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my SMART Life

Deliverable due date: M36 – November 2019

D4.17 Innovative electromobility charging node in operation

(WP4, Task 4.7, Subtask 4.7.4)

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Project Acronym	mySMARTLife
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**
Project Duration	1st December 2016 – 30th November 2021 (60 Months)
Deliverable	D4.17 Innovative electromobility charging node in operation
Diss. Level	PU
Status	☐ Working ☐ Verified by other WPs ■ Final version
Due date	30/11/2019
Work Package	WP4 Demonstration in Helsinki
Lead beneficiary	VTT
Contributing beneficiary(ies)	FVH, HEL
Task description	Subtask 4.7.4: Innovative mobility services An innovative electromobility charging node, which integrates fast charging for e-bus, fast charging for the city maintenance fleet and commercial logistic fleet, charging of the autonomous e-buses will be implemented. Currently there are separate systems for charging the electric buses and no charging stations for commercial electric maintenance fleet machinery and commercial logistics trucks or other commercial vehicles. The first intervention consists in modifying two electric bus-charging stations with automatic opportunity charging by equipping them with the additional function of high power (~100 kW) socket chargers using the CCS standard, so that this enables the charging of the maintenance fleet and logistics (Action 22). With the uptake of the electric maintenance fleet, logistics operations and normalization of the autonomous e-bus routes the issue of usage load of the charging system arises, especially with the more expensive fast charging stations: how to ensure the charging system infrastructures are not overlapping and in low use each. This requires monitoring the system and fleet status including the availability and status information of the chargers, possibly also ensuring the right prioritisation for using them. The integration includes also technical and invoicing aspects. The charging node will be set up in project area to support the maintenance fleet and autonomous e-buses uptake. An innovation intervention is to chart out the technical, operational and innovation aspects for scaling up such multi-use commercial electric vehicles charging nodes for wider market up-take of the systems. This part is carried out in co-operation between all parties active and will lead to concrete rollout plan and actions.

Date	Version	Author	Comment
01/10/2018	0.1	Marko Paakkinen (VTT)	Initial draft.
17/10/2018	0.2	Marko Paakkinen (VTT)	HSL and HKL comments merged in.
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		(VTT)	
29/10/2018	0.4	Marko Paakkinen (VTT)	Merged comments from HEL
14/10/2019	0.5	Mikko Virtanen, Mikko Pihlatie, Esa Nykänen (VTT)	Identified the contents to be updated
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21/11/2019		Gustavo Caceres (NBK)	Internal review of deliverable
25/11/2019	0.7	Farzam Far Mehrnaz Joel Anttila Tota Sai Santosh (VTT)	Improvements to the deliverable according to internal review
27/11/2019	1.0	Mikko Virtanen Esa Nykänen Joel Anttila Tota Sai Santosh (VTT)	Finalizing the deliverable for submission

Table of Content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Table of Figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Table of Tables

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 731297.

Abbreviations and Acronyms

Acronym	Description
AC	Alternating Current
ACD	Automated Connection Device
CCS	Combined Charging System
DC	Direct Current
DoW	Description of Work
GIS	Geographical Information System
HKL	Helsingin Kaupungin Liikenneliikelaitos, Helsinki City Transport
HPC	High Power Charging
HSL	Helsingin Seudun Liikenne, Helsinki Region Transport Authority
kW	kilowatt
kWh	kilowatt hours
LTO	Lithium Titanate Oxide
MAC	Media Access Control
NMC	Nickel Manganese Cobalt
PPP	Public-Private Partnership
SOC	State Of Charge
TAMK	Tampere University of Applied Sciences
VCCU	Vehicle Charging Control Unit

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1. Executive Summary

This deliverable describes the process of establishing a shared e-mobility charger (electromobility node) in the city of Helsinki, as part of Action 26 in Work Package 4 in mySMARTLife. Sharing of charging infrastructure, especially for heavy-duty vehicles within cities, where electric vehicles of different classes such as buses, delivery trucks, refuse trucks or municipal work machines are using the same-shared fast charging infrastructure, is an appealing opportunity to improve the return on investment and increase the usage of the chargers. However, the sharing has to be planned carefully not to distract the operation of the different users, taking into special attention the public transport needs. One has to plan the sharing such that the public transport is given the necessary priority to be able to maintain reliable operation of the whole city's transport system. Thus in practice, the charging equipment should have modularity in power output, allowing certain connection interfaces to deliver increased charging power. As a case example, a charger with separate automated high-power interface for electric city buses and low-power manual plug for other vehicles should be able to cut down the power output for the manual interface for the duration when an electric bus is connected to the charger. After the electric bus has been charged, increased charging power can be directed back to the manual interface. All in all, collaboration within the cities' divisions, that utilise the charger, is required, and may sometimes prove to be difficult for example from electricity billing perspective. The charging events need to be carefully managed, potentially by a specified operator, to ensure reliable operation and to act as a link between the stakeholders. Also, a SWOT analysis for heavy duty fast charging infrastructure was done.

Once the charger is operational, the performance of it will be analysed according to the list of key performance indicators. This deliverable also describes the planned monitoring and analysis methods used to evaluate the shared charger pilot.

At the time of writing this deliverable, the installation of the shared e-mobility charger is still underway. The delays in the process of installing it has been caused by the difficulties to obtain a building permit for the charger. Discussions are underway between the city building board and mySMARTLife project staff to obtain a resolution to the matter.

