Technical Support Document

E-mobility in city logistics

Interreg Baltic Sea Region Project #R032 "Sustainable and Multimodal Transport Actions in the Scandinavian-Adriatic Corridor"

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Abbreviations / acronyms used in the report

CO	Carbon Monoxide, a toxic by-product of burning fuels in combustion engines
CO_2	Carbon Dioxide, emitted by combustion engines affecting climate change.
GHG	Green-House-Gases: Gases, affecting climate change.
HGV	Heavy Good Vehicle
Light vehicle	In this case: transport vehicles with a gross mass >3.5t.
NO_x	Nitrogen Oxide a toxic by-product of burning fuels in combustion engines

Executive Summary

Electric mobility is especially well suited in order to install green solutions in city logistics. On the one hand, range constrictions are less of a challenge, as city logistics-applications usually call for short range deliveries with many stops. On the other hand, low noise and non-existent local gaseous emissions make electric mobile solutions highly attractive in densely populated areas with high standards concerning environmental impact. Additionally, particle emissions are greatly reduced, compared to vehicles with conventional combustion engines.

As opposed to other drive-train and energy-storage solutions, it is not necessary to install large Meta-infrastructure for the operations of battery-electric vehicles, as the electric grid for recharging electric vehicles is already in place, while other solutions would need their own supply and production infrastructure (e.g. for hydrogen or bio-methane).

The report covers Germany, Sweden, Norway, Finland and Denmark, but is focused on use cases from Berlin and derives its conclusions from the Berlin use cases.

In general, four factors can be identified, that make an urban-logistics-centric electric-mobility solution successful:

- Necessary Range: The use case needs to call for a range short enough to make the use of electric vehicles viable.
- Maintenance possibilities: Commercial vehicle users require quick maintenance service, in order to minimize down-times. Vehicle manufacturers should therefore have viable maintenance facilities close to the use-case area.
- Subsidies: Subsidies that lower purchasing costs for the user can have a large (perhaps the largest) influence on the decision of purchasing an electric vehicle,
- Temperatures: The Belin use cases were all tested in rather mild central-European climate. This needs to be considered, when transferring use cases to colder (or hotter) climates.

The report also describes a step by step process, in order to purchase (and operate) commercial electric vehicles successfully:

Step 1: Define your objective
Step 2: Estimate the necessary range and annual mileage
Step 3: Decide on Gross-Mass and Payload
Step 5: Estimate your costs
Step 6: Estimate CO_2-savings
Step 7: Choose the proper vehicle and contact the vendor
Step 8: Talk to your vendor about charging infrastructure and maintenance
Step 9: Choose a funding program

1 Introduction

Scandria2Act-project brings together regions located along the Baltic Sea Region stretch of the Scandinavian-Mediterranean Core Network Corridor (ScanMed).

The project aims to answer major regional development challenges associated with future transport development along the newly established ScanMed corridor. It supports regional activities to foster the corridor deployment and to adopt regional development measures to the opportunities provided by the European transport policy approach.

Scandria2Act covers partners from all member states and Norway located along the ScanMed Corridor. It represents relevant urban nodes as well as multimodal nodes along the corridor.

The project coordinates efforts related to the deployment of the ScanMed Core Network Corridor as one of four Core Network Corridors connecting the Baltic Sea Region to the rest of the European Union.

The major objective of Scandria2Act is to foster clean, multimodal transport through the corridor regions to increase connectivity and competitiveness of corridor regions while at the same time minimising negative environmental impact induced by transport activities.

To achieve this objective, the project partners have developed a joint approach that addresses:

- the deployment of clean fuels,
- the deployment of multimodal transport services and
- the establishment of a multilevel governance mechanism based on mutual dialogue between decision makers at regional, national and European level.

This report shall provide solutions for the direct substitution of conventional diesel-driven vehicles, in order to provide green transport chains. Within the context of the Scandria2Act project, this report presents work relating to the deployment of clean fuels. Specifically, the report looks at cases and experiences from e-mobility in city logistics with a focus on Berlin. This report provides input to the Assessment Report of clean fuel deployment experience in the Scandria2Act corridor regions, for which the aim is to make the extensive experience in the region available for the deployment of clean fuels in the northern Scandria2Act-corridor. The evidence and findings aim to support the dialogue between decision makers at municipal, regional, national and European level.

1.1 Background to e-mobility in city logistics

Due to their still limited range, electric-mobile solutions are usually confined to operational contexts, in which only shorter daily mileages are required. Depending on the vehicle and the geography, these mileage limits usually lay between 60 and 150 km until a battery recharge becomes necessary. Larger Batteries could increase the vehicle range, but also come with a penalty in vehicle purchasing costs and payload (due to high battery prices and battery mass).

On the other hand, electric-mobile solutions offer a number of advantages that are of specific interest in urban mobility: Noise and (local) gaseous emissions, are perceived as major problems in urban areas and urban planners are increasingly interested in mobility solutions that can solve these problems.

Logistics operations in urban areas usually also do not require long range tours from vehicles, so that the limited range of electric vehicles is not necessarily an issue.

A large-scale introduction of electric vehicles into logistics operations in urban areas, could allow for new planning and legislative measures. As measures cutting down on the use of conventional (usually Diesel-driven) vehicles would impair the vital supply functions that cities have to provide, if no “green” substitute could be found.

1.2 Why is this report of interest?

A number of European cities have tested different approaches in introducing electric-mobile solutions into urban logistic-operations. This report provides the reader with an overview of such solutions and with concrete advice in how to develop such solutions, which was derived from these practically demonstrated solutions.

This report shall give the target group a short overview of what to expect, when they are interested in introducing electric freight vehicles, and get a short overview of what steps to take next.

1.3 Structure of this report

This report consists of roughly four parts: The first part (chapters 2 and 3) describe the general basics for electric-mobile city logistics-solutions, based on the current discussions on electric mobility in city logistics. These basics are derived from the general political discussion (chapter 2) and more or less describe the expectations that are connected with the implementation of electric-mobile logistics solutions in urban areas. Chapter 3 gives a short overview of the standardization issues connected to electric mobile solutions in Europe.

