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my SMART Life

Deliverable due date: M36 – November 2019

D4.19 Roadmap for city maintenance fleet and commercial city logistics electrification (WP4, Task 4.7, Subtask 4.7.6)

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.

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Project Duration	1st December 2016 – 30th November 2021 (60 Months)	
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26/07/2019	0.1	Marko Paakkinen (VTT)	Initial draft.
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Abbreviations and Acronyms

Acronym	Description
AC	Alternating Current
DC	Direct Current
GIS	Geographical Information System
HKL	Helsingin Kaupungin Liikenneliikelaitos, Helsinki City Transport
HSL	Helsingin Seudun Liikenne, Helsinki Region Transport Authority
kW	kilowatt
kWh	kilowatt hours

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1. Executive Summary

This deliverable establishes an initial roadmap for the electrification of the Helsinki city maintenance fleet and commercial city logistics. In addition to charting the possible approaches for the electrification, this report is taking a look also at non-technical measures.

The roadmap for the electrification of Helsinki city maintenance and logistic fleet is based on the information of the existing fleets. The Helsinki City Construction Service Stara is responsible of roughly 60 % of the city's street maintenance. A database of the current maintenance fleet of Stara was available to the project, which allowed an analysis of the fleet constitution, and analysis of the most impactful electrification targets, in regards to the carbon emissions and the city air quality. The different vehicle and machine types were also analysed for the availability of commercial electrified vehicles.

The starting points selected for the development of the roadmap for the electrification of city maintenance and logistics fleet were: i) Central role of interoperability in charging infrastructure. Interoperability increases utilization rate and enables cost efficiency and fosters adaptation of electric vehicles by increasing the service level of charging the vehicles ii) Urban platform development is seen as vital enabler for the smart electric logistic and city maintenance operations by interconnecting various systems. Urban platform also enables the analysis of performance of the logistics fleet in whole.

The progress beyond mySMARTLife project is also discussed in the deliverable, since the work done in regards to the electrification of the city fleet has already inspired several spin-off projects. These projects are expected to extend the impacts of the mySMARTLife electro mobility achievements.

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2. Introduction

2.1 Purpose and target group

The purpose of this deliverable is to establish an initial roadmap for the electrification of the Helsinki city maintenance fleet and commercial city logistics. In addition to charting the possible approaches for the electrification, this report is taking a look also at non-technical measures, such as tax reductions or changes to the parking or access policies.

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 the further development of the city's transport electrification strategy.

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
Stara	Providing input

2.3 Relation to other activities in the project

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.
D4.17	The results from the shared charger demonstration in Hakaniemi are used in building the roadmap.

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3. Methodology

The construction of a roadmap for the Helsinki city maintenance and logistic fleet electrification is based on the information of the existing fleets. Currently, the Helsinki City Contstruction Service Stara is responsible of roughly 60 % of the city's street maintenance. The division is such that Stara is taking care of the public roads, public transport stops etc, and property owners are responsible of maintenance within their properties and sidewalks next to their property. A database of the current maintenance fleet of Stara was available to the project, which allowed an analysis of the fleet constitution, and analysis of the most impactful electrification targets, in regards to the carbon emissions and the city air quality. The different vehicle and machine types were also analysed for the availability of commercial electrified vehicles.

Simulations, using VTT's GIS simulation tool, were performed on the maintenance vehicles, to determine the needs for energy, find out charging needs and to assess the suitability of the electrified equipment to the common maintenance tasks. Similar simulation was done also on the Niinivirta e-truck participating in the project.

4. Background

4.1 Helsinki city maintenance fleet

The Helsinki city maintenance fleet consists partly of the city-owned fleet, which is owned and operated by the Helsinki City Construction Service Stara. The other part is the equipment owned by commercial maintenance operators, handling for example the maintenance for businesses and housing companies. An accurate number of the total number of maintenance vehicles running in Helsinki is not available, as some of the equipment is registered in the neighbouring cities.

In the D4.1 baseline document, 5,510 trucks, 2,622 municipal vehicles and 1,755 tractors are registered in Helsinki. The share of trucks used for maintenance and logistics is not available.

The maintenance fleet of Stara, with the fleet size, and emitted CO_2e, PM and NOx emissions are listed in Table 3. The emissions are given as a percentage of the whole fleet to improve comparability, and to identify the largest emitters of each category.

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Table 3: Maintenance fleet of Stara

Machine and fuel type	Fleet size	CO_2e	PM	NO_x
Truck, diesel	124	30 %	17 %	42 %
Van, diesel	485	23 %	11 %	13 %
Multi-purpose vehicle Wille, fuel oil	139	16 %	30 %	17 %
Passenger car, gasoline	355	9 %	1 %	0 %
Passenger car, diesel	64	3 %	2 %	4 %
Street sweeping/washing machines, diesel	11	3 %	1 %	3 %
Lawnmower, fuel oil	30	1 %	8 %	2 %
Grader, fuel oil	14	1 %	5 %	3 %
Multi-purpose truck, diesel	12	1 %	1 %	2 %
Multi-purpose vehicles, fuel oil	8	1 %	1 %	1 %
Tractor, fuel oil	5	0 %	1 %	0 %
Excavator, fuel oil	2	0 %	1 %	0 %
Park maintenance machines, fuel oil	20	0 %	3 %	1 %
Vibrating roller, fuel oil	4	0 %	1 %	0 %
Forklift, fuel oil	7	0 %	0 %	0 %
Total	**1 280**			

The largest impact with electrification can be made by electrifying the truck, van and multi-purpose (Wille) machine fleets. These three machine classes are by far the largest emitters of both carbon dioxide and local emissions. If the passenger cars are also considered as potential electrification targets, this would impact 90 % of the whole fleet's CO_2-emissions, and would have potential to cut 60 % of the direct particle emissions and 76 % of the NOx emissions. Fuel oil operated lawnmowers and park equipment are responsible of a significant amount of PM and NO_x emissions, and are therefore recommended for replacement.

