NORTH SEA REGION ELECTRIC MOBILITY NETWORK

e-mobility NSR

Technical Report on EV Field Tests

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Executive summary

This report refers to the field tests conducted on EVs and e-Buses in the work-package "Smart Grid Solution". Carried out on vehicles currently on the market simulating their daily utilisation, the field tests had the scope of measuring EVs storage capacities as well as their charging needs and their energy consumption.

The first part of the repoert describes the test rationale set-up, having the scope of choosing test typologies, fixing operational rules and procedures, and finally selecting places, users and operators.

Field tests have produced as main outcome a robust collection of quantitative and qualitative data. The quantitative data have been collected by means of five different tools: a data logger installed in the vehicle, a GPS, the CAN-bus, the RFID scans of participants' badges, and finally the charging pole meter.

It was also possible to monitor EVs' different travel behaviours by using the MOVE-platform.

To complement quantitative data, surveys were distilled to tests' participants and qualitative data collected. These data have had the scope of evaluating in a dynamic way test participants perception of the EVs', and then to investigate of their potential change in culture and consciousness.

The selection of the test typologies has taken into account the two main mobility patterns (private EV and public transportation), the very limited number of vehicles to test (about eight EVs and one e-Bus) and the EV potential to bring a new mobility system giving centrality to 'economies of access' vs 'economies of ownership'. Therefore, the team planned two services able to compete with the private owned car in terms of convenience and cost-structure and, at the same time, contributing to reduce negative externalities in the cities.

For the private EV field test, the mobility pattern selected has been the car sharing, generally identified as "a short-period automobile rental services intended to substitute private vehicle ownership". In order to organise a service, which with a limited number of vehicles could fully meet the needs of test participants. Therefore, the team organised a car sharing system with EVs for "cohousing" communities. Cohousing is a special type of collaborative housing in which residents actively participate in the management of their own neighbourhood.

For the public transportation, the current availability on the market of full e-Buses (Class 1) is limited to small buses, running shuttle services or performing regular lines in historic centres. For the scope of the test, that is, a continuous daily use in real service conditions, the second option could be the most valuable for measuring the e-buses cycles of charging and discharging. However, the number of e-buses used in the test should be enough to perform a regular service in a medium size historic centre and provide a real service. Considering the limited available resources, that solution was not feasible. The chosen alternative was running the service for smaller communities in well-circumscribed areas, such as hospitals or university campuses.

For the private EV test, the team selected four different cohousings, two small urban communities in Ghent – Papegaaistraat and Sint-Pietersaalststraat - without parking places, and two larger semi-urban communities, one located near the city of Brussels (La Placette in Wezenbeek-Oppem) and the other located near the city of Ghent (Vinderhoute), both characterised by open common spaces and parking facilities.

The two urban communities received pre-paid cards for using EVs supplied by Cambio as part of their fleet. Cohousers had to follow all Cambio rules for the booking, parking, and charging, and EVs were available connected to a charging box in parking facilities not far from the cohousings.

Each of the two semi-urban communities received two leased EVs (3 Nissan Leaf and 1 Peugeot Ion) and a charging box was installed inside their parking facilities.

For the qualitative data, questionnaires provide a survey of the 78 cohousers (47.5% men, 52.5% women) living in the selected four Flemish cohousing units, in terms of population composition and mobility behaviours. Then, they investigated their motivations to participate to the tests, relevant factors in the car choice, and in particular, about EVs and their expected use of the EV sharing in the cohousing.

After six and twelve months, surveys have been repeated in order to investigate the cohoursers' car sharing experience, as well as to compare differences between small community car sharing and the traditional one, as perceived by the cohousers.

The car-sharing test conducted with the cohousing communities has provided interesting findings. First, it defines a potentially new car sharing model, which can provide value added to EVs in terms of significance, utility and performance.

The test population has been segmented into at least two different geographical clusters, urban and semi-urban.

That selection points out the importance of variables, such as culture, socio-economic status, familial composition, and geographical location. Noticeably, geographical location and familiar status seem influencing mobility choices more than educational level, common cultural background on EVs and shared "green" attitude.

Secondly, from the qualitative data it emerges that the urban cohouser is highly educated, green oriented, predominantly single, does not own a car, and uses the train for commuting to work and the bike for shopping and leisure. For rare events, s/he uses the car (mainly a shared one). The semi-urban cohouser, also highly educated and green oriented, on the contrary is married with children, and owns a car, which is his or her main means of transport.

When analysing cohousers behaviours in the tests, some relevant topics emerged. The urban cohousers use car sharing as a secondary mode of transport to increase their mobility and, therefore, accessibility. Nonetheless, for them the EV sharing, being 'green', risks being an alternative to soft mobility, biking and walking, and public transport, and not to the privately owned car. On the contrary, semi-urban cohousers replaced their private car with the shared EVs, developing daily and weekly repetitive car sharing behaviours (semi-organised), in contrast to the completely non-organised behaviours of the urban cohousers. In addition, some of them demonstrated an interest to continue the car sharing also after the end of the test, and others to buy the leased EV.

All of them felt having a pioneering role in testing sustainable mobility patterns, where EVs could replace conventionally fuelled vehicles. By developing new mobility patterns, the test benefited from cohousers towards the exploration (new technology, developing the future, charging at home with renewable energy, etc…) and provided them in exchange with the possibility to verify by themselves the EV convenience (low refuelling costs, less maintenance possibility of using self-produced energy, etc…).

Looking at the charging experience, urban cohousers with Cambio were obliged to behave not very efficiently, charging when not necessary and using a more expensive energy (related to energy prices varying between peak and off-peak supply). On the contrary, semi-urban cohousers, which have to pay for energy consumption, mainly charged only when necessary and if possible at night time.

It is possible to remark that sharing EVs amongst small communities represents a powerful tool for promoting their zero-emission approach, and their potential of lower charging and maintenance costs.

The second field test was about e-Buses. Its main objective was to measure e-buses interaction with the electric grid and, in particular, the battery operational capacity and ageing, charging time, battery accumulation potential, electric consumption, auxiliary systems absorption, and average distance covered with one charge.

The original idea of testing the e-Bus running a regular public transport service in a historic urban centre, characterised by varied topographic and traffic settings, with a service frequency not different from the other regular buses, was not feasible.

After several unsuccessful negotiations with the Flemish Regional Public transportation company, De Lijn, which refused to use the e-Bus in their regular lines, the team decided for a different solution. Following the same criteria used for the private car test, it was decided to define a small-scale daily service, which a single e-Bus could perform, and at the same time to acquire data from an existing e-Bus line in a historic town.

For the small-scale test, the team explored the possibility to use an e-Bus shuttle service in the campus of the University Hospital of Ghent (UZ-Campus), where actually a campus taxi service is in use. The e-Bus would expand the service by transporting disabled people (wheel chair user and elderly people), visitors, staff and students.
Also that test failed, this time because no bus drivers ware available at UZ.
Finally, the team organise a demonstrator by transporting Ugent staff and students from the Gent central railway station to the Ardooie Campus, with a route length of 6 km. Before this demonstration started, the bus has often been used in events related to the University. The demonstrator would provide a fine tune to the data analysis from the Rome case-study.

In addition, the acquisition of the e-Bus experienced many problems for the renting of the vehicle, showing still some relevant problems for opening EU market. At the end of a long process, an used Tecnobus Gulliver U530 ESP was purchased at the same price of an annual leasing. That is exactly the bus assigned by the public transport company of Rome, ATAC, in a fleet of 60 electric powered buses, to operating bus routes in the historic centre of Rome, on streets that are too narrow for standard sized buses. Additionally, because these buses' electric engines are so quiet, they do not create noise pollution that might be harmful to old structures in the ancient city centre.

Through Tecnobus, UGent has acquired operational field data from the ATAC fleet in Roma for the period Jul 2012 to Mar 2014. Serviced routes are typically 7 km taking about 30 minutes one-way.

The analysis refers to the battery charging and ageing and highlights some interesting elements, which should more widely investigated.

Glossary

Battery management system (BMS): is any electronic system that manages a rechargeable battery (cell or battery pack), such as by monitoring its state, calculating secondary data, reporting that data, protecting the battery, controlling its environment, and / or balancing it. The BMS also controls the recharging of the battery by redirecting the recovered energy (i.e. from regenerative braking) back into the battery packs (a pack is typically composed of a few cells).

EV Charging station (or electric recharging point, charging point and Electric Vehicle Supply Equipment): is an element in an infrastructure that supplies electric energy for the recharging of electric vehicles, plug-in hybrid electric-gasoline vehicles or semi-static and mobile electrical units such as exhibition stands.

Data Logging: is the process of recording events, with an automated computer program, in a certain scope in order to provide an audit trail that can be used to understand the activity of the system and to diagnose problems. For EVs is necessary to collect information about travel performance, consumption, driving behaviours, and energy absorption.

Electric Vehicle (EV): uses one or more electric motors or traction motors for propulsion. Three main types of electric vehicles exist: directly powered from an external power station (Tram, trolley bus); powered by stored electricity originally from an external power source (Battery Electric Vehicle, BEV), and powered by an on-board electrical generator, such as an internal combustion engine (Hybrid Electric Vehicle, HEV) or a hydrogen fuel cell.

Renewable energy (RE): is energy, which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services

Smart Grid: is an electrical grid that uses computers and other technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.

Sustainability: is the capacity to endure. For humans, sustainability is the long-term maintenance of responsibility, which has environmental, economic, and social dimensions, and encompasses the concept of stewardship, the responsible management of resource use. Sustainability interfaces with economics through the voluntary trade consequences of economic activity. Moving towards sustainability is also a social challenge that entails, among other factors, international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. Ways of living more sustainably can take many forms from controlling living conditions (e.g., Eco-villages, eco-municipalities and sustainable cities), to reappraising work practices (e.g., using permaculture, green building, sustainable agriculture), or developing new technologies that reduce the consumption of resources.

Vehicle-to-Grid (V2G): a system in which plug-in electric vehicles, such as electric cars (BEVs) and plug-in hybrids (PHEVs), communicate with the power grid to sell demand-response services by either delivering electricity into the grid or by throttling their charging rate. Vehicle-to-grid can be used with such gridable vehicles, that is, plug-in electric vehicles (BEVs and PHEVs), with grid capacity. Since most vehicles stay parked an average of 95 percent of the time, their batteries could become accumulators and to let electricity flow from the car to the power lines and back.

Well-to-wheels (WTW): analyses of emissions from both the vehicle operation and fuel source. WTW emissions are divided into two components: the fuel cycle, or well-to-tank (WTT), emissions and the vehicle cycle, or tank-to-wheels (TTW). WTT impacts include all emission events from fuel production to final transport and vehicle fuelling. TTW impacts include vehicle exhaust and evaporative emissions.

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1. Introduction

The work-package “smart grid solution” aims at developing models of smart grid capable to support a sustainable use of the electric mobility in the NSR region. Objective of a smart electric grid is to integrate the actions of all connected actors, producers and consumers, for distributing and consuming energy in efficient, sustainable, reliable and safe mode. Relevant elements for developing a smart grid approach in the field of the electric mobility are:

- Renewable energy production (solar, wind, …)
- EVs electricity consumption (vehicle performance, batteries, battery management systems (BMS), transportation service, users behaviours, etc)
- Charging stations (slow & fast charging modes), metering, V2G-applications and other grid connections

Although the renewable energy production was not a topic for this project, it is a common believe that its efficient integration in the grid could be facilitate by an interaction with the EVs, which can provide additional capability for integrating energy from renewable sources and achieve sustainability from well to wheel. However, a lot of information are still missing from both the energy and the transport sides.

Main goals of these field tests are to measure the EVs storage capacities, their charging needs and their energy consumption. However, in order to be effective, the team had to perform the test on EVs actually on the market and simulating their daily utilisation. Considering the market growth and the evolving awareness of the users, an exclusive laboratory test or a short running field simulation could fail to provide robust results about the capacity of the EVs introduced to the market during the project life.

However, running tests based on real operational conditions requires a shared strategy and the definition of a common system of rules, procedures, and tools. First step in that direction was the set-up of a test rationale for coherently choosing test typologies, then to fix rules and procedures to run them, and finally to provide indicators for selecting places, users and operators. Therefore, the first part of the report will describe the rationale, providing field tests common elements, such as:

- Glossary
- EVs field test typology
- Main indicators
- Expected outcomes

The second part will focus on the two chosen field tests: the first related to a car sharing services managed and exploited in small communities, the second to a public transportation service performed with electric buses.