The second part (chapter 4) describes six use cases: Projects through which electric-mobile solutions were already implemented in the Scandria2Act region. This part of the report is meant to give the reader an idea of what has already been done in the field and therefore can be considered practical.

The third part is a detailed description of how to implement electric mobility solutions. These step by step instructions are based on the knowledge and the experience from the projects, described in the earlier chapters.

1.4 Target group for this report

The target group for this project are operators of logistic vehicles. These operators are mainly private companies but can also be found among smaller municipalities in the ScanMed Corridor, as well as regions along the north Scandria2Act corridor. This report should function as a supporting document for knowledge and experience exchange between regions in the north Scandria2Act corridor, thus enabling establishment and expansion of clean fuel infrastructure.

2 Electric Mobility in City Logistics

Electric mobility is especially well suited in order to install green solutions in city logistics. On the one hand, range constrictions are less of a challenge, as city logistics-applications usually call for short range deliveries with many stops and the battery capacity increases overtime in the vehicles. On the other hand, low noise and non-existent local gaseous emissions (CO, CO_2 and NO_X) as well as particles make electric mobile solutions highly attractive in densely populated areas with high standards concerning environmental impact.

As opposed to other drive-train and energy-storage solutions, it is not necessary to install large Meta-infrastructure for the operations battery-electric vehicles, as the electric grid for recharging electric vehicles is already in place, while other solutions would need their own supply and production infrastructure (e.g. for hydrogen or bio-methane).

2.1 Specific properties of electric-mobile logistics solutions

Besides the obvious properties in terms of emissions, electric vehicles have some other properties, that have to be considered, when introducing them into operations.

Operations: The specific characteristics of electric drivetrains have a number of additional positive effects in an urban environment:

- **HIGH EFFICIENCY** in urban areas: Electric motors provide their maximum torque across the complete performance spectrum, enabling quick accelerations at any speed, while conventional engines only provide maximum torque over a certain rate of rotation. Practically this means, that an electric motor can accelerate with less energy-demand than a conventional motor. This leads to a lower energy-demand, especially in urban environments, where vehicles have to decelerate and accelerate often. This leads to a more efficient energy use from “tank/battery” to wheel. Conclusions about the total energy efficiency can only be drawn, when the whole energy-supply chain is considered and will differ, depending on the method of electricity production.

- **REDUCED NOISE EMISSIONS** could allow for new logistics concepts: e.g. night deliveries in urban areas for example to stores. It also allows for direct delivery into buildings, for example: transportation of trailers with production material, directly to production/assembly lines, without additional transshipment at a loading dock. Tough loading and unloading can still emit noise, this noise can be minimized by technical solutions (rubber wheels on transport carts, rubber buffers etc.). The relative quietness of electric vehicles can make them a hazard, when other road users (mainly pedestrians and cyclists) are not able to hear the electric vehicle. Technical solutions, such as noise emitters are currently being discussed.

- **RECHARGING AND RANGE:** Range is an important issue in the operation of electric vehicles. A number of demonstration projects (compare chapter 4) have tested recharging processes in between tours during one day. However, this has often proved to be impractical, as delays in deliveries often lead to a shortage of time for the recharging process. It seems generally more practical to recharge vehicles during longer non-operations-periods (e.g. during the night). Tests with battery-changing systems (i.e. the whole empty battery is being swapped for a recharged battery) have yet not been proven to be practical, as the very high costs of batteries lead to very high additional investment costs.

Infrastructure: As opposed to other green fuels, the use of battery-electric vehicles also has a number of advantages in urban infrastructures:

- **ELECTRICITY** is already being produced on a very large scale. No additional production facilities (as in the case of hydrogen or biogas) are necessary.
- **DISTRIBUTION**: Distribution Networks already exist, in the form of the electric grid. No specific delivery and storage infrastructure necessary, as in the case of hydrogen and biogas.
- **AREA CONSUMPTION**: For safety reasons, specifically assigned spaces in the city are necessary for onsite storage and distribution of biogas and hydrogen. Electric charging stations are not much larger, then the parking space of the electric vehicle.
- **GRID CAPACITY**: Up to this point electric-mobile solutions have only been tested on a small scale. There is no real experience, if (local) urban grids would be able to handle large numbers of vehicles being charged at the same time.

Macro-Economic level: On a macro-economic level, fostering electric mobility also can have a positive impact on at least two fronts:

- **INDEPENDENCE** of national economies from oil and thereby from oil producing countries
- **ADDED DEPENDENCIES** on certain materials, such as rare earth metals, which are mainly manufactured in China.
- **NEW** and different **MANUFACTURING CHAINS** could also change global production map, with a chance of investment into new technologies. For example: The main value-added in today's automobile production stems from the development and production of motors. Electric motors however, are technologically very simple and can be produced with less development and production-resources. On the other hand, batteries are complex and the development of batteries meeting the requirements for the use in vehicles (e.g. lightweight, high energy-density) is still in its very early stages, opening chances for those company-clusters, able to provide new solutions. The main value added in electric vehicles lay in batteries, as opposed to vehicles with combustion engines, where the main value added for the manufacturer lays in the engine.

Environment:

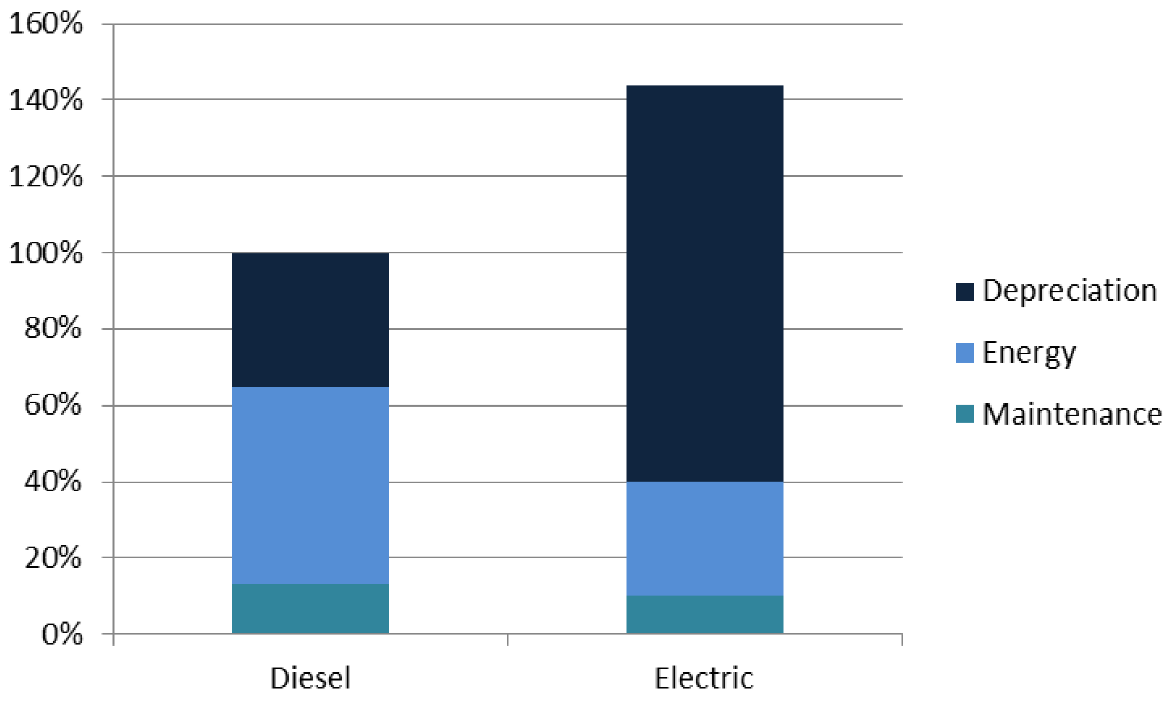
- Generally electric vehicles do use **LESS ENERGY**. For example: The project KV-E-Chain determined, that an electric 40t-truck needed about 0.3 kWh/ton-km, while a corresponding diesel-truck needed about 0.5 kWh/ton-km.
- The lower energy consumption usually translates into a **LOWER CO_2 EMISSION**, though the actual CO_2-emission varies greatly, depending on the type of electricity-production. The Smartset project showed, that CO_2 emissions for electric power production can vary widely from region to region, from Sweden with 0.017 kg/kWh up to 0.47 kg per kWh in Germany (with values up to 0.98kg/kWh in regions were brown-coal was used for power-production).[1]

[1] Smartset project 2013-2016: „D6.3 Impact Evaluation". – Smartset was an IEEE-funded project, aiming at developing and transfering solutions for smart city logistics.

- Of course, electric vehicles have the added benefit of not generating any **LOCAL GASEOUS EMISSIONS**.

Cost implications: The following graphic shows typical cost-categories for electric and Diesel-driven vehicles, in percentage-points. These data have been derived from the analysis of eight different projects, operating vehicles in size from 3.5t to 44t (gross-mass). The proportions of depreciation, energy and maintenance costs have been proven to be about the same (each for electric and diesel vehicles), regardless of vehicle size[2].

These costs represent, costs carried by the vehicle operator. Due to the high purchasing costs, depreciation costs, are about three times higher, than those of conventional vehicles. However, more efficient energy use and the lower costs of electricity (as compared to diesel-fuel) in most European countries, as well as the simpler construction of electric motors, lead to lower energy- and maintenance-costs.



[2] Project KV-E-Chain (2013): “KV-E-Chain Gesamtbericht“.Wildau.

3 Standardization

Though standardization is an issue that is occasionally discussed, most necessary standards are already in place: Necessary construction codes for vehicles do not differ from those already in place for conventional vehicles. Of course, additional standards, for specific electric components (batteries, battery-management systems etc.) are needed, but are mainly being defined by vehicle manufacturers, as development and production grows.

Charging infrastructure and especially the interface between the charging station and the vehicle are already standardized, and so is, of course, the public grid. The grid throughout the Scandria2Act project region is standardized to a Voltage level 400 V (three-phase) or 230 V (single-phase).

In principle, electric vehicles can be charged at any household socket, but these are not designed for permanently high currents) and therefore used as slow charging over night. So for practical reasons, an additional specialized charging station (for quick charging) or an industrial socket is often needed (the latter usually exists at many commercial vehicle depots). The properties of charging station are defined in internationals norm for charging electric vehicles:

IEC 62196-1:
For the performance spectrum up to 690 V alternating current and a charging current up to 250 A (AC charging) and up to 600 V DC voltage and a charging current up to 400 A (DC charging).

IEC 62196-1 defines four charging modes:
Mode 1: Slow charging of household socket outlets with SCHUKO connectors (Charging current up to 16 A, maximum charging power 3.68 kW)
Mode 2: Charge with charging current up to 32 A with one or three phase supply voltage; A signal contact is used in the plug, which is used as "Switch" and allows for higher charging currents
Mode 3: Quick charge with charge current up to 250 A; Sensors in the plug determine whether the vehicle is suitable for this charging mode Charge with alternating current with direct current
Mode 4: Quick charge via an external charger with charging current up to 400 A; Sensors in the plug determine whether plugs and cables are suited for this mode of charging.

Plugs and sockets are also standardized:

The plugs and sockets for charging electric vehicles are also standardized and follow international standards. The socket and plug used would vary with the vehicle operated and with the charging properties (i.e. quick-charging or standard charging or semi fast charging).

The plugs listed below are the possible standards a user could face. The most common plug in Europe would be the Type 2-plug. Some manufacturers will also offer a CCS or CHAdeMO plug. This needs to be clarified with the vendor, when purchasing a vehicle.

The graphic below, shows, that a European logistics vehicle operator, will face the decision between two possible plugs, which are compatible to one another: The Type 2-plug and the CCS-plug, which can be used the Type 2 –socket, but allow (if a CCS socket is available) for faster charging.