4.2 Commercial logistics in Helsinki

Helsinki Region Transport (HSL) conducted a survey in 2012-13 about delivery logistics in the Helsinki region, utilizing GPS tracking of truck and van deliveries. A total of 11 delivery companies, with 66 vehicles, participated in the survey. Table 4 is listing the daily delivery route lengths of different vehicle classes. The route lengths of trucks were on average slightly longer than vans.

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Table 4: Daily delivery route lengths in HSL survey

	Min [km]	Average [km]	Max [km]
Trucks (n=40)	14	131	282
Vans (n=24)	45	115	250
All vehicles (n=66)	14	125	282

Almost all of the vehicles operated in the Helsinki capital region, and approximately one fifth of the vehicles had the route solely within the central district.

4.3 Charging infrastructure in the Helsinki region

4.3.1 Public transport

In July 2019, 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. A shared charger will be demonstrated in Hakaniemi, Helsinki as part of mySMARTLife project. The charger is installed next to existing electric bus charging point and will be serving the electric city maintenance and logistics fleet.

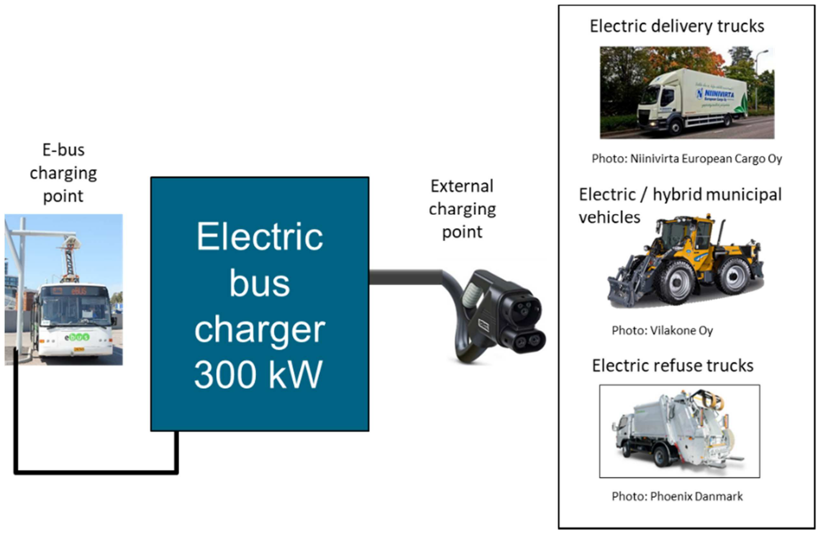

Figure 1: Shared charging arrangement in Hakaniemi

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5. Use cases and potential for electrification

5.1 Maintenance fleet

5.1.1 Electrification potential of Stara fleet

The potential of electrification of different types of machines of the city owned maintenance operator Stara and the expert estimates of the impact this potential provides is presented in
Table 5.

Table 5: Electrification potential of different machine types

Machine and fuel type	Fleet size	Electrification potential	Impact
Truck, diesel	124	HIGH	HIGH
Van, diesel	485	HIGH	HIGH
Multi-purpose vehicle Wille, fuel oil	139	MEDIUM	HIGH
Passenger car, gasoline	355	HIGH	MEDIUM
Passenger car, diesel	64	MEDIUM	LOW
Street sweeping/washing machines, diesel	11	LOW	LOW
Lawnmower, fuel oil	30	MEDIUM	MEDIUM
Grader, fuel oil	14	LOW	LOW
Multi-purpose truck, diesel	12	LOW	LOW
Multi-purpose vehicles, fuel oil	8	LOW	LOW
Tractor, fuel oil	5	MEDIUM	LOW
Excavator, fuel oil	2	LOW	LOW
Park maintenance machines, fuel oil	20	LOW	LOW
Vibrating roller, fuel oil	4	LOW	LOW
Forklift, fuel oil	7	HIGH	LOW
Total	**1 280**		

5.1.2 Passenger cars and light vans

Passenger cars are increasingly available as electric versions. The passenger cars could be replaced by implementing new policies for new vehicle purchases, and let the fleet renewal replace the fleet. Diesel vehicles can still be kept for long-distance driving as long as there is a need.

Light vans are available from almost all European OEM's in 2020 as electric versions, and the van replacements should be considered.

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Table 6: Electric vans coming to market

Brand and model	Battery size [kWh]	Maximum range [km]	Max. charging power [kW]	Sales start
MAN eTGE		172		2021
Mercedes eVito	41.4	150		available
Mercedes eSprinter	41.4 - 55.2	114 - 150		2020
VW e-Caddy		257		2019
VW e-Transporter	38.8 / 77.6	209 / 402	40	2020
VW e-Crafter	35.8	172		2020
Renault Master z.e.	33	193		2019
Renault Kangoo z.e.	33	274		available
Opel Vivaro				2020
Fiat Ducato Electric	47 / 79	220 / 360	50	2020
Nissan e-NV200	40	280	50	available
Peugeot Partner electric				2021
Citroen Berlingo electric				2021
Peugeot Expert electric				2020
Peugeot Boxer electric	44	160 - 225	22	2021
Citroen Relay electric	44	160 - 225	22	2021
Toyota Proace Electric				2020
Ford Transit electric				2021
Streetscooter Work	40	205	2,7	available
Streetscooter Work XL	76	200	11	available
BYD T3	50.3	300	40	
Iveco Daily electric	28.2	200	22	2019

5.1.3 Trucks

Trucks are utilized for multiple purposes - bulk and goods transport, street cleaning, snow plowing. The availability of e-trucks is beginning to increase. So far, e-trucks have been available from retrofit companies, like Emoss or E-Force, but during 2020 the availability from major OEM's is also increasing. Companies such as Volvo, Renault, Daimler, MAN and DAF have introduced e-trucks, and many are entering production during 2020.