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2. Introduction

2.1 Purpose and target group

Nowadays, human activities that increase greenhouse gases and accelerate the climate change are the main concerns of different nations, including the EU. To tackle climate change and its negative impact on our planet, the EU have committed to activities that reduce the greenhouse emission. As example, the EU is aiming to reduce the greenhouse gas emissions by 80-95% by 2050 compared to 1990 levels (European Council 2019). Helsinki aims to be carbon neutral by 2035 and one of the major contributors to the target is the electrification of the city maintenance and logistics fleet. Transport sector is one of the sectors that plays a key role in achieving this aim, by utilizing cleaner energy and reducing petrol and diesel consumption. This approach will naturally increase the number of electric vehicles and the need of sufficient accessible charging infrastructure. Innovative plans are required to optimize the charging infrastructures usage and help the city planning to keep pace with the anticipated growth in e-mobility sector. One appealing plan that improves the return on investment and increases the usage of the chargers is sharing of charging infrastructure (electromobility node), especially for heavy-duty vehicles within cities. Currently, there are separate systems for charging the electric buses and no charging stations for commercial electric maintenance fleet machinery and commercial logistics trucks or other commercial vehicles.

This deliverable report and document the process of establishing a shared e-mobility charger in the city of Helsinki. An innovative electromobility-charging node, which integrates fast charging for e-bus, fast charging for the city maintenance fleet and commercial logistic fleet, charging of the autonomous e-buses will be implemented. The first intervention consists in modifying two electric bus-charging stations with automatic opportunity charging by equipping them with the additional function of high power (~100 kW) socket chargers using the CCS standard, so that this enables the charging of the maintenance fleet and logistics (Action 22). With the uptake of the electric maintenance fleet, logistics operations and normalization of the autonomous e-bus routes the issue of usage load of the charging system arises, especially with the more expensive fast charging stations: how to ensure the charging system infrastructures are not overlapping and in low use each. This requires monitoring the system and fleet status including the availability and status information of the chargers, possibly also ensuring the right prioritisation for using them. The integration includes also technical and invoicing aspects. The charging node will be set up in project area to support the maintenance fleet and autonomous e-buses uptake. An innovation intervention is to chart out the technical, operational and innovation aspects for scaling up such multi-use commercial electric vehicles charging nodes for wider market up-take of the systems. This part is carried out in co-operation between all parties active and will lead to concrete rollout plan and actions.

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The deliverable is targeted at city public transportation planners, area development responsibilities, public transportation authorities and city maintenance management personnel. This deliverable serves as a basis for creating visibility for the sharing of charging infrastructure.

2.2 Contributions of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
VTT	Compilation of the deliverable, main contribution
HSL, HKL	Commented on the content on their part
HEL	Commented on chapter 5.3.3, peer review

2.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the mySMARTLife project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D4.1	This deliverable provides the overall description of the mySMARTLife project and the specific KPIs and baseline values. Deliverable also provides a comprehensive overview of Helsinki on various aspects, also on the mobility point of view.
D4.19	The results from this deliverable are used in compiling the deliverable D4.19 (roadmap for the logistics and maintenance fleet in Helsinki).

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3. Sharing of charging infrastructure

The rationale in sharing fast charging infrastructure lies in increasing the value of the investments in the charging infrastructure and the vehicles. Currently, many of the activities around electric mobility are happening in silos, not considering the big picture in cities. Public transportation authorities in various cities are planning their own electric bus charging networks, logistics companies are investing in electric trucks and vans, with charging typically happening overnight, and city maintenance fleets may include electric vehicles, which can not really take advantage of the charging infrastructure in the cities. The utilization rate of Helsinki electric bus charging infrastructure is presented in Table 3. The utilization percentages are very low and the remaining time can be used for charging other vehicles by the means of shared charger, for instance. This trend has also other drawbacks in addition to profitability. In public transport, at least some part of the charging infrastructure can be left with very little usage. Especially end stop chargers, that only serve a single line, can have very small utilisation ratios. This leads into a drop of efficiency, as the chargers do have significant idle losses.

Table 3: Key performance indicators for Helsinki charging infrastructure

Action KPIs	**Unit**	**Baseline**
Utilization ratio of charging points (6.4.-6.10.2017)	%	Ruskeasuo: 4.6% Koskela: 4.4% Hakaniemi: 0% Malminkartano: 0%. NOTE: Hakaniemi and Malminkartano were just installed, not in line use yet during the measuring period for KPI
Utilization ratio of charging points (26.5.-26.11.2019)	%	Hakaniemi: 2.6% Koskela: 2.9% Ruskeasuo: 4.9% Malminkartano: 3.1%
Electricity charged by charging point (total)	kWh	On 26.11.2019: Hakaniemi: 71 681 kWh, Koskela: 210 730 kWh, Ruskeasuo: 253 234 kWh, Malminkartano: 91 578 kWh

When the vehicles are not able to utilise the existing high-power charging infrastructure, they need to be designed to be with adequate autonomy, which is leading into large batteries. As the batteries are the highest cost components in electric vehicles, the current trend is leading into significant investments into

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both charging infrastructure and vehicle batteries. Every vehicle has its own dedicated charger, and the vehicles have large batteries, such that they can operate the whole desired operating cycle without recharging.