Type 1-plug:
Performance up to 7.4 kW (230 V, 32 A)
Mainly used in Asia

Type 2-plug:
Performance up to 22kW kW (230 V, 32 A)
Standard in Europe

Combined Charging System CCS
Quick Charging system for up to 170 kW

CHAdeMO
Quick Charging system for up to 100 kW
This system was developed in Japan, and a number of car-manufacturers offer cars compatible with this type of plug (among others: Honda, KIA. Citroen, Nissan, Peugot and Toyota)

Tesla Supercharger
Quick Charging system for up to 100 kW
This system is currently used exclusively by TESLA

4 Case studies

The following cases give a short overview of projects demonstrating electric mobility solutions in cities throughout the Scandria2Act corridor. Vehicle sizes range from light vehicles up to 44t-HGV. Cargobikes and similar small vehicles were excluded, as this report shall provide solutions for the direct substitution of conventional diesel-driven vehicles, in order to provide green transport chains. Though Cargobikes theoretically could serve as a substitute for diesel-driven vehicles, they lack the payload capacity of conventional vehicles (and often also the operational flexibility in cold weather), so that a cargobike-substitution would often also call for a redesign of the particular delivery system.

Due to a large-scale effort of the German government in the time period from 2009 to 2013 a large number of projects were launched in the Berlin capital region, so that four of the six projects described here are from Berlin, though these examples can be transferred into any other urban area.

All projects described here went operational in a timeframe between 2011 and 2016. All solutions (i.e. vehicles) are still operational, albeit some of the underlying (research-)projects may be defunct.

All concepts were introduced for their low emissions (CO_2 as well as noise). All vehicles also had very high purchasing costs which can be seen as the main reason for the small number of electric vehicles per fleet. Though the range of these vehicles is shorter, than that of comparable diesel vehicles all vehicles were pre-configured with batteries, that allowed for the requested range in the operational context they were used in.

All cases listed here, were still operative as this report was written (January 2018)

4.1 Case study 1: KV-E-Chain – The full electric, intermodal transport chain

Project name:	KV-E-Chain
City:	Berlin (DE)
Number of vehicles tested:	1
Size of vehicles tested:	40-44t
Typical range of vehicles:	40km – 80km
Manufacturer of vehicles:	Terberg
Geographical context:	Densely populated inner-city districts.
Operational context:	Last mile of rail based intermodal transport. Heavy Goods, mainly containers with a mass up to 25t.
Short description:	Demonstration of a fully electric long-haul delivery transportation chain. Containers were delivered by train from Western Germany and for the westrange- and northrange ports to the Berlin Westhafen container terminal. They were then transported on a fully electricfied vehicle in the last mile.
Picture:	 Source: TH Wildau
Contact:	Dipl.-Ing. Philip Michalk Research Group Transport Logistics, TH Wildau Hochschulring 1 15745 Wildau T +49-3375-508201 E-Mail: michalk@th-wildau.de www.kvechain.de

4.2 Case study 2: Dislog – Small goods distribution in an urban context

Project name:	DisLog
City:	Berlin (DE)
Number of vehicles tested:	6
Size of vehicles tested:	3,5-7t
Typical range of vehicles:	80-150km
Manufacturer of vehicles:	Renault, Empro,
Geographical context:	Densely populated inner-city districts.
Operational context:	Parcel services, short range, small-sized deliveries to specialized retail shops. Vehicles did not serve fixed tours, but instead were used on tours which could vary greatly in length and payload mass, which is typical for the operators which used these vehicles
Short description:	The main goal of this project was the introduction and tests of electric-drive and hybrid utility vehicles in inner-city freight transport for the purpose of promoting the economic, transport-efficient and ecological design of delivery processes. All tested vehicles were full-battery electric.
Picture:	 Source: Berlin agency for electromobility
Contact:	Werner Schönewolf Fraunhofer-Institut für Produktionsanlagen und Konstruktionstechnik IPK Pascalstr. 8 – 9 10587 Berlin T +49-30-39006-145 schoenewolf@ipk.fraunhofer.de www.emo-berlin.de

4.3 Case study 3: ElektroAES – Electric mobility in waste disposal

Project name:	ElektroAES
City	Berlin and Potsdam (DE)
Number of vehicles tested:	3
Size of vehicles tested:	20t
Typical range of vehicles:	Electric-only: 2-3km
Manufacturer of vehicles:	Volvo
Geographical context:	Urban, living areas
Operational context:	Waste disposal for private households
Short description:	Three hybrid-Waste disposal vehicles were tested in Berlin, Potsdam and Oranienburg. All vehicles were hybrid-vehicles, which used their electric drivetrain for operations on their actual collection route. The onboard garbage compactors were also operated electrically (via a separate battery set) in order to reduce noise levels.
Picture:	 Source: Berlin agency for electromobility
Contact:	Dr. Jörg Vogler Hüffermann Transportsysteme GmbH Kampehler Str. 10 16845 Neustadt/Dosse T +49-33970-996-10 joerg.vogler@hueffermann.de www.emo-berlin.de

4.4 Case study 4: NANU! – Multi-shift deliveries for retail supply

Project name:	**NANU!**
City	Berlin (DE)
Number of vehicles tested:	2
Size of vehicles tested:	3,5t-12t
Typical range of vehicles:	100-120km
Manufacturer of vehicles:	MAN, IVECO
Geographical context:	Densely populated inner-city districts.
Operational context:	Parcel services and delivery of goods to department stores
Short description:	The project tested multi-shift operations using medium-weight utility vehicles with fully electric drive systems. In order to improve the overall economic efficiency of e-commercial vehicles, deliveries took place during low-traffic nighttime hours and use schedule-based charging.
Picture:	 Source: Berlin agency for electromobility
Contact:	Werner Schönewolf Fraunhofer-Institut für Produktionsanlagen und Konstruktionstechnik IPK Pascalstr. 8 – 9 10587 Berlin T +49-30-39006-145 schoenewolf@ipk.fraunhofer.de www.emo-berlin.de