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Table 7: Electric trucks coming to market

Brand and model	Gross weight [tn]	Battery size [kWh]	Maximum range [km]	Max. charging power [kW]	Sales start
Volvo FL electric	16	100 - 300	300	150	2019
Volvo FE electric	27	200 - 300	200	150	2019
MAN eTGM	18 - 26		200	150	2020
Mercedes eActros		240	200	150	2021
Renault D z.e.	16	200 - 300	300	150	2019
Renault D.WIDE z.e.	26	200	200	150	2019
DAF LF electric	19	222	220		
DAF CF electric	37	170	100		
BYD T6	7.5		240	96	
BYD T9	28	217	200	120	
Fuso e-Canter		82.8	100	66	available

The lifespan of a medium or heavy duty truck is rather long in Finland (the average age of a truck is 13 years in 2017, see

Table 8, and the renewal of the fleets take time. One option to speed up the up-take of e-trucks is retrofitting the vehicle's drivetrain with an electric powertrain. This business area is picking up especially in the U.S, but also globally it is becoming a new business. TM4 (Dana), Cummins, ZF, Allison AXE. Table 9 lists the current retrofitted electric trucks in the market with the selected properties.

Table 8: Age distribution of registered trucks and vans in Finland

Year of commissioning	Percentage of vans	Percentage of trucks
-1996	3.8	2.2
1997-2001	13.8	7.7
2002-2006	22.3	19.9
2007-2011	29.5	30.8
2012-2016	30.4	39.2

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Table 9: Retrofit electric trucks in the market

Brand and model	Gross weight [tn]	Battery size [kWh]	Maximum range [km]	Max. charging power [kW]	Production start
eMoss EMS18	18	120 - 240	100 - 250	44	available
E-Force EF18	18	105 - 630	500	350	available
E-Force EF26	26	105 - 630	500	350	available

5.1.4 Urban maintenance machines

Multi-purpose urban maintenance machines, for example the Wille series from Vilakone or Avant, are popular machines in the city maintenance operations in Finland. The machines are utilized for all city maintenance purposes, for example street sweeping and washing, snow plowing, lawn mowing etc. Avant has currently two battery electric models in their offering. Stara is testing a series hybrid version of the Wille machine, which will be converted into a battery electric version in the mySMARTLife project (Action 22).

Figure 2: Wille 665 multi-purpose urban maintenance machine (picture: Vilakone)

An electric powered municipal work machine capable of sweeping, snow removal, sanding and construction tasks will be facing problems when being operated for longer shifts, e.g. during a long snowfall. These vehicles typically have compact dimensions, which currently inhibit the installation of very large batteries. Utilizing a series hybrid approach, where the vehicle is capable of carrying out a portion of

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the work as full electric means that in longer duration, most of the work is going to be performed using the range extender. Should the vehicle be equipped with fast charging, the on-board energy storage could be fitted with the normal daily duty cycle, including lunch and coffee breaks of the operators. This means that charging could be performed without excess idle time, but at the same time, unlimited mobility could be provided with a smaller battery than by sizing the energy storage for whole day's needs.

5.1.5 Street cleaning

Helsinki has a small number of dedicated street cleaning machines, mainly combined washing and sweeping machines. These machines are readily available as electric, for example from Dulevo, Tennant and Tenax, and Bucher. As an example, the Bucher CityCat 2020ev municipal street sweeper has a 56 kWh battery, and a built-in 22 kW charger. It is capable of 8 hours of operation with a single charge, thus not requiring fast charging during operation, and can be recharged from a normal Type 2 AC charging station in 2.5 hours.

Figure 3: Bucher CityCat 2020ev battery electric street sweeper (picture: Bucher)

The street cleaning equipment is likely not to be needing fast charging infrastructure, but requires depot charging.

5.2 Commercial logistics

5.2.1 Long-haul transport

At the moment, the options for long-haul transport electrification are limited, mainly due to the limitations in energy storage. There are battery electric vehicles also for long-haul transport coming up for example from Tesla and Nikola Motors, but they are not yet in production. Also, experiments are on-going with dynamic in-motion charging of trucks in Germany and Sweden, utilizing both contacting and wireless charging methods. These are currently under development, and it is difficult to predict, which systems

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shall be winning in the long run. One promising option for long-haul transport is hydrogen fuel cell based propulsion. This would be very viable option for example in transporting goods from factories that are producing hydrogen as a side stream. At the moment, the best option for decreasing the carbon intensity of the long-haul transport is biofuels.

5.2.2 Local delivery

Electric vehicle offering suitable for intra-city deliveries is currently expanding at a fast pace. All major brands are introducing light vans suitable for this purpose. The requirements of these vehicles are close to the requirements of passenger EV's, and thus they are fully compatible with the commercial charging networks.

6. Charging infrastructure

The charging infrastructure required by the electrified vehicles can be quite different, depending on how well the electrification is planned within the city. When the work is siloing, and all city units and commercial operators are acting on their own, the result can be very diverse charging infrastructure, consisting of proprietary charging systems for each owner and vehicle type. And as the current situation is, as presented in Figure 4, that many of the activities around electric mobility are happening in silos, not considering the big picture in cities. Public transportation is planning their own proprietary 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. 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. However, if the work is performed in collaboration with all stakeholders as Figure 5 suggests, some investments can be avoided and better service level for the users can be guaranteed especially with shared fast charging networks.

