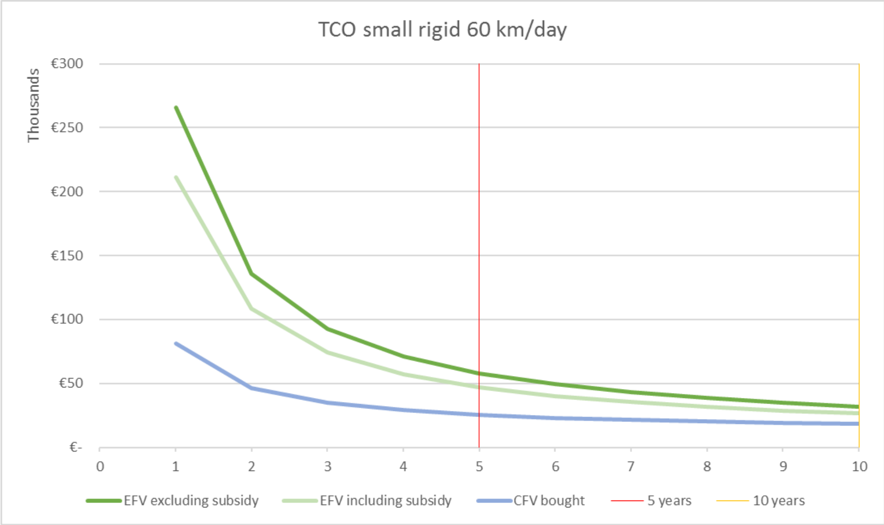

Figure 61. Development of yearly TCO per year-operated small rigid vehicle (average 60 km / day)

Figure 61 to Figure 63 show the TCO comparison for the small rigid vehicle, travelling on average 60 kilometres per day (comparable to some of the Heineken vehicles in Amsterdam). Figure 61 shows that the total cost of ownership significantly decreases per year for the electric freight vehicle in comparison to the conventional vehicle, but that there is no break-even point with the comparable CFV (not even with subsidy) within 10 years of ownership. Figure 62 shows the subdivision of cost elements in five years' time (i.e. Figure 62 shows the cross-section depicted by the red line in Figure 61 and Figure 63 the cross-section depicted by the yellow line) and Figure 63 shows the subdivision of cost elements in ten years' time.

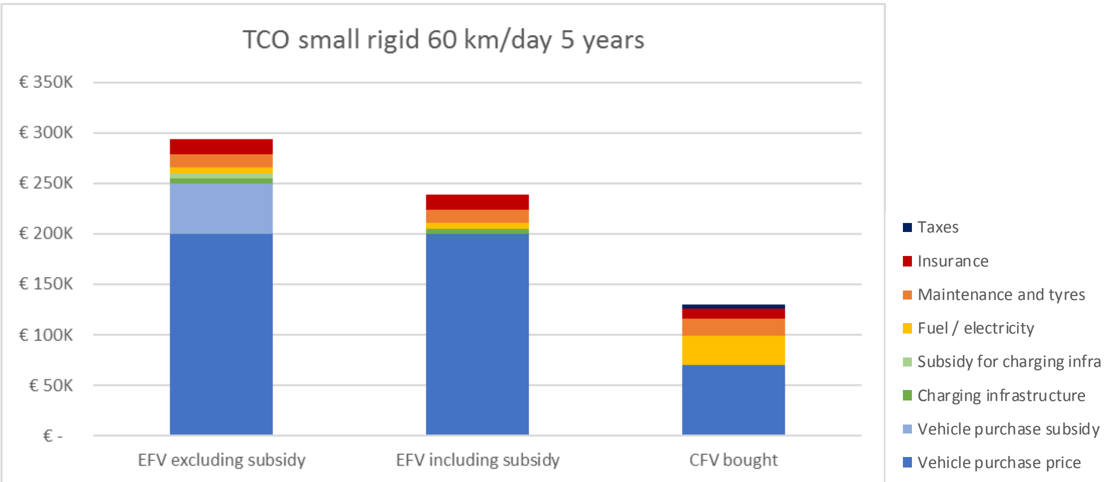

Figure 62. TCO small rigid vehicle (5-year cross-section - 60 km / day)

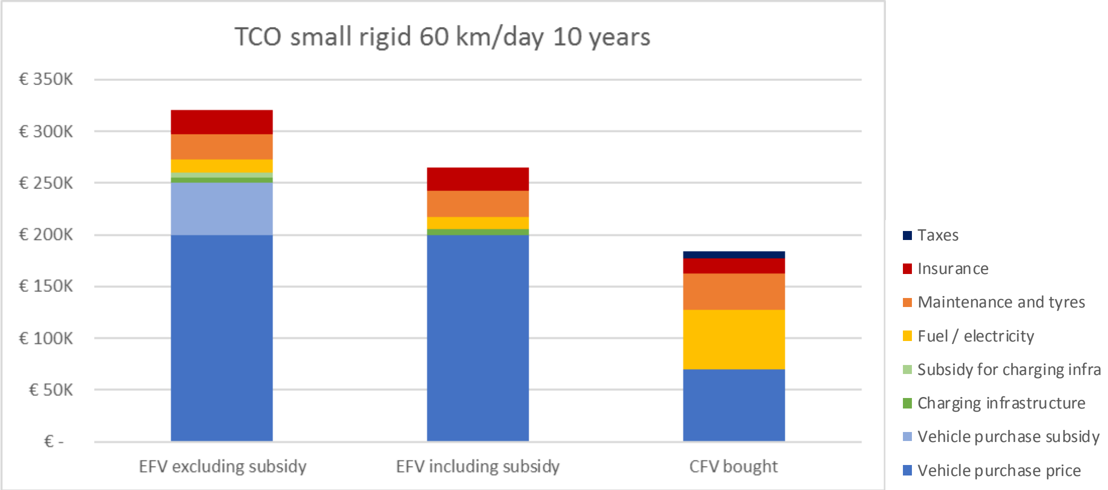

Figure 63. TCO small rigid vehicle (10-year cross-section - 60 km / day)

Figure 64 to Figure 66 are similar to Figure 61 and Figure 63 but the average distance driven is doubled (from about 60 km / day) to about 120 kilometres per day, which as a result also increases the operational cost advantages of the EFV (on electricity) in comparison to the CFV using diesel. As the operational costs for EFVs are lower than the CFVs', the TCO comparison shows that the difference is smaller between the CFV and EFV. And although fuel makes up for a large part of the total costs of owning and operating a CFV, under the presented circumstances (120 km / day) there is no positive TCO situation yet for the small rigid electric freight vehicle, not even with a FREVUE subsidy contribution.

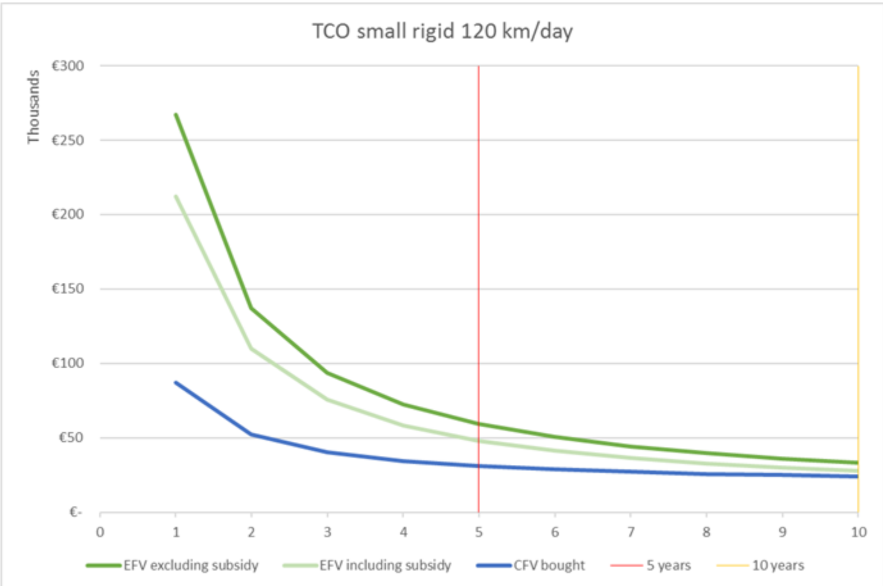

Figure 64. Development of yearly TCO per year-operated small rigid vehicle (average 120 km / day)

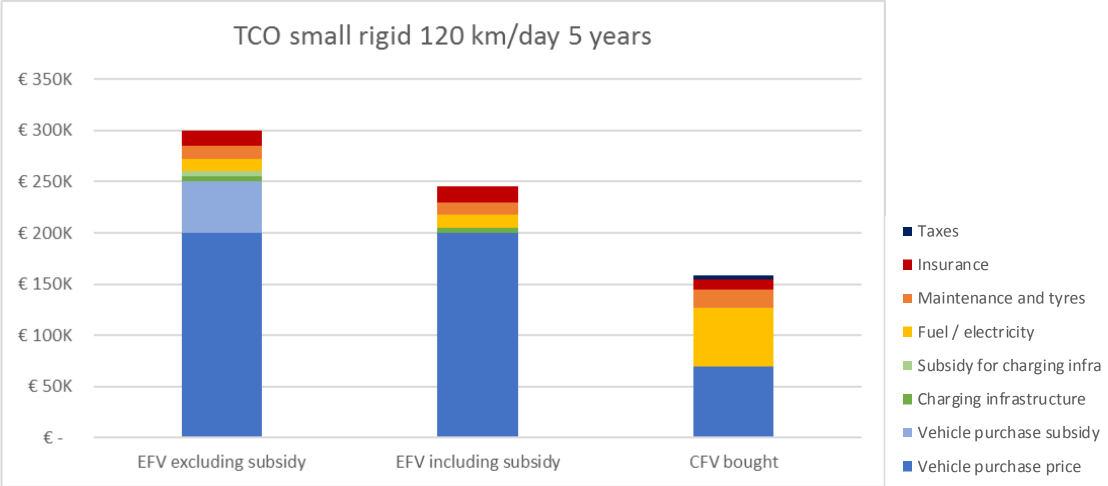

Figure 65. TCO small rigid vehicle (5-year cross-section - 120 km / day)

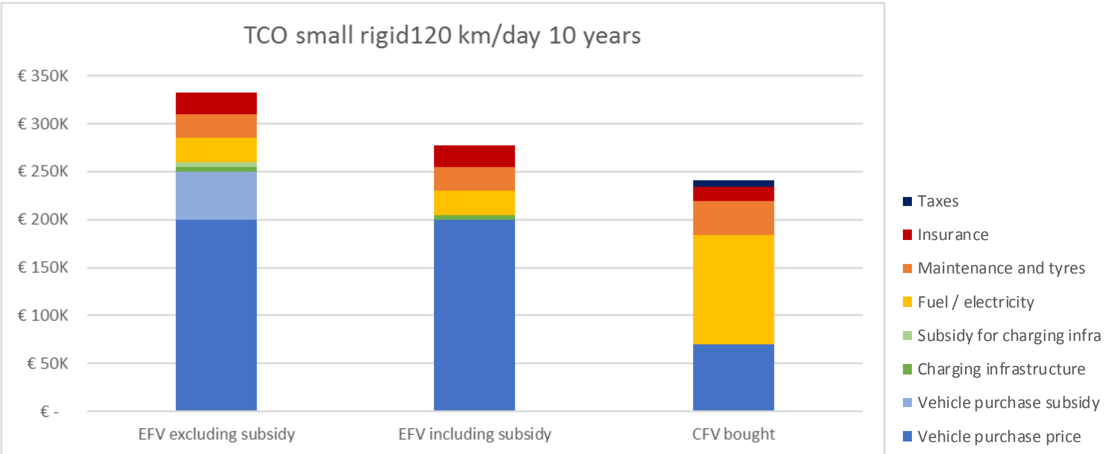

Figure 66. TCO small rigid vehicle (10-year cross-section - 120 km / day)

Several elements are not included in Figure 61 to Figure 66, which could affect the business case for an operator. We do not present potential extra cost for grid investments (but the impacts of having a large fleet can be derived from the medium vehicles, see Figure 60) nor the advantages of congestion charge exemptions for EFVs. Congestion charging, like in London, and the exemption from the charge for electric freight vehicles can clearly support the business case for an EFV. We refer to the TCO comparison for operating a medium size EFV and a medium size CFV in a congestion-charged area for the impacts of the EFVs' congestion charge exemptions (see Figure 56 and Figure 57). We do not repeat this TCO comparison for large vehicles as we did not have data of large trucks active in London's congestion charge area, and the results could be generalized to the large trucks as well.

Figure 67 and Figure 68 show the results of the TCO comparison in case a limited part of the large initial truck investments still provide value after 5 or 10 years, i.e. the residual value (estimated as explained in section 3.2). What the residual value of an EFV will be is one of the main uncertainties operators currently face. What the second-hand market will be for EFVs or for the battery in the EFV is at this moment not known and we did not learn it from the FREVUE demonstrators as all new procured vehicles are still operational.

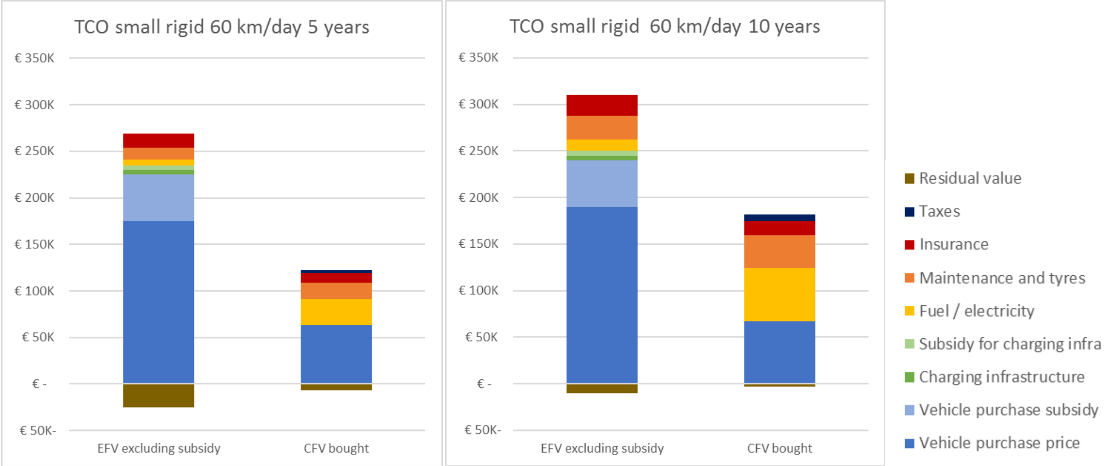

Figure 67. TCO small rigid vehicle (including estimated residual value- 60 km / day)

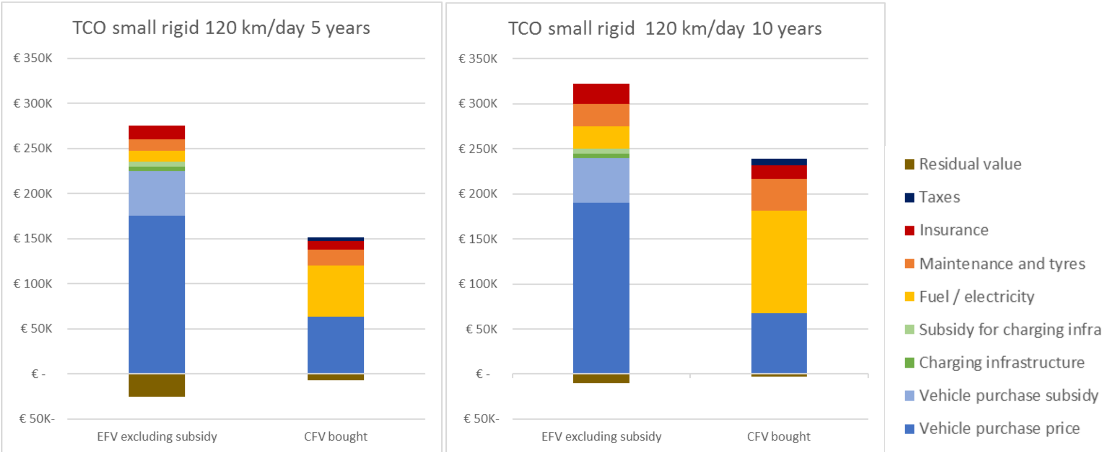

Figure 68. TCO small rigid vehicle (including estimated residual value - 120 km / day)

The difference in the TCO comparison between the EFV and CFV (both for 5 and 10 years, and 60 and 120 kilometres per day) are smaller if residual value is added. However, there is still a big gap between the TCO for an EFV and the TCO for a CFV. The high vehicle purchase price is the main factor. Obviously, this high purchase price is partly due to the fact that a new CFV truck is retrofitted into an EFV. As a result, one has to pay for the original CFV including the diesel engine. The diesel engine on its own is often sold for a low price (as there is no good market for it) and an electric drive line as well as a large battery pack have to be added to the vehicle. The gap in the TCO comparison between the large truck (i.e. the small rigid) CFV and the EFV is big, also when compared to the comparison for small vehicles and medium sized vehicles.

The second class in the large EFV category is the medium rigid, which includes 18 and 19 tonne trucks, such as the BREYTNER truck used in Rotterdam or the Heineken truck in Rotterdam. The TCO comparisons for the medium rigids are comparable to the small rigids' TCO comparisons, although the gap between the CFV and the EFV is even slightly larger due to the higher EFV purchase price.

Figure 69 to Figure 71 show the TCO comparison for the medium rigids (in case 60 kilometres per day are travelled for a depreciation time of 5 and 10 years, comparable to the Heineken truck in Rotterdam). Figure 69 shows that the total cost of ownership significantly decreases per year for the electric freight vehicle in comparison to the conventional, however that a break-even point (even with subsidy) cannot be reached within 10 years (assuming that the battery lasts a decade). Figure 70 shows the subdivision of cost elements in five years' time and Figure 71 for 10 years.

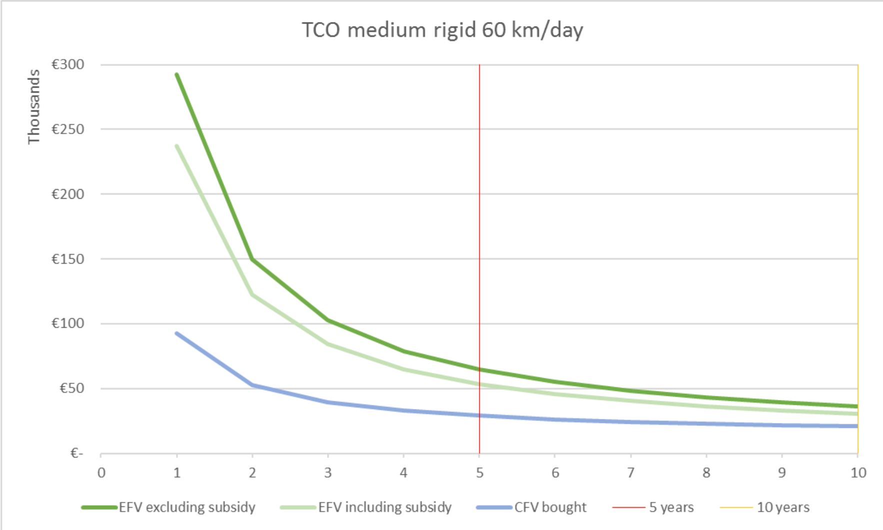

Figure 69. Development of yearly TCO per year-operated medium rigid vehicle (average 60 km / day)

For the situation in which the electric medium rigid drives only an average of 60 kilometres per day, and as a result cannot really take advantage of the lower operating costs for an EFV, the total cost of ownership for a CFV for 10 years is even lower than the purchase price of the EFV (even with subsidy), so without any other costs for operating.

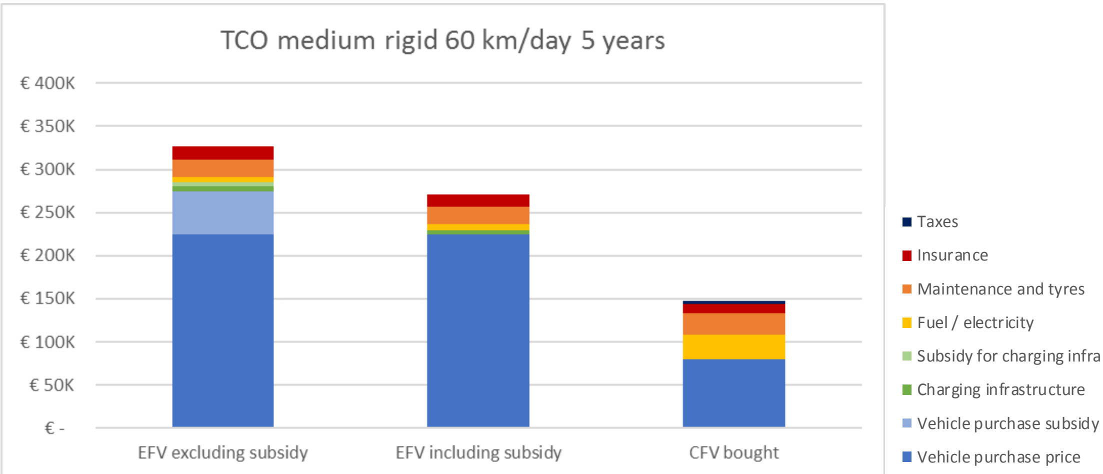

Figure 70. TCO medium rigid vehicle (5-year cross-section - 60 km / day)

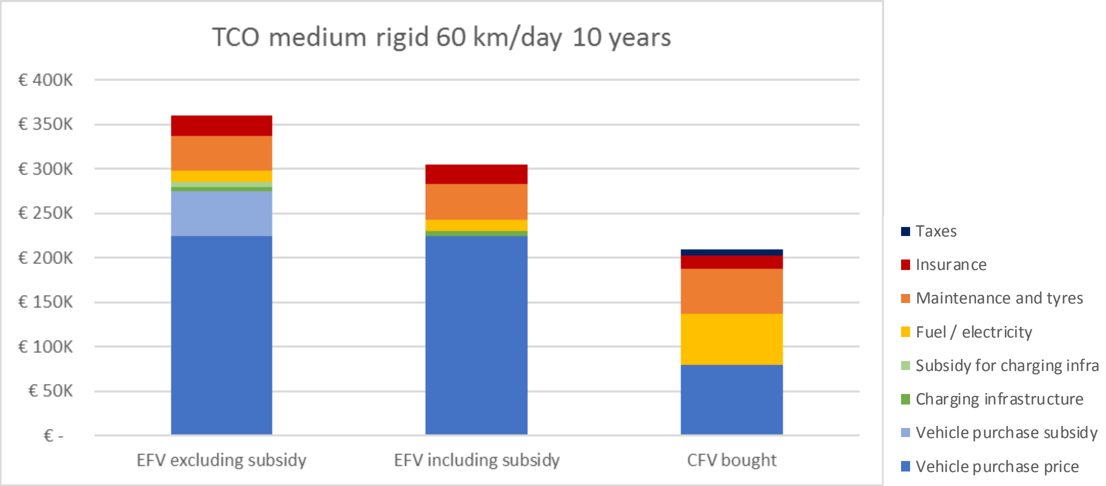

Figure 71. TCO medium rigid vehicle (10-year cross-section - 60 km / day)

BREYTNER shows in Rotterdam that the medium rigid can make more kilometres per day, which positively influences the business case (i.e. the gap between the TCO for CFV and EFV). Notice that the battery pack allows for traveling a longer distance per day with the EFV. This large battery pack is also one of the main cost components in the high EFV purchase price, and therefore it makes sense to look at the case in which the battery pack is used to a larger extend (see for more information on differences in battery packs the analysis in chapter 5). Therefore, Figure 72 shows the TCO development for medium rigids in case 120 kilometres are driven per day. Figure 73 shows the TCO development for medium rigids in case these vehicles travel even 180 kilometres per day. Note that 180 kilometres per day is close to the maximum range of the vehicles, but has been proven feasible (see demonstration by BREYTNER, in section 2.44).

Figure 72 shows that for a ten year period the TCO for a medium rigid EFV is still higher (even with subsidy) than for a CFV, and under the assumption that the battery does not have to be replaced during these 10 years. Figure 73 finally shows that the gap in the TCO comparison becomes smaller between a CFV and EFV (in 10 years, no battery replacement and 180 kilometres per day). In case a medium rigid can be used 180 kilometres per day, the operational advantages, i.e. the EFV has a cost advantage per kilometre compared to the CFV, almost balance the high initial purchase price for the electric medium rigid. In case of a subsidy comparable to the FREVUE contribution, the medium rigid breaks even with the CFV just before 10 years if travelling 180 kilometres per day. So, at the time of writing, for the electric medium rigid a logistics operator could find a relatively cost-neutral business case, if the logistics operator can use the medium rigid for 180 kilometres per day, the battery lasts 10 years and an initial purchase subsidy is available. However, Figure 69, Figure 72 and Figure 73 show that it is not easy to find a favourable TCO for the medium rigid EFV in comparison to the CFV (next to the presented barriers in section 3).

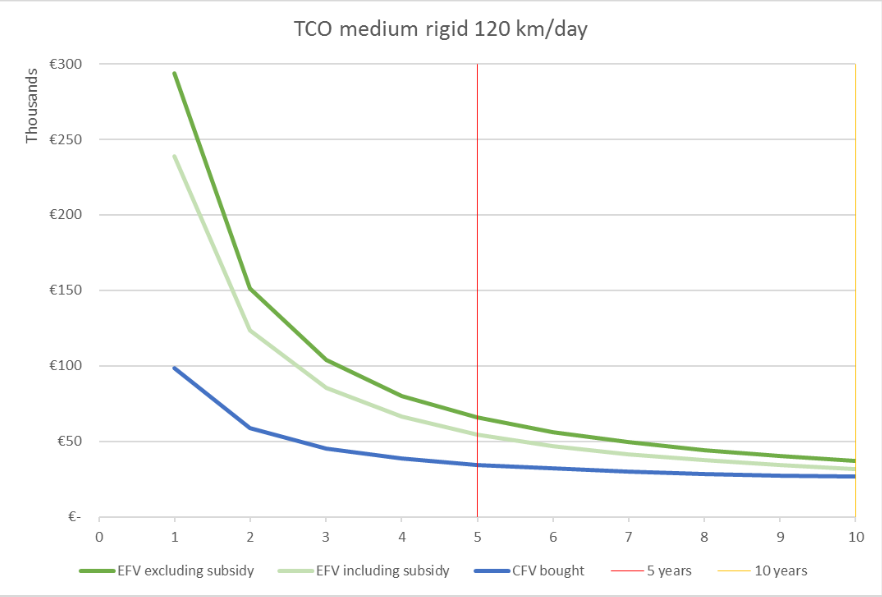

Figure 72. Development of yearly TCO per year-operated medium rigid vehicle (average 120 km / day)

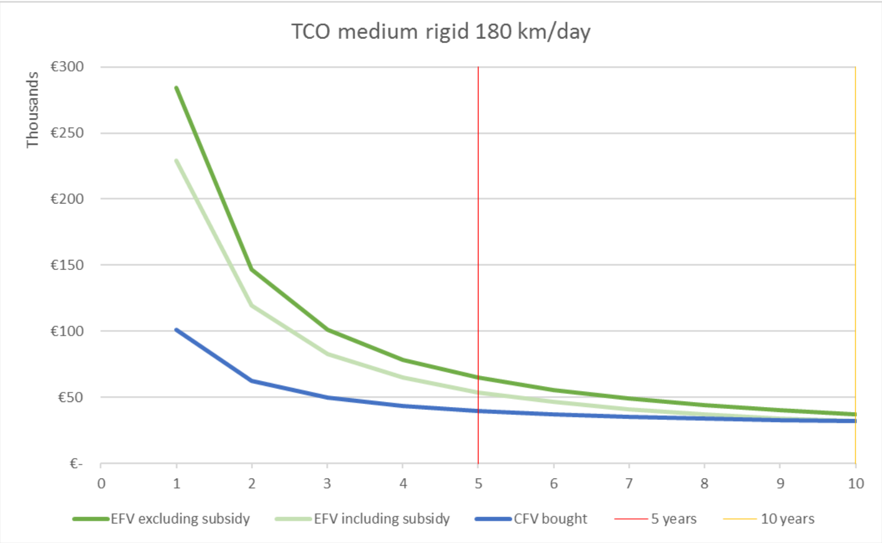

Figure 73. Development of yearly TCO per year-operated medium rigid vehicle (average 180 km / day)

Finally, Figure 74 to Figure 76 show cost break-downs for the TCO development. Figure 74 shows the TCO comparison for a medium rigid driving 120 kilometre per day after 5 years, and Figure 75 after 10 years.

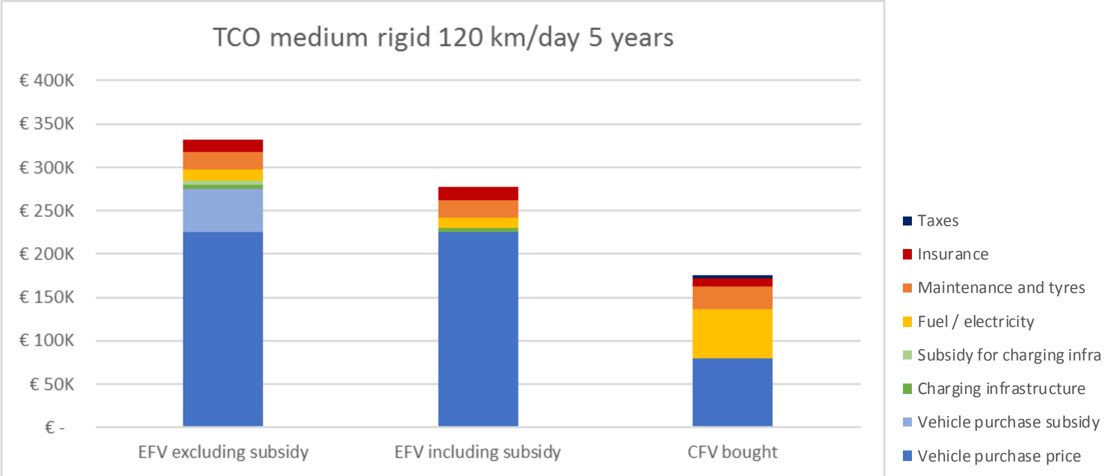

Figure 74. TCO medium rigid vehicle (5-year cross-section - 120 km / day)

Figure 75 shows that the EFV has an advantage in operating costs (fuel vs. electricity), but that the vehicle purchase price is still too high for a favourable TCO comparison. In case the EFV travels 180 kilometres per day, this advantage increases. In the operations, see also chapter 2, we looked at the effects of supporting policies for EFVs. Although we learned from operators that policy exemptions were appreciated, we were not able to find the effects on operational performance based on the trip data as exact comparisons between CFV and EFV trips were not possible due to changing circumstances in e.g. number of drops and pick-ups in time (in Amsterdam, see for more information FREVUE, 2016b).