4.5 Case study 5: Stadsleveransen – Inner city deliveries with light electc vehicles

Project name:	Stadsleveransen
City	Gothenburg (SE)
Number of vehicles tested:	2
Size of vehicles tested:	<3,5t
Typical range of vehicles:	75 km
Manufacturer of vehicles:	Alke
Geographical context:	Densely populated inner-city districts.
Operational context:	Last mile transport for deliveries to retailers in inner city areas
Short description:	The main goal of this project was the introduction and tests of a last mile transport system for vendors in the inner city districts of Gothenburg. The scheme calls for closing this districts for heavy freight vehicles and instead utilize a small Urban Freight Terminal to consolidate deliveries on light electric vehicles.
Picture:	 Source: City of Gothenburg
Contact:	Anette Thorén Project manager, ”Hållbara godstransporter” T +46 31-368 26 24 anette.thoren@trafikkontoret.goteborg.se

4.6 Case study 6: eTruck – Electric vehicle tests in cold weather conditions

Project name:	eTruck
City	Tampere (FI)
Number of vehicles tested:	1
Size of vehicles tested:	16t
Typical range of vehicles:	180-250km
Manufacturer of vehicles:	EMOSS, DAF
Geographical context:	City districts and close by areas
Operational context:	Delivery of goods
Short description:	The project defines and implements a research platform for studying usability and total cost-effectiveness of electric transport equipment considering the energy efficiency and investments. The complex is still being developed to suit the Finnish conditions. At the same time, the effects of weather conditions and driving style on energy efficiency and especially regeneration of energy are being studied.
Picture:	 Source: Niinivirta Ltd., European Cargo
Contact:	Jukka Pellinen Tampere University of Applied Sciences (TAMK) Tampereen ammattikorkeakoulu, Kuntokatu 3, 33520 Tampere, Finland T +35850 408 6383 jukka.pellinen@tamk.fi

5 E-mobility: success factors and challenges

5.1 What can we learn from the cases?

A number of Lessons Learned can be taken from the Berlin-Brandenburg case:

- **Politics and regulations:**

  Played a rather small role and consequently had no large impact, however two political measures were discussed, but have not come to fruition yet:

  a) **Drivers permit (or something like that)** Allowing drivers two drive electric vehicles with more than 3.5t gross mass with a normal class B license. Background: electric vehicles often have a lower payload, due to high battery mass. At the same time drivers with class C licenses (trucks > 3.5t) are highly sought after. From the view point of logistics operators, this puts electric delivery vehicles in a disadvantageous position.

  b) **Nighttime deliveries.** Allowing electric delivery vehicles to make nighttime deliveries into certain densely populated urban areas at night. This is currently not allowed in most of the urban living areas of Berlin. Though loading- and unloading noises might be an issue, they can be reduced by technical means (rubber buffers and rubber wheels on carts). A significant portion of loading and unloading activity, especially for department stores and shopping malls, also takes place within building-courts, thus minimizing the noise impact for the local population.

- **Geographical conditions:**

  Berlin is in a very advantageous geographical position for electric vehicles. Highly and densely populated inner-city districts allow for very short delivery-ranges, while still reaching a large enough customer base for deliveries. Cold temperatures did not prove to be a problem in the showcase projects (KV-E-Chain, DISLOG, ElektroAES, NANU! – compare chapter 4). However, temperatures only reached values of less than -10° on a few days per year, so that this experience cannot be directly transferred to colder areas.

- **Costs and Finances for the operator:**

  Electric vehicles still come with very high purchasing costs (about three times as high as a corresponding conventional vehicle). And though low maintenance and operational costs are lower than those of conventional vehicles, they cannot make up for the higher investment cost (compare chapter 2.1 for further information). This also means, that subsidies and other measures to influence potential buyers, should concentrate on the purchasing costs of the vehicle.

Transferability of the Berlin-Brandenburg case:

The chances and challenges met by the Berlin-Brandenburg cases are not be expected to differ largely if implemented elsewhere. Four issues could influence the success of an implementation project and need to be considered:

- **Necessary Range**: The use case needs to call for a range short enough to make the use of electric vehicles viable.
- **Maintenance possibilities**: Commercial vehicle users require quick maintenance service, in order to minimize down-times. Vehicle manufacturers should therefore have viable maintenance facilities close to the use-case area.
- **Subsidies**: Subsidies that lower purchasing costs for the user can have a large (perhaps the largest) influence on the decision of purchasing an electric vehicle.
- **Incentives**: CO2 taxation and other environmental taxing on conventional fuels might be needed as well. Environmental zones in the cities (prohibiting vehicles with certain CO2-emissions) might also be an alternative.
- **Temperatures:** The Belin use cases were all tested in rather mild central-European climate. This needs to be considered, when transferring use cases to colder (or hotter) climates.

6 Step by Step instruction to purchase battery-electric vehicles for logistics applications

6.1 Introduction

As electric vehicles come with certain constraints, the purchase process differs greatly from that of conventional vehicles. For example: The range of an electric vehicle depends greatly on its battery capacity. However, batteries are the most expensive component of any electric vehicle, with prices between 500 € and 1.000 € per kWh. A battery too small would lead to a vehicle that would not meet the operator's demands, a battery too large, would lead to much higher operating costs, than necessary.

The following step by step instruction shall help you to conduct an introductions process for electric vehicles into your fleet as well as help in purchasing the necessary infrastructure. This instruction only covers full-electric, battery vehicles, though the funding opportunities listed in Annex II, also cover other types of "green" vehicles.

Step 1: Define your objective

To make you introduction process a success, you first should define your objective, in order to have clear indicator for your success. So, ask yourself the following question:

- Why do you want to introduce electric vehicles?
- Do you hope for a positive marketing or public relations effect? In that case you should design an accompanying Marketing strategy, utilizing media outlets, but also cooperating with other institutions (such as universities or government authorities) in order to multiply your PR-effect.
- Do you want to save CO_2 emissions? Could this become part of larger "going green" strategy?
- Do you want to replace your complete fleet, or do you only want to introduce a few electric vehicles into your fleet?
- What is your time frame? Do you want to change your fleet on a long term or are you looking for a short-term effect?

Step 2: Estimate the necessary range and annual mileage

The estimation of your necessary range and mileage differs from the type of vehicle-substitute you are planning:

a) You want to substitute your complete fleet by electric vehicles.
b) You want to substitute a certain conventional vehicle by an electric vehicle.
c) You want to substitute part of your fleet by electric vehicles.