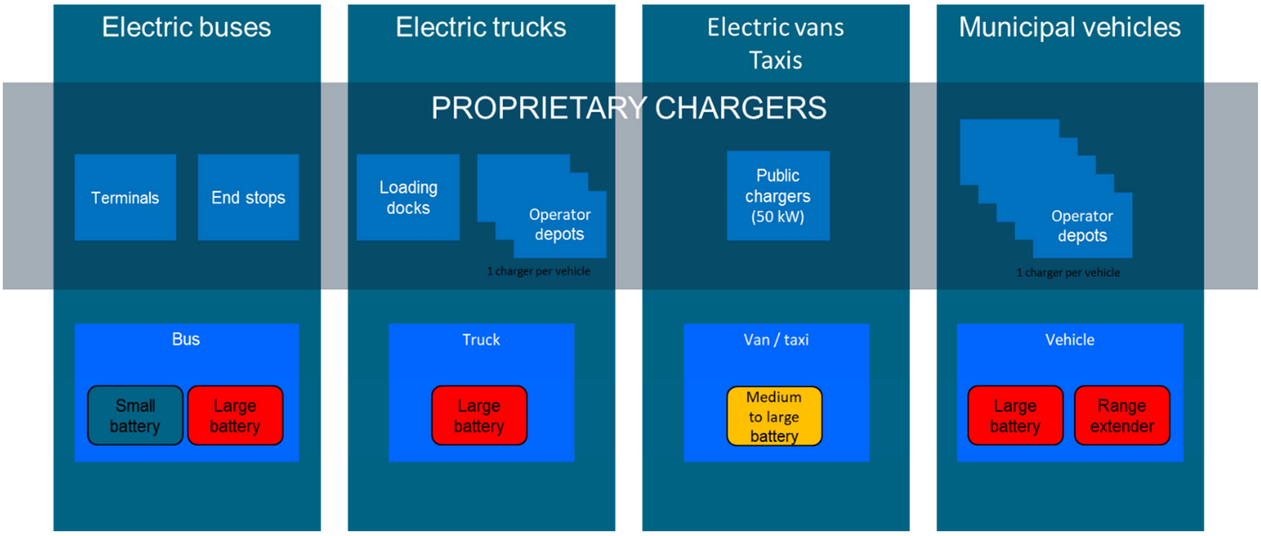

Figure 1: Siloing in the current development of EV deployment

3.1 Limitations

3.1.1 Interoperability

Sharing of fast charging infrastructure requires interoperability between the vehicles and chargers. The targeted different vehicular groups need to be able to connect to the charger. For example, ABB has been advertising their infrastructure mounted ACD solution for a long time as a solution for interoperability between vehicle classes. In the infrastructure mounted ACD, the pantograph is lowered from the charging mast down to the vehicle roof. This is lower weight solution compared to the vehicle mounted ACD solution. However, the infrastructure mounted ACD also has its limitations. The ACD's reach might not be able to cover all vehicle classes, which can limit for example smaller vans or work machines from charging with it. A bigger limitation comes however from the fact that if the vehicles are using the same parking spot for charging, then an external vehicle charging at an electric bus stop would not provide a working solution. At least an additional ACD needs to be organized for the external vehicles, to avoid blocking of the charger.

Especially in the smaller vehicles, like municipal work machines or vans, there may not be sufficient space for an ACD. As the standards are already existing with the CCS Type 2 Combo plug, the easiest interoperable way of sharing the charging is by using the standard manual plug. At the moment, many of the solutions are using the currently standardised plug version, which is limiting the charging current to

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200A. Update on the standards is on its way to support the already emerging connectors supporting up to 500A charging current, allowing charging power of 200 - 300 kW, depending on the battery voltage.

3.1.2 Electricity billing and taxation

In Helsinki, the charging infrastructure is owned by the Helsinki City Transport (HKL). HKL is also organising for example the tram and metro electricity supply in the city. As the electricity for rail-based transport in Finland is free from production taxation (Vero, 2019), it is creating one difficulty in electricity billing, as HKL has all of its electricity supply under the same contract. The same tax exemption is being currently pursued also for electric buses. Sharing of the charging and providing electricity to commercial non-public vehicle operators requires therefore changes to the current electricity supply contracts or metering. In planning sharing of charging infrastructure, the effects on taxation and electricity supply contracts needs to be taken into account.

3.2 Prioritisation

It was identified very early in the process that the sharing of chargers that have been primarily acquired for the public transport, cannot happen without prioritising the public transport's needs first. Should the external vehicles occupy or reserve the charging capacity when a public transport vehicle would need it, it would lead into delays in the schedules, which would not be acceptable. Thus, prioritisation of charging is important to take into account when planning to share the charging infrastructure.

In addition to prioritising the charging in terms of available charging location, prioritisation is also needed on the charging power. If a same charger is to be used for charging of two vehicles, that happen to connect to the charger at the same time, the charger either needs to be able to dynamically allocate power to both of the vehicles with prioritised power levels, or simply charge only the higher priority vehicles first. A better option is of course the dynamic power allocation, but that is not yet being supported by the chargers. Therefore, in the Hakaniemi demonstration, the project team ended up in choosing a simple prioritisation, where the electric buses will always get full charging power, and if an external vehicle connects to the charger while a bus is charging, the vehicle charging will not start before the bus has finished charging. Typically, an electric bus charging takes time in Helsinki approximately 4 - 5 minutes, which is not considered to be too long delay for the external users.

3.3 SWOT analysis for heavy duty fast charging technology

A SWOT analysis for heavy duty fast charging technology is based on (Lunz & Sauer) and findings in mySMARTLife project work. The analysis is presented in Table 4.

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Table 4: SWOT analysis for heavy duty fast charging technology

Strengths • Less charging time • Efficient • Higher power capability • Smaller battery size	**Weakness** • Standardization in process • High capital cost • Maintenance • Chicken-or-egg-problem: infrastructure is needed before vehicles can be used and vice versa
Opportunities • Interoperability • Synergies with renewable electricity development • Shared between logistics and city maintenance fleet • Improved profitability due to increased utilization rate	**Threats** • Potentially high grid loads • Visual Pollution • Shorter battery life • Multitude of actors (Error fixing agreements)

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4. Charging infrastructure in the Helsinki region

In October 2018, city of Helsinki has 6 electric bus chargers installed and operational, that are part of HSL's pre-commercial pilot project called ePELI, which is preparing the ecosystem around electric buses for the commercial operation. The pilot project also includes 12 electric buses, which of 2 are operating in Espoo, and 10 in Helsinki. The key performance indicators for the installed charging infrastructure are presented in Table 3.