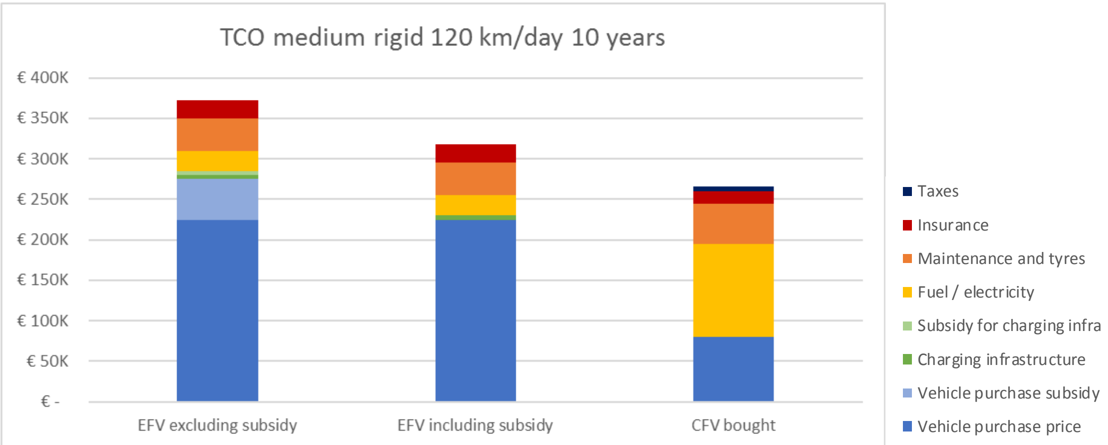

Figure 75. TCO medium rigid vehicle (10-year cross-section - 120 km / day)

Finally, Figure 76 provides the cost break down for the medium rigid (120 kilometre per day, 5 and 10 years) in case we assume a residual value (for the truck and the battery). Though this decreases the TCO gap, there is no break-even point within 10 years even with residual value. Impacts of congestion charge exemptions and extra grid investment are not specified for the medium rigid but could be derived from the results presented in section 3.32.

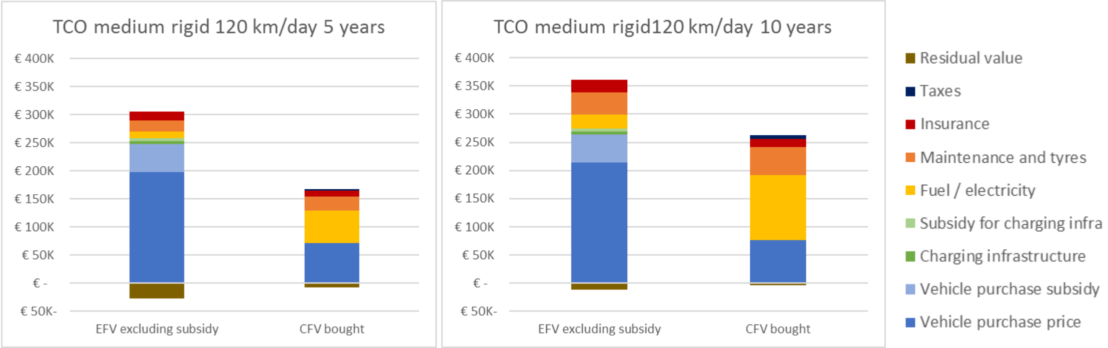

Figure 76. TCO medium rigid vehicle (including estimated residual value - 120 km / day)

To conclude we can say that for the large electric freight vehicles (both for the small and medium rigids) the TCO is currently worse than for a comparable CFV. The current generation of EFVs are tested and demonstrated in daily city logistics operations, but not yet long enough to say more about the actual residual value at the end of life, or the actual deterioration (or not) of the batteries. As long as battery lifetimes cannot be guaranteed, in most procurement decisions (i.e. TCO calculations by operators) the operator calculates with a smaller depreciation period than the 10 years we used in this TCO comparison. Using the (almost) maximum range allowed by the battery provides the maximum in operational cost-advantages, and as a result positively contributes in closing (or at least narrowing) the gap between the CFV's TCO and the EFV's TCO. In other words, the TCO calculations show that increasing the number of kilometres driven does have a positive impact on the EFV's TCO. In the end, the TCO depends – next to the number of kilometres – on the cost advantages due to lower costs for operating per kilometre with an electric vehicle than with a conventional vehicle. These cost advantages come from lower costs per kilometre (diesel versus electricity) and lower maintenance costs. For the electricity versus fuel costs we did not make a future price projection in this analysis, but used current data from the operators. See Chapter 5 for a more elaborate analysis on electricity and fuel price projections, and how this influences the TCO. For maintenance, we assumed the costs are lower due to a limited number of moving parts in the EV-driveline; however, we do not have data supporting that nor the opposite:

- the vehicles' lifetime in the project is too short;
- the reported EFV issues (initial communication issues with CAN bus and drive line) have to do with fact that the EFV is not an OEM product (in comparison to an CFV), but retrofitted;
- most operators have a contract for maintenance which is either part of the producer's warranty or a fixed costs maintenance agreement, which means that no specific data on maintenance issues is collected.

Similarly, we do not have supporting data on battery deterioration or the lack thereof that show that it is (im)possible to make use of the EFV during a long (i.e. 10-year) period with almost a maximum number of kilometres (i.e. 180 kilometres, close to the vehicle's range) allowed by the battery.

3.4 Conclusions: TCO comparison and changes in value network

Operators who decide to procure an EFV or more EFVs face challenges as the value network analysis shows that new knowledge and relations need to be established. In other words, for a logistics operator – at this moment – to switch from the existing diesel-powered vehicles towards electric vehicles, requires more than just buying another vehicle. It requires new relationships, time investments and unknown risks in areas that normally only ask for a limited effort from the operator, which can be (and indeed turned out to be) a barrier for operators in moving from CFVs to EFVs. Therefore, the development of OEMs starting to produce these vehicles will be removing one barrier in the transition from CFV-dominated city logistics to EFV- dominated city logistics, as the operator can then use the regular maintenance network and buy the vehicles from known suppliers.

In addition to these many unknowns and new areas, the total cost of ownership is an important decision criterion for logistics operators in the EFV purchasing decision. The TCO differs per vehicle type and usage. The TCO also depends on many other elements, that can be country or even company specific. The results presented in this chapter are generalized based on the inputs and experiences from the FREVUE demonstrators (completed with some anonymous cases to guarantee that the presented results cannot be traced back to a single FREVUE demonstrator).

For small electric freight vehicles, lighter than 3.5 tonnes, the TCO can be favourable for an EFV within about five years, where the vehicle drives 60 kilometres a day. The more kilometres the vehicle can be used and the longer the time it can be used, the larger the TCO advantage becomes for a small EFV. Obviously, the size of the vehicle does not allow for transporting high volumes, and the limited range can also be challenging from a logistics operator's planning perspective. But if this is not a barrier, a favourable TCO for EFVs is feasible, even without subsidy, in about five years, depending on country specific elements like taxes and tax advantages for EFVs and the compared CFV (leased or bought).

For a medium sized electric freight vehicle, weighing between 3.5 and 7.5 tonnes, the TCO comparison shows that under specific circumstances a positive business case for using an EFV is challenging, but possible. The more kilometres an EFV is deployed, the more favourable the comparison is, as kilometre costs are lower for an EFV (lower costs for electricity instead of fuel, and lower maintenance costs). Special circumstances, like the exemption for paying the congestion charge for EFVs, have a very positive effect on the business case for the EFV (this also applies to small and large EFVs, but it is only shown here for the medium size vehicles). Next, many uncertainties still exist around the residual value. The current generation of EFVs are tested and demonstrated in daily city logistics operations, but not yet long enough to say more about the actual residual value at the end of life, or the actual deterioration (or not) of the batteries. As long as battery lifetimes cannot be guaranteed, in most procurement decisions (i.e. TCO calculations by operators) the operator calculates with a smaller depreciation period than the 10 years we used in this TCO comparison.

For the large EFVs, divided in small rigids and medium rigids in the TCO comparison, the TCO of a CFV remains lower than that of an EFV. The purchase price for the individually retrofitted large electric freight vehicle is currently so much higher than for the OEMs' conventional truck, that advantages due to lower operational costs (from lower costs per kilometre (diesel versus electricity) and lower maintenance costs), do not result in a positive business case for the large EFV. Even a depreciation time of ten years, and a (purchase) subsidy do not currently allow for a cost-neutral business case for a logistics operator.

However, note that driving the maximum number of kilometres the battery allows for together with a purchase subsidy can almost result in a cost-neutral business case.

4. Implementing EFVs: requirements of logistics concepts

4.1 Introduction

Where chapter 2 focused on the actual FREVUE demonstrations and the way the demonstrating partners changed their operations in order to do parts of their city logistics operations with electric freight vehicles and chapter 3 examined the changes the operator faced in its network as well as in the costs, this chapter looks at the logistics concept on a higher level. This chapter evaluates the required changes in the operator's logistics concept, which is more than replacing one conventional vehicle with an electric freight vehicle (or replacing a few), to make electric powered city logistics feasible on a larger scale. In this chapter, we look at the lessons from cases where not only CFVs are replaced by EFVs, but also the logistics concept had to be reorganized either to accommodate the EFV characteristics or to develop a feasible business case.

We discuss in the following chapter (FREVUE) examples and lessons where the question was 'how can we (re)organize logistics in such a way that electric vehicles can be used in the last mile'. In answering this question, decoupling the urban freight transport from the transport to (and from) the city is a key point. Notice that in city logistics literature this is a topic addressed many times, apart from enabling electric freight vehicles (see for more information on business models for urban consolidations centres for example STRAIGHSTOL 2014ab). This deliverable does not aim at contributing to that discussion, as we look at (small scale) decoupling points that specifically make it possible to do last mile deliveries by electric freight vehicles, rather than at UCCs (urban consolidation centres) bundling shipments from different shippers at the city border (although the one does not exclude the other).

4.2 Current demonstrations: replacing ICEs with EFVs

Currently the demonstration projects where EFVs are used in city logistics operations often 1) either replace an ICE vehicle's roundtrip that in the existing situation already fits the technical characteristics of an EFV (e.g. limited length of roundtrip, many stops) – see for example UPS, TNT in Amsterdam and Rotterdam, CTT and Heineken in FREVUE, or 2) get an EFV as an additional vehicle to get experience with this type of technology (see for example Madrid's TNT and SEUR). As a result, these demonstrations show – as we also presented in chapter 2 – that indeed EFVs can be deployed in daily city logistics operations.

Although these approached are perfectly reasonable to learn and get experience with a new technology, it does limit the potential amount of EFVs that can be used in city logistics and some issues on scaling are not touched on. Besides, it also – in the longer run – even limits the business case of the EFVs in city logistics. In the case an operator decides based on the current fleet and existing roundtrips what can be replaced, there is no consideration on how the logistics system can be adapted to better fit EFVs and corresponding characteristics. If these considerations are not made, the potential for EFVs is limited to those trips that can be directly replaced. For a larger transition, apart from what is available from the OEMs and the TCO as discussed in chapter 3, towards achieving essentially CO_2 free city logistics in major urban centres by 2030 (EC, 2011), only replacing the roundtrips that match EFC characteristics won't be sufficient. On the other hand, by only replacing CFVs by EFVs, chapter 3 showed that a business case for the operator is also challenging. The problem here is that the costs per kilometre are lower for an EFV, but that due to looking at the relatively small roundtrips the EFVs won't make many kilometres.

4.3 Adapt logistics system to EFVs

The existing logistics systems evolved based on (among other things) the characteristics of the diesel vehicles. As electric freight vehicles are different from CFVs, rethinking the existing systems based on the characteristics of EFVs could enable new logistics concepts that better fit the EFV's characteristics. Obviously, reconsidering the way city logistics operations are organized is even more challenging then replacing vehicles (and chapter 3 discussed already the challenges and barriers operators face when replacing CFVs with EFVs). Therefore, it is good to keep in mind that actually reorganizing the existing logistics concept will make the transition for an operator even more difficult. However, FREVUE demonstrated some directions that show:

- Rethinking the logistics operations with electric freight vehicle characteristics in mind can contribute to a feasible business case (or a prospect to a feasible business case) that was not feasible by replacing CFVs with EFVs, and
- The rethinking of the logistics concept can be stimulated by other actors than the (existing) logistics operator, for example a new start-up transport company or the actor commissioning city logistics operators.

In this chapter we shortly discuss these alternative models that (could) enable electric freight vehicles in city logistics operations on a larger scale, also where it is not (only) a replacement of a diesel-powered vehicle with an electric freight vehicle[25]. We especially focus on how these models might convince others to rethink the current way logistics is organised. For more information on other logistics models implemented in FREVUE we refer to FREVUE (2016c). In this chapter we discuss alternative models that could enable electric freight vehicles. As a consequence some of the logistics models (see FREVUE 2016c) are not discussed, as in these models mainly CFVs were replaced by EFVs, and the logistics concept was not changed considerable or not at all (this means the London and Milan cases are not discussed here, for more information we refer to FREVUE 2016c and ARUP, 2014 and 2017).

4.31 An example of rethinking existing logistics organization: Transmission in Amsterdam

One case of an operator adapting its logistics concept in order to allow electric freight vehicles to perform its city logistics operations in Amsterdam was already discussed in FREVUE (2015b), i.e. Transmission using its Cargohoppers from a transhipment point in the outskirts of Amsterdam. In this case the transport company Transmission was not able to operate its electric freight vehicles (i.e. the self-designed Cargohopper 2) if it replaced its conventional trucks and vans that made the operations in Amsterdam from their depot in Almere. Travelling the distance, via the highway, between Almere and Amsterdam (and back) would take too much of the battery, so that it could not do the deliveries and pick-ups

[25] Note: there is nothing wrong with replacing CFVs with EFVs; however, due to the limited range of EFVs some vehicles cannot be simply replaced. Next to looking at technical solutions, such expecting improved batteries (more capacity), or a network of fast chargers to charge during the trips, some issues could also be solved by rearranging the exiting logistics concept so that it enables the use of EFVs. This rearrangement is the focus of this chapter.

in Amsterdam. So replacing the CFVs by EFVs was not an option, and therefore Transmission rethought its logistics and came up with a system that did fit the EFVs and enabled a feasible business case.

In this chapter we do not discuss this case in detail (for more information please read FREVUE 2015b, Quak et al. 2016) but we shortly explain it as an example of what we mean with reorganizing / rethinking the logistics concept from the characteristics of how it would enable the use of EFVs in city logistics. So the starting point here of Transmission was how they could operator their EFVs in Amsterdam. In order to do so, they needed a location close to the city centre of Amsterdam, as this is the geographical area where the vehicles operate, from where the EFVs start and where the EFVs return to and where they can be parked and charged overnight. The search for such a location took long (as most available locations were not suitable and couldn't be too expensive as this would jeopardize the business case). Transmission also needed to reorganise its goods flows – where in the old situation separate CFVs would deliver parcels (vans) and pallets (trucks), these flows were combined in the EFVs to increase the drop density. Between Almere and Amsterdam a larger tractor trailer replaced several vans and rigid trucks, which also contributed to a concept that enabled a (more or less) comparable business case for Transmission.

The case of Transmission shows that if the point of departure would have been to examine where EFVs could replace CFVs, Transmission would have ended up not using EFVs in Amsterdam city centre. However, by starting from another point, i.e. the question 'how can we find a feasible way to do our city logistics operations in Amsterdam with electric vehicles' Transmission ended up rethinking their logistics concept to make deliveries and pick-ups in Amsterdam. The fact that Transmission operated with EFVs in Amsterdam did not directly result in new clients, but over time some advantages for zero-emission deliveries (via public procurement) enabled Transmission to offer new (zero-emission) transport services and win some specific tenders for transport in Amsterdam's city centre.

4.32 Binnenstadservice in Rotterdam

One way to reorganize logistics is by making use of an urban consolidation centre. Binnenstadservice (BSS) Rotterdam is the local franchise urban consolidation centre in Rotterdam. The concept of BSS evolved over time; it started in the Dutch city of Nijmegen (see also Van Rooijen and Quak, 2010) and from there it started operating in several Dutch cities. The business model first focused on a small fee from local receivers who then change their address to that of BSS, which receive, bundle and deliver goods to the receivers at an agreed time. Later it continued to also attract national shippers as clients that ask their customers to use a BSS if there is a location in a city. So far for the customer side of BSS's model. From the cost-side: the national organization tried to find local franchisers that can combine BSS activities with other activities, so that is can be at low costs (as the franchiser already owns a depot and runs vehicles in the city).

The entrepreneur of BSS Rotterdam also runs another courier services (with, in addition to diesel vehicles, an electric vehicle and bikes) from its depot, i.e. Roadrunner couriers. The combination of low costs for BSS Rotterdam due to using an existing depot – that is financed by operations of another courier service – and a national branding, enables this foundation (i.e. BSS) to run a UCC although the amount of volume is limited, as are the supporting policy measures. (Notice that Rotterdam is a very good accessible city, also for large trucks). BSS Rotterdam noticed that due to the ban of trucks at one of Rotterdam's central roads (i.e.

‘s-Gravendijkwal), with the exemption of electric freight vehicles, some transport companies started to make use of BSS’s services. This concerns especially transport companies that have to use the ‘s-Gravendijkwal for a single drop. However, the amount of volume to be transport that BSS Rotterdam attracts is too small to run an UCC by itself.

In conclusion, the BSS Rotterdam UCC enables electric last mile deliveries in Rotterdam, but only a limited amount of companies make specific use of the BSS’s services. For electric deliveries the city’s ban of diesel trucks on the ‘s-Gravendijkwal enabled some extra deliveries, but it is still a very small amount and by far not enough to run an UCC. This solution provides a way to decouple transport to and from the city from city logistics, but at the moment only a few companies make use of it (mainly due to the truck ban on one of the main roads). This case shows a feasible business model (for the UCC), but it also shows that it attracts a very limited amount of customers who do want to use an UCC for decoupling and zero-emission last mile deliveries (and only for the area where trucks are banned and electric trucks have an exemption).

The BSS Rotterdam model, as also demonstrated in FREVUE, enables electric last mile deliveries (and first mile pick-ups) in Rotterdam. However, it does hardly convince others to rethink the current way logistics is organised at this moment. The service is running without subsidy, as it benefits from the usage of an existing courier depot. Another insight is also making use of an UCC can be an option for other transporters to make zero emission deliveries or pick-ups for an area with strict access regulations (and where it is not feasible to procure an electric vehicle for that limited part of the operations).

4.33 Decoupling swap bodies

BREYTNER asked itself the question with which we started this chapter ‘how can we (re)organize logistics in such a way that electric vehicles can be used in the last mile’ and in such a way that it is possible to construct a (profitable) zero emission transport company with it. BREYTNER examined current logistics operations (in the Netherlands) and in Rotterdam in particular. BREYTNER realized that smooth decoupling with minimum handling (and therefore also minimum costs) would be necessary to convince shippers or transport companies to use BREYTNER’s zero emission transport services for the last mile, and to offer a feasible zero emission last mile service. BREYTNER currently offers two separate clients different services, where they use detachable swap bodies as an easy way to decouple between diesel trucks for the transport to and from the city and a battery electric vehicle for the transport into the city (see Figure 77).

The detachable swap body makes decoupling easy, but still more is needed to be able to make a serious offer to convince clients to do (parts of) their logistics differently. At this moment – but BREYTNER is negotiating with potential new clients – this start-up company does fashion retail distribution for large retail chain’s fashion stores in the Rotterdam-region and furniture home deliveries in the Rotterdam region. BREYTNER first examined all transport in the region of Rotterdam using detachable swap bodies, to make a potential transition for their future clients as easy as possible. This obviously limited the amount of potential clients. BREYTNER developed several business cases, of which at this moment two are actually put in daily city logistics practice:

- Fashion retail distribution: early in the morning (before 6:00 a.m.) a conventional truck (combination) brings two swap bodies to the south hub and another combination truck two swap bodies to the north hub[26] in Rotterdam. Around 7:00 a.m. BREYTNER's EFV picks up a swap body from the south hub and leaves it at a large fashion store during the day. Then it gets the second swap body from the south hub and leaves it another large fashion store in the city centre during the day. The EV continues to the north hub and makes a round trip passing three fashion stores. Around 11:30 the driver is back at the north hub to swap the bodies and makes another roundtrip passing three other fashion stores. In the afternoon the EV picks up the two swap bodies in the city centre one by one and brings them back to the south hub. Between 4:00 p.m. and 5:00 p.m. the fashion route is finished.

- Home delivery of furniture: another business case BREYTNER developed is furniture deliveries to private homes; the main cost advantage – next to reduction in emissions, which is an important factor for this client – is that the decoupling of the first mile and last mile makes it possible to put the second man that is necessary for these trips (to carry heavy furniture into the homes) in the truck for the last mile only. The first mile a conventional truck again delivers the swap body / swap bodies (from about 60 km away from Rotterdam) to the BREYTNER hub. There an EFV (see right image in Figure 77) takes the swap body and the second man comes in the truck at the hub (instead of from the origin). Overall this saves two times the costs for the second man (trip to and from Rotterdam), as well as it enables a trip to and from Rotterdam outside peak hours (and reduces therefore driving time as congestion is lower).

Figure 77. BREYTNER's e-trucks (fashion and furniture)

BREYTNER uses the fact that they only operate electric freight vehicles as an extra argument to sell their service to operators and shippers. However, BREYTNER also emphasises to their (potential) customers that it is hard to get a feasible business case by just replacing a conventional vehicle by an electric vehicle, since vehicle and battery costs are very high for EFVs (see also TCO in chapter 3). So it is important to change the logistic concept (and BREYTNER supports shippers in this change), examples:

- Use swap bodies for goods that should be handled as little as possible (e.g. hanging transport: (un)loading takes a lot of time. The fashion retailer already used swap bodies, so you can leave the goods in the container and this concept requires minimum change from the client).

[26] A hub in this case is a location where the truck can off load full swap bodies and pick-up empty ones. The local authorities assisted BREYTNER in their search for suitable hub locations.

- Extra staff (for furniture deliveries / two men distribution) can be used only where deliveries are made. An assistant for heavy goods deliveries joins inside the city to help unloading, so no costs for the second man while driving from and to the city.
- Road train (combination trucks) to the city and split to different electric trucks within the city.
- Drive with conventional vehicles to the city outside rush hours (if it is at least a one hour drive) and use swap bodies to change to EFVs.
- Use the EFV for a long time with as many stops per day as possible (like the fashion retail chain, the EFV is running for about 11 hours per day); as an operator makes money by transport services (and not by being parked).

It takes serious effort to convince potential customers of a new logistic concept. This is not 'just' a cost-decision, as also the customer faces new uncertainties, e.g. a new company, new technology, a different logistics concept that is limited to a certain geographical area. In other words, the easiest solution is keeping everything as it is (see similarities for the transition that was discussed in chapter 3, Figure 41 and Figure 42).

In this way BREYTNER answers the question 'how can we (re)organize logistics in such a way that electric vehicles can be used in the last mile' and in such a way that it is possible to construct a (profitable) zero emission transport company with it. This is not easy, but BREYTNER provides a way to do it for (some) shippers.

4.34 Set up of a cross dock centre in Madrid

A different approach was taken in the Madrid demonstration where the local authorities developed and provided a cross dock location where goods can be transferred from conventional vehicles to electric vehicles. In this way the Madrid authorities facilitated electric last mile deliveries.

The City of Madrid provides the previously unused Legazpi market (but specially reconditioned for being a cross dock centre) to FREVUE participating operators free of charge, including running costs such as electricity (for lighting but not for charging). The financial contribution of participants is limited to cleaning costs (co-shared by the users) as well as other maintenance costs and the costs for charging their own vehicles. This cross dock facility enables the carriers to operate in Madrid with EFVs, even if their own facilities are not located close enough to Madrid centre, or if their own facilities do not have charging infrastructure in place. Note that for other cases finding a location to charge EFVs, transfer goods from CFV to EFV, was one a serious issue (see for example Transmission and BREYTNER) for two reasons: i) extra costs for a facility negatively influence the already difficult business case (especially considering that the facilities are used only a limited time per day) and ii) suitable locations are not easy to find. Besides, chapter 3 showed that for an operator investing in charging infrastructure negatively influences the business case for an EFV.

From these facilities, TNT and Leche Pascual made their EFV last mile operations in FREVUE (see also chapter 2). By providing such a low cost cross-dock facility (at least low costs for the operators, for the local authorities this facility is quite expensive – without the prospect to earn back the investments with renting it to logistics operators)[27], the Madrid authorities removed one barrier for operators in answering the question ‘how can we (re)organize logistics in such a way that electric vehicles can be used in the last mile’. However, the operators still have to reorganise the operations. The facilitated Legazpi cross-dock location did not attract other operators to make EFV operations in central Madrid. The main lesson is that municipally owned facilities potentially are able to host this type of cross dock facility (i.e. micro hubs); but that removing a barrier does not mean that the operators start operating EFVs by themselves and that it can be a costly way for local authorities. Another way can be (as long as it concerns small scale operations of one or a few operators) is for local authorities to look together with these interested operators for suitable locations for micro hubs (like what happened in Amsterdam – Transmission and Rotterdam – BREYTNER), as this can be a lower-cost strategy for local authorities at this moment than the full reconditioning of an old market place like was done in Madrid.

4.35 Consolidation in Stockholm

In Stockholm, additional to the planned construction consolidation centre, the local authorities also developed a demonstration where an urban consolidation centre enables electric freight vehicles doing operations that were carried out by CFVs before.

First, we shortly discuss the CCC, and in particular the way the business model was set up for this consolidation centre. (Note that the fact that a CCC is very close to the construction side, the potential for EFV deliveries making the last mile does fit the EFV’s range characteristics, but that the gains are limited due to the very short trips and the fact that the heavy goods and materials cannot be transported with EFVs (yet)). However, what the CCC shows is that the City of Stockholm can use the fact that it is actually the developer of the region, to require companies that do want to develop, construct or work in this area to comply with the constraints of using the CCC. In this way, it is unlike many of the UCCs (see for example Allen et al., 2012) that have issues in developing a business case, as there is no real value proposition for operators, shippers and receivers (see also STRAIGHSTOL, 2014ab). Due to attracting limited volume to transport, these UCCs are often not able to have enough scale to be actually cheaper in doing last mile deliveries in comparison to the regular operators.

The Construction Consolidation Centre provides services for the Stockholm Royal Seaport development and has been in operation since May 2013. The construction site is a fenced area and parking at the construction site is not allowed – only loading and unloading. The CCC is located in the vicinity of the development area. The CCC system has been much debated and was not appreciated in the beginning. However now, through a combination of education and enforcement, it has been accepted and even to some extent appreciated as the working environment is much improved. The city of Stockholm owns the CCC, an operator (i.e. Wiklunds Akeri) runs the operations. The operator won the tender to operate the CCC. Since the city owns the land on which constriction takes place, they could enforce the use of the CCC in the building regulations (the city is also an developer itself, and from that role it can also require the use of the CCC of builders). “All vehicles with less than 5

[27] At least, the current model provided more or less free usage of the cross dock facilities for FREVUE participants, so the local authorities do not develop a business model for this facility (from which investment costs can be recovered; the fact that the facility will be upgraded to other purposes that can bring money to the city only shows that).

euro cargo units that deliver to the building sites are forced to unload at the CCC. Fully loaded vehicles or deliveries over 5 euro cargo units may deliver straight to the building sites. The CCC also offers possibilities for indoor and outdoor storage and the first 14 days this storage is free." The costs related to using the CCC are a fixed fee (related to the m^2) for traffic, waste and storing. Next, a fee has to be paid for entering the area. The volume that is delivered via the CCC depends (among other things) on the different phases during the construction.

This CCC model was used as an example to develop an UCC in Stockholm to answer the question 'how can the local authorities facilitate or enable the (re)organizing of logistics in such a way that electric vehicles can be used in the last mile and private sector companies can develop a feasible business case[28].

In addition, the City of Stockholm started developing an UCC; the model was not easy to copy, as the city does not have a similar developing role as with the CCC. The City of Stockholm is currently trying to identify how to consolidate goods deliveries to public sector organisations within the city, such as offices, schools and care homes. These goods should be delivered together from one or a few locations outside the city centre and they should be delivered by clean vehicles.

Another flow that the city can influence is waste collection and this flow of goods is now part of the volume that is collected with an electric freight vehicle using the UCC (from the garage underneath Vasakronan's head office on Mäster Samuelsgatan). The model shows similarities to BSS (Rotterdam); once operations are running with waste collection (and maybe City of Stockholm procures goods flows later as well), it is easier to included participants to sign on for using the UCC electric last mile services, as the cost can be low. Indeed, many of the costs are already covered and adding delivery services is then only a marginal cost increase. In this way, a relatively low barrier is created for using an (or several) EFV(s) to do last mile deliveries in Stockholm. Other elements can then add to the (future) success: operators can do deliveries to the UCC outside peak hours, the UCC's EFV(s) is allowed to make deliveries during restricted times and to pedestrian areas. The UCC's electric truck has already been used for one year to collect recycled goods such as glass, plastic and paper. Now, these collections are combined with the first outgoing goods (for some zip codes Bring delivers its goods via the UCC, which means Bring can save one vehicle trip), so that the vehicle both leaves and collects goods during its runs – resulting in fewer journeys.

At the moment, the UCC is still developing. How this UCC solution in practice facilitates or enables the (re)organisation of logistics in such a way that electric vehicles can be used in the last mile on a larger scale (and how it will make the transition easier for the operators) is still unknown.

