D3.5 EV mobility integration and its impacts in Espoo

30/09/2022

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Deliverable administration

No & name	D3.5 EV mobility integration and its impacts in Espoo				
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Description of the related task and the deliverable. Extract from DoA	**T3.4 E-mobility integration (ESP) M1 – M60** The task develops new E-mobility solutions, demonstrates the integration of EV charging to the local grid, evaluates its impact, studies EV charging as a storage solution, analyses opportunities for new business models and the uptake of E-mobility. Block and macro level subtasks include: Subtask 3.4.1 Boosting E-mobility uptake in the Espoonlahti district, Lippulaiva blocks • Integrating and grid impact assessment of community and residential EV parking in the Lippulaiva blocks: charging units (CIT will decide the specific amount in 2020, from 20 to 140 EV parking spaces, currently grid access dimensioned for 400 EV). • Develop opportunities to support and enable E-bicycling with appropriate parking and charging infrastructure (inverters, parking facilities, size demands, secure charging infrastructure) boosting the E-mobility in the whole Espoonlahti district. • Boosting the uptake of E-mobility: Sustainability strategy for accessing the Metro and Lippulaiva with other mobility modes, developing a hub for shared EVs and commercial electric vehicle charging services. Analysis of energy demand for electric buses, taxis, garbage and delivery trucks and other service vehicles and impact on electric grid. Development of smart charging services. Subtask 3.4.2 New E-mobility hub in Leppävaara center • Developing Leppävaara EV-mobility hub as a whole. The Leppävaara center will be developed into a new E-mobility hub connecting local and long distance trains, city E-buses, and a new fast E-tramline. First mile/last mile services will be enhanced with car sharing. Interoperable charging infrastructure will be provided taking into account need of electric service vehicles, such as refuse trucks and mobile machinery as well as taxis. The requirements and impacts on the electrical grid will be analysed. • EV mobility integration to the Sello energy system. Development of EV charging for customers of the shopping centre and commuter parking as a part of the total building power management and microgrid solutions. EV and peak load prediction, monitoring and control including charging integrated with the whole Sello Energy system, digitalisation for managing peak loads from EV / micro grid control, dynamic pricing models for electric vehicle				

	parking and price of electricity. Evaluate shopping behaviour in the EV charging concept. • Optimization of charging strategies for commercial vehicle fleet. Utilization of activity-based models for demand response prediction. Subtask 3.4.3 E-mobility solutions replication and uptake in Kera • Replication of e-mobility solutions. Further development and implementation of Leppävaara e-mobility solutions to applicable parts. Charging stations for company-owned electric vehicles. Multi-modal transport solutions with focus on last-mile. Subtask 3.4.4 E-mobility urban planning requirements • Optimal integration of EV charging, in the E-mobility nodes of Leppävaara, Espoonlahti and Kera, managing of peak power demand and related effects. Analysis of future demand and development of smart charging strategies for different scenarios up to 2030 and beyond, and the impact to the grid.
Participants	ESP, VTT, KONE, SIE, PIT, CIT
Comments	

V	Date	Authors	Description
0.1	02.09.2022	All	Draft ready for internal review
0.2	28.09.2022	All	Finalisation of deliverable based on review comments
0.3	28.09.2022	WP leader	Deliverable checked by WP leader and released to the Coordinator and the Quality Manager for quality check and subsequent submission to the EC.
0.4	30.09.2022	VTT ESP SIE KONE	Quality review comments implemented
1	30.09.2022	VTT	Coordinator submits the deliverable to the EC

Dissemination level		
PU	Public	√
CO	Confidential, only for members of the consortium (including the Commission Services)	

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About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. SPARCS facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating VirtualPositiveEnergy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organizations, city planning and decision making entities, transforming cities to carbon-free inclusive communities. Lighthouse cities Espoo (FI) and Leipzig (DE) implement large demonstrations. Fellow cities Reykjavik (IS), Maia (PT), Lviv (UA), Kifissia (EL) and Kladno (CZ) prepare replication with hands-on feasibility studies. SPARCS identifies bankable actions to accelerate market uptake, pioneers innovative, exploitable governance and business models boosting the transformation processes, joint procurement procedures and citizen engaging mechanisms in an overarching city planning instrument toward the bold City Vision 2050. SPARCS engages 30 partners from 8 EU Member States (FI, DE, PT, CY, EL, BE, CZ, IT) and 2 non-EU countries (UA, IS), representing key stakeholders within the value chain of urban challenges and smart, sustainable cities bringing together three distinct but also overlapping knowledge areas: (i) City Energy Systems, (ii) ICT and Interoperability, (iii) Business Innovation and Market Knowledge.

Partners

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EXECUTIVE SUMMARY

The deliverable 3.5 *EV mobility integration and its impact in Espoo* is the final deliverable of the actions targeted at electric mobility in the SPARCS project in Espoo. The SPARCS project is mainly focused on the development of the three demo sites in Espoonlahti, Leppävaara and Kera. When it comes to the mobility related activities, the main target has been to develop the demo sites as e-mobility hubs and boost the uptake of electric mobility in the city. A variety of actions have been carried out in order to reach the target; some actions are clearly related to a certain demo site while other activities are more general in nature or relate to the macro level of the whole city. Fast charging infrastructure for buses operating in the Leppävaara/Sello area was installed already at an early phase of the project. The infrastructure allows for charging of up to 10 buses simultaneously, but it could be further extended and used for other user groups, too. Charging infrastructure for private vehicles have been installed in Espoonlahti/Lippulaiva and solutions for bikes (both conventional and electric) have also been actively promoted. Both Sello and Lippulaiva act as mobility hubs already now in their own areas. During the upcoming years, the extension of the metro line and the construction of the fast tram line will change the mobility patterns of the inhabitants and further increase the importance of the hubs. In order to support the upcoming developments and share and spread knowledge also outside the SPARCS partners, workshops have been arranged with different stakeholders and user groups of all ages. Based on the outcomes of the workshops, the needs and pain points relating to various mobility modes and user groups have been crystallized and guidelines for the future have been formulated. The knowledge and understanding of topics related to e-mobility hubs, smart pricing of charging and vehicle-to-grid services have also been enhanced through literature reviews. In order to gain understanding of future scenarios with a higher uptake (up to 100%) of electric mobility solutions, simulation methods have been developed. The impact of all mobility modes on the grid has been analyzed by means of the simulations and different pricing schemes have been evaluated. By applying different pricing schemes within the simulation, the charging behaviour can be controlled e.g. to make the vehicles prefer charging during off-peak hours. Means to optimize the charging and minimize the costs at a given location have also been studied. The Kera area is planned to be a new residential area relying on smart and sustainable mobility solutions with a minimal need for private cars. The learnings and outcomes of all activities have been utilized to support the development of Kera, and the SPARCS mobility partners have actively participated in the planning phase. This report describes all activities carried out and the main results so far. The report is structured according to the project plan, going through each demo site one by one and concluding with the macro level activities.

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1. INTRODUCTION

In order to reach the ambitious climate target of the Paris agreement, a rapid transition to carbon-neutral solutions is required. Sustainable mobility, and green solutions for urban mobility in particular, is one of the key aspects when addressing this challenge. On the EU level, transportation accounts for about one-third of the CO2 emissions, and the majority arises from the road transportation. Private car use is a major factor in the emissions as around half of the transportation related emissions globally are produced by road passenger traffic (including cars, motorcycles, buses and taxis)[1]. With an increasing share of the population living in urban environments, it is evident that the development of mobility solutions for cities can have a substantial impact on the emissions. Electric vehicles are often seen as the solution to decarbonization of transportation; with zero tail pipe emissions, the electric vehicle is a clear improvement compared to conventional vehicles. Nonetheless, the total emissions caused by the vehicle usage depend on the electricity production source as well as emissions arising from the vehicle production – EVs are truly zero-emission vehicles only if the electricity used to run them is clean. However, due to the high energy efficiency, the total emissions of EVs are lower than for conventional vehicles even when using electricity from non-renewable sources.

The introduction of electric vehicles is as an essential part of reaching sustainable mobility, but it is not sufficient. The use of private cars has a negative impact on the spatial usage; in large cities, a lot of time and money is lost as people sit in the traffic, and parking requires even more space as the vehicle sizes increase. Additionally, private cars are a major cause of urban sprawl, air and noise pollution. Due to the high up-front costs, electric vehicles are still not an option for many low-income households, instead, many are forced to rely on conventional solutions even when fuel prices surge. Thus, sustainable mobility is not only about technological choices, but a more holistic approach is required. Improvements in walking and bicycling conditions, and in the usability of public transportation or shared mobility services, are some of the key elements in developing a sustainable urban mobility system. There is potential for reducing private car use: for example, currently 40% of all trips made by car in Finland are less than five kilometers in length and 28% under three kilometers in length[2]. Such relatively short trips are targets for active mobility modes, public transportation and shared 'last mile' solutions.

Cities have an important role in shaping the urban environment and affecting the everyday mobility choices of the inhabitants. The City of Espoo aims to be carbon neutral by 2030, and one part of achieving this is to support the development of sustainable and smart solutions in the mobility sector. The SPARCS project supports this goal with the focus on positive energy districts (PEDs). In simple terms, a PED is a district producing more energy than it consumes. Contrary to conventional vehicles running on fossil fuels, electric vehicles interact with the electricity system. Unsupervised charging can cause very high power peaks and have a negative impact on the electric grid. Smart charging systems and vehicle-to-grid (V2G) services can provide support and ease the stress on the grid. Hence, including an analysis of mobility in the development of PEDs lead to better results than focusing solely on the energy use of buildings.

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[1] https://ourworldindata.org/co2-emissions-from-transport

[2] Henkilöliikennetutkimus 2016. *Suomalaisten liikkuminen.* Helsinki: Liikennevirasto 2018.

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The SPARCS actions in Espoo are concentrated to the three demonstration areas of Espoonlahti area/ the Lippulaiva blocks, Leppävaara area/ the Sello blocks and the Kera area. Espoonlahti and Leppävaara are two of the largest city centres in Espoo while Kera is an old logistics centre that is planned to be turned into a residential area. Whereas the heart of Leppävaara, the Sello block, has remained similar throughout the SPARCS project, the shopping centre of Lippulaiva in Espoonlahti has been totally renewed. This has brought an excellent opportunity to learn from the solutions already adopted and tested in Sello and adapt to new mobility solutions in the construction phase. The area of Kera, on the other hand, is a unique opportunity to focus on the planning phase and enable extensive uptake of smart and ecological mobility solutions instead of residents becoming reliant on private car usage.

One of the central aims of the SPARCS project is to 'boost' electric mobility, or e-mobility in the project's three demonstration areas and to support smart mobility modes. One part of the activities has been focused on the practical implementation of mobility solutions, e.g. EV charging systems and electric bike systems. Mobility solutions that cannot yet be implemented and future scenarios with a higher uptake of electric vehicles have been studied by means of simulations. Workshops and discussions with citizens have been arranged in order to share and gather knowledge and encouraged the uptake of new solutions. Literature reviews have been carried out to increase the level of understanding of new solutions among the project partners and provide support for further decisions and actions. This deliverable presents an overview of all actions related to mobility within the SPARCS project in Espoo. The activities and the most central outcomes and learnings are described for each demo site as well as for the macro level of the whole city.

1.1 Purpose and target group

This Deliverable is the final report of the demonstrations in Task 3.4 'E-mobility integration', in Work Package 3 'Demonstration Lighthouse City Espoo'. The Task is a collaborative effort between the City of Espoo (ESP), VTT Technical Research Centre of Finland (VTT), Kone Oyj (KONE), Siemens (SIE), Plugit Finland Oy (PIT) and Citycon Oyj (CIT) partners. Additionally, the SPARCS's Associated Partners Helsinki Region Transport Authority (HSL) and Helsinki Region Environmental Services Authority (HSY) have been included in the organized events and workshops (where applicable), as they are responsible of the public transportation and waste management (in respective order) in the Helsinki Metropolitan area, including Espoo area.

The Task work covers in total ten (10) different Actions grouped into four different subtasks (T3.4.1-.4). The subtasks deal with Actions located in the four different demonstration areas / scales (Lippulaiva blocks/Espoonlahti, Sello blocks/Leppävaara, Kera, and macro-level, respectively). The Actions relate to different aspects of supporting the further development and local increase of e-mobility solutions.

The document is aimed for SPARCS project partners, other EU projects, and other parties and cities that share interest with e-mobility development in urban settings.

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1.2 Contributions of partners

The following Table 1 depicts the main contributions from the Task 3.4 partners contributing to the activities and this Deliverable. The Deliverable covers the demonstration activities done on e-mobility solutions in all the Espoo demonstration sites, including the city-wide macro level. Some of the Actions described here also continue up to M60 (project end). The partners responsible of the activities are also responsible writers of their activities.

The Task 3.4 group has had monthly meetings from 01/2020 onwards, organized and chaired by the Task Leader ESP. The Task group has also organized a meeting with the corresponding Task group T4.4 (*E-mobility integration*) from Leipzig to exchange experiences and learnings between the Lighthouse cities. The group has also collaborated with other Finnish Lighthouse cities and projects on e-mobility issues and mobility hub development, including knowledge exchange and a joint workshop.

Table 1. Contributions of partners

Partner	Contributions
VTT	• Chief Editor of the Deliverable • Subtask 3.4.4 (Macro level demonstrations) Leader • Action Leader in E18-1 • Work in Actions E2-1, E2-3, E7-1, E7-2, E7-3, E13-2
ESP	• Task 3.4 Leader • Editor of the Deliverable • Subtask 3.4.3 Leader • Action Leader in E2-3, E13-1, E13-2 • Work in Actions E2-2, E7-1, E18-1.
CIT	• Subtask 3.4.1 (Espoonlahti & Lippulaiva blocks) Leader • Action Leader in E2-1, E2-2 • Work in Action E2-3.
PIT	• Subtask 3.4.2 (Leppävaara & Sello blocks) Leader • Action Leader in E7-1, E7-3 • Work in Actions E2-3, E7-2, E13-2, E18-1.
SIE	• Action Leader in E7-2, E8-3 • Work in Actions E2-3, E13-2, E18-1.
KONE	• Work in Action E2-3.

1.3 Baseline

The SPARCS Task 3.4 *E-mobility integration* is comprised of ten (10) individual Actions that are located in three physical demonstrations areas: Leppävaara and Sello blocks, Espoonlahti and new Lippulaiva blocks, and the future Kera area. The Actions aim to support the transition towards greener urban mobility locally, by developing electric mobility solutions and further accelerating shared mobility service usage and

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implementation. Electrification of vehicles can cut down emissions both in private and public transportation, and the further utilization of public transportation and shared mobility services as ‘first/last mile’ solutions can decrease the overall emission production and energy demand through shared and common use. The SPARCS demonstration actions increase local e-mobility infrastructure (EV-charging and e-bike facilities in Lippulaiva blocks), supports the further optimization and utilization of an e-bus charging system and EV charging points (Sello blocks), provides new perspectives to e-mobility’s role in urban planning and urban mobility development (Kera area), and gives insight to the future growth of e-mobility charging demand and its effects to the electricity grid (macro-level).

1.3.1 Case Espoo

Espoo is part of the capital Helsinki Metropolitan Region, located in the southern coast of Finland. Currently, there are around 300.000 residents in Espoo, which makes it the second largest city in the country by population. Espoo is characterized, and actively developed, as a ‘network’ type of urban structure, as stated in the city strategy for the council term 2021-2025.[3] The city is composed of five urban centers - with all the relevant public services in each center - that are connected by rail and/or motorway connections (Figure 1). These centers are *Espoo centre, Tapiola, Leppävaara* (SPARCS demo site Sello blocks are located here), *Matinkylä* and *Espoonlahti* (SPARCS demo site Lippulaiva blocks are located here). In addition to the five city centres, there are also multiple other smaller urban cores in between, such as the new and actively developed *Kera* (SPARCS demo site) and *Finnoo* (SPARCS replication site) districts.

The different urban centers are developed as mobility hubs, connecting ‘last mile’ solutions to rail-based public transportation (metro, commuter trains, fast tramway). These major mobility hubs are actively developed by the city and different stakeholders, and they are used to house both public and private services. Leppävaara and Espoo centre have had train connections for a longer period of time, but the other centres have been connected to a rail-based public transportation only rather recently, in 2017 through the opening of the city’s first metro line (which is directly linked to the metro line in Helsinki, opened in 1972) and its upcoming extension in 2023. Additionally, the Jokeri fast tramway will open in 2024, connecting the eastern parts of Espoo to a tramway line covering also areas in the neighboring Helsinki and Vantaa cities. In 2018, 46% of all trips in Espoo were made by private car, 26% on foot, 18% with public transportation, and 9% with bicycles.[4] These numbers are rather common for cities in Finland - the share of trips made by private car in Helsinki is 39% (2018) and in Tampere 45%[5] (2016). In Espoo, 32% of CO_2 emissions were transport related in 2020[6]: roughly half of the mobility-related emissions are caused by private car use. Park & ride type of concepts are encouraged in local transportation planning, and parking facilities have been allocated in

[3] https://www.espoo.fi/en/city-espoo/espoo-story

[4] Espoon kaupunki 2021. *Liikennekatsaus 2021*. Report.

[5] https://www.tampere.fi/tiedostot/k/NhbU13wr1/Kestavan_kaupunkiliikkumisen_suunnitelma_SUMP.pdf

[6] https://www.hsy.fi/ilmanlaatu-ja-ilmasto/kasvihuonekaasupaastot/

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the main mobility hubs. Operators providing shared car services also act in the Espoo area.

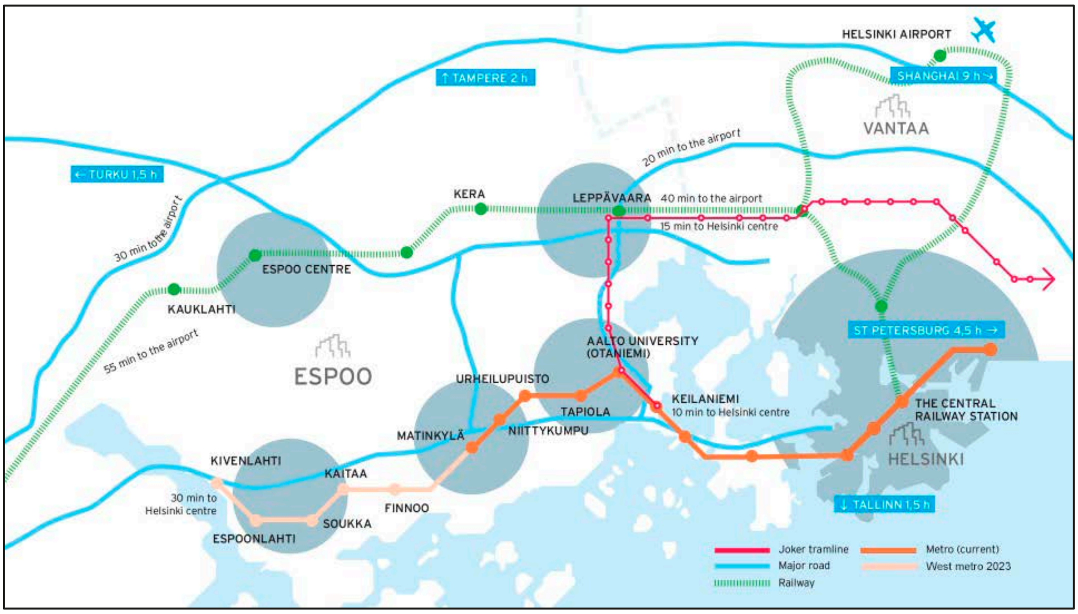

Figure 1. The five Espoo city centres - Espoo centre, Leppävaara, Tapiola, Matinkylä and Espoonlahti - and the major transportation connections depicted, including trains, metro (with the upcoming extension in 2023) and the upcoming Jokeri fast tramline (2024). SPARCS Espoo demonstrations sites are: Sello blocks in Leppävaara, Lippulaiva blocks in Espoonlahti, and Kera area. Finnoo is also a pre-identified replication area for the developed solutions. Source: City of Espoo.

There were approximately ~500 public charging points for EVs in Espoo in around 80 charging stations before the inclusion of the SPARCS demonstrations.[7] Most of these chargers are found in the city centers and shopping mall parking garages, gas stations or supermarket parking lots. The City of Espoo only owns and operates around 45 charging points which are mostly located next to sports venues and other outdoor areas, such as the Halti visitor center in the Nuuksio national park. The city is currently examining the role of different stakeholders - including the city itself - in the further acceleration of the construction of charging spots in the city to answer the growing demand in the near future in a project under the Sustainable Espoo programme.

In 2021, there were around 30 e-buses operating in the Espoo area, each utilizing the e-bus charging system in Leppävaara that started operation in 2020. Public transportation services in Espoo, and in the whole Helsinki Metropolitan Region, are organized by HSL (Helsinki Region Transport), which is an organization co-owned by the municipalities in which it operates. HSL has set an ambitious target to electrify the bus fleet that operates on the routes by setting standards for e-bus uptake in the procurement process. The aim is to have one-third of the operating fleet electric by 2023, which means 400 electric

[7] Espoon kaupunki 2022. *Espoon liikennekatsaus 2022.* Report.

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buses.[8] The buses use certified RES-produced energy. The bus fleets are owned and maintained by different companies through a procurement process and contracts organized by HSL.

Espoo's public shared city bike system was launched in 2018. The system is in use both in Espoo and Helsinki, and the users can use the same bicycles and docking stations between the two cities. There are currently 460 docking stations and 4.600 bicycles (non-electric) in the system, of which 110 stations are located in the Espoo area. The system is managed by HSL. There are also multiple micromobility service providers active in Espoo area. Privately operated electric kick scooters have been available in the city since 2019, and multiple different operators are currently providing their services in Espoo area. In 2022, electric bicycle operator also began operating in the eastern Espoo area. The City of Espoo works in collaboration with the service providers to set the common framework for the operation in the area.

Sustainable and smart urban solutions are actively developed in the city together with companies, organizations and users/citizens. Different projects under the Sustainable Espoo Programme have organized public procurement processes to test and pilot new urban mobility solutions, such as in the project *SixCities: Low-carbon mobility in mobility hubs* (2019-2022), *Smart Stations* (2018-2021) and *SixCities: Partnership model for sustainable neighbourhoods* (2019-2021).

1.3.2 SPARCS demonstration areas

A brief overview of the SPARCS Espoo demonstration areas is presented below. As mentioned, there are three Espoo demonstration areas: Espoonlahti district and Lippulaiva blocks, Leppävaara district and Sello blocks, and Kera area. There are also Actions on the city-wide level.

1.3.2.1 Espoonlahti district and Lippulaiva blocks

Espoonlahti area is located in the south-western part of Espoo. The Greater Espoonlahti area is second largest of the seven Greater districts in Espoo, with 55,620 residents (in 2019) and 9,840 workplaces (in 2017). The Greater Espoonlahti comprises of multiple smaller areas, including the Espoonlahti centre, where the SPARCS demonstration site new Lippulaiva blocks are located.

The large-scale Lippulaiva project includes the new shopping centre Lippulaiva, eight residential buildings, and a residential care home for senior citizens. The residential buildings will have a total of 560 apartments. The Lippulaiva development project includes the demolition of the old shopping centre and construction of the new shopping centre, which has an area of 42,000 m^2.

Espoonlahti is in the process of rapid redevelopment. Multiple active processes are on-going that will affect the area in near future, the construction of the new metro line being one of the major investments. The metro connection to the area is to be opened in 2023, strengthening the area's public transportation services through a rail-based connection. The metro line is an extension to the first phase metro line in Espoo that opened in 2017

[8] https://www.hsl.fi/hsl/sahkobussit

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with 6 stations (from Keilaniemi to Matinkylä). The extension, or the second phase, will add 5 new stations to the line (from Matinkylä to Kivenlahti), including the one in Espoonlahti (under Lippulaiva blocks), and others in Finnoo, Kaitaa, Soukka and Kivenlahti that are all part of the Greater-Espoonlahti area.

The new Lippulaiva shopping centre forms an important mobility hub in Espoonlahti. The bus terminal in Lippulaiva will connect feeder bus traffic to the metro, creating an important point of transferring from one mobility mode to another. The bus terminal will be opened when the metro begins running. There are direct escalator and lift access to Lippulaiva from Espoonlahti metro station and bus terminal.

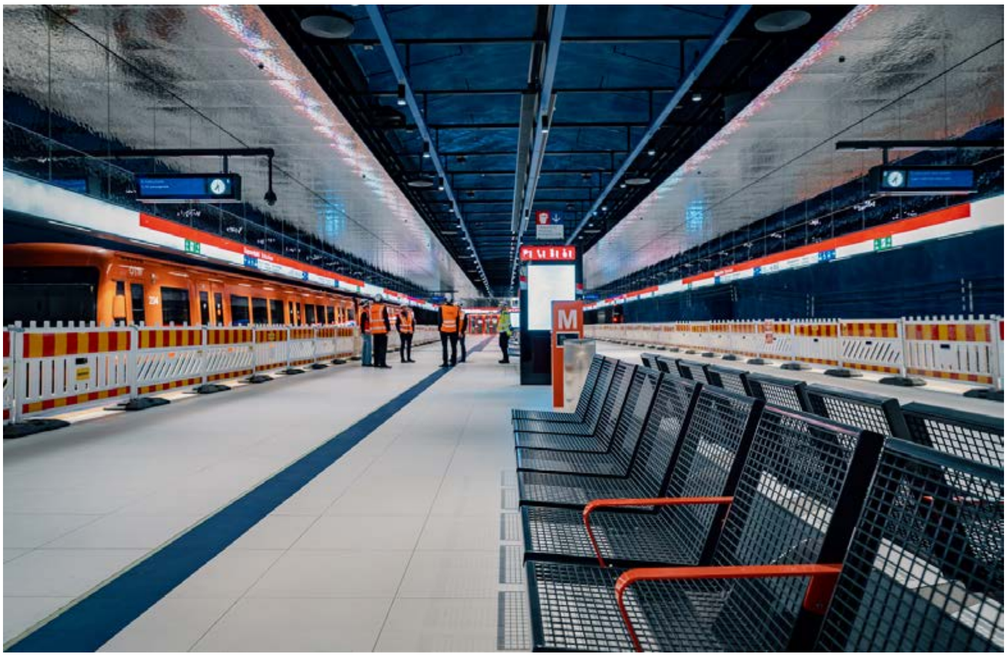

Figure 2. Espoonlahti metro station (Source: Citycon)

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Figure 3. Lippulaiva in March 2022 (Source: Citycon)

1.3.2.2 Leppävaara district and Sello blocks

Leppävaara is the largest urban centre in Espoo, with around 71.000 residents in the Greater Leppävaara area. Leppävaara is located in the eastern part of Espoo, right next to the Espoo-Helsinki municipality boarder. The area is composed of multiple city districts, including the Leppävaara centre (34.000 residents) where the main mobility hub of the area is situated.

The demo area in Leppävaara is located around Sello shopping centre. The shopping centre opened in the area in 2003. In addition to the shopping centre, Leppävaara area has residential buildings, public services and entertainment. This part of the city keeps evolving, and it is one of the fastest growing areas in Espoo. The shopping centre itself has energy management solutions by Siemens, which include solar panels, battery energy storage and can also control loads in the district. Energy efficiency solutions have been tested in Sello for years, and the shopping centre has been awarded with EU energy service award and LEED Platinum level certification. There are also electric car charging points in the parking floor.

Leppävaara is one of the central traffic nodal points in Espoo. The Sello shopping centre is located next to the railway and bus station, whereas Ring Road I provides easy access by car. Furthermore, the Jokeri Light Rail starts to operate through the area in 2024. There are also city bikes in the area, and multiple e-scooter operators. The area has started to transform into an e-mobility hub, as most of its public transport is electrified. The Jokeri Light Rail is expected to increase the share of electric transport modes. Electric cars and

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hybrid electric cars are also rapidly increasing in Espoo; the number of electric vehicles has almost doubled every year.

Figure 4. Sello blocks in Leppävaara. The e-bus chargers and the bus terminal are located just outside the shopping center Sello. The trains station is located next to the bus terminal. Source: PIT.

Figure 5. A close-up picture of the Leppävaara train station outdoor platform area, and a pedestrian path inside the Sello blocks in October 2021. Source: ESP.

1.3.2.3 Kera district

Kera is an old logistics area, which is being transformed into a new urban district during the next decades. The district will provide housing for 15.000 residents and 10.000 workplaces, and it aims to be an international example for a new type of urban district

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where sustainability and circular economy are on the front of all activity in the area. Kera is actively developed together with a broad array of stakeholders, including organizations, companies, landowners, research institutions, and citizens. Technological companies and polytechnical university premises are located in the area, making it an interesting hub for learning and innovation. The new Kera area is developed through three master plans in total: the first one of these is already finished and the other two are in the planning and decision-making process. The construction of new buildings is expected to begin in the upcoming years. Multiple development projects are piloting new urban and circular economy solutions and practices in Kera, including SPARCS.

Figure 6. An overview of the Kera area in development, and a close-up of the logistics halls that have housed temporary uses during the area's re-development phase. Source: City of Espoo.

Kera has also become known for its temporary uses of the old logistics halls for various activities. Keran Hallit or Kera Halls[9] premises have been actively developed to house temporary uses during the time when the previous activity in the halls ended (in 2019) and the re-construction phase of the area has yet to begun. The temporary and pop-up type of uses have included sports areas, breweries, workspaces, festival areas, art exhibitions, and others. The site has also been used as a living lab for new sustainable, circular and smart urban solutions, including urban farming, autonomous transport, and street design. The Kera Hub space, which is operated by the City of Espoo to host different local events and meetings related to the development of the area and sustainable development solutions, is also located in the premises. In 2022, the first parts of the halls were demolished, and rest of the halls will eventually follow suit as the area is redeveloped.

[9] https://www.keranhallit.fi/en/etusivu-english/

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Figure 7. The approved master plan for the southern Kera area. The station area (south from the train tracks) is developed into a mixed-use area (marked as Red/C1 Blocks). Parking in the area is mostly organized into dedicated parking garages (marked as Pink/LPA Blocks). Source: The City of Espoo. A sketch image of the area following the master plan. Source: City of Espoo

Kera is a unique site in the sense that it already has a working train station with an active commuter train connection that is located in the heart of the soon-to-be redeveloped area. Walking, bicycling and public transportation are emphasized in the area's transportation planning, and the existing commuter train station can aid in realizing this vision by providing fast, rail-based transportation with a frequent service from the first development phases onwards. Often, new urban districts face the challenge that public

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transportation options might come into the picture late in the area's development phase. The first residents might have low or non-existing public transportation service available, or a level of service which is inadequate to attract users, which can lead to the vicious cycle that results into car dependency, and which affects the future development of the area. In Kera, the area is already served by a reliable and frequent rail-based public transportation connections. The station area itself might be used as a physical platform for pop-up services and activities in the construction phase, including explorative tests and pilots, mirroring the temporary uses -attitude from rest of the Kera Halls. For example, an automated bus has been tested publicly in the area in 2019, connecting the Kera train station to the office campus area nearby.[10]

Figure 8. The old logistics hall in the area have been transformed by temporary uses in the area. The Kera train station area. Photos from October 2021. Source: ESP.