One of the charging stations, located at the central railway station square, is a dual charger, with a total of 4 charging points, which of two can be used simultaneously. The other chargers are single chargers, located at the end stops of the bus lines. The arrangement in Helsinki is set up such, that each bus line has opportunity chargers at both ends of the bus line. This is giving enough redundancy in case of charger failures or maintenance.

The current chargers are serving bus lines 23, 51 and 55. Also the bus line 133 in Espoo is served by the HSL pilot buses, and the city of Espoo has one additional charger of their own. The infrastructure is starting to grow during next year, when new chargers are installed in Vuosaari to serve lines 90/96 and in Leppävaara, Espoo, where the local feeder lines are being procured requiring a certain number of electric buses. The Leppävaara terminal feeder lines will be the first commercial electric bus procurement in Helsinki.

All the currently installed chargers are owned by the cities of Helsinki and Espoo. The chargers within the city of Helsinki are owned and maintained by Helsinki City Transport (HKL). There are currently chargers from two suppliers, Heliox and Ekoenergetyka. A third supplier is introduced in Leppävaara, where the complete charging system including maintenance is being procured as a service. Currently, the city of Helsinki continues to own the charging infrastructure, but the city of Espoo is testing the charging as a service business model in Leppävaara.

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Figure 2: Installed electric bus chargers in Helsinki, October 2018

HSL has made a decision to utilise the vehicle mounted pantographs, where the Automated Connection Device (ACD) is mounted on the vehicle roof. The ACD is raised by operator's command to meet the counterpart in the charging mast. One restriction in installing the charging infrastructure in Helsinki is architecture. As an example, the charging masts located at the central railway square were required to be as little visible as possible. That was one of the reasons for selecting the vehicle mounted ACD.

The chargers have power levels from 300 to 350 kW, and all other chargers are single output chargers, except the central railway square charger, which has dual chargers, capable of simultaneously charging two buses at full power. The railway square has also two extra charging masts, which can be taken into use in case of a breakdown or as part of future development.

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5. Hakaniemi demonstration

In the Description of Work, it was initially planned that two chargers would be converted in Helsinki for the shared use. However, when this was being discussed in the Action Group responsible of organising the demo, it was quickly found out that there was at the moment only one viable location to organise the share charging point - at the Hakaniemi market square. The centre of Helsinki has only two chargers, one in Hakaniemi and another at the central railway station. The charger at the central railway station is located in the middle of a very busy bus terminal, where a lot of bus lines have their end stop. For Niinivirta and Stara, the location at the railway station square was not very suitable, as there is no space for additional vehicles, and logistically it is also difficult to reach.

Hakaniemi, on the other hand, proved to be an ideal test location. The square and the surrounding areas include a lot of sweeping, snow clearing and other maintenance tasks that could be performed with the Stara's work machine. For Niinivirta, the location is easily accessible from the city's enter or exit routes, and they can serve the city centre's deliveries from their own terminal in Vantaa with the charger being close to the city center. The location allows for intermediate charging during deliveries, allowing also ad-hoc deliveries within the city.

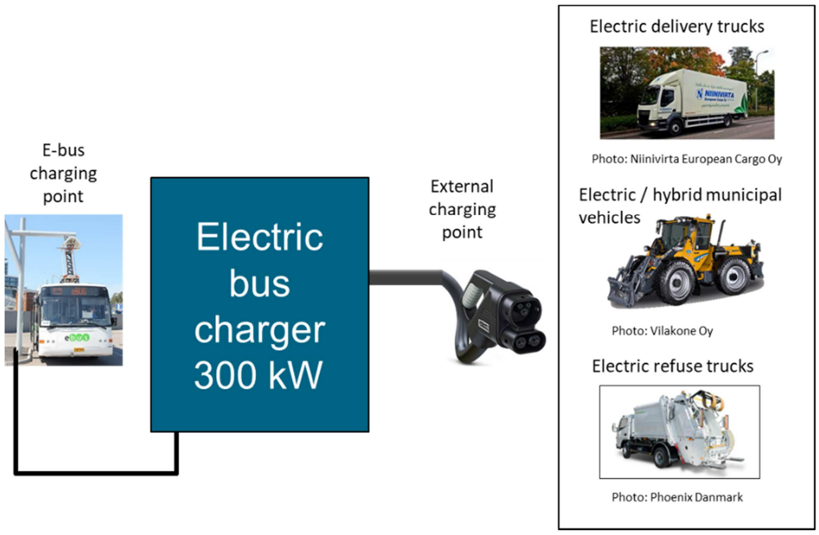

Figure 3: Shared charging arrangement in Hakaniemi

Based on the reasoning above, it was chosen to implement only one shared charger in the demonstration. This would leave some budget unused, but as it was later found out in the planning, the Stara vehicle would require a battery update to support full power fast charging, so it was decided to be used for that purpose. Having a true 300 kW fast charging in the municipal work machine means that in the pilot vehicle it can operate for two hours with electricity and then be recharged in 6 - 10 minutes. This means that the

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recharging can happen during the operator's coffee and lunch breaks, and it won't distract the machine operation. This also means that the machine can operate around the clock, if required, for example during a large snow storm. Without the adequate power in fast charging, the machine would have limited operating time, and fast charging in this case is meaning almost unlimited autonomy, which is changing the machine's utilisation possibilities in great extent.