4.4 Conclusions: first steps in reorganizing logistics concepts

For a larger-scale transition towards electric freight vehicles, which is necessary to achieve essentially CO_2 free city logistics in major urban centres by 2030, the reorganisation of

[28] Especially since the CCC actually functions well as a consolidation centre, but no electric freight vehicles are used (in the end), the idea was to learn from the successful CCC model, but apply it to an area where EFVs can do operations.

existing diesel based / evolved logistics systems is necessary[29]. Reorganising the existing logistics concepts, in which the city operations are decoupled from the kilometres driven outside the city, are necessary to use the potential of electric freight vehicles for city logistics. This chapter examined the question how logistics could be (re)organised in such a way that electric vehicles can be used in the last mile, also for those trips where a CFV cannot simply be replaced by an EFV at a feasible business case.

A location, hub, cross-dock facility, UCC or any other form is necessary to transfer goods somewhere near the city border from conventional vehicles to electric vehicles. The examples discussed show that there is no easy proposition yet to convince existing logistics operators or shippers to use (or set-up) a zero emission alternative for city logistics operations, even if these operators / shippers do not have to invest in battery electric vehicles themselves. Reducing barriers by facilitating the use of EFVs is not enough to persuade potential EFV-users or clients of EFV transport. However, making it as easy as possible helps (some) operators / shippers to take the first steps.

[29] Next to waiting on technical developments that bring the performance of EFVs closer to that of CFVs, e.g. large battery capacity will enable a longer vehicle range in the future (however, question is when this will be, and also how the development will continue if most actors wait, and limited EFVs are bought at the moment).

5. Transition towards wide-scale electrification

5.1 Introduction

This section extends the analysis of the FREVUE demonstrators from section 3 and section 4, thereby focussing (1) on the technical and economical possibilities for scaling-up (a few of) these demonstrators, and (2) exploring the technical and economic possibilities for scaling-up the considered vehicle (weight) classes in a more generic context[30].

Within this analysis, the envisioned result of each up-scaling activity is a fleet that is capable to perform the presumed future operations both technically and economically. In an effort to obtain more information about the presumed future operations of the involved FREVUE partners, the considered partners were questioned about the conditions which are - for their case - relevant for taking the next steps towards scaling-up. The two most relevant questions for these partners (fleet owners) were: (1) what are the differences in operating conditions between your Electric Freight Vehicle (EFV) fleet and your Conventional Freight Vehicle (CFV) fleet? And (2) under which conditions would you consider replacing (another part of) your CFV fleet with a fleet of EFVs?

The outcomes from this analysis are used in this section to enrich and nuance the view forward as described in sections 3 and 4. More specifically, the outcomes are used to visualize the relations between the key parameters that will influence the differences in Total Cost of Ownership (TCO) of a CFV and a (comparable) EFV of the same weight class.

The key parameters turned out to be (1) the (difference between the) fuel and electricity[31] prices, (2) battery investment prices, (3) the lifetime of the battery and (4) the extra costs for converting a CFV into an EFV. Obviously, the extra costs for conversion will disappear when EFVs are produced in series. Moreover, it is expected that replacing the combustion engine, the engine after-treatment system, clutch and the complex gearbox with an electromotor, an inverter, and an on-board (slow) charger, will not affect the bill of material. The battery costs are however expected to become the major price differentiator between the CFV and the in-series produced EFV.

Worth mentioning is that the up-scaling from this section not only considers a more generic context than the FREVUE demonstrators, it also considers the envisioned/future situation where EFVs are expected to be mass produced, resulting in significant cost reductions. This in contrast to the TCO as presented in chapter 3, that really focuses on the current situation.

5.11 Key partner considerations

Three partners, namely TNT, Heineken and BREYTNER offered their support for the additional work as presented in this section of D3.2. The very different application domains

[30] Notice: This extension (chapter 5) was added to D3.2 as it was perceived to be of added value for both the FREVUE partners, as well as for dissemination purposes. As this extension was not part of the FREVUE Description-of-Work, it was quite constrained both in time as well as in size. As a consequence, only three FREVUE partners, representing the vehicle (weight) classes: <3.5, 13 and 19 tons, were selected for the analysis of their electric, and not yet electrified fleet operations. Nonetheless there are already quite some communalities observed between the considered three partners/vehicle (weight) classes, which supports the perceived genericity of the presented results.

[31] Including charging infra costs

and business cases gave a good spread of use cases for this task. The following considerations were common amongst these supporting partners:

- Vehicle mileage (operational distance per trip or day) limitations and high vehicle purchase costs are considered as roadblocks towards a positive TCO;
- Upscaling of electrical fleet operation will also depend on operational time competitiveness (which is related with the quality of the EFVs and also with the time required for opportunity charging) when compared to conventional diesel operation. Any resulting additional costs will have to be paid by end customers or via subsidies;
- Uncertainty on battery capacity degradation during the operational lifetime will affect the vehicle specifications (battery dimensioning), battery replacement costs and residual value of the EFV.

The only exception for the common consideration of competitiveness to conventional diesel operation is BREYTNER, as BREYTNER has no conventional diesel fleet. For them upscaling is more related to generating more business for their comparatively expensive fully electric fleet.

5.12 Key research questions

With the key considerations of the partners in mind, as well as the context of this deliverable, the following research questions are formulated:

1) What are, from a TCO perspective, the most feasible applications / scenarios characteristics allowing for a profitable fleet electrification?
2) What are the sensitivities for the TCO and what will be the effects in the case that a pessimistic or optimistic scenario (instead of a nominal / likely scenario) comes true?

5.13 Methodology

To answer 5.12's research questions, the following steps are carried out:

1. **Technology and pricing projections research:** Trends, which are to be expected in the market of EFVs in the time frame 2017 – 2024 are analysed, thereby providing inputs for the vehicle purchase costs and vehicle depreciation costs. Here, the projections of battery, fuel, energy and maintenance costs are considered

2. **Partner scenario assessment:** The operations of the contributing partners are analysed on a case-by-case basis, as follows:
    a. *Baseline operation assessment:* an inventory was made on how the partners within the FREVUE project are operating their electric and (as far as possible) also their conventional fleet. For this purpose, information from D3.1 (Technical Suitability of EVs for Logistics - Report) and from section 2 was analysed. Where available, also usage pattern information from the not (yet) replaced conventional vehicles was obtained. This provided important baseline information for the upscaling analysis. Important information drawn

from this assessment includes kilometres per day, kilometres per trip[32] and minimum time between trips[33]

b. *Profitability assessment:* with this baseline information, the contexts from the contributing FREVUE partners will be scaled up, thereby showing the factors that are to be considered when aiming for a positive TCO within the aforementioned timeframe. This gives an indication on the timespan and conditions under which a profitable operation with an electric fleet becomes feasible. The analysis of the operational, and cost related, aspects will be driven by answering the following research questions in the best possible way:
    i. Given the current operation with the current EFV fleet (which is demonstrated / proven to be feasible) and considering the most likely price projections and assumptions from section 5.2, then under which EFV purchase price conditions[34] would the TCO balance become positive when compared with a conventional fleet of diesel vehicles?
    ii. What will change in the operation in case that also the rest of the conventional fleet will be electrified? How will a (worst case) mission profile look like (required range per day and per trip)?
    iii. Will it be technically feasible to scale-up the operation (here also including the additional worst case mission profiles) by just purchasing more of the same EFVs? If not, what range (battery size) would be demanded from the EFV and what charging infrastructure, thereby striving for the lowest TCO?

c. Sensitivity analysis: Here the sensitivity of the main factor affecting the electric fleet's TCO, namely the battery pricing, is assessed. For this purpose, next to the nominal pricing scenario, also an optimistic and a pessimistic pricing scenario will be considered.

d. *Generalized profitability assessment:* Here the conditions needed for profitable electrification of a vehicle fleet is assessed, not only for the specific partner use case and used vehicle configuration (read: battery size), but more generalized thereby focussing on a vehicle (weight) class in general. In this part of the assessment, the effects of opportunity/fast charging on the TCO are considered in an effort to either reduce the investment costs, or to extend the daily range of the EFV. Another reason for reducing the battery capacity, is to reduce its effect on the payload.

3. **Qualitative upscaling assessment:** In this section, a brief analysis of the impact of series products (or scale) on the financial attractivity of electric commercial vehicles is made on a qualitative basis.

Following from the above, conclusions are drawn and recommendations made for next steps. This section is structured with sections reflecting the aforementioned steps in the methodology.

[32] A trip is defined here as a trajectory along which (fast) charging will not be possible

[33] Is an indication of the time available for opportunity charging (without affecting the original planning), and therefore not introducing additional costs (driver and/or extra vehicles)

[34] Considering the purchase price of the EFV (the reader may presume its own possibilities for obtaining incentives, thereby allowing this purchase to become higher)

5.2 Pricing projections

This section reports the results of research into the projections of battery, fuel, energy and maintenance costs.

5.21 Battery price projections

There is a considerable uncertainty in the predictions for battery[35] prices for the upcoming years, with projections varying by more than a factor two for 2020. Therefore, for this research it was chosen to use a variety of sources to arrive at an informed prediction of battery costs in the time period considered (i.e. up to 2024).

A prominent (and often quoted) source for battery projections is Nilsson 2015, which uses a systematic review of 80 different estimates reported in the timeframe 2007 to 2014 in order to arrive at projections for battery costs. The observed trend in battery prices has been summarised in Figure 78.

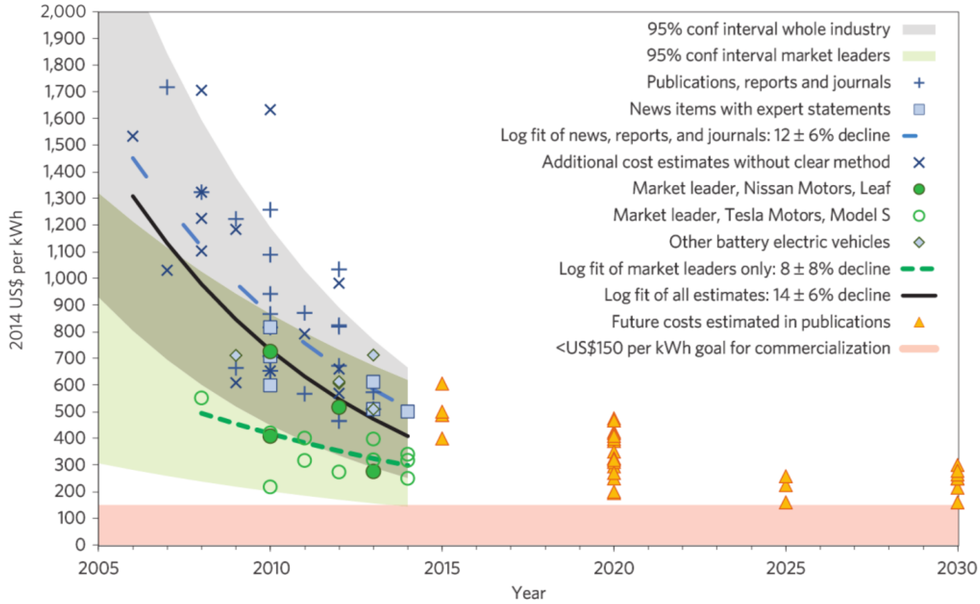

Figure 78: Past and future battery pack prices (Nilsson 2015)

Figure 78, along with several others (Bloomberg New Energy Finance 2015, BNP Paribas/Economist.com, NEDO battery roadmap, Frost & Sullivan 2013/2014, Nilsson 2015) were used to determine a mean battery price projection, which will be used further in the upscaling assessment. The different battery price projections and the corresponding mean is shown in Figure 79.

[35] In this section, wherever the word "battery" is used, the battery pack is meant!

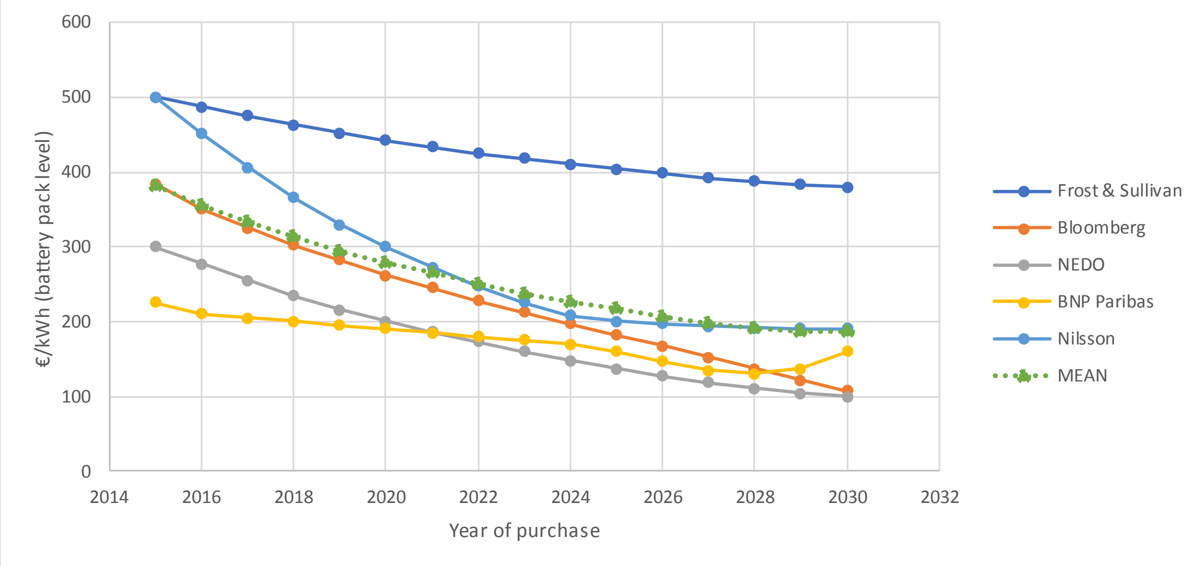

Figure 79: Updated battery pack price projections

From Figure 79 a more abstracted graph, as visualized by Figure 80, was derived. Figure 80 provides an impression of the bandwidth between the maximum and minimum battery costs as reported by the aforementioned references, relative to the mean. It can be observed that the mean price trend tends more towards the lower estimates in literature, indicating confidence among most of the sources that the battery prices will progress towards a price just over 250 €/kWh in 2022, following the trend further down towards 190 €/kWh in 2030. It must be emphasized that economies of scale are expected to have a significant impact on battery prices, for example Tesla currently already claims a price of 175 €/kWh, and is expected to drop to 91 €/kWh between 2025 and 2030 (McKinsey 2017, dollar prices converted to Euro).

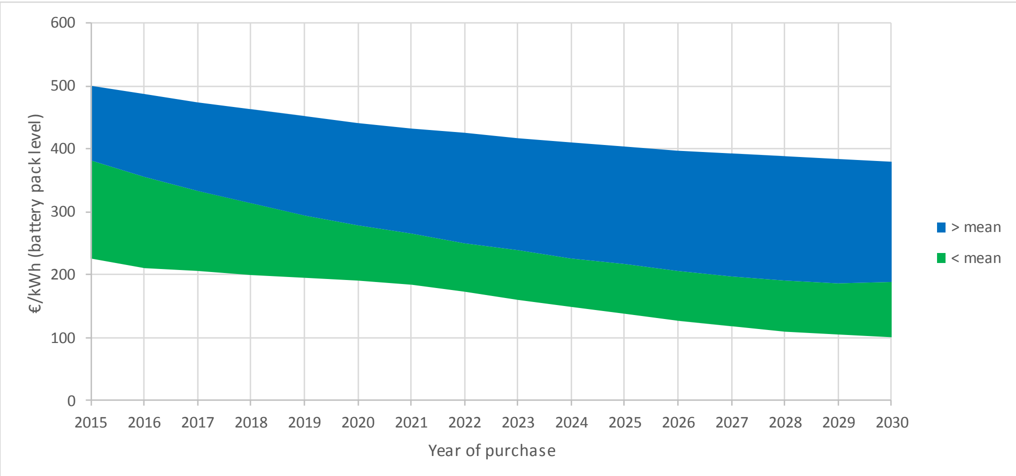

Figure 80: Bandwidth between maximum and minimum reported prognoses of battery prices in literature

5.22 Battery cycle life projections

Next to the battery price, the depreciation of the battery is an important parameter. This depreciation is predominantly determined by its expected technical lifetime. Much research has been done and is ongoing on these aspects. Lifetime is typically defined as the timespan in which the battery capacity has decreased below 80% of the initial capacity. There are examples in the market that have shown a cycle life of 3000 cycles (Akasol 2017), and the ambition is to move towards a cycle life of 5000 (Eurobat 2005). These figures have been used as the basis for Table 16, which is the baseline presumed in this report for cycle life. The figure for cycle life in 2016 is for a Li-ion NMC chemistry, while that for 2024 reflects the ambition of Eurobat (the association of European Storage Battery Manufacturers) for Li-ion chemistries in general.

The battery cycle life projection is used in this section to visualize that both battery price, as well as battery cycle life, are parameters that will (or might) affect the TCO.

Table 16 Baseline projection of expected cycle life based on info from (AKASOL 2017) and (EUROBAT 2005)

	year of battery purchase								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
expected cycle life	3000	3250	3500	3750	4000	4250	4500	4750	5000

5.23 Electricity price projections

In case that the transition from conventional vehicles to electric vehicles is not facilitated by either direct financial incentives, or by a less constrained operation (such as extended time windows for operating the vehicle), then the extra investment in the electric vehicle needs to be recovered by lower operational costs for energy and maintenance. This is the reason why projections of both electricity and diesel (reference/baseline vehicle) will be provided.

Electric vehicles can typically be charged through an AC charger (using the (typically "slow") on-board charger of the vehicle), or a DC (off-board, typically "fast") charger. The prices of non-public AC chargers are typically below 1000 € per vehicle (source: www.laadpaal24.nl). Installation costs may add a few hundreds euros to the bill. Depreciation can be done over a longer period of time (say 10 years). When presuming an electricity use of 10000 kWh per vehicle per year, then the costs associated with such installation will typically not exceed 0.01 €/kWh[36]. Presuming an electricity price of around 0.136 €/kWh[37] will result in a price of <u>0.146 €/kWh for electricity coming from a slow charger</u>.

A DC fast charger will cost around 1k€/kW. A wired fast charger is typically 50 kW (rationale: for significantly more power, a liquid cooled cable would be required, which is more expensive). Pantograph and inductive fast charging solutions may go up to 300 kW. For the TCO it is presumed that each fast charger will charge at least 6 (F)EVs per day, resulting in - say - 500,000 kWh per charger per year. Depreciation over 10 years will result in 0.01 € per kWh. In addition, an investment in the fast charger environment (such as a parking for

[36] A 3 ton vehicle, driving 30 k km per year, will typically use around 100000 kWh during a 10 year period. This would imply 0.01 € per kWh. For a heavier vehicle, the AC charger may be somewhat more expensive, but this vehicle will use significantly more energy. Therefore the mentioned price indication is believed to be a maximum price indication.

[37] Prices vary across different user categories and EU countries between 0.07 €/kWh (Bulgaria, < 5 MWh, ex. VAT) to 0.23 €/kWh (Denmark, < 5 MWh, ex. VAT) for small companies and between 0.06 €/kWh (Sweden, > 2 GWh/year, ex. VAT) and 0.15 €/kWh (Italy, > 2 GWh/year, ex. VAT) for bigger companies (ECOFYS 2016, figure 1 and figure 2). For the analysis in this chapter, an average of 0,136 €/kWh (price level corrected from 2015 to April 2017) will be considered as the nominal case. However, since the differences are significant, a sensitivity analysis on the electricity price (combined with the diesel price) will be performed to assess the effects on the TCO calculations.

charging) and a connection to the grid will be required. Annual fees will then need to be paid to maintain the installation and the connection with the grid[38].

This is why, from a TCO perspective, adding 0.03 € per kWh on top of the presumed net electricity price of around 0.136 €/kWh is expected to be enough for getting access to electric energy that can be charged at a 2C charging rate.

Alternatively, a public fast charger can be used. In case of a contract with a provider of fast charger services[39], <u>it is presumed that an all-inclusive price per kWh of 0.19 €/kWh for fast charging seems reasonable</u>. In this report (where applicable), the use of public fast charging will be presumed (which will add 0.054 € per kWh for fast charging, thus proving a 0.024 € per kWh margin for the fast charge operator).

Worth mentioning is also that the annual costs for an increased capacity connection with the grid that is required to support the charging of a fleet of electric vehicles will typically not exceed the 0.0009 € / kWh[40]. The initial investment for obtaining a higher capacity grid connection may however be significant, but can typically be depreciated over a longer period of time (say 10 years) and may translate to 0.011 € / kWh[41].

The electricity prices, as well as their price projections, as presumed for the (future) TCO analysis in this section are shown in Table 17.

Table 17 Projection of expected average electricity prices

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
slow charging (€/kWh)	0,141	0,146	0,150	0,155	0,159	0,163	0,166	0,170	0,173
fast charging (€/kWh)	0,185	0,190	0,194	0,199	0,203	0,207	0,210	0,214	0,217

As the electricity prices will have a significant effect on the TCO, it is worth considering both an optimistic as well as a pessimistic electricity price scenario for the TCO analysis as presented in this section.

For this purpose, the electricity price situation for a medium company in Sweden and a small company in Germany are considered. From ECOFYS, 2016 it can be derived that the price level for electricity for companies using between 2 GWh and 20 GWh (see Figure 56) is quite low in Sweden (approximately 0.06 €/kWh, ex. VAT) and that the price level for electricity in Germany for small companies/households (see Figure 55) is quite high (approximately 0.24 €/kWh, ex. VAT).

[38] Presuming that a connection with an existing and sufficiently strong grid that is not too far away can be made.

[39] Source: https://fastnet.nl

[40] In the Netherlands, upgrading from a 1750 kVA t/m 3000 kVA grid connection, which costs 1352 € annually, to a 3000 kVA t/m 10000 kVA grid connection, which costs 7000 € annually, represents a relative big (read: worst case) increase in price. Presuming however 261 days of operation, a relative small increase of peak power from 2 MW to 5 MW and an average to peak ratio of 25% during a day of operation, then the grid connection costs per kWh would only increase from 0.0004 to 0.0009. This translates to a few euros annually extra for a van-type vehicle and to 10 to 25 € annually extra for a big truck. This is perceived to be irrelevant.

[41] In the Netherlands, a 175 kVA t/m 630 kVA connection is relatively expensive with 35.5 k€ per connection (+ 80 € per meter in the case that the cable length is exceeding 25 meters). Presuming a 10 year depreciation period for this connection, 261 days of (fleet) operation, a 200 kVA actual peak load, an average to peak ratio of 25% during a day of operation, then the grid connection costs per kWh would be approximately 0.011 €.

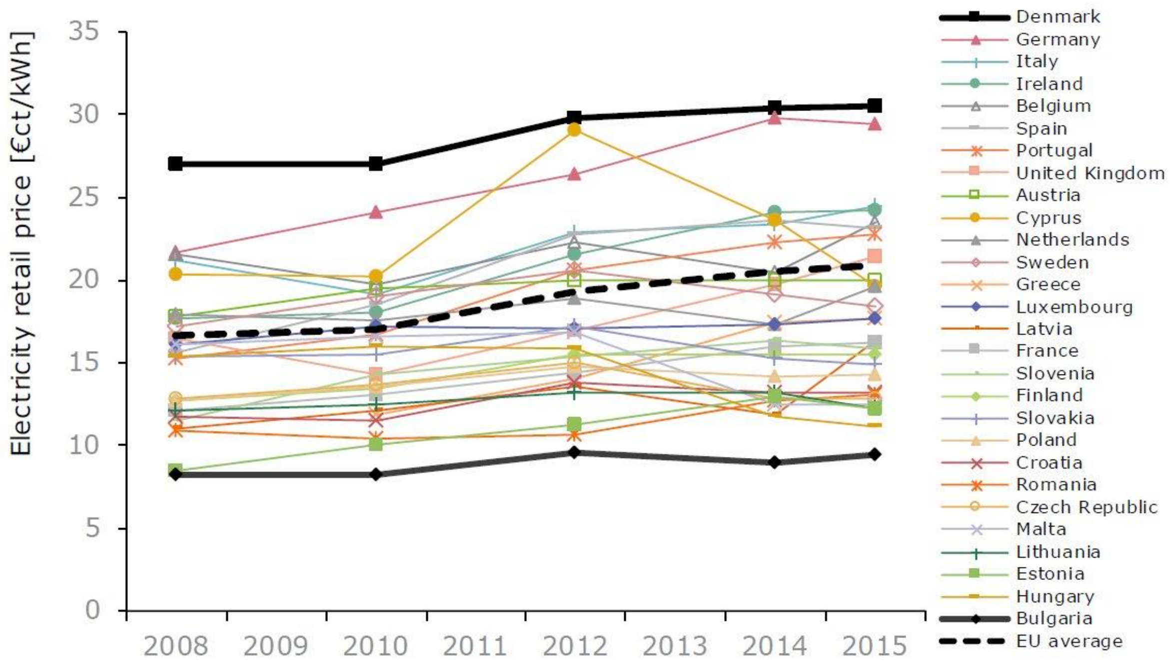

Figure 81: Total electricity price development for households (Band DC, source: European Commission, prices incl. VAT, ECOFYS 2016)

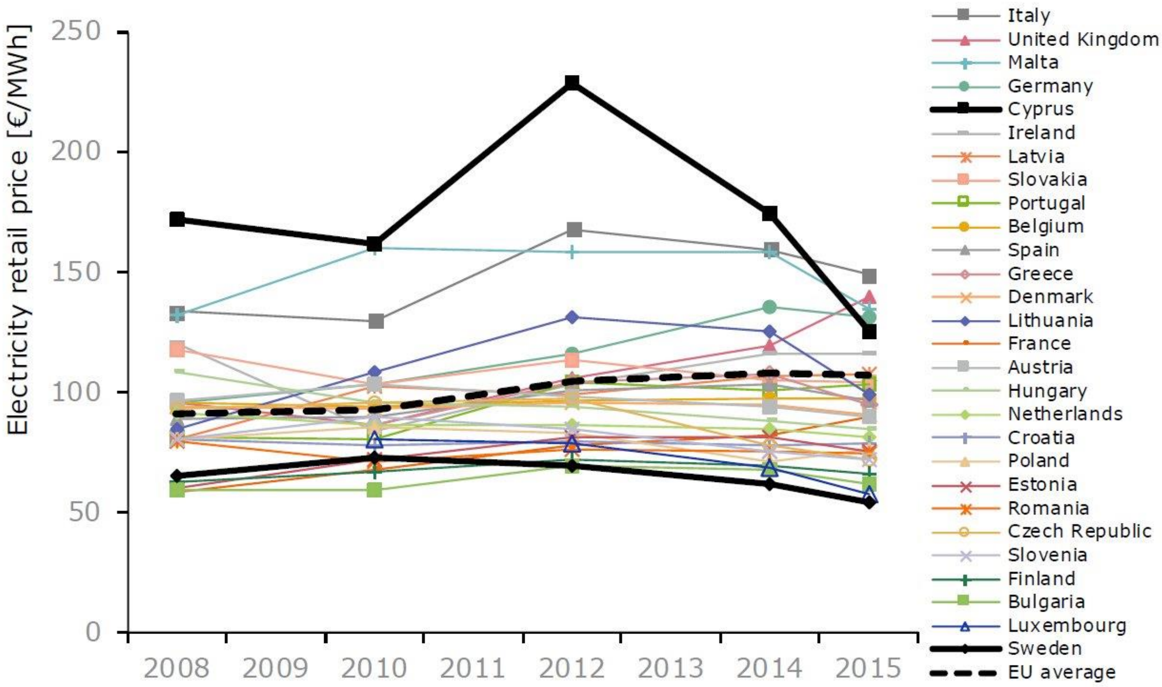

Figure 82: Total electricity price development for industrial consumers (Band ID, source: European Commission, prices ex. VAT, ECOFYS 2016)

The Swedish electricity price scenario, combined with the earlier used percental price projection results in Table 18.

Table 18 Projection of expected electricity prices in Sweden

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
slow charging (€/kWh)	0,068	0,0704	0,0723	0,0748	0,0767	0,0786	0,0801	0,082	0,0834
fast charging (€/kWh)	0,112	0,114	0,116	0,119	0,121	0,123	0,124	0,126	0,127

The German electricity price scenario, combined with the earlier used percental price projection results in Table 19.

Table 19 Projection of expected electricity prices in Germany

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
slow charging (€/kWh)	0,242	0,2506	0,2574	0,266	0,2729	0,2798	0,2849	0,2918	0,2969
fast charging (€/kWh)	0,286	0,295	0,301	0,310	0,317	0,324	0,329	0,336	0,341

5.24 Diesel price projections

In the TCO comparison between conventional vehicles and electric vehicles, the price difference in energy costs per kilometre is key, since this is the main (and sometimes the only) contributor towards a TCO that is in favour of the EFV. The price for diesel is heavily influenced by the oil price and therefore quite unstable. Within this report it is presumed that the future price development of diesel follows the same percental trend as the projection of the expected electricity prices (Table 17) [42]. The resulting diesel prices are shown in Table 20. [43]

Table 20 Projection of expected diesel prices

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
diesel price (€/l)	1,062	1,100	1,130	1,167	1,198	1,228	1,250	1,280	1,303

For the optimistic as well as a pessimistic electricity price scenario as described in the previous section, also the corresponding (Swedish and German) diesel prices will be considered, especially since the corresponding price differences will increase the difference in operational costs even further as in Sweden the price for diesel is above the European average (1.18 €/l, ex. VAT) and in Germany (with 0.99 €/l, ex. VAT) below the European average[44]. For this comparison, the earlier used percental price projection is presumed. This results in Table 21 and Table 22.

[42] This is quite conservative since the price projection from the World Bank Oil Price Forecast (continuous 2,7% annual increase) and the EIU Oil Prices Forecast (continuous annual increase of around 3%) are somewhat higher, see also: https://knoema.com/yxptpab/crude-oil-price-forecast-long-term-2017-to-2030-data-and-charts.

[43] With diesel, the Netherlands is approximately the EU average (ECOFYS 2016, figure 6). In April 2017, the diesel advice price in the Netherlands was around 1.33 €/l incl. VAT, translating to 1,10 €/l ex. VAT. Since the differences in diesel price are significant within Europe (UK: 1.41 => 1.18 ex. VAT, Luxembourg: 1.02 => 0.87 ex. VAT), a sensitivity analysis on the diesel price (combined with the electricity price) will be performed to assess the effects on the TCO calculations.