For each of them, the report will firstly specify their organisation, management, development and monitoring procedure. In particular, it will shape the following elements:

- Technological requirements (EVs, energy, charging places, data loggings, database)
- Legal requirement (EVs leasing/rental contracts, test runners contract, insurance, assistance)
- Operational requirements (procedures, test management, user role, responsibility, measurability, time planning, EV training and assistance)
- Monitoring and assessment (monitoring procedures, questionnaires, data metering, reporting forms).

Finally, it will summarise tests development and main results, as well as problems and difficulties encountered, introducing quantitative and qualitative data. About the battery issue, field tests datasets have been forwarded to the Northumbria University team, which has compared them with data resulting from their laboratory tests.

2. Field test rationale

2.1 Test Definitions

A first relevant step for defining a field tests' common basis was the set-up of a glossary about the main proposed concepts (see glossary). Subsequently, the team introduced key performance indicators (KPIs) for a smart grid usage of EVs, such as charging and energy consumption (e.g. energy density, power density, battery cycle life, charging rate, temperature stability, safety).

Many of the chosen indicators were analysed previously throughout lab tests on EVs (see Report 5.1). However, by testing the vehicles in different conditions (temperature, weather, and traffic), different services (public, semi-private, private) and with numerous different driver typologies (sex, age, education, occupation) was possible to compare in different contexts such a general indicators.

2.2 Expected outcomes

Field tests were expected to produce as main outcome a robust collection of quantitative and qualitative data. The quantitative data, mainly from the previously defined indicators, have been collected by means of five different tools: a data logger installed in the vehicle, a GPS, the CAN-bus, the RFID scans of participants' badges, and finally the charging pole meter. Thanks to the real time data collection, it was also possible to monitor EVs' different travel behaviours through the MOVE-platform (http://move2.ugent.be/index.php/en/).

Quantitative indicators have been not only the result of EV laboratory tests, as reported in 5.1, but also a specific request of Northumbria University, which was involved in lab tests on batteries, in order to develop comparable datasets. In particular, measurements from the battery and the vehicle include energy consumption and charging/discharging indicators.

The qualitative data have had the scope of evaluating in a dynamic way test participants perception of the EVs', and then to investigate of their potential change in culture and consciousness. The team planned three questionnaires to be filled out online before, during and after the test period by each participant.

2.3 Field test goals

The field test goal was to collect information on EVs charging and consumption in real daily transport operations. The field tests decided to take into account only BEV (battery electric vehicles) and full electric buses actually on the market, excluding prototypes and new research.

2.4 EV test typologies

Transport on road can be grouped into two main categories: transportation of goods and passengers. The first category was excluded by the tests, being the main WP7 topic. Passengers are transported on the road in either private cars or public transport vehicles (taxis, minicabs, coaches, buses).

Private cars can be used by one or more people, and owned by a natural person or a company. It is possible to consider four prevalent typologies, according ownership, number of users and function:

- Private owned vehicle, few known users for non-commercial use (e.g. family vehicle)
- Private owned vehicle, few know users for commercial use (company service vehicle)
- Private owned vehicle, many not-known users for non-commercial use (car sharing, and car renting)
- Public owned vehicle, few/many users for service use (public service vehicle)

Hence, the team synthesised all potential typologies in two main ones:

- Private transport
- Public transport

For the private transport, the simplest option could be to provide the EVs to the project participants, to rotate them every month and to monitor their results. Considering the very limited number of vehicles to test (about eight EVs), this option provided too small results and a limited sampling of driving behaviours. In addition, considering that EVs will probably bring a new mobility system giving centrality to transport connections and promoting a shift from 'economies of ownership' to 'economies of access', field tests could be an opportunity for developing new patterns. Therefore, the test choice had to propose services able to compete with the private owned car in terms of convenience and cost-structure and, at the same time, contributing to reduce negative externalities in the cities.

The mobility pattern selected for the field test has been the car sharing, generally identified as "a short-period automobile rental services intended to substitute private vehicle ownership" (UTIP Secretary General 2002).

Nonetheless, for its set up the test could not follow existing large urban or regional car sharing experiences, too big for the size of the project and the maximum available number of EVs. Therefore, it was decided to design a service, which could fully meet the needs of small communities with a limited number of vehicles. Moving from an unpretentious but easily manageable car test to the development of a new system, demanding for the search of a sampling population, their training and then the monitoring of their activities, was a relevant challenge. On the other hand, the team considered the risk well balanced by the opportunity to obtain future collective behaviours answering to the hypermobility topic and to define a wider sampling of driving behaviours.

Obviously, in order to perform as well or better than the private car system, car sharing has to offer access to a vehicle whenever test participants require it. Its efficiency depends on the vehicle accessibility (within easy walking distance of people's homes), affordability (reasonable rates, suitable for short trips), convenience (vehicles that are easy to check in and out at any time), and reliability (available vehicles and a reliable booking and access system). The first option was to provide EVs, charging boxes, and monitoring applications to large condominiums, which internally had to organise their booking and car access system. However, practical experience says that condominiums have very limited capacity in sharing common goods, and the test could fail because internal conflicts on the EV use. In order to avoid that risk, the team decided to experiment with a car sharing approach in "cohousing" communities.

For the bus transportation, the current availability on the market of full e-Buses (Class 1) is limited to small buses, running shuttle services or performing regular lines in historic centres. For the scope of the test, that is, a continuous daily use in real service conditions, the second option is the most valuable for measuring the e-buses cycles of charging and discharging. In order to analyse the ageing of the batteries and to have a robust data set, the test should run in different geographical locations and seasons, for a period of at least of one years with similar buses. In that case, as well as for the car sharing, the number of e-buses used in the test should be enough to perform a regular service in a medium size historic centre and provide a real service. Considering the limited available resources, that solution was not feasible. An alternative was running the service for smaller communities in well-circumscribed areas, such as hospitals or university campuses.

3. Private car tests

3.1 Cohousing EV-sharing

What is Co-housing?

Cohousing is a special type of collaborative housing in which residents actively participate in the management of their own neighbourhood. Cohousers are consciously committed to live in a community and to take care of common property. That builds a sense of working together, trust and support (c.f. Ruio, 2014), which was a guarantee for the success of the car sharing tests. In addition, the new generations of cohousers are at least assumed to be getting much "greener" and, in general, are committed to develop photovoltaic or wind energy production and to start investigating EVs use too. They generally aspire to 'improve the world, one neighbourhood at a time' (c.f. cohousing.org). This desire to make a difference often becomes a stated mission, as the websites of many cohousing communities demonstrate. While a certain flexibility characterises the cohousing design and organisation, easily adaptable to people's needs in different cultural contexts, two main typologies are predominant, the urban community and semi-urban/rural village. The first type, located right in the city centre, is organised in vertical buildings with

***Figure 1: The cohousing "Vinderhoute*"**

common rooms (dining room, sport rooms and other facilities) but is lacking parking facilities and green areas. The size is very variable, from one building with about 10-12 people up to 184 apartments in 13 buildings accommodating more than 400 people (e.g. Stoplyckan in Linköping, Sweden) (see Krause, ed., 2012). The second type, on the contrary, is a village-like community, usually organised in attached or single-family homes along one or more pedestrian streets or clustered around a courtyard. In this type too, the size range is very variable, from seven to 67 people, but the majority of them houses 20 to 40 households (see, for instance, Institute for Creative Sustainability 2012).

Cohousing selection

In Flanders, cohousing is a growing way of inhabiting, but few ones are effective and many are still under construction. The team selected four different cohousings, two small urban communities in Ghent – Papegaaistraat and Sint-Pietersaalststraat - without parking places, and two larger semi-urban communities, one located near the city of Brussels (La Placette in Wezenbeek-Oppem) and the other located near the city of Ghent (Vinderhoute), both characterised by open common spaces and parking facilities.

Vinderhoute, a nearly new cohousing not far from Ghent (about 10 km), has been the first to receive the invitation to participate to the project tests. It is the association of seventeen families, mainly composed of young couples with children. The community shares a large parking area and a community building with a spacious kitchen, a large dining space, offices, workshops, a music room, a children's playroom and some guest rooms. Cohousers can easily book online the facilities and their joint management strengthens social contact and encourage spontaneous encounters between members. In addition, the community shares also a photovoltaic system for the production of energy (10 kW), used for supplying the common facilities, and all buildings are passive and low energy constructions. They were already thinking about installing a charging box in the parking, and accepted enthusiastically to test EVs with a car sharing approach. Furthermore, they have informed the cohousing of 'La Placette' in

Wezenbeek-Oppem about the possibility to take part to the test.

Figure 2: The cohousing "La Placette"

Built in 1986, La Placette is the result of the association of eleven families wishing to live together in a co-housing, based on the principles of "non-violence, self-management and social cohesion". Each family owns a house, a private garden and a common garden. In addition to the garden, they have multiple common premises: a mini Amphitheatre, located on the side of the housing, a common house, a place of temporary home and a parking. In the interviews for the project, they acknowledged their interest in EVs and in participating in the test.

The two small urban communities, both situated in the centre of Ghent (Papegaaistraat and Sint-Pietersaalststraat), have private apartments and common rooms, but no parking facilities. Living in a mostly pedestrian and biking area, where parking is expensive and limited, only few of them owned a car and others were already customers of 'Cambio', the main commercial Belgian car sharing company. After some internal meetings, both communities accepted to take part to the tests.

Test Objective

The declared test objective was to measure EV interaction with the electric grid, then monitoring different drivers in different hours, with different behaviours and EVs. Nevertheless, the need of metering charging and consumption in real daily transport operations invested that field tests with the possibility of acquiring new meanings. It was a remarkable opportunity for investigating new potential cultural changes related to the imminent EVs market penetration, and assisting the project's aim of "fostering the diffusion of the electric mobility and stimulating the use of public and private electric car transport as well as freight across the North Sea Region (NSR)".

3.2 The test organisation

The first part was dedicated to the selection of the co-housing communities and the organisation of the test. As already described, four cohousing communities have been chosen. During a test period of about one year, these selected four cohousings had to guarantee to organise a system for sharing the EVs among their members, to maintain and charge the EVs, to answer to the project questionnaires and to participate to events or demonstrations organised by the project.
On the other hand, the project team had to lease EVs, stipulate a contract with each cohousing community, training the participants on EV driving, charging, and identification systems, installing GPS-loggers and other ancillary monitoring systems in each vehicle. In addition, the team had to manage an emergency number for any car default, designing and elaborating on questionnaires to deliver to the participants, advancing monitoring tests, and providing feedback to the test participants about any technical and organisational topic.

The subsequent part was to define the methodology for running the tests and collecting data, combining quantitative data about EV charging and consumption dynamics and qualitative data about perceptions of EVs and experiences with online questionnaires filled out by test participants.

The initial idea was to provide the communities with leased EVs, one or two according the population size, and to install charging boxes inside their parking facilities. However, the participation of the two urban co-housing without parking facilities needed and demanded a different approach. That opened the way to another very fascinating investigation, made possible thanks to the support of Cambio (see box next page), which was also starting to operate a car sharing service with EVs. The two urban communities received pre-paid cards (with a distinct ID per each participant) for using EVs supplied by Cambio as part of their fleet. Cohousers had to follow all Cambio rules for the booking, parking, and charging, and EVs were available connected to a charging box in parking facilities not far from the cohousings. In that way, thanks to the quantitative data collected by Cambio and delivered to the team, it was possible to compare the performance of a small community car sharing with a traditional one, and evaluating their results in terms of energy consumption, car performance and battery ageing.