5.1 Electric bus charger

The electric bus charger in Hakaniemi was ordered by HKL from Ekoenergetyka Polska, and it was installed in 2017. Initially there were interoperability issues with the charger and the pilot's Linkker vehicles, and the charging session kept breaking prematurely. This took quite a long time to fix, and it is partly explaining the delays in the shared charging connection installation.

The charger is equipped with a charging mast supporting the vehicle mounted Automated Connection Device (ACD), where a pantograph is at the bus roof, and it is raised to meet the counterpart in the mast. The moving part in this setup is in the vehicles. The operator is pressing a button to raise the ACD, and the charging is started automatically when the connector is mated. When the battery State Of Charge (SOC) has increased to the pre-set limit value (typically 80%), the charging session is automatically ended, and the ACD is lowered. The bus is prevented to start driving during a charging session.

Figure 4: Electric bus charging at Hakaniemi charging point

The charging mast is located at the bus stop, which is also the end stop for the bus line 51, which currently has two electric buses operating. The charger itself is housed in a separate electrical cabinet, that is located approximately 50 meters from the bus stop.

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Figure 5: Charger electrical cabinet. The charging mast is behind the trees at 50 m distance

When the charger was installed, it was already prepared for the future installation of the external charging connection. Figure 6 shows the covers for the outputs and the extra cabling in the foundation and in the asphalt.

Figure 6: Reserved spot for installing the cabling for the additional electrical cabinet

5.2 Shared sharging point

When discussing about the possibility to use the Hakaniemi charger for the shared charging demonstration, it was obvious that the bus stop, where the charging mast is located, would not be possible

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to use as the charging point for external vehicles, as the external vehicles would block the bus stop during charging.

A location close to the charger's electrical cabinet was selected. The locations of the charging mast, charger electrical cabinet and the new shared charging point and the new electrical cabinet for the charging cable can be seen in Figure 7.

This location allows parking of the vehicles using the shared charging for a longer duration. It is also close to the charger itself, and logistically in a very good place. The Hakaniemi market square and its surroundings have a lot of places for lunch or coffee, and the nearest metro station is within 100 meters, so even if the truck driver would need to charger for a longer time, like 30 - 60 minutes, he/she can have lunch or break during the time nearby.

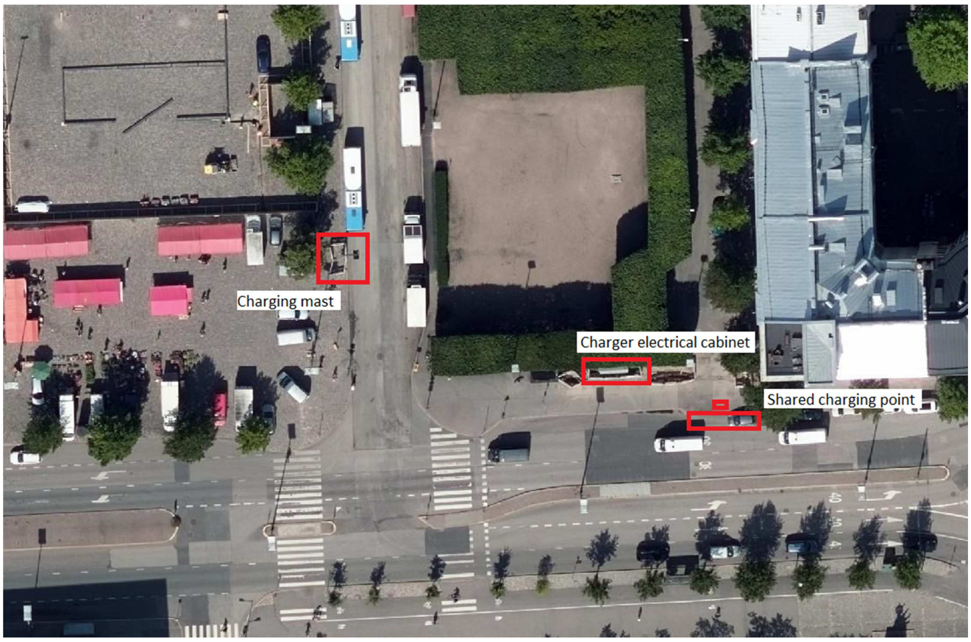

Figure 7: Locations of the equipment

5.3 Modifications to the charger

The charger will be receiving the modifications listed below, as agreed with the charger supplier.

- An external vehicle charging point will be arranged near the charger. Two residential parking spots are converted to a parking slot for the vehicles included in the pilot (electric truck and a municipal work machine).
- An additional electrical cabinet is installed near the external vehicle charging parking slot, which houses the cooled cable, to protect it from vandalism. The cabinet shall be locked and the pilot vehicle drivers will get keys to the cabinet. City requirement for the installation height of the

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cabinet was maximum 120 cm, which was causing some problems with the supplier in the beginning.

- A water cooled cable and connector from Phoenix Contact is used for the external charging connection, allowing charging at full 300 kW power (600V, 500A). The cable requires a cooling system, which is housed also in the new electrical cabinet.

To guarantee that the public transport will always have priority in the charging, a simple prioritisation system shall be programmed in the charger. The use cases for defining the logic are presented in chapters 5.3.2 and 5.3.3.

5.3.1 Vehicle identification and electricity billing

The external vehicles need to be identified and the electricity that has been charged, need to be billed from the vehicle owner. The arrangement in the demonstration is similar to what is currently being used in the electric buses. The vehicle's charging control unit (VCCU = Vehicle Charging Control Unit) communicates with the charger, and the charger is reading the MAC address of the VCCU. The charging system back-end, operated by company Virta Ltd, identifies the vehicles based on the MAC address, and can bill the electricity automatically after the charging session ends.