[44] Prices per April 2017 obtained from https://www.anwb.nl/vakantie/reisvoorbereiding/dieselprijzen-europa

Table 21 Projection of expected diesel prices in Sweden

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
diesel price (€/l)	1,140	1,180	1,213	1,253	1,286	1,318	1,342	1,374	1,399

Table 22 Projection of expected diesel prices in Germany

	year								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
diesel price (€/l)	0,960	0,994	1,021	1,055	1,083	1,110	1,130	1,157	1,178

5.25 Maintenance price projections

There is future potential for a lower maintenance bill for EFVs, since the repair and maintenance costs for OEM produced electric passenger cars are around half of the maintenance costs of a comparable conventional vehicle. However, since EFVs are - at the moment of writing (except for the smallest EFVs, such as the Nissan eNV 200) - only available through product converters that are not able to provide the same product quality as the OEM produced vehicles, it is presumed that for the TCO comparison there is no cost benefit from maintaining an EFV in comparison to maintaining a conventional freight vehicle. See also section 5.43 for more backgrounds.

Engine-, engine-after-treatment- and battery-replacement will be expensive. It is perceived that such investment in the (already aged) vehicle is typically not desirable, as such investment will not pay back in the residual value of the vehicle. For the considered FREVUE cases, this condition will be checked.

For a relatively small battery that is recharged during the day it may however be profitable to replace the battery while the EFV has not reached its economic lifetime limit. Such replacement will be taken into account in the TCO analysis whenever applicable.

5.26 Other price projections and assumptions

The distance per year is calculated by multiplying the (FREVUE case dependent) daily distance by the number of workable days (i.e. a factor 260, which is in line with the data from operators as used in chapter 3)[45], which is the presumed to be the number of working days per year.

The driving time per day is considered to be a FREVUE case-dependent variable.

5.3 Partner scenario assessment

This task was performed to gather information from the considered project partners (TNT, Heineken and BREYTNER) on the operation of their distribution vehicles, thereby focussing on an upscaled electric fleet operation. The latter implies that the focus of this assessment moved from their current full electric fleet towards their conventional fleet operation and the possibilities (and roadblocks) to electrify (part of) this fleet as well. As BREYTNER does not have a conventional fleet, for them upscaling is more related to generating more business for their comparatively expensive full electric fleet.

For this assessment both the FREVUE data (as presented in D3.1 and in the previous sections from this report), as well as direct input from the mentioned partners, were used to

[45] 52 week per year * 5 working days per week = 260 working days per year

perform the upscaling assessment. Two important pieces of information required for the assessment that are worth mentioning here already are (1) the operational daily distance and (2) possibilities in the operation (time) for easy opportunity charging.

This assessment is constrained by the assumption that for the upscaling of a zero emission operation to a larger part of the fleet, the EFVs should be able to operate similarly to the conventional vehicles. In other words, the operational values of conventional vehicles for time and distance will be used as a baseline for the upscaling analysis. The latter allowed the analysis to be constrained in both time and effort, while remaining focussed on the potentially most profitable application domain for EFVs. (Note that section 4.3 Adapt logistics system to EFVs qualitatively presents the cases where these operational values changed).

In the subsections that follow, the earlier mentioned three FREVUE cases will be analysed case by case.

5.31 TNT scenario assessment (3.5-tonne EFVs)

Baseline operation assessment: operational time

The operational time for the 3.5 tonne vehicle class was obtained from partner TNT (in the Netherlands, based on the vehicles operating in and around Rotterdam and Amsterdam). The time for actual driving is also obtained, which suggests that the remainder of the time is spent waiting/(un)loading. In the case of EFVs, this may also be used for opportunity charging. The operational time and the driving time for the 3.5 tonne vehicles (BD e-Ducato) operated by TNT is shown in Figure 22.

To obtain a baseline for the total time that is available for opportunity charging of the vehicles, the difference between the representative minimum total time and the representative maximum of the total driving time has been used, thereby considering (also) the operation of the conventional fleet. This is considered as a representative worst case available time for fast charging the vehicles during upscaled operation. In the case of TNT the available time for fast charging is obtained as approximately 10 minutes. From a discussion with the TNT fleet manager, it was however concluded that a 30-minute mid-day combined lunch/charge break would be feasible without introducing extra labour costs.

Baseline operation assessment: operational distance

The total operational distance per day is important to assess the battery sizing in terms of the required range, as well as calculate depreciation-related figures. The total operational distance for the 3.5 tonne vehicles operated by TNT is shown in Figure 23.

In this figure, the top boundary of the dotted line is representing the operational distance for 99.65% of the monitored urban conventional vehicle fleet. With a value of 165 kilometres, this is very close to the range of the current EFV fleet which have a 62 kWh battery system. From this it can be concluded that the intended operation can still be done with overnight charging only.

Worth mentioning is however that there are also regional parcel routes around these cities where 400 kilometres per day may be possible. For the Netherlands the worst case TNT route length may be even as long as 450 kilometres.

Given the restriction of the GVW of the considered vehicles (3.5 tonnes[46]), there will be - even for optimistic battery price scenarios - little possibility for extending its practical range beyond the 165 kilometres, as the current payload of the e-Ducato is already very low with only 850 kilograms. This means that opportunity charging will be required in order to cover these distances. For this reason, both one-time opportunity charging and two times opportunity charging will be considered.

Profitability assessment

In the TNT situation 7 Mercedes Sprinters were replaced by 7 electrified Fiat Ducatos (which were converted by BD) with a 62 kWh battery capacity and a range of approximately 167 kilometres. These vehicles are presumed to be usable for the scaled-up operations of TNT as well. The current (2016) purchase costs for the Mercedes will be around € 23000, whereas the current (2016) purchase costs for a (converted) e-Ducato will be around € 75000.

Presuming the nominal battery price scenario from section 5.2, the e-Ducato is expected to become less expensive over time. How the price of the e-Ducato is expected/projected to evolve is expressed in Table 23.

Table 23 3.5 tonne vehicle investment price (nominal battery scenario, small series)

	year of purchase								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
FEV purchase price (k€)	75	74	73	71	70	70	69	68	67

The resulting cumulative costs as a function of the year of purchase, thereby presuming an 8-year depreciation period and presuming the energy prices from section 5.2, are shown in Figure 83.

For Figure 83 the following assumptions were made:

- Distance per day: 110 km[47]
- Days of operation per year: 260
- Depreciation time: 8 years
- Resulting in total distance: 229000 km
- Mercedes Sprinter average fuel consumption: 0.106 l/km
- Mercedes Sprinter purchase price: 23000 €
- Mercedes Sprinter maintenance costs during depreciation period: 8800 €
- BD/Fiat e-Ducato average energy consumption: 0.37 kWh/km
- BD/Fiat e-Ducato purchase price: 75000[48] €

[46] There are discussions with relevant EU authorities ongoing on extending the vehicle weight class for a B-type driver's license to 4250 kg as an exemption for electric vehicles. The outcome of these discussions are - at the moment of writing - unclear.

[47] This is an average daily (median in Figure 23) distance already for an upscaled situation. The EFVs monitored in the FREVUE pilot were traveling on average little more than 80 km per day. It was however observed that this operation can easily be extended by driving the other inner-city routes also.

- BD/Fiat e-Ducato maintenance costs during depreciation period: 8800 €

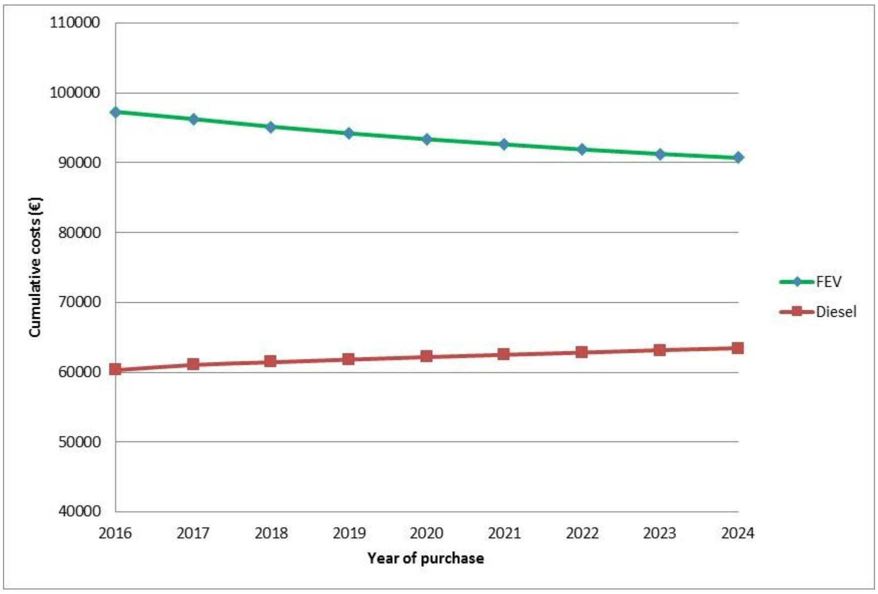

Figure 83: Cumulative cost comparison between the Sprinter (diesel) and e-Ducato for an 8-year depreciation period, as a function of the vehicle purchase date

From Figure 83, it can be observed that currently there is a “gap” of almost 37 k € to bridge to obtain a comparable TCO situation. With the expected price developments of the battery system, this “gap” is expected to shrink by 10 k € to 27 k € by 2024.

With this information, it is possible to answer the question under which EFV purchase price conditions the TCO balance would become positive when compared with a conventional fleet of diesel vehicles. This information is expressed in Figure 84. The horizontal axis represents the year of vehicle purchase. The vertical axis represents the price difference between an EFV and a conventional vehicle that is allowed for an equal TCO after the depreciation period[49].

[48] For the future projection, the purchase costs for the e-Ducato were reduced by the expected (nominal) price reduction of its battery pack of 62 kWh. Other costs were presumed to remain the same.
[49] This analysis does not take the costs for acquiring the extra CAPEX into account. This means that in reality the allowed price difference may be somewhat smaller, especially in the case of longer presumed depreciation periods (see also chapter 3).

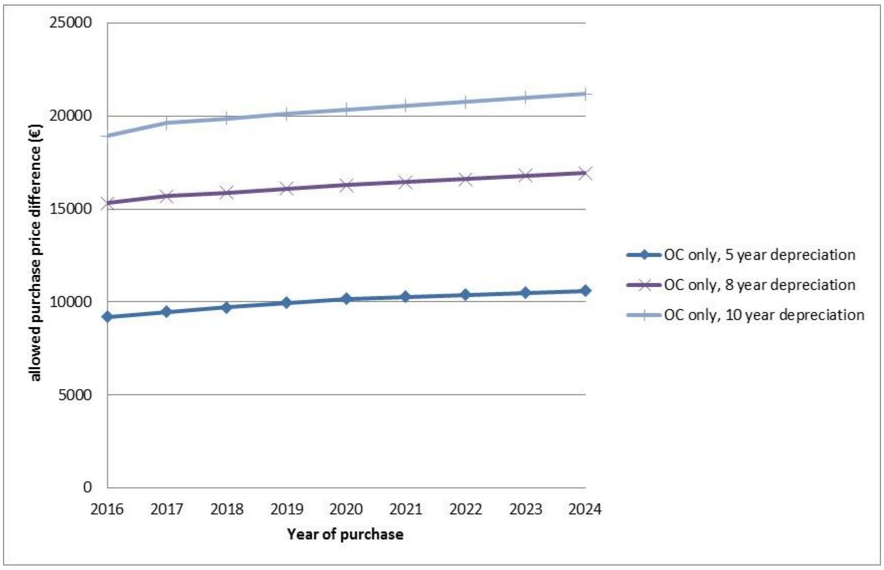

Figure 84: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only)

Figure 84 reveals that a difference in purchase price, ranging from 9 k € up to 21 k € may be justified from a TCO perspective. The difference in purchase price depends on the depreciation period (indicated by separate trend lines) and the year of purchase (which determines the expected increase in energy prices and therefore the expected increase in energy price differences, which explain the upward trends of the trend lines[50]). This purchase price of the battery pack is (implicitly) part of the mentioned price range.

Sensitivity analysis on energy costs

As the electricity and diesel prices will have a significant effect on the allowed price difference (between a conventional freight vehicle and an EFV) for reaching an equal TCO after a given/presumed depreciation period, it is worth considering both an optimistic as well as a pessimistic energy price scenario for the EFV. For this purpose, the Swedish and German price scenarios as sketched in section 5.23 and section 5.24 will be used.

With the Swedish energy price scenario, the allowed price difference is shown in Figure 85. With the German energy price scenario, the allowed price difference is shown in Figure 86. From these figures (in with the nominal battery price scenario is assumed) it can be observed that in Sweden a price difference of around 25 k € is allowed for a depreciation time of 8 years, whereas in Germany the price difference need to be smaller than 3.5 k € in order to earn back the extra investment in the FEV within 8 years. This is a significant difference!

[50] Note: if a vehicle is purchased in 2017 and is depreciated for 8 years, then the average energy prices from 2017 up to 2024 are considered. If a vehicle would be purchased in 2021, then only the average of the energy prices from 2021 up to 2024 will be considered, whereas it should have been up to 2028. Therefore, if energy prices would increase (beyond typical inflation rates), then the trendlines from Figure 84 would have shown a steeper inclination. Predictions beyond 2024 are however not considered in this report!

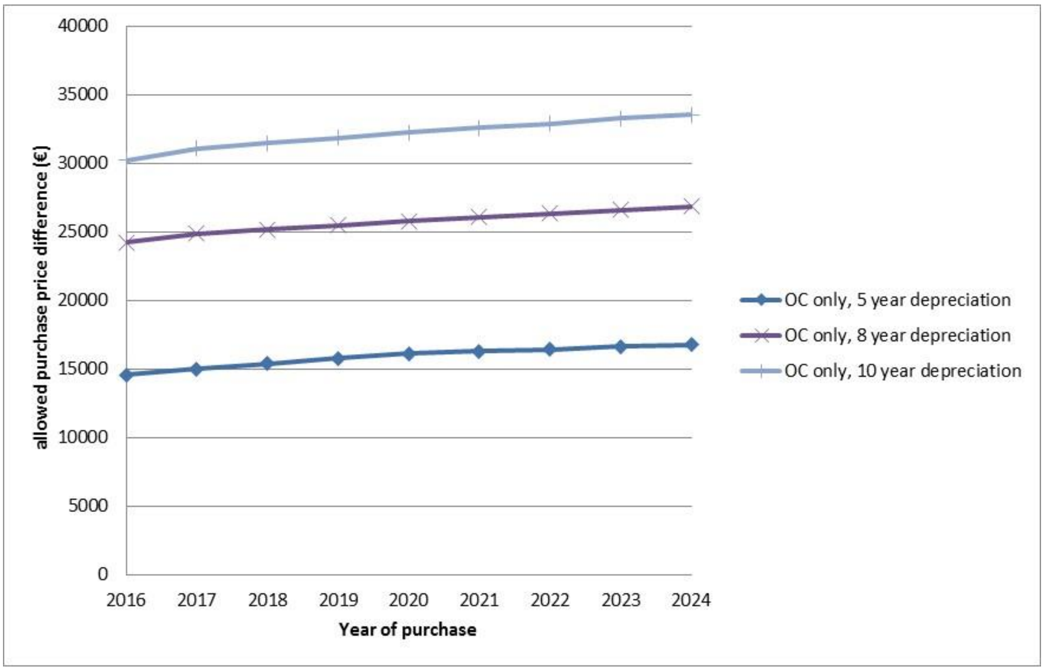

Figure 85: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Sweden)

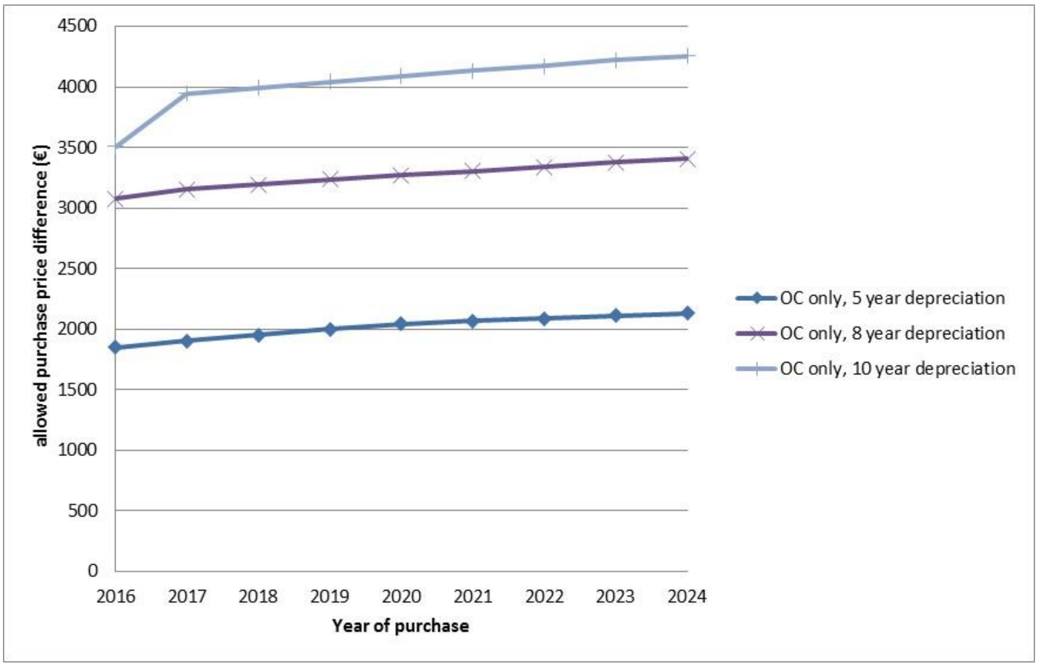

Figure 86: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Germany)

Budget for converting a conventional vehicle into an EFV

Now, let's go back to the nominal (European average) energy price scenario. In this case the battery pack capacity is known and also price projections for such battery packs can be provided. This is why Figure 84 can be extended, thereby incorporating information about the battery purchase costs. In case that the initial battery pack purchase costs are already taken into account, the budget available for converting the conventional vehicle (Fiat Ducato) into a EFV (e-Ducato) can be estimated / calculated. The latter is visualized in Figure 87.

From Figure 87 it can be observed that, under the presumed conditions, a depreciation time of 5 years is not feasible at all, presuming that the production costs for the electric vehicle without the battery pack are more or less equal to the production costs of the conventional vehicle. With the current situation, where conversion companies are the only commercial parties providing EFV solutions, even a 10 year depreciation time is not a financially feasible situation.

However, in the case that energy (fuel and electricity) costs increase (in a similar way), then more budget will be available for the conversion. Also, it is believed that the transition to an in series produced vehicle will result in an ex-battery vehicle which has a price that is comparable with the price of a conventional vehicle.

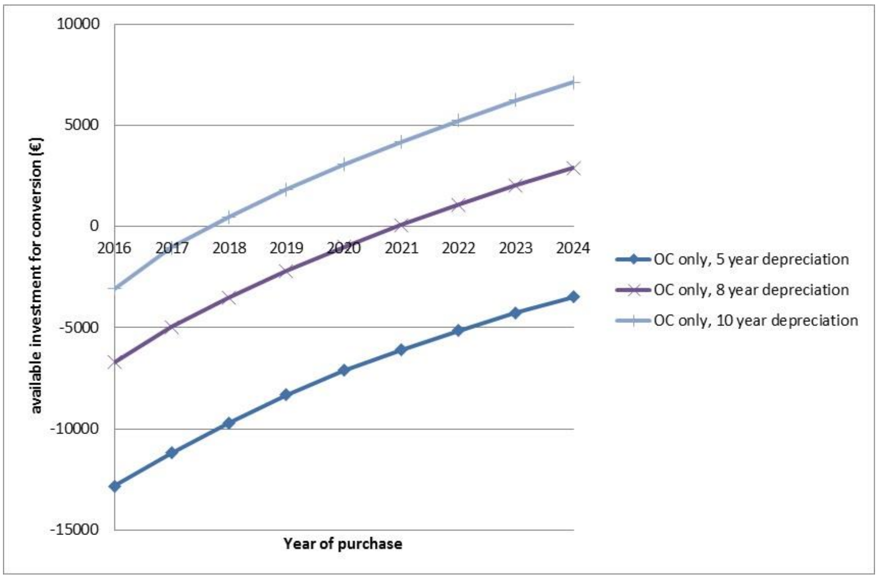

Figure 87: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included)

Sensitivity analysis on battery pack pricing

Given the former information, a sensitivity analysis can be performed on one of the main contributor to the EFV price: the battery price. Presuming little price difference between an in-series produced conventional vehicle and an in-series produced electric vehicle without battery system, this sensitivity analysis is considered to be important for the 2019-2024 timeframe (in which the first in-series produced EFV are expected). For this purpose both the pessimistic as well as the optimistic battery price scenarios (as visualized in Figure 80) are determined and expressed by Figure 88 and Figure 89 respectively.

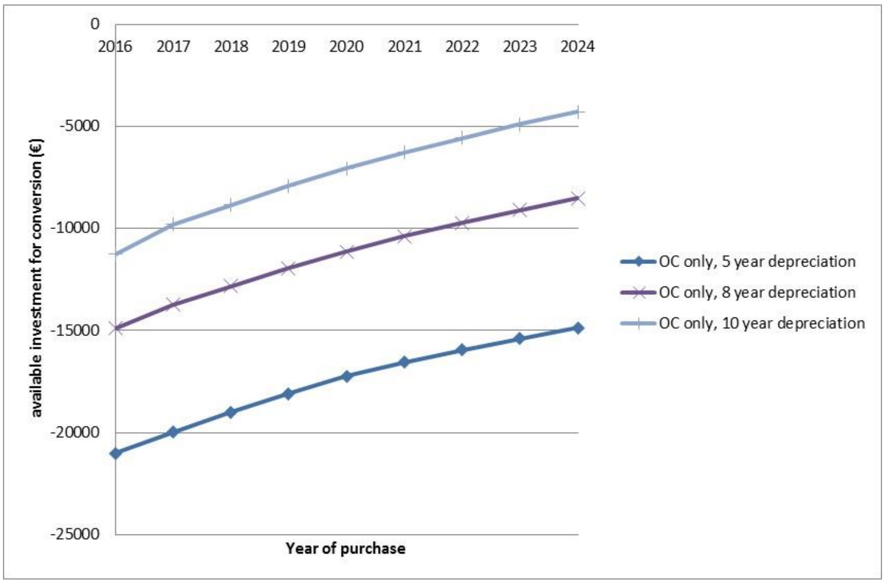

Figure 88: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a pessimistic battery price scenario

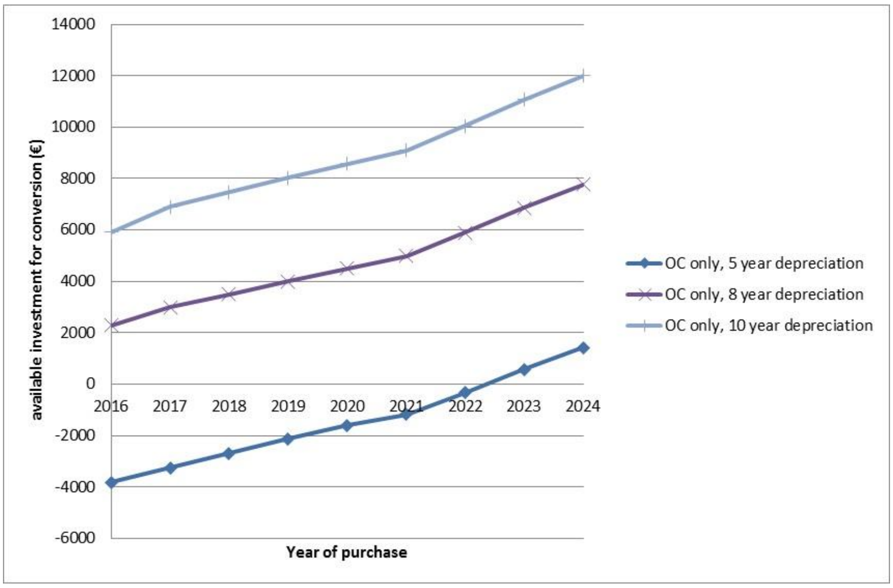

Figure 89: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming an optimistic battery price scenario

From Figure 88 it can be observed that for the pessimistic scenario, based on the TNT operation and no incentives, there will not even be a positive business case for an in-series produced EFV.

From the optimistic scenario from Figure 89 it can be concluded that an in-series produced EFV may already be economically feasible as of 2016 with a depreciation time of approximately 7 years.

Worth mentioning in this context is that it is expected that there will be a strong and negative correlation between production series and battery price. It is therefore believed that the negative battery pack price scenario is more likely to be applicable for the in small series produced EFV, whereas the positive battery pack price scenario is more likely applicable for the in-series produced EFV.

Generalized profitability assessment for 3.5 ton EFV case

Given the restriction of the GVW of the considered vehicles (3.5 tonnes), there will be - even for optimistic battery price scenarios - little possibility for extending its practical range beyond 150 kilometres, as the current payload of the e-Ducato is already very low with only 850 kilograms.

This means that the vehicle's range of approximately 167 kilometres is a quite representative maximum range for a 3.5 tonne class EFV.

However, the daily range of this 3.5 tonne EFV can be extended by opportunity charging. In general it can be said that if opportunity charging events can be fitted both in time and location with fast charging events without affecting the normal operation (e.g. during loading, unloading, rest breaks of the driver), then the penalty for fast charging can remain limited to a higher cycle life of the battery and a higher price for electricity[51]. In this context, TNT reported that it would be fairly easy to use the 30 minutes lunch breaks of the drivers and reloading events for fast charging their EFVs.

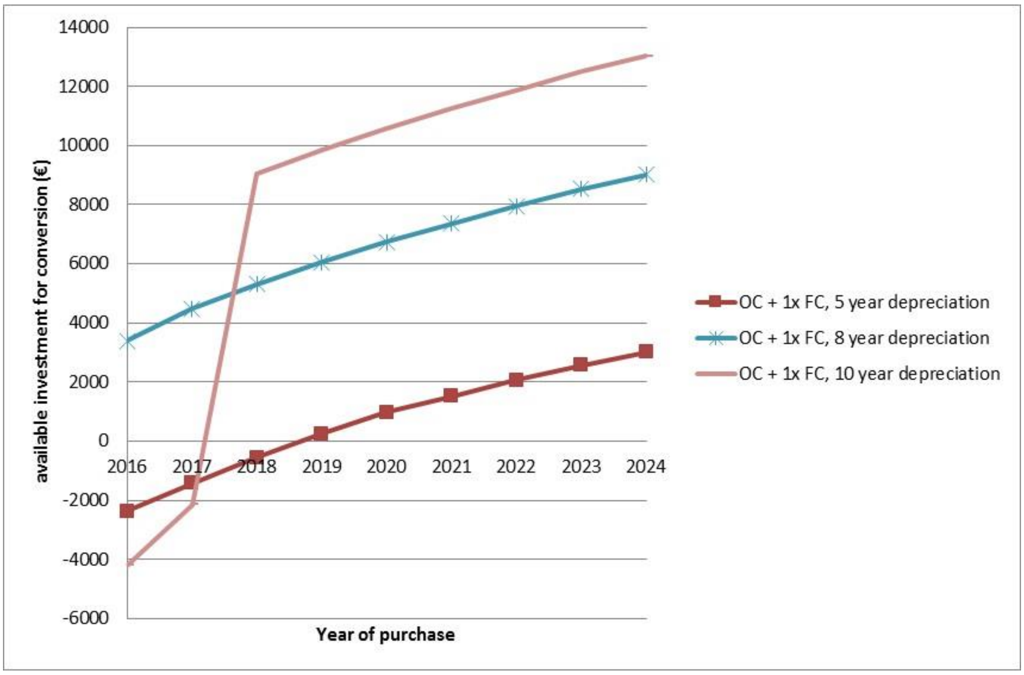

Figure 90: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a 31 kWh battery system with 1x Overnight Charging and 1x Fast Charging

Let's therefore consider the case where the 110 km/day operation stays the same, but the battery size is reduced to 31 kWh (i.e. half of the original capacity) and is recharged halfway

[51] Incorporating the depreciation of the fast charging equipment; see also section 5.23.

the daily operation. Also consider (from this point onwards) the nominal battery price scenario again.

From Figure 90 (compared with Figure 87[52]) it can be observed that reducing the battery size significantly helps the TCO. The reduced investment in battery capacity may be used to reach a positive business case and/or to reach a positive business case with a shorter depreciation time.

One aspect that becomes relevant when a battery pack is charged more than once during the day is that its cycle life may be reached before the EFV has been fully depreciated. This effect can also be observed in Figure 90 for the 10 year depreciation case. For the 10 year depreciation case it can be observed that if the EFV is purchased in 2016 or 2017, then the expected cycle life is such that this battery needs to be replaced within the 10 year time frame. This will require an extra investment, which basically undoes the financial advantage of using a smaller battery[53]. However, based on the trend in cycle life, replacement of the 31 kWh battery for this particular application is not considered to be required from 2018 onwards.

Worth mentioning here is also that the price trends for the fast charged battery will be less steep than the previous trends for overnight charging. The reason for this is that the kWh price for fast charging is somewhat higher, thus reducing the difference in operational costs between the conventional freight vehicle and the EFV.