In cases a) and b), range and mileage will most probably be very similar to your current vehicles.

In case c), you should do an in-depth analysis of your current vehicle utilization.

As battery-capacity is a main driver of vehicle costs, you might want to only substitute those tours with a minimum daily mileage by electric vehicles, so you can use smaller batteries.

If you are looking for large CO_2-savings, you will need to either substitute a larger number of tours by electric vehicles or fewer “large-mileage” tours. In any case you need a clear idea of your tour-structure.

If you have your vehicle logbook in a digital format (e.g. Excel) you could proceed as follows:

- Sort all logbook entries by days, so that you get a list for each day.
- Sort each day by tour-length, starting with shortest tours.
- Now you can build categories for short, medium and long tours.
- Evaluate the numbers of each tour-category by length, number of tours per day. Calculate the necessary range a vehicle would need to cover per day, in order to get a value for your range demand. Examine, if perhaps a tour category (depending on your objective) could be covered by electric vehicles. Tweak the category, in order to optimize according to your objective

Suggestions:

⇒ You will get the best results if you use this method with the log-entries of a complete year, however a month or a week can also give you a good indication, if your tours are usually very similar. However, if you plan to substitute your complete fleet, you will have to keep in mind, that tours could get longer over time and that you will not have the luxury of conventional back-up-vehicle.

⇒ Our experience with past projects shows, that intermediate charging (i.e. charging during the day, between two tours), is practically often unrealistic. For example: If a vehicle comes back late from a tour (perhaps because of a traffic jam), there might not be enough time for a charging phase. So, you should select a minimum range-requirement for your electric vehicle that will cover all tours of one day.

Step 3: Decide on Gross-Mass and Payload

You can use the gross-mass of your current fleet as an indicator and choose a gross-mass as large as the one of the vehicle(s) you wish to replace.

Alternatively, you can use the necessary payload you need to transport and use the vehicle-list in the Annex to find the corresponding gross mass of a listed vehicle and thereby the right vehicle-size for your needs.

Step 4: Estimate the necessary Battery capacity

To calculate the necessary battery capacity in order to reach the required range (estimated in Step 2), the following formula can be used[3]:

Battery-Capacity [kWh] =

(max. Range [km] * 0,3413 + Vehicle-Gross-Mass [t] * 1,3579 + 28,57) * 1,2

You should try to find a vehicle with a battery capacity at least as large as the one calculated.

Step 5: Estimate your costs

Calculate purchasing price:

The purchasing price need to be established by procure price estimates from the vehicle-manufacturer or vehicle-vendor. To get a first estimate of the purchasing price (on the German market), you can use the following formula[4]:

Purchasing price [€] =

Vehicle-Gross-Mass [t] * 2810 + Battery-Capacity [kWh] * 920 + 2262

For all other costs, you can use the current costs of your existing fleet as a basis in order to estimate the operating costs of an electric vehicle:

- Maintenance costs: Maintenance costs for electric vehicles can be estimated to be about 60%-80% of the maintenance costs of a corresponding Diesel-vehicle[5].
- Energy-costs can be estimated as follows:

  Estimate the consumption by using the values you calculated / used in Step 4:

Consumption (kWh/km) = Battery-Capacity [kWh] / max. Range [km]

[3] This formula was developed through a regression analysis with n=10. It also includes a 20% safety-addition on capacity.

[4] This formula was developed through a regression analysis with n=10.

[5] Please consider, that there no large scale, long-term data exist in order to estimate maintenance costs of electric vehicles. The given value, is what (from our experience), can be expected in a four year-time frame.

⇒ This is of course only a very rough estimate and it will vary greatly with load, but also with weather and road conditions.

Multiply consumption with the current price you pay per kWh of electric energy to get the consumption costs per km.

Multiply consumption costs per km with the expected mileage in our calculating-time-frame (e.g. one year).

Step 6: Estimate CO_2-savings

In order to estimate your current CO_2 emission, determine the average fuel consumption per km of the vehicles you wish to substitute and multiply this number with the mileage you wish to substitute. Than multiply the result with

- In case of a Diesel-vehicle: 3.16
- In case of a Gasoline-vehicle: 2.88

The results are your current CO_2 emissions in kg, for the vehicles/tours you wish to substitute.

In order to estimate the CO_2 emissions for your planned electric vehicle(s), first ask you energy supplier for the CO_2-factor per kWh. Than multiply this CO_2-factor with the total consumption, you calculated in Step 5.

⇒ This is again only a very rough estimate. For more precise estimates, an in-depth analysis utilization- and tour-profile and perhaps additional simulations would be necessary.

Step 7: Choose the proper vehicle and contact the vendor

Using the input data from Step 3 and 4, you can use the vehicle catalogue in Annex I to choose some matching vehicles and contact the vendor.

Step 8: Talk to your vendor about charging infrastructure and maintenance

Using the inputs, you determined form Steps 1 to 7, clarify the following questions with your vendor:

- Will you need your own charging stations or are there public charging stations you could use.

  You can find public charging stations on the internet, for example here:
  www.plugsurfing.com
  www.chargemap.com

- What would a quick-charging station cost and how much faster would a quick-charging station charge?
- Is it possible to install the necessary charging station on your own electric house-connection/property-connection/company connection/municipal connection.

  ⇒ You might also need to clarify this question with your energy provider.

- Will the available electric-power be sufficient (especially when charging several vehicles)
- When using a quick charging system: Will you need a load management system?
- Can/shall the charging station-status be diagnosed via the internet for maintenance purposes?
- What services are offered within the maintenance contract for your charging station?

- Does the vendor offer a maintenance contract for the vehicle?
- What services are offered within the maintenance contract for the vehicle?
- Does the vendor offer you a guarantee on battery-life?
- Does the vendor offer you a battery exchange after a certain mileage?
- Where are the next maintenance service stations for your electric vehicle?

Step 9: Choose a funding program

Use the tables in Annex I to find a funding program.