Four EVs, three Nissan Leaf and one Peugeot Ion, were leased and delivered to the two semi-urban co-

Cambio is a car-sharing organisation and operates in several Belgian cities. Wallonia was the first Belgian Region to start in 2002. Then in May 2003, Brussels followed and in September 2004 the Cambio car sharing system also started in Flanders. According their website (http://www.cambio.be/), Cambio Belgium has more than 15,000 users, a car fleet with more than 500 cars spread across 220 stations in 27 Belgian cities. The company cooperates closely with VAB (the largest Flemish automobile association), De Lijn (public transport operator in Flanders), MIVB/STIB (the public transport operator in the Brussels metropolitan area) and TEC (the public transport operator in Wallonia). In 2009, the NMBS-holding (Belgian railways) also decided to participate in the project. This completes the cooperation between Cambio and public transport. Furthermore, local, regional and federal authorities participate: they help with the financing, give policy support and provide the necessary car sharing stations (parking places).

housings, together with a charging box installed in each cohousing parking facility. Quantitative data was collected by means of five different tools: a data logger installed in the car, a GPS, the CAN-bus (decrypted as in Figure 3), the RFID scans of participants’ badges, and finally the charging pole meter to retrieve information of the energy charging and accumulation in the batteries.
Thanks to the real time data collection, it was possible to monitor cohousers’ different travel behaviours through the MOVE-platform (see BOX) (http://move2.ugent.be/index.php/en/).

Figure 3: CAN-bus decrypted

In order to evaluate in a dynamic way cohousers’ perception of the EVs’, and then to investigate of their potential change in culture and consciousness, the team prepared three questionnaires to be filled out online before, during and after the test period by each participant. At the time of writing this report, the questionnaire survey cycle has not been completed yet, but there is enough data to provide a comparison between the results of the first questionnaires, where respondents generally had a blurred idea of EVs, and the intermediate ones, where test participants started to know more about EVs than the majority of the population.
The first questionnaire was addressed to the selected groups, in order to have a clear view about drivers (age, sex, activity, and education level), current driving behaviours, and their vision and expectation about EVs, car sharing and the test. All the information have been collected in a database.

The MOVE-platform

Developed at the Ghent University, the **MOVE** is a mobility platform, which allows to consistently collect data from different sources in a cost efficient way. It integrates data from mobile sensors like GPS, Wi-Fi, cell, Bluetooth, NFC, accelerometer, image, audio. Data also includes activity received through user interface actions, mobile surveys, social network interaction etc. MOVE has a number of mobile apps that allow data acquisition, either as an electronic mobility diary (rich information, high interaction level) or a mobility service app (less information, low interaction level).

http://move2.ugent.be/index.php/en/

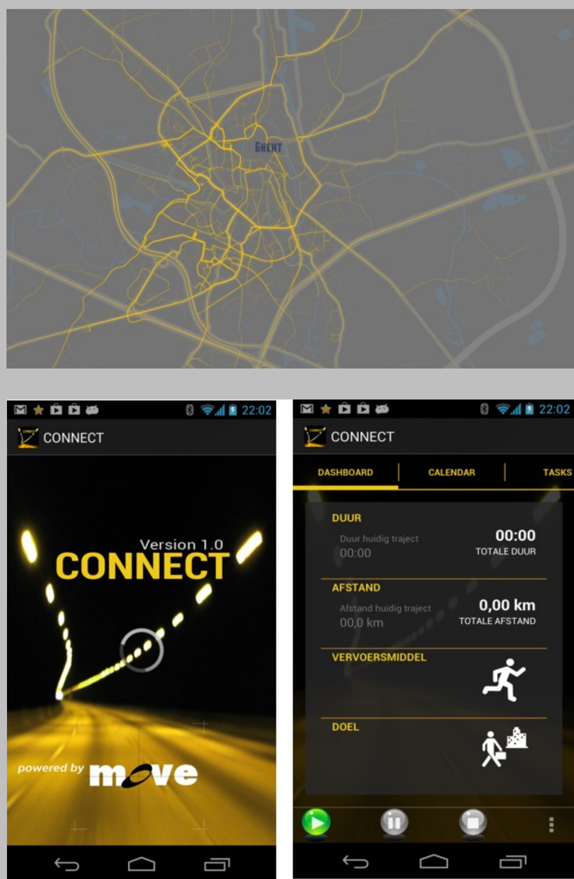

Figure 4: The Move-Platform in Ghent

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Legal frame

From the legal point of view, UGENT subscribed leasing contracts with two leasing companies for a period of one year. Each cohousing community signed an agreement with UGENT for the test of EVs during a period of one year, in order to cover the excess refund costs for any car damage. UGENT provided for a training session to the test participants, for both driving and charging the vehicles. A contract of car assistance was stipulated for the test duration with a specialised garage, in order to provide test participant with a first aid 24h/7days.

Figure 5: One of the Nissan Leaf used for the tests

Figure 5b: Vinderhoute Cohousing: the charging box and the Nissan Leaf

Figure 5c: "La Placette" Cohousing: the Peugeot Ion used for the tests

3.3 Results

Qualitative dynamic analysis

The questionnaires intended to provide a survey of the 78 cohousers (47.5% men, 52.5% women) living in the selected four Flemish co-housing units, which had accepted to participate in the tests.
In terms of the test population composition (Table 1), the urban and semi-urban cohousing communities displayed relevant differences in size, marital status and number of children, which suggested clustering test populations in two groups and comparing behaviours and needs. In fact, the two urban communities have a small number of cohousers (5-7), predominantly with an age range from 18 to 35 (only one is older), singles (though two are co-habiting), and all with no children. The two semi-urban ones have a bigger population (33-35), composed mainly by families with children (under 18 not counted in the test population). At Vinderhoute, participants' age ranges from 26 to 50 years, while La Placette has a very mixed composition of elder and younger people (as it already consists of two generations of familiar groups).

Table 1: Composition of the sample population per co-housing community

		La Placette	Papegaaistraat	Sint-Pieter-saalststraat	Vinder-houte	Total
Number of inhabitants		35	7	5	33	80
Participants in the survey		34	7	4	33	78
Gender	Male	16	3	2	16	37
	Female	18	4	2	17	41
Age	18-25	8	2	0	0	10
	26-35	7	5	3	13	28
	35-50	0	0	1	16	17
	51-65	19	0	0	4	23
Marital status	Single	9	6	3	3	21
	Married	19	0	0	25	44
	Co-habiting	6	0	2	5	13
Number of children	0	7	6	5	7	25
	1	7	0	0	4	11
	2	4	0	0	13	17
	3+	16	0	0	9	25

In terms of education of the stakeholders, i.e. school diplomas and professional status (Table 2), the differences between the two clusters are not very relevant, with 95% of the participants having a high school or university educational attainment level and 77% of the participants a part- or full-time job. That confirms the picture of the cohouser as a highly educated and professionally integrated person, searching for a more social and liveable way of inhabiting. In addition, most of the working participants have a daytime job and a regular working address out of the home (77 %).

Table 2: Education attainment level and professional situation of the sample population (n.)

	La Placette	Papegaaistraat	Sint-Pieter-saalststraat	Vinder-houte	Total
Highest educational attainment					
Secondary school or lower	4	0	0	2	6
High school	15	2	2	16	35
University	15	4	3	15	37
Professional status					
Student	6	0	0	0	6
Inactive	2	1	0	4	7
Part-time job	9	2	1	8	20
Full-time job	15	3	3	19	40
Blank	2	0	1	2	5

Subsequently, the survey investigated participants' mobility behaviours for different purposes, in terms of frequency and travel mode. In terms of trip frequency per purpose (Table 3), all working participants travelled more often to work (daily or at least several times a week), less frequently for shopping or for recreation (from once to several times a week). The only relevant difference between urban and semi-urban cohousings was the frequency of trips to take or collect other people, where urban cohousers travelled monthly or never and semi-urban ones daily or weekly, clearly because their different familiar composition.

Table 3: Frequency of trips for different purposes (n.)

	To work	To a shop	To take or collect other persons		For recreation
			Urban	Semi-urban	
Daily	46	4	0	14	5
several times a week	26	28	0	13	37
Weekly	1	35	1	21	27
Monthly	1	11	9	12	9
Never	4	0	2	6	0

In terms of travel mode, participants had to specify the mode predominantly used for different purposes. In general, the car is the dominant travel mode (Table 4), but differences between urban and semi-urban clusters are very relevant, mainly because of their geographical location and their familiar status. For commuting to work, urban cohousers mainly use the train (50%), with the bicycle as the main alternative (33%).

For semi-urban cohousers, the car (private and company car) is the main means (47%), although with a lower rate than for other purposes, and bicycle (26%) is the main alternative. For shopping, almost all urban participants use the bike, being already in the shopping area (83%), whereas semi-urban ones tend to take the car (68%), with the bicycle as a remoter alternative (14%). Only for taking or collecting other persons (i.e. children, parents, friends, colleagues), the two sample populations have similar behaviours (although with completely different frequencies) with the car being the most common travel mode (41% for urban people, 68% for semi-urban). It is interesting to remark that 25% of urban cohousers use shared cars for such a more sporadic activity. The main alternative for semi-urban cohousers is walking (11%), using a shared car (9%) or cycling (9%). Finally, for recreational trips, urban cohousers use the bike (75%) in contrast with the semi-urban ones, which most often use the car (59%), with biking (24%) and shared cars (11%) as the most common alternatives.

Table 4: Most frequently used transport mode for different purposes

	To work		To a shop		To bring or get other persons		For recreation	
	Urban	Semi-urban	Urban	Semi-urban	Urban	Semi-urban	Urban	Semi-urban
Car	17%	47%	8%	68%	41%	64%	8%	59%
Private car	17%	32%	8%	56%	41%	53%	8%	44%
Company car	0%	15%	0%	12%	0%	11%	0%	15%
Shared car	0%	1,5%	0%	9%	25%	9%	8%	11%
Bicycle	33%	26%	83%	14%	17%	9%	75%	24%
Train	50%	6%	0%	0 %	8%	1%	0%	0%
Tram or bus	0%	7,5%	8%	4,5%	0%	3%	0%	4,5%
On foot	0%	9%	0%	1,5%	8%	11%	8%	0%
Other	0%	3%	0%	3%	0%	3%	0%	1,5%

A second part of the questionnaire asked for project-related questions, starting by their motivations to participate to the tests. As reported in Figure 6, for more than 70% of the participants the main motivations are to help the environment, to contribute to the development of electric cars, and the belief in electric cars as the vehicles of the future. That emphasises participants' strong environmental and social commitment.

A confirmation of the common cultural approach comes out from the participants' answers on what aspects are determining their choice of a car (Figure 7). Both groups answered similarly, assigning priority to environmental impact criteria (emissions, safety) and tangible car values (reliability, price and fuel consumption). More than 70% of the participants find these attributes (very) important.

Figure 6: Motivations to participate in the e-Mobility project

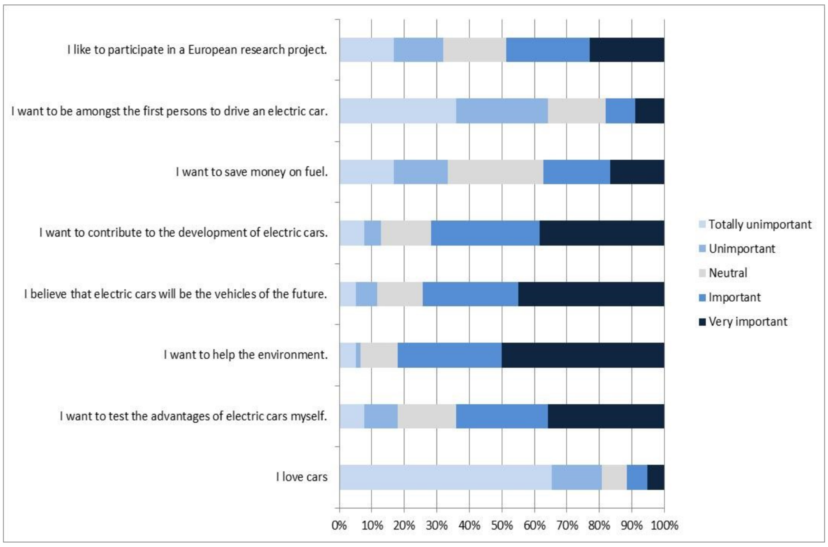
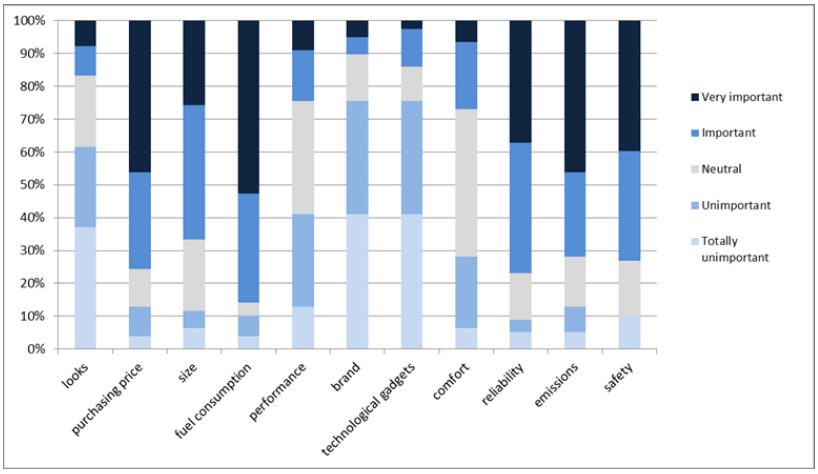


Figure 7: Attributes' relevance in the choice of a car



Over 60% of the participants judge luxury criteria, such as car appearances, brand and technology gadgets as unimportant. The two cohousing types also provided homogenous answers about aspects that (may) keep them from purchasing an electric vehicle (Figure 8). The most important barriers to buying an EV are their actual high purchasing price (more than 80%), the limited driving range (more than 60%) and the problems related to battery charging, such as time needed, and charging point availability (ranging from 30 to 50% of the participants). Other possible topics, such as the EVs' limited performances or the limited number of brands and types, are not a problem for over 50% of the participants. In addition, unfamiliarity with electric cars or safety doubts are not considered an issue at all.