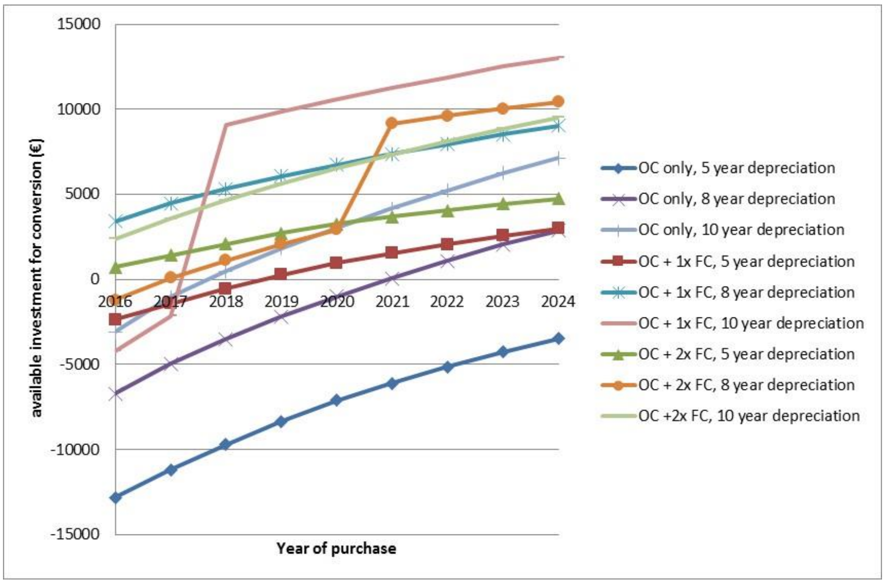

Figure 91: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming the 62 kWh battery (OC only), the 31 kWh battery (1xFC) and the 21 kWh battery (2x FC)

In Figure 91 the information from Figure 87 is combined with the information from Figure 90 and extended with the EFV configuration with an even smaller battery capacity of 21 kWh,

[52] Figure 91 contains both plots, which makes comparison easier

[53] Another benefit of using a smaller battery is -of course- the reduced weight/increased cargo capacity and the reduced energy consumption of the (lighter) vehicle. A disadvantage is that fast charging equipment will be required and this equipment needs to be depreciated (which is done through the presumed higher kWh price)

requiring 2x fast charging to approximately 80% of the full battery capacity. From Figure 91 it can be observed that further decreasing the battery capacity to 21 kWh will not significantly decrease the TCO. This is because the (presumed) cycle life limitation will require replacement within the depreciation period. Also more (expensive) power from a fast charger will be required to fulfil the daily operation.

The question may rise on what will happen in the case that the EFV will be used to drive more kilometres? This seems a relevant question, since TNT already indicated that next to the inner-city operations, as considered above, there are also rural routes where daily distances of 400 kilometres (worst case Netherlands for TNT: 450 km) are common. Besides, chapter 3 already showed that a difference in daily distance (within the battery allowed range) makes a big difference in the TCO comparison of EFV and CFV.

Before considering these longer distances, which need to be combined with fast (opportunity) charging, let's first consider an operation that allows the eDucatos to drive on average 150 km/day (which is very close to the range of this vehicle), instead of the earlier presumed 110 km/day. This will result in the situation as expressed by Figure 92.

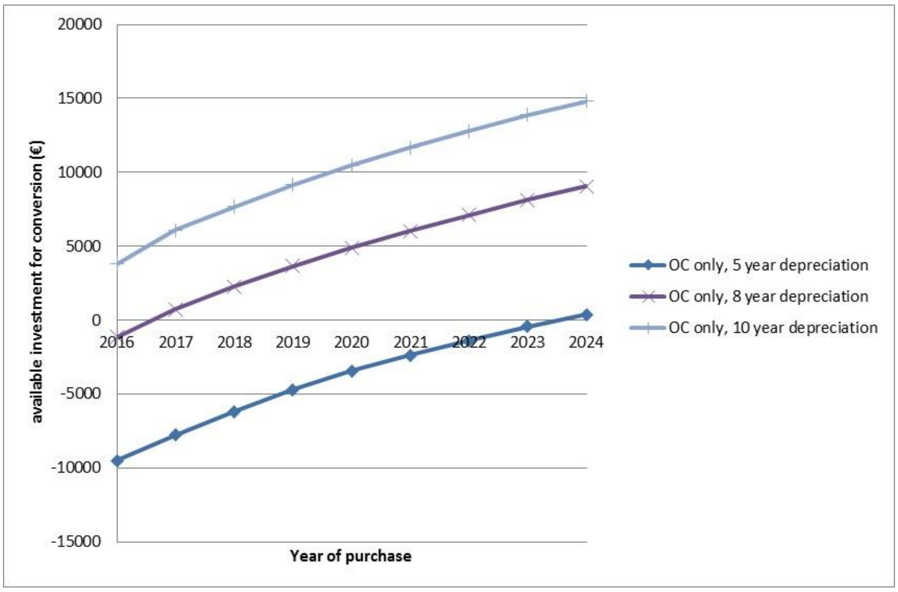

Figure 92: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming an average daily distance of 150 km

From Figure 92 (compared with Figure 87) it can be observed that driving more kilometres significantly contributes to a positive TCO for electric vehicles, as was also concluded in chapter 3. However, assuming that the conversion costs for a conversion company will never be significantly lower than 18k € and assuming that there are no other incentives/enablers (like tax reductions, extended time windows for operating emission free vehicles in certain areas, etc.), observing Figure 92 it looks rather difficult to create a positive business case for conversion companies (> 10 year depreciation, or lower battery prices than the presumed mean trend).

From this it can also be concluded that when driving less kilometres per day the possibilities for obtaining a positive TCO will be even further reduced.

For longer daily routes with the 3.5 tonne EFV it was already concluded that opportunity charging would be the only option. In Figure 93 the situation for a daily route of 400 km is sketched, thereby presuming the 62 kWh battery from the TNT vehicle (as described earlier) to be recharged twice to perform the 400 km operation.

From Figure 93 it can be observed that this longer daily operation is really positive for the TCO, although only for the 5 year depreciation case there is no battery replacement required from 2017 onwards and for the 8 year depreciation case no battery replacement is expected only from 2024 onwards. For the 10 year depreciation case it is expected that if the EFV would have been purchased in 2016, that even 2 battery replacements would have been required.

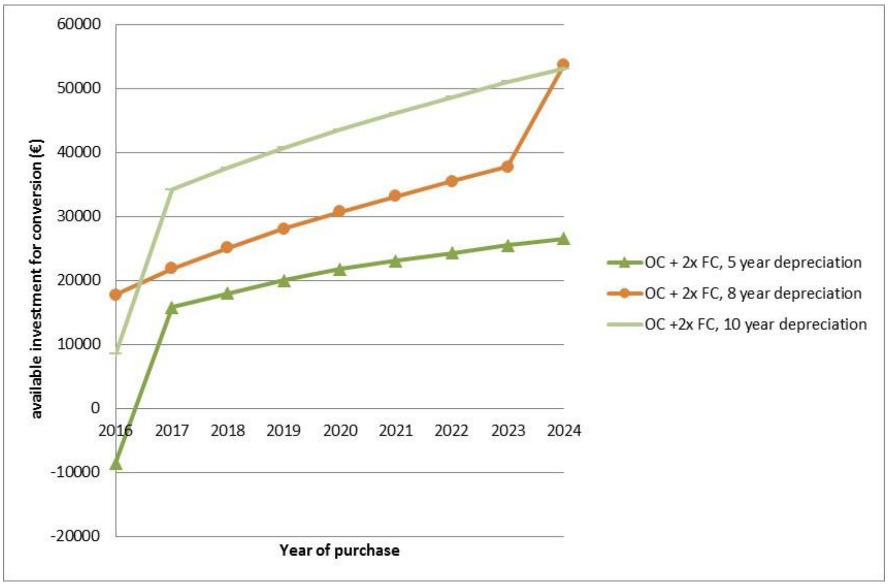

Figure 93: Available budget for converting a Ducato into an e-Ducato for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming 400 km/day, a 62 kWh battery and 2x per day Fast Charging

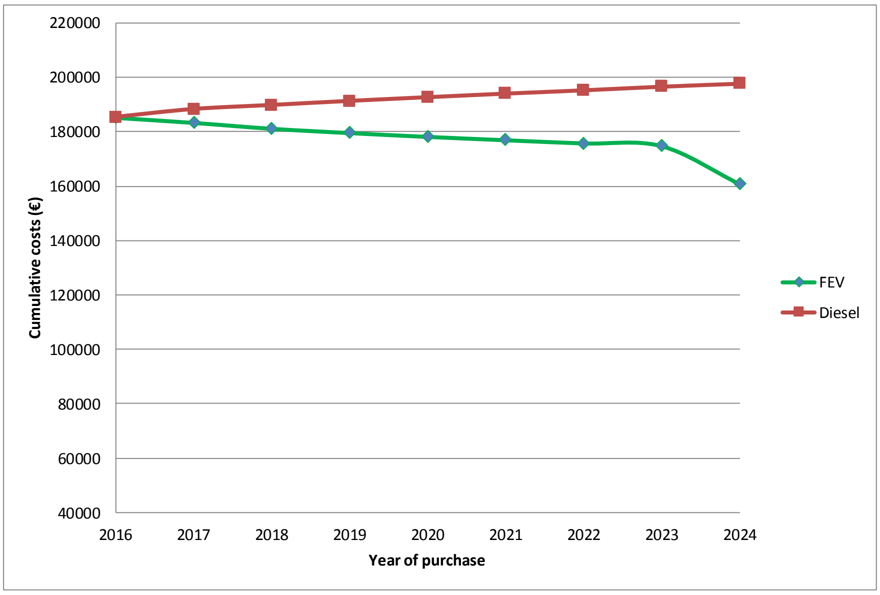

Figure 94: Cumulative cost comparison between the Sprinter (diesel) and e-Ducato (presuming 400 km/day, a 63 k € EFV and 8 year depreciation)

Figure 94 reveals that, presuming a 400 km daily operation and 8 year depreciation, there is a positive business case for a 63k € EFV, with the restrictions that the EFV battery is capable of charging 2C, that there are easy possibilities within the operation to recharge the EFV two times per day and that (commercial) fast chargers are available.

To complete the analysis for the 3.5 tonne (van-type) vehicles, a mileage vs. saving relation is provided in Figure 95. In Figure 95, the horizontal axis represents the amount of kilometres driven during the depreciation period. The vertical axis shows the savings in energy costs during these kilometres. This relation is determined by:

- the projection of the diesel price: see Table 20
- the Mercedes Sprinter average fuel consumption: 0.106 l/km
- the projection of the electricity prices: Table 17
- BD/Fiat e-Ducato average energy consumption: 0.370 kWh/km

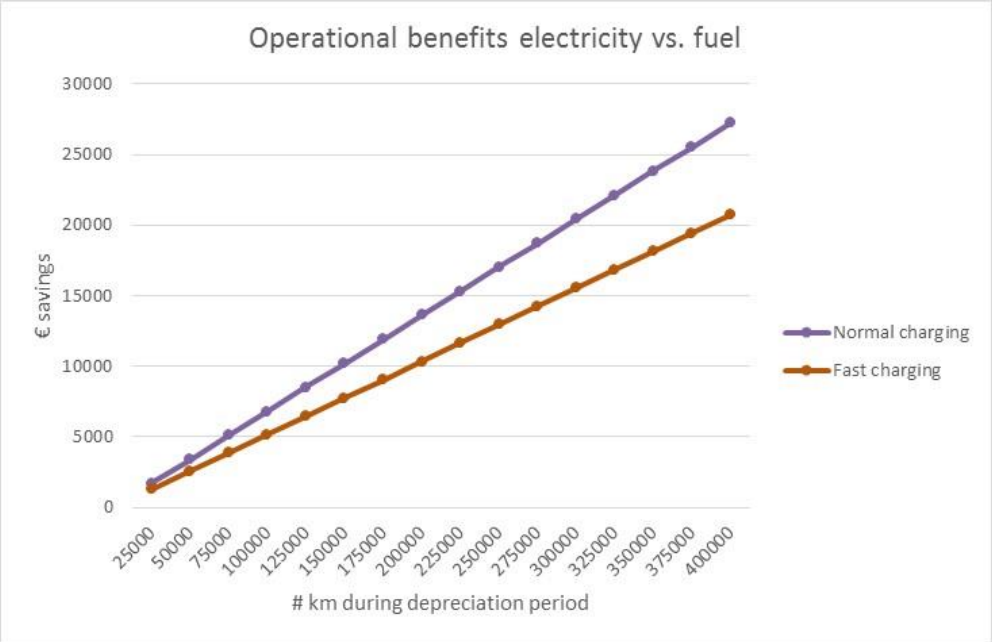

Figure 95: Operational benefits electricity vs. fuel as presumed in this report

5.32 Heineken scenario assessment (13 ton class EFVs)

Baseline operation assessment: operational time

The operational time for the 13 tonne vehicle class was obtained from partner Heineken. The operational time and the driving time for the 13 tonne vehicles (Ginaf)[54] operated by Heineken is shown in Figure 31 (Rotterdam) and in Figure 35 (Amsterdam). From these figures, it can be observed that for the worst case there may be little time left for (fast) opportunity charging. On the other hand it is known that for the Rotterdam case the truck is on average standing still for 6 hours per day. From the Amsterdam case it is known that the truck is driving 2 routes per day and will therefore return back to the distribution centre halfway during its operation, where it will be standing still for unloading and loading. This implies that there will (typically) be time available during operation for opportunity charging.

[54] Next to the Ginafs, Heineken also operated a single EMOSS 19 ton EFV (see chapter 2). The analysis for Heineken will be constrained to the seven 13 ton EFVs, and for the large vehicle (19 ton) the case of BREYTNER is analysed in chapter 5.

Baseline operation assessment: operational distance

The total operational distance per day is important to assess the battery sizing in terms of the required range, as well as calculate depreciation-related figures. The total operational distance for the 13 tonne vehicles operated by Heineken is shown in both Figure 32 (Rotterdam) and in Figure 36 (Amsterdam).

In these figures, the top boundary of the dotted line is representing the operational distance for 99.65% of the monitored urban conventional vehicle fleet. With a value of 120 km[55], this is also close to the range of the current EFV fleet (which have a 120 kWh battery system and an expected range of over 150 km[56]). From this it can be concluded that the intended operation can still be done with overnight charging only, thereby using the same vehicle specifications as used for the FREVUE pilot. The initial profitability assessment will therefore be done presuming the same vehicle as used for the pilot.

Profitability assessment

For the Heineken inner city operations (Amsterdam and Rotterdam), 8 DAF CF conventional trucks were replaced by 8 Ginaf trucks with a 120 kWh battery capacity and a range of approximately 155 km. These vehicles are presumed to be usable for the scaled-up operations of Heineken as well. The current (2016) purchase costs for the DAF will be around € 100000, whereas the current (2016) purchase costs for Ginaf will be around € 220000. Presuming the nominal battery price scenario from section 5.2, the Ginaf is expected to become less expensive over time. How the price of the Ginaf is projected to evolve is expressed in Table 24.

Table 24 13 ton vehicle investment price (nominal battery scenario, small series)

	year of purchase								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
FEV purchase price (k€)	220	217	215	213	211	209	207	206	205

The resulting cumulative costs, thereby presuming an 8 year depreciation period and presuming the energy prices from section 5.2, are shown in Figure 96.

For Figure 96 the following assumptions were made:

- Distance per day: 58 km[57]
- Days of operation per year: 260
- Depreciation time: 8 years
- Resulting in total distance: 120600 km
- DAF CF average fuel consumption: 0.22 l/km
- DAF CF purchase price: 100000 €

[55] The longest distance has been registered for the EFVs in Rotterdam. For the conventional vehicles, the longest registered distance is approximately 110 km (both for Amsterdam as well as for Rotterdam).
[56] This is a typical range. Under worst case conditions, the range is expected to be significantly reduced.
[57] This is an average daily (median in Figure 32 and Figure 36) distance already for an upscaled situation. The EFVs monitored in the FREVUE pilot were traveling on average little more than 60 km per day. It was however observed that this operation can easily be extended by driving the other inner-city routes also.

- DAF CF maintenance costs during depreciation period: 9000 €
- Ginaf average energy consumption: 0.77 kWh/km
- Ginaf purchase price: 220000[58] €
- Ginaf maintenance costs during depreciation period: 9000 €

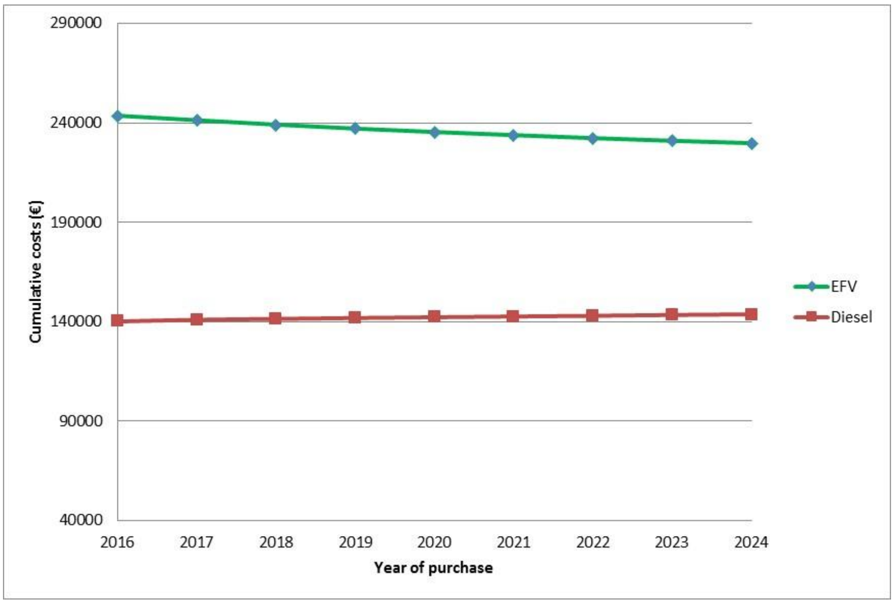

Figure 96: Cumulative cost comparison between the DAF CF (diesel) and Ginaf for an 8 year depreciation period, as a function of the vehicle purchase date

From Figure 96, it can be observed that currently there is a gap of approximately 103k € to bridge to obtain a comparable TCO situation. With the expected price developments of the battery system, this gap is expected to shrink by approximately 17k € to approximately 86k €. With this information, it is possible to answer the question under which EFV purchase price conditions the TCO balance would become positive when compared with a conventional fleet of diesel vehicles. This information is expressed in Figure 97.

In Figure 97 the horizontal axis represents the year of vehicle purchase. The vertical axis represents the price difference between an EFV and a conventional vehicle that is allowed for an equal TCO after the depreciation period[59].

Figure 97 reveals that a difference in purchase price, ranging from 10k € up to 23k € may be justified from a TCO perspective. The difference in purchase price depends on the depreciation period (indicated by separate trend lines) and the year of purchase (which determines the expected increase in energy prices and therefore the expected increase in

[58] For the future projection, the purchase costs for the Ginaf were reduced by the expected (nominal) price reduction of its battery pack of 120 kWh. Other costs were presumed to remain the same.
[59] This analysis does not take the costs for acquiring the extra CAPEX into account. This means that in reality the allowed price difference may be somewhat smaller, especially in the case of longer presumed depreciation periods.

energy price differences, which explain the upward trends of the trend lines[60]). This purchase price of the battery pack is (implicitly) part of the mentioned price range.

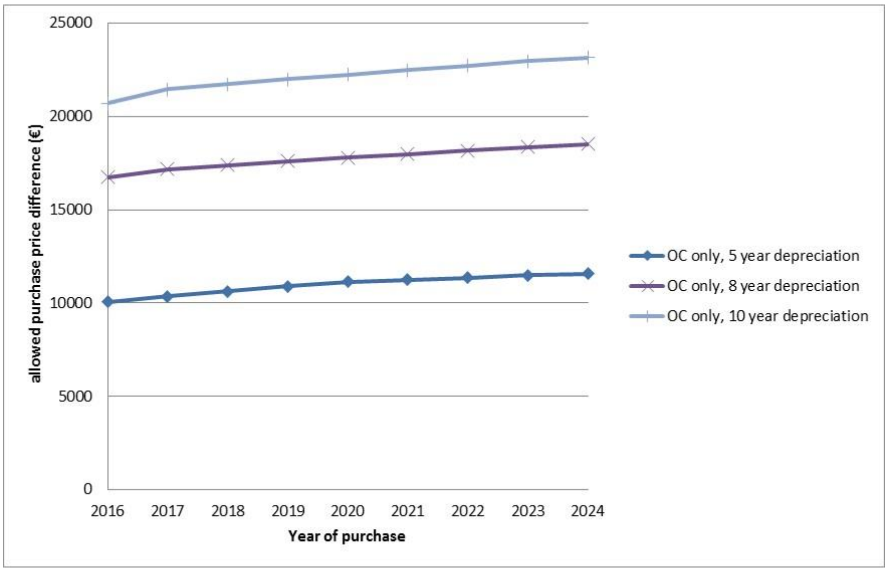

Figure 97: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with Overnight Charging only)

Sensitivity analysis on energy costs

As the electricity and diesel prices will have a significant effect on the allowed price difference (between a conventional freight vehicle and an EFV) for reaching an equal TCO after a given/presumed depreciation period, it is worth considering both an optimistic as well as a pessimistic energy price scenario for the EFV. For this purpose, the Swedish and German price scenarios as sketched in section 5.23 and section 5.24 will be used.

With the Swedish energy price scenario, the allowed price difference is shown in Figure 98. With the German energy price scenario, the allowed price difference is shown in Figure 99. From these figures (in which the nominal battery price scenario is assumed) it can be observed that in Sweden a price difference of around 28k € is allowed for a depreciation time of 8 years, whereas in Germany the price difference need to be smaller than 3.5k € in order to earn back the extra investment in the EFV within 8 years. This is a significant difference.

[60] Note: if a vehicle is purchased in 2017 and is depreciated for 8 years, then the average energy prices from 2017 up to 2024 are considered. If a vehicle would be purchased in 2021, then only the average of the energy prices from 2021 up to 2024 will be considered, whereas it should have been up to 2028. Therefore, if energy prices would increase (beyond typical inflation rates), then the trendlines from Figure 84 would have shown a steeper inclination. Predictions beyond 2024 are however not considered in this report!

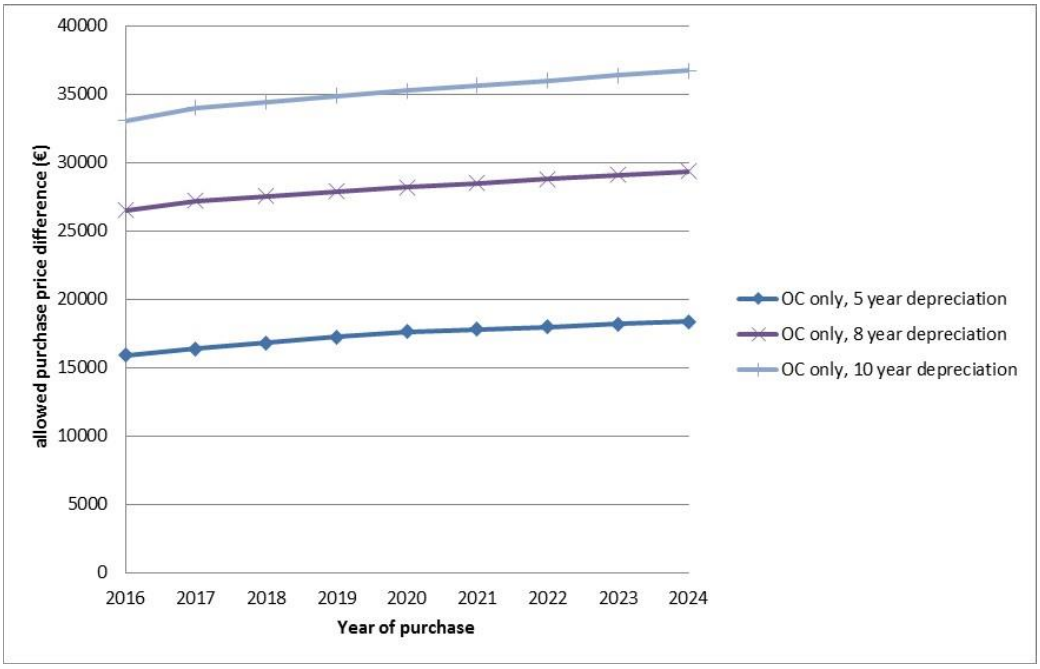

Figure 98: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Sweden)

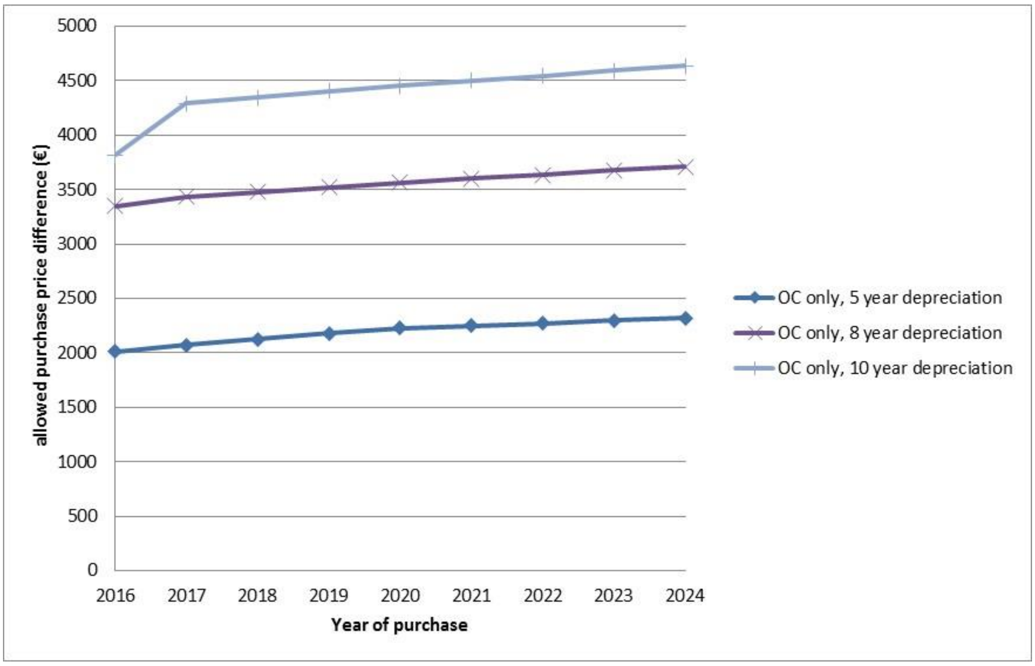

Figure 99: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Germany)

Budget for converting a conventional vehicle into an EFV

Now, let's go back to the nominal (European average) energy price scenario. In this case the battery pack capacity is known and also price projections for such battery pack can be provided. This is why Figure 97 can be extended, thereby incorporating information about the battery purchase costs. In the case that the initial battery pack purchase costs are already taken into account, then the budget available for converting the original conventional vehicle (Mercedes Atego) into an EFV (Ginaf) can be estimated/calculated. The latter is visualized in Figure 100.

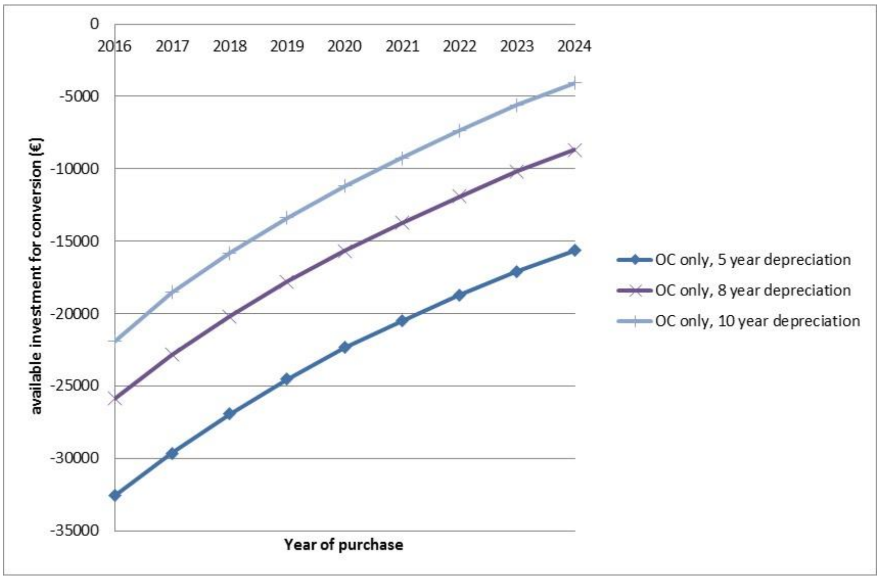

Figure 100: Available budget for converting a Mercedes Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included)

From Figure 100 it can be observed that, under the presumed conditions, a depreciation time of even 10 years is not feasible even with the additional restriction that the production costs for the electric vehicle without the battery pack will not be higher than the production costs of the conventional vehicle. With the current situation, where conversion companies are the only commercial parties providing EFV solutions, this is not a financially feasible situation.

However, in the case that energy (fuel and electricity) costs increase (in a similar way), then more budget will be available for the conversion. Also, it is believed that the transition to an in-series produced vehicle will result in an ex-battery vehicle which has a price that is comparable with the price of a conventional vehicle.

Sensitivity analysis on battery pack pricing

Given the information provided above, a sensitivity analysis can be performed on one of the main contributors to the EFV price: the battery price. Presuming little price difference between an in-series produced conventional vehicle and an in-series produced electric vehicle without battery system, this sensitivity analysis is considered to be important for the 2019-2024 timeframe (in which the first in-series produced EFV are expected). For this purpose both the pessimistic as well as the optimistic battery price scenarios (as visualized in Figure 80) are determined and expressed by Figure 101 and Figure 102 respectively.