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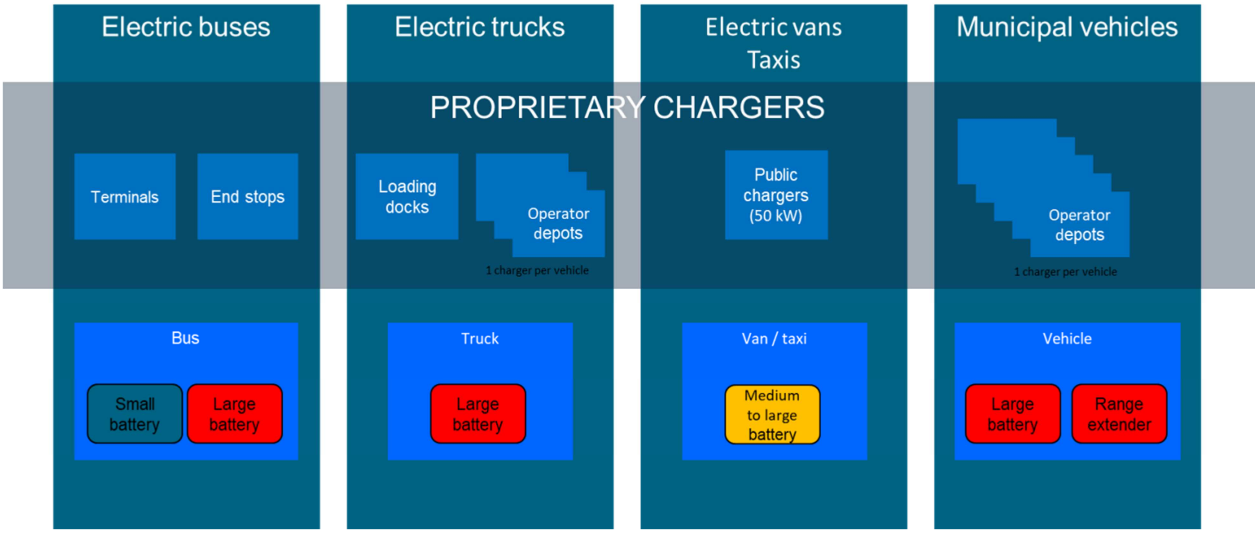

Figure 4: Siloing of the charging infrastructure

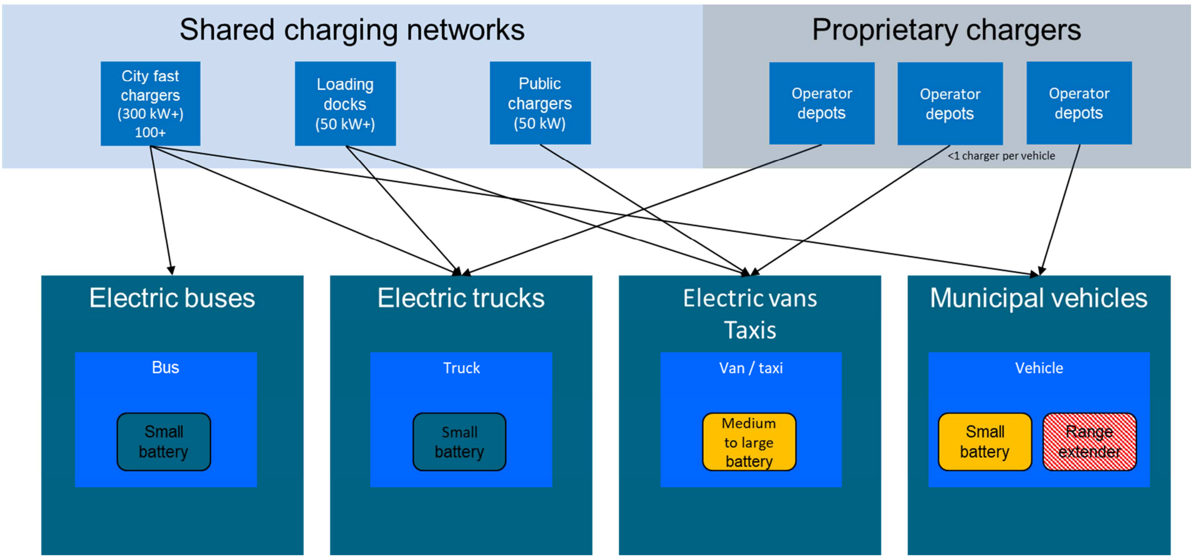

Figure 5: Shared charging infrastructure

6.1 Fast charging for ECV's

Fast charging of commercial electric vehicles has similar benefits as in electric buses. The vehicles can have basically unlimited autonomy, meaning that with periodic fast charges, the vehicles can operate continuously, without needing to be taken to depot for charging. The vehicles can also have smaller batteries, which yields in increased payload or more capacity, as the battery size and weight is not decreasing the load carrying capacity of the vehicle. Third benefit of fast charging is that the smaller battery also has smaller capital expense, as the batteries are still the most expensive single component in an electric vehicle.

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Currently, the research work is going on dynamic inductive and conductive charging. In conductive dynamic charging, An overhead line or a wires placed within the road, is used to transmit electrical energy to trams, trolleybuses or trains at a distance from the energy supply point. A movable pantograph or arm is placed above or underneath the vehicle and connected to high voltage electric lines for charging while in motion. An example of a pantograph underneath the vehicle is presented in **Figure 6** while an example of overhead dynamic charging is presented in Figure 7. Using this technology, lower battery capacity can be used in vehicle, which decreases vehicle cost but increases the charging infrastructure cost.