When asked about which measures could stimulate the purchase of an electric car, most participants answered that they believed in the effectiveness of some type of public financial support (Figure 9). Over 60% think that exemption from taxes, free charging or an EV purchasing subsidy could be (very) important governmental actions.

Figure 8: Importance of aspects retaining people from purchasing an EV

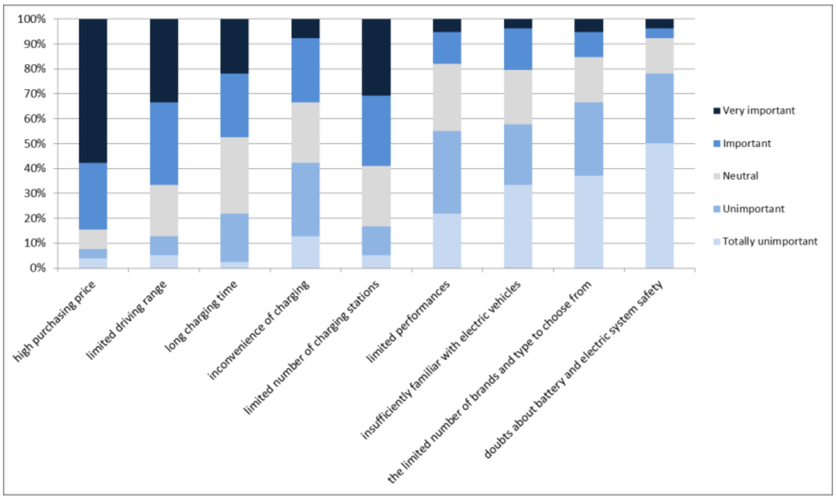
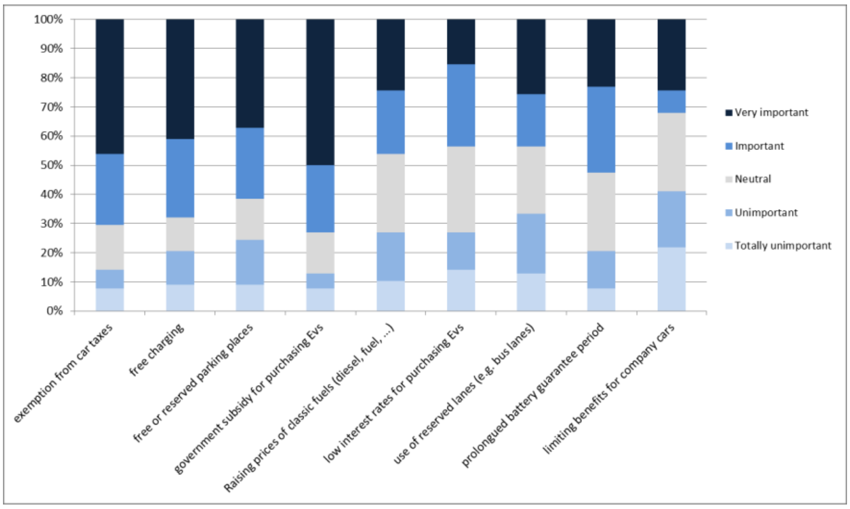


Figure 9: Belief in government actions to stimulate the purchase of an electric vehicle



As a proxy for their initial expectations about the EV, participants answered as to how the EV would score for a number of criteria, in comparison to a conventional car (Figure 10). They expected that EVs could outperform conventional cars in terms of facility to use and acceleration. On the other hand, people assumed that conventional cars would score better in terms of top speed, the ease of charging (refuelling) and the availability of charging stations (fuel stations). Concerning safety, design and car interiors, there is no clear preference and a large share of the participants express no opinion. It is interesting to see that for the over-all impression, people tend towards the EV, although 50% participants state no opinion.

In terms of expectations about the EVs' performances, in absolute terms, they are higher for energy consumption, environmental score and vehicle noise: over 80% have high to very high expectations about all these items. Also about the ease of driving, the reliability and the safety of the EV over 50%

have high to very high expectations. On the other hand, over 40% of the participants have (very) low expectations about the cars' top speed and acceleration and about the options and gadgets in the car.

Figure 10: Expectations about the performances of the electric car, compared to a classic car

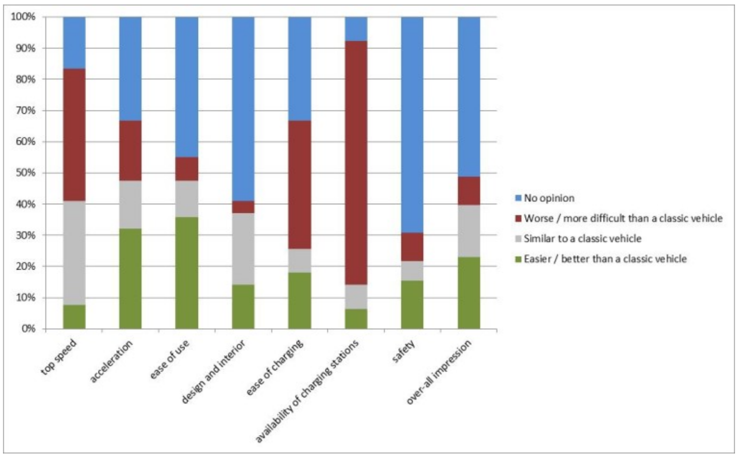
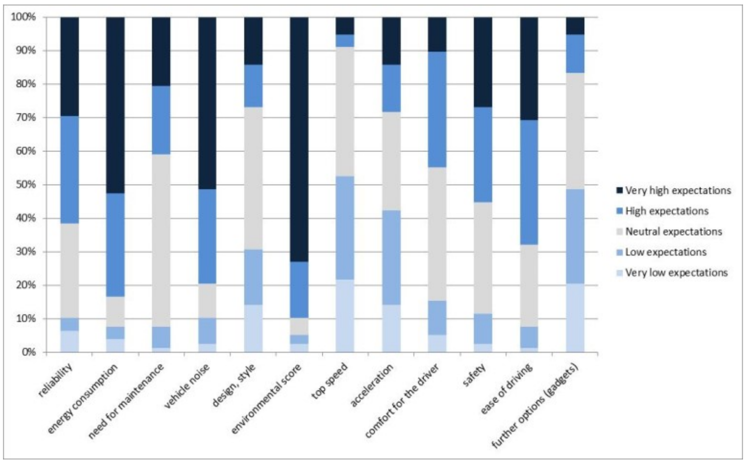


Figure 11: Expectations about the performances of the electric car



In addition, participants were asked to answer about their expected use of the EV sharing in the cohousing. Again, their answers expressed relevant differences between urban and semi-urban cluster. Urban cohousers expect a limited use of the shared car: only 25% at least twice per week, and more than 33% less than once per week. The semi-urban ones, on the contrary, expect a higher use of the EVs, at least twice per week (71%) or once (27%). To the question as to when they planned to use the shared EV, on weekdays or weekend, and during daytime or in the evening, both clusters anticipated weekend days during daytime as the busiest period (Table 5). Only 17% of the urban participants planned to use the car during the week during daytime, revealing a certain tendency to consider the car sharing as a part of the free time lifestyle. The semi-urban cluster, on the contrary, gave the idea of a certain willingness to integrate this new car sharing into their daily activities.

The reason for that come out from the participants' answers to the question "how do you plan to use the shared vehicle" (Table 6). In the urban cluster, only 33% of the participants own a car and consider the shared car as an extension of their mobility, and the others did not intend to change their pre-existing behaviours. In the semi-urban cluster, although 59% of the participants only considered the shared car as a second car, very promisingly 20% considered disposing of their current car and replacing it with the shared vehicle.

Table 5: Expected use of the shared vehicle: when do you plan to use the shared vehicle?

When do you plan to use the car?	Urban	Semi-urban	Total
On week days, during the daytime	17%	35%	32%
On week days, during the evening	25%	30%	29%
On weekend days, during the daytime	58%	48%	50%
On weekend days, during the evening	42%	27%	29%

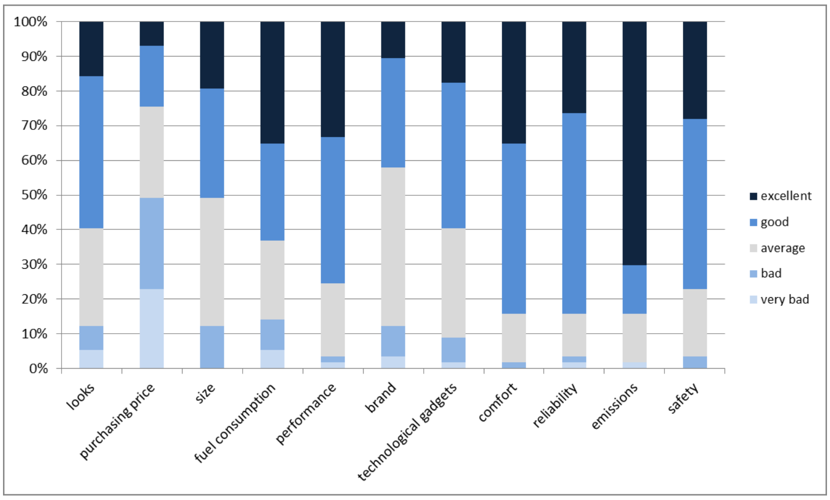
Table 6: Expected use of the shared vehicle: how do you plan to use the shared vehicle?

How do you plan to use the car?	Urban	Semi-urban	Total
As an addition to my current car (as a second car).	33%	59%	55%
I don't own a car	67%	14%	22%
To replace my current car.	0%	20%	17%
(blank)	0%	8%	6%

After six months of EV sharing, cohousers responded to a second round of survey. Results show how the participants' perception of EVs have changed, due to their tangible experience. Participants answered questions about the main aspects relevant for the choice of an EV, the actual barriers to purchasing one, EVs' performances in absolute terms and compared to conventional cars, and reasons for not using them during the tests (but one should note peer communication amongst cohousers may well still have influenced their perceptions of EVs after 6 months). The two clusters, this time, did not show relevant differences, featuring a common cultural background.

The main relevant aspects in choosing an EV (Figure 12) are comfort, reliability and emissions (84% each), followed by safety (77%), performance (75%), fuel consumption (63%), design and technology (60% each). The only aspect relevant for not preferring an EV is its high purchasing price (only 25% rated this as excellent or good). Comparing these participant responses with those in Figure 7 referring to a generic car, the attributes matching their car choice priorities are reliability, emissions, safety, and fuel consumption.