1.4 Relations to other activities

Table 2 depicts the main relationships of this deliverable to other activities, milestones or deliverables within the SPARCS project.

Table 2. Relationship to other SPARCS activities

Activity	Description
D3.3	Deliverable 3.3 presents the overall summary of WP3 demonstration activities across the different Tasks and Actions.
D3.6	There are shared activities between Tasks 3.4-3.6 that have included both stakeholder engagement and thematical development of mobility solutions. The stakeholder engagement perspective is described in Deliverable 3.6.
WP2	Monitoring and KPI work of the Actions presented also here are developed in Work Package 2.

[10] https://sensible4.fi/company/newsroom/gacha-pilot-in-kera-espoo-begins/

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WP4	Exchange of lessons learned between the Task 3.4 (Espoo e-mobility solutions) and Task 4.4 (Leipzig e-mobility solutions).
WP5	Project upscaling and replication work is done in Work Package 5.
WP7	Business model development is done in Work Package 7.
WP8	Dissemination and communication work is led by work in Work Package 8. Some of the activities presented here have also been already highlighted in the project website and newsletter, as well as presented in different seminars.
WP10	Research ethics support is given by Work Package 10.

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2. BOOSTING E-MOBILITY UPTAKE IN ESPOONLAHTI DISTRICT

Mobility has a large impact on sustainable urban development from ecological, economic, and social perspectives. The objective of Intervention E2 is to boost electric mobility (e-mobility) in the Espoonlahti district, Lippulaiva blocks by offering EV parking and charging capacity as well as facilities for e-bicycles. Espoonlahti will be a future transit hub of the south-western Espoo, along the metro line, and the increasing stream of passengers provides a huge potential for retail, business and residential developments. E-mobility solutions have strong potential in the area when the subway extension is finished and in operation.

Table 3. Actions for Espoonlahti area outlined in the Grant Agreement.

Subtask 3.4.1	Boosting E-mobility uptake in the Espoonlahti district, Lippulaiva blocks
Responsible partners	CIT, VTT, ESP, KONE, SIE, PIT, (HSL, HSY)
Actions	**E2-1** Integrating and grid impact assessment of community and residential EV parking in the Lippulaiva blocks: up to 140 charging units, currently grid access dimensioned for maximum 400 EV. (CIT, VTT) **E2-2** Opportunities to support and enable e-bicycling with appropriate parking and charging infrastructure (inverters, parking facilities, size demands, secure charging infrastructure) boosting the E-mobility in the whole Espoonlahti district. (CIT, ESP) **E2-3** Boosting the uptake of e-mobility: Sustainability strategy for how to access Metro and Lippulaiva with other sustainable mobility modes, developing Lippulaiva as hub for shared eVs. Development of commercial electric vehicle charging services. Analysis of energy demand for electric buses, taxis, garbage and delivery trucks and other service vehicles and impact on electric grid. Development of smart charging services. (ESP, CIT, VTT, KONE, SIE, PIT, [HSL, HSY])

2.1 Community and residential EV parking

Providing charging points for electric vehicles supports people to use more environmentally friendly modes of transport. The charging points for electric vehicles are one part of the sustainability strategy of Citycon. Citycon's goal is to have electric vehicle charging possibility in all its assets.

The Action E2-1 focuses on integrating and grid impact assessment of community and residential EV parking in the Lippulaiva blocks. A literature review and workshops have also been utilized to examine the current state of e-bicycle development both locally and globally, and to identify the possibilities, barriers and possible next steps in the further uptake of e-bikes in Espoonlahti, Espoo city, and beyond.

2.1.1 EV chargers

During the project, Citycon and Plugit implemented 134 charging points in the Lippulaiva shopping centre. There are 124 AC-chargers and two (2) DC chargers located in parking levels P1 and P2. These are designed for customers and residents with electric cars.

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Residents can reserve a parking spot equipped with a charger if they have an electric car. Lippulaiva is currently one of the biggest single locations with EV chargers in Finland. The total capacity for electric vehicle charging is 4000 kVA. The implemented charging system can currently serve 311 cars simultaneously, and there is a possibility to expand the charging services in the future. Due to the large transformer capacity, commercial charging could also be implemented in several locations.

The charging system contains four (4) 1000kVA transformers, which are used only for the electric vehicle charging system. The system itself consists mostly of busbars feeding the AC chargers. The size of a single busbar is either 400A or 250A, which is enough for feeding several AC chargers. The busbar solution is a flexible solution for the future, too; it provides lots of free connection space, which can be used later. The busbars are produced by Schneider Electric, and they can be used with any type of charger. The chargers in Lippulaiva are KEBA KeContact P30 X-series, which is a 22 kW AC charger. This charger is an intelligent one and could be used with different load management strategies. Currently there is so much power in Lippulaiva, that the system does not require any load management. The chargers are equipped with Type 2 connector and have a LAN connection to data cabinets. The total maximum power of AC charging is currently 2700 kW.

Lippulaiva also has ten (10) DC charging points. Maximum power for each point is 90 kW. The DC chargers are manufactured by Plugit and they are fed from the main switchgear. Charger models are Hube S and Hube L. Hube S has 360 kW charging cabinet with two (2) satellites. Hube L has 540 kW charging cabinet with three (3) satellites. Each satellite has two (2) CCS cables for charging and a screen for interaction. The charging cabinet contains power modules for every satellite.

Figure 9. EV charging points in Lippulaiva (Source: Citycon)

Plugit is responsible for maintenance, invoicing and software solutions of the charging system. A charging session can be initiated with a RFID tag or via the Plugit app. The charging system is implemented using a CaaS (Charging as a Service) model, where Plugit

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takes responsibility of the whole system. Citycon as a customer is paying a monthly fee for the service.

Plugit Cloud is a platform for the charging system. Citycon can see an up-to-date charging situation in Lippulaiva and statistics on charging transactions.

Figure 10. EV charging statistics from Lippulaiva (Source: PlugitCloud)

2.1.2 Vehicle-to-grid (V2G) literature review

A literature review on the topic V2G was carried out as a part of action E2-1. This is a summary of the review presented in a separate internal document. The term V2G refers to the possibility to have bidirectional charging, i.e. energy flowing from the vehicle battery back to the grid. V2G is closely linked to smart charging, and many research papers study both smart charging and V2G. Smart charging typically means scheduling of the charging in such a way that negative impacts, e.g. power peaks, can be minimized. A literature review was carried out targeting general knowledge about the subject and gathering some takeaways to a general audience and the SPARCs partners. The literature on V2G is already quite extensive and it has been a hot topic for research during the last years. Hence, the review is not covering all issues related to V2G and, for instance, technically and mathematically oriented papers were left out.

In order to understand the possibilities of V2G services, some basics of the power market should be understood. In any electric system, the amount of produced energy has to be equal to the consumed energy at all times in order to maintain stability in the electric grid. In the Nordic countries, the energy spot price is formed in the day-ahead market on an hourly basis based on estimations of the consumption and production capabilities. The

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energy price is determined by the most expensive production form that is required to meet the expected demand.

The electricity demand is characterized by rather large fluctuations, the demand is at highest during the morning and afternoon, and at lowest during the night. As the energy demand cannot be precisely known in advance, ancillary services are necessary in order to stabilize the grid. The target of the ancillary services is to maintain a constant frequency and voltage level of the grid, and to provide compensation of active power losses. In other words, the ancillary services are used to fine-tune the production to meet the consumption level at all times. Frequency regulation includes both up- and down- power regulation, and both consumers and producers can participate in the market. Different products exist on the market and they are activated depending on the severity of the situation, i.e. the level of frequency deviation and elapsed time. The fastest products can be activated within seconds, and full power response is expected within a few minutes. The frequency regulation products are handled by yearly contracts as well as hourly bidding, and the revenue is based on both capacity and amount of energy sold. Batteries are technically suitable for frequency regulation as they have a very short reaction time.

Some of the very first papers published on V2G discussed potential business models for these services. The capacity of a vehicle battery is very small in the context of the electricity transmission network, and players on the energy market deal with much higher power and energy levels than can be offered by a single vehicle. To overcome this and bring economies of scale to the services, aggregation of multiple vehicles has been identified as the most suitable solution. Through the aggregator, the vehicle owner could sell both energy and/or power capacity for frequency regulation. The aggregated vehicles do not necessarily need to be located in the same place as long as they have a formal relationship to the same aggregator. Different parties could take the role of an aggregator, it could be for instance a transmission company or a charging service provider or a totally independent third party (Kempton and Tomić, 2005; Guille and Gross, 2009).

The actual impact on the energy transmission system has also been the focus of many studies. As the energy production strives away from fossil fuels to renewables, such as wind power and PVs that cannot be controlled in the same manner as traditional power plants, the importance of energy storages will increase. V2G services can help in storing energy on a short term, e.g. charging extra energy during cheap night hours and discharge during the day to lower power peaks. Hence, the V2G services can reduce the stress on the transmission system. Even though this effect should not be neglected, many studies concluded that the major impact in fact comes from smart charging. Smart control charging of single vehicles, and in particular fleets of vehicles can have a substantial impact on the overall carbon emissions of the electricity production as smart charging strategies reduce the need for non-renewable energy sources (Lund and Kempton, 2008; Heinisch et al., 2021; Schuller et al., 2015; Noel et al., 2018).

Participation in V2G services might have negative effects for some users. The Li-ion batteries utilized in electric vehicles experience degradation both due to calendar aging and cyclic aging. One of the main concerns from the vehicle owner perspective regarding V2G is that it could accelerate the degradation due to the additional charging cycles, and, thus, shorten the battery lifetime (Dubarry et al., 2017; Darcovich et al., 2021). As a consequence, revenues from selling energy could be outweighed by the need to replace the relatively expensive battery at an earlier stage than planned. The research outcome

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on battery degradation in combination with V2G is rather diverse. The extent to how much the battery suffers from these services depend highly on the frequency of V2G utilization and the power levels used. Vehicle batteries are primarily meant for driving, and very frequent (e.g. daily) high-power discharge of the energy in order to support the grid is most probably not the most beneficial option. However, such extreme usage is not very probable. Furthermore, research papers focusing on the financial impact of V2G seem to conclude that the most benefits would come from capacity payments and not energy payments. I.e. the main financial benefits come from participating in ancillary services such as frequency regulation, not from selling energy (Noori et al., 2016; Heilmann and Friedl, 2021).

Contracts for ancillary services typically set requirements on availability and the capacity provider is compensated not only for the amount of energy but for being available; even though the service is not activated very frequently, the vehicle owner is compensated. The inconvenience comes from the limitation of the vehicle usage and the necessity to be connected to the grid according to rules set out in a predefined contract. Hence, this kind of contract has to be carefully shaped so as to not put unnecessary restrictions on the vehicle, but to allow the vehicle owner to use the vehicle whenever needed. In order to reach the full potential and the potentially rather high (hundreds of euros per year) revenues that have been reported by several researchers, there have to be enough chargers available. Privately owned vehicles are typically parked up to 95% of the time, and many studies assume that the vehicle would be connected to the grid most of this time. This means that it is not sufficient to provide chargers enough for the vehicles to charge the energy they need for driving, but chargers should rather be available practically at every parking slot.

The impact of V2G always depends on local factors: the energy and capacity prices, energy production composition etc. So how to understand the reviewed studies and translate the outcomes for the city of Espoo in Finland? To answer this, we need to understand some of the characteristics of the Finnish society and Espoo in particular. First of all, the wind power production capacity is growing at a very high rate in Finland as well as in the other Nordic countries. The wind power capacity in Finland is currently around 4000 MW, but it is expected to reach about 5000 MW by the end of year 2022 and 10 000 MW within a few years. The wind power has a high impact on the electricity price; during windy days, the price can become almost negative while very high prices can be observed during days with less wind. Secondly, the city of Espoo stands out in Finland due to its rapid population growth. Furthermore, the population is fairly young and the income level is relatively high. The mobility has traditionally been quite reliant on private vehicles in Espoo, and one can expect that the share of electric vehicles will rise more quickly in Espoo than in other parts of Finland.

Smart charging of electric vehicles can have a substantial impact on the energy balance of the positive energy districts developed in the SPARCs project. The implementation of smart charging at residential locations can be fairly straightforward; the charging can be programmed to activate during the cheap night hours. Public chargers at shopping centres require more effort; ideally, the user can define when the charging should end at latest and the system takes care of charging each vehicle according to the requests without stressing the transmission network more than necessary. Determination of the energy to be charged can be challenging, though. A full charge, particularly in the middle of the day, is often not required, but it might be difficult for the driver to estimate the actual

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upcoming energy need. There is also a psychological factor involved; a full charge might feel safer as it maximizes the range of the vehicle.

The introduction of V2G services could further support the energy positive districts. As the share of renewable electricity production is growing, energy storages will for sure become more important. Small scale sales of energy is already possible for owners of PVs, but selling energy from a battery electric vehicle can be somewhat more difficult contract-wise as the location is not fixed. Furthermore, selling capacity is totally new to private customers, and it can be considered as limiting the freedom of the vehicle owner if designed poorly. It remains to be seen how willing vehicle owners are to sign such contracts. Financial benefits that are high enough are, of course, very tempting, but as this kind of services is very new to most people, the awareness of the possibilities has to be raised among the public. One of the main pain points for electric vehicle owners today is the diversity of charging services available and the need for separate IDs and apps for each service provider. The threshold for agreeing on selling capacity would most probably be lower for the vehicle owner if the service would not set unnecessary limitations on the location of the vehicle, i.e. the vehicle would be considered connected to the grid regardless of what company is providing the actual charger. It is worth noting that V2G services require a high availability of chargers in order to work in practice and to be a tempting option for the vehicle users. To continue the work initiated in SPARCS, Espoo could be a suitable place to test V2G services in practice and push the development forward. This would require active collaboration with stakeholders, creation and testing of different business models and engagement of the community, among other things. In other words, just installing bidirectional chargers is not enough, but the potential benefits for the society, vehicle owners, energy transmission companies and other service providers are worth the effort.

2.2 Development of E-bicycling

Electric bicycle use can potentially play an important role in sustainable urban mobility systems by providing a low-carbon mobility mode that is suitable for diverse user groups and applicable in both short and long journeys. As an 'active' mode of mobility, it supports personal well-being and the utilization of public transportation as a 'last mile' solution.

The Action E2-2 focuses on developing e-bicycle infrastructure in Lippulaiva blocks. A literature review and workshops have also been utilized to examine the current state of e-bicycle development both locally and globally, and to identify the possibilities, barriers and next steps in the further uptake of e-bikes in Espoonlahti, Espoo city, and beyond.

2.2.1 Lippulaiva e-bicycling development

Several solutions aiming to boost e-bicycling in Lippulaiva blocks have been implemented. There is a warm storage room for bicycle parking with 20 secure bicycle racks. In addition, there is a bicycle repair station with integrated pump which provides cyclists a stable workstation to tune their bike and make repairs.

Citycon has also decided to invest in two charging cabinets. Charging cabinets for e-bicycle batteries provide charging possibilities and safe storage for 10 batteries of e-bicycles. Due to challenges of global supply chains, the charging cabinets are not yet in place in Lippulaiva.

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Overall, there are parking facilities for 1383 bikes in Lippulaiva blocks. More than 530 bicycle racks are under cover.

Figure 11. A warm storage room for bicycles.

Figure 12. A bicycle repair station in a warm storage room

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Figure 13. Bicycle racks under cover in Espoonlahdentori (Lippulaiva). There is a two-tier storage system for bicycles.

Figure 14. Bicycle racks in Lippulaiva.

An e-mobility event was organized in Lippulaiva in 26th of August 2022. The event was a part of Espoo 50th anniversary as a city. The aim of the event was to provide possibilities for users to test different e-bikes and e-scooters, to provide information and get familiar

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with a sustainable lifestyle – and to promote SPARCS themes in general. Originally, a small-scale e-bicycling/micromobility event was expected to be organized in Kera in August 2021 (M23). However, the Covid-19 situation that worsened in Finland during the summer 2021 did not allowpublic events and the event had to be cancelled in mid-August.

Figure 15. E-mobility event in Lippulaiva in August 2022.

2.2.2 E-bike development in Espoo and learnings from elsewhere

A review of bicycling and e-bicycling concepts, project example cases, and local developments in the field was carried out by ESP. This is a brief summary of the separate report, available in the project resource bank.

2.2.2.1 (Electric) Bicycles and urban development

Bicycle traffic is increasingly seen as a central element of sustainable urban mobility systems. The bicycle provides an active, personal, and low-carbon mobility mode for daily travel in urban areas (and beyond). Bicycle-use can have a major impact on local greenhouse gas emissions reduction through its potential to replace private car use, especially on shorter trips in the city.[11] *The Finnish National program for advancing walking and bicycling* states that walking and bicycling conditions need to be improved to support the decrease of transportation related greenhouse gas emissions, and to improve public health.[12] Cities that are good at providing high-quality bicycling infrastructure and biking possibilities are also cities that experience less traffic congestions, have healthier people, and have more lively public spaces and urban environments, together with other benefits supporting carbon-neutrality and other sustainable development targets of cities (see e.g., Fishman 2016; Vaismaa et al. 2011).

During the past few decades, the markets have gradually been introduced to *electric* bicycles with sales increasing rapidly. In 2020 in the EU, already 17% of all new bicycles sold were electric bicycles - and the Covid-19 outbreak seems to have been one further

[11] In 2016 in Finland, 28% of all private car trips were less than three kilometers in length, and roughly 40% of all car trips were under five kilometers in length. Henkilöliikennetutkimus 2016. Suomalaisten liikkuminen. Helsinki: Liikennevirasto 2018.

[12] *Kävelyn ja pyöräilyn edistämisohjelma.* Liikenne- ja viestintäministeriön julkaisuja 5/2018.

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key accelerator of this development.[13] The advancements in battery technologies in recent years have made electric bicycles and other light electric vehicles (such as e-kick scooters) more readily available for consumers - both through ownership and shared services - which has also pushed the legislation and urban policy side on the issue forward, sometimes in a rather hurry. This development has taken place simultaneously with the overall *reappraisal* (Fishman 2016) of bicycles in urban mobility and policy, which has in many cases been part of the larger emergent discussion on sustainable urban mobility, which has been further accelerated by the ongoing climate crisis and its global acknowledgement. This, in turn, has pushed the technological development of e-mobility in general onwards through the increasing need for zero-emission urban mobility.

The benefits of the e-bicycle for the user are that it puts less physical strain on the rider than a traditional non-electric bicycle (but is still considered as an 'active' form of mobility), which makes it easy to use for commutes, transport of heavy things, and it makes longer bicycle journeys possible, which can translate into a broader palette of use cases (Johnson & Rose 2013; Behrendt 2018) and car trip replacement (Söderberg, Adell & Hiselius 2021). The purchase of an electric bike is reasoned by the possibility to replace car use, extending the range of use (in comparison to non-electric bicycle) and environmental concerns (Johnson & Rose 2013). However, the initial cost of purchase is here significantly higher than with the non-electric bicycles, and it is a significant barrier for a broad utilization in different socio-economic groups (Behrendt 2018)

For the urban environment, bicycle-use can help to decrease car traffic congestion, and decrease air pollution, and increase the quality of the local environment as a replacement for private car use. Bicycle-friendly environments require active decision-making in urban planning and development processes, supportive urban policies, and investments into the infrastructure. Some of the key elements of favorable bicycle environments have been identified in earlier research and practice. The examples are often drawn from the Netherlands and Denmark, which as frontrunner countries in developing bicycling as a mode of urban transportation, have done active work to create bike-enabling urban environments for decades (Vaismaa et al. 2011). The identified activities include a wide scale of practices, including the more holistic approaches of re-examining critically the urban form to favor bicyclists through street and path designs, taxation issues, and land use policies, to the more detailed and tangible approaches, including dedicated bike path and lane infrastructure planning and development, intersection planning and modification for bicycle-favoring model, (motor) traffic calming measures, safe and rightly placed and sized bike parking facilities, integration of bicycle use to public transportation, and training, education and promotion of bicycle use in different age groups (Ibid.; Pucher & Buehler 2008). 'Bikeability' has recently emerged as term to describe the bicycling-enabling or bicycling-hindering qualities of the urban environment, which, in essence, aims to highlight the possibilities (or the lack of them) of bicycle use in cities, and more broadly, and the urban environment's capacity to support lifestyles where daily trips are made with the bicycle. High bikeability[14] corresponds to high bicycle

[13] *European Mobility Atlas. Facts and figures about transport and mobility in Europe 2021. Brussels: Heinrich Böll Stiftung, 2021.*

[14] One such index is the Copenhagenize Index by Copenhagenize Design Co., where cities of over 600.000 inhabitants are scored through different parameters, including bicycle infrastructure, bicycle facilities,

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use, and this, in turn, has effects to the city's mobility system, public health, urban environment quality and the like. (Castañon & Ribeiro 2021.)

The *Road map for pedelecs* (2015) report[15] presents survey and workshops results together with project reviews on the potential of e-bicycling as a mode of sustainable urban mobility. It further notes that e-bicycles can play a crucial role in mobility hub development as 'last mile' solutions and decrease the required assigned space in comparison to private car use in dense transportation hub areas. The e-bicycle-friendly environment does not require additional elements in comparison to high-quality bicycle environment. The report also lists different roles that stakeholders have as 'gatekeepers' for e-bicycling development, including the state (legislation, national health programs), municipalities (infrastructure), energy companies (energy counselling, cooperation in pilot projects), as well as user groups, such as the teenagers (trends, schools, leisure activities) and the elderly (active mobility, safety). The state-owned Motiva and Mobinet companies have created a guide for housing companies to promote bicycling parking.[16] The guide provides a checklist for assessing the current level of bicycle parking in the building through different categories, such as spatial requirements, safety, accessibility, and specific safety issues related to e-bike charging. In Horizon 2020 Lighthouse project *Sharing Cities,* the role of electric bikes in a city e-mobility strategy. and practices and experiences related to e-bike use, have been examined, and how they might support the decrease of car ownership.[17]

The other types of light electric vehicles that often utilize mostly same infrastructure as bicycles can further increase the access to private transportation in different types of user groups. The mobility-as-a-service (MaaS) type of solutions can further provide access to occasional needs. However, as the Eurocities report notes, the widespread rapid utilization e-kick-scooters have caused some unforeseen issues related to traffic safety, spatial uses, and the lack of parking etiquette. The report stresses that cities play an active role in how e-scooter usage and operation develops, and that they can affect this development by for example, limiting the number of vehicles, creating license fees for additional vehicles, and defining ride and parking areas. Additionally, cities can favor operators with fleets with low ecological life cycle impacts (such as easily reparable vehicles), requiring zero emission electricity in the fleet charging, and requiring end-of-life pathways for the used batteries.[18]

2.2.2.2 Bicycle development in Espoo

The role of bicycling in the sustainable urban mobility system has been acknowledged in Espoo as well. Bicycling traffic is on the city's agenda, including a program for advancing

traffic calming, gender split, modal share, safety, politics, and urban planning actions. See: https://copenhagenize.eu/

[15] *Road map for pedelecs. The potential of this transport mode to promote a sustainable transport system.* Finnish Transport Agency, Planning Department. Helsinki 2015.

[16] *Pyörällä koko talo. Opas taloyhtiöille parempaan pyöräpysäköintiin.* Motiva & Mobinet 2019.

[17] *Electric Bike Sharing. Towards a healthy new mobility model.* Smart booklet. Sharing Cities 2020.

[18] *Playing by the rules. Report on e-scooter operators and fleets in cities - a survey of city approaches and options to optimize regulations.* Eurocities reports, 2020.

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bicycling 2013-2024[19], which grew from the identified need to develop bicycling to support the upcoming investments into rail-based transportation. The program defines two central goals for Espoo: the city is a model city for travel chains and high-quality bicycle paths, and that by the end of the program in 2024, 15% of all the journeys made in Espoo are made by bike (in comparison to 8% at the time), in accordance with The Charter of Brussels[20] from 2009. The program identifies twenty-one (21) separate action points that should be completed in order to reach the set targets. The action points can be divided under different categories, including the increase of political will and the allocation of resources, the development of the transportation system, the building of high-quality biking paths, the ensuring of safe biking routes, the development of station areas' accessibility, communication and marketing activities, and the close monitoring of these actions. In practical terms, the action points cover issues related, for example, to the improvement of bicycle parking facilities and guiding, optimizing and safe-guarding bicycle travel in intersections, creating high-quality biking paths, and taking bicycling better into account in the master planning phase of urban development processes. The local action points are also guided by other national, regional (including the regional bicycles path network) and international guidelines.

The City of Espoo introduced a public bike sharing service in 2018. Currently, there are 110 city bike stations in Espoo, located mostly in the eastern parts of the city. The stations are situated next to major mobility hubs, such as metro and commuter train stations, and other populous areas, such as the Otaniemi campus. Espoo and Helsinki both utilize the same system, which means that users can use the same city bikes in both Espoo and Helsinki cities' areas. Therefore, there are together over 460 stations and 4.600 bikes available for shared use in the two neighboring cities.[21] The shared city bike service has been popular, and a survey by the City of Helsinki notes that the city bike system in Espoo-Helsinki is one of the most often used in the world, with close competition with cities like Dublin, Valencia, Barcelona and Lyon. The survey notes that the high use of the bike system might decrease the user satisfaction as bicycles are less available, and require increases in the maintenance and operation budget, but at the same time it creates visibility for the service, makes it more financially feasible, creates environmental and health benefits, and creates more buzz around bicycle infrastructure development and the general attitude towards cycling.[22] One of the key identified challenges of the city bike service in Espoo is the lack of service in many parts of the large municipality area as the current stations are located mostly in the eastern and south-eastern areas. The increase of stations will be a relevant point of discussion in near future, especially in connection with the upcoming metro extension line (2023) and its' new station areas acting as local mobility hubs. Also, discussions about full/partial electrification of the bikes might be relevant, as they have been popular in other Finnish cities. Additionally, in the northern latitudes of the Nordic, winter-time bicycle use has been growing in popularity. Winter-

[19] *Pyöräilyn edistämisohjelma 2013-2024.* City of Espoo 2013.

[20] The Charter of Brussels, developed in Velo-city conference in Brussels in May 2009, called policy-makers to set targets for cities in terms of bicycle modal share (>15% by 2020) and bicycle road fatalities reduction (>50% reduction).

[21] https://www.hsl.fi/kaupunkipyorat/helsinki

[22] *Helsingin kaupunkipyöräjärjestelmän suosiovertailututkimus.* Helsingin kaupunki 2019.

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time use of the public city bike service can also play a key role in making bicycle use a year-round possibility and habit.

Figure 16. City bike docking station in the Sello blocks area, Leppävaara, in October 2021. Source: ESP.

Regarding electric bicycles, the City of Espoo currently has no officials plans or set strategies, and there is no overall e-mobility advancement framework either. From an urban development perspective, bicycling and e-bicycling do go hand in hand to some extent - both working on mostly similar principles, including infrastructure, policies and investments - but there are also some additional issues to be covered regarding e-bicycling development and planning, including practical issues related to charging and safe parking solutions. A shared e-bike system started operation in the eastern Espoo in 2022 in a free-floating/undocked operation system.

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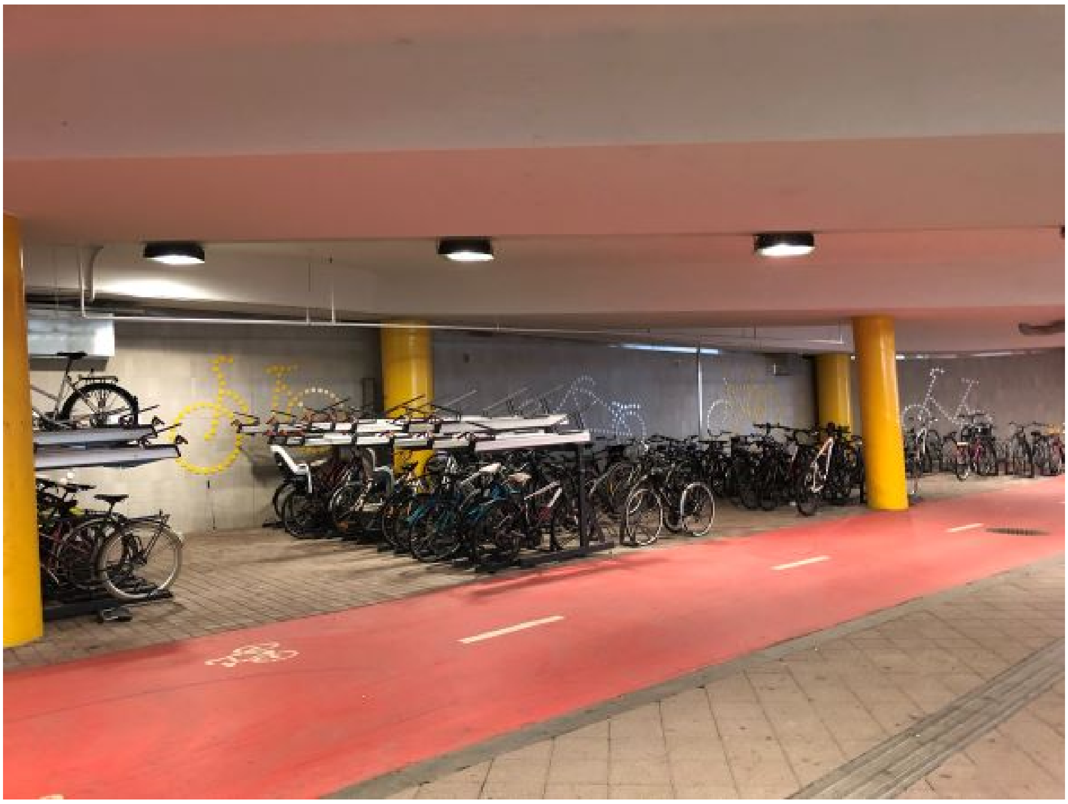

Figure 17. Bicycle park under the Leppävaara train station. Source: ESP.

In recent years, there has been different projects under the Sustainable Espoo development program that support achieving the city's carbon-neutral by 2030 and UN Agenda2030 Sustainable Development Goals by 2025 targets. The projects have also covered issues related to e-bicycling, including introducing different types of bikes for company workers on 'last mile' trips, e-cargo bikes in shared use in apartment buildings, and public e-bike battery charging cabinets in mobility hubs, through trials and pilots.

2.2.3 E-bicycling barriers and possibilities: E-bike SWOT Workshops

In order to identify the current challenges and possibilities related to the further (public or private) uptake of e-biking in Espoonlahti, Espoo, and beyond, two (2) SWOT (strengths, weaknesses, opportunities, threats) workshops were organized by ESP for mobility experts. The workshops were organized for (1) SPARCS partner organizations and (2) the City of Espoo departments on e-bicycling development trends, barriers, and possible futures. The participants were all experts in mobility or other related fields. Both workshops were held in May 2021 in a remote online format (due to Covid-19 restrictions) utilizing MS Teams and Miro whiteboard tool, which was utilized to enable remote real-time co-working on the SWOT tables.