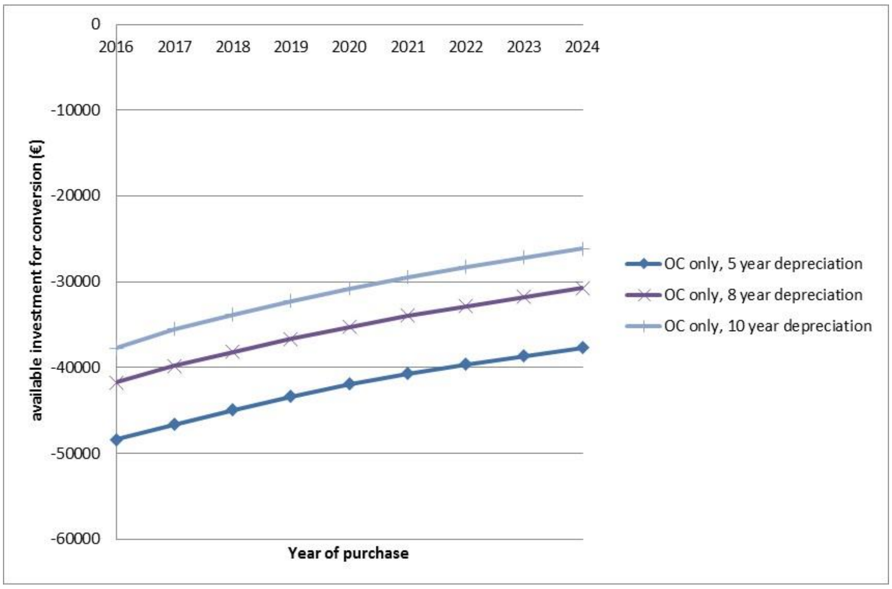

Figure 101: Available budget for converting a Mercedes Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a pessimistic battery price scenario

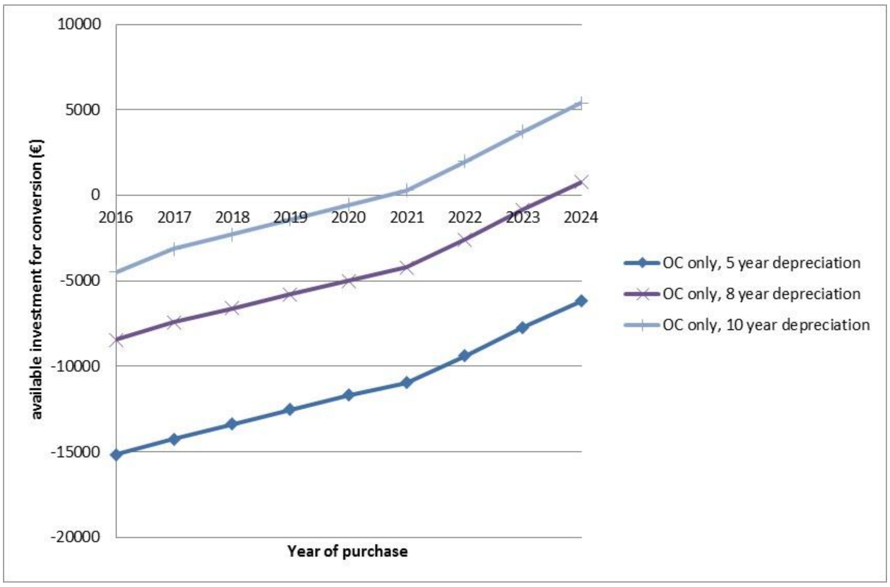

Figure 102: Available budget for converting a Mercedes Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming an optimistic battery price scenario

From Figure 101 it can be observed that for the pessimistic scenario, presuming the Heineken operation and presuming no incentives, there will not even be a positive business case for an in-series produced EFV, regardless of the depreciation period.

From the optimistic scenario from Figure 102 it can be concluded that an in-series produced EFV may become economically feasible for the considered application as of 2021 for a 10 year depreciation period. For an 8 year depreciation period an economically feasible situation is expected after 2024.

Worth mentioning in this context is that it is expected that there will be a strong and negative correlation between production series and battery price. It is therefore believed that the negative battery pack price scenario is more likely to be applicable for the in small series produced EFV, whereas the positive battery pack price scenario is more likely applicable for the in-series produced EFV.

For the heavier EFVs (13 tonne class and above) it is however expected that a standardisation of battery packs may help the OEMs produce these standardized packs to reach high volumes, from which the companies that convert these freight vehicles into EFVs may also benefit.

Generalized profitability assessment for 13 ton EFV case

Given the restriction of the GVW of the considered 13 tonne class vehicles, there will be - even for optimistic battery price scenarios - little possibility for extending its practical range beyond 150 km, as the current payload of the Ginaf is already significantly reduced (from 8230 to 7500 kg).

This means that the vehicle's range of approximately 156 km is considered as a quite representative maximum range for a 13 tonne class EFV. The daily range of this 13 tonne EFV can however be extended by opportunity charging. In general it can be said that if opportunity charging events can be fitted both in time and location with fast charging events without affecting the normal operation (e.g. during loading, unloading, rest breaks of the driver), then the penalty for fast charging can remain limited to a higher cycle life of the battery and a higher price for electricity[61]. In this context, Heineken Amsterdam indicated that every truck has two routes per day. At the DC possibilities for (fast) charging could be put in place. In Rotterdam the trucks have typically one route per day, but there the payload limitation is more critical. Also here it is expected that it would be fairly easy to use the 30 minutes lunch break of the driver for fast charging its EFV.

Let's therefore consider the case where the 58 km/day operation stays the same, but the battery size is reduced to 60 kWh (i.e. half of the original capacity) and is recharged halfway the daily operation. Also consider (from this point onwards) the nominal battery price scenario again.

From Figure 103 (compared with Figure 100[62]) it can be observed that reducing the battery size significantly helps the TCO. The reduced investment in battery capacity may be used to reach a positive business case and/or to reach a positive business case with a shorter depreciation time.

Worth mentioning here is that a Ginaf truck with a 60 kWh battery will already be able to drive more than 70% of the daily operations without opportunity charging. As fast charged energy will be somewhat more expensive, the available budget for conversion will therefore be somewhat higher than indicated in Figure 103.

[61] Incorporating the depreciation of the fast charging equipment; see also section 5.23.

[62] Figure 104 contains both plots, which makes the comparison easier

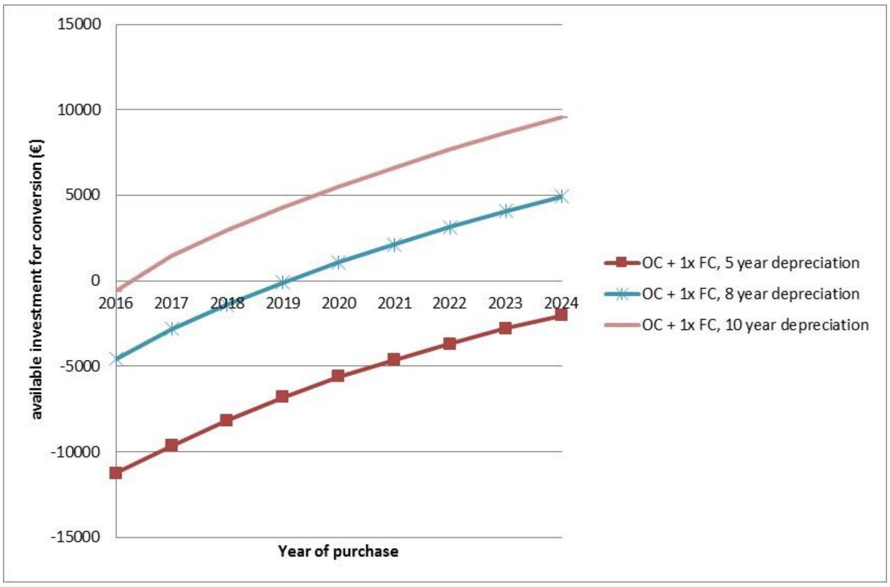

Figure 103: Available budget for converting a Mercedes Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a 60 kWh battery system with 1x Overnight Charging and 1x Fast Charging

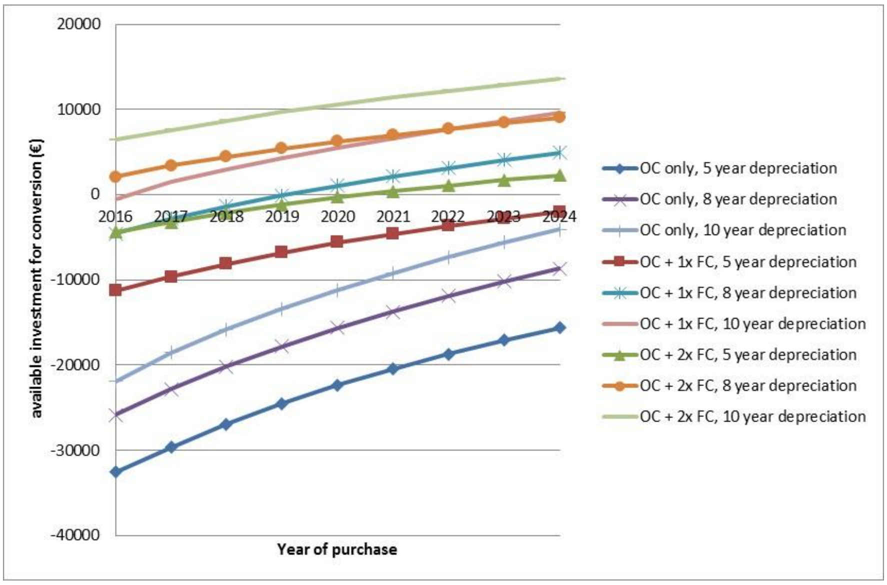

Figure 104: Available budget for converting a Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming the 120 kWh battery (OC only), the 60 kWh battery (1xFC) and the 30 kWh battery (2x FC)

In Figure 104 the information from Figure 100 is combined with the information from Figure 103 and extended with the EFV configuration with an even smaller battery capacity of 30 kWh, possibly requiring 2x fast charging to approximately 80% of the full battery capacity. From Figure 104 it can be observed that further decreasing the battery capacity to 30 kWh will decrease the TCO for the EFV somewhat further.

The question may rise on what will happen in the case that the EFV will be used to drive more kilometres?

Let's first consider an operation that allows the Ginaf trucks to drive on average 145 km/day (which is very close to the range of this vehicle), instead of the earlier presumed 58 km/day. This will result in the situation as expressed by Figure 105.

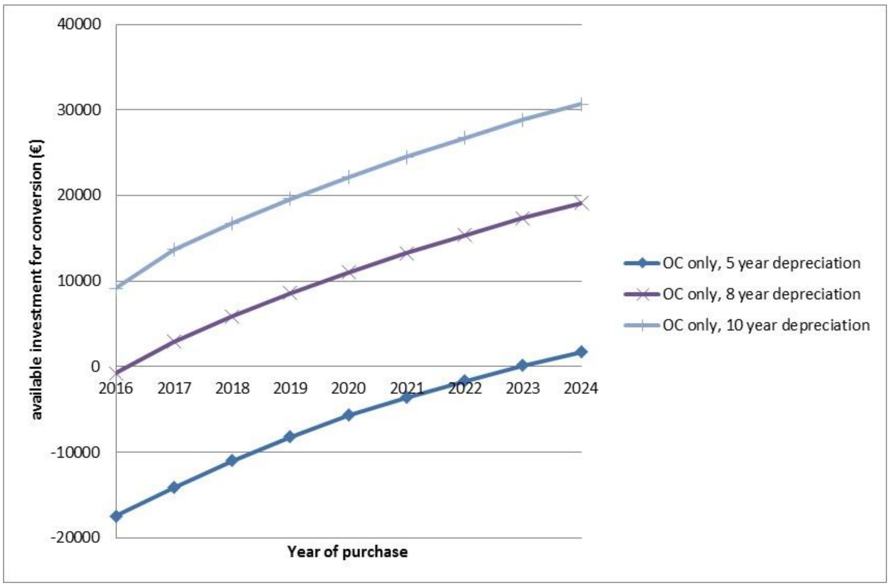

Figure 105: Available budget for converting a Atego into a Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming the optimistic battery price scenario and presuming an average daily distance of 145 km

From Figure 105 (compared with Figure 100) it can be observed that driving more kilometres combined with presuming low battery prices, helps a lot in reaching a positive TCO for electric vehicles.

However, assuming that the conversion costs for a conversion company will never be significantly lower than 50k € and assuming that there are no other incentives/enablers (like tax reductions, extended time windows for operating emission free vehicles i certain areas, etc.), based on Figure 105 it does not seem realistic to provide a positive business case for conversion companies.

From this it can also be concluded that when driving less kilometres per day the possibilities for obtaining a positive TCO will be further reduced.

For longer daily routes with the 13 tonne EFV it was already concluded that opportunity charging would be the only option. In Figure 106 the situation for a daily route of 400 km is sketched, thereby presuming the 120 kWh battery from the Ginaf trucks (as described earlier) to be recharged twice to perform the 400 km operation.

From Figure 106 it can be observed that this longer daily operation significantly contributes to a positive TCO. With this operation battery replacement will typically be required, although for the 5 year depreciation case there is no battery replacement required from 2018 onwards[63]. For the 10 year depreciation case it is expected that if the EFV would have been purchased in 2016 or 2017, even 2 battery replacements would be required.

[63] The curve for the 5 year depreciation time is less steep, because no battery replacement is required and therefore there will be less benefit from the projected battery price reduction

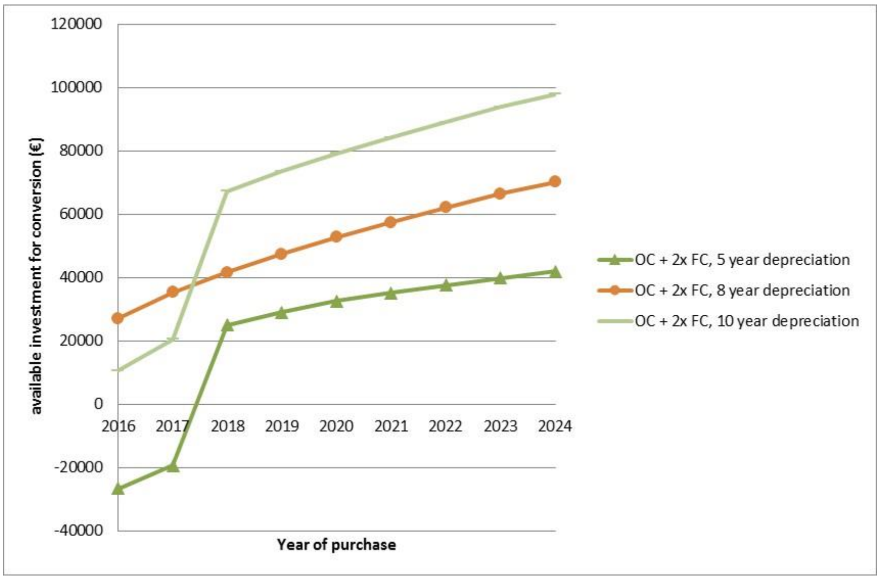

Figure 106: Available budget for converting a Atego into an Ginaf for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming 400 km/day, a 120 kWh battery and 2x per day Fast Charging

Figure 107 reveals that, presuming a 400 km daily operation and 8 year depreciation, there may be a positive business case for a € 220,000 EFV from 2024 onwards, with the restrictions that the EFV battery is capable of charging 2C, that there are easy possibilities within the operation to recharge the EFV 2x per day and that (commercial) fast chargers are available.

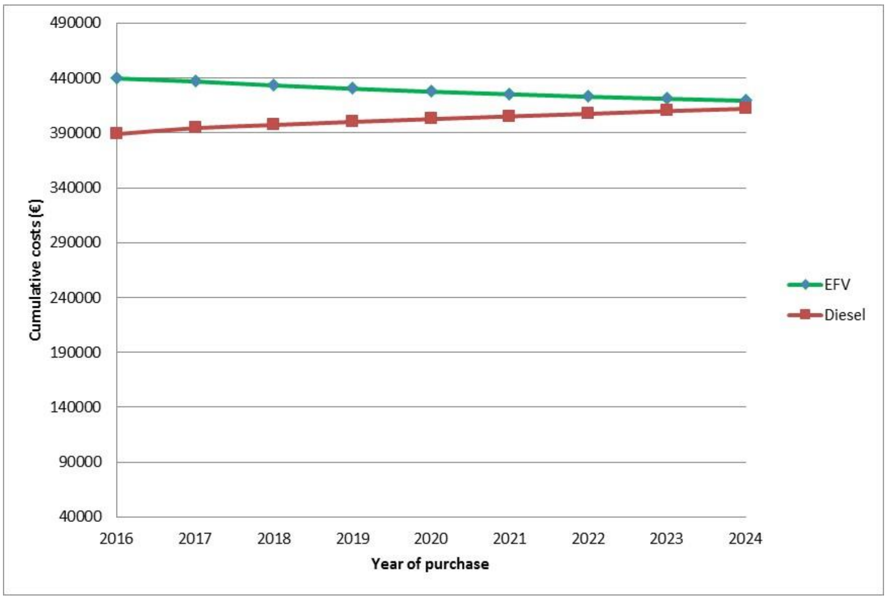

Figure 107: Cumulative cost comparison between the DAF CF and Ginaf (400 km/day)

To complete the analysis for the 13 tonne distribution truck, a mileage vs. saving relation is provided in Figure 108. Here the horizontal axis represents the amount of kilometres driven during the depreciation period. The vertical axis shows the savings in energy costs during these kilometres. This relation is determined by:

- the projection of the diesel price: see Table 20
- the DAF CF average fuel consumption: 0.22 l/km
- the projection of the electricity prices: Table 17

* Ginaf average energy consumption: 0.77 kWh/km

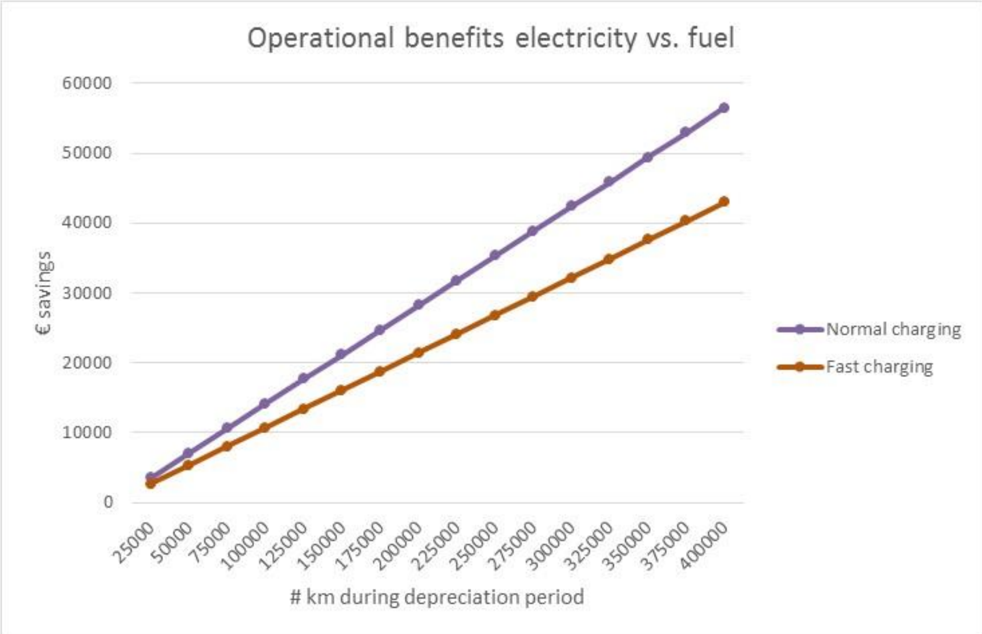

Figure 108: Operational benefits electricity vs. fuel as presumed in this report

5.33 BREYTNER scenario assessment (19 ton class EFVs)

Baseline operation assessment: operational time

The operational time for the 19 tonne vehicle class was obtained from FREVUE partner BREYTNER. From this partner, only the operational time was registered and not the driving time (see Figure 38).

From BREYTNER themselves it became clear that for fashion (clothing) transport there are at least two intermediate stops for container swapping, which takes between 5 and 10 minutes, from which one stop may be combined with the lunch break of the driver. Therefore, an analysis again presuming 1 and/or 2 fast charging events seems feasible.

BREYTNER is currently also delivering to customers from residential warehouses. This operation was not covered by the FREVUE measurements, but is interesting from an upscaling perspective, since it typically involves higher payloads and more highway usage, resulting in higher energy consumption.

Baseline operation assessment: operational distance

The total operational distance per day is important to assess battery sizing in terms of the required range (maximum distance), as well as to calculate TCO-related figures (average distance). The total operational distance for the 19 tonne vehicles operated by BREYTNER is shown in Figure 38 as well.

In the right part of this figure, the top boundary of the dotted line is representing the operational distance for 99.65% of the monitored urban conventional vehicle fleet. With a value of 215 km, this is very close to the range of the current EMOSS fleet (which have a

200 kWh battery system and an expected range in access of 220 km[64]). As BREYTNER does not have conventional trucks, no conclusions can be drawn on range requirements for upscaling. It is however clear that, considering the residential warehouse operation it is not desirable to further reduce the payload. On the other hand the delivery need to be carefully planned, ensuring a good balance between cargo management (heaviest freight delivered first) and route management (lowest energy round trip).

Profitability assessment

For the BREYTNER operations (Rotterdam), 2 EMOSS trucks with a 200 kWh battery capacity and a range of approximately 220 km are deployed. The current (2016) purchase costs for the baseline vehicle (MAN TGM) is estimated to be around € 110,000, whereas the current (2016) purchase costs for EMOSS truck will be around € 290,000.

Presuming the nominal battery price scenario from section 5.2, the EMOSS truck is expected to become less expensive over time. How the price is projected to evolve is expressed in Table 24.

Table 25 19 tonne vehicle investment price (nominal battery scenario, small series)

	year of purchase								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
FEV purchase price (k€)	300	296	292	288	285	282	279	277	274

The resulting cumulative costs, thereby presuming an 8 year depreciation period and presuming the energy prices from section 5.2, are shown in Figure 109.

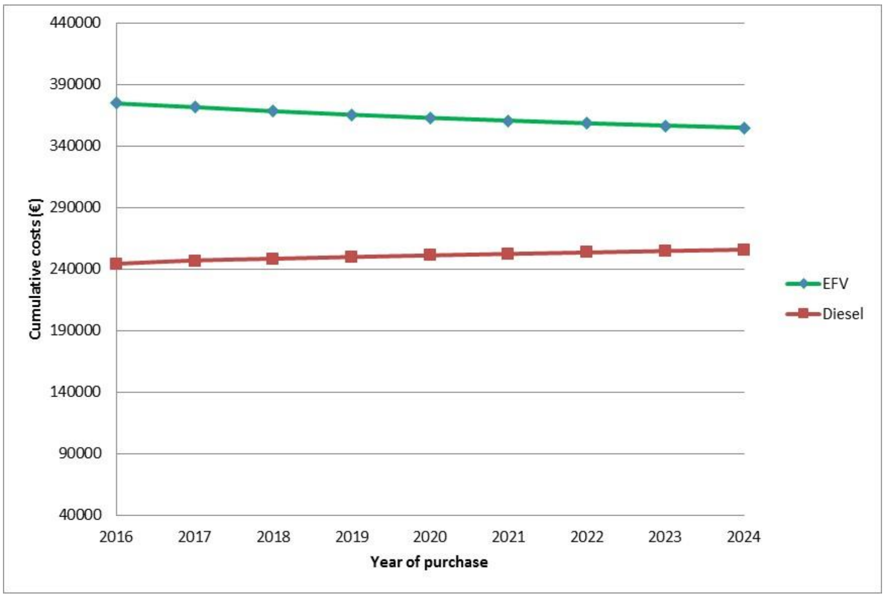

Figure 109: Cumulative cost comparison between the MAN TGM and EMOSS for an 8 year depreciation period, as a function of the vehicle purchase date

For Figure 109 the following assumptions were made:

- Distance per day: 173 km[65]
- Days of operation per year: 260

[64] This is a typical range. Under worst case conditions, the range is expected to be significantly reduced.
[65] This is an average daily (median in Figure 38) distance.

- Depreciation time: 8 years
- Resulting in total distance: 359800 km
- MAN TGM average fuel consumption: 0.26 l/km
- MAN TGM purchase price: 110000 €
- MAN TGM maintenance costs during depreciation period: 24000 €
- EMOSS average energy consumption: 0.91 kWh/km
- EMOSS purchase price: 296000[66] €
- EMOSS maintenance costs during depreciation period: 24000 €

From Figure 108, it can be observed that currently there is a gap of 131k € to bridge to obtain a comparable TCO situation. With the expected price developments of the battery system, this gap is expected to be reduced by approximately 32k € to approximately 99k €.

With this information, it is possible to answer the question under which EFV purchase price conditions the TCO balance would become positive when compared with a conventional fleet of diesel vehicles. This information is expressed in Figure 110.

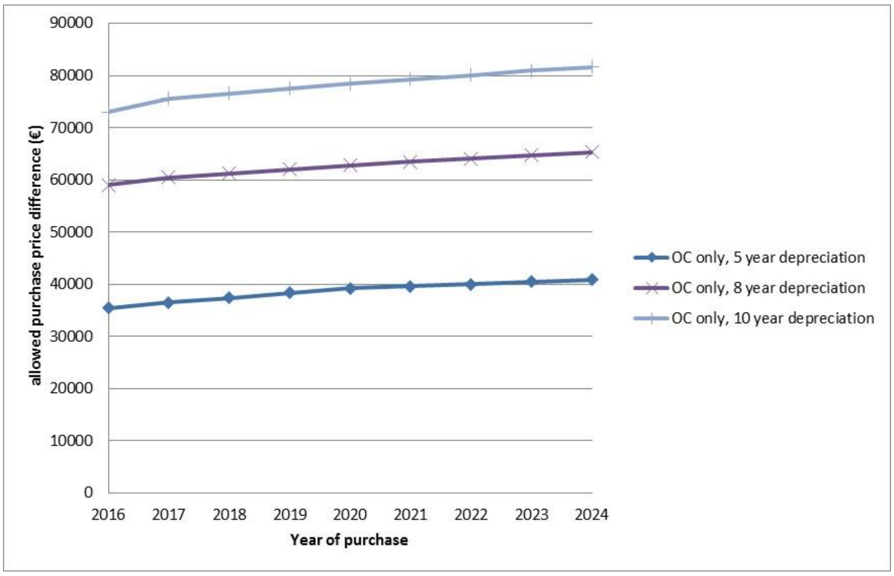

Figure 110: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with Overnight Charging only)

In Figure 110 the horizontal axis represents the year of vehicle purchase. The vertical axis represents the price difference between an EFV and a conventional vehicle that is allowed for an equal TCO after the depreciation period[67].

Figure 110 reveals that a difference in purchase price, ranging from 35k € up to 82k € may be justified from a TCO perspective. This difference in purchase price depends on the depreciation period (indicated by separate trend lines) and the year of purchase (which determines the expected increase in energy prices and therefore the expected increase in

[66] For the future projection, the purchase costs for the EMOSS were reduced by the expected (nominal) price reduction of its battery pack of 200 kWh. Other costs were presumed to remain the same.

[67] This analysis does not take the costs for acquiring the extra CAPEX into account. This means that in reality the allowed price difference may be somewhat smaller, especially in the case of longer presumed depreciation periods.

energy price differences, which explain the upward trends of the trend lines[68]). This purchase price of the battery pack is (implicitly) part of the mentioned price range.

Sensitivity analysis on energy costs

As the electricity and diesel prices will have a significant effect on the allowed price difference (between a conventional freight vehicle and an EFV) for reaching an equal TCO after a given/presumed depreciation period, it is worth considering both an optimistic as well as a pessimistic energy price scenario for the EFV. For this purpose, the Swedish and German price scenarios as sketched in section 5.23 and section 5.24 will be used.

With the Swedish energy price scenario, the allowed price difference is shown in Figure 111. With the German energy price scenario, the allowed price difference is shown in Figure 112. From these figures (in which the nominal battery price scenario is assumed) it can be observed that in Sweden a price difference of around 100k € is allowed for a depreciation time of 8 years, whereas in Germany the price difference need to be smaller than 13k € in order to earn back the extra investment in the FEV within 8 years. This is a significant difference.

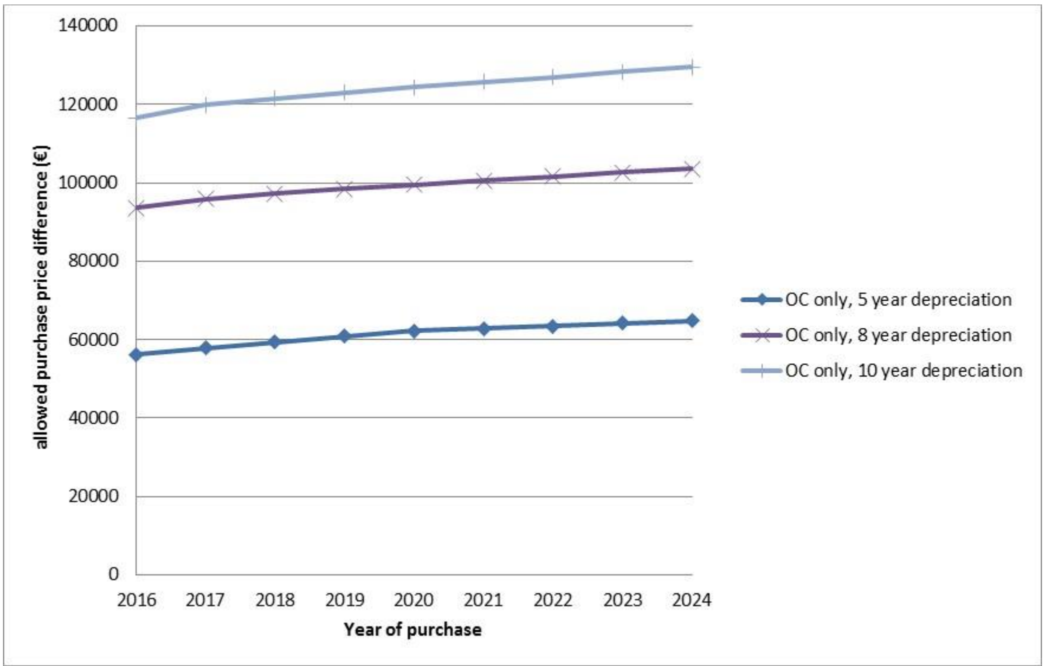

Figure 111: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Sweden)

[68] Note: if a vehicle is purchased in 2017 and is depreciated for 8 years, then the average energy prices from 2017 up to 2024 are considered. If a vehicle would be purchased in 2021, then only the average of the energy prices from 2021 up to 2024 will be considered, whereas it should have been up to 2028. Therefore, if energy prices would increase (beyond typical inflation rates), then the trendlines from Figure 113 would have shown a steeper inclination. Predictions beyond 2024 are however not considered in this report!