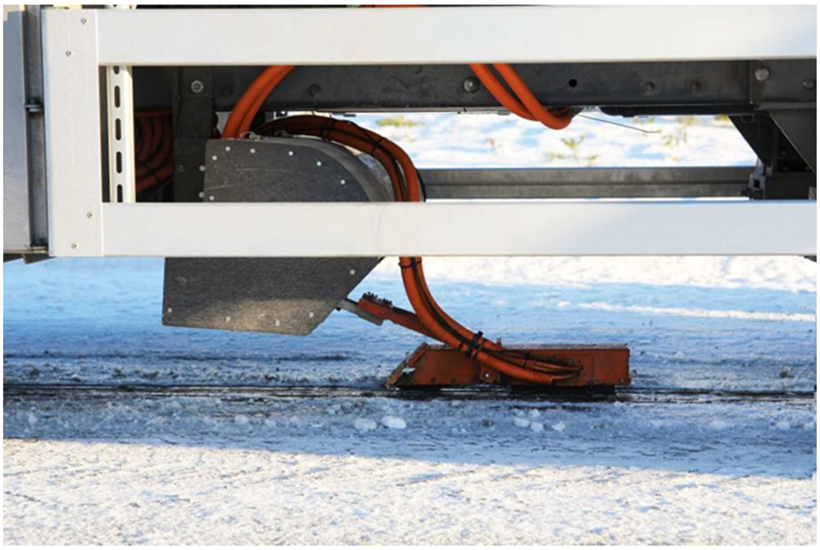

Figure 6: An example of conductive dynamic charging with a movable arm or a "ski" (Source: Dezeen)

Figure 7: An example of conductive dynamic charging with two overhead pantographs (Source: Scania)

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In dynamic inductive charging, dynamic power is transferred to the vehicles from the roads they are driving on. The energy is transferred wireless through a magnetic field and no physical connection between the road and the vehicle is required. A conductor (comparable to the primary side of a transformer) inside the road generates a magnetic field that can be obtained in the vehicle and converted into electrical current. The power train of the truck needs to be tightly integrated with the power transfer technology, which needs to be integrated with the electric road design, which in its turn needs to be integrated with the regional power grid (Viktoria Swedish ICT, 2013).

For logistics vehicles, unlimited autonomy means that the vehicles can utilize dynamic routing, as they do not need to care about battery capacity or range. The route or operating area needs to have enough fast charger coverage though. Partly, the public fast charging infrastructure can be utilized as a back-up, when charging infrastructure targeted at commercial vehicles is not available. For municipal work machines, unlimited autonomy means that the vehicles can operate in special circumstances, for example during a long snow storm, in three shifts, without interruptions.

6.2 Depot charging infrastructure

All electric vehicles need depot charging infrastructure, even though they would rely on fast charging in the operation. Even for the fast charging only electric buses, which are currently used in Helsinki, it would be beneficial to start the shift with a full battery, and avoid issues for example with slow charging of a cold battery in the beginning of the day. Even though this can be avoided by fast charging the vehicles before taking them to the depots, it will save time and effort to slow charge the vehicles at the depot.

6.2.1 DC depot charging

Slow DC charging is a new emerging trend also in the passenger vehicles, meaning charging at ~22 kW power level. In DC charging, the charger is external to the vehicle, which is saving some weight and space from the vehicle. DC charging also allows better controllability on the charging power than by using the built-in AC charger. The cost of a DC charger is higher than an AC charging point. At the moment, a dual DC charger, capable of 11 - 22 kW charging power per charging point, costs roughly 20 000 €, whereas a dual AC charging point with similar capacity costs roughly 3000 - 5000 €.

6.2.2 Loading docks (logistics)

For delivery vehicles, an optimal charging location is at the loading docks, when the vehicle is standing and waiting for loading or unloading. Loading docks could be equipped with fast chargers, which would allow vehicles to be effectively charged during use.

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7. Progress beyond mySMARTLife

An innovation intervention in Action 26 has been to chart out the technical, operational and innovation aspects for scaling up shared multi-use commercial electric vehicle charging nodes for wider market uptake of the systems. This has been performed in the Action Group E-mobility, and it has gained ground already before the first such node has been yet in operation. As a result, several spin-off projects have started, which are further extending the work of mySMARTLife.

7.1 ELENA project

For scaling up of the Helsinki e-bus, logistics and maintenance fleet charging infrastructure, a separate project proposal has been prepared. The funding has been agreed with European Investment Bank's ELENA facility. The project shall be carried out by HSL, with a VTT employee working full time as a project manager at HSL's premises. The project is focusing in planning the large-scale roll-out of e-buses and shared charging infrastructure in the Helsinki region.

7.2 E-Retrofit project

As part of Action 22 and Action 26, innovative means for accelerating the electrification of the maintenance fleet have been surveyed. One option is retrofitting of the vehicles with a battery-electric powertrain. This has started to gain traction especially in the United States, but also within Europe.

The Helsinki City Innovation Fund granted funding for a pilot project, where one diesel truck from Stara will be converted to a battery electric vehicle. The conversion shall be performed by the Tampere University of Applied Sciences, in close collaboration with the Stara fleet maintenance personnel. The aim is to learn about the retrofitting process, including technical and financial feasibility, and to learn about the usability of the electric trucks in maintenance operations. A separate project is being setup to start building an ecosystem around the retrofitting business, with funding from Business Finland.

7.3 Silent Refuse Truck

As part of an ecosystem called "Smart Otaniemi", a pilot project for an electric refuse truck, equipped with full electric actuators in the garbage packer, has started in May 2019. The goal of the project is to pilot the refuse truck for 18 months in the central district of Helsinki, testing also nightly refuse collection, which has very good potential for reducing the disturbances that the normal office hours refuse collection is causing for the city traffic and traffic safety. The pilot period is planned to start in fall 2020.

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The refuse truck in the pilot is going to utilize the shared charging point in Hakaniemi, and based on the vehicle's operational data and experiences, it is further studied in the ELENA project that what kind of charging infrastructure would be required for expanding the battery electric refuse collection fleet.

The partners of the project are Helsinki Region Environmental Services (HSY), VTT, NTM (producer of garbage collection systems) and Motiomax (manufacturer of electric actuators).