The workshops used a version of a basic SWOT (strengths, weaknesses, opportunities, threats) framework as a mode of operation. The main idea in the workshops was to identify what are the current potentials (or Strengths) and risks (or Weaknesses) related to e-bicycling in the local context (Espoo and Helsinki Metropolitan Area) and what kind possibilities (or Opportunities) and potential pitfalls (or Threats) in a more general and global perspective had the participants identified in their own work. The insights

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gathered here are treated anonymously. The key findings are presented in Figure 18. It is evident that some of the issues noted are specifically related to electric bicycles whereas the majority of concerns are also translatable to non-electric bicycle use as well.

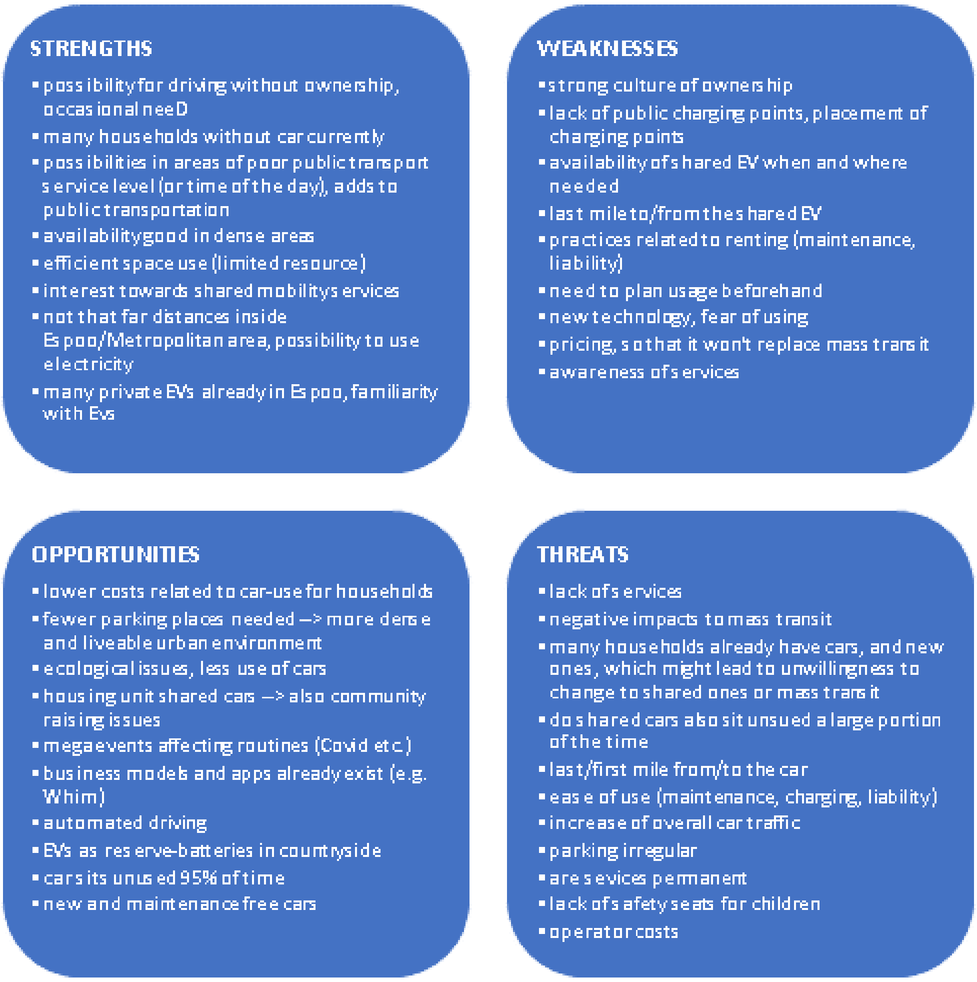

Figure 18. The main findings of the workshops (combined from the two workshops). Source: ESP.

The key identified *strengths* of e-bicycles in urban mobility system is that they enable active mobility for different user groups beyond the traditional non-electric bicycle. The motor support makes longer distances possible with less physical strain. The e-bike can potentially provide similar freedom of movement and door-to-door access than private cars (depending on the urban structure and design principles favoring specific mobility modes), thus potentially substituting personal car use and ownership. The experts saw that the current bicycle infrastructure in Espoo is enough to support e-bicycling, and that services are close enough to most residents to make e-bicycle trips in daily use feasible, although future investments to the infrastructure are also needed.

The identified *weaknesses*, on the other hand, list current barriers. One often listed issue is the inadequate level parking facilities for e-bicycles, including the lack of safe locking

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mechanisms and surveillance of the parking facilities in the case of a theft. The experts noted that more benchmarking from successful solutions need to be done, such as from Denmark and the Netherlands that are the frontrunners in bicycling infrastructure development. Bicycle traffic planning is still lumped together with pedestrian traffic planning, which is not a situation for either mobility modes. Bicycle paths, even if they provide sufficient coverage, do not form logical entities in all places, and construction sites often disrupt the existing paths. Similarly, there is catching up to do in terms of facilitating winter-time bicycling on snow covered paths in most northern-European cities.

Opportunities for e-biking are clearly identifiable. Shared mobility services are also becoming more popular, which lowers the threshold of utilizing new services, including shared e-bikes. The increase of utilization of different light electric vehicles, and micromobility in general, can also lead to the increasing quality of the (bicycle) infrastructure as the different modes often utilize the same networks. As an active mobility mode, the health benefits of e-biking are noteworthy, and it also supports the 'health' of the whole transportation system by encouraging active modes of mobility and the use of public transportation (where bicycles are used as a 'last mile' solution). The purchase price of e-bicycles is also decreasing, which makes it accessible for broader user groups in the future.

The identified *threats* relate to the lack of information sharing about e-bicycling possibilities and the persisting notions and attitudes of bicycling as a weather-dependent activity. E-bicycling is also still rather expensive (in comparison to non-electric bicycles that are also readily available as second hand) and takes up natural resources (battery) to manufacture. Cars and bicycles are also often steered to the same sections of the street which reduces (e-)bicycling safety, and as e-bikes are expensive, the concerns for thefts were also highlighted. The lack of universal charging ports for e-bikes means that there are also few public charging possibilities for the bikes - although much of the charging might happen at home. Bicycle parking location and availability was also noted as one major element. More funding for the maintenance of already existing and the creation of new biking infrastructure was also called for.

The workshops also identified key steps that the city could take to further progress e-bicycle uptake in the area. These included:

- developing and adding more bicycle paths
- providing possibilities to test e-bicycles
- developing new practices to the year-round maintenance of bicycle paths
- enforcing a city-wide policy to support walking and bicycle use
- providing safe bicycle parking
- adding electric bicycles to the public city bike system
- paying attention to cargo bike use in the infrastructure development
- providing financial support for employees for e-bicycle purchases

The city's current *Program for advancing bicycling 2013-2024* comes to its end in 2024, which could be used as a reflection point, and to add e-bicycling elements to the possible future iterations of the program. As noted above, many issues related to bicycle traffic in general is also applicable with electric bicycles, but there are also aforementioned specifics that should be considered when developing e-bicycle traffic in the city.

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2.3 EV hub in Espoonlahti

The development of mobility hubs that support sustainable mobility behaviour requires that the local solutions and elements affecting the mobility system and user experience are examined in combination with the district and city-wide elements. Here, the barriers and possibilities related to the uptake of e-mobility and shared mobility solutions were examined in the Espoonlahti context, and how the new upcoming rail-based public transportation connection - the extensions of the city's metro line - will affect the area and sustainable mobility behaviour in the area. The new Lippulaiva blocks will form a major mobility hub in the area. A workshop and co-creation events were organized with different stakeholders, focusing on the different perspectives and elements that contribute to the local travel behaviour and the uptake of sustainable mobility solutions in order to provide a strategic approach to supporting the further development of the local mobility system. The future charging scenarios of the area were also examined.

2.3.1 Espoonlahti and Lippulaiva blocks sustainable urban mobility

A review of the current mobility development in Espoonlahti (including the upcoming addition of the metro line in 2023) was conducted by the Task partners. This is a brief summary of the separate report that collected these insights and which is available in the project resource bank.

2.3.1.1 Sustainable mobility in Espoonlahti

Espoonlahti is one of the main urban centres in Espoo. The area is currently being re-developed on multiple fronts, including the construction of the new Lippulaiva shopping centre with both private and public services and the new metro line extension (the extensions running from Matinkylä to Kivenlahti) to be opened in 2023. New residential housing is also added to the area and the blocks. The metro line will run directly under the Lippulaiva, which, together with a feeder bus terminal, will turn the Lippulaiva blocks into a major mobility hub in the area, with a fast rail-based connection to the other Espoo city centres and the Metropolitan Area in general.

The new metro station areas, currently under construction, will form important, densely built, urban areas in Espoo, attracting both residents and companies around rail-based public transportation. The metro line forms an important development corridor for the urban structure, as stated in the previous city strategy (Espoo Story 2017-2021). New building stock is added alongside the metro line.

The new Lippulaiva shopping centre will not only act as an important local service centre - with both private and public services under its roof, including a library and a day-care centre - but also acts as an important mobility hub in the whole Espoonlahti area. The new Lippulaiva blocks provide new public transportation, e-car and e-bike service possibilities for the area, which have the capacity to affect the mobility behaviour of the local residents and workers. In Lippulaiva:

- An estimated 14,000 passengers will use the Espoonlahti metro station daily.
- 22 000 - 24 000 visitors per day in Lippulaiva blocks.
- 105 logistics trucks daily.

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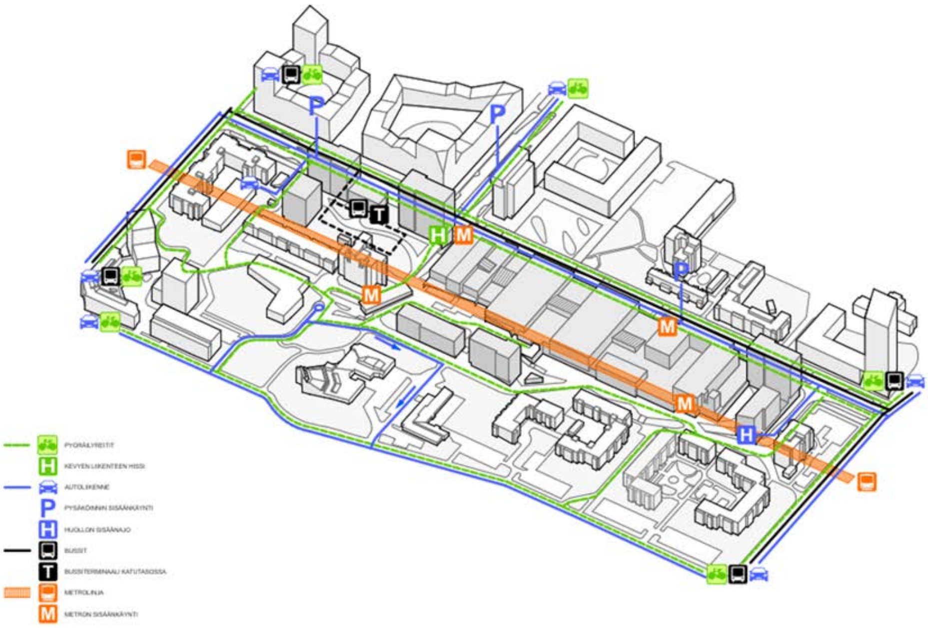

Figure 19. Lippulaiva blocks mobility connections. Source: Citycon.

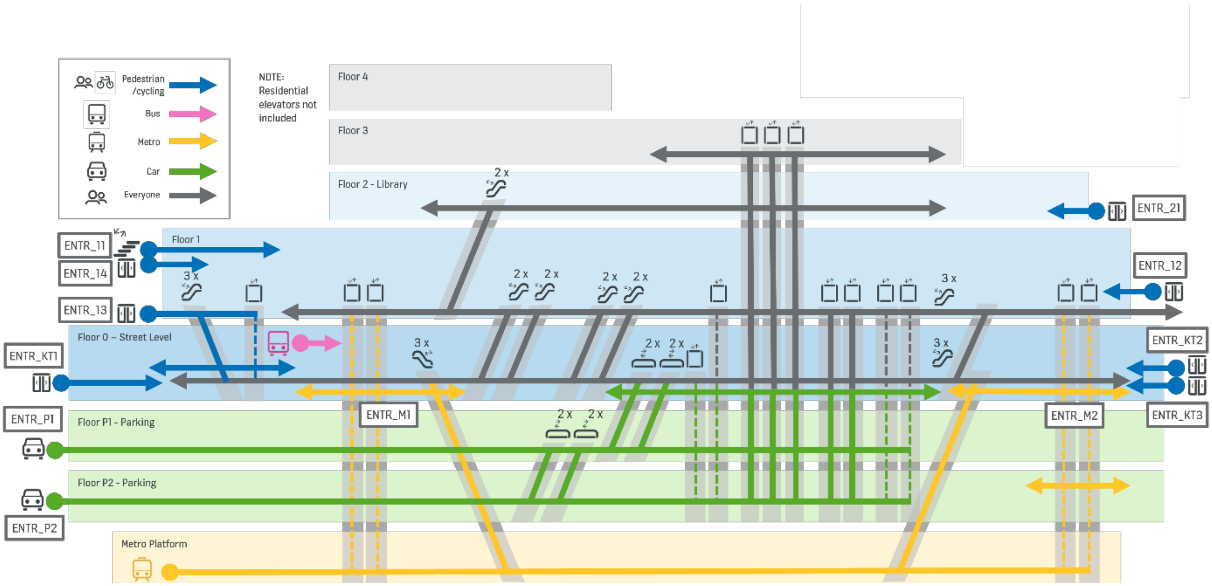

Figure 20. Vertical mapping of visitor flows in Lippulaiva blocks – post metro. Source: KONE People Flow Consulting, 2020.

The bus terminal in Lippulaiva will connect feeder bus traffic to the metro, creating an important point of transferring from one mobility mode to another. The used buses will be electrified at some point in the future as HSL, the local transportation authority, aims

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to electrify the routes with a goal of already ~30% electric buses in use in 2023. At some point in the future, also autonomous bus services might be an option.

Figure 21. A visualization of the Espoonlahti metro station available on the West Metro organization webpage. Source: https://www.lansimetro.fi/asemat/espoonlahti/#e6a79854

The mobility hub will most likely attract new ‘last mile’ service providers to the area in increasing numbers to tackle the journeys to/from the hub locally. Different shared light electric vehicle services have appeared globally in recent years. The electric kick scooters have probably been the most visible additions to the urban mobility system, but also different (e-)bicycle services have been piloted and put into use. Dedicated parking facilities/areas and clear codes of conduct in the Lippulaiva premises might be key steps in ensuring a smooth travel experience for the service users as well as other people moving in the area, avoiding some of the negative impacts experienced elsewhere, for example through the unorganized parking practices. The public shared city bike system is not currently available in the Espoonlahti area but (e-)bicycling is supported through infrastructure and facilities:

- Parking for 1.500 bicycles.
- Charging opportunity for e-bikes, lockable cabinets for e-bike batteries.
- DIY parking repair facilities for free use.

The Lippulaiva blocks are also major hub for e-mobility. Lippulaiva has space reservations for all EV modes, with 4MW charging power reserved for EV charging. The charging infrastructure is ready for 311 charging points of which 134 are already in use (10 DC charging spots, 87,5 kW, and 124 AC chargers, 22 kW).

2.3.1.2 Simulated future energy demand in Espoonlahti – Learnings from Leppävaara area

The area is likely going to electrify its transport in significant numbers, but what happens to the grid if there are 100% electric vehicles? In section 5.2.6.1 we estimate the load for the whole Espoo city to hover around 1 GWh/day. Given that there are now around 290 000 inhabitants, this translates to roughly 3,4 kWh/(day * inhabitant).

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Lippulaiva is expecting up to 7,000 new inhabitants. Given the possibility to linearly scale the problem, this would imply about 24 MWh per day of transport-bound electricity just for the new inhabitants. If all the people had charging habits that would be characterized by immediately charging after coming home from work, it could present a significant strain on the grid even while private mobility is only part of this demand. Therefore, it is important to identify the possibilities to regulate this behaviour. In a similar study for the Leppävaara hub VTT has deployed a simulation based on vehicle-level optimization of charging price throughout the day. This is a viable approach for studying the temporal variety in demand throughout the day. Applying the patterns we used for Leppävaara and scaling for the right numbers in Lippulaiva we get the following figures:

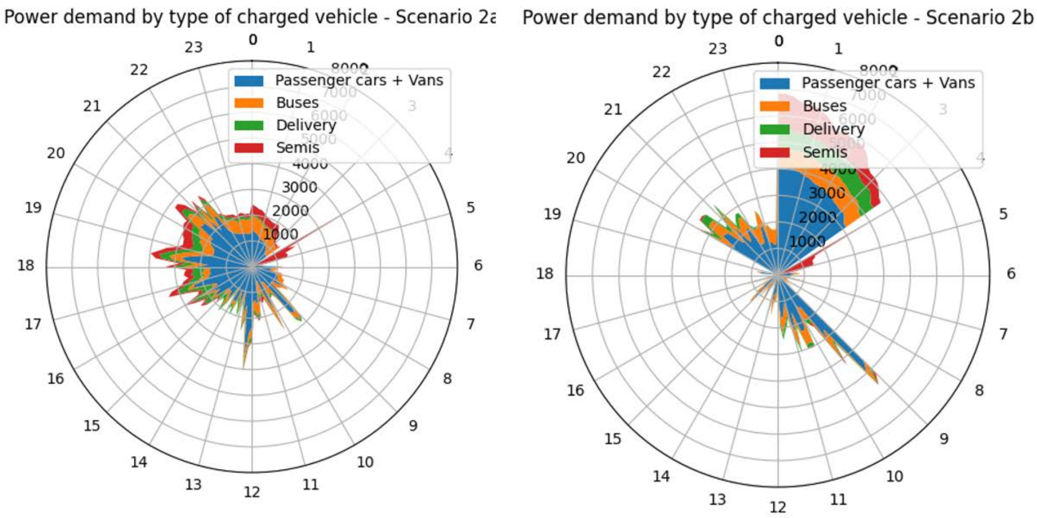

Figure 22. Simulated energy demand scenarios of different vehicle types during a day. Source: VTT.

The left figure shows the grid load caused by charging with flat price during the day while the right one shows what happens when there is smart pricing in place. The pricing curve that we used in the right scenario is somewhat amplified reflection of the spot price (the price paid at the electricity stock exchange for electricity in the very moment).

While none of these scenarios exceeded 10 MW in maximum charging power, the smart pricing scenario is loading the grid in times when it is less strained by other loads such as factories and working machines. The grid operators are also charging extra for maximum power used between 7 AM and 10 PM. Therefore, smart pricing scheme would be recommended for future deployments of charging systems.

2.3.1.3 Boosting sustainable mobility in Espoonlahti - Workshop

A SPARCS workshop was organized in February 2022 in order to address the potential of shared e-mobility solutions and services in Espoonlahti. The workshop on the future of sustainable urban mobility in the Espoonlahti are and Lippulaiva blocks identified some key drivers and barriers related to the uptake of shared e-mobility solutions and the specific characteristics of the area that affects its local contextualisation. The shared

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solutions can include anything from shared e-bikes and other light vehicles to shared cars. The workshop utilized some of the already conducted surveys, studies and forecasts on transportation during the planning and design phase of Lippulaiva and the metro extension, as well as results and insights from earlier SPARCS activities, including previous workshop results on shared vehicles and e-mobility hub development. The workshop was organized as an internal event of the Task 3.4 group in February 2022. ESP was responsible of planning, organizing and facilitating the workshop. CIT, VTT, PIT and KONE participated in the workshop, providing their expertise on the aforementioned questions related to the future Espoonlahti and Lippulaiva blocks development as a mobility hub. CIT also provided pre-existing data and material for the workshops about the relevant new Lippulaiva shopping centre transportation and freight related plans that had been produced in the various stages of planning and construction of the new shopping centre. The workshop was held online (1,5 hours), and most of the co-working was conducted on the Miro platform.

The main issues examined and insights produced in the workshop were:

- *Question#1: What kind of challenges and possibilities does the Espoonlahti area and Lippulaiva blocks provide for shared e-car use in the future?*
    - Insight#1.1: E-car sharing can lead to the decrease of general car use in the area, as only selected trips are made with the shared car, and other trips are conducted with other mobility modes. Less traffic can lead to better quality and safer urban environments. However, if the shared e-cars are readily available at a low cost, the effect can be the opposite and lead to increased car usage. This can lead to further traffic congestions and the decrease of public transportation popularity (which in turn can lead to decreased service level as users and resources are lowered) if current public transportation users switch to shared vehicles.
    - Insight#1.2: Shared e-cars need fast charging infrastructure to work, which requires service-based approach and development of the charging infrastructure, as well as the service models related to the charging event (e.g., incentives for users to charge the vehicle, ease of use of the charging infra/apps).
    - Insight#1.3: The irregular use of the shared cars makes it difficult to predict local parking space needs and their temporal fluctuations on a daily/weekly level. This challenge can be tackled through predictive simulations and by incentives in the pricing schemes of the service in the initial stages. In further use data gathering and experience of the service operation can help to further optimize the usage of parking spaces.
- *Question#2: What kind of challenges and possibilities does the Espoonlahti area and Lippulaiva blocks provide for shared e-bike use in the future?*
    - Insight#2.1: E-biking decreases the physical strain of bicycle use, which can increase and broaden the potential user base, and to make it more applicable in different contexts. High quality and interconnected bicycle paths are needed to make bicycle use an attractive daily mobility mode. The effects of construction sites in the developing areas needs to be mitigated in advance to ensure smooth bicycle journeys.
    - Insight#2.2: The charging infrastructure is relatively easy to integrate to new or existing buildings. No universal charging plugs exist for e-bicycles,

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which means that the charging infrastructure needs to cater for different technical solutions.
  - Insight#2.3: Winter-time bicycling is highly relevant issue in the Nordics. Bicycling needs to be a viable mobility mode for all kinds of trips throughout the year, and in all kinds of weather conditions. This requires maintenance and infrastructural investments to bicycle routes and parking, as well as active support in shared services (e.g., winter tyres).
  - Insight#2.4: Safe and weather-proof parking support bicycle use. The location of the parking facilities needs to be favoured in mobility hub planning to ensure quick and easy access between the bicycle parking and services.
  - Insight#2.5: City bike systems have been popular so there is proved market for shared bicycling services.
- *Question#3: How does the electrification of mobility and the increasing role of shared mobility services in urban mobility affect the Espoonlahti hub in the future?*
  - Insight#3.1: The core requirement of the hub is the availability of the shared mobility services. Shared bicycles, for example, need to be actively relocated based on demand and use rate. Through a dynamic pricing strategy, demand can be directed and controlled, tackling both the lows and the peaks of shared service use and demand.
  - Insight#3.2: The future hub could benefit from an app that gathers all relevant shared mobility services under it to increase the usability and visibility of all the available transportation options. The location of the mobility services and their interconnections (changing from one mobility mode to another on foot inside the hub) needs to be carefully planned and taken into consideration when planning the placement of the services (both mobility-related and others) in the hub.
  - Insight#3.3: The charging infrastructure for all vehicle types needs to be easy to use and well maintained with a quick customer support to increase their usability. Dynamic pricing schemes can be used to encourage flexibility in travel and charging behaviour.
  - Insight#3.4: To accommodate the daily routes and practices of professional and commercial drivers (taxis, logistics, deliveries etc.), the charging event needs to be easy to conduct inside the narrow charging windows available during the workday. The chargers need to be located in the same areas where the professional drivers need to be anyway to carry out their related work tasks.
- *Question#4: What are the main effects of the Covid-19 pandemic to the 'new normal' of urban mobility? The Covid-19 pandemic, since 2019, has had an enormous effect on societies. From a mobility perspective, mass transportation services experienced a major decrease in both operation and usage during the hights of the pandemic. The various 'social distancing' measures have also meant the increase of remote working practices (where possible), the increase of online shopping behaviour, and the sprouting up of new logistics and mobility services, catering for personal mobility needs (over mass transportation). The 'new normal' after the pandemic is difficult to forecast. Two scenarios were formed: an optimistic and a pessimistic scenario of the effects of the pandemic to shared mobility service and public transportation use and popularity.*

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- Insight#4.1: The *optimistic* post-Covid-19 scenario presents that the importance of bicycling is strongly increased after the pandemic. This will support shared services, such as the city bike system or other shared (e-)bike services that will see an increase in popularity. Public mass transportation services will also see a growth in its use, partially connected to the increase of bicycling as part of the travel chain as 'first' and 'last mile' journeys.
- Insight#4.2: The *pessimistic* scenario, on the other hand, suggests that people continue to avoid public mass transportation and favour personal mobility modes instead. This can lead to the further decrease of shared and public service availability, which, in turn, can lead to the further decrease of the user base. The increase of personal mobility modes can increase traffic congestion and the requirements for parking facilities, especially in terms of private car use. The increase of online shopping might also decrease the number of purchases of goods and services locally.

Shared e-mobility services have potential to be central pieces in the local sustainable urban mobility system. Paying money only from use is a strong incentive for shared use, and if the services are readily available, accessible and affordable, the threshold for their use should be low. The mobility hub, as a 'station' for different services, plays here an important role in tying together the shared 'last mile' services and public transportation options.

Based on the workshops results presented above, some possible next steps can be identified for the further development of the services, which are presented in Figure 23. The common guidelines can be distilled to these basic principles:

- The availability of services when needed need to be secured – different methods can be used to direct the demand.
- The placement of the services in the hub and their connections matter in their popularity.
- A balance between shared mobility service use and traditional public transportation needs to be found to make the most out of both.
- Mobility connections during an area's construction and (re-)development phases need to be considered carefully, especially in terms of enabling walking and bicycle traffic (that also affects light electric vehicles).

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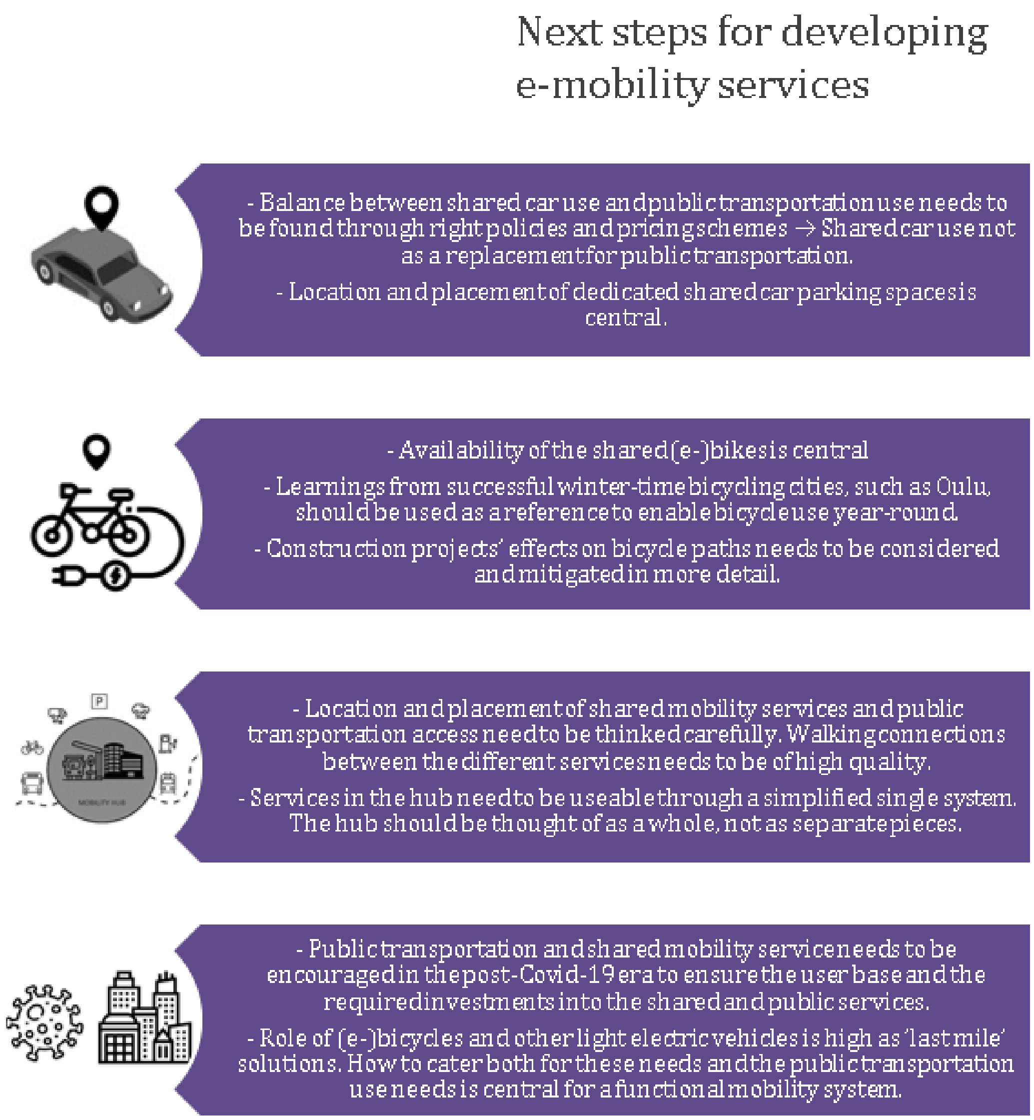

Figure 23. Next steps for developing e-mobility services in Espoonlahti, as identified through the workshop results. Source: ESP

Policy and service model development, location and placement of services in the designated area, and the communication of the strengths of sustainable urban mobility options are some key steps for further development of the local urban mobility system.

2.3.2 Mobility in Espoonlahti now and in the future - Insights from young peoples' perspectives

ESP and CIT have both invited a Buddy Class – two classes from *Maininki school* and *Espoonlahti school,* both located in Espoonlahti – to co-develop future sustainable urban environments. The Buddy Classes promote sustainable lifestyles for the duration of the

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pupils' upper comprehensive school years from the seventh to the ninth grade (2020-2023). The "Buddy Class activities" aim to share knowledge on sustainable development and sustainable lifestyles, to develop the skills of the youngsters, and to gain new insight to the city's practices from the pupils. The Buddy Class activities are organized under several themes, including energy, mobility, circular economy, smart cities, UN Agenda 2030 work (including Sustainable Development Goals or SDGs), and participation and co-development processes in the city. The Buddy Class activities are not tied to any specific subject; instead, activities have substituted for variety of subjects.

The Buddy Class activities by the City of Espoo are conducted mainly under Task 3.6 Citizen engagement, Action E19-2 Sustainable lifestyles, with linkages to activities in other tasks and work packages (such as energy, e-mobility, urban transformation) (see D3.6 for more details). The Buddy Class activities by Citycon are conducted under Task 3.6 Citizen engagement, Action E3-3 Co-creation of shopping centre in collaboration with young consumers (see D3.6 for more details).