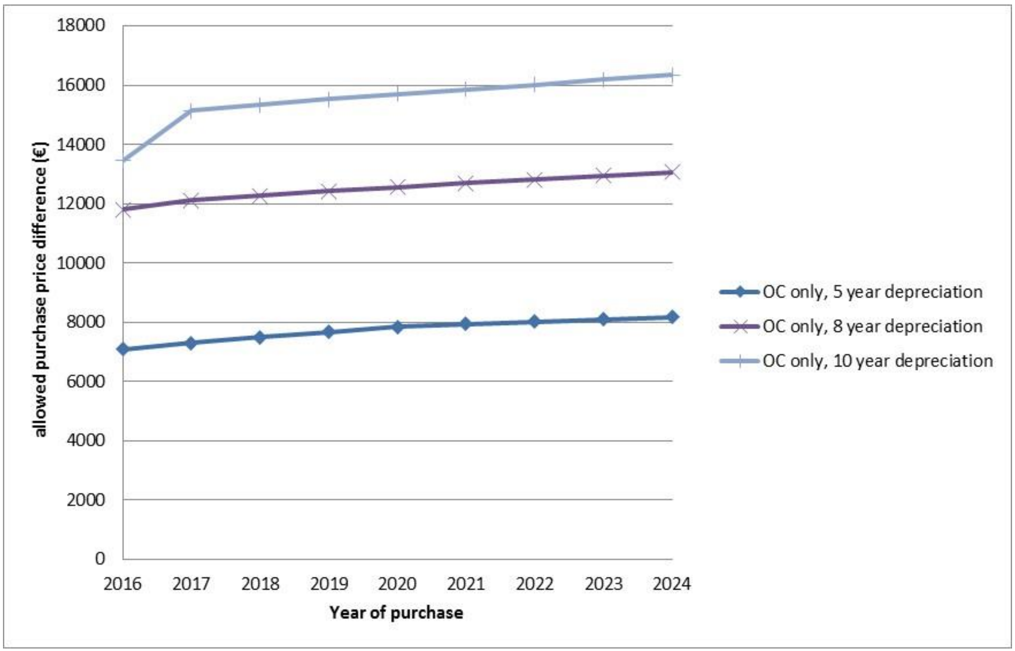

Figure 112: Allowed conventional- vs. EFV-purchase price difference for an equal TCO (with overnight charging only, Germany)

Budget for converting a conventional vehicle into an EFV

Now, let's go back to the nominal (European average) energy price scenario. In this case the battery pack capacity is known and also price projections for such battery pack can be provided. This is why Figure 110 can be extended, thereby incorporating information about the battery purchase costs. In case that the initial battery pack purchase costs are already taken into account, then the budget available for converting the original conventional vehicle (MAN TGM) into a EFV (EMOSS) can be estimated/calculated. The latter is visualized in Figure 113.

From Figure 113 it can be observed that, under the presumed conditions, a depreciation time of 8 years seems feasible from 2019 onwards with the additional restriction that the production costs for the electric vehicle without the battery pack are not higher than the production costs of the conventional vehicle. This may be the case for an in-series produced vehicle. However in the current situation, the conversion companies are the only commercial parties providing EFV solutions. As these companies are presumed to invest more than 80k € in the electrification of a truck of this size, there seems to be no business case for the considered operation from a conversion company's perspective.

However, in the case that energy (fuel and electricity) costs increase (in a similar way), then more budget will become available for the conversion (presuming an equal TCO for the conventional vehicle and the EFV). Next to this, it is believed that the transition to an in-series produced vehicle will result in an ex-battery vehicle which has a price that is comparable with the price of a conventional vehicle.

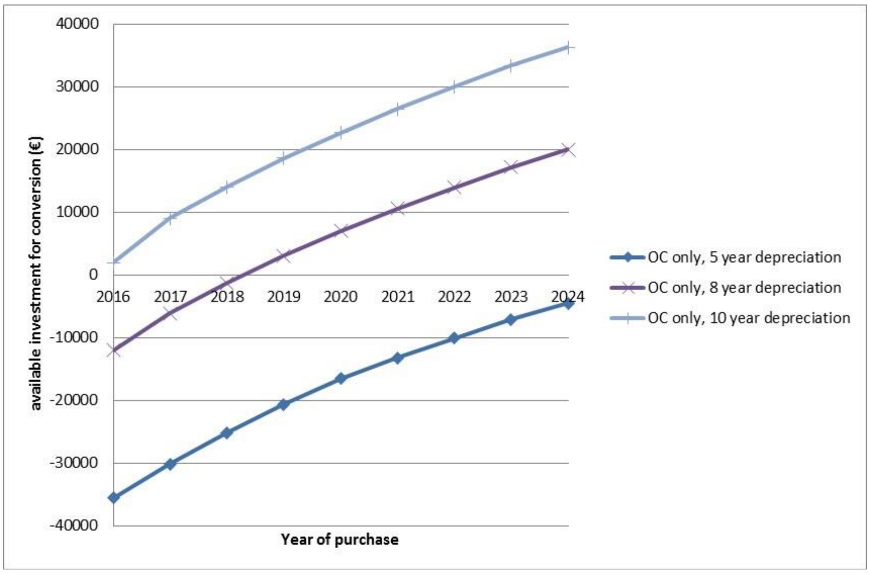

Figure 113: Available budget for converting a MAN TGM into an EMOSS CM-1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included)

Sensitivity analysis on battery pack pricing

Given the former information, a sensitivity analysis can be performed on one of the main contributors to the EFV price: the battery price. Presuming little price difference between an in-series produced conventional vehicle and an in-series produced electric vehicle without battery system, this sensitivity analysis is considered to be important for the 2019-2024 timeframe (in which the first in-series produced EFV are expected). For this purpose both the pessimistic as well as the optimistic battery price scenarios (as visualized in Figure 80) are determined and expressed by Figure 114 and Figure 115 respectively.

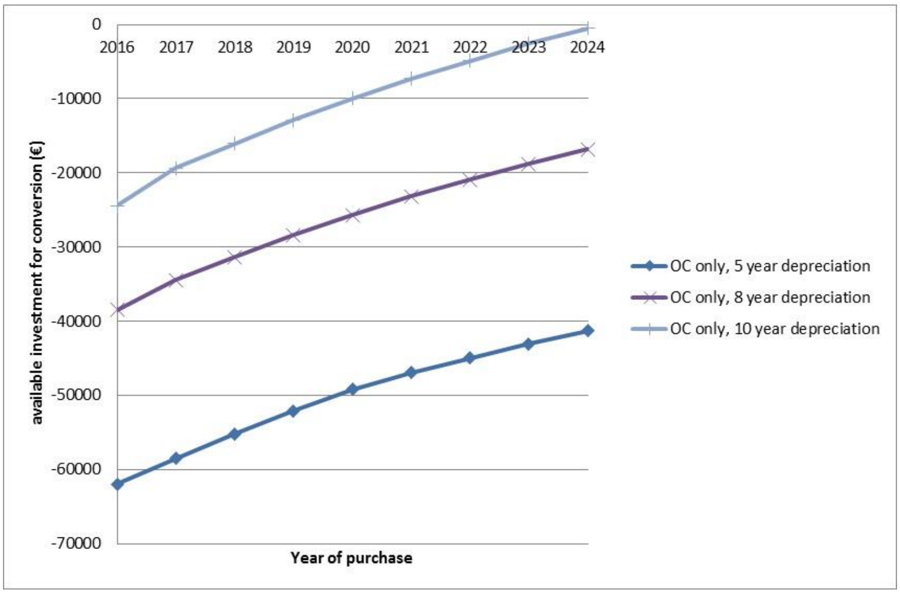

Figure 114: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a pessimistic battery price scenario

From Figure 114 it can be observed that for the pessimistic scenario, based on the BREYTNER fashion operation and no incentives, there may only exist a positive business case for an in-series produced EFV, purchased beyond 2024 and thereafter depreciated with a 10 year depreciation period.

From the optimistic scenario from Figure 115 it can be concluded that an in-series produced EFV is already economically feasible as of 2019, even when combined with a 5 year depreciation period, or already from 2017 with a 6 year depreciation period. Presuming the BREYTNER fashion operation, there may be a business case for the conversion companies as well, but only when combined with a long depreciation period (10 years) and further reduced purchase and production costs.

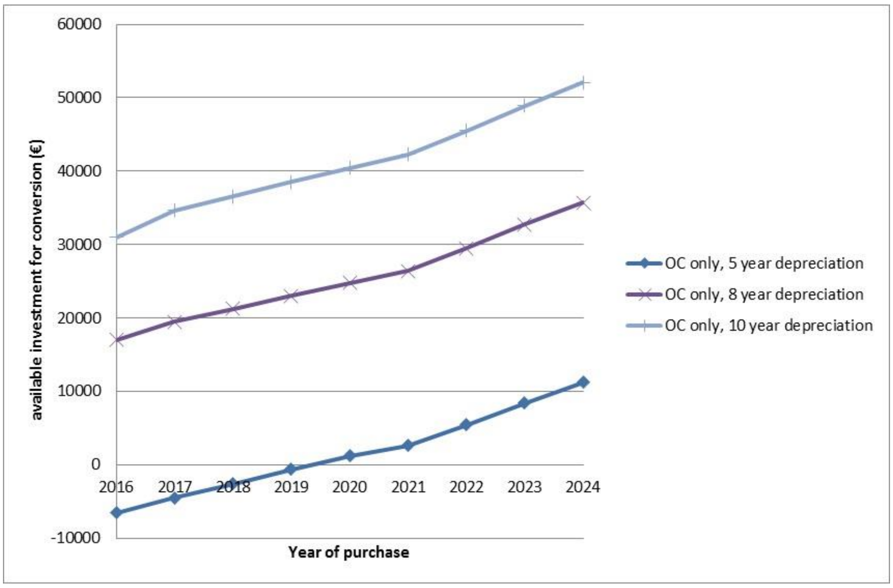

Figure 115: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming an optimistic battery price scenario

Worth mentioning in this context is that it is expected that there will be a strong and negative correlation between production series and battery price. It is therefore believed that the negative battery pack price scenario is more likely to be applicable for the in small series produced EFV, whereas the positive battery pack price scenario is more likely applicable for the in-series produced EFV.

For the heavier EFVs (13 tonne class and the 19 tonne class) it is however expected that a standardisation of battery packs may help the OEMs produce these standardized packs to reach high volumes, from which the companies that convert these freight vehicles into EFVs may also benefit.

Generalized profitability assessment for the 19 ton EFV case

Also for the 19 tonne class EMOSS EFV the payload can be a critical factor (for residential warehouse services the amount of deliveries may sometimes be payload limited, which may result in suboptimal logistics). Increasing the already large and heavy battery system is less desirable. This means that (without having access to significantly higher density battery systems that have competitive lifetimes and costs) extending this 19 tonne EFVs range significantly beyond the 220 km is not a likely option.

This means that also for this case the vehicle's current range of approximately 220 km is considered as a representative maximum range for a 19 tonne class EFV.

If desired, the daily range of this 19 tonne EFV can be extended by opportunity charging. In general it can be said that if opportunity charging events can be fitted both in time and location with fast charging events without affecting the normal operation (e.g. during loading, unloading, rest breaks of the driver), then the penalty for fast charging can remain limited to a higher cycle life of the battery and a higher price for electricity[69]. In this context, BREYTNER indicated that every truck will make at least 2 intermediate stops at fixed locations per day: i.e. at the hubs where containers are swapped. Swapping containers takes 5 to 10 minutes. The first swap will typically take place at 7:00pm (start of the operation is 6:00pm). The second container swap takes place around 11:30pm. At these places it is possible to apply opportunity charging. The second stop may be combined with the lunch break of the driver, allowing more time for charging (30 minutes is presumed).

Let's therefore consider the case where the 173 km/day operation stays the same, but the battery size is reduced to 100 kWh (i.e. half of the original capacity) and is recharged halfway through the daily operation. Also consider (from this point onwards) the nominal battery price scenario again.

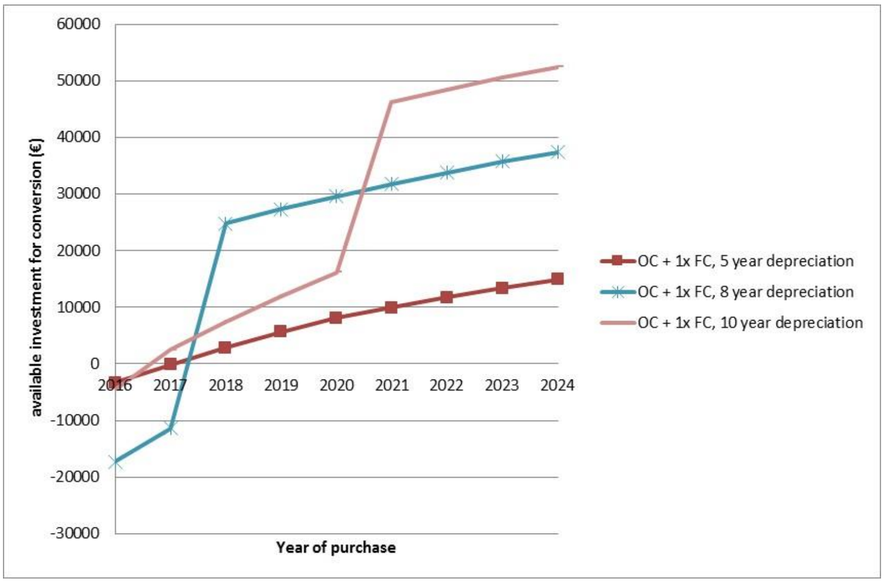

Figure 116: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming a 100 kWh battery system with 1x Overnight Charging and 1x Fast Charging

From Figure 116 (compared with Figure 113[70]) it can be observed that reducing the battery size improves the TCO for the EFV. The reduced investment in battery capacity may be used to reach a positive business case and/or to reach a positive business case with a shorter depreciation time.

Worth mentioning here is that already with 1x fast charging, combined with a depreciation time of 8 years or longer, the battery needs a replacement. More specifically, if the battery system is purchased before 2018 (8 year depreciation), or before 2021 (10 year

[69] Incorporating the depreciation of the fast charging equipment; see also section 5.23.

[70] Figure 117 contains both plots, which makes the comparison easier

depreciation), then replacement will be required. When opportunity charging is considered, then it will become more important to consider the cycle life of the used battery system.

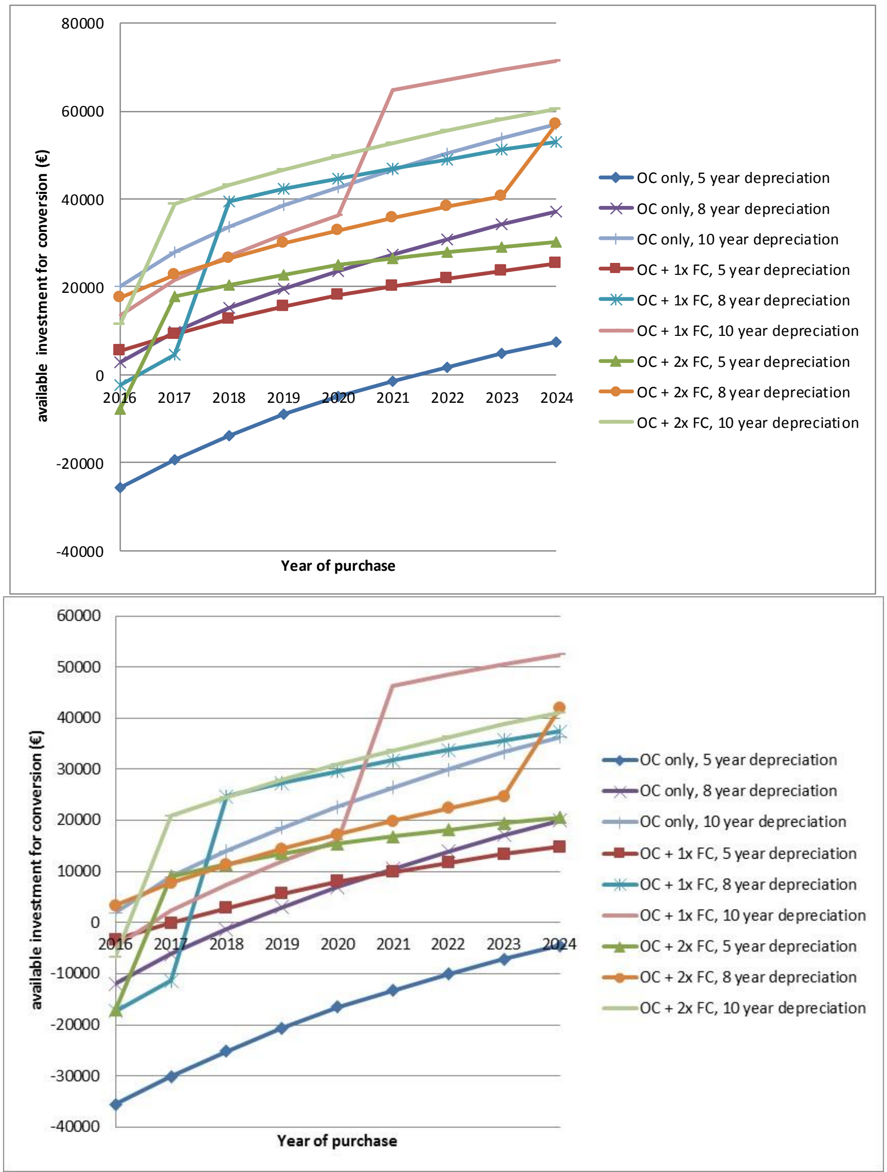

Figure 117: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming the 200 kWh battery (OC only), the 100 kWh battery (1xFC) and the 67 kWh battery (2x FC)

In Figure 117 the information from Figure 113 is combined with the information from Figure 116 and extended with the EFV configuration with an even smaller battery capacity of 67 kWh, probably requiring 2x fast charging to approximately 80% of the full battery capacity. From Figure 117 it can be observed that further decreasing the battery capacity to 67 kWh will decrease the TCO for the EFV somewhat further.

The question may rise on what will happen in the case that the EFV will be used to drive more kilometres?

Let’s first consider an operation that allows the EMOSS EFVs to drive on average 200 km/day (which is very close to the range of this vehicle), instead of the earlier presumed 173 km/day. This will result in the situation as expressed by Figure 118.

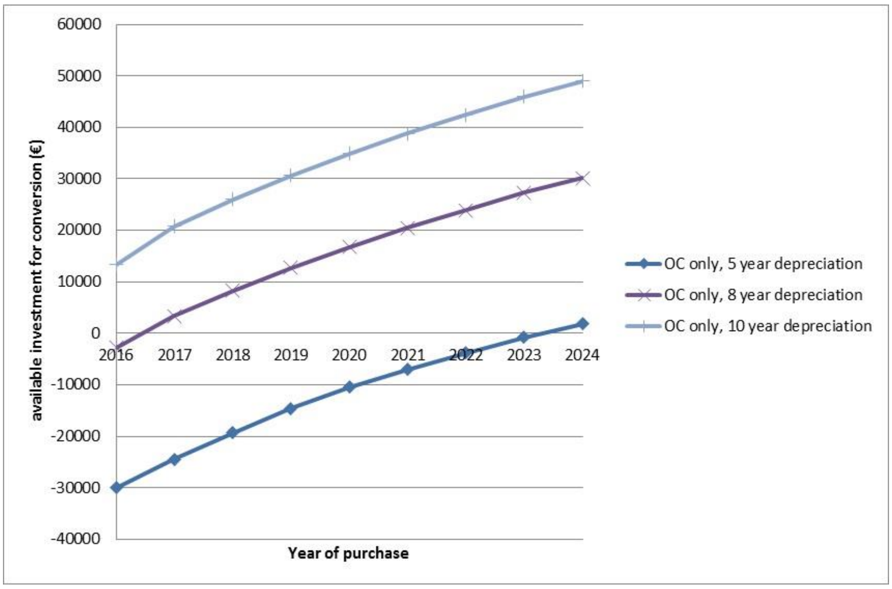

Figure 118: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming an average daily distance of 200 km

From Figure 118 (compared with Figure 113) it can be observed that driving more kilometres significantly contributes to reaching a positive TCO for electric vehicles.

However, assuming that the conversion costs for a conversion company will never be significantly lower than 80k € for this type pf vehicle and assuming that there are no other incentives/enablers (like tax reductions, extended time windows for operating emission free vehicles is certain areas, etc.), observing Figure 118 it seems to be impossible to provide a positive business case for conversion companies.

Based on the above it can also be concluded that when driving less kilometres per day the possibilities for obtaining a positive TCO will be further reduced.

For longer daily routes with the 19 tonne EFV it was already concluded that opportunity charging would be the only option. In Figure 119 the situation for a daily route of 500 km is sketched, thereby presuming the 200 kWh battery from the EMOSS EFVs (as described earlier) to be recharged twice to perform the 500 km operation.

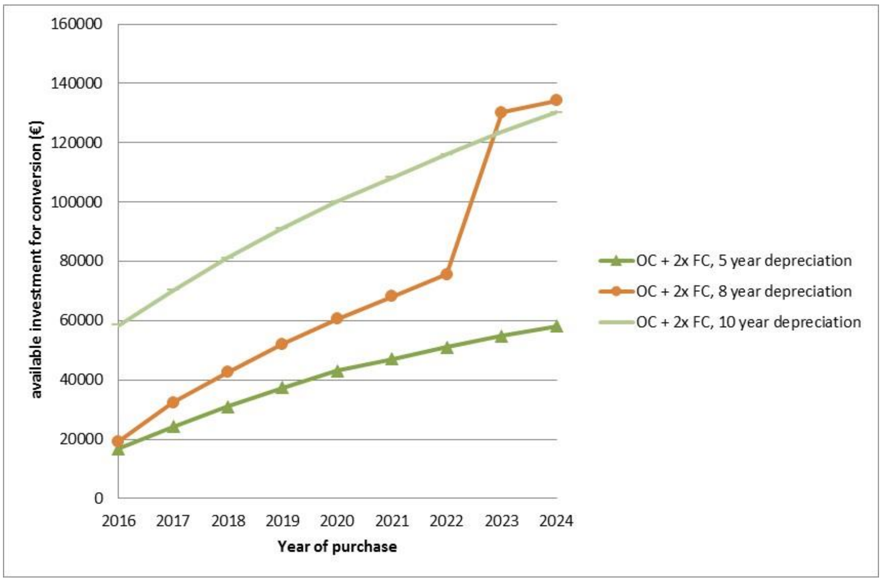

Figure 119: Available budget for converting a MAN TGM into an EMOSS CM 1820 for obtaining an equal TCO after the mentioned depreciation period (battery costs already included), thereby presuming 500 km/day, a 200 kWh battery and 2x per day Fast Charging

From Figure 119 it can be observed that this longer daily operation is really positive for the TCO. With this operation 1x battery replacement will be required in case the battery is depreciated over 10 years. For an 8 year depreciation period, replacement is expected to be required in the case that the EFV (battery) is purchased before 2023[71].

Figure 119 reveals that, presuming a 500 km daily operation and 8 year depreciation, there is a positive business case for a € 290,000 EFV from 2023 onwards, with the restrictions that the EFV battery is capable of charging 2C, that there are easy possibilities within the operation to recharge the EFV 2x per day and that (commercial) fast chargers are available.

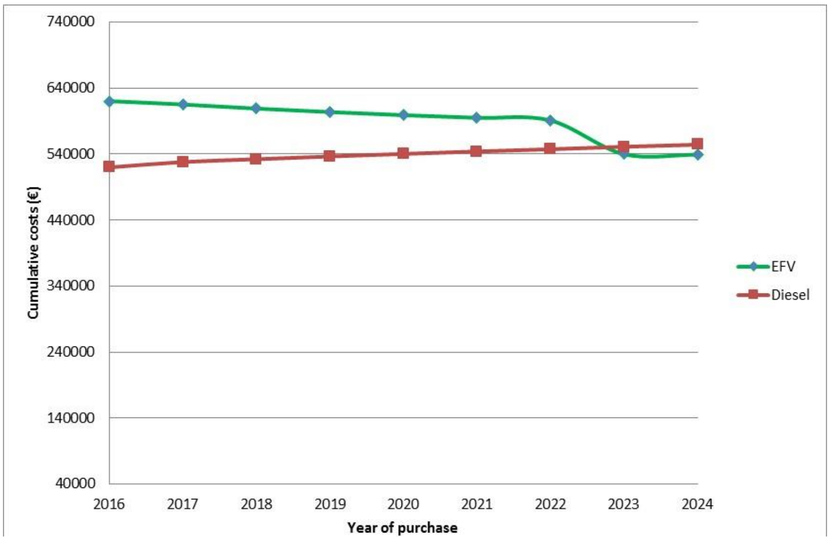

Figure 120: Cumulative cost comparison between the MAN TGM into an EMOSS CM 1820 (500 km/day)

[71] The curve for the 5 year depreciation time is less steep, because already from 2016 onwards no battery replacement is required and therefore there will be less benefit from the projected battery cycle life

To complete the analysis for the 19 tonne distribution truck, a mileage vs. saving relation is provided in Figure 121.

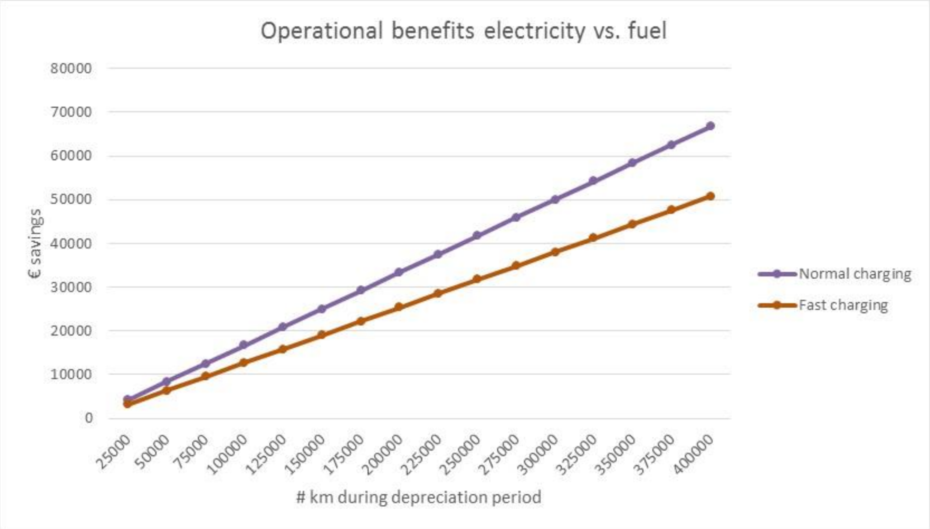

Figure 121: Operational benefits electricity vs. fuel as presumed in this report

In Figure 121, the horizontal axis represents the amount of kilometres driven during the depreciation period. The vertical axis shows the savings in energy costs during these kilometres. This relation is determined by:

- the projection of the diesel price: see Table 20
- the MAN TGM average fuel consumption: 0.26 l/km
- the projection of the electricity prices: Table 17
- the EMOSS 1820 average energy consumption: 0.91 kWh/km

5.4 Qualitative upscaling assessment: conversion versus series products

5.41 Introduction

In the market of electric commercial vehicles, there is a clear distinction in sizing versus scale: the smaller vehicles (e.g. Renault Kangoo ZE, Nissan eNV200) are mostly OEM products, produced on a relative large scale. The larger vehicles however, are produced in very small series or even on a one-off basis. This is the case for the vehicles used in the analysis above: 3.5 tonne eDucato, 13 tonne GINAF, 19 tonne EMOSS. In this section a brief analysis of the impact of series products (or scale) on the financial attractiveness of electric commercial vehicles is made on a qualitative basis.

5.42 Impact scale on cost price

When considering conversion products and a relatively small scale, the impact of higher volume on cost price is rather limited. For conversion companies, a yearly volume of e.g. 100 is already significant and often much lower in reality, where truck OEMs would need series of at least say a 1000 per year for an interesting business case. For passenger cars, the required volume is factors higher. Note that the technology for vehicles like Kangoo ZE and eNV200 is derived from passenger cars.

As indicated earlier, battery costs are the most significant portion of the total electric vehicle costs. For conversion products, there is only a very limited influence of volume on the battery costs, as the volume is too low. It is even more important for conversion companies to have a proper relationship with a battery manufacturer and benefit from their economies of scale, despite the low volume. As discussed earlier, expected costs for battery packs are 210 – 487 €/kWh for 2016. Low volume conversion companies can play in that range, although there are indications that some companies are closer to the upper boundary of this range. Note that the expected and not confirmed costs for Tesla, which are lower than the used references (see section 5.21), are said to be 150 – 200 €/kWh in 2016. A careful expectation is that the costs have to drop below 200 €/kWh (with a cycle life supporting fast opportunity charging at least once per day without the need for battery replacement during its economic lifetime when driving a limited amount of kilometres per day (< 150 km)) to reach the situation where batteries become commodity products for automotive propulsion, where the costs are predominantly determined by the amount of material used.

In the cost analysis from 5.21, the average expected battery price reduction is used for the calculations. In this average, a portion is due to new materials and other innovations and another portion is due to a higher expected scale. The bandwidth shown is very large, though. Conversion companies can benefit from the expected reduction in costs as shown by the average rate, but probably not from the economies of scale as shown in the bandwidth of Figure 78 and Figure 79. In the latter graph, one can clearly see that the lower end of the bandwidth indeed drops well below 200 euro/kWh.

Other cost benefits for conversion companies when their volume goes up, is lower production time and effort, lower development costs per vehicle and better contracts with OEM vehicle manufacturers for the costs of the original products before conversion. For the latter, the current situation is such that conversion companies often have to pay the full price for the original products and only very little is returned for the engine/transmission which is not used.

5.43 Impact scale on repair and maintenance

In the sections above it is explained how the costs for repair and maintenance are taken into account in the costs calculations. Again, a clear distinction between conversion products and OEM products should be made. In the (Dutch) FREVUE cases used for the analysis, the repair and maintenance costs are certainly not lower for the used electric vehicles. On the contrary: the low volume products are often suffering from teething troubles, which may significantly influence the operational costs. In most cases however, these troubles get solved and costs go down to normal maintenance levels. There is future potential though, since the repair and maintenance costs for OEM produced electric passenger cars are currently already around half of the maintenance costs of a conventional vehicle.

Here it becomes apparent that conversion products are still in a steep learning curve and that there is a lot of potential to decrease the repair and maintenance costs.

5.44 Possible short term market stagnation

Especially for heavier commercial vehicles, the number of available electric products is very limited and without exception based on conversion products. In the interviews with users of electric commercial vehicles it became apparent, that there is an increasing and alarming uncertainty about the next steps. In most cases drivers are happy, there is growing customer-base willing to pay (a little bit) more for green transport and in some cases it is (also) possible to make use of incentives. However, as there is quite some uncertainty about when to expect OEM-made EFVs, the purchase of the more expensive conversion products is postponed. Especially the announcement of Mercedes to bring a heavy electric (rigid) truck on the market in 2020, raises discussions on the vehicle purchase (and depreciation) strategy.