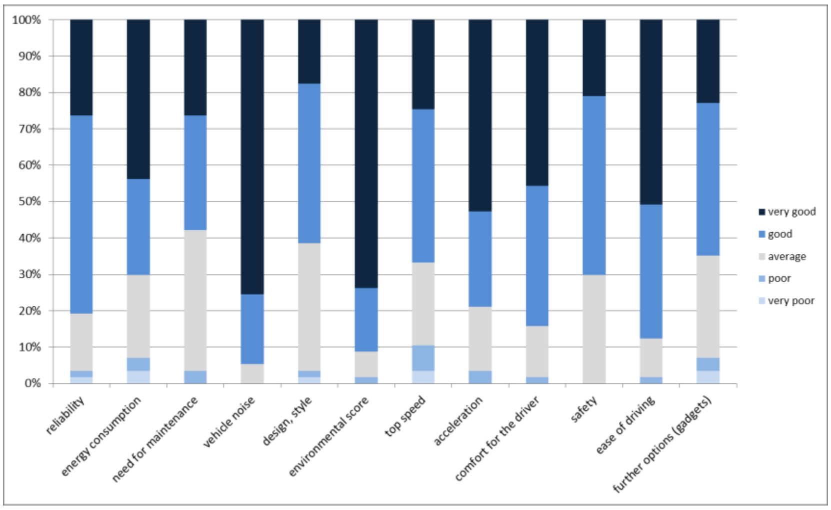
Figure 12: Attributes' relevance in the choice of an EV



Participants' experience confirmed their opinion about barriers to EV purchasing. Furthermore, the EV score compared to a conventional car has not changed in a relevant way. However, they developed an awareness and 'no opinion' responses disappeared completely. Major changes can be seen in the EV performance evaluation (Figure 13). Their EV appreciation has increased in terms of reliability

(60% to 80%), maintenance (40% to 60%), vehicle noise (80% to 95%), design and style (27% to 60%), top speed (less than 10% to 65%), acceleration (30% to almost 80%), driver comfort (45% to 85%), safety (55% to 70%), ease of driving (65 to 90%), and accessories and gadgets (15% to 65%). Reversely, it has diminished in terms of energy consumption (85% to 70%) and it is stable on the environmental score.

Figure 13: Evaluation of the performances of the electric car after six months use



The intermediate survey was also a good opportunity to investigate the cohoursers' car sharing experience, as well as to compare differences between small community car sharing and the traditional one, as perceived by the cohousers. Consequently, the two clusters have been analysed separately and then compared. The first question is about barriers to the use of the EV in a shared mode (Figure 14 a-b). Both urban and semi-urban cohousers, in a mainly positive evaluation, consider the insufficient driving range of the EVs as the main barrier (important to very important for 50% of urban cluster and for 70% of semi-urban cluster). Ranked in second place of importance, both groups mention the problem of the non-availability of an EV (40% urban and 35% semi-urban). For the large majority of urban participants, the other potential barriers, such as car reservation, delays in obtaining the car from the previous user, or insufficient charge, were not important.

The semi-urban participants reveal wide-ranging opinions, with some of them considering as important the need for car reservation (for 30% important to very important), the preference for the independence of owing a car (30%), the non-practicality of the car (23%) and the EV often not sufficiently charged (21%).

Figure 14a: Barriers to the use of EV shared after six months use (Cambio case)

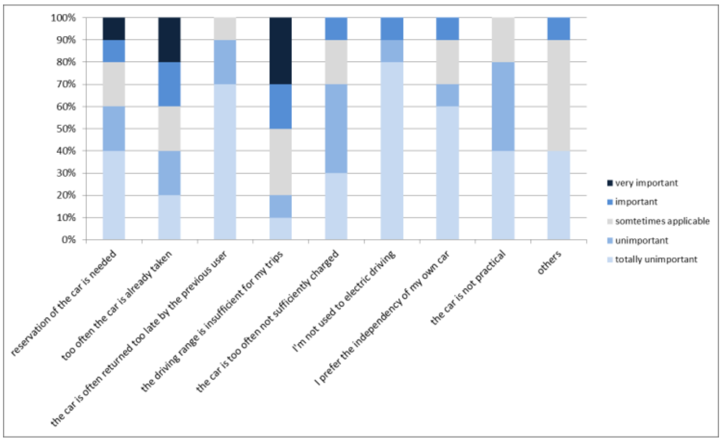
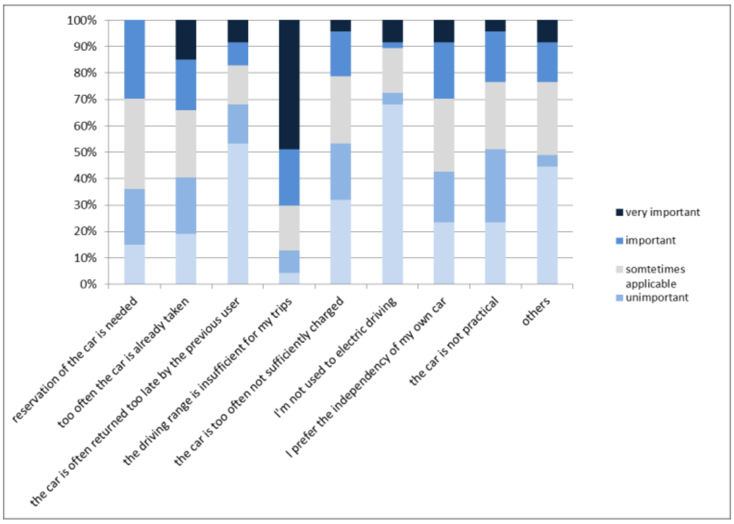


Figure 14b: Barriers to the use of EV shared after six months use (small community EV sharing)



The second question was about how they used the shared car, in order to have a comparison with their initial expectations. The small number of answers received (return of 57 out of 78) do not permit a comparison yet; nonetheless, seven of them confirmed the willingness to replace their current car with an EV. Finally, participants were asked to answer as to how they would make their trips, if the shared car had not been there (Table 7). The car is the first option for the 70% of urban cohousers and 87% of semi-urban ones. However, in connection with the second option the two clusters provided very relevant differences. Without car sharing, 40% of urban cohousers would have used public transport or bikes to make their trips. On the contrary, 19% of the semi-urban would not have been able to do the trip, and only 13% would have used a bike and even less public transport (6%).

Table 7: If the EV sharing would not be available, how would you make those trips?

	Urban	Semi-urban	Total
Not do those trips	10%	19%	17%
Use another car	70%	87%	84%
Use public transport	40%	6%	12%
Use the bike	40%	13%	18%
Choose a closer destination	10%	4%	5%

If confirmed by the quantitative data, that information could be the most relevant one for developing a sustainable transportation approach. Car sharing, on the one hand, for the urban cohousing rivals with public transportation and soft mobility (active travel or reduced mobility). On the other hand, for the semi-urban communities it definitely rivals with the private car and represents a relevant extension of the users' mobility.

Analysis of travel and charging behaviours

Although tests are still running and data collection is not yet completed, it is already possible to have a preliminary insight into how cohousing communities use and share electric vehicles, by analysing trip distances and charging behaviours. For the charging data, participants are clustered into urban and semi-urban cohousers, similarly to the qualitative data presented above, in order to filter results according their different geographical positioning and car sharing organisation. In particular, although this is not a critical characteristic for understanding the way they use EVs, the different organisation of the EV sharing service provided to cohousing community surely influences the interpretation of some of the findings. In particular, having to pay the electric bill for the EV charging, semi-urban cohousers pay more attention to the energy consumption, charging EVs possibly night time and only when necessary. On the contrary, Cambio users are obliged to charge the car once they finished using it.

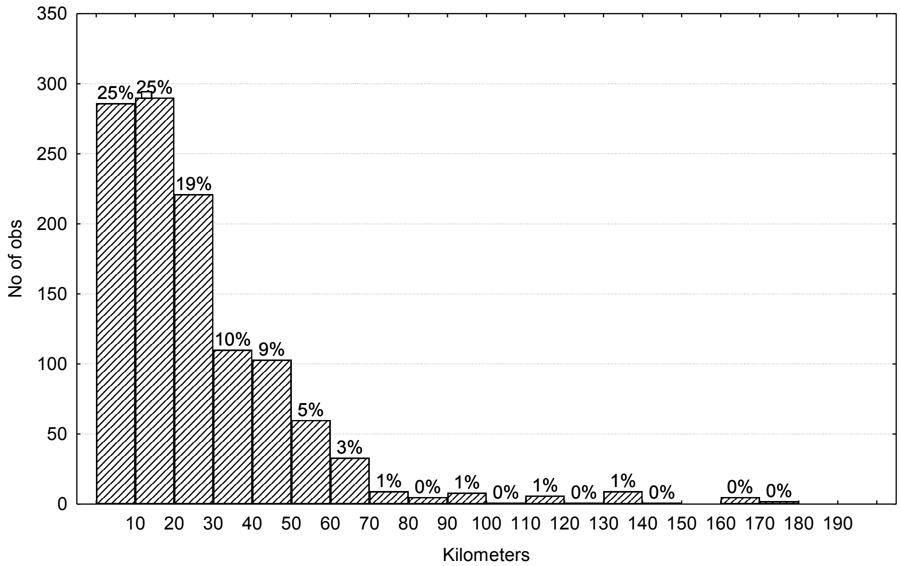
A. Trip distance analysis

Taking into account official statistics for the whole Flanders region, the average trip distance is 28,795 km. However, the numbers are quite different for the Ghent urban area, where trip distance average is only 11.964 km (Reports OVG Flanders, 2013). When measuring cohousing trips, for one trip we mean a round journey to destination and back to the starting point (including all intermediate stops made during this trip). Therefore, if a user goes to pick up kids from school and on the way to school stops at supermarket to buy groceries for dinner, that all would be considered one trip (not three separate trips). Table 8 provides a summary of descriptive statistics for trip distances travelled by the cohousers during the period of nine months and Figure 15 shows the distribution of trip distances over the same period, with trip distances measured in km, and number of observations (= obs) to mean number of trips as defined as above.

Table 8: Trip distances descriptive statistics (km)

Mean	Median	Minimum	Maximum
27,044	20,00	0,00	172,00
Lower Quartile	**Upper Quartile**	**Quartile range**	**Standard deviation**
11,00	37,00	26,00	25,055

Figure 10: Distribution of trip distances (n. of obs)



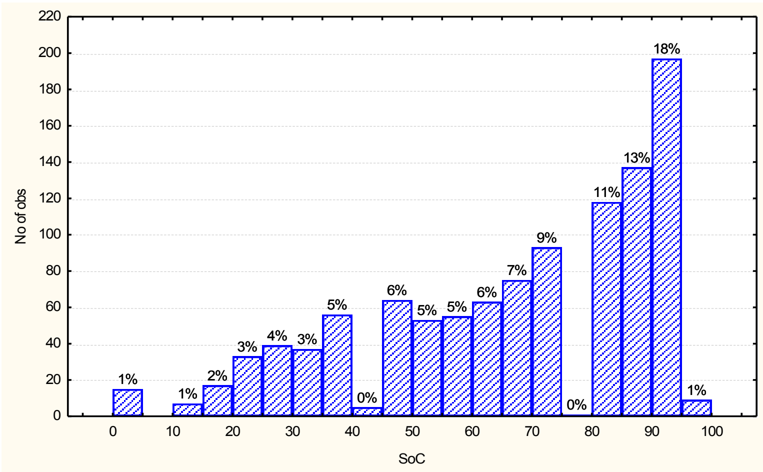
The average trip length is around 27 km, with a median of 20 km and a standard deviation of around 25 km. The shortest trip recorded is less than 1 km long, while the longest trip is 172 km long. 25% of all trips are less than 11 km long, and 25% of them are longer than 37 km, which means that half of all trips made are over a distance of between of 11 and 37 km. When taking a closer look at the graphical representation of trip distances, 50% of all trips are shorter than 20 km and just 4% of trips are longer than 70 km. If we consider that the autonomy of a fully charged EV ranges between 80 and 140 km, it is possible to have at least three trips with one charge, which means that EVs do not need to be fully charged before each trip.

The trip distance analysis is only at the beginning and, once completed the data collection, it will compare differences between urban and semi-urban clusters' travel behaviours, also segmenting participants in terms of age and familiar status. In addition, there will be a check of the daily number of trips per EV and per community, frequency of use per participant and in which part of the day/week. All those data will be compared with the qualitative surveys and provide information on the level of the service acceptance for both different car sharing approaches.