7 Recommendations for decision-makers

The following recommendations are of a very general nature, but therefore applicable throughout the whole Scandria2Act project region:

- **Subsidies** are still needed in order to make electric mobility in logistics viable. As high purchasing costs are the main barrier, subsidies should mainly reduce the purchasing costs for the operator.

- **Training of personnel** Logistics operators need easily available maintenance services, in order to minimize down-time of the vehicle. This is still an issue to be solved, as many electric vehicle operators to find qualified repair-shops. This problem could be diminished by training and fostering training of maintenance personnel.

- **Schemes,** that put a financial burden on operators of conventional vehicles, when entering – for example – an inner city area and diminishing taxes and fees on the operators of electric vehicles have the potential to foster the use of electric vehicles.

8 Annexes

8.1 Vehicle catalogue

The following vehicles are generally available in the whole project region, as of January 2018:

8.1.1 Light trucks

Manufacturer	Vehicle-Name	Total Gross-Mass [t]	Payload [t]	Engine power [kW]	Max. Battery-Capacity [kWh]	Min. Battery-Capacity [kWh]	Manufacturer Website
Renault	Kangoo Z.E.	2,13	0,65	44	33	N/A	www.renault.de
Citroen	Berlingo Electric	2,18	,46 bis 0,6	49	22,5	N/A	business.citroen.de
Peugeot	Partner Electric	2,23	0,59	49 - 67	22,5	N/A	www.peugeot-professional.de
Mercedes	Vito	2,8	N/A	70	36	N/A	www.mercedes-benz.de
Mercedes	Vito	2,8	N/A	70	36	N/A	www.mercedes-benz.de
Smith	Edison	3,5	2,3	90	40	40	www.smithelectric.com
IVECO	Daily 35S	3,5	N/A	60	N/A	N/A	www.iveco.com
Orten	Orten ET 35M	5	1,8	60 / 81	87	58	www.electric-trucks.de
IVECO	Daily 50C	5,2	bis 2,6t	80	N/A	N/A	www.iveco.com
Orten	E75	7,5	2,3	81	72,5	72,5	www.electric-trucks.de
Framo	e75	7,5	2,8	180	318	57	www.framo-et.com
Mercedes	Spinter	2,8;3,6; 4,6	N/A	70	36	N/A	www.mercedes-benz.de
Mercedes	Spinter	2,8;3,6; 4,6	N/A	70	36	N/A	www.mercedes-benz.de
Mercedes	Spinter	2,8;3,6; 4,6	N/A	70	36	N/A	www.mercedes-benz.de
Emovum FIAT	E-Ducato	N/A	0,94	60	43	N/A	www.emovum.com
Emoss	EMS 304	N/A	N/A	135	42 - 84	N/A	www.emoss.nl

8.1.2 Medium and heavy trucks

Manufacturer	Vehicle-Name	Total Gross-Mass [t]	Payload [t]	Engine power [kW]	Max. Battery-Capacity [kWh]	Min. Battery-Capacity [kWh]	Manufacturer Website
Smith	Newton	12	6,9	120	120	80	www.smithelectric.com
Framo	e120	12	6,15	320	318	57	www.framo-et.com
Framo	e180	18	11,3	320	318	57	www.framo-et.com
Emoss	CM18	18	10 bis 11	250	240	160	www.emoss.nl
E-Force	E-Force ONE	18	10	300	240	N/A	eforce.ch
Framo	e260	26	17,5	320	318	57	www.framo-et.com
E-Force	E-26	26	17,5	440	260	120	eforce.ch
Framo	e 440	44	26	480	231	57	www.framo-et.com
Terberg	YT-202 EV	44	34	138	169	112	www.terbergspezialfahrzeuge.de
E-Force	E-40	44	26	550	250	98	eforce.ch

8.1.3 Busses

Manufacturer	Vehicle-Name	Total Gross-Mass [t]	Payload [t]	Engine power [kW]	Max. Battery-Capacity [kWh]	Min. Battery-Capacity [kWh]	Manufacturer Website
VDL	Citea LLE Electric	14,4	4,4	153	N/A	N/A	www.vdlbuscoach.com
Sileo	Sileo S10	18	N/A	240	200	N/A	www.sileo-ebus.com
Sileo	Sileo S12	18	N/A	240	230	N/A	www.sileo-ebus.com
VDL	Citea SLF Electric	19,5	6,8	153	N/A	N/A	www.vdlbuscoach.com
Sileo	Sileo S18	28	N/A	480	300	N/A	www.sileo-ebus.com
VDL	Citea SLFA Electric	29	10,8	210	N/A	N/A	www.vdlbuscoach.com
Solaris	New Urbino 12 electric	N/A	N/A	160 / 250	N/A	N/A	www.solarisbus.com
Solaris	New Urbino 18 electric	N/A	N/A	240 / 250	N/A	N/A	www.solarisbus.com
Solaris	Urbino 8,9LE Electric	N/A	N/A		N/A	N/A	www.solarisbus.com
Emoss	MB16	N/A	.6 Person	158	42 - 84	N/A	www.emoss.nl