Here, two classes from the Maininki school Buddy Class that *focused on urban mobility* are examined in more detail.

2.3.2.1 'My mobility habits'- Sustainable mobility themed Buddy Class event, June 2021

ESP organized a mobility themed workshop for the students of Maininki school in June 2021 with a title 'My mobility habits'. The workshop followed mostly a similar structure as one organized by CIT, KONE and ESP earlier in December 2020 for Espoonlahti school. The aim of the workshops was to provide insight to the current issues on transportation and mobility development in Espoo, and to gain the pupils' perspectives on mobility in Espoo based on their own day-to-day experiences in Espoonlahti and beyond. The meeting was held as a mixed online/live event utilizing Google Hangouts and Google Documents for co-creation between the pupils.

The workshop began with a brief lecture on mobility issues by ESP. The lecture gave an overview of what mobility means, what kind of transportation modes are in use in Espoo, how people move in the city, and what kind of new mobility solutions are currently developed in Espoonlahti and beyond. One of the key messages here was that mobility can be thought of as a larger than transportation-only issue, relating to all facets of urban life, including the experienced quality of living environments and how different mobility modes affect it and our own well-being, the importance of equal access, and the effects of different mobility modes on ecological sustainability.

The brief lecture was followed with a co-creation session that took up most of the class's duration. The focus of the session was to ponder the future of mobility together with the pupils. A Mentimeter question in the beginning revealed that most of the student had arrived by walking (43%) or by bus (43%), and the rest driven there by their parents (14%). The questions for the workshops were: *How would you like to travel in the future urban environment? What would your dream mobility experience be like?* These questions were approaches by co-examining different mobility modes that the pupils use in their daily life, and what are the current negative or challenging issues related to them, and how they could be solved in the future.

Walking was regarded as a slow, time consuming, and tiresome way of moving around. In general, walking is a boring experience, and it is not regarded safe in all places and times

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of the day. Weather also affects the experience. With bicycles, the youngster's noted traffic safety issues, the physicality of bicycle use, and the lack of good biking paths. They also noted the need for more bicycle parking that are also secure and safe. For buses, the youngster's hoped more precise schedules, and faster bus routes with less detours to the centre. Regarding shared mobility services, they noted age limits, insufficient personal funds, and low availability of services as central elements preventing their use. When asked about station areas, they noted the possibility of social disturbances and the lack of things to do as some of the key current challenges.

As solutions for these issues, the pupils suggested better quality pedestrian and bicycle paths and environments, and the addition of 'nice' sceneries. The pupils also suggested the creation of walkable shortcuts to cut travel times in areas they frequently use, addition of benches and services in stations areas, addition of bus routes, lower cost (or even free) public transportation tickets, faster and more direct bus routes, and more frequent service. They also pondered if age limits in shared mobility services could be lowered, and more docking station or places for returning the shared vehicles could be added. Safety issues in station areas could be tackled by increasing security and restricting the number of users at a time, e.g. providing entrance only with a valid metro ticket.

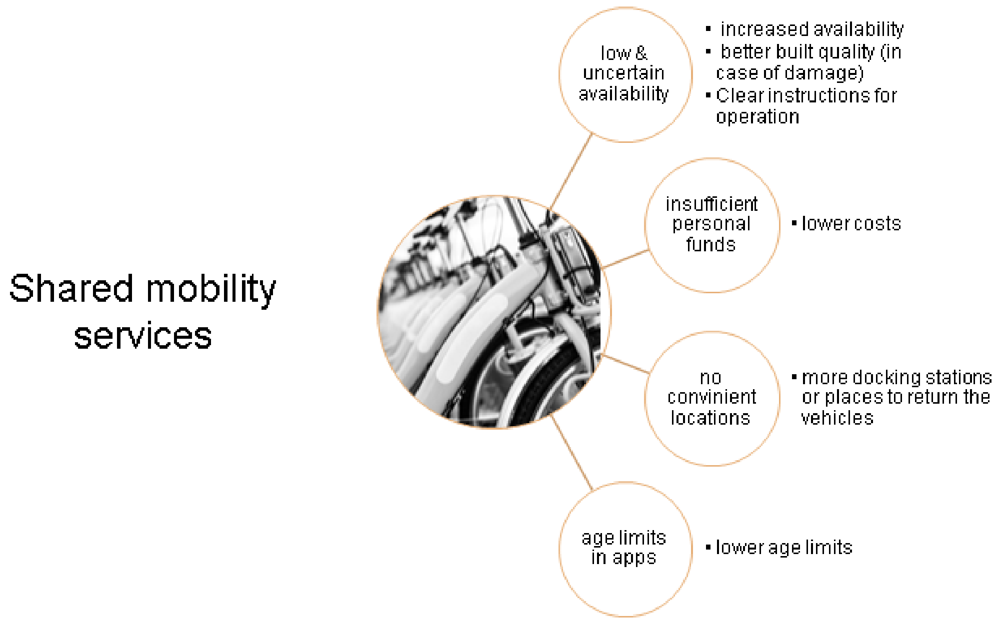

Figure 24. Example of the youngster's views on negative and challenging issues related to different mobility modes, and their suggestions for improvement. The example relates to shared mobility services. Source: ESP

In the end of the workshops, as a final assignment, the pupils were also asked to look ahead into the future. The given task was to envision the world in thirty years from now and write down ideas of how people will travel in the future city (of their preference). In their answers, the year 2050 will mean some modest development of current trends, such as the increase of electric buses, 'faster' bicycles, high-speed rail, and the uptake of self-driving vehicles, as well as introduce new futuristic types of mobility related to daily

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urban travel. The flying car - the long-lasting epitome of future mobility - also gained some support in these future visions.

The views on current challenges and possible solutions provide important insight to current urban mobility in Espoo and Espoonlahti, and highlight some key insights - such as age limits in mobility service use, and feelings of uneasiness in station areas, as brought up in the workshop - to urban mobility development that are perhaps not so often noted. Individual workshops are not enough to provide full view to the point out all the issues that could be the subject of future development, but they provide variety, width and depth to such notions.

2.3.2.2 Orientation in the future city, April and June 2021 - A sustainable urban environment themed Buddy Class event

ESP and CIT organized a themed class on ‘Orientation in the future city’ for both Buddy Classes in April (Espoonlahti school Buddy Class) and June (Maininki school Buddy Class) 2021. The aim was to conduct a predefined walking route in Espoonlahti where the pupils could think about their ideal future urban environments by reflecting their experiences on walking in the actual, physical environment. A route in the areas in Espoonlahti close to the school were designed in advance, and specific points of interaction were chosen where the pupils could reflect their thoughts with pen and paper.

The route consisted of some predefined points of interest. These included the new Lippulaiva center construction site (with interactive QR codes on the construction site’s fences, which leads to the Lippulaiva virtual showroom), a large mural on the side of a residential building, a building with a distinctive modernistic architectural style, and a local sports facility area.

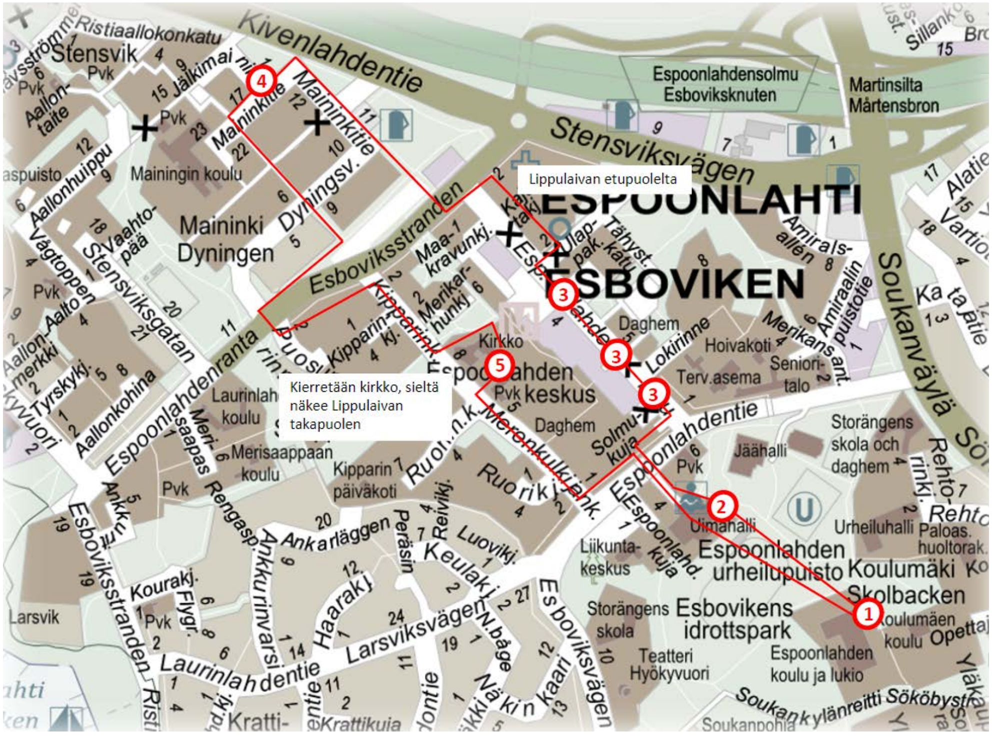

Figure 25. The orientation route in Espoonlahti. Source: Citycon

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The pupils were asked to describe their ideal city in 2035 through their reflections in the actual environment during the walk. The elements that were repeated in many of the answers were the proximity of green spaces and urban forest areas, art and aesthetical urban environment, availability of different kind of services (e.g. food delivery services), and active city life but also peace and quiet. They also visioned that public transportation could be used to get everywhere, and streets populated by numerous shops and restaurants. Some answers also highlighted that the seafront in Espoonlahti would be in better use and access to it would be easier.

These insights shine some light to the different elements in the urban environment that the youngsters pay attention to, and what they consider as key ingredients of 'good' urban spaces. The experienced quality of the urban environment is closely tied to the willingness and want to spend time in the spaces, contributing to the use of active mobility modes (walking, bicycle use) and shared mobility services and public transportation in the day-to-day life.

2.3.3 Micro mobility design sprint and online survey

A micro mobility design sprint was conducted in the spring 2021, including an online survey, a field visit, qualitative interviews and a workshop with 7 Espoonlahti residents to identify existing micro mobility needs and solutions, and to develop new solutions. As part of the design sprints, existing micro mobility solution providers were also mapped out and benchmarked. In the study, micro mobility included walking, biking and all sorts of light mobility devices that people might use for last-mile mobility, including but not limited to, ordinary and electric bicycles, city bikes, kick bikes, e-scooters, one- and two-wheelers and so on.

To engage a wider public and to gain understanding of the current state of micro mobility solutions at Espoonlahti, KONE and Citycon organized an online survey to collect first-hand experiences from the residents. In total, 79 residents from Espoonlahti responded the survey. Through the survey, it was found that the current infrastructure for bicycling and walking in Espoonlahti is excellent and that relatively many citizens already have an experience in electric bikes or smaller electric vehicles. The local improvement suggestions are related to the limited availability of shared city bicycles and safer locking and parking solutions in public transport connection points, such as Lippulaiva area. Due to the rich nature and extensive seaside micro mobility routes, Espoonlahti provides urban city dwellers a place to enjoy recreational activities and nature resorts. There is a high interest to try out electric vehicles (cars, bikes, e-scooters), but lack of trust in shared mobility and a need for effortless registration and payment systems for multiple mobility modes and services. The survey was replicated in Leppävaara area with 41 respondents. In the Leppävaara area, the ongoing construction sites were impacting the use of micro mobility vehicles and compromising the routes. The survey respondents in Leppävaara were living in smaller households and were owning fewer cars compared to Espoonlahti respondents. Short distances in Leppävaara and easiness to use micro mobility devices were also increasing the use of bicycles and walking.

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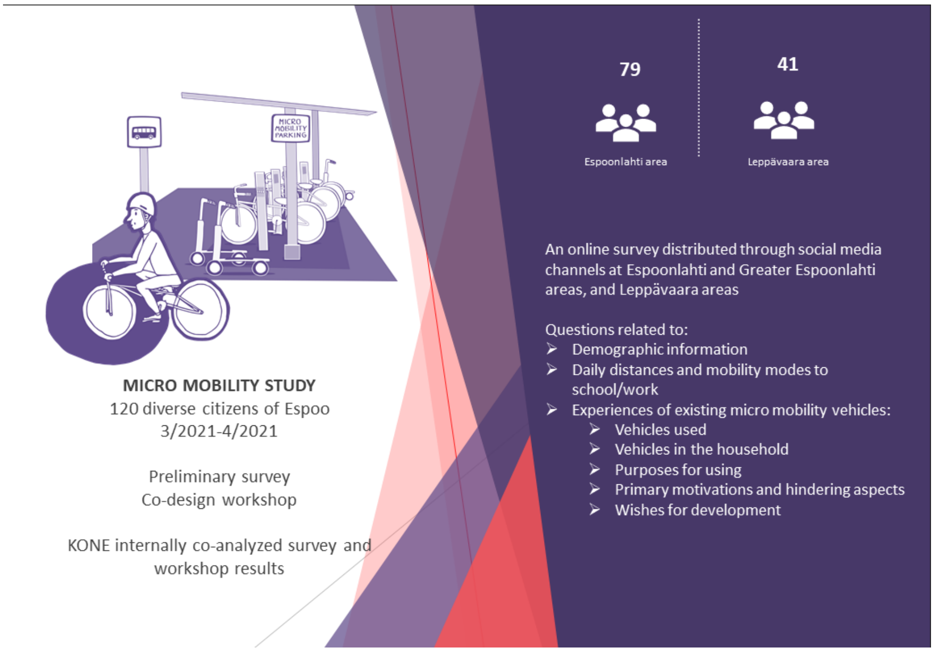

Figure 26. Results of Leppävaara and Espoonlahti. Source: Merja Ryöppy, Saga-Sofia Santala and Satu Niemi, KONE

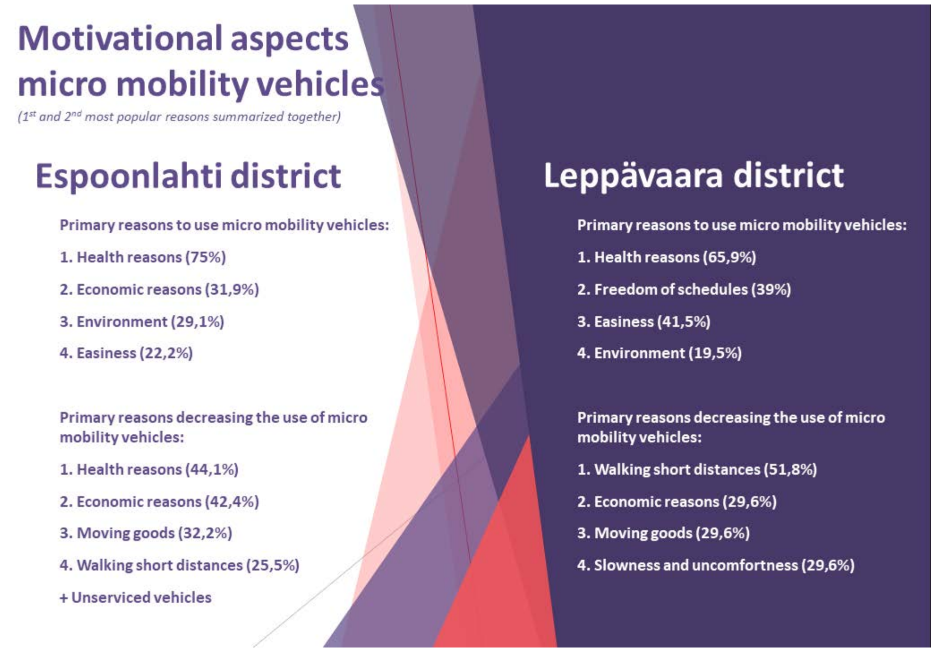

Figure 27. Results of Leppävaara and Espoonlahti. Source: Merja Ryöppy, Saga-Sofia Santala and Satu Niemi, KONE

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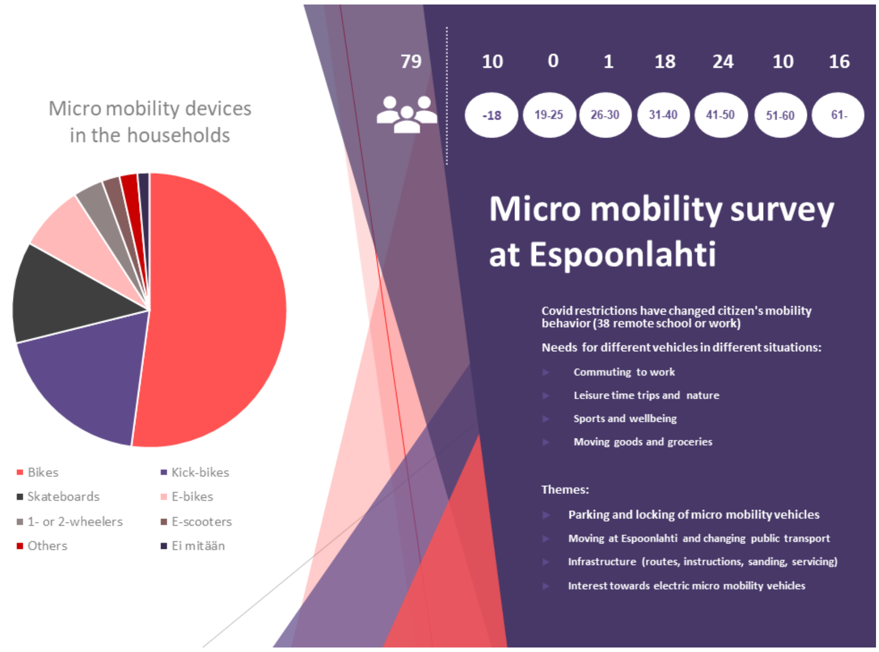

Figure 28. Results of Espoonlahti. Source: Merja Ryöppy, Saga-Sofia Santala andatu Niemi, KONE

Figure 29. Results of Espoonlahti. Source: Merja Ryöppy, Saga-Sofia Santala and Satu Niemi, KONE

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3. LEPPÄVAARA CENTRE

Leppävaara is one of the biggest and most rapidly growing areas in Espoo. As one can tell, mobility is an important subject in these kinds of areas. The Sello district is a big nodal transport point in the area (and in the whole Espoo). In this area public transport is becoming fully electric. There are electric buses, railway tracks and even Jokeri Light Rail coming to help in moving many people. This intervention aims to research and implement electric vehicle solutions for areas like Leppävaara. The research is used to develop this area and help other areas to replicate the best solutions. Leppävaara has a shopping center called Sello. Future charging systems could be integrated with the shopping centre's energy management system. In addition to that, the activities reflect on the future of the area by carrying out simulations on the upcoming charging energy demand and impact on the electricity grid.

Table 4. Actions for Leppävaara area as outlined in the Grant Agreement.

Subtask 3.4.2	New E-mobility hub in Leppävaara center
Responsible partners	PIT, VTT, ESP, SIE
Actions	**E7-1** Developing Leppävaara EV-mobility hub as a whole. Helsinki Regional Transport (HSL) and the City of Espoo have high targets for the electrification of transport. The Sello block and area will be developed into a new E-mobility hub connecting local and long-distance trains, city E-buses, and a new fast E-tramline. First mile/last mile services will be enhanced by including charging services for car sharing. Interoperability of charging infrastructure will be ensured to provide access for other user groups, e.g. electric service vehicles and mobile machinery. The requirements and impacts on the electrical grid will be analysed in collaboration with all relevant stakeholders. (PIT, VTT, ESP) **E7-2** Development of EV charging for customers of the shopping centre and commuter parking as a part of the total building power management and microgrid solutions. Optimisation of EV car charging and power management. Utilisation of activity-based models for load prediction and development of energy demand response services (V2G), control strategies based on business models (Park&Charge concept). Dynamic pricing models for electric vehicle charging and price of electricity depending on the flexibility resource the EV can bring. Test would focus also to gain user experience data out of the EV charging usage for the future energy optimization purposes and to connect EV charging stations to VPP. Integrating data and services. 5G is enabling the data transfer. (SIE, PIT, VTT) **E7-3** Optimal charging strategies for commercial vehicle fleet. Utilisation of activity-based models for demand response prediction. Plugit Finland will be responsible for developing the services related to electric commercial vehicle charging. (PIT, VTT) **E8-3** Evaluate feasibility for shopping behaviour in the EV charging concept. (SIE)

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3.1 E-mobility hub in Leppävaara

The target of the activities has been to develop the e-mobility hub in Leppävaara both for commercial and private customers. High-power charging infrastructure has been implemented for electric buses, and the same charging infrastructure could also be used for other heavy-duty vehicles. This kind of interoperability of charging systems will become more and more important in the future, especially in traffic nodal points like this. The interoperability was also examined and tested in this action. The focus point on behalf of private customers has been the investigation of opportunities for enhancing last mile services and car sharing. The current charging system contains eleven fast charging spaces, and could be expanded with many more.

3.1.1 Implementation of EV charging system

During the project, Plugit Finland implemented a charging system next to the Sello shopping center. The EV charging infrastructure implementations in Leppävaara area were finalized by M24. This charging system was done for HSL (Helsinki Regional Transport) to support the electrification of buses. The implemented bus charging system is currently serving around 20 buses located next to the Sello shopping centre. As the charging system is at the nodal point of traffic, it serves as end of the line charging. Buses operating here will also charge at the depot, and this is just top-up charging between routes. The implemented bus charging system consists of 6 GB/T cable charging spots (120kW), 1 CCS cable charging spot (120kW) and 5 pantograph charging spots (350kW). In pantograph charging event, the pantograph is lifted from a bus to charging hood. This kind of charging event can be seen in Figure 32. Some chargers are serving the same parking spot, so we had only 11 charging spots in the beginning. Before M24 there were some changes due Jokeri Light Rail, and currently the number of charging spots is reduced to 10. The charging system can be found in the figure below. Four pantograph domes are next to the train railway. In the middle of the area there is one pantograph dome and six satellites for cable charging.

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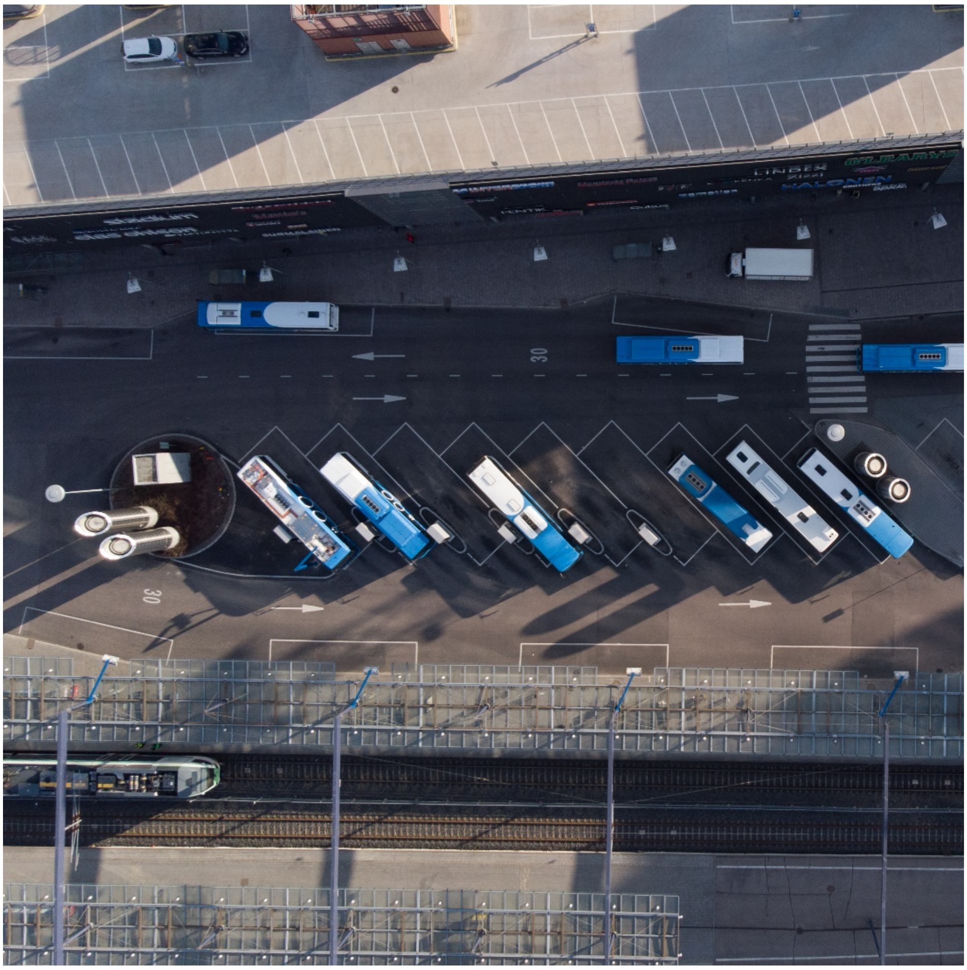

Figure 30. The bus charging system next to Sello shopping centre (Source: Plugit)

The charging system is built on two floors, the parking garage and ground level. Buses operate only at ground level, and all charging happens there. The chargers themselves are located in the parking garage. Below you can find images of these two charger types, the pantograph charger and the cable charger. Pantograph chargers are made by polish manufacturer Ekoenergetyka. This can be found in the left picture. The power of one pantograph charger is 350kW, which was requested by HSL. The charger is fed with AC cables, which come from switchgear. DC cables and a communication cable go from the charger to ground level and to the pantograph mast. At the top of the mast there is a pantograph dome, which is the contact point for the bus. Buses operating in the area have a rising pantograph on the roof, which works as the contact point from the bus.

Cable chargers are made by Plugit Finland, and this kind of charger can be found in the right picture. These chargers are made robust and movable, withstanding also outside usage. This will be useful if these need to be moved in the future. The cable charger has a power of 120 kW, but could be upgraded to 180 kW. Cable chargers could also be expanded with a second charging cable, but there has not been an opportunity for that implementation during this project. Cable chargers are also fed from switchgear. DC cables and communication are connected to the satellite above. Every satellite has a screen for user information and charging cable, which is connected to bus. The buses in

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this area are using GB/T-standard. Charging starts automatically when a cable is connected.

Figure 31. Electric bus chargers and satellite (middle). (Source Plugit)

This charging system has a medium voltage grid connection to (Caruna) electric grid. The maximum power of this charging system is 3000 kVA, and it could be expanded into 4000 kVA. Currently there are 3 pcs of 1000 kVA (20kV/0,4kV) transformers. These transformers feed low voltage (400V) switchgear, which consists of three parts. Each transformer is feeding one switchgear part. A switchgear has a remotely controlled circuit breaker for each charger. This can be useful if a hard reset is needed due some software bug. System uses AC electricity feeding the chargers. The charger transforms AC into DC electricity, which is fed to the cars. The medium voltage of this system is 20 000 V, the low voltage is 400 V and DC voltage is requested by bus (< 1000 V). Buses in this area are using 600 – 700 V charging voltage. An up-time requirement for this system is 99 %, which is demanded by HSL. Basically this means that the system must work 99 % of the time. PIT has reached this goal all months after a test period in the beginning, so this demonstration has been successful. The charger technology has evolved since this installation, but the layout and system level planning can be replicated to other locations .

The existing bus charging system can be expanded into an EV-mobility hub for various user groups. It is also possible to serve multiple vehicle fleets with the implemented charging system, but this area is limited to bus usage only. Shared chargers will be important in the future, when electric cars are a majority in urban areas like this. This charging system has already been tested with passenger cars and it could easily be expanded with six more CCS cable charging spots. The overall power of the system is currently 3 MW and it is expandable to 4 MW. In addition to this charging system, the Sello shopping center has also 22 AC chargers (22kW) for customers. The number of AC parking spots in the shopping center will be increased if needed in the future. While these systems are separate, it would be ideal if charging systems like these would be combined into one bigger system. This kind of bigger charging system could be optimized further and the impact on the grid would be easier to control. Lippulaiva is a great example for this kind of planning, although Leppävaara has currently more diversity in the electric vehicles. This optimization and future scenarios are further researched in the action 7-3.

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Figure 32. Bus charging system in Sello (Source: Plugit)

This bus charging system has been operative for two years now. The up-time, usability and feedback have been really good. This was the most powerful charging system in Finland at the time, and has impacted the electrical public transport in a positive way. After the first demonstrations and experiments, HSL has decided to have mostly electric buses in new tenders. This is also boosting the number of electric buses in the capital region of Finland. PIT has also replicated the idea and learned from this charging system to other locations. This location is for top up charging for buses, and it cannot be optimized much more. Due to that, grid optimization and charging strategies are mostly done in the task 7-3.

Figure 33. Electric bus charging at winter in Sello (Source: Plugit)

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3.1.2 Possibilities of shared EVs

Car sharing services, in general, refer to car fleets that are in shared use, nowadays mostly rented through digital apps with various pricing schemes and wireless payment options. Usually, these cars are rented for a short time period, the pricing accounting hour-by-hour or even minute-by-minute rates. The system can be fully privately operated (private dedicated car fleet) or peer-to-peer (users renting their own cars). The system can be free-floating (park anywhere) or organized around dedicated parking spaces / mobility stations. With e-car sharing, the same principles apply but the fleet is consisted of full electric (or hybrid) cars.

There are currently companies providing car sharing services in Espoo. The city cooperates with the companies related to the principles in operating in the area, including special parking permits. Additionally, there have also been pilots, where car sharing services have been tested in Espoo, such as a regional-level car sharing pilot as part of the *SixCities: Low-carbon transportation in mobility hubs* (2019-2022) project under the Sustainable Espoo programme. These services and pilots, however, have utilized mostly combustion-engine cars, with singular hybrid or full-electric cars as exceptions. There are currently no dedicated e-car sharing service operating in Espoo.

3.1.2.1 SWOT Workshop: Shared e-car possibilities in Espoo area

ESP organized two SWOT (strengths, weaknesses, opportunities, threats) workshops for SPARCS partners to examine the current status and future possibilities of e-car sharing services. The workshops aimed to identify what characteristics in Espoo support or hinder the utilization of e-car sharing services, and what could be done to support their future utilization in the local mobility system. The workshops were organized for 1) SPARCS partners and 2) representatives of different City of Espoo departments. The workshops were organized in September 2021. The workshops were organized online due to the Covid-19 pandemic, and utilized MS Teams and Miro online whiteboard tool for co-creation.

One of the most clearly identified *strengths* of shared e-car services is that it makes driving possible without car ownership. This supports efficient urban space use, as shared cars are circulated between users, which further supports sustainable travel modes, such as walkable environments through the decreased parking demand. There are many households in Espoo without a car currently (36% in 2021[23]), which suggest a possible user base for the commercial services. In areas of inadequate public transportation services, shared e-cars could act as additions to the mobility service line-up. In more densely built areas with already high-level public transportation services, usage would mostly be directed to areas with limited reach with public transportation. The fact that there is a growing interest towards shared mobility services - e.g. e-kick scooters - the threshold of shared car use might be lowered as well. Distances in the Metropolitan region are short enough to support the use of electricity as a powertrain, and smaller vehicle types with smaller battery capacities.