B. Charging behaviour analysis

Charging behaviour is analysed based on two observed values, battery State of Charge (SoC) and the time of the day when the vehicle is plugged in for recharging (and unplugged). Figure 16 shows the distribution of battery SoC value at the start of recharging event for the Cambio service users, while Figure 17 shows the same distribution for cohousing community where vehicles were provided for research purposes.

Figure 16: Distribution of battery SoC at the start of recharging event for Cambio users



In Figure 16 it can be seen that values are quite oriented towards a higher battery SoC, and that the highest value for SoC, at the beginning of the recharging event, is between 90 and 95, meaning that 18% of times recharging stated when SoC was in this interval. This is due to the Cambio car sharing rules / terms of conditions for users that after every trip users should start recharging of the battery for the next user so as to have as high as possible battery's state of charge at the start of the trip. Therefore, Figure 16 gives a good overview of how much battery is degraded during the individual trips. Figure 17 gives a better description of cohousing members' behaviour regarding when they consider themselves that they should recharge their car's battery. The distribution of values of the SoC at the start of recharging event in Figure 17 is also oriented towards a higher battery State of Charge but with highest frequencies of SoC values in interval between 80 and 90. Also, 55% of users will consider that they should recharge even if the SoC is higher than 70, while only 5% of users will wait till SoC gets below 15 and none of the users waited till SoC is lower than 10 to start recharging electric car's battery.

Figure 18 and 19 provide an overview of the SoC value at the end of recharging process. For Cambio users we can see that batteries are charged to its maximum capacity and that users unplug vehicle in 89% of cases when it is full. This also means that in between vehicles users prefer to share the one with highest SoC, while leaving others to recharge, and it can only happen if there is always sufficient number of EVs available for the users to share.

As the number of available EVs for non-Cambio users is five times less than for Cambio users, the distribution of SoC values are different in the case of the Wezenbeek-Oppem cohousing community. In Figure 19 it can be seen that just in 43% of cases battery's SoC was recharged to its highest value and this is less than half of the percentage for the same values at Papegaaistraat and Sint-Pietersaalststraat.

In Wezenbeek-Oppem cohousing, 12% of times recharging was stopped although SoC value was below 50. Differences in the times of the day when users start (Figure 20) and stop (Figure 21) the recharging process suggest that different SoC distributions can not only be explained by the availability of shared vehicles, but also by the differences in cohousing's population characteristics.

Figure 17: Distribution of battery SoC at the start of recharging event for Wezenbeek-Oppem cohousing

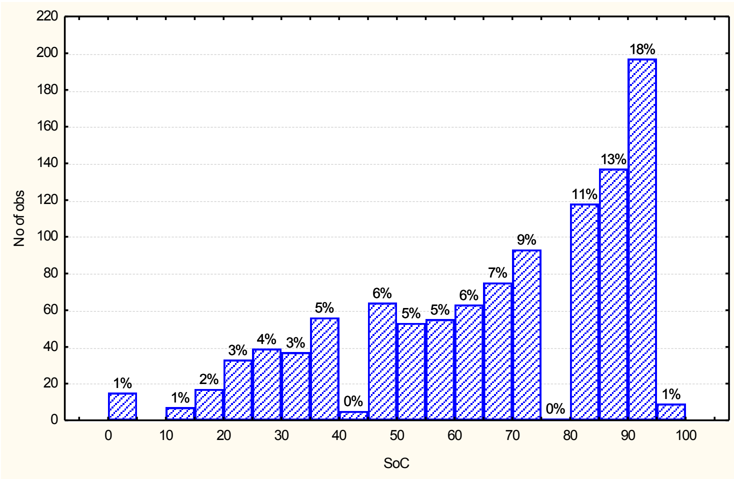


Figure 18: Distribution of SoC values at the end of recharging event for Cambio users

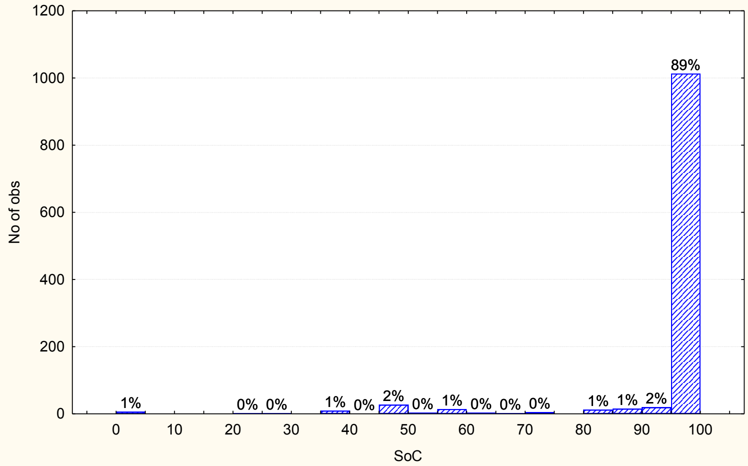


Figure 19: Distribution of SoC values at the end of recharging event for Wezenbeek-Oppem

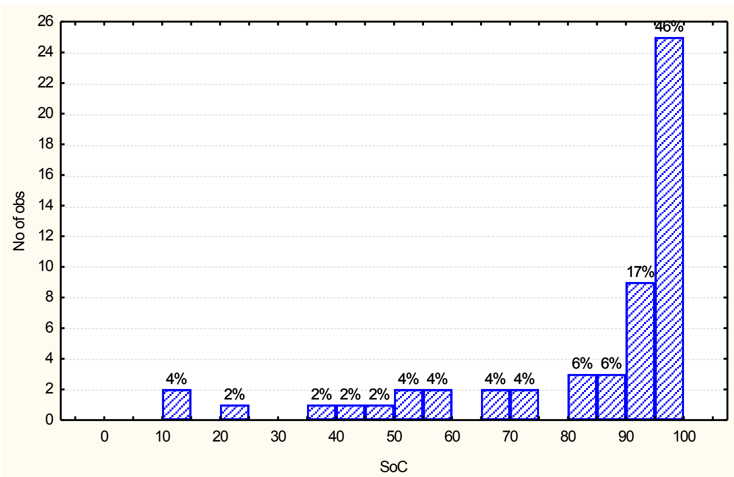
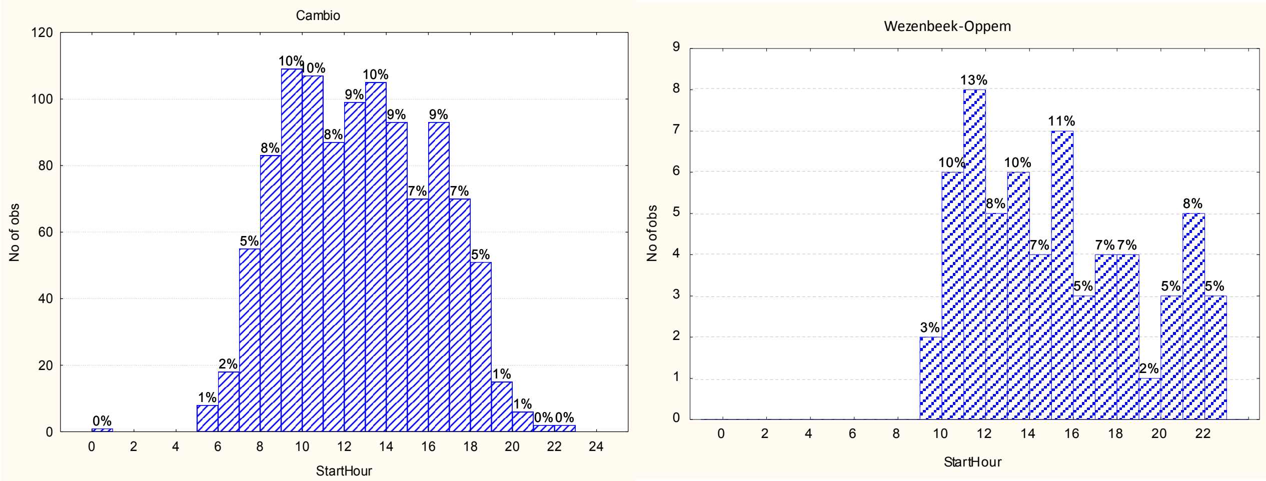
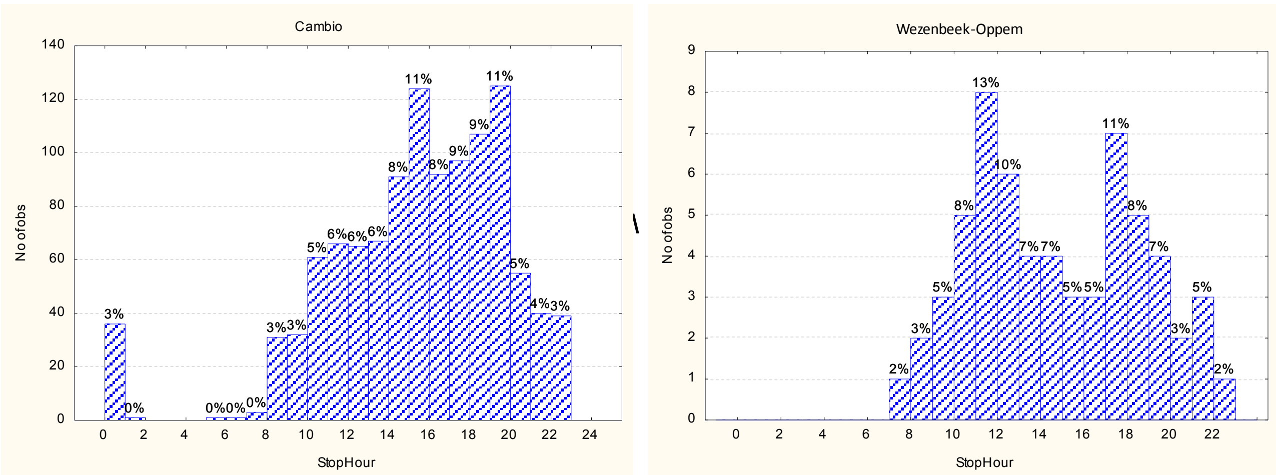


Figure 20: Time of day when recharging is started (left: Cambio users, right: Wezenbeek-Oppem cohousing)



For Cambio users, the average time of the day when they return and plug in the car is 13:17h, though the time window is wide enough, and the distribution of starting time of day for recharging time's distribution has quite normal shape. For Wezenbeek-Oppem cohousing, the time window in which recharging starts is more narrow (from 10h until 23h) and has an average value of 15:45h, with peaks at 11h, 15h and 21h. On the other hand, the time of day when recharging is finished for Cambio users has a rather similar shape as the distribution of start of the recharging times though with a bit more of a shape towards the end of the day. The average time of day when Cambio users end battery recharging is at 15:53h, and this has two modal values (15h and 19h); for the Wezenbeek-Oppem users the average time of day when recharging is finished is quite similar (15:17) but with two peaks, a late morning peak at 11h and an afternoon peak at 17h.

Figure 21: Time of day when recharging stops (left Cambio users, right Wezenbeek-Oppem cohousing)



When considering how long the battery is charged (Figure 22), Wezenbeek-Oppem users most of the times recharge for an hour, with 67% of times less than 2 hours and never longer than 13 hours. Cambio users on average recharge the vehicle for a duration of 4:18 hours, with 36% of times less than two hours and 2% of times the vehicle stays in charge more than a day. In line with that, Cambio users recharge the vehicle on average 0,44 times per day, while users in Wezenbeek-Oppem averagely recharge three times more (1,3 times per day), as shown in Figure 23.