There are signs that this might cause a short term market stagnation in the electrification of freight vehicles. It obviously is good news that the OEM companies are serious in their role in electric transport and express ambitions to scale up. However, it might cause a "waiting time" in the coming few years and therewith a stagnation in gaining experience with electric commercial fleets. Building up experience gradually is perceived to be important, since organisations need to learn how to deal with aspects like limited range and efficient/smart planning of (opportunity) charging events. A stagnation in the growth of an EFV fleet will most likely also cause a stagnation in the development of the required planning tools and the build-up of a (fast) charging infrastructure. In other words: upscaling in terms of number of vehicles in the fleet and yearly mileage still shows a huge improvement potential and requires further innovation and experience in daily practice.

5.5 Generalized TCO comparison considerations

At the time of writing large / heavy EFVs are only available through companies that convert these vehicles to their full electric counterparts. This conversion implies significant costs. This results in an EFV purchase price that will always[72] be at least twice the price of its conventional counterpart, but currently is typically closer to three times more expensive.

For a positive TCO, these purchase costs need to be earned back by lower operational costs. Lower operational costs are to be obtained through lower energy costs, summed up for the applicable depreciation period. With electric vehicles there is potential for lower maintenance costs as well, but these lower maintenance costs are not expected from the EFVs that are made by companies that convert the conventional vehicles into electric vehicles (the rationale for this is provided in section 5.43). The effects of the lower operational costs due to differences in energy consumption and (expected) energy prices, as a function of the travelled (total) distance during the depreciation period, are shown in Figure 122.

From Figure 122 it can be derived that if a positive TCO for an EFV (when compared with a conventional freight vehicle) is demanded before its odometer touches the 250,000 kilometres boundary, then the following maximum price differences will be applicable:

- <3.5 tonne vehicle class: around 20k €
- 13 tonne vehicle class: around 42k €
- 19 tonne vehicle class: around 49k €

How fast, or how slow, the price difference may be earned back heavily depends on the electricity and diesel prices. The higher the diesel prices and the lower the electricity prices, the earlier the price difference between the conventional vehicle and the electrical vehicle can be earned back. From ECOFYS 2016 it was concluded that already within Europe the price differences in especially electricity are huge. For assessing these effects, two cases were considered: (1) Sweden and (2) Germany. For the Swedish case a medium company with an electricity usage of 2 GWh – 20 GWh is considered, whereas for the German case a small company with less than 5 MWh is considered. These countries were selected because

[72] Even when considering the battery prices to drop over time

in Sweden the electricity price is quite low and the diesel price somewhat higher than the European average, whereas in Germany the electricity price is quite high and the diesel price somewhat lower than the European average.

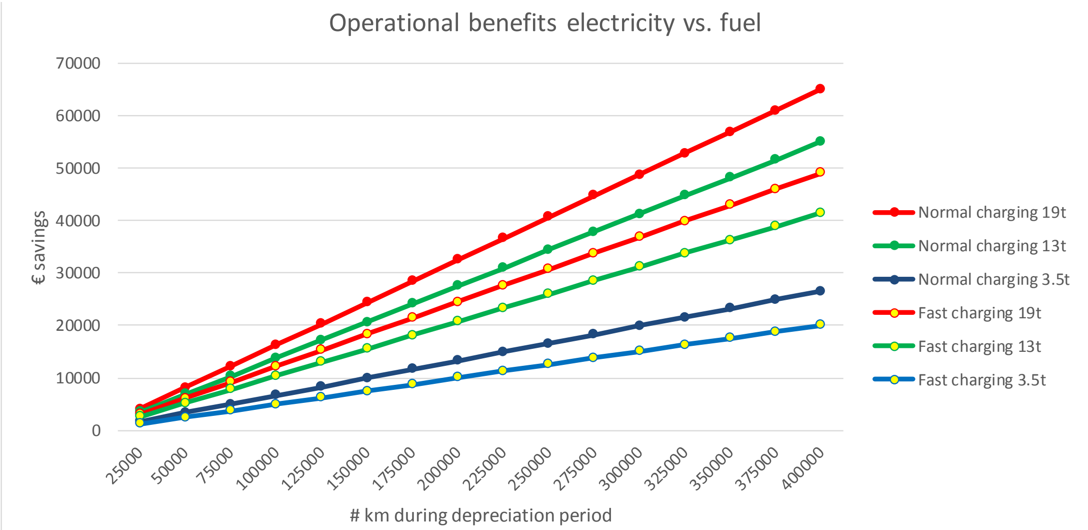

Figure 122: Operational benefits of EFVs compared with CFVs (Europe average)[73]

Figure 123 shows the situation for Sweden.

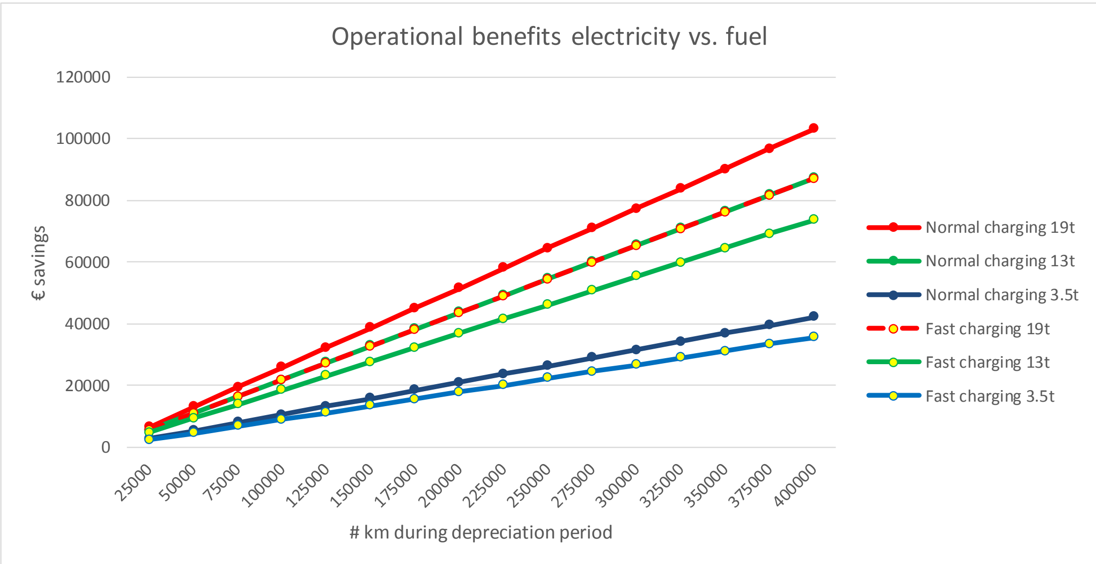

Figure 123: Operational benefits of EFVs compared with CFVs (Sweden)[74]

Figure 124 shows the situation for Germany.

[73] This figure presumes the nominal/average EU diesel and electricity price projections from section 5.2 for the year 2019 and typical energy consumption as mentioned on page 116, page 124 and page 137

[74] This figure presumes the Swedish diesel and electricity price projections from section 5.2 for the year 2019 (which constitute a positive energy pricing scenario for the EFV) , combined with the typical energy consumption as mentioned on page 116, page 124 and page 137. Notice that the curves for Fast Charging 19t and Normal Charging 13 coincide!

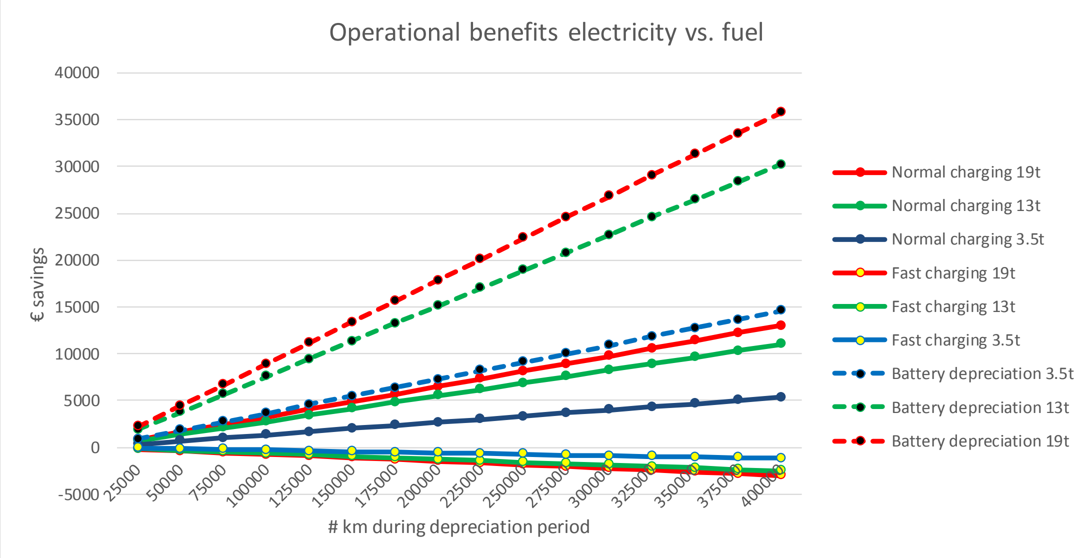

Figure 124: Operational benefits of EFVs compared with CFVs (Germany)[75]

From these figures it can be observed that for the normal charging case the costs can be earned back more than 50% faster in Sweden than the European average, whereas in Germany it will take at least 80% more time to earn back the same investment. Presuming the MEAN 2019 battery price from Figure 79 and the predicted cycle life from Table 16, then the depreciation costs for the battery (for all three weight classes) can also be included in Figure 124 (dotted lines). From Figure 124 it can now also be concluded that without incentives there is no positive business case possible for the German case under the presumed conditions. Moreover, when considering the EFV to be charged through fast charging only, thereby considering the extra costs for public fast charging as presumed earlier (i.e. 0.054 €/kWh), then the energy costs for an electric vehicle will be even higher than the energy costs for a conventional vehicle.

Another observation is that, even when considering the Swedish situation, the price difference between an EFV produced by a converter company and its conventional counterpart is observed to be higher than the energy price advantage that can be reached within an acceptable mileage. This effectively means that for a mileage of 250,000 kilometres there will not be a business case for the considered categories of EFVs (considering the earlier assumed prices for the converted vehicles).

A possible pitfall that can be dug in the transition towards the use of more renewable energy sources is to earn back the costs for this transition through higher electricity tariffs only, as this may affect the earn back time for an EFV. To underpin this statement, the following first order approximation, derived from the calculations behind Figure 122, need to be considered:

$$CostSaving = \#kilometres * (FuelConsumptionCFV * FuelPrice - ElectricityConsumptionEFV * ElectricityPrice)^{76}$$

[75] This figure presumes the German diesel and electricity price projections from section 5.2 for the year 2019 (which constitute a negative energy pricing scenario for the EFV), combined with the typical energy consumption as mentioned on page 116, page 124 and page 137

[76] Fuel consumption in l/km, electricity consumption in kWh/km, fuel price in €/l, electricity price in €/kWh

Considering the typical energy consumption from the EFVs and CFVs, this formula can be rewritten in:

$$\left(\frac{FuelPrice}{3.5} - ElectricityPrice\right) = \text{CostSavingPerKm}$$

This implies that in the case the electricity price needs to be increased by 0.01 €/kWh, then the fuel (diesel) price needs to be increased with (at least) 0.035 €/l.

For an in-series produced EFV, the price difference is expected to be predominantly determined by the battery subsystem, as the price of the base electric vehicle without its battery subsystem is expected to be in the same order of magnitude as its conventional equivalent. This implies that the price of the battery system needs to be earned back by the operational price differences. For this comparison the relations from Figure 122 are applicable as well, but remember that there also is potential for a lower maintenance bill.

Presuming the 278 €/kWh investment in the battery pack, in combination with a cycle of around 3750 cycles (of 80% depth), combined with a (typical) energy consumption ratio “electricity consumption” (kWh/km) / “fuel consumption” (l/km) of 3.5, a pre-condition for earning back the extra investment for an in-series produced fleet of EFVs can be defined by the following relation/formula:

$$\left(\frac{FuelPrice}{3.5} - ElectricityPrice\right) \geq 0.10$$

This formula can be applied as a first (coarse) step in future business case assessments around fleet electrification. For converted EFVs, the expected EFV depreciation costs per km shall replace the factor 0.10 to make this formula applicable.

An alternative way of looking at the TCO differences is to consider typical prices for converted vehicles and expected prices for the in-series produced vehicles and thereafter determine the mileage that would be required to obtain an equal TCO for the conventional and electrified freight vehicle of the same weight class. The results for this comparison are provided in Table 26 (presuming the nominal/expected battery pack price scenario), Table 27 (presuming the optimistic battery pack price scenario) and Table 28 (presuming the pessimistic battery pack price scenario), thereby presuming the European average energy price scenario as expressed by Figure 122.

Table 26 Mileage for earning back the investment in an EFV (battery pack: 278 €/kWh)

vehicle class	expected purchase price difference (€)						required mileage for TCO conventional = TCO EFV (km)					
	converted EFV			series EFV			converted EFV			series EFV		
	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging
<3.5 ton	46000	40000	37000	15000	9000	6000	697000	666000	652000	233000	145000	105000
13 ton	111000	97000	91000	32000	18000	12000	805000	787000	779000	233000	145000	106000
19 ton	159000	142000	136000	38000	21000	15000	980000	984000	985000	233000	145000	106000

Table 27 Mileage for earning back the investment in an EFV (battery pack: 195 €/kWh)

vehicle class	expected purchase price difference (€)						required mileage for TCO conventional = TCO EFV (km)					
	converted EFV			series EFV			converted EFV			series EFV		
	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging
<3.5 ton	47000	42000	40000	11000	6000	4000	705000	709000	712000	163000	102000	74000
13 ton	111000	101000	97000	23000	13000	9000	807000	825000	833000	164000	102000	74000
19 ton	165000	153000	148000	27000	15000	10000	1012000	1055000	1074000	164000	102000	74000

Table 28 Mileage for earning back the investment in an EFV (battery pack: 452 €/kWh)

vehicle class	expected purchase price difference (€)						required mileage for TCO conventional = TCO EFV (km)					
	converted EFV			series EFV			converted EFV			series EFV		
	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging	slow charging	1x fast charging	2x fast charging
<3.5 ton	45000	34000	30000	25000	14000	10000	680000	574000	526000	379000	236000	172000
13 ton	110000	87000	78000	52000	29000	20000	799000	708000	666000	379000	236000	172000
19 ton	148000	120000	110000	62000	34000	24000	912000	834000	799000	379000	236000	172000

For Table 26, Table 27 and Table 28 the following assumptions are made:

- EFV range: 150 km
- Battery lifetime: 3750 cycles ~ 560000 km[77]
- Prices obtained from the FREVUE demonstrators, however compensated for the required battery size (i.e. the 150 km range) and corrected for the battery price levels in 2019.

From these tables it can be observed that, next to the energy price differences, also the battery price is a key sensitivity factor in an EFV TCO. For the in-series produced EFV there is presumed to be a direct and linear relationship (for a given/fixed energy pricing scenario) between the battery pack price and the amount of kilometres that need to be driven in order to earn back the extra investment in the EFV. For an EFV that was made by a conversion company the same relation is applicable, however the relative influence of the battery pack price is significantly lower. Worth mentioning is that there are reasons to believe that the battery pack prices for the in-series produced EFVs will typically be lower than the battery pack prices for the in small series produced EFVs.

For the remainder of these considerations, the nominal battery scenario (Table 26) will be presumed. Following the approach from Table 26 it can -again- be concluded that an EFV produced by a converter company in small series requires typically too many kilometres to be driven before the TCO becomes comparable with its conventional counterpart, without additional incentives.

From Table 26 it can however be derived that there will be many applications where an in-series produced EFV can be operated with a positive TCO without the need for additional incentives. There obviously is also an area in the middle of very small series by converter companies and series production by OEMs. The table suggests that there might be applications where converter products can be operated with a positive TCO, in case larger series and thus lower prices can be achieved.

In general it can be concluded that the more kilometres are travelled, the more positive the TCO in favour of the EFV will become. Focussing on high (daily) mileage applications seems therefore logical. However, for high daily mileages also larger batteries will be required, which will increase the purchase price (and - as a consequence - the earn back time) of the vehicle. To get around this problem/paradox, fast charging may be considered. In the case that the operation allows for a ‘painless’ integration of fast charging, then this will typically help to solve the range issues and/or issues related with the (lack of) payload.

Fast charging also helps to reduce the initial investment and is therefore an effective means to reduce the depreciation time. As for the in-series produced EFV the battery system is the

[77] In the case that the required distance is longer than the battery can handle, then extra costs/kilometres will be added

main price differentiator, allowing a smaller battery has a major effect on the price difference and therefore on the depreciation period.

Fast charging however has its own additional costs: for example the higher energy prices because of higher investments in the charging infrastructure. The latter is expected to be translatable into a price difference with slow charging (with an estimated 0.01 €/kWh depreciation of charging equipment) of around 0.045 €/kWh, in the case that this service is provided by a (public) fast charging service provider. This means that although the investment in the battery will decrease, the speed with which this smaller investment can be earned back will also be reduced. In the case that the battery price is the main price differentiator between the EFV and the CFV (as is the case with an in-series produced EFV), then reducing the battery size and (also) apply fast charging will decrease the earn back mileage. However if the price difference between the EFV and CFV is high and the battery price has less significance in this price difference, then the reduction of the battery size in combination with applying fast charging will even <u>increase</u> the earn back time. This effect can be observed in Table 26 for the converted (presumed) 19t EFV and in Table 27 for all the converted (presumed) EFVs, where the required mileage increases in the case that fast charging is applied.

Another very important aspect of fast charging is that if fast charging would not (entirely) fit within the existing operation, then extra labour costs or even extra EFVs might be required to fulfil the existing operation. For example, in case of 0.5 hours extra labour costs per day for opportunity charging and presuming 25 €/hour of labour costs, then these costs will add up to 3k € per year, which needs to be compensated with driving around 35,000 km per year for the <3.5 tonne EFV class, or driving around 15,000 km for the 19 tonne EFV class.

Also beware that smaller batteries, which typically need extra recharging during the day, may need to be replaced during the economic lifetime of the EFV. This will have a negative effect on the TCO. One should therefore carefully select the battery (technology) with the most appropriate lifetime specifications, or deliberately over-dimension the smaller battery somewhat.

Another aspect, which is related with vehicle planning, is that it really helps to operate the EFVs such that the typical trip distance is close to the range of the vehicle. This ‘trip distance balancing act’ might require an additional planning iteration that is not required for a conventional fleet, but it may save some time and money that would otherwise been spent on fast charging or extra vehicles.

Worth realizing is that the purchase and maintenance costs for a CFV are likely to increase in the (near) future, as Engine After Treatment (EAS) systems are getting more complex and therefore more expensive due to the (ever) increasing environmental requirements. It is believed that to keep these systems in the required condition, more maintenance costs are to be expected. This means that next to the expectancy that EFVs will get less expensive, it is also likely that CFVs will get more expensive. These effects might result in an expedited transition towards a positive TCO for the EFVs for more application domains and countries. At the moment of writing, it is however not possible to come up with proper estimations about these effects.

6. Conclusions

FREVUE's deliverable 3.2 'Economics of EVs for City Logistics' shows:

- the operational experiences and lessons from using EFVs in real-life city logistics demonstrations (in chapter 2);
- the total cost of ownership comparisons between conventional and electric freight vehicles, as well as the barriers to switch from the CFV to the EFV based on the logistics operators value network (in chapter 3);
- the required changes in the logistics concepts to make EFVs fit city logistics better and the experiences with making these changes (in chapter 4); and
- the technical and economic possibilities for scaling-up (a few of) the electric city logistics operations as well as the exploration of the technical and economic possibilities for scaling-up the considered vehicle (weight) classes in a more generic context (in chapter 5).

All individual chapters already contained concluding remarks. This overall conclusion recaps the main findings concerning the economics of EFVs in daily city logistics operations. Overall, this deliverable shows that city logistics operations can be performed by electric freight vehicles, but that at the moment of writing the high vehicle purchasing costs are still a barrier for large scale utilisation of (especially large) EFVs for logistics operations.

6.1 Electric freight vehicles in city logistics operations

The FREVUE demonstrations, in which a variety of vehicle types operated in several different logistics segments in different climate zones, showed that EFVs can be deployed in daily city logistics operations. A total of fifteen cases in seven European cities where electric freight vehicles have been tested and demonstrated has shown us that it is very well possible to carry out at least part of the city logistics operations with EFVs. Both 'last mile' deliveries (e.g. from a consolidation centre to a city centre) by EFVs and replacement of entire trips formerly carried out by conventional vehicles have been tested and proven to be operationally feasible. The smaller EFVs in the demonstrations were used in a number of cases for last mile deliveries and led to changes in the logistics concept. Where these replaced CFVs, the EFVs drove more fixed trips/routes and did less ad hoc pick-ups and deliveries. For the cases with medium electric freight vehicles (especially parcel deliveries) no major changes were made to the logistics concepts (as most parcel deliveries start already from a hub close to the city), but in some cases the EFV trips were of shorter distance than the CFV trips and the EFVs did relatively more deliveries and fewer pick-ups than CFVs. For the cases with large electric freight vehicles it was very case-dependent whether or not changes were made to the logistics concept. The large electric vehicles in the demonstrations show that electric trucks can be used to deliver a variety of goods (retail, drinks and beer, furniture) to various addresses in the city.

For all vehicle types there is a reduction of flexibility due to range limitations and charging times when it comes to the use of EFVs. However, the experiences in FREVUE show that with some minor adaptations to the operations, using EFVs in city logistics operations is possible. This is especially the case for companies with a large enough volume to deliver that it can also operate one or more CFVs next to the deliveries with EFVs. In that case, the routes can be planned in a way that these best fit the positive characteristics of both the EFV and the CFVs.

6.2 Total costs of ownership and changes in the value network

Logistics operators who decide to procure an EFV or more EFVs face challenges as the value network in which they act requires several changes, i.e. new knowledge and new relations need to be established. In other words, for a logistics operator – at this moment – to switch from the existing diesel-powered vehicles towards electric powered vehicles, requires more than just buying another vehicle. It requires new relationships (other vehicle producers as large vehicles are not yet offered by OEMs, and questions concerning electricity, charging and the grid are often new), time investments and unknown risks. When buying a CFV these issues normally require limited effort from the operator. Also convincing others (e.g. higher management) in the company to invest in EFVs can be challenging for an operator's fleet manager. These extra elements can be (and indeed turned out to be) a barrier for operators in moving from CFVs to EFVs, next to sometimes unfavourable total cost of ownership for EFVs. The development that OEMs will start producing these vehicles will remove one barrier in the transition from CFV-dominated to EFV- dominated city logistics, as the operator can then use the regular maintenance network and buy the vehicles from familiar suppliers.

The total cost of ownership (TCO) comparison between an EFV and a CFV is an important purchasing decision criterion for logistics operators. The TCO comparison's results differ per vehicle type and usage. The TCO also depends on many other elements that can be country or even company specific.

For small electric freight vehicles, lighter than 3.5 tonne, the TCO can be favourable for an EFV within about five years, in case the vehicle drives 60 kilometres a day. The more kilometres the vehicle can be used and the longer the (depreciation) period in which it operates, the larger the TCO advantage becomes for a small EFV. Obviously the small size of this EFV type does not allow for transporting high volumes, and the limited range can also be challenging from a logistics operator's planning perspective. But if this is not a barrier, a favourable TCO for the small EFVs is feasible, even without subsidy, in about five years, depending on country specific elements like taxes and tax advantages for EFVs and the compared CFV (leased or bought). Small EFVs are already available from some OEMs, which reduced the purchase barrier even more.

For a medium sized electric freight vehicle, weighing between 3.5-12 tonnes, the TCO comparison shows that under specific circumstances a positive business case for using an EFV is, although challenging, possible. The more kilometres an EFV is deployed the more favourable the comparison, as kilometre costs are lower for an EFV (lower costs for electricity instead of diesel and lower maintenance costs). Special circumstances, like the exemption for paying the congestion charge for EFVs, have a very positive effect on the business case for the EFV (this also applies to small and large EFVs, but it is only showed for the medium size vehicles). Next, many uncertainties still exist around the residual value. The current generation of EFVs are tested and demonstrated in daily city logistics operations, but not yet long enough to say more about the actual residual value (of the vehicle or of the battery, which is a major contributor to the relatively high vehicle costs) at the end of life, or the actual deterioration (or not) of the batteries. As long as battery lifetimes cannot be guaranteed, in most procurement decisions (i.e. TCO calculations by operators) the operator calculates with a shorter depreciation period than the 10 years we used in this TCO comparison.

For the large EFVs, divided into small rigids and medium rigids in the TCO comparison, the TCO of a CFV is lower than that of an EFV. The purchase price for the individually retrofitted large electric freight vehicle is currently so much higher than for the OEMs' conventional truck that advantages due to lower operational costs do not result in a positive business case. Even a depreciation time of ten years, and a (purchase) subsidy do not currently allow for a cost-neutral business case for a logistics operator. Note that by driving the maximum number of kilometres the battery allows for together with a purchase subsidy can almost result in a cost -neutral business case.

6.3 Adapting the existing logistics concepts

For a larger scale transition towards electric freight vehicles, which is necessary to achieve essentially CO_2 free city logistics in major urban centres by 2030, the reorganisation of existing diesel based / evolved logistics systems is necessary. Reorganising the existing logistics concepts, in which the city operations are decoupled from the kilometres driven outside the city, are necessary to use the potential of electric freight vehicles for city logistics.

Several different ways to (re)organise city logistics in such a way that electric vehicles can be used for the last mile are experimented with, especially for those trips where a CFV cannot simply be replaced by an EFV (due to costs disadvantages or range issues). A location, hub, cross-dock facility, UCC or any other form to transfer goods somewhere near the city border from conventional vehicles to electric vehicles seems essential in this reorganisation. The examples discussed show that there is no easy proposition yet to convince existing logistics operators or shippers to use (or set-up) a zero emission alternative for city logistics operations, even if these operators / shippers do not have to invest in battery electric vehicles themselves. Reducing barriers by facilitating the use of EFVs is not enough to persuade potential EFV-users or clients of EFV transport. However, making it as easy as possible helps (some) operators / shippers to take the first steps.

6.4 Towards large scale EFV usage

A quantitative TCO-focussed analysis of upscaling the electric fleets of three FREVUE partners (with EFVs in the GVW categories 3.5t, 13t and 19t) revealed that large / heavy EFVs are -at the time of writing- only available through companies that convert CFVs to their full electric counterparts and revealed that these converted vehicles are at least twice the price of their conventional counterparts. For a positive TCO difference, these extra purchase costs need to be earned back by lower operational costs. These lower operational costs need to be obtained through lower energy costs, summed up for the applicable depreciation period. To allow large-scale transitions towards full EFV fleets, these lower operational costs shall compensate the higher investment costs within the targeted depreciation period.

With electric vehicles there is potential for lower maintenance costs as well, but these lower maintenance costs are not expected from the EFVs that are made by companies that convert the conventional vehicles into electric vehicles (the rationale for this is provided in section 5.43) yet.

A first order approximation of the costs saving (per km) for an EFV compared with an CFV is provided by the following formula:

$$\text{CostSavingPerKm} = \left(\frac{FuelPrice}{3.5} - ElectricityPrice\right)$$

Notice that there is only a cost saving potential in case that the diesel price per litre is at least 3.5 times as expensive as the electricity costs per kWh, thereby presuming the depreciation costs for the charging equipment to be included in the kWh price.

Presuming a 278 €/kWh investment in the battery pack, in combination with a cycle life of around 3750 cycles (of 80% depth), combined with a (typical) energy consumption ratio “electricity consumption” (kWh/km) / “fuel consumption” (l/km) of 3.5, then the battery depreciation costs will approximate to 0.10 €/km. For an in-series produced EFV, the price difference with a comparable CFV is expected to be in the same order of magnitude as the battery costs for such an EFV. This would imply that for a positive TCO for an in-series produced EFV, the cost savings per kilometre shall be higher than 0.10 €/km.

Battery costs (and therewith the initial investment) can be reduced by using a smaller battery. As for the in-series produced EFV the battery system is presumed to be the main price differentiator, allowing a smaller battery has a major effect on the price difference and therefore on the depreciation period. However to maintain the required daily mileage, fast charging needs to be applied. Fast charging is expected to cost 0.03 €/kWh to 0.06 €/kWh more than slow charging, because of a higher depreciation of the charging equipment and higher costs for the connection with the grid. This means that although the investment in the battery will decrease, the speed with which this smaller investment can be earned back will also be reduced. In the case that the battery price is the main price differentiator between the EFV and the CFV (as is expected with in-series produced EFVs), then reducing the battery size and (also) applying fast charging will decrease the earn back mileage.

However if the price difference between the EFV and CFV is high and the battery price has less significance in this price difference (as is the case with CFVs that were converted into EFVs), then the reduction of the battery size in combination with applying fast charging might even increase the earn back time.

If fast charging would not (entirely) fit within the existing operation, then also extra labour costs or even extra EFVs might be required to fulfil the existing operation. Often however, fast charging is the only means to fulfil the (worst case) daily operational requirements, and / or to realize the desired or required payload.

Next to the quantitative analysis, also a qualitative analysis of upscaling electric fleets was performed and was based on interviews with the contributing partners. It was found that for larger commercial vehicles, production happens mostly on a very small series or even on a one-off basis, by companies involved in converting conventional commercial vehicles to electric ones. At such production scales, the effect of volume on battery costs is limited. Furthermore, these companies are confronted with labour intensive (reverse) engineering activities, and will therefore typically not be able to drive the production and maintenance costs significantly lower than for the in-series produced vehicles.

Ultimately, a short-term market stagnation where transport companies are waiting for robust OEM products can be anticipated, given that they are faced with uncertainties on the purchase of higher priced products from conversion companies. This stagnation is not desirable, since there is a significant optimization potential by a combination of smart fleet planning and optimal charging regimes, as also seen from the partner scenario analyses. Here national or more localized legislation, and/or incentive programs, can play a significant role in encouraging the uptake of electric commercial vehicles in the next few years.

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