These strengths might be hard to utilize, however, as some key *weaknesses* of the service in Espoo can be identified as well. One, there is still a strong culture of ownership, which might deter potential users. The availability and ease-of-use of the private car is difficult

[23] https://www.espoo.fi/fi/uutiset/2022/02/yhteiskayttoisten-autojen-suosio-kasvussa-espoossa

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to match with shared services if there is a danger that the service is not available when needed, and the renting practices are not fluent and hassle-free enough. How the 'last/first mile' to the vehicle is conducted also has an impact on the popularity of the service, as does the amount of pre-planning needed for the travel with shared vehicles. Lack of information about the services available, fears and bias related to new technology utilization, uncertainties related to the renting practices (maintenance, charging, liability in case of accidents) and pricing schemes might be other possible barriers as well for the wide-spread use of shared services. Additionally, the pricing needs to be on a level that it does not replace public transportation use where the quality and availability of the service is on a high level. The availability and placement of charging points is also important in the utilization of a shared e-car fleet.

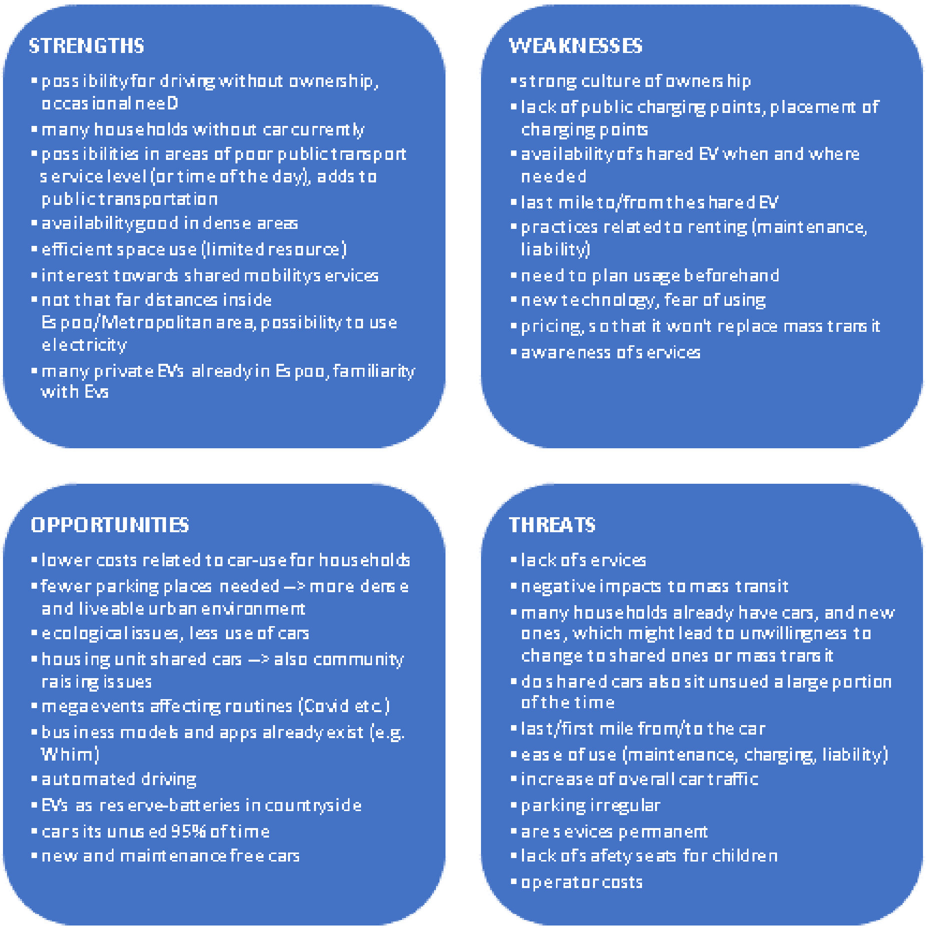

Figure 34. The generated SWOT table on Shared e-car services in Espoo that combines the results from both workshops. Source: ESP

The identified *opportunities* relate to the lower cost of the occasional shared car use in comparison to ownership, and that different proven business models and apps already exist, lowering the threshold for use. Shared cars can lead to less car use in general, affecting the local ecological sustainability and air quality. The shared use also means that fewer parking places are needed, which can help to create livelier, densely built urban

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environments favoring other mobility modes. Shared car use can also contribute to feeling of a community and 'knowing your neighbor' kind of situations.

The identified *threats*, on the other hand, are related to the current lack of services, and the situation where many households already own a car, which can mean a slow change towards shared use from ownership. The 'first/last mile' to/from the shared car is also an issue as the supply of available cars can be vary greatly in different areas and neighborhoods. The services have not yet been able to secure their role in the mobility system, which means that people can also be unwilling to organize their daily mobility routines on a service which might not be a permanent solution in the long run. Shared cars - and the pricing schemes utilized - can also lead to increased car use on the expense of mass transportation, decreasing the public transportation service quality and frequency.

The shared e-car SWOT highlights that the issues related to its implementation as part of a city's transportation network are mostly related to practices, policies and its indirect effects to the city's mobility system as a whole. The technological issues - both in terms of the cars and the apps utilized in the renting process - were not seen as major issues. The infrastructure, meaning EV chargers, is one of the only technological issues noted, although it is more of a financial (who invests, who operates), geographical (where the chargers are located in relation to the shared vehicles), and practice (are people interested in using shared cars when many already have their own) related question rather than a technological barrier.

3.2 EV mobility integration to the Sello energy system

The sophistication of global energy systems has increased dramatically, with more data, interfaces and parties merging at the grid edge than ever before. The concept of grid edge refers to the interface of distributed energy demand and distributed energy supply with the electricity grid. (Siemens, 2020) There is significant innovation in both hardware and software components of the grid edge to support the rapidly changing electricity system which is moving away from the centralized paradigm to a more decentralized.

A decentralized energy system provides far greater opportunity to make smart, data-driven decisions at a detailed and specific level in order to optimize the energy system's efficiency and extract value. EVs, battery storage and on-site generation represent some of the levers that enable energy companies through smart business models to balance energy systems and counteract some of the challenges associated with intermittent renewable generation.

In action E7-2 Sello 24x22kW AC chargers are integrated to the local building management system via microgrid controller, that enables for Sello to include EV chargers in peak shaving, load shedding and to provide services to the grid that involve adjusting the amount of power the vehicle pulls while charging, in response to signals from the grid. See Figure 35.

The integration of EV chargers are done via OCPP interface. The type of AC chargers in Sello (Ensto chargers EVF200W-BSC) does not have Modbus interface that would be a preferred integration protocol for the load management applications. With this action integration for power limitation via OCPP will be also demonstrated. In Action E15-1,

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1xDC charger and 8xAC chargers will be integrated to the building management system using Modbus TCP protocol. This demonstration is done to Ilmatar Areena in Espoo.

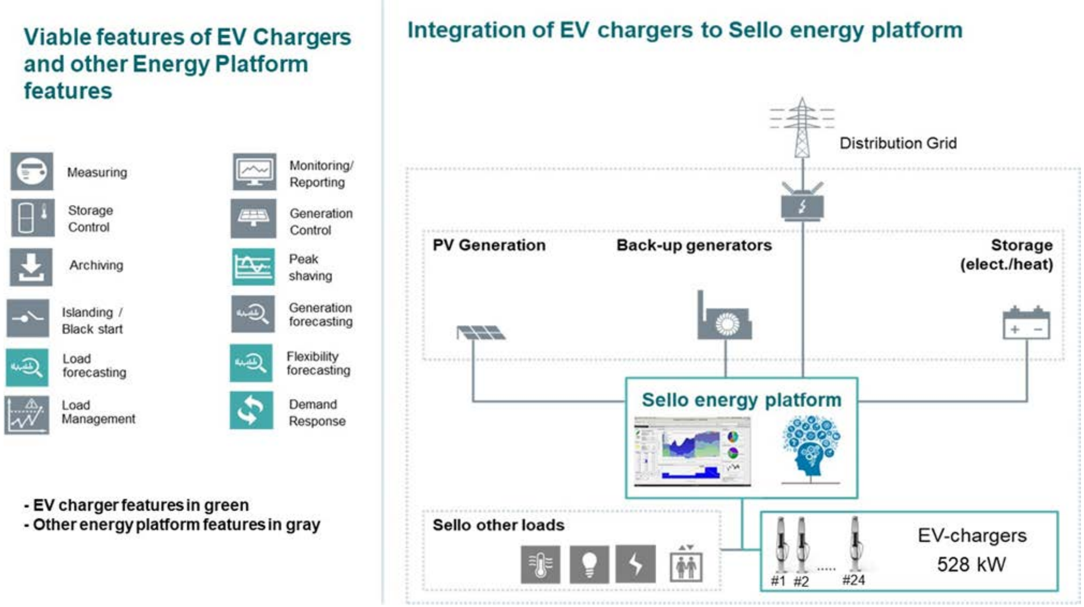

Figure 35. Sello EV chargers integrated to Sello energy platform

As mentioned, the Ensto chargers do not have the Modbus interface and instead use the OCPP protocol. A microgrid controller (MGC) is installed that translates the OCPP protocol to Modbus TCP so that a connection can be established between the EV chargers, Desigo CC, and eCarOC AWS to implement the load managing applications. This setup is visualized in Figure 36.

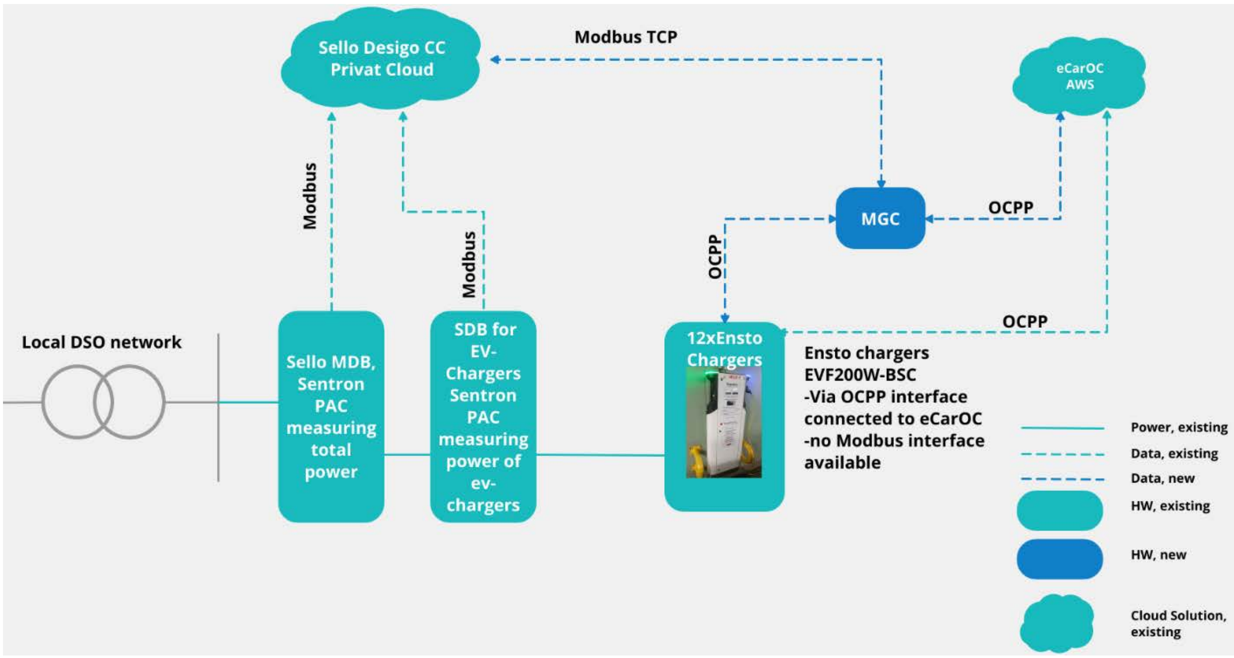

Figure 36. Solution for dynamically controlling loads of Sello shopping mall, including EV Chargers, based on peak load limitation

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By analyzing graphs displayed in Figure 37 of charging power (top graph) and rest of Sello's power (bottom graph), we can see that there is a correlation between the two. The load management applications being used to control the EV chargers results in the EV chargers' power being limited during Sello's other assets peak demand. We also see that there is no need for limiting the power of the chargers in the evening when Sello's other assets demand starts declining.

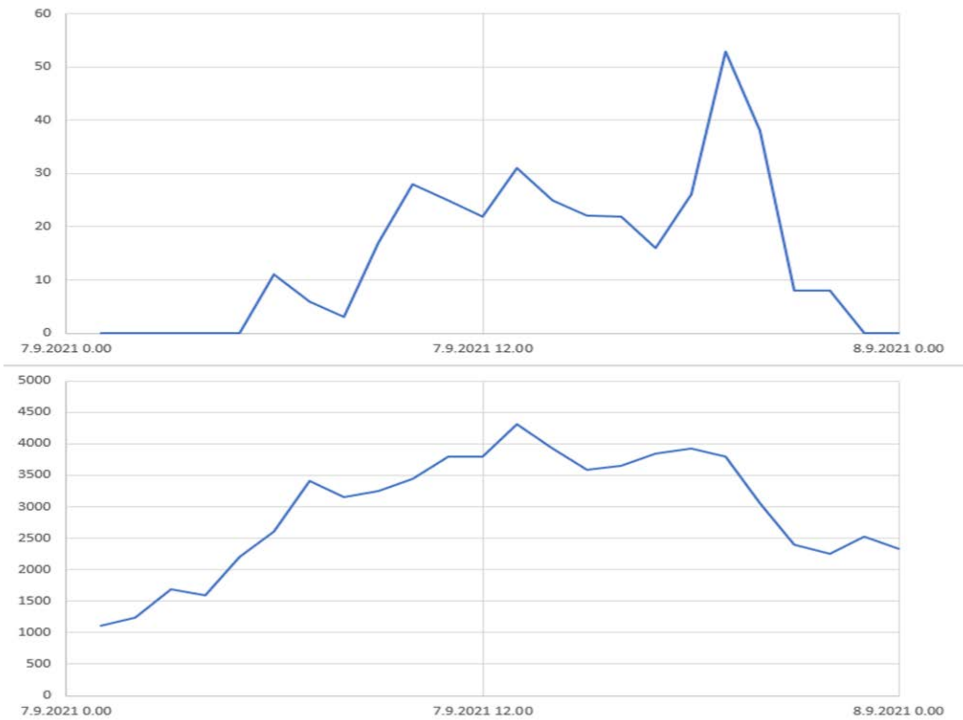

Figure 37. Charging power demand and Sello's other assets' power demand during an example day

In order to verify the solution, the test was executed on the simulation for 12x44kW chargers to evaluate the functionality of the load management control.

Control software was executed with the same hardware as installed on-site. Only chargers were simulated and limitation setpoints were given manually. Simulation target was to verify functionality of the control software.

Two different scenarios were selected. First one with the full power and no limitation, second one with random charging power and power limitation set to 200kW.

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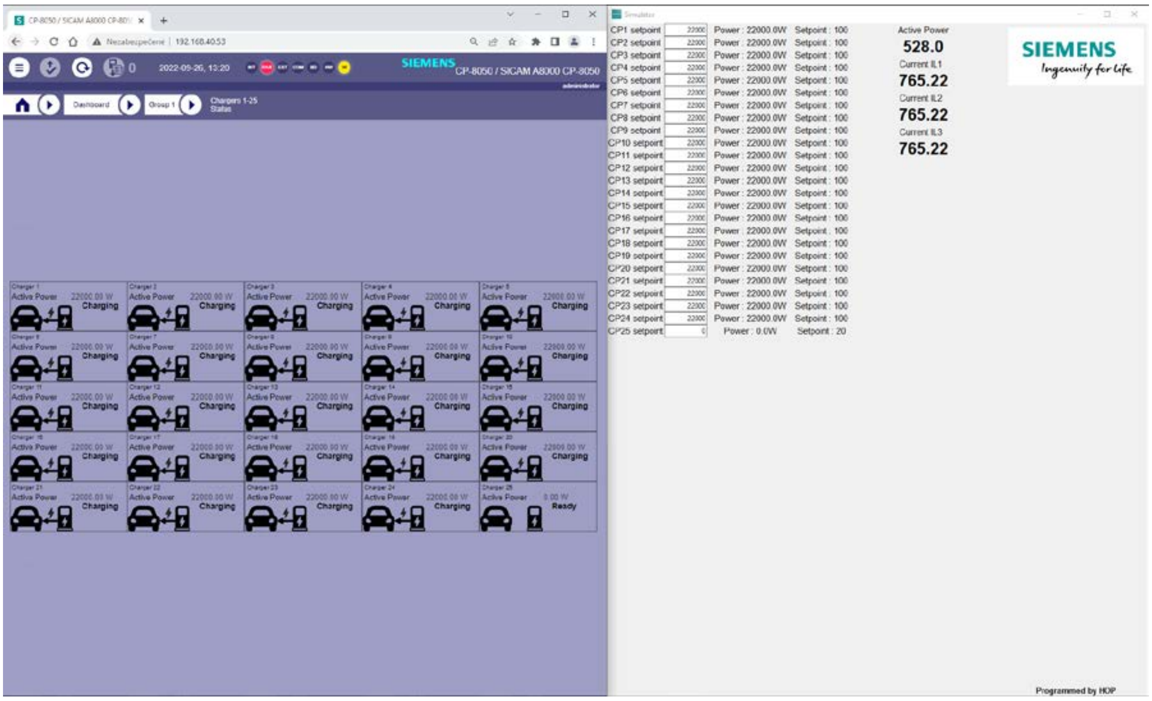

Figure 35. Visualization of charger status on the screen. Maximum power with the full load (22kW) at all charging points (24pcs) is 528kW. Controller on the left side and simulator on the right side. (Source: Siemens)

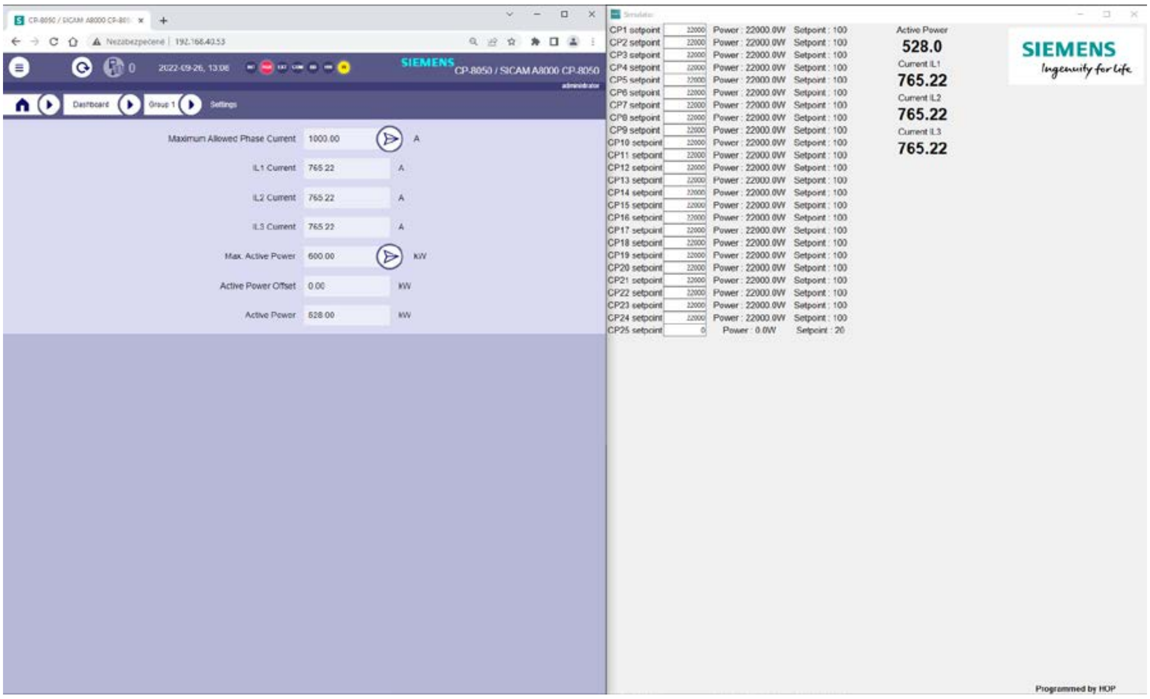

Figure 36. Maximum power with the full load (22kW) at all charging points (24pcs) is 528kW. Controller on the left side and simulator at the right side. (Source: Siemens)

In the first scenario maximum power limit is set to a value greater than the full maximum power consumption, therefore no limitation is applied and all the chargers are having the full power.

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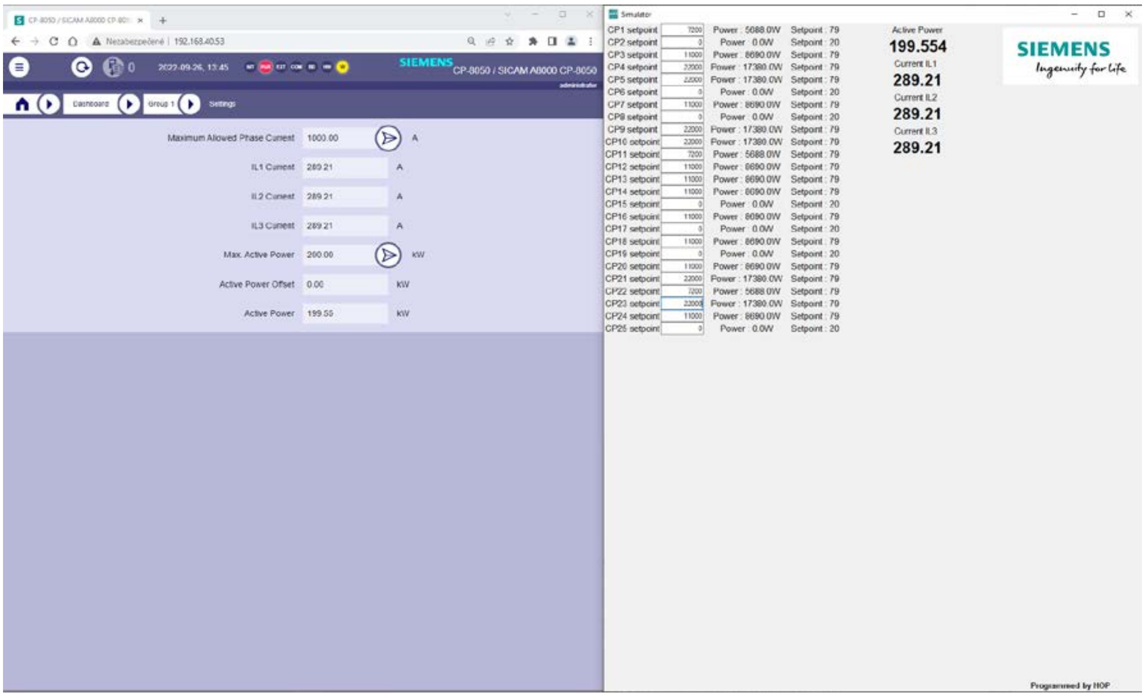

Figure 37. Power limitation 200kW executed with random loads on the charger side. Controller on the left side and simulator on the right side. (Source: Siemens)

In the second scenario the charging power is random between the charging points. When the total power limit is set to 200kW, the power is limited evenly in percentage between the charging points. PID-control will make sure that the limitation will be applied smoothly. Any changes within charging power at the charging points will be actively taken into consideration and the load will be reallocated accordingly.

3.3 Optimization of charging

The optimization of charging services was studied by means of simulations. The bus charging infrastructure has been built to be able to accommodate a further expansion of the electric bus fleet, and there is currently no urgent need to optimize the system. Furthermore, the current contracts do not allow restrictions in the usage; the buses have to get access to charging whenever required. However, the growing needs for charging, not only of buses but also of other commercial vehicles, will increase the potential of a smart charging system and cost benefits can be reached by keeping the power peaks as low as possible. The developed simulation methods and the simulation results are discussed in this section. The simulations have been developed by VTT in collaboration with Plugit.

3.3.1 Description of Models

The simulation has been written in Python 3 with several external modules. The reason for the decision was to have the full flexibility that comes with the Python ecosystem (network simulation, plotting libraries etc.)

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Two simulation approaches were tested. First, a simple time-series simulation was made. During each time step, each vehicle could either be in driving mode, in terminal or in depot. The vehicles consumed a predefined amount of energy during driving mode. Basic charging logic was applied for terminal and depot modes, e.g. the charging cannot exceed the capacity of the chargers. There proved to be many challenges in deriving the demand for charging so as to generate the demand that would approximate the validation provided by Plugit.

The shortcomings of the first simulation led to a development of new methodology for the second simulation. The second approach focuses on properly deriving the charging demand through optimization of charging costs while still being able to fulfill the daily cycle. This approach behaved much better and a good match with validation data has been achieved, except for an outlier in the evening hours, where it was not possible to derive the demand for the late evening charging.

The second approach is also more flexible as it simulated the duty cycles based on Markov chain patterns. This allows for controlled derivation of a variety of duty cycles which should match the duty cycles experienced in reality. Through a charging price optimization of charging for each duty cycle, it is possible to show the demand from the whole charging network caused by the studied vehicles and it is also possible to filter the charging happening in a single e-hub. This allows for optimization studies where we not only focus on a single hub, but we can also observe global changes in charging demand, therefore the whole optimization task is better anchored to reality.

3.3.2 Scenarios done with Model 1

Plugit offered VTT insights into the vehicles being charged in the Leppävaara hub now and in the future. The assumptions are shown in Table 5. All chargers are connected to the same transformer having a maximum capacity of 4000 MW.

Table 5. Charging specifications for scenarios now and in the future. If there is a range for the future scenario, it means that multiple options were studied. Source: VTT

Vehicle type	Charging specification	Maximum charging capacity (amount of vehicles)	
		Now	Future
Car	22 kW AC #	40 (20 PHEV)	40-120
Car	50 kW DC #	1	1
Bus	120 kW DC cable	5	5-10
Bus	300 kW DC overhead	6	6-12
Heavy truck	100 kW DC	0	1

Data from the existing charging infrastructure was provided by Plugit for calibration and validation of the simulation models.

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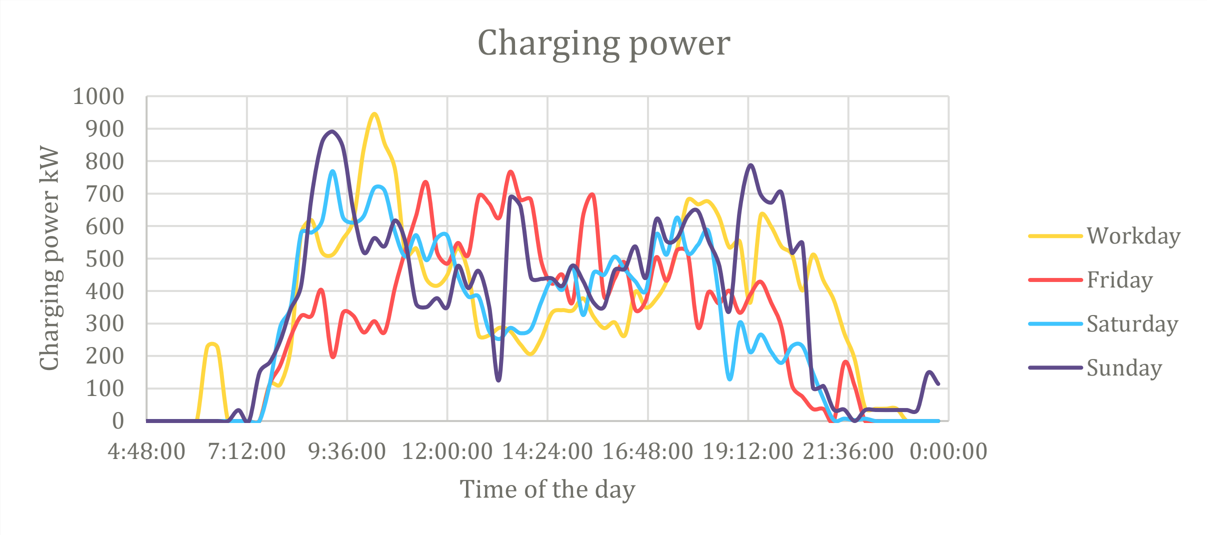

Figure 38. Real charging data for buses charging in Leppävaara e-hub - February 2020 (Source: Plugit, processed by VTT)

In Figure 38 we can observe that charging activity typically starts roughly at 7 AM and ends at midnight. The powers in the winter reach up to 950 kW, well below the transformer limit of 4 MW mentioned earlier. The workday data has been used to further calibrate the simulation.

Three different scenarios were evaluated utilizing the time series model. First, a base scenario simulation including 10 buses, 20 BEVs, 7 HEVs and one truck was carried out. The range of the buses was assumed to 300 km.

The base scenario had to be adjusted so that the charging events match the expected outcome from Figure 38. This has been done by the trial and error method until the result looked satisfactory (Figure 39).

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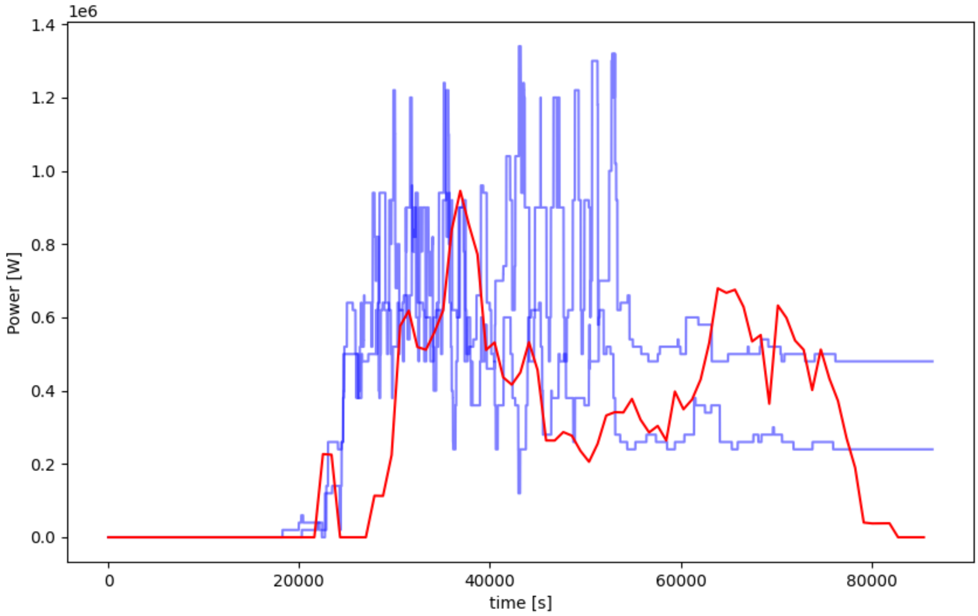

Figure 39. The result achieved for the Base Scenario, x axis in seconds after midnight, y axis in MW. The blue lines represent randomized scenarios, while the red line represents the validation data. Source: VTT

As second scenario with several buses was set up similarly to the previous one, but instead of 10 buses, 20 buses were simulated. The results are illustrated in Figure 40.