8. Roadmap

The starting points selected for the development of the roadmap for the electrification of city maintenance and logistics fleet were:

-Central role of interoperability in charging infrastructure. Interoperability increases utilization rate and enables cost efficiency and fosters adaptation of electric vehicles by increasing the service level of charging the vehicles.

-Urban platform development is seen as vital enabler for the smart electric logistic and city maintenance operations by interconnecting various systems. Urban platform also enables the analysis of performance of the logistics fleet in whole.

The proposed roadmap is presented in Figure 8.

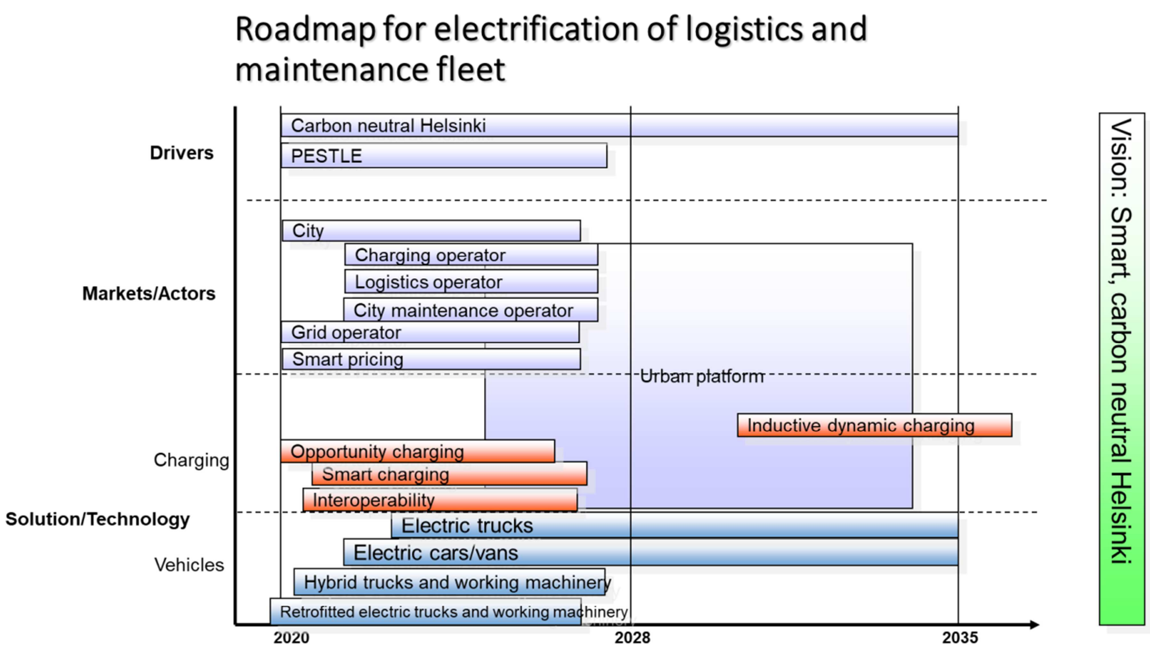

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Figure 8: Proposed initial roadmap for the electrification of Helsinki maintenance and logistics fleet

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Actors in the roadmap are starting from the city itself. The city acts as an important policy stakeholder via permissions, regulations and also owns the biggest maintenance fleet operator in the city. The operators follow the regulations and market development. The urban platform is expected to act as an integrator of all the services and operations within the timeline of the vision.

Technologies and solutions to achieve the vision will start from retrofitting existing maintenance and logistics fleet into electrical. And ending with total electric fleet incorporated with smart and inductive dynamic charging.

8.1 Drivers

The vision, which the roadmap development serves, is the carbon neutral Helsinki goal set by the Helsinki city council. The Carbon-neutral Helsinki 2035 Action Plan presents the actions required to achieve Helsinki's climate objectives. Helsinki is committed to doing its part in mitigating climate change. The objective of the Helsinki City Strategy 2017–2021 is to make Helsinki carbon-neutral by 2035. This goal will be achieved by reducing the greenhouse gas emissions in Helsinki by 80 per cent. The remaining 20 per cent will be compensated for by Helsinki taking care of implementing emissions reductions outside the city. The majority of Helsinki's emissions are generated by the energy consumption of buildings and traffic. The volume of greenhouse gas emissions from traffic in Helsinki amounted to approximately 600 kilotonnes (CO2e) in 2015 as presented in Figure 9. The volume has decreased in the last few years: in 2015, the emissions were 15 per cent lower than in 2005. To reach the goal of becoming carbon-neutral, the traffic emissions were set a separate gloal: the objective is to reduce greenhouse gas emissions by 69 per cent from the level of 2005 by 2035 (this would mean a reduction of 60 per cent from the level of 2015: 363 kt CO2e). (City of Helsinki, 2018).

Helsinki City Transport has already included Electric buses in their fleet. Their goal is that by 2025, 30 per cent of buses used on services are electric. (HSL, 2018).

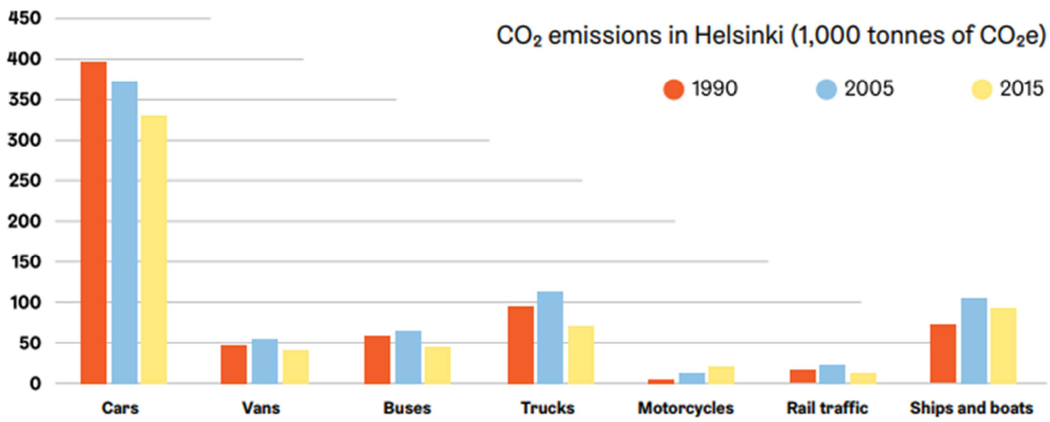

Figure 9: The CO2 emissions from traffic in Helsinki. (City of Helsinki 2018)