HKL is planning to update their electricity supply contract to support external charging, depending on the possible tax exemption also for the electricity used for electric buses.

5.3.2 Use case 1: Bus is charging. An external vehicle arrives at the charging point

A new charging session is not allowed to be started before the bus charging has finished. This will be signalled to the driver with an indicator in the electrical cabinet. This will require the driver to wait for the charger to become available, so this would require more work in the future, to allow the driver to plug in, and the charger would start the session automatically. However, to keep things simple, this was chosen as the implementation in the demonstration.

When the bus has finished charging, it is indicated to the driver of the external vehicle, and the driver can plug in the cable. A charging session is started automatically. When the driver wishes to stop charging, there is a “Stop” button in the electrical cabinet for ending the charging session.

5.3.3 Use case 2: External vehicle is charging. Bus arrives and initiates a charging session

As the bus always needs to have priority in the charging, the external vehicle's charging session is paused, and a new session for the electric bus is started. When the bus charging has finished, the external vehicle's charging session is continued automatically.

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6. Process of the charger delivery

6.1 Action group Electromobility

Already in the mySMARTLife kick-off in Helsinki, an action group for the task 4.7 was formed, and the first meeting of the action group was held in January 2017. The action group consists of the partners listed in Table 5. Later on in the project, also Metropolia joined the Action Group on the robot bus part, and Helen also on the solar chargers for e-bikes.

Table 5: Action Group electromobility members

Member	Role in the demonstration	Project partner
VTT	Coordinator, simulations, monitoring, reporting	Yes
FVH	FVH has the budget for the task, they are arranging orders and following up.	Yes
HSL (Helsinki Region Transport Authority)	HSL is the local PTA, so their role is in ensuring a fluid connection with public transport.	No
HKL (Helsinki City Transport)	HKL owns the charging infrastructure, and has permitted mySMARTLife to modify the Hakaniemi charger for the demonstration.	No
Stara	Stara is testing a fast-charging municipal work machine during the demonstration. Stara is also arranging the foundation and permitting for the additional electrical cabinet related to the charger.	No
Helen	Helen was originally responsible for the chargers, but at the moment, the responsibility has been transferred to HKL.	Yes
Niinivirta	Niinivirta is a logistics company, bringing a battery electric truck to the demonstration.	No
TAMK (Tampere University of Applied Sciences	TAMK is partnering with Niinivirta, and TAMK is responsible of the vehicle modifications for the electric truck.	No
HEL (city of Helsinki)	Helsinki has a role in ensuring that all targets can be met, and collaboration is working within the Action Group. Helsinki has reserved the parking spot for the charger.	Yes

The Action Group has been responsible for planning the actions 21, 22, 24 and 26 in Helsinki, and following up on the Actions 23, 25 and 27.

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6.2 Other stakeholders

Discussions have also been held with the manufacturer of the Stara's demo vehicle (municipal work machine manufacturer Vilakone), who is not part of the mySMARTLife project. A plan for introducing the vehicle to the Hakaniemi demonstration has been formed together with Vilakone, Stara and VTT. Adding fast charging support to the vehicle will require updating the vehicle's battery, as the current battery has been designed for overnight charging, and cannot take the full 300 kW charge allowed by the charger.

6.3 Demonstration planning

This chapter is documenting the process of planning the demonstration, the steps needed to realise it, and obstacles met during the process.

6.3.1 Location for the shared charger

The Action Group had first a couple of meetings, where the idea of shared charging was developed, and potential ways of realizing the charging point were studied. Permissions for the demonstration were obtained from the owner of the charging infrastructure in Helsinki, HKL, and also the local PTA, HSL. In the meetings, the effects on the public transport were discussed, and potential risks were charted out. In the end, considering also the requirements from the users of the shared charger in the demonstration (Stara and Niinivirta), the location in Hakaniemi was chosen as the pilot site. A workshop was held to plan the Hakaniemi demonstration in detail on 19 April 2017. The workshop included people from the Action Group, but also external stakeholder were invited.

Based on the workshop results and planned actions, three follow-up meetings were held, where more detailed planning was performed, such as preparations required for the soon to be installed charger to support shared charging in the future. The standard electric bus charger was installed in Hakaniemi during summer 2017, and commissioned during autumn 2017.

6.3.2 Charger modifications

Different options for implementing the shared charging point were evaluated, such as tendering the modifications locally, but as the Hakaniemi charger is still under the manufacturer's warranty, and adding external connection to the charger would void the warranty, it was chosen to have the modifications for the charger to be ordered from the original charger manufacturer. Requirements were gathered in the Action Group, and the first quote was received from Ekoenergetyka in autumn 2017. The quote was reviewed in the Action Group, and some modifications were requested, for example lower electrical cabinet height and a quote including a cooling system for the water-cooled cable.

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Already in the beginning, it was decided that the demonstration is aiming to exceed the target in DoW for the maximum charging power. The original plan was to use standard 150 kW CCS cable, but that would limit the external charging power to only half of the charger's capacity. Therefore, VTT was seeking an alternative solution, and found two options for higher power cabling, utilising water-cooled cables. After evaluation of the two potential solutions, VTT ended in suggesting the Phoenix Contact HPC (High-Power Charging) connector solution to the charger manufacturer, and it was selected to be the charging connector in the demo. Also the vehicle charging inlets were selected to be ordered from Phoenix Contact. Special inlets were needed, as the current standard inlets do not support 500A charging current.