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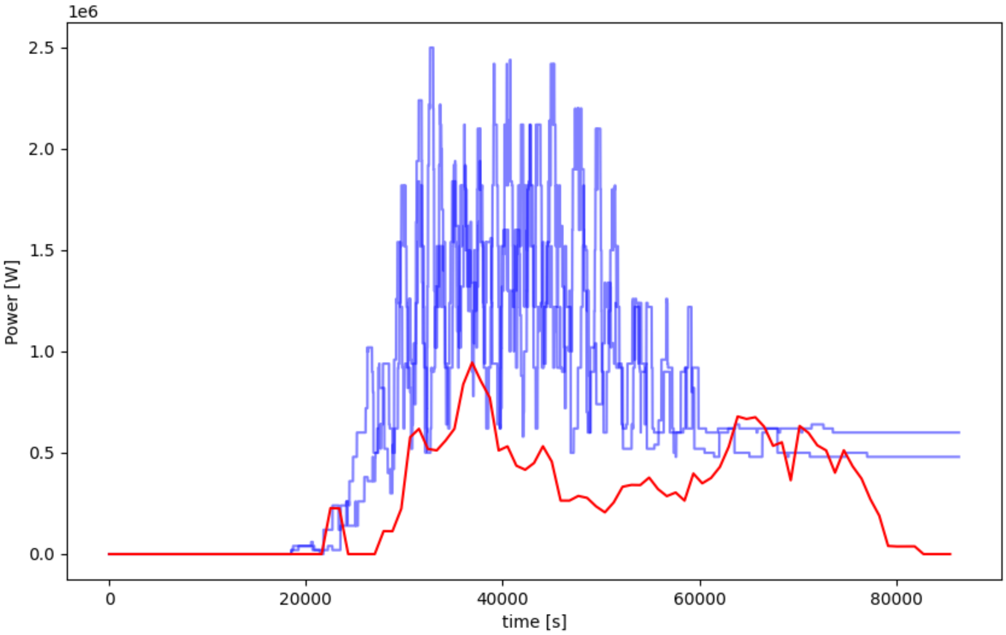

Figure 40. The result achieved for the Increased Buses Scenario, x axis in seconds after midnight, y axis in MW. The blue lines represent randomized scenarios, while the red line represents the validation data. Source: VTT

Last, a simulation with 60 cars instead of 20 was simulated while the other settings remained the same as in the first simulation (Figure 41).

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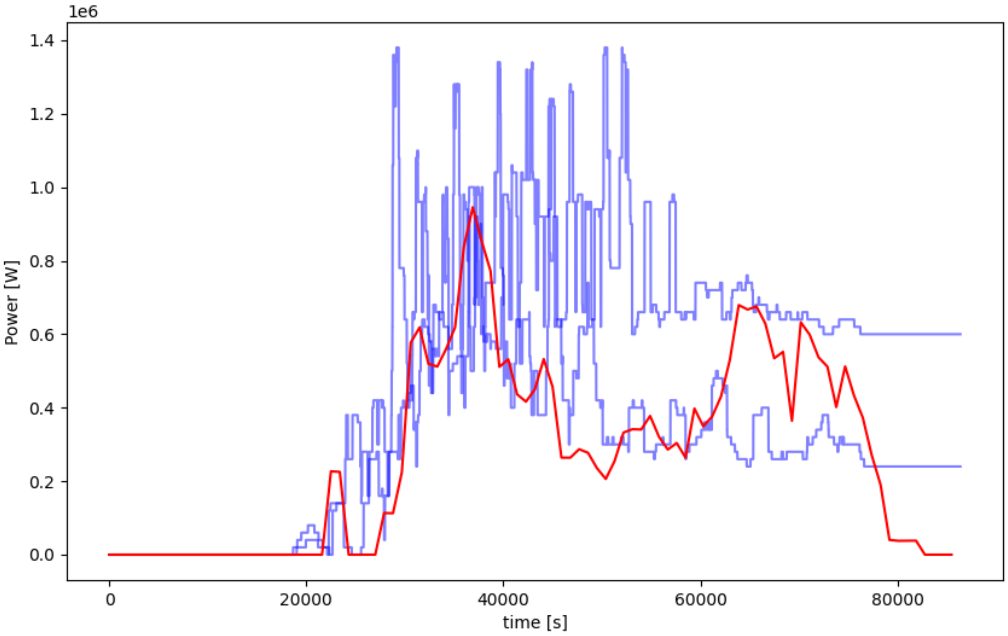

Figure 41. The result achieved for the Tripled cars Scenario, x axis in seconds after midnight, y axis in MW. The blue lines represent randomized scenarios, while the red line represents the validation data. Source: VTT

While the first model gives us some impression about how charging events combine to produce a charging demand curve at the e-hub, the results are not very satisfactory. i.e. a rather high deviation between the simulated result and the validation data can be seen in Figure 39 - Figure 41. This influenced the decision to start building a second model with different philosophy in mind.

3.3.3 Scenarios done with Model 2

One of the key elements in the task E7-3 was to achieve reduction in peak power through charging optimization. With simulations we can prove that there are possibilities to adjust the charging schedule, but it requires different architecture for the simulations. Distributing the charging events around the day is not satisfactory anymore, we need to keep track on the SOC in order to be able to prove that the adjustment does not affect the daily operation of the bus. And in order to do that we need to have at least a vague idea about the needs for driving energy throughout the day (Figure 42). Then we need to know more about the whereabouts of the vehicle when it is stationary, but it is enough to know the type of the charging possibilities.

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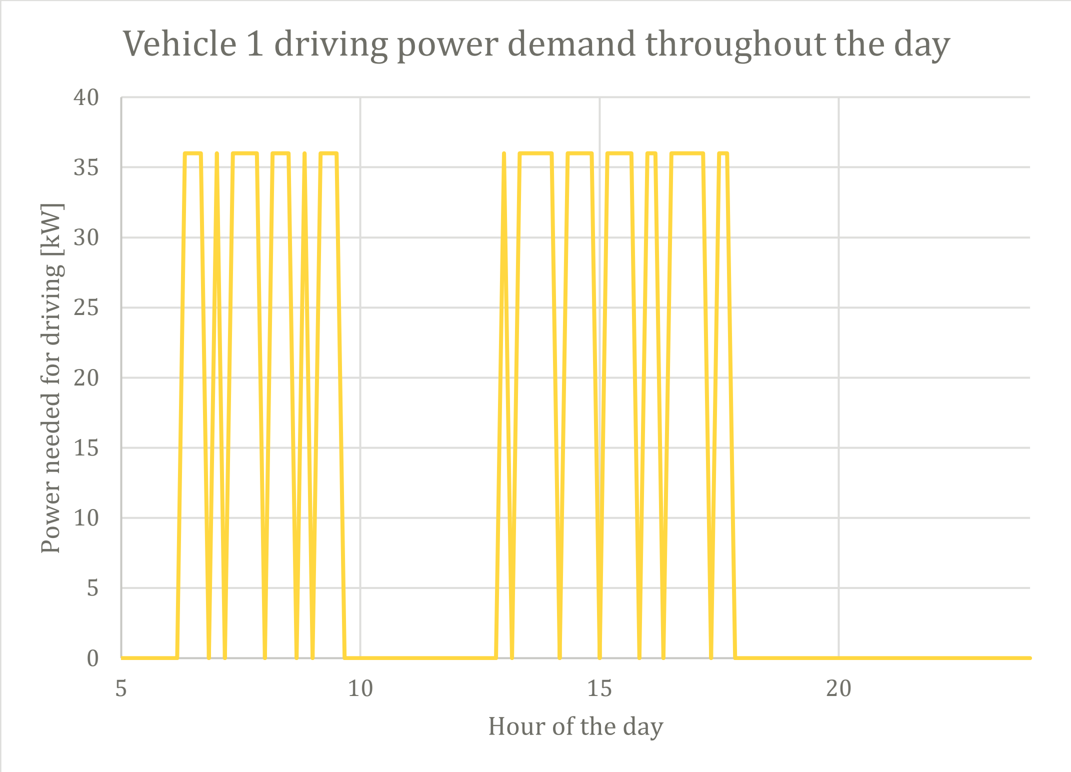

Figure 42. A theoretical example of the needed power for the bus during the day. Source: VTT

Obtaining the driving need throughout the day in a meaningful way is a challenging task since the records of driving per vehicle are not publicly available (public trips are available, but not all the deadheading). As a solution Markov chain based on the observed activity could be used to generate synthetic driving demand. In addition to that we could use the Markov chain to infer if the vehicle is waiting in terminal or in depot.

For the simulations, we derive a Markov chain with varying matrix based on the available schedules. A Markov chain is a stochastic model describing the transitions from one state to another. The probability of the transition is dependent on the current state. In our case, the vehicle activity is treated as a state, i.e. the bus can be parked at a terminal or at the depot or it can be driving. The vehicle states are updated for each timestep (in this case one timestep = 10 min) With probability x coming from the matrix, the bus would switch for the next possible state. For example, if the states have chances:

Depot = 0.6

Terminal = 0.2

Drive = 0.2

Then the vehicle would most likely end up in depot in the next timestep. These probabilities depend on the time of the day as well as the current activity/state. An example of duty cycles derived from the Markov chain can be seen in Figure 43.

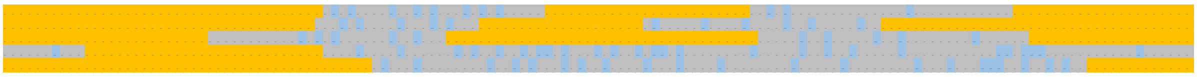

Figure 43. Chart representing the duty cycles obtained from the Markov chain. There are 5 rows representing 5 buses, yellow = depot, grey = drive, blue = terminal. Source: VTT

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After having the schedules, we established the boundaries for optimization for each vehicle. We have the times when it can be charged and we know the times when the vehicle is discharged by driving. Now if we turn this space into a traversable graph, we can try to find an optimal "route" from the beginning to the end of the observed charging period. The idea is that the nodes are representing possible combinations of SOC and timestep, so for example if we have 10 nodes for each timestep and we have 144 timesteps we'll have a chart with 1440 nodes. The edges connecting the nodes should only connect the nodes in the nearby timesteps and they should only exist if such behavior is possible for the vehicle. In timestep when the vehicle is driving, there will be only one edge going to only one possible next state which reflects the SOC reduced by driving. On the other hand, for charging, we'll have many edges pointing upwards to nodes with higher SOC as well as an edge reflecting zero charge. And to study the V2G option we could have edges pointing downwards. The cost on these edges then needs to reflect the cost of each behavior. Depending on the pricing scheme, upward edges have the same cost throughout the day or various to reflect for smart pricing. Downward edges have negative price to reflect for the money being paid to the operator of the vehicle.

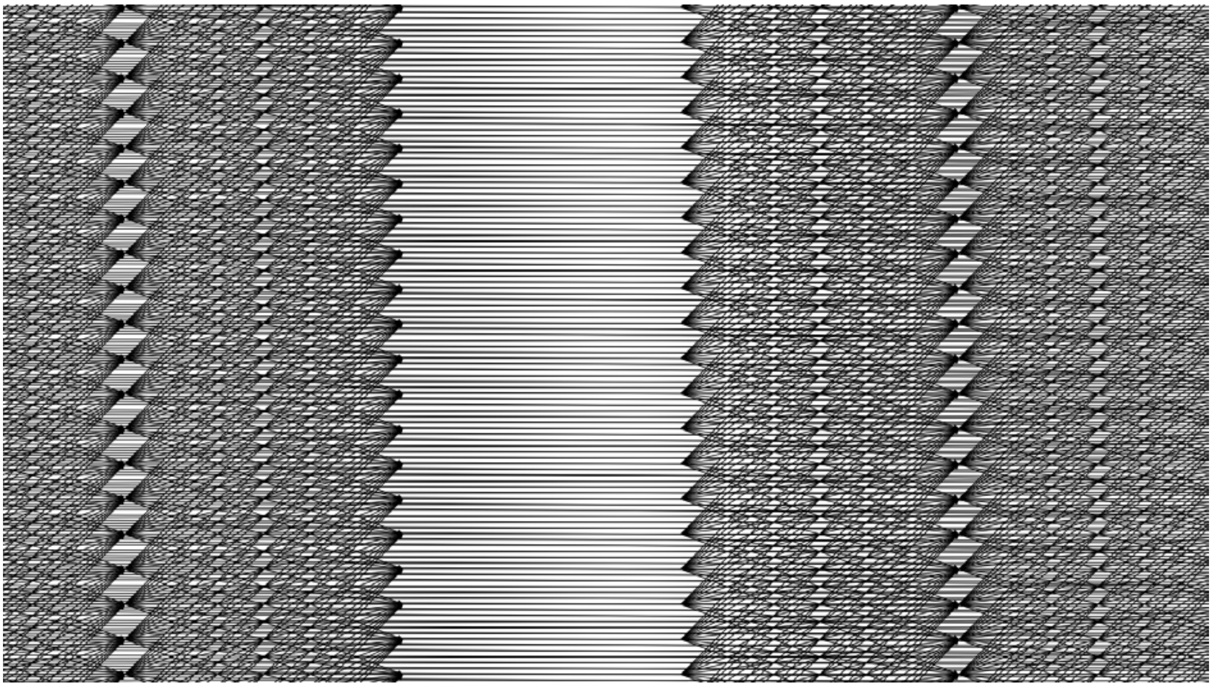

Figure 44. Zoomed-in part of the time-SOC graph to be traversed, x axis represents time, y axis represents SOC. Source: VTT

Having found the optimal charging curve for the situation we are able to aggregate those together to get different scenarios for charging. Nine different scenarios showing the impact of various pricing schemes and charging power levels were evaluated. The scenarios are outlined in Table 6. Slow charging means that the buses can charge only at the depot whereas fast charging means that charging at the depot is not available and all charging happens at the terminal under study (Leppävaara e-hub). Mixed charging means that both charging locations can be utilized. The pricing curve for spot charging is shown in Figure 45. The price for constant charging was set to 0,1 €/kWh. All scenarios are here

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simulated with 100 buses, but they are scaled for 20 buses which causes the peaks to be somewhat less pronounced.

Table 6. Simulated scenarios

Scenario name	Constant price	Spot pricing	V2G
Slow charging	B1a	B1b	B1c
Mixed charging	B2a	B2b	B2c
Fast charging*	B3a	B3b	B3c

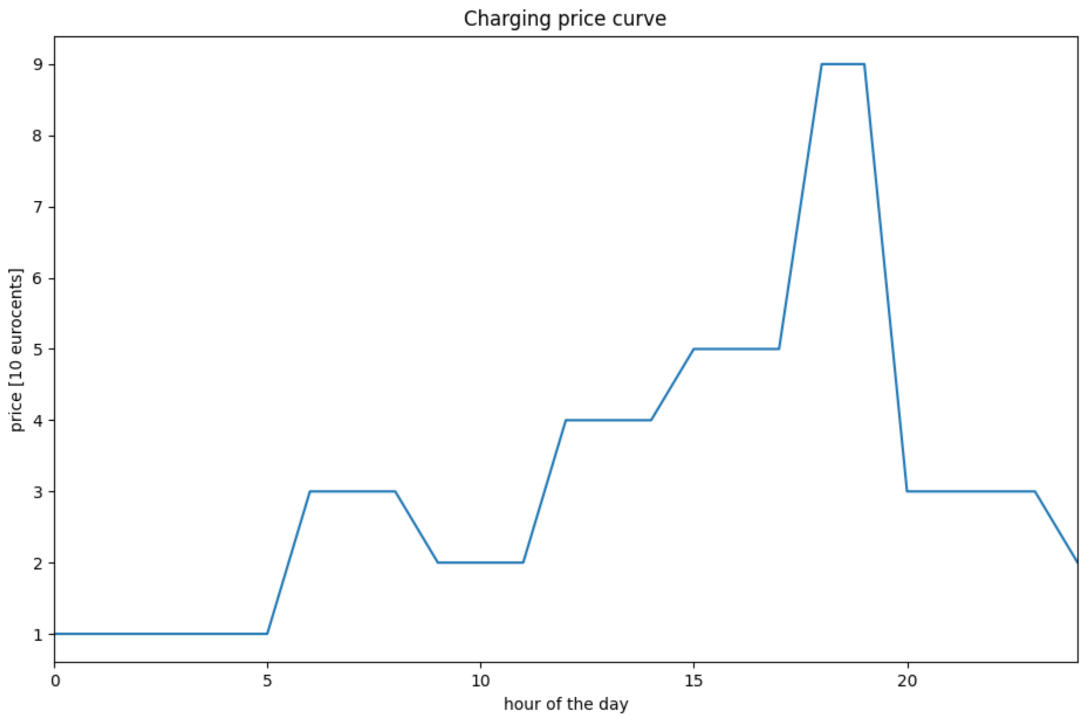

Figure 45. Pricing for smart charging example. Source: VTT

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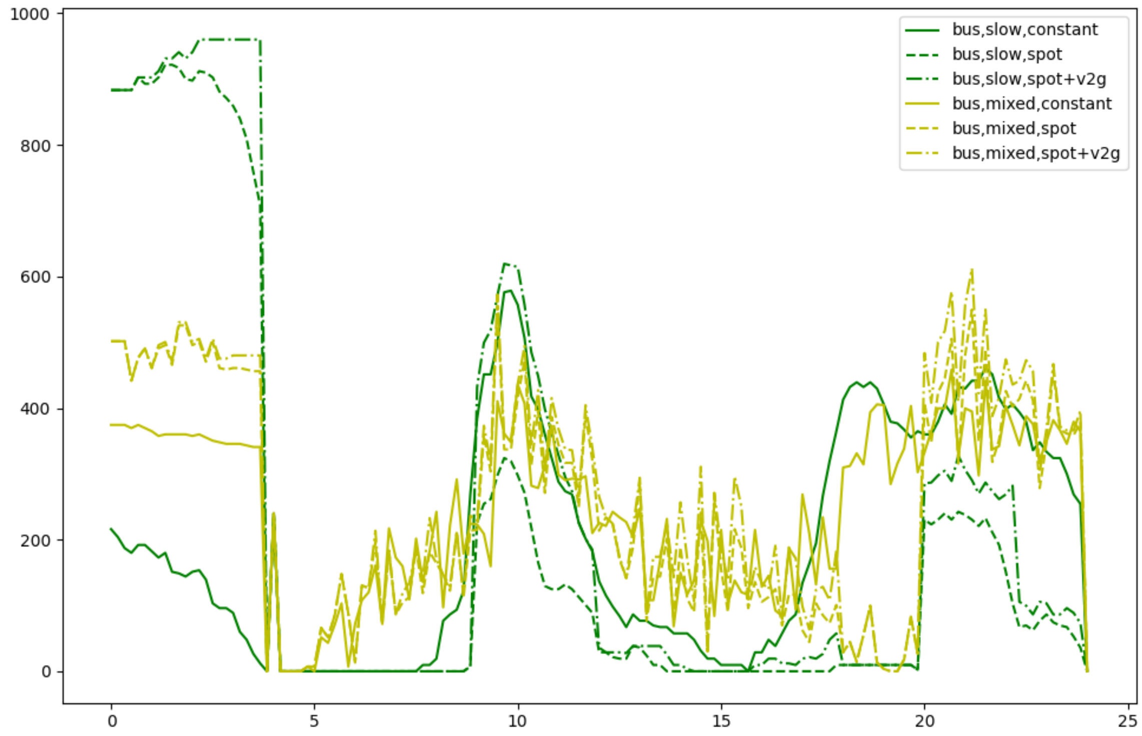

Figure 46. Charging powers during the day for different scenarios with buses, x axis for hour of the day, y axis for power (kW). Source: VTT

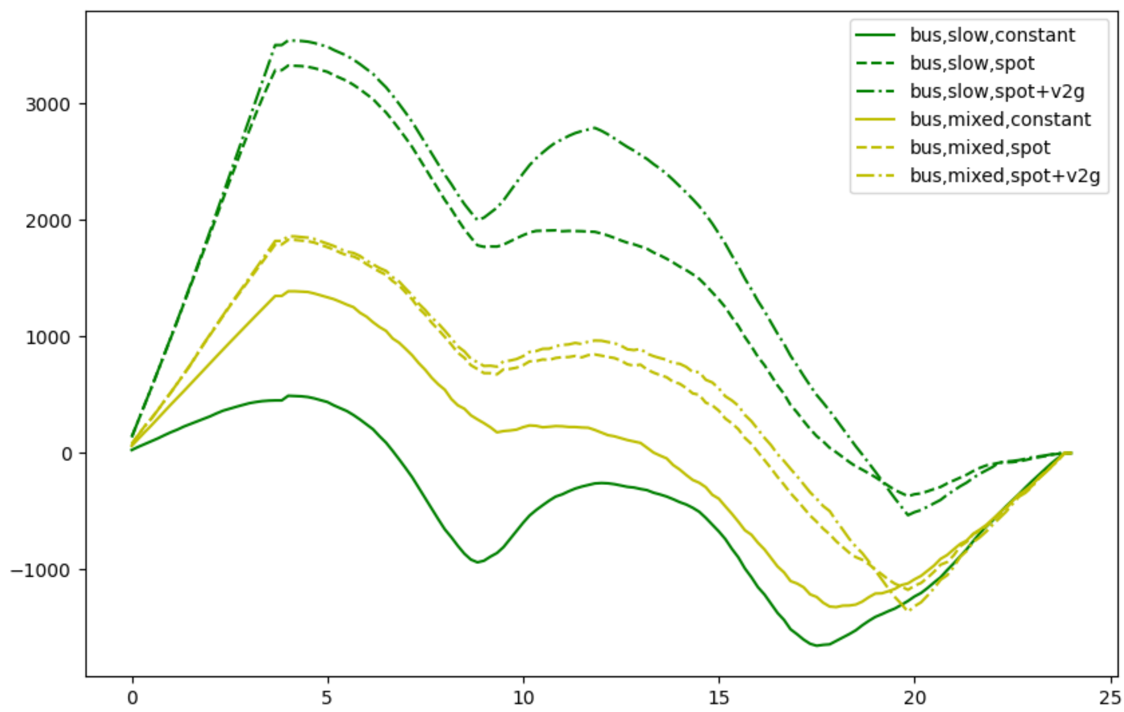

Figure 47. Charge of buses during the day. Source: VTT

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Table 7. Maximum charging powers for each scenario in kW

	Constant price	Spot price	V2G
Slow	578.4	921.6	960
Mixed	458.4	555.6	612

The simulation with fast charging only did not work as the buses were not able to operate the whole day without depot charging. Depot charging has the highest power peak, but it occurs during the night when the electricity demand in general is at lowest.

3.3.3.1 Grid fee optimization

Next, the possibility to minimize grid fees by optimizing the charging to have as low power peaks as possible was investigated. It was assumed that the grid fee increases by 2 €/month for each 1 kW that the peak power increases. The charging price was kept constant at 0,1 €/kWh.

For the optimization, a mutation algorithm has been applied. The main idea of the mutation algorithm was to limit the charging if it reduces the peak power fee. The grid fee optimization was tested with two scenarios, B2b and B2a in Table 6. The resulting power limitation is shown in Figure 48 and Figure 49.

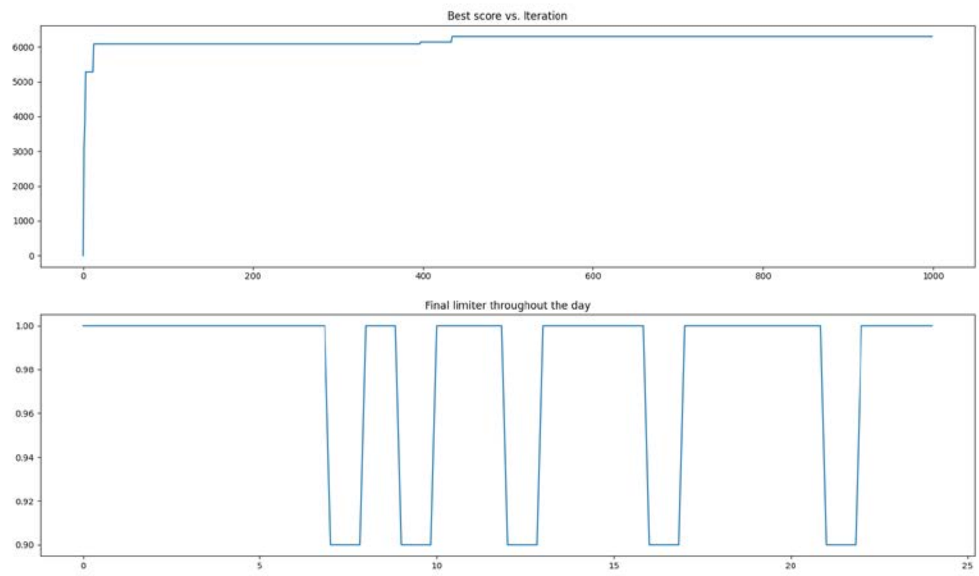

Figure 48. Scenario B2a optimization. Source: VTT

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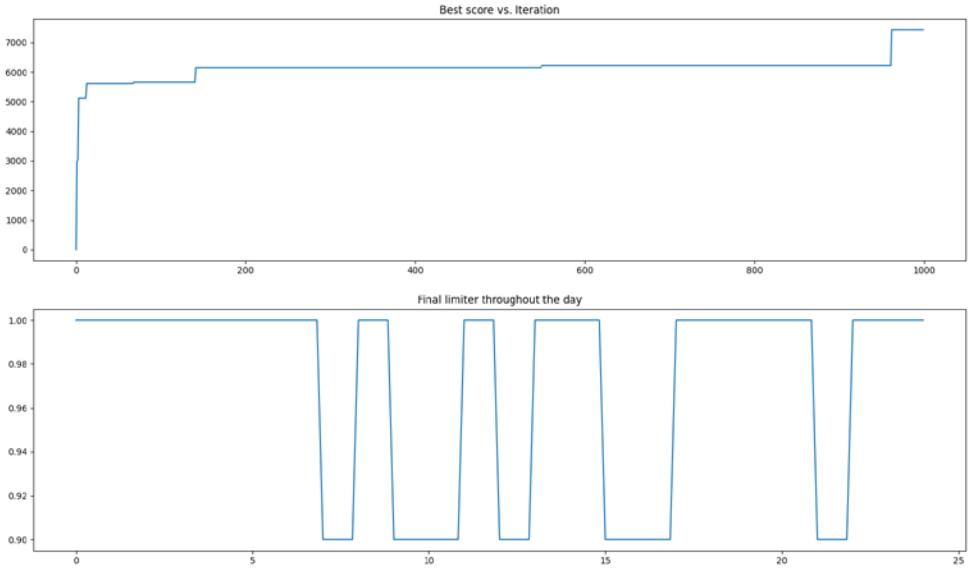

Figure 49. Scenario B2b optimization. Source: VTT

Before the optimization, there was 1960 kWh / 6534 kWh charged in the eHub. Due to the optimized power limiter, 1457 kWh /6462 kWh was charged in the eHub after 100 iterations. The reduction in total energy charged is due to reallocation of some of the charging to depot charging. The energy charging curves before and after the optimization are shown in Figure 50 and Figure 51. The way that the optimization limits the maximum charge for each bus can be seen in Figure 52, note that the values are for 10-min interval (multiply by 6 to get the charging power).