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According to the City Strategy, “Traffic emissions will be reduced across the city’s transport system by promoting both cycling and pedestrianism and by raising the proportion of e-vehicles and buses and rail transport. Helsinki paves the way for a strong surge in the number of e-vehicles by enabling the market-driven construction of a public charging infrastructure.” The non-technical drivers and barriers will be investigated using the PESTLE approach.

The BAU (business as usual) scenario for Helsinki’s greenhouse gas emissions for 2030 and 2035 describes the development of climate change mitigation in Helsinki based on the current political measures and actions already decided on (**Figure 10**). Active measures are needed for the BAU scenario to be realized. It involves shutting down the Hanasaari B power plant and substituting its production with other energy sources and solutions, as per Helen’s development programme. Moderate future estimates were also sought from the base scenarios presented in the energy and climate strategy 2016 of the Ministry of Economic Affairs and Employment, as well as VTT’s models. (City of Helsinki 2018).

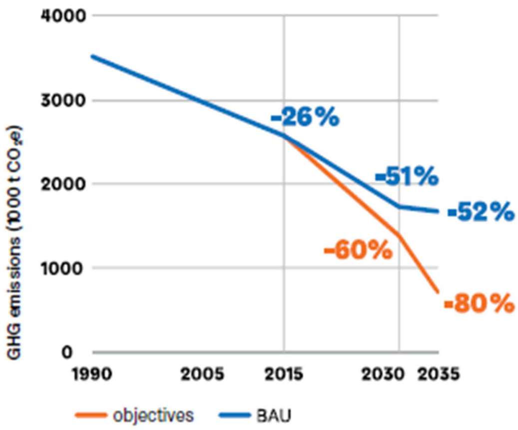

Figure 10: Helsinki’s emissions reduction objectives for 2030 and 2035, and the development estimated using current decisions (BAU). (HSY 2017)

8.2 Markets and actors

The City has limited opportunities to influence the renewal of the vehicle stock in the City. In the procurements for the City's own vehicles, the prioritization of low-emission vehicles is essential. The City of Helsinki will develop and tighten the environmental criteria (incl. alternative fuel sources, emission classes) in all competitive bidding processes for delivery services, heavy delivery services and utility vehicle and machinery services. The environmental criteria will be applied to procurement of the City’s own vehicles and leasing vehicles. The fleets of City’s construction company, Stara and Helsinki City Transport, HKL will only use vehicles that run on biofuels or renewable electricity by 2020. Stara has created a programme of its own, stating that it will become carbon-neutral by 2030. With procurements,

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available steering measures, and other means, the City will support the creation of a market for new products and services that residents, companies and communities can use to reduce their own emissions.

8.2.1 City

City has the most important part as an enabler and manager of the electrification of the transport network. Not only it owns significant amount of vehicles itself directly or through its companies, but also it has leverages on planning of the charging infrastructure, transport-related policies. City's roadmap should account for the electrification process through planning policies and include incentives and penalizations to achieve its set green mobility targets. In some cases cities might need to push the central governments to adopt certain policies at higher level since they are not set at the municipality level. A good example of incorporating the electrification development in the city's vision can be found in Helsinki's Vision for year 2050 - part City of Sustainable Mobility (City of Helsinki, 2013).

"The majority of private cars are electric or hybrids. The electrically assisted bicycle, the electric scooter and other electric means of transport have become more common. Goods delivery and distribution occur in accordance with schedules by means of delivery methods suited to the urban environment".

8.2.2 Charging operator

Charging operator is the company or institution responsible for operating the charging infrastructure. It could be owned publicly or privately and the chargers could have limited of full accessibility to public. Charging operators should strive for maximum utilization of the chargers while minimizing the fixed and operating costs. One of the key measures to increase the efficiency is the standardization and interoperability (more in Chapter 8.3.4). Another idea is to make the chargers open even if they are built primarily for private use and therefore make use of them when they are not needed for the private customer.

8.2.3 Logistics operator

Logistics operator's role is to take care of logistics within the designated area. There are different possibilities to implement the electrification of logistics operations as presented in Table 10.

Table 10: Operational schemes for vehicles and chargers

Type	Logistics operator owns	Other stakeholders own
Vehicle owner only	vehicles	chargers
Vehicle lease only	-	chargers, vehicles
Vehicle and charger owner	vehicles, chargers	other public chargers

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The electrification implementation should depend on the local market and topology conditions, possible synergies from not owning the chargers, and available vehicle technology. For example if the vehicles include large batteries for depot charging it would make more sense to have private depot charging (with possible public use during the day), but vehicles oriented on fast-charging could benefit more from public network of fast chargers.

8.2.4 City maintenance operator

The aim of the city maintenance operator should be to maximize the synergies in electrification efforts with the city itself. An example of such synergy is piloting the city's charging network with the city maintenance vehicles. In addition to that there could be some more specific solutions due to access to other city's operators like making use of the existing tram network in terms of reusing the wasted braking energy or night charging of winter maintenance from the existing tram wires (provided that a viable market solution exists). The maintenance operator should serve as a flagship of electrification and its benefits such as lower noise and lower emission, which will have direct impact on citizen's quality of life.