Figure 22: Duration of recharging (left Cambio users, right Wezenbeek-Oppem cohousing)

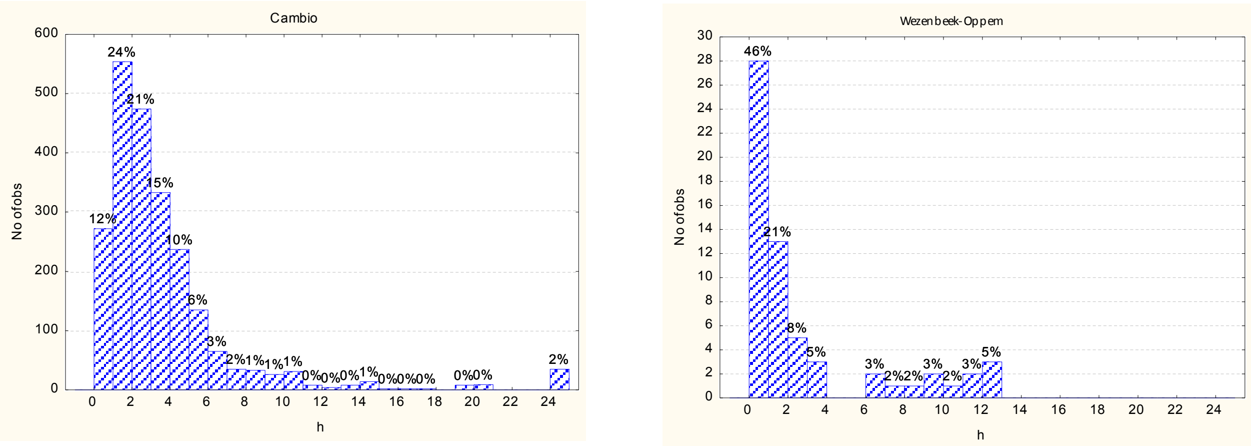
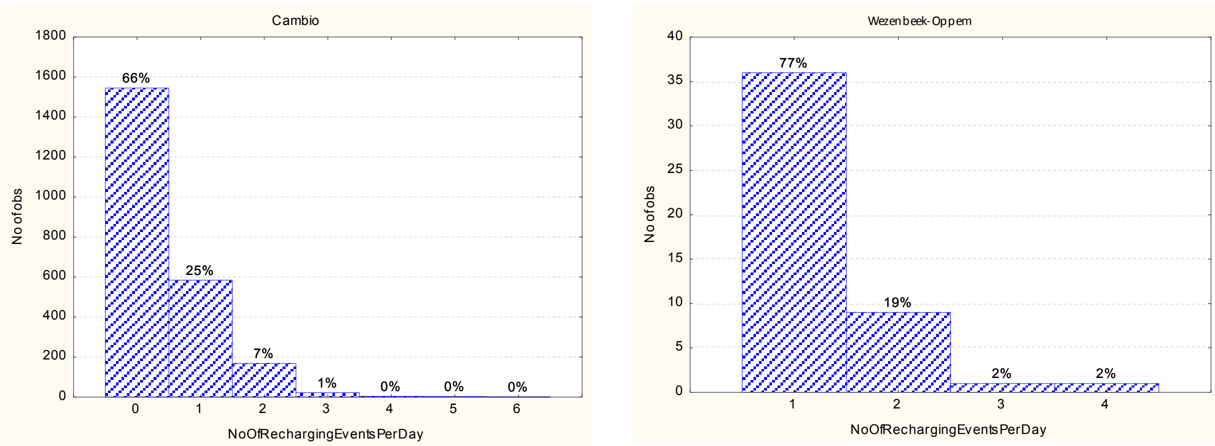


Figure 23: Number of recharging events per car per day (left Cambio users, right Wezenbeek-Oppem cohousing)



3.4 Some conclusions

The car-sharing test conducted with the cohousing communities, although not complete yet, has provided some interesting findings. First, it defines a potentially new car sharing model, which can provide value added to EVs in terms of significance, utility and performance. The test population has been segmented into at least two different geographical clusters, urban and semi-urban. That selection points out the importance of variables, such as culture, socio-economic status, familial composition, and geographical location. Noticeably, geographical location and familiar status seem influencing mobility choices more than educational level, common cultural background on EVs and shared "green" attitude.

Secondly, from the qualitative data, it emerges that the urban cohouser is highly educated, green oriented, predominantly single, does not own a car, and uses the train for commuting to work and the bike for shopping and leisure. For rare events, s/he uses the car (mainly a shared one). The semi-urban cohouser, also highly educated and green oriented, on the contrary is married with children, and owns a car, which is his or her main means of transport. In the Wezenbeek-Oppem cohousing, there is a relevant percentage of youngsters, whose behaviours could provide an interesting insight and validate their potential as target group.

When analysing cohousers behaviours in the tests (though not concluded yet, as noted above), some relevant topics emerged. The urban cohousers use car sharing as a secondary mode of transport to increase their mobility and, therefore, accessibility. Nonetheless, for them the EV sharing, being 'green', risks being an alternative to soft mobility, biking and walking, and public transport, and not to the privately owned car. On the contrary, semi-urban cohousers replaced their private car with the shared EVs, developing daily and weekly repetitive car sharing behaviours (semi-organised), in contrast to the completely non-organised behaviours of the urban cohousers. In addition, some of them demonstrated an interest to continue the car sharing also after the end of the test, and others to buy the leased EV.

All of them felt having a pioneering role in testing sustainable mobility patterns, where EVs could replace conventionally fuelled vehicles. By developing new mobility patterns, the test benefited from cohousers towards the exploration (new technology, developing the future, charging at home with renewable energy, etc…) and provided them in exchange with the possibility to verify by themselves the EV convenience (low refuelling costs, less maintenance possibility of using self-produced energy, etc…).

Looking at the charging experience, urban cohousers with Cambio were obliged to behave not very efficiently, charging when not necessary and using a more expensive energy (related to energy prices varying between peak and off-peak supply). On the contrary, semi-urban cohousers, which have to pay for energy consumption, mainly charged only when necessary and if possible at night time.

Finally, although based only on pre-experience and 6 months intermediate surveys and driving/charging data, it is nevertheless possible to remark that sharing EVs amongst small communities represents a powerful tool for promoting their zero-emission approach, and their potential of lower charging and maintenance costs.

4. Public transportation tests

4.1 e-Buses in historic centre

The use of small electric buses for public transport in historic centres is a consolidated practice in several European cities, since the beginning of the '90. Relevant examples are the Art cities of Rome, Florence and Naples in Italy, Madrid and Zaragoza in Spain, where only small size electric buses are able to approach narrow streets and pedestrian areas, providing accessibility to monuments and characteristic places without the typical external effects of traditional diesel buses (air pollution, noise, and vibrations). That reduces monuments and palaces' damaging by polluting elements, as well as renovation and maintenance costs of historic buildings.
The main development of these buses depends on the battery evolution, which must guarantee a continuous and safe daily service for each vehicle. In the last ten years, there have been used more and more sophisticated batteries, passing from Lead Acid to Sodium Nickel Chloride (ZEBRA) or Lithium Ion batteries. These lasts easily permit to cover total distances for a daily service in urban areas, with an average operational speed of 15 km/h.

4.2 The test organisation

Test objectives

The main objective of this field test was to measure e-buses interaction with the electric grid and, in particular, the battery operational capacity and ageing, charging time, battery accumulation potential, electric consumption, auxiliary systems absorption, and average distance covered with one charge.

Test selection

The first part of the test was focused on the design of the test typology.
The basic idea was to test the e-Bus running a regular public transport service in a historic urban centre, characterised by varied topographic and traffic settings, with a service frequency not different from the other regular buses. Therefore, the target was to use an existing line for the test, and to operate the e-Bus mixed to other bus typologies (hybrid, diesel, LPG,CHG), in order to provide a comparison on the overall energy consumption. In that case, being a regular service, the e-buses would take the place of regular buses without additional costs for the test participants (if necessary a ticketing machine can installed on-board and its consumption metered). From the line-mission point of view, stops should be between 250 m and 500 m, in order to have data about doors openings, electric ramps, and air conditioning consumption. The daily distance covered would be at least 150 km or/and the service time of 10 hours, with the test running for 12 months in order to investigate performance in different weather conditions.
In Flanders there are many cities satisfying these prerequisites, but not the same can be said about the bus lines, which usually combine both urban and extra urban service. Some lines are more urban with a lower average speed and shorter daily distance, but in general it is not possible to assign a specific bus to only one line. Buses usually perform their service on different lines. In addition, only in large cities bus frequency is higher than 30 min. The better option was clearly a pure urban line in an historic centre, such as Bruges or Ghent, but that meant a change in the service management, with additional costs for the public company.
After several unsuccessful negotiations with the Flemish Regional Public transportation company, De Lijn, which refused to use the e-Bus in their regular lines, and to compare it with their diesel (or hybrid) buses, the team decided for a different solution. Following the same criteria used for the private car test, it was decided to define a small-scale daily service, which a single e-Bus could perform, and at the same time to acquire data from an existing e-Bus line in a historic town.

For the small-scale test, the e-Bus would be used on the campus of University Hospital of Ghent (UZ-

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Campus). The surface of this campus is 43 hectares with different buildings.
Currently, a campus taxi service is in use but existing taxis could not guarantee the services for enough people. The specifications of the bus should make possible of transport disabled people (wheel chair user and elderly people), visitors, staff and students. For that reason, the bus should be low-floor and should facilitate independent access for wheelchair users.
The aim was to give the transport facilities on different spots on the campus and without a time schedule or reservation. The service was planned to be free of charge for patients (day clinic patients or patients for different medical examinations), visitors, staff and students in the UZ-campus. The e-Bus mission was operating on a fixed route without a timetable, from morning until evening, answering to the users' calls.

Operationally, there was a need for training taxi-drivers to get a driving license for busses. The training for bus drivers was provided for three drivers (UZ-campus). In addition, two Ugent staff members followed the training course.
However, only the two Ugent staff members got the driving license for busses, not the three drivers (UZ-campus) getting the driving licence. Because no bus drivers ware available this demonstration project was stopped and a new demonstration project was set up: the Ugent staff and students transport from the Gent central railway station to the Ardooie Campus, with a route length of 6 km. Before this demonstration started, the bus has often been used in events related to the University.

The vehicle selection

The second part of the test was focused on the selection of the vehicle. As for the EVs, the team philosophy was to test only vehicles effectively on the market and possibly already performing such a public service. Therefore, the selection criteria were that the vehicle could not be a prototype, must have already operated as a bus in a regular public transport service and its daily driving range could cover the whole bus daily task. However, differently from the private car test, where it is possible to test a consistent number of new EVs, for the e-buses the selection was limited in type and quantity. In addition, applying the EU tendering procedures, an open tender was launched for the leasing (or renting) of an e-BUS.

Only a full electric bus could meet the demands of the tender. In order to be able to judge the quality, the tenderer had to present an appendix to the application form containing a minimum of five pages describing the following items:
1. Low-floor bus (full length of the bus)
2. Independent access for wheelchair users
3. Average range of the bus expressed in kilometres
4. Charging time of the battery
5. Auditory information
6. Temperature Control
7. Assistance and training of the drivers

Together these technical questions, the bus should have met the requirements for the demonstration. Regarding this award criterion, the tenders received judgement and quotation per plot (1-7), by the application of the method mentioned hereunder:
6/6: very excellent, 5/6: excellent, 4/6: good, 3/6: sufficient, 0/6: insufficient
That procurement procedure caused many problems. A first leasing of an e-Bus (Renting of a full electric bus for a period of 12 months) was awarded to a French company, which did not fulfil the leasing contract. This was because it was not possible to register in the short time the (French) bus. Obtaining a (Belgian) number plate (register of the bus) was very difficult: a leasing bus could not be registered if the owner was from another country. In fact, a Belgian insurance company could not insure a bus that is owned by a French company. Driving with a foreign number plate was neither allowed.
After two months of discussion with the Belgian administration, the registration was made possible by showing the original invoice to the Belgian customs. Finally, the problems' solution was communicated to the French company, but they were no longer prepared to lease the vehicle: it was already sold.
A new tender was launched an only one firm made an offer. After negotiation, this firm would only sell the bus for the same price as the leasing. UGent decided to buy the bus: there was not a difference between the leasing cost and the purchase of the bus.
The problem with this bus was that no registration was possible because the bus did not have ABS (by European directives a bus could only be register if it is equipped with ABS). Therefore, the manufacturer was contacted and the bus was sent back to them in Italy and ABS was built in. A new EU certificate of conformity was produced by the manufacturer, and vehicle registration and new plate easily obtained.