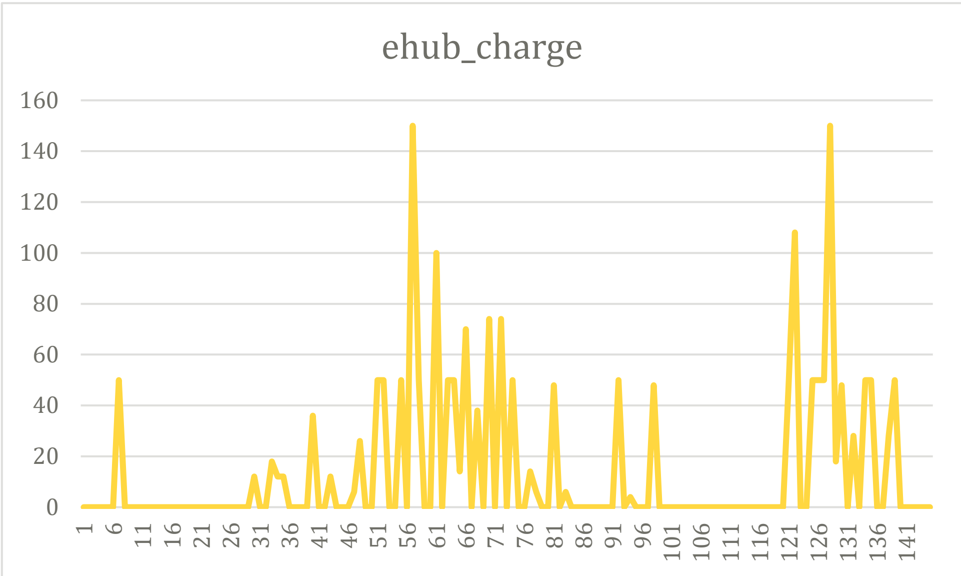

Figure 50. Energy charged during each 10-min section of the day before optimization. Source: VTT

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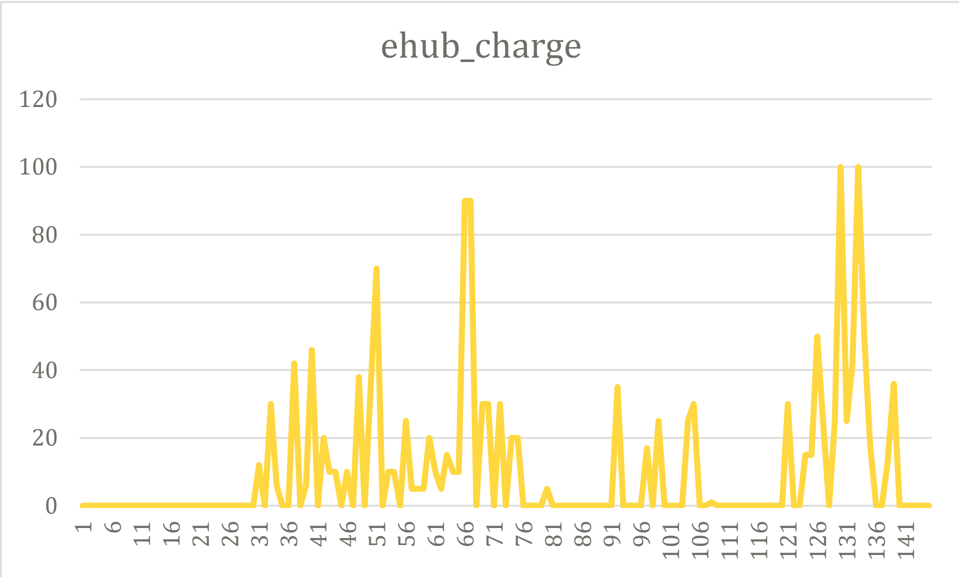

Figure 51. Energy charged during each 10-min section of the day after optimization. Source: VTT

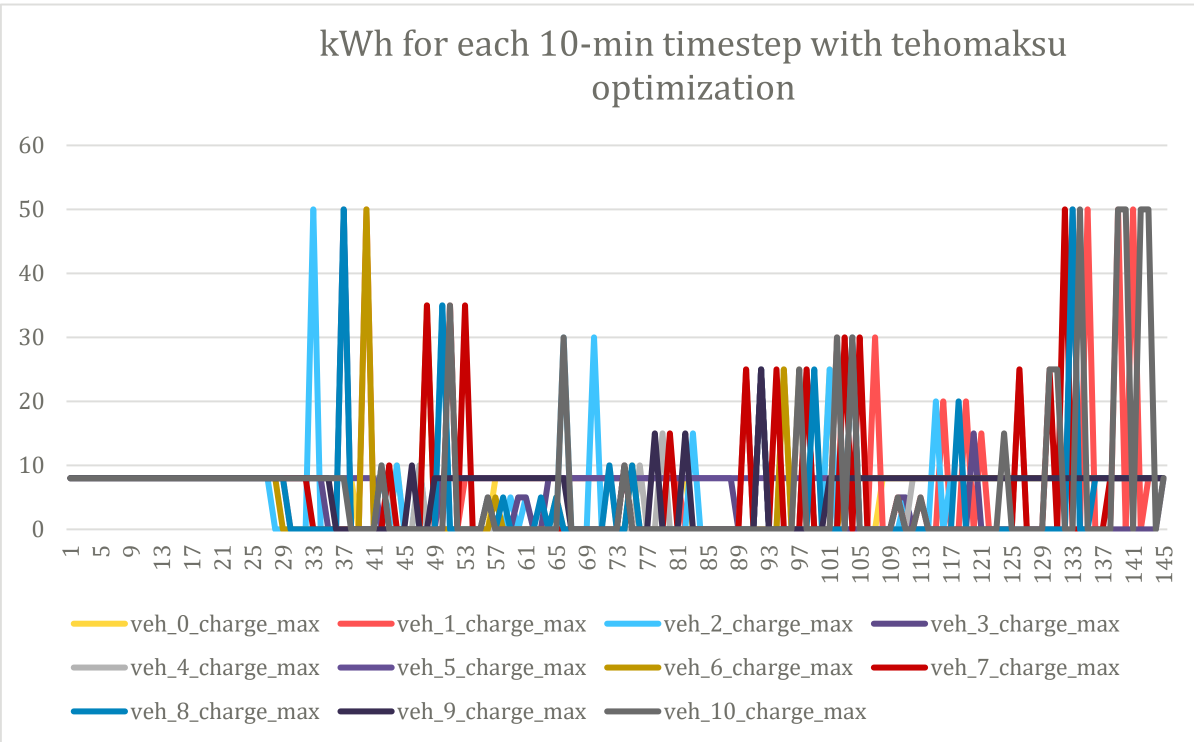

Figure 52. Energy (kWh) chargeable in each 10-min section of the day after power fee optimization. Source: VTT

The optimization leads to a power limitation of about 90% of the original resulting in a slight improvement of the profit of the charging stations. However, it led to significant reduction in the energy charged overall, since many buses ended up charging more in the depot locations.

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3.4 Evaluate shopping behaviour in the EV charging concept

A literature review was carried out in order to evaluate the feasibility of dynamic pricing for EV charging. The findings and a reflection of the results in the case of the Sello shopping centre are presented here.

3.4.1 Literature review on dynamic pricing models and their suitability for charging operations

As the role of electric vehicles (EVs) in reducing carbon emissions becomes increasingly important, the demand for efficient charging of EVs also increases. Uncoordinated and uncontrolled charging of EVs can lead to difficulties in guaranteeing the quality of the distribution network performance. To overcome this issue, it is possible to influence charging activities by utilizing dynamic pricing based on demand. In addition, charging operation providers face uncertainties in determining charging prices due to volatility in the wholesale electricity price, nature of renewable energy generation, and spatial-temporal EV charging demand (Luo, Huang & Gupta, 2018). Several dynamic pricing models are identified by Amin et al. (2020) in their research for an optimal electric vehicle charging strategy and addressing uncertainties related to EV charging. The role of energy storage in the charging operations can also be important in smoothing charging price volatility.

Real Time Pricing (RTP) refers to adjusting the price at consistent intervals as short as a few minutes. This leads to increased uncertainty for the customers, but it is efficient for the charging operations as it reflects the actual supply costs. The desired load curve can be achieved by adjusting the pricing for each customer individually. This model's suitability is good when it comes to adjusting supply and demand, but it will increase uncertainty on the customer's side. RTP could be implemented for charging stations in a way that customers can get information about optimal charging stations which will also reduce queues.

Time of Use (ToU) is a pricing model where the price is based on time block rates of electricity. These rates are announced significantly in advance and are based on historical data. During the off-peak period there is more supply than demand, so prices are lower. During mid peak capacity and demand are close to each other so pricing is moderate. To meet demand during peak hours expensive additional power generation has to be activated and prices are high. When we think about this option's suitability for charging operations, we see that if we were to charge all EVs during off-peak periods we might create a new peak period.

Critical Peak Pricing (CPP) is similar to ToU, but it relies on forecasting high demand periods with present conditions instead of historical data. CPP is better at peak load reduction than ToU as sophisticated algorithms can be used to decide when peak prices should be triggered. CPP events are triggered for longer time periods when electricity grids are being strained more than usual.

Peak Time Rebates (PTR) offers customers rebates for using less than the preset limit during peak hours. It gives customers more control of their electricity usage and they view

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shifting consumption to off-peak periods more favorably. It is costlier for electricity providers to implement as it requires precise estimation of customer baseline load.

Determining which pricing model is most suitable for EV charging operations depends on what we are looking to optimize. Power loss minimization can be achieved by implementing an optimized charging schedule. Electricity cost minimization can also be achieved by scheduling charging to off-peak hours. Peak load minimization can effectively be achieved by utilizing RTP to create preferred charging time slots that consider the varying electricity price. Dynamic pricing can also be used for profit maximization from smart electric vehicle charging stations (EVCS) that are equipped with photovoltaic and energy storage systems. EVCS can be operated with the help of machine learning to find optimal schedules for profitable selling and buying price and charging or discharging of EVs (Lee & Choi, 2021). Vehicle-to-grid (V2G) services can be used for discharging and they play an important role in the process of optimizing the load of the grid.

All in all, RTP seems to be the preferred pricing model as it helps regulate the load on the grid with price signals and EV customers can manage their charging activities with high flexibility. On the other hand, implementation requires sophisticated communication infrastructure between the different stakeholders of the charging operations to get current data on the charging activities. It is important that the customer's confidence in the dynamic pricing can be gained for them to accept it.

3.4.2 Understanding how to implement EV charging business models to enable EVs to participate in balance management

Continuing to build on what we discussed in the last part, there are EV charging business models available to assist in balance management. By for example utilizing the V2G option, which means utilizing EVs to transfer energy from the battery of an EV into the power grid (Virta, 2022), EV customers can help in managing the load of the grid as they can essentially be seen as self-contained mobile resources that can help in balance management and aid in the transition to carbon neutrality (Sovacool & Hirsh, 2009). V2G also leads to a decrease in lifetime costs for EV users.

Sovacool et al. (2020) discuss business models for V2G based on research from Nordic countries. The research identifies the following stakeholders: automotive manufacturers, battery manufacturers, vehicle owners, energy suppliers, transmission and distribution system operators, fleets, aggregators, mobility as a service providers, renewable electricity independent power providers, public transit operators, secondhand markets, and secondary markets. These stakeholders are strongly connected, and their business models often rely on the actions of the other stakeholders. For example, all the stakeholders are dependent on the battery manufacturers as well as the automotive manufacturers as they enable the existence of the other stakeholders and their business models. For EVs to participate in balance management these two stakeholders must create EVs that are able to participate in the V2G operations and they should work on improving the efficiency of these EVs. We then have the stakeholders focusing on the grid. They must create a grid that can balance the load dynamically and maintain charging points (commercial and residential) to enable V2G services. Then there is the operators

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and owners of the EVs. They must be willing to provide energy and energy services to the grid which can then be utilized in balance management. Peak load can be levelled with V2G, and renewable energy can be utilized more efficiently as it can be stored better with the help of EVs.

Implementation of these business models requires that all the stakeholders strive to work together to guarantee efficient compatibility of their respective parts in the system. This could be for example achieved by regulatory means for standardization that are developed together with the most important stakeholders in balance management. It is also important to think about the social aspect of implementing V2G. Sovacool et al. (2017) highlight the need of understanding sociotechnical barriers in V2G acceptance. They propose focusing on underlining the climate change benefits of V2G and correcting EV customers view on privacy and battery degradation in relation to the concept of V2G. Lessons in widespread acceptance can be learned from for example earlier smart meter rollouts that lacked consumer focus and V2G pilot projects should be utilized to gather insights into the relevant social themes.

Another important theme that arises from implementation of charging business models is data privacy. Han & Xiao (2016) bring attention to the way that V2G networks can facilitate privacy attacks on the users' data, which is further aided by the mobile nature of the communication as vehicles are involved. Several privacy preservation practices for protecting users' data already exist, but it is important that privacy is not an afterthought but a priority in the implementation of charging business models in balance management.

3.4.3 Researching dynamic pricing business models for EV charging in Sello

To find a suitable business model for Sello we must first analyze the installed EV charging infrastructure in Sello which is presented in Figure 53.

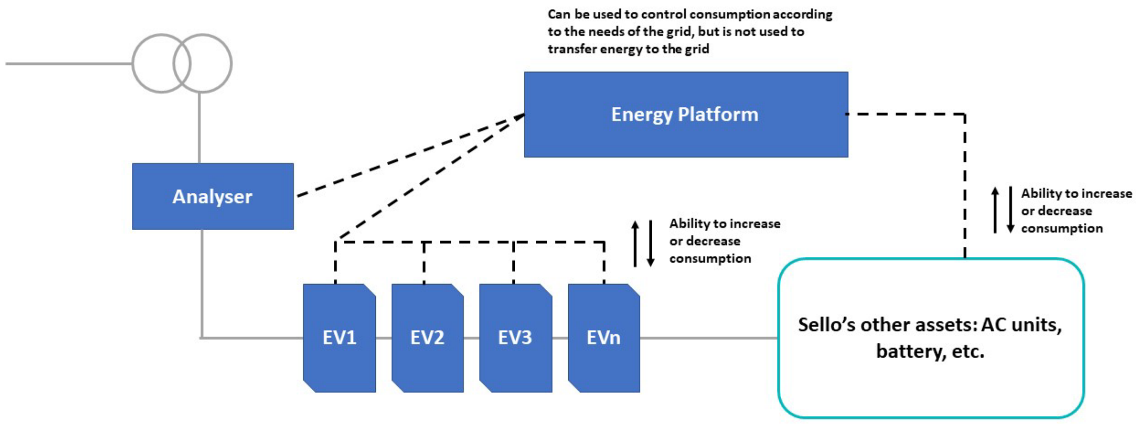

Figure 53. Sello EV charging setup

Sello's EV charging and other assets can increase or decrease their consumption based on the needs of the grid. These assets are connected to an energy platform that can control consumption based on what an analyzer of the grid tells it to do. It is important to note that energy is not transferred back into the grid which means that implementing V2G in

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Sello is not possible yet. Siemens and Sello already have similar solutions with the grid provider related to flexibility, for example Sello's virtual power plant. Dynamic pricing is thus a viable solution for controlling the balance of supply and demand in the EV charging case.

We must also account for the different customer profiles in EV charging. According to Fuels Institute EV Consumer Behavior report (2021), customers have different preferences when it comes to for example preferring speed of charging versus price. Sello's chargers are able to accommodate both customer profiles as pricing can be based on €/kWh or on getting a certain charging speed which is based on power. A more price sensitive customer might be ready to be more flexible in their charging needs depending on the grids needs while a customer in need of full charging power would be willing to pay a higher price for peak power increase.

The Fuels Institute report (2021) also finds that when charging costs are low customers tend to spend more time dwelling in shops and thus increasing how much they spend. Generally charging is cheaper when consumption is lower and thus demand is lower. Looking at an example graph of Sello's total consumption (Figure 54.) reveals that demand is generally the highest during the middle of the day and lower during the morning and evening.

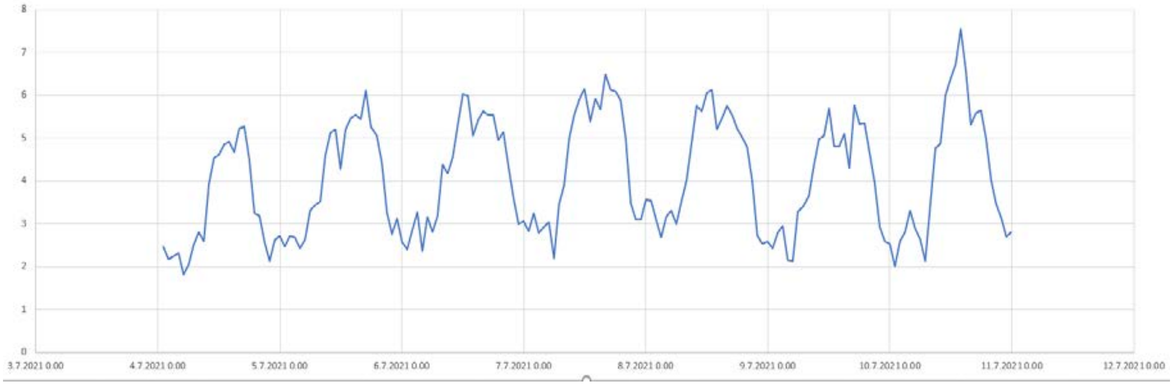

Figure 54. Sello's total consumption in MWh from 4.7.2021 to 10.7.2021.

By subsidizing EV charging during off-peak hours demand could potentially be evened as more customers arrived during these hours and they would spend more time and money in the shops while charging their vehicles.

The Real Time Pricing (RTP) model described earlier would be a good fit for Sello's dynamic pricing solution for EV charging as it is able to accommodate the different customer profiles when it comes to charging behavior. This solution would be aligned with future advancements as an interview conducted by McKinsey & Company (2021) on the topic of the future of EV charging infrastructure points into the direction of developing more advanced RTP models to accommodate a more dynamic and flexible smart grid.

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4. E-MOBILITY SOLUTIONS IN KERA

The Actions in the Kera demonstration area focus on the planning and design phase of new urban areas, and the questions related to implementation of e-mobility and sustainable urban mobility solutions in an area already in the construction phase and beyond. Kera is developed into a new urban district with both residency and workplaces, and it will emphasize walking, bicycling, public transportation and shared mobility service use.

The Actions focus on replicating the key learnings and insights from the other Task 3.4 Actions and supporting their implementation in Kera in the planning and design phase. The Actions aim to support the creation of a multimodal mobility system in the area, utilizing the existing train station as a hub for e-mobility and mobility services, which support the sustainable urban mobility targets of the area. Workshops are utilized to produce new insight about the possibilities of mobility hub development next to the increase of e-mobility solutions utilization.

Table 8. Activities for Kera area as outlined in the Grant Agreement.

Subtask 3.4.3	E-mobility solutions replication and uptake in Kera
Responsible partners	ESP, VTT, SIE, PIT
Actions	**E13-1** Multi-modal transport solutions with focus on last- mile including charging of the e-fleet. The aim is for an emission-free, clean multi-use area (living, shopping and services) by minimizing the need for private cars. (ESP) **E13-2** Replication of e-mobility solutions. Further development and implementation of Leppävaara e-mobility solutions. (Action E7-1) Charging stations for company-owned electric vehicles. (ESP, VTT, SIE, PIT)

4.1 Multi-modal transport solutions

The future Kera district is developed actively as an area that emphasizes walking, bicycling and public transportation and shared mobility service use. The already existing commuter train station in the heart of the developed area will form the multimodal heart of the area, supporting various types of trips and journeys both inside and outside the area.

4.1.1 Developing the e-mobility hub concept

A review of mobility hub concepts, project example cases, and local developments in the field was carried out by ESP. This is a brief summary of the separate report, available in the project resource bank.

Mobility hubs - such as a metro station or a bus terminal - are spaces that gather mass transportation and shared mobility services under ‘one roof’, and they have an increasingly important role to play in sustainable urban mobility systems. They act as intermodal links where mobility mode is changed, and they usually are also social gathering and meeting places as sites of day-to-day mobility habits and routines. Mobility

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hubs have grown in popularity in mobility design in recent decades, which has been pushed by the increasing demands for carbon-free transportation (together with calls for carbon-free societies in general) - the increase of rail-based mass transportation in specific - and the need to combat the negative impacts of automobiles on the urban structure and human health and well-being. The hubs have been connected, in specific, to the aims to create densely built urban areas that are walkable and bicycle-friendly, or otherwise accessible through public transportation and different shared 'last mile' solutions (shared vehicles, mobility-on-demand, automated solutions etc.).

Mobility plays a key role in cities: it is a major source of greenhouse gas emissions - and its role and share of the total emission output will most likely only *increase* in the future. Urban mobility is also something that has a huge impact on the planning and design of cities, and how we conduct and organize our daily lives. As much as mobility is about (green) vehicle technologies, (shared) mobility service models, and big data analytics on urban flows, it is about the subjective travel experiences, affordability and questions of access and inclusivity of public space. Thus, the mobility hub - as a central piece in the overall urban ensemble - is a complex matter, its impacts resonating on multiple different thematical (ecological, social, economic sustainability) and geographical (street, neighborhood, district, city, region) scales.

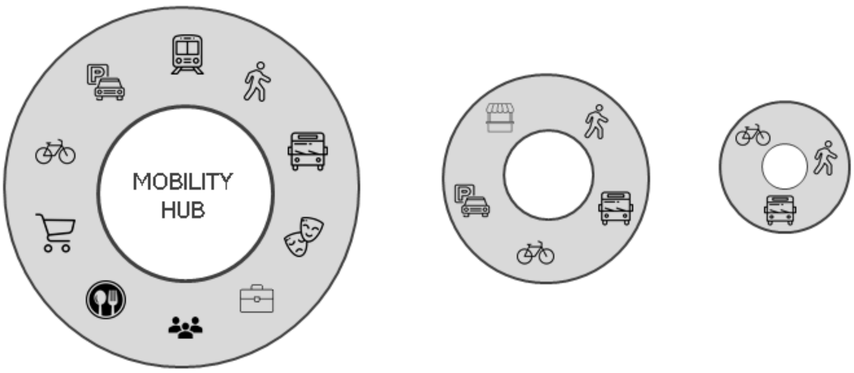

Figure 55. Mobility hubs can vary in size, providing a varying degree of mobility-related and other services. Source: ESP.

Transit oriented development (TOD) is one way of framing a planning and design thinking that is built around the idea of the mobility node as the heart and core of the area (Cervero et al. 2017). As the name suggests, transit, or public transportation, is taken as the driving force of organizing the local (or regional in some cases) urban districts or areas. The transit station - i.e. a metro station, a bus terminal, a tramway-stop - acts as the heart of the area, and the transportation and non-transportation related services and further connections to the blocks and areas surrounding the hub area, are built around the station. Walking and bicycling conditions are essential here as they connect the people in the area to the public transportation routes, and also help to generate liveliness and social activity in the area as people spend time in the public space.

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The *Institute for Transportation & Development Policy* has listed key TOD benefit, which include environmental, societal, equality, health, road safety and city efficiency benefits.[24] These benefits are gained through the minimization of urban sprawl, by better addressing the needs of marginalized populations, enabling active mobility modes, reducing the number of car trips, and by encouraging efficient use of city resources.[25] The *15-minute city* approach is one specific form derived from the aforementioned approaches that favor dense urban areas and mixed-use zonal planning, together with active mobility modes and public transportation. The 15-minute city is based on the idea that all daily services would be in the reach of fifteen minutes travel, made up of interlinked five-minute neighborhoods. This also means that areas have not only housing, office spaces, or specialized activities, but provide the necessary everyday services. In contrast to thinking about how different services can be reached from specific areas in the planning process, the 15-minute city planning principles aim to bring the services to the districts (Moreno, Allam, Chabaud, Gall and Pratlong 2021; Pozoukidou and Chatziyiannaki 2021.) Here, as noted above, the question about accessibility and inclusion are central - for *whom* the city is reachable, both physically and socially.

New policies, targets (e.g., carbon-neutrality), planning and design paradigms, technologies, and daily practices of travelling, working and consuming affect the way a hub looks and operates - the 'how' and the 'why' we move both change and transform in time. Service availability, information and signage, safety, and accessibility are some of the regularly identified key elements of mobility hubs from a user perspective.[26] However, all the aspects of a 'successful' hub that gathers high numbers of users are difficult to define as the hubs also act as (semi)public spaces where other uses of the urban space - such as social gatherings, interactions and encounters - combine with mobility practices that are perhaps more functional and utilitarian in nature.

Multiple global processes are currently transforming urban mobility: rapid global urbanization, increase of shared mobility services and digitalization, broad electrification of different vehicle types, and the effects of global pandemics to urban mobility behavior, are all some of the key trends affecting urban mobility and public spaces at the moment. Mobility hubs can play a key role in fostering further sustainable mobile behavior in such a setting, connecting the spaces people live and work into mass transportation and different 'last mile' services between the hub and the ultimate destination of the journey. Efficient mass and shared mobility also make room for public spaces and green areas, as the need for vast car parking lots is decreased through the decreased car-use and ownership. New possibilities related to increasing interest towards service economy and shared mobility services, as well as the general electrification of different vehicles and the introduction of new ones, provide also potential for new approaches towards urban mobility.

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[24] https://tod.itdp.org/why-tod-matters.html

[25] Institute for Transportation and Development Policy 2017. *TOD Standard,* 3rd edition. New York: ITDP.

[26] Aono, S. 2019. *Identifying Best Practices for Mobility Hubs.* TransLink report.; A Better City 2016. *A Guide to Placemaking for Mobility.* Report.; Shared-use Mobility Center 2018. Mobility Hubs. Report.; Heddebaut, O. 2018. Creating Sustainable and Efficient Transport Interchanges: Some Findings of the City-HUB Project. *AdvancementsinCivilEngineering&Technology* 2018:1.; Metrolinx 2011. *Mobility Hub Guidelines For the Greater Toronto and Hamilton Area*. Report.; SHARE North 2019. *Mobility Hubs Guidance.* Report.

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The Covid-19 virus pandemic has been a major force that has reconfigured many day-to-day travel habits anew. The public transportation use decreased as people opted to avoid mass transit options, the need for private mobility increased. In the capital metropolitan region in Finland, the reported decrease of public transportation use in 2021 was 40% lower in comparison to 2019.[27] As mass transportation modes were affected by the corona virus as decrease of users, this has also had effects to mobility hubs. The station areas became places people avoided (if possible), which also caused negative impacts to the different services in the hub area. Some European cities initiated measures to increase the walking and bicycling facilities in their street spaces, for example by closing streets completely from motor traffic, or by transforming one car lane into a bicycle path.[28] It remains to be seen what the 'new normal' of transportation and urban mobility will be in the upcoming years. There are some indications that the biggest dip in mobility of 2020, has been already caught up, at least on some fronts. It remains to be seen whether the positive effects the Covid-19 pandemic had on walking and bicycle use outweigh the negative developments, i.e. the decrease of public transportation use and the increase of car use.

Mobility hubs have been developed in Espoo through recent Sustainable Espoo development program's projects that are related to the city's overall sustainable development work and aims towards low carbon transportation. They support the Carbon neutral Espoo 2030 target and the achievement of the United Nation's Agenda2030 Sustainable Development Goals by 2025, as stated in the city's strategy[29]. The projects have, in specific, focused to tackle the 'last mile' (or 'first mile') issue, meaning how to create sustainable mobility possibilities for the part of the trip that extends beyond the hubs utilized on the journey. These include tests and pilots on the use of autonomous robot buses (in the Kera area) and mobility services in hub areas (*6Aika: Low-carbon mobility in transportation hubs* project, 2019-2022[30]), the city-as-an-employer policies supporting the use of sustainable mobility modes for its employees, and the identification of possible hub areas (*Sustainable mobility as part of The Espoo Story city strategy KESTO*, 2019[31]), and the development of mobility and logistics services on existing station areas (*Smart mobility services ÄLLI*, 2019; *Smart Stations*, 2018-2021[32]).

If we look at similar international examples, there has been major active work ongoing on the development of mobility hubs, e-mobility and shared mobility services in different projects recently. These projects, similarly to SPARCS, approach the challenges and possibilities brought on by to the global trends of increasing electrification of all vehicle types and the increase of shared mobility service offering and use in urban environments. These activities include the development of new small-to-medium sized on-street e-

[27]https://www.sttinfo.fi/tiedote/hsln-tilinpaatos-2021-matkustajaluvut-kavivat-pohjalukemissa?publisherId=4396&releaseId=69936467&lang=fi

[28] https://www.theguardian.com/lifeandstyle/2021/mar/12/europe-cycling-post-covid-recovery-plans

[29] https://www.espoo.fi/en/city-espoo/espoo-story

[30] https://6aika.fi/project/vahahiilinen-liikkuminen-liikennehubeissa/ (in Finnish)

[31] https://www.traficom.fi/sites/default/files/media/file/Espoo_Loppuraportti_KESTO_2019.pdf

[32] https://www.asemanseutu.fi/in-english/

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mobility hubs (*eHUBS - Smart Shared Green Mobility Hubs,* 2019-2022[33]), economic and service models of EV car-sharing (*GrowSmarter.* 2015-2019[34]), and developing e-mobility solutions in, often neglected, suburban environments, together with city-wide master plan for EV charging (*CIVITAS ESSENTRIC,* 2016-2020[35]).

Also other, perhaps even more innovative real-life or concept-level solutions have been in development, which provide new perspectives to mobility hub development and what urban mobility might be in the near future, such as modular mobility hub concepts with transferable 'building blocks' that compose the hub (developed for the *Innovation Programme InfraSweden 2030*[36]), a high-end bicycle parking garage (*Stationsplein* in Utrecht, the Netherlands[37]) and innovative vertical underground bicycle parking that save above-ground space for urban life (*Eco Cycle*[38]), new kinds of bus stops incorporating art and innovative design to make the travel experience better (*Station of Being*, 2019[39]), and the conceptual re-thinking of what we mean with a mobile space (*Spaces on wheels*, 2018[40]).

Regarding mobility hub development, there are multiple pieces of the puzzle currently in the air. Service based mobility is creating a new kind of basis for future mobility hubs in connection with traditional public transportation service. Public transportation itself might be experiencing some kind of an overhaul in upcoming years as developments in automation and technologies facilitating mobility-on-demand solutions are advancing, and new service models are tested and piloted. The electrification of all types of vehicles changes also infrastructural requirements and introduces time and synchronization of different mobility practices and charging scheduled into the picture in a new way, as the grid stabilization and peak-prevention becomes important (including vehicle-to-grid practices).

4.1.2 Workshop series on E-mobility hub conceptualization

In 2021, SPARCS partners from Task 3.4, 3.6 and 3.8 organized a series of workshops that aimed to further conceptualize and envision e-mobility hubs of the future with ESP leading the process.

The general idea behind the workshop series was to examine what the general electrification of the mobility hubs – in the wake of the (possible) future electrification of most vehicles in transport, from buses and cars, to bicycles and kick-scooters – would mean for the design and planning of future mobility hubs. What should we take into

[33] https://www.nweurope.eu/projects/project-search/ehubs-smart-shared-green-mobility-hubs/news/amsterdam-launches-its-last-ehubs-and-much-more/

[34] GrowSmarter n.d. *Implementing sustainable urban mobility in European cities - conclusions from GrowSmarter.* Report.

[35] https://civitas.eu/projects/eccentric

[36] https://www.ri.se/sites/default/files/2020-12/RISE-Arup_Mobility_hubs_report_FINAL.pdf

[37] https://www.utrecht.nl/city-of-utrecht/mobility/cycling/bicycle-parking/bicycle-parking-stationsplein/

[38] https://www.giken.com/en/products/automated-parking-facilities/eco-cycle/

[39] http://www.rombout.design/station-of-being.html

[40] https://space10.com/project/spaces-on-wheels-exploring-a-driverless-future/

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consideration as mobility hubs are transforming (both through organized processes from the 'top-down' as well as the more organic developments from the field, led by the evolving markets and user preferences) into nodes facilitating the use of e-mobility? What happens on the 'frontstage' related to the usage of the hub and its (mobility) services as part of trips in the city, and what needs to happen in the 'backstage' to make it happen (e.g. supportive infrastructure, charged vehicles, vehicle availability, ease of use). The insights and learnings gained from the workshop series are also used to sketch further guidelines for Kera's (e-)mobility hub development in order to create a new kind of an urban area with a multimodal mobility focus, relying on mass transit (already existing commuter train station), walking and bicycling, and shared (e-)mobility services.

Different stakeholders were invited to participate in four workshops that were organized between May and December 2021: 1) local WP3 SPARCS partner organizations (workshop organized in May 2021), 2) citizens and end users (June 2021), 3) mobility service providers (September 2021), and 4) other SPARCS partner cities (December 2021). In total, over forty (40) individuals (representatives of companies, organizations, cities, SPARCS partners, and citizens) participated in the workshops. The workshops were all held online, utilizing MS Teams and Miro digital whiteboard tools due to the Covid-19 pandemic.

The workshops examined following issues:

1. The first workshop was organized for WP3 SPARCS partners and it was used as a pilot to test the workshop process and to gain first insight to the issue. The workshop examined user experiences and practices through imaginary route narratives. The key interaction points between the user and the hub environment were identified through route narratives that utilized different user profiles with specific needs and requirements for travel. The route consisted of 'first' and 'last mile' trips to/from the station, and the process focused on the user-hub interaction by zooming into the events taking place in the hub, e.g. the change from one mobility mode to another, purchase of travel tickets, the use of hub services, and orientation in the hub area.
2. The second workshop reproduced the first workshops with actual users. Here the route narratives were based mostly on the experiences of the users themselves, and what kind of needs and requirements they have on trips utilizing such *first_mile-hub-last_mile* type trips.
3. The third workshops took the insights from the first two workshops, and further examined those and other specific needs and requirements service providers have in order to set up and operate mobility services in a hub environment. The workshop was outlined by an expert panel in the beginning, with experts from Finnish Environment Institute (SYKE), VTT, and City of Espoo discussing the electrification and future transformation of mobility hubs and mobility practices in general.
4. The fourth workshop was organized for the other SPARCS cities to further study how the key elements for future e-mobility hubs identified in the earlier workshops could be further developed and better understood when they were reflected with other geographical, cultural and social contexts round Europe. The workshop also acted as a possibility to have a dialogue about the current challenges, development processes and identified city targets on general mobility and e-mobility issues between the project cities.