VTT was also assisting the charger manufacturer in the selection of the cooling system for the water-cooled cable. The charger itself is air-cooled, so the cooling was not available at the charger itself. It was selected together with the charger manufacturer that the cooling system would be integrated in the same electrical cabinet as the cable itself. The cabinet's maximum height of 120 cm was causing initially some problems, but a solution was found in collaboration with the manufacturer.

At the same time, when the quote for the modifications was being prepared, the charger supplier was testing their newly installed chargers in Hakaniemi, Malminkartano and central railway station. Issues were found in the interoperability between the current buses and the new chargers. The root cause was finally the signal level in communications, and after adjustments, the chargers started working normally. However, finding the root cause took quite a long time. Due to the problem solving, it took until May 2018 to receive an updated quote on the charger modifications. FVH, who was responsible for signing the supply contract, decided that they want to have a separate contract, instead of relying on the supplier's general terms. This was lessons learned from the previous charger installations. At the time of writing of this report, the contract terms are being negotiated with the charger manufacturer.

At the moment, it is expected that the contract will be signed by the end of October 2018, which would mean that the charger should be ready for testing in May 2019, according to the quote.

6.3.3 Preparing the vehicles for the demonstration

Vehicles have been prepared for the demonstration. TAMK has been making a test installation on their own test electric truck, and after the fast charging has been verified in their truck, the installation shall be made to the actual Niinivirta truck. TAMK has also created a lab test environment for the vehicle charging control in which the operability of the charging control has been tested and verified.

As mentioned in the beginning of chapter 4, only one charger has been modified in the project for the shared use, thus freeing some budget in the project for other use. As the planning with Stara and Vilakone proceeded during 2017, it became evident, that in order to be able to fully utilise the shared charger, the battery on the municipal work machine would need to be updated, as the current battery of the vehicle

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would limit the maximum charging power to only 55 kW, which doesn't give any advantage over the vehicle's built-in AC charging. The vehicle originally had a $LiFePO_4$ battery, which was not suitable for very fast charging.

A plan was made that the excess budget from the charger modifications would be utilised for updating the battery of the municipal work machine, to either a NMC or LTO battery, which each can support higher charging power. The aim was to be able to utilise almost the full power of the charger. The only limiting factor is the battery voltage of the vehicle, which is currently set at 400V, and exceeding that would mean larger changes to the vehicle (replacement of the current electric drivetrain), so it was not a feasible option. However, at 400V, the vehicle can support up to 200 kW charging power, with the 500A maximum charging current of the charger.

The planning for the municipal work machine update is continuing between Stara, Vilakone and VTT. Stara and Vilakone have another project to finish first, where the same prototype machine is being used, and the project will end by the end of 2018. At that time, a new project can be started on the machine. VTT is currently seeking funding for the vehicle design modifications from Business Finland. The idea would be to finance the required mechanical design from Business Finland, and an updated battery and fast charging related electrical equipment through mySMARTLife project. The machine will require mechanical changes, depending on which configuration is selected for the demonstration. Currently, the options are to use a series hybrid or full battery electric configuration.

6.4 Permissions

6.4.1 Charger installation permit

It has been agreed in the Action Group meetings, that Stara will arrange the foundation for the charger, which shall be prefabricated at Stara, according to the dimensions obtained from the charger manufacturer. This will be easy to install at the site, and enables also to remove the installation, should it be needed later. As the installation will not be permanent, a temporary installation permit shall be applied from the city, which allows five years of placement. The permit can be renewed easily after the 5 year period. This allows to perform the demonstration, and should this become a permanent arrangement, a permanent building permit is requested. Stara has committed to apply for the necessary permits. At time of writing this deliverable the acquiring the building permit was still in process.

6.4.2 Traffic sign

A traffic sign was requested from the city traffic planning, and has been already installed in the external vehicle charging point. Stopping at the parking slot is denied, except for charging of electric trucks and

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work machines. Currently the traffic sign is covered, to allow the residents parking until the charger is operational.

Figure 8: Traffic sign at the Hakaniemi external vehicle charging point

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7. Analysis of the demonstration

7.1 Key Performance Indicators

Once the charger is operational, the performance of it will be analysed according to the list of key performance indicators for Action 26 presented in Table 4. Once the charger has been installed, these indicators shall be produced on an annual basis. This deliverable also describes the planned monitoring and analysis methods used to evaluate the shared charger pilot.

Table 6: Key Performance Indicators for Action 26.

Indicator	Description
Total number of charges per year	Total number of charging events annually
Number of different users per year	Users per vehicle class: e-bus, truck, work machine etc
Annual energy delivered by charging points per year	Energy delivered from the two different connectors
Average occupancy time of charging stations	Occupancy time for both e-bus and external charging point
Total operating time (for charging)	Charger's operating time in hours
Total occupancy time of charging stations	Occupancy time in hours for both e-bus and external charging point
Number of external charging events	Number of charging events at the external connection
Total charged energy from the external connection	In kWh
Percentage of electricity charged from the external connection	In percent
Utilization ratio of external charging point	In percent
Station uptime per year	In hours
Charging capacity installed	Number and charging power of installed shared charging stations
Percentage of electricity supplied by renewable energy sources in the total annual energy delivered by the stations	In percent

7.2 Simulations

To support the planning for the Niinivirta electric truck pilot, and the Stara municipal work machine usage with the shared charger, simulations have been performed using a GIS (Geographical Information System) tool. The tool allows simulation of electric vehicles on pre-defined routes. The routes are constructed using a map tool that takes also account the locations of traffic lights, elevation, bus stops etc. The tool allows to add distractions, such as other traffic, to perform sensitivity analyses for the vehicle operation. The simulations were performed as part of the Action 22 of the project.