8.2.5 Grid operator

Grid operator has a challenging task to accommodate the new emerging technology in the smoothest way possible. If planned well, transport electrification can even serve to stabilize the grid through the vehicle2grid technology, nevertheless if planned wrong there might be a heavy strain on the network leading up to blackouts.

Grid operator should already be preparing for the new era by transforming into smart grid technologies that allow for much more flexible and efficient use of the generated technology. Since night slow charging has a beneficial effect on the network as a "peak shaving" technology, the attention should be shifted towards fast-charging technology and energy storages covering for quick opportunity charging demands.

8.2.6 Smart Pricing

Smart pricing is a very efficient tool for the grid operator to bring the load curve closer to the production curve with high percentage of renewables. Due to the possible high percentage of solar plant installations the biggest lack of produced power will occur in the morning and in the evening. A smart pricing measure could shift the charging to night period with abundance of wind and water power while also making the electricity cheaper around noon due to abundance of solar power. The main point of such solution could be to increase the amount of power generated by renewable energy while lowering the need for energy storage.

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8.3 Charging solutions

Charging stations are regarded as the point of fuelling EVs. Cords, connectors, and interface with the power grid are the key equipment of charging station. Good charging infrastructure is one of the key factors for deployment of EVs. There are several technologies available for charging an electric vehicle. Charging solutions have been described in detail in Chapter 6.

Electric buses in Helsinki are now charged using depot charging and opportunity charging. Depot charging allows e-buses to be connected and charged while parked at the bus depot,

Figure **11**. Vehicle is connected to charging equipment using plugs and cables. Energy transfer depends on power handling capacity of the cable connecting the charger to the vehicle. The technologies can be combined together to harness the advantages from multiple approaches.

Figure 11: Charging Electric Bus with Depot Charger (https://newmobility.news/2017/07/26/polish-electric-buses-brussels/)

8.3.1 Opportunity charging

In opportunity charging, the pantograph charger delivers a high conductive energy transfer in short time from the charging infrastructure to heavy-duty vehicles like electric busses, trucks and special vehicles. Two types of pantograph charging are being applied for electric busses. There is a so-called ‘top down’ or ‘inverted pantograph’, which is integral part of the charging infrastructure. The other type is mounted on the roof of the vehicle, the so-called ‘Up’ or ‘rooftop pantograph’. Examples of different types of opportunity chargers are presented in Figure 12. Helsinki has installed 6 rooftop opportunity chargers to charge the city transport electric buses.

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Figure 12: Inverted pantograph and rooftop pantograph (http://www.vdlindustriesga.com/news/vdl-presents-unique-charging-plaza-in-valkenswaard)

8.3.2 Induction charging / Wireless charging

Through electromagnetic fields, the current is transferred to the car. The field starts charging when the electric car is parked at the charging point. The car drives over an induction plate located in the road surface of a parking space. Charging can be started with the aid of an app. This technology is still in development and it is not clear when the consumer market will be able to use this technology. In addition to wireless charging in parking spaces, work is also being carried out on technologies which will enable electric cars to be charged whilst being driven. (Netherlands Enterprise Agency, 2019)

In Europe inductive charging is still in testing phase and several companies are experimenting with induction charging. It is yet not clear if / when this form of electric vehicle charging will get a substantial market share. (Smartroad Gotland).

8.3.3 Smart Charging

Smart charging refers to a system where an electric vehicle and a charging device share a data connection, and the charging device shares a data connection with a charging operator. It allows for adaptive charging habits, providing the electric vehicle with the ability to integrate into the whole power system in a grid- and user-friendly way. Smart charging must facilitate the security (reliability) of supply while meeting the mobility constraints and requirements of the user.

8.3.3.1 Grid-to-vehicle (G2V)

Grid-to-vehicle-technology enables vehicles to charge at varying capacities, depending on energy availability. Electric vehicle batteries can be charged in a smart way to prevent peak loads on the grid. This can be based on energy demand and available capacity on a local level. The vehicle to grid technology determines when, and at which capacity, the vehicle will be charged. (Nederland Elektrisch).

8.3.3.2 Vehicle-to-grid (V2G)

Vehicle-to-grid-technology enables vehicles to feed electricity back into the grid. The battery in the vehicle can be used as a buffer to store energy in times of high (sustainable) energy production, but also to act as an energy supplier in times of low (sustainable) energy production. Vehicle-to-grid technology contributes to optimizing sustainable energy usage.

8.3.4 Interoperability

"Interoperability" refers to the ability of EVs to interact with a range of different chargers, for those chargers to interact with each other and with other charging management systems. Innovative charging strategies like shared charger between eBuses and Stara fleet will help drive down the total cost of ownership for electric fleet operators and also increase the operating time for the work machines, helping increase adoption of eBuses and eTrucks and enabling a more sustainable future in which both noise and air pollution is significantly reduced. New standards for opportunity charging are being designed as part of EU H2020 ASSURED project. (ASSURED) If the designed standards are put to practice then Stara and Helsinki city transport buses and logistics fleet can share the same chargers which leads to reduction in investment costs of the electrification and improves occupancy rate of the chargers, resilience to disturbances and robustness of the system. Standardization can also prevent vendor lock-ins.

9. Conclusions

The main objective of this deliverable was to establish an initial roadmap for the electrification of the Helsinki city maintenance fleet and commercial city logistics. Two main points identified for the development of the roadmap were: i) Central role of interoperability in charging infrastructure. Interoperability increases utilization rate and enables cost efficiency and fosters adaptation of electric vehicles by increasing the service level of charging the vehicles ii) Urban platform development is seen as vital enabler for the smart electric logistic and city maintenance operations by interconnecting various systems. Urban platform also enables the analysis of performance of the logistics fleet in whole.

As presented in the vision, 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. This roadmap serves as a part of filling Helsinki targets within mySMARTLife project.

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