The e-Bus selected

The selection process ended with the purchase of a Tecnobus Gulliver U530 ESP. It is a low-floor bus with an extremely reduced size (width 2.03, length 5.32 m), able to carry over 30 passengers and compliant with the requirements of Directive 2001/85/EC for buses used for public transport of Class I. The bus is homologated with Ni – NaCl ZEBRA (Zero Emission Battery Research Activities) batteries exclusively designed and built for it, which guarantee a daily driving range of 150 km (400 km tested on circuit), with an operational speed of 34 km/h.
The considerable energy quantity stored in the high-tech battery modules makes it possible to use auxiliary accessories, such as an integral air-conditioned system, a route indicator and GPS systems. More than 600 Gulliver buses are in operation in different European countries, as well as in Canada, and the manufacturer promised the availability of last two years' data from the e-Buses in service in the city of Rome.

Figure 24: The Tecnobus Gulliver U530 ESP purchased by Ugent

4.3 The Rome case study

ATAC has a fleet of 60 electric powered TecnoBus Gulliver buses. These buses are assigned to bus routes in the historic centre of Rome, operating on streets that are too narrow for standard sized buses. Additionally, because these buses' electric engines are so quiet, they do not create noise pollution that might be harmful to old structures in the ancient city centre.

Tecnobus Gulliver U520 EP

Capacity – 14 standing + 8 seating places;

Length 5.30m; Width 2.07m;

Maximum Speed 33 km/h

Consumption (100 km) – 75.5 kWh;

Batteries autonomy – 4 to 6 hours; Time required for replacing the Batteries – 4 minutes;

Manufacturer – Tecnobus; Price – 200 000€

Figure 25: A Tecnobus Gulliver servicing in Rome

Through Tecnobus, UGent has acquired operational field data from the ATAC fleet in Roma for the period Jul 2012 to Mar 2014. Serviced routes are typically 7 km taking about 30 minutes one-way.

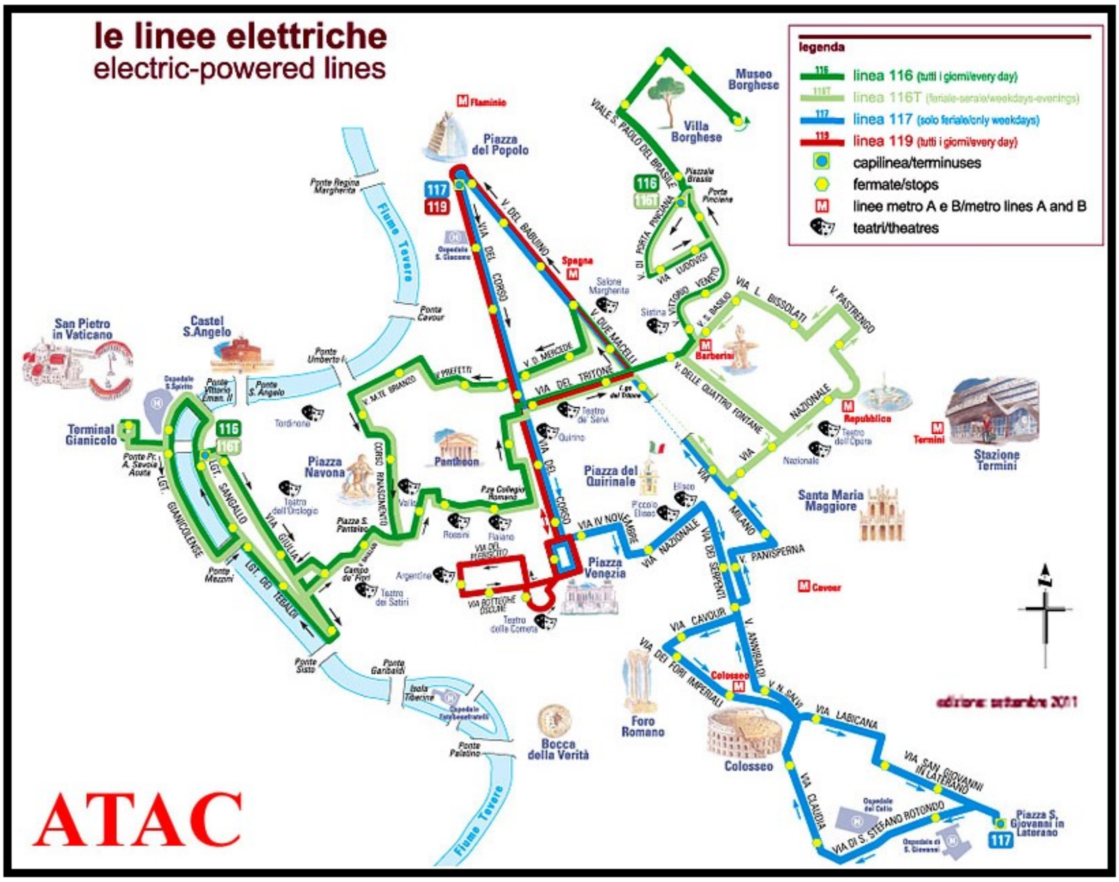

Figure 26: Selection of electric serviced bus routes (Linea 116, 116T, 117 and 119)

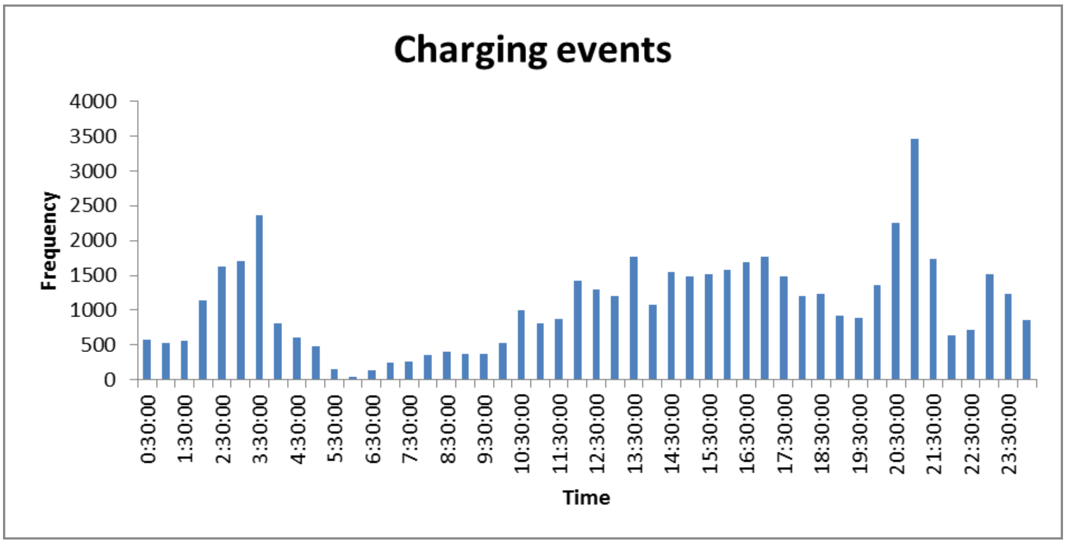

Figure 27: Histogram of daily charging events of ATAC fleet

Figure 27 shows the histogram of recorded charging events over the monitored period for the 60 Gulliver buses in operation. The histogram shows when charging most likely occurred during the day. It shows clear peaks at night around 3 am and in the evening around 21 pm. However, the buses are also charged evenly spread throughout the day between 12am and 18pm. The charging pattern of an individual bus (cfr. Fig. 28) shows that this pattern is generated by the operation of the buses, where a single bus can be designated the morning, afternoon and evening shift depending on its schedule.

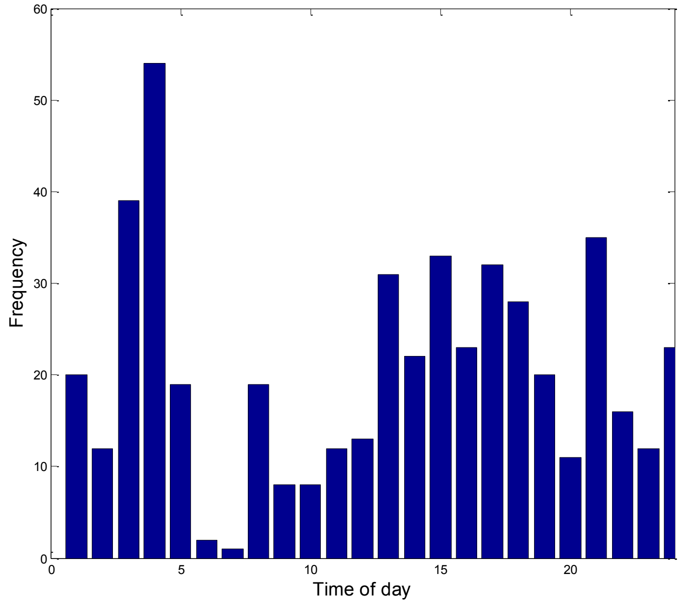

Figure 28: Histogram of daily charging events of ATAC bus 247

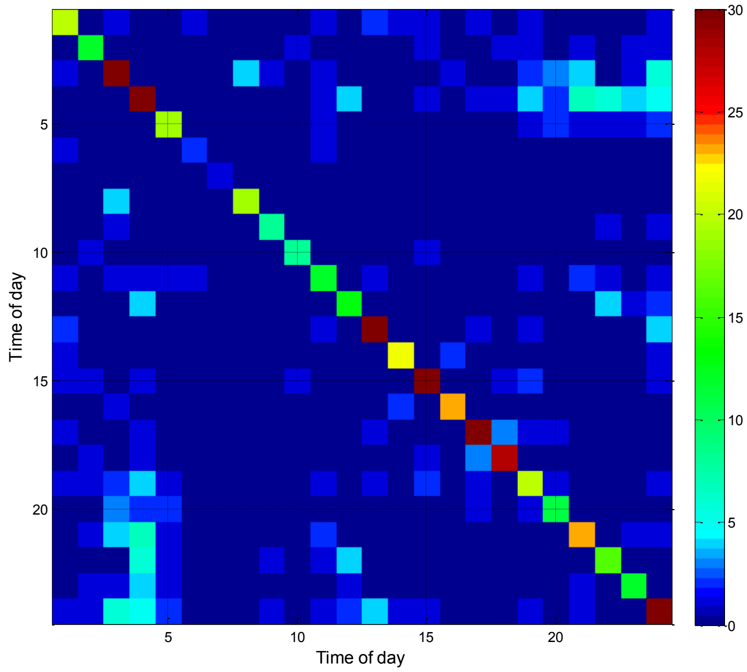

Figure 29: Typical co-occurrence charging pattern

Table 9 gives a summary of the statistics of the operation of the electric fleet for the observed period.

Statistics show that multiple charging sessions per day can occur, on average 1,45 times per day or 3 times every two days. Figure 29 illustrates in closer detail when charging is most likely to co-occur during the day. The diagonal shows the same pattern as Figure 28, but the full co-occurrence matrix shows when charging sessions can co-occur within the same day. The most likely pattern here is a charge in the early morning around 4am and again in the evening around 22pm. We can expect the next charge to be in the early afternoon, not shown in the co-occurrence matrix.

Number of buses	60
Number of individual batteries (incl. replacements)	221
Observation period	Jan 2012 – Mar 2014
Observed days	669 days
Average SoC on recharge	56,4%
Average operating days per bus	484 days (72% of the time)
Average charge sessions per day per bus	1,45
Average battery age upon replacement	509 ± 132 rated cycles
Average range per day	58 ± 18 km

Table 9: Fleet statistics

Batteries have a unique identifier in our data and can be monitored during operation in the fleet. They always operate in pairs. As shown in Table 9, the average battery age upon replacement is 509 rated cycles. The battery age is the number of rated cycles of a battery observed on battery replacement. For the ATAC Roma operation, we observe on average a rated cycle per operating day ratio of 1.63, meaning that one rated cycle corresponds to 1.63 operating days. Using this ratio, observed battery life corresponds to 831 operating days or approximately 3.16 years taking into account the 72% service time. This explains the large number of battery swaps, which have been observed during the sample period. The first buses have been put in operation in 2010-2011.

NORTH SEA REGION ELECTRIC MOBILITY NETWORK

e-mobility NSR

About E-Mobility NSR

The Interreg North Sea Region project North Sea Electric Mobility Network (E-Mobility NSR) will help to create favorable conditions to promote the common development of e-mobility in the North Sea Region. Transnational support structures in the shape of a network and virtual routes are envisaged as part of the project, striving towards improving accessibility and the wider use of e-mobility in the North Sea Region countries.

www.e-mobility-nsr.eu

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