7.2.1 Electric truck

The electric truck's planned operation was simulated with the GIS tool. It was originally planned to have two fixed delivery routes for the truck, morning and afternoon, and simulation was used to verify how much battery capacity will be left for the mid-day break, and whether mid-day charging is required. Preliminary simulation results show, that the truck would use 50% of the battery capacity for the morning delivery, and approx. 60% of battery capacity for the afternoon round. The initial simulation was performed with the planned battery capacity of 130 kWh.

The simulation results indicate, that the battery capacity is not enough to cover the full day deliveries with a single charge, so either the battery size needs to be increased or charging needs to be organised for the mid-day break. The initial simulation assumed that the truck is driven back to the terminal for charging, where the charging would take time approximately 76 minutes. Between the morning and afternoon routes, there is a 4 hour period, when the truck needs to be loaded again, and with the investigated battery size, charged.

Utilising fast charging, the truck could be recharged during the mid-day break in approximately 15 minutes (assuming 300 kW charging power and 65 kWh required charge capacity). This would mean that the truck would be free for ad-hoc deliveries during the day for almost 4 hours, before it would need to return to the terminal to be loaded again for the evening delivery route. This will change the truck's operation capabilities a lot compared to a truck that is only charged at the terminal.

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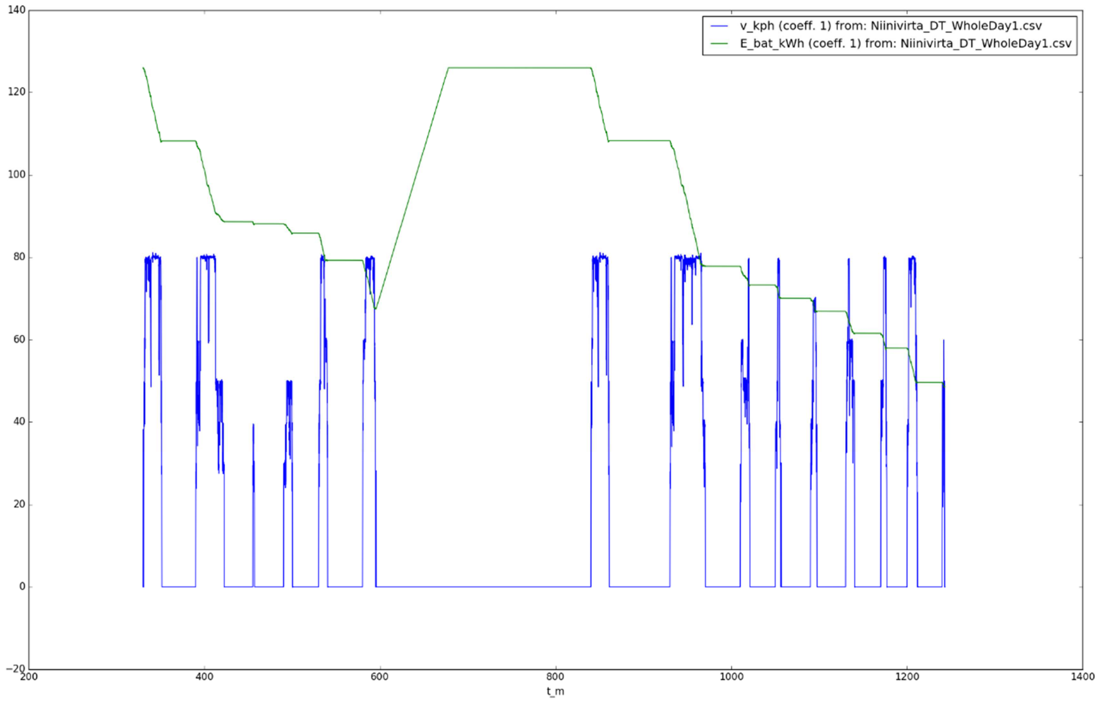

Figure 9: Simulation results of the electric truck

7.3 Shared charger analysis

The shared charger's feasibility shall be analysed by modelling the different vehicle usage patterns and charging requirements to find out the maximum capacity of a single shared charger, and the potential bottlenecks. The analysis is performed on the Hakaniemi charger, taking into account the current and future electrified bus lines, and their charging requirements, the simulated external vehicle charging requirements, based on the simulations and use cases for the electric truck and the municipal work machine.

7.4 Scalability and replicability

Based on the results in the deliverable of D4.17, a roadmap for the electrification is created for the Helsinki logistics and municipal fleet in deliverable D4.19, on a city-wide basis.

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8. Conclusions

Sharing of fast charging in cities can be one way to speed up the electric vehicle up-take, increased profitability by higher utilization rate and increase the competitiveness of EV's in city logistics and municipal work. Arranging shared charging will require good collaboration within the region and between the city's internal divisions and units. Careful planning is required to minimise the effects on public transport and other vital city functions that are the primary users of the charging infrastructure. A working Public-Private-Partnership (PPP) is required to include the external commercial users for the charging infrastructure early in the process to take into account their needs in planning.

A SWOT analysis for heavy-duty fast charging infrastructure was made. The analysis is showing the present weaknesses such as the issues caused by the ongoing standardization process. For example, the investments to the charging equipment can be risky because the investors cannot be sure whether the equipment meets the requirements of the upcoming standards. The strengths of the fast charging infrastructure includes less charging time which leads to smaller battery sizes. Also, as one of the opportunities, interoperability enables higher utilization rate which results in increased profitability. Currently in Helsinki, the utilization rate of heavy-duty fast chargers is very low leaving much potential for the interoperability.

Due to the complex nature of city decision making process, the building permit has not been granted yet for the shared charger. The work is continuing to pursue for the shared charging point.

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