8.2 Funding schemes

8.2.1 Germany

Name of the Subsidy	Funding Through	Region	Subsidy for	Heigth of Subsidy	Available	Who can apply
BAFA - Umweltbonus	Bundesamt für Wirtschaft und Ausfuhrkontrolle	Germany	Investment in vehicles (private and commercial)	1.500 € - 4.000 €	2016-2019	Private persons, companies, foundations
KMU-innovativ: Elektroniksysteme; Elektromobilität	Federal Ministry of Education and Research	Germany	R&D	50%-100& of projectcosts	ab 2016	SMEs (Universities in cooperations with SMEs)
KMU-NetC (KMU-zentrierten, strategischen FuE-Verbünden in Netzwerken und Clustern)	Federal Ministry of Education and Research	Germany	R&D	50%-100% of projectcosts	2017-2022	SMEs (Universities in cooperations with SMEs)
Förderrichtlinie zur Phase II des NIP: Marktaktivierung	Federal Ministry of Transport and Infrastructure	Germany	Investment in vehicles (commercial) and charging infrastructure	45% of additional investmentcosts	2016-2019	Companies, Foundations, communal organisations
Innovationsforen Mittelstand	Federal Ministry of Education and Research	Germany	R&D	up to 100% of projectcosts der Projetkosten	ab 2016 - kontinuierlich	SMEs, Universites
Förderrichtlinie Elektromobilität - Fahrzeug- und Ladeinfrastrukturbeschaffung	Federal Ministry of Transport and Infrastructure	Germany	Investment in vehicles (for communes) and charging infrastructure	40% of additional investmentcosts	2015-2019	Communes, Authorities
Förderrichtlinie Elektromobilität - Erarbeitung kommunaler Elektromobilitätskonzepte	Federal Ministry of Transport and Infrastructure	Germany	Development of communal electric-mobility concepts	up to 80% of projectcosts	2015-2019	Communes, Authorities
Förderrichtlinie Elektromobilität - Förderung von Forschung und Entwicklung	Federal Ministry of Transport and Infrastructure	Germany	R&D	up to 50% of projectcosts	2015-2019	Companies, Foundations, communal organisations, universities
Neue Fahrzeug- und Systemtechnologien	Federal Ministry of Eceonomics and Energy	Germany	R&D	50% - 85% of projectcosts	2015-2019	Companies, universities
Klimaschutzförderrichtlinie Kommunen – KliFöKommRL M-V (Richtlinie für die Gewährung von Zuwendungen des Landes Mecklenburg-Vorpommern zur Umsetzung von Klimaschutz-Projekten in nicht wirtschaftlich tätigen Organisationen)	Ministry of Energy and Infrastructure of the State of Mecklenburg Vorpommern	Mecklenburg Vorpommern - Germany	Investment in vehicles (for communes) and charging infrastructure	50% - 80% of projectcosts	ab 2014	non-commercial organisations

8.2.2 Sweden

Name of the Subsidy	Funding Through	Region	Subsidy for	Heigth of Subsidy	Available	Who can apply
Supermiljöbusspremie (Super Green-Bus Bonus)		Sweden	Investment in vehicles	2016: 50 million SEK, 2017-2019: suggestion of 100 million per year. 200 000 - 700 000 SEK per bus	2016 -	Regional public authority
Stadsmiljöavtal (Environmental Urban Agreements)	Trafikverket (Transport Administration)	Sweden	Promote sustainable urban environments through creating a higher share of personaltransport with public transport with low emission-levels	Total 2 billion SEK 2015-2018, maximum 50 % of the investment	2015-2018	Municipalities and regional authorities
Klimatklivet	Naturvårdsverket (Environmental Protection Agency)	Sweden	Promote local climate-investments	2015: total 125 million SEK, 2016-2018 another 600 million SEK	2015-2018	Public and private sector
Fordonsskatt (Vehicle tax)	Transportstyrelsen (The Swedish Transport Agency)	Sweden	Decrease the number of vehicles with high emissions.	Dependant on vehicle-type, fuel and CO2-emissions. Basic amount of 360 SEK per year plus 22kr per gram CO2 over 111 gram CO2 per km.		Every purchase of new vehicles.
Förmånsvärdesreduktion (Reduction in cost of benefit for company car)	Skatteverket (The Swedish Tax Agency)	Sweden	Increase the number of green vehicles that are sold as a company car	Reduction of the benefit-sum of 40 %, maximum 10 000 SEK per year.	2017-2020	Company-employees
Supermiljöbilspremie (Super Green-Car Bonus)	Transportstyrelsen (The Swedish Transport Agency)	Sweden	Encourage purchase of electric vehicles	Grant for purchase of a vehicle with emission slower than 50 g CO2 per km. 40 000 SEK for electric vehicle and 20 000 SEK for a chargeable hybrid.	- 2018, then it will be replaced by the bonus-malus	Privately purchased vehicles and company cars

8.2.3 Finland

Name of the Subsidy	Funding Through	Region	Subsidy for	Heigth of Subsidy	Available	Who can apply
Yritysten investointituki sähköautojen julkisille latauspisteille (Smart charging infrastructure subsidy scheme)	Ministry of Economic Affairs and Employment (Coordinated by Eera Ltd.)	Finland	Subsidy scheme aims to leverage €15 M worth of investments for smart public charging infrastructure.	Total 4,8 million euros. 30 - 35 % of the investment subsidized (Public quick charging points enjoy 35 % of subsidy)	2017 - 2019	Public and private sector, excluding private persons and some other actors such as farms and housing cooperatives
Registration Tax Benefits	Tax Agency	Finland	Tax model favoring low CO2-emission vehicles. Finnish car registration tax system is based on CO2-emissions and as EVs have 0-emission levels they only pay the minimum tax (3,3 % 2018 and 2,7 % 2019).	During 2018 the registration tax is 3,3 % and in 2019 it is 2,7 % It has been lowered annually since 2016.	2016 - 2019	Registration tax applies basically to every new car purchased in Finland. It also applies to imported used cars.
Ownership Tax Benefits (The vehicle tax, paid annually)	Tax Agency	Finland	Tax model favoring low CO2-emission vehicles. Finnish car ownership tax model is based on CO2-emissions and as EVs have 0-emission levels they only pay the minimum tax. However they are subjected to pay the tax on driving power.	Electric vehicles only pay the minimum basic tax.	Continuous	Allmost all cars are subject to the vehicle tax.

8.2.4 Norway

Name of the Subsidy	Funding Through	Region	Subsidy for	Heigth of Subsidy	Available	Who can apply
Registration Tax Benefit	Tax Agency	Norway	When registering a electric or hybrid-vehicle, no registration tax needs to be payed	indirect subsidy - no registration tax	Continuous	Any vehicle buyer
VAT Tax benefit	Tax Agency	Norway	When buying a electric or hybrid-vehicle, no value added tax needs to be payed	indirect subsidy - no registration tax	Continuous	Any vehicle buyer

8.2.5 Denmark

DK	Funding Through	Region	Subsidy for	Heigth of Subsidy	Available	Who can apply
Import Tax Benefit	Tax Agency	Denmark	Whenbyuging a electric or vehicle, noimport tax needs to be payed	indirect subsidy - no import tax	until 2019	Any vehicle buyer