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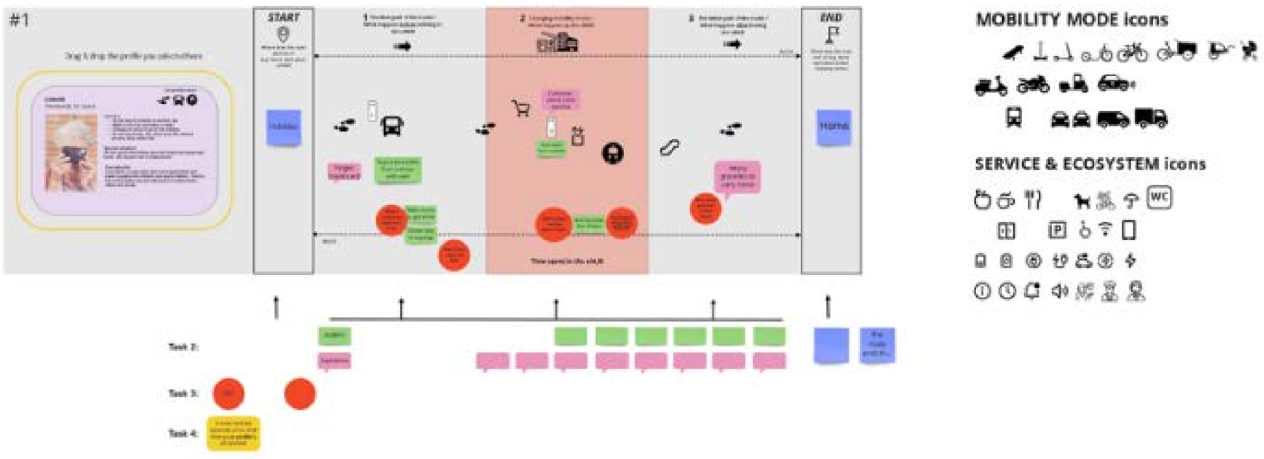

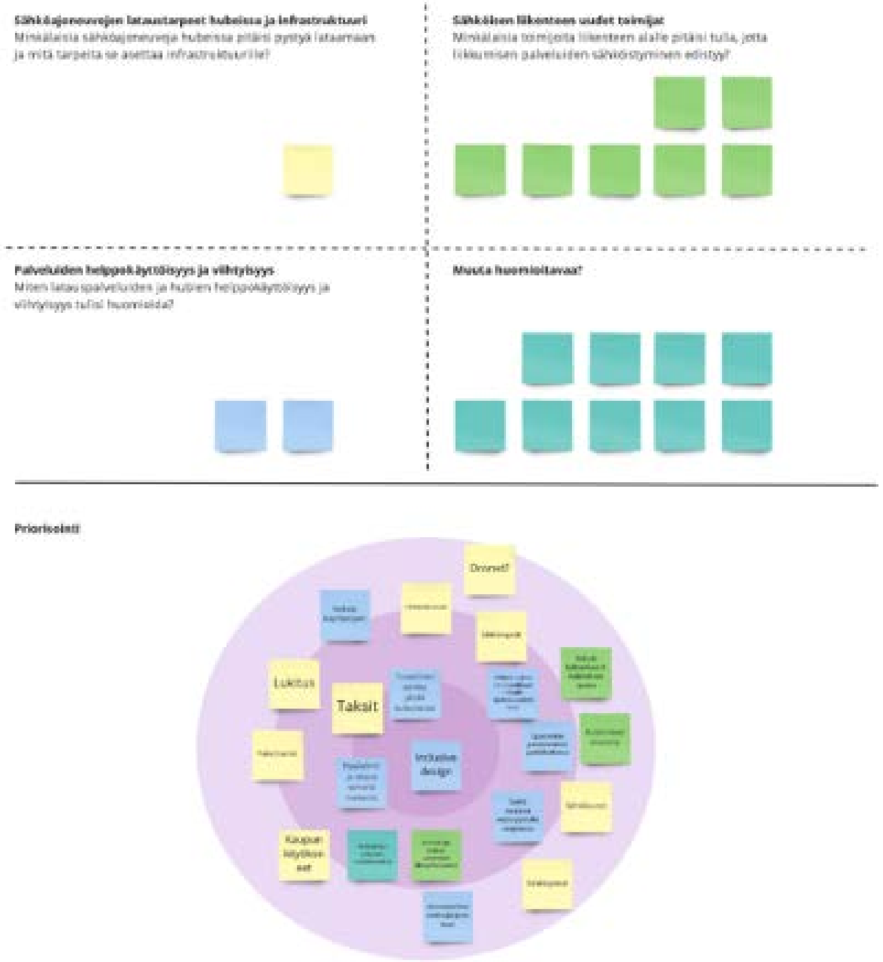

Figure 56. Examples of the Miro boards used to co-develop e-mobility hubs from two iterations of the workshop series. Source: ESP

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Below, the key results and outputs of the workshops are presented. For more details about the *participatory and engagement process* regarding these workshops, see D3.6.

4.1.2.1 Guidelines for a future e-mobility hub

The workshops aimed to identify key elements for future e-mobility hubs on a concept level - what needs to be taken into consideration when developing mobility hubs that facilitate a good user experience and a fast and smooth travel experience - i.e. the 'frontstage' - and provides the necessary elements for (both public and private) service providers to operate their e-mobility service and shared mobility services - i.e. 'the backstage'? The key elements from the user, service provider, and city / policy perspective are presented in Figure 57.

The *user* related elements of the hub - i.e. the frontstage of the hub - relate to the availability of mobility service, and the up-to-date information regarding their current status of availability, and orientation information to reach them in the hub. The travel information in general about the whole trip - including the movement in the hub and change of mobility mode (e.g. from a shared bicycle to the metro), as well as the ways to reach the hub from the point of origin, and the rest of the trip after departing the hub - were considered as important for efficient and smooth travel experience. Safe and ample parking facilities for different vehicles - including reservable spots - were regarded as necessary hub elements, together with clearly mapped and high-quality walking and bicycling environments in and around the hub. Seating and other 'street furniture' that makes spending time in the hub possible were also named as key elements. Hub design that also affects feelings of personal safety, such as lighting, cleanliness, and overall hub space design, were considered important.

The *service provider* related elements (i.e. the backstage of the hub) relate to the availability of dedicated space for mobility services in the hub area, both from the usability (hub design and layout, taking different user groups into account, accessibility) and charging infrastructure perspectives. Charging infrastructure that enables Charging as a Service (CaaS) operational models were called for, with shared UX design and data sharing between operators. Simple and automated payment methods were also favored to increase the overall use of the services. Up-to-date information about the charger utilization and other mobility services (e.g. docking stations and available shared vehicles) can support optimization of the system as a whole. Safe parking spaces for the vehicles was also considered important. Responsive support for users - e.g. helplines - need to be facilitated by the hub design as well. Dedicated short-term parking spaces for maintenance workers related to the services and delivery operators in appropriate locations were also key elements in optimizing the service upkeep. Drone logistics, in the context of further robotization and automation of both mobility and logistics services, were seen as one possible future technology and operational model that might require new kind of spaces and infrastructure from the hub environment although its current need is minimal.

The elements of the *city organization and policy level* relate to the development of further guidelines and codes of conduct between the service providers and the hub operators (the city or others). This includes both how the different roles in terms of infrastructure development investments, operation, user interaction, and service maintenance are

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organized, together with policies related to proper practices, such as e-scooter parking and use, and (e-)car sharing services. Real-time open data about the use of the hub and the services support the management of the hub, and pinpoint possible issues for further (re)development both for the hub operator(s) and the individual service providers. Social safety, accessibility and availability of services were considered as key elements to attract users to the hub, which supports the cities' sustainable urban mobility targets on a larger front.

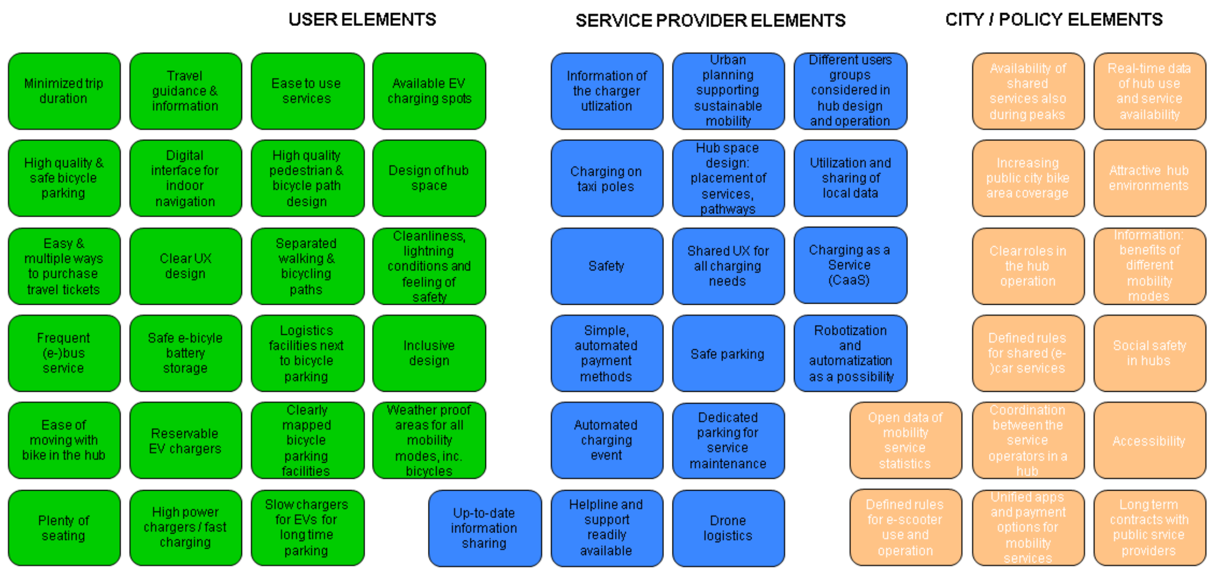

Figure 57. Identified elements for future e-mobility hubs from User, Service provider, and City / Policy perspectives. Source: ESP

Furthermore, stakeholders' different pain and gain points of a service need to be considered and appreciated to achieve a truly functional service platform. This challenge is demonstrated in Figure 58, illustrating the relative importance of different characteristics of a mobility hub gathered during the workshops. The relative importance is determined by weighing by the number of workshop responses in that category of each stakeholder by the total number of responses of the stakeholder. Thus, the result is to be considered only indicative.

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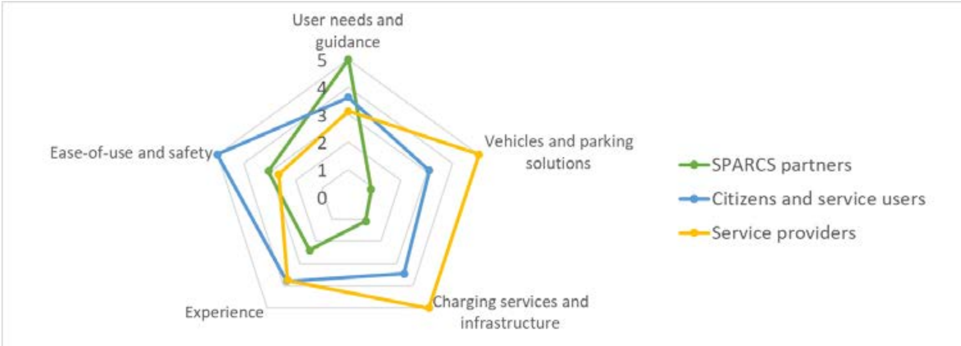

Figure 58. Radar map with weighted relative importance (5 being of the highest importance) of mobility hub characteristics for each stakeholder group. Source: KONE

The different identified elements contributing to a 'good' or high-quality e-mobility hub from different perspectives (user, service provider, city/policy) can be utilized in hub planning from the initial planning phase to the maintenance and utilization phase. The elements are usable both in the context of fully new mobility hubs - designed to cater e-mobility from the start - as well as the re-development of already existing hubs to accommodate the general shift towards electricity utilization across different vehicle types. The shift towards e-mobility mostly relates to infrastructural elements, together the increased need for digital solutions in connection with shared mobility services. The basic elements of the hub, however, as a nodal point in the urban network, does not drastically change when mobility is electrified. Human-scale and human-centric design of the hub, enabling smooth transfers from one mobility mode to another, providing up-to-date travel information, providing high quality walking and bicycling networks in and beyond the hub environment, creating safe and enjoyable hub environment, providing local daily services, and designing street furniture enabling social interaction, are all elements that are necessary regardless of the power trains utilized in the vehicles operating in, from, and to the hub.

4.1.3 Developing Kera multimodal ecosystem

A challenge with new urban districts is that the local services, including mobility services, walking conditions, and public transportation, are lacking during the construction phase, which often takes years or even decades. Systematic changes require a broad transformation of societies and new ways of both using and providing mobility services in urban environments.

To tackle this challenge, an open working group was formed to develop the future visions and goals for transportation and logistics services for Kera area up to 2030 and beyond, and to create a basis for the formation of a (e-)mobility service ecosystem in the area that could foster the development of a local 'last'/'first mile' services in the area already in the construction phase of the area. As noted earlier above, Kera is planned as a new type of an area that emphasizes smart solutions and circular economy, and favors walking, bicycling and public transportation use through the already existing commuter train connection and the station area, local pathway and green area planning, and dedicated carpark facilities.

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The group was led jointly together by multiple the City of Espoo's sustainable development projects: *Clean & Smart Kera,* SPARCS*, SixCities: Low-carbon mobility in transportation hubs*, and *Smart Station*, and consisted of city's Kera developers and different companies and organizations - including Helsinki Regional Transportation Authority HSL and Metropolitan Smart and Clean Foundation (both SPARCS Associated Partners) - that operate in the transportation sector. The group held altogether seven meetings and workshops (during M9-19) in order to develop a mobility and logistics vision for Kera in 2030.

The meetings/workshops addressed:

- *The development of a shared urban mobility and logistics vision for the Kera area for 2030.*

The generated vision states, among other things, that mobility in Kera is based on walking, bicycle traffic, public transportation, shared mobility services and low-carbon car traffic and shared cars. Shared and sustainable mobility services are easily connected in Kera, and they support Kera station area as a local node for transportation, residency, workplaces and services. Mobility services in Kera are designed from human-centric perspectives, and they aim to provide required services for different kinds of life situations. The Kera area is also seamlessly connected to the rest of Espoo. The proper timing of both private and public (mobility) services in the area, together with infrastructure development, is essential. Logistics services in Kera are smart and automated, and they reduce the need for personal mobility. The services are integrated to the urban structure and buildings. Shared and automated deliveries are used in the construction sites, and the builders are also included in the design of the local mobility to minimize the obstacle type effects of the active construction sites.

Further examining the vision through specific themes:

- *The development of bicycling infrastructure in the area.*
- *The public transportation service timeline in the developing area, where the construction period spans multiple years and decades.*
- *The necessary evolutionary development process of the already existing Kera station area to support the area's sustainable mobility development.*

Regarding the station area development, the group identified critical first steps to make use of the rail-based mass transportation. These include reconstructing the station area to be accessible, and the area to be easily reached on foot and with bicycle, including proper signage and guidance. Lockable cabinets for bicycles, and a station of the public city bike system, would support sustainable mobility behavior in the area. The safety and comfortability of the station area is also developed as part of the first steps, and city services are brought to the station area. The following key steps include taking active care of the needs of the growing number of people using the station and providing up-to-date travel information, adding an indoor space as part of the station area for additional services, attracting private service providers to the area, piloting new mobility and logistics services together with mobility service providers, and further developing the station area aesthetics and enjoyability. It is critical that the easiness and comfort of utilizing the train from the users' perspectives is considered in all planning and development work, and its operation ensured through all the stages of the construction of the area.

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The insights gained from the group's work has supported the development of the Kera development commitment that sets shared guidelines for the area's development. The annex was approved by the city council in 2021, supporting the development of the area based on the visions and aims created, focus areas including cooperation, clean energy, circular economy services, and mobility and logistics.

Figure 59. An overview of the Kera Mobility & Logistics ecosystem working group, with the main themes covered and outputs produced. Source: ESP

4.1.3.1 Replication of E-mobility solutions

The solutions developed and insights gained in the other Task 3.4 Actions are examined from Kera development perspective, and their future replication planning is supported. The work done in Espoonlahti, Lippulaiva blocks, and Leppävaara, Sello blocks, provide replicable possibilities in e-mobility development that can be especially beneficial for areas such as Kera, that go through major re-development. The best practices, solutions and insights can be utilized already in the design and planning phase of the Kera area.

4.1.4 Dissemination and dialogue about SPARCS e-mobility insights with Kera developers

Since October 2020, ESP has organized regular meetings between Kera developers from the different sectors and departments of the city organization (including the Kera area manager, urban planners, Clean and Smart Kera and other Sustainable Espoo development projects) and the relevant WP3 SPARCS partners on e-mobility development in the Kera area. There has been around 30 people participating in the group from different organizations. The meetings have been used as a platform to provide both up-to-date insight about the Kera area development process for SPARCS partners, and to present the results and learnings of the SPARCS demonstrations from the other two Espoo demonstrations areas (Leppävaara and Espoonlahti) for the Kera developers. The

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platform has also been used to further probe the themes in the form of dialogue and further workshops. The learnings and insights of SPARCS project can help to shape the Kera area into a new smart and sustainable urban district that favors walking, bicycling and public transportation as main mobility modes, by incorporating novel solutions, ideas and approaches already in the planning, design and construction phases of the area that will span multiple decades. The meetings have been held remotely through MS Teams due to Covid-19 pandemic.

There have been seven meetings in total, and they have covered a range of themes related to the development of mobility in Kera and the learnings and insights developed in the other demonstration sites in SPARCS (Leppävaara/Sello blocks demonstration site in specific). Two workshops on developing further the insights on e-mobility hubs and e-car sharing in other SPARCS Actions have also been arranged. The workshops have also provided insight on what their application in the Kera context could entail and what they require to succeed.

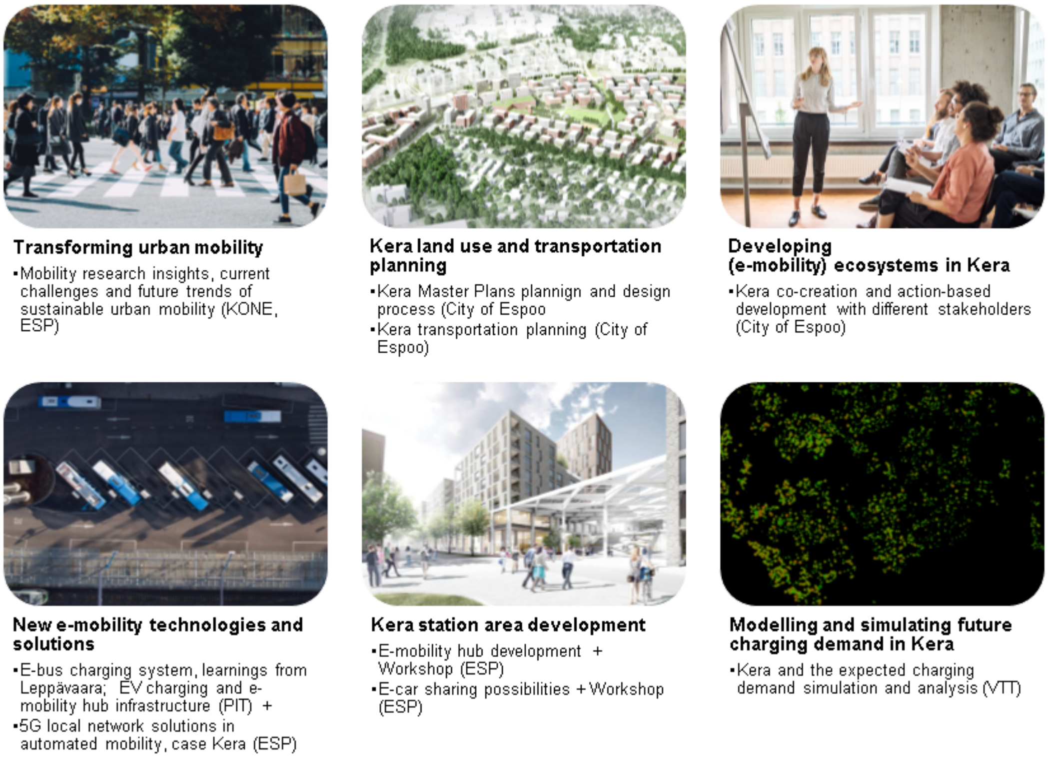

Figure 60. Themes and replicable solutions covered in the meetings on future e-mobility in Kera. Source: ESP.

Transforming urban mobility: KONE representatives presented insights gained from mobility probing studies conducted in Espoonlahti and Leppävaara (see D3.6). Current and future trends in mobility were examined together with potential mobility solutions that could be incorporated in Kera.

Kera land use and transportation planning: Representatives from the City of Espoo presented the planning and design process of Kera so far, together with the initial targets

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and goals for the area's development. The transportation planning principles and guidelines of the area were also examined, and their connections to the developed SPARCS solutions examined.

Developing an (e-mobility) ecosystem in Kera: The co-creative and collaborative mode of working between city, landowners, companies, organizations, and citizens in Kera, and its connections to SPARCS e-mobility solutions and the ecosystems that the successful replication of the solutions could require have been examined. The Kera development commitment were also reflected with the potential of SPARCS activity replication.

New e-mobility technologies and solutions: Representative from PIT presented the work done on the Leppävaara e-bus charging system in SPARCS, and the technical considerations related to e-mobility charging hubs. The discussions that followed revolved around the feasibility of these systems in the Kera area, and how they could support the local sustainable urban mobility system. Representative from ESP presented results from a questionnaire aimed at mobility professionals on the potential of 5G in automated mobility. Kera houses a 5G pole network that provides a platform for testing and piloting new solutions utilizing fast connectivity and big data sets and real-time data gathering.

Kera station area development: The development of the Kera station areas was addressed through the SPARCS E-mobility conceptualization workshops series. Insights from the series so far were presented by a representative from ESP, and an additional workshop with the group was organized to contextualize the initial learnings from the workshop series to the Kera setting (see section 4.2.1.1).

Modelling and simulating future charging demand in Kera: Representative from VTT presented SPARCS work on e-mobility charging demand simulation in the Espoo area, including Kera. The different scenarios of e-charging and e-mobility uptake were discussed and reflected with the simulated results.

4.1.4.1 Kera e-mobility hub development

The initial insights from the E-mobility hub conceptualization workshops (see section 4.1.2) were reflected in the working group in a workshop in August 2021. The insights from the workshop series were contextualized in the Kera case, focusing on the specific character of the area and highlighting the importance of the construction phase. As noted earlier, a commuter train station operates already in the Kera area, which will form a major mobility hub in the area and plays a key part in realizing the visions of the Kera as a walking, bicycling and public transportation focused sustainable and smart urban district.

Based on the insights from the earlier workshops, the key first steps for the Kera station area development were identified as follows: securing the availability of local mobility services, developing walking and bicycling pathways in and around the station area, and securing frequent public transportation service. The key second stage steps included: developing orientation and guiding in the station area, designing and implementing seating and other possibilities for staying, further securing frequent public transportation service, optimizing travel time (including the change from one mobility mode to another), providing trip planning possibilities in the station area, and having day-to-day services, like a grocery store, in the station area. Additional key features for the station area evolution that make use of the Kera area's unique character and specifications were also

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identified. These included: creating an aesthetically high quality station environment, including street and environmental art, developing automated logistical and parcel delivery services, developing EV charging points and shared (e-)car services, adding shared services (e.g. shared city bike system) to the service portfolio, creating good and inviting lighting conditions (safety and security), dedicating station area space for shared mobility services, securing seamless transfers from one mobility mode to another, developing high quality bicycle parking facilities, securing good pedestrian and bicycle access during the re-development and construction phases of the area and the station, and creating a clear meeting place in the station area with unique and identifiable street furniture.

4.1.4.2 Kera EV sharing approach

The key insight gained from the E-car sharing SWOT workshops (as part of E7-1, see section 3.1.2) were further developed in a workshop arranged for the Kera and SPARCS e-mobility group participants. The group consists of SPARCS partners and city workers working on the planning and development of the Kera area. The workshop was organized online due to the Covid-19 pandemic, and utilized MS Teams and Miro online whiteboard tool. The workshop examined the possibilities and challenges related to shared e-car use in Kera. The insights are also applicable in the development of other 'new' urban districts similarly to Kera.

The workshop participants highlighted that as Kera is developed as a 'new' area due to the extent of the redevelopment, the mobility practices are also renewed in the area. The new area provides a context where shift from ownership towards shared services can take place, and where interest towards new kinds of services can be gained. The new buildings constructed in Kera can integrate the e-car sharing supporting infrastructural elements from the start. As Kera is developed as an area that emphasizes walking, bicycle traffic, public transportation and shared mobility services, the need for car-use is mostly related to trips taking place outside Kera, and trips to areas lacking high-quality mass transportation service, i.e. rail-based connections.

Necessary steps for supporting e-car sharing in Kera were also identified. These include providing EV charging points in the area for shared e-car use, promotion of (future) shared services, and stream-lined permit processes for quick charging point installation from the city's side, and innovative business schemes and discounts from the service providers side to attract the large enough user base for a sustained service. The next steps include further collaboration between the city and service providers, followed by the creation of dedicated parking places for shared vehicles.

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Figure 61. Identified steps for supporting the development possibilities for e-car sharing in Kera. Source: ESP

4.1.5 Co-creation model for sustainable and smart urban areas - Key insight for e-mobility solutions

Cities are becoming more complex environments as new practices and behaviours, smart and clean technologies, spatial uses and commercial and public services are applied and introduced in the wake of the transition towards more greener and sustainable cities. As part of Actions E14-1 and E22-1 under Tasks 3.5 and 3.9, ESP has initiated a work process to develop a *co-creation model* for sustainable city development. The co-creation model - developed together with WSP Finland and Korkia Consulting who won the procurement process organized by ESP in fall 2021 - develops a toolbox that can be used to develop (future) smart and sustainable urban districts and areas together with different stakeholders, including organizations, companies (e.g., through alliance models), landowners, and citizens. The aim is to develop urban areas (or redevelop already existing ones) to incorporate new innovative smart and sustainable solutions in the energy and mobility sectors, and to support their development into zero or low-carbon areas, positive energy districts, or otherwise sustainable areas and communities. Rather than having a smart and zero-carbon building or buildings, or singular, isolated smart and sustainable solutions, we would have a PED-like district or an area where the solutions support one another as a system and utilize e.g. excess energy or data from one solution in the operation of another, and that the solutions are incorporated into the urban environment in such a manner that it supports a human-centric (rather than technology-centric) uses of the space. The model is created during 2022 through co-creation methods with different stakeholders. Kera district has been used as a case example for the model's development in early 2022.

Here, the implications of the model and its development on e-mobility solutions is briefly examined. For more details about the model and the work in general, see Deliverable 3.4 (on the model as a whole) and D3.6 (on the co-creation process and engagement activities through which the model was developed with different stakeholders).

4.1.5.1 Co-developing and co-managing district-level e-mobility solutions

The model for co-developing mobility solutions is presented below. Here, mobility is linked inseparably together with service development, as transportation trips are often done to access different services. The availability of local services also has an effect on the

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public space quality and liveliness, which affect the mobile experience and the use of walking, bicycle use, and public transportation use as preferred modes of mobility.

Figure 62. The co-creation model - focus on district-level development of new mobility and service solutions. (In Finnish, translated into English in the text below.) Source: ESP

The model (Figure 62.) presents the identified eleven (11) steps that are required in the co-development and co-maintenance of new mobility (and service; or 'L&P=Liikenne & Palvelut' / 'Mobility and Services') solutions in the area or district level context:

- L&P1: Setting the targets for sustainable and smart mobility and service solutions together with the local stakeholders
- L&P2: Assessing the service and mobility needs of the local users together with service providers and users
- L&P3: Developing the local service and mobility network together with the local stakeholders
- L&P4: Identifying and accommodating local sharing economy, circular economy and data service possibilities in relation to the plan
- L&P5: Developing a joint general plan with the local mobility network and assessing zoning impacts
- L&P6: Developing an area-based visualization model for the local service and mobility network, and putting it under general review
- L&P7: Developing and securing adaptability in the zoning process. Assessing the adaptability together with the stakeholders
- L&P8: Test and pilots in the district as an open platform that engages the whole community. Specific solutions for the area's construction phase and flexible procurement of public transportation
- L&P9: A unified notification channel for the modifications of the transportation and street network that is open for all
- L&P10: Identification and co-development of the modification needs of adaptable spaces
- L&P11: Monitoring of the maintenance quality through mandated reports and user feedback

The above steps in co-creation cover different phases of the selected solutions, from the planning phase to implementation and monitoring. The steps also form a cycle which

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means that once the solution is in operation and monitored, a new cycle can begin, e.g. when the solution is re-examined and further developed in the context of the dynamic and transforming operational environment. In practice, of course, the different aspects interconnect and overlap with one another in various configurations, relating to the local context, timeline, and stakeholder interaction, among others.

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5. E-MOBILITY URBAN PLANNING REQUIREMENTS

This action is focused on studying the deployment of EV systems at large scale within multiple districts in the city of Espoo. The study starts by estimating the demand of all modes for the potential case of full electrification of all traffic within Espoo. It is assumed that all scenarios would fit somewhere in between no electrification and full electrification. Different estimates can then be obtained by the usage of linear scaling. A similar approach should work for each district that has been focus of the SPARCS project. The rationale for preferring full city scope for demand estimation is that for most modes the data is very hard to isolate for a single district, especially in the heavy traffic sector.

Once a full picture of electrified road transportation is estimated for the city of Espoo, the estimates for districts can be obtained as fractions of the overall demand.

Table 9. Activities on macro level as outlined in the Grant Agreement.

Subtask 3.4.4	E-mobility urban planning requirements
Responsible partners	VTT, ESP, PIT, SIE
Actions	**E18-1** Optimal integration of EV charging, taking into account all modes and types of electric vehicles, commercial as well as private, in the E-mobility nodes of Leppävaara (Sello block), Espoonlahti (Lippulaiva blocks) and Kera, managing of peak power demand and related effects from the urban planning. Analysis of future demand and development of smart charging strategies for different scenarios. This takes into account predictions of expected numbers of electric vehicles in each use case segment up to 2030 and beyond, the foreseen demand for power and energy and their impact to the grid. (VTT, ESP, PIT, SIE)

5.1 Transportation energy demand

The model for electricity demand of Espoo's future road transport starts with the review of the available statistics. These statistics represent different types of views on current energy demand, vehicle fleet composition and driven km by each type of vehicle class. Together they form a basis for further analysis using more detailed models and simulations for each type of transportation.

First comes the current distribution of energy consumed in road transportation based on its source. As Figure 63 shows, diesel and motor gasoline were still absolutely dominating in 2020. Electricity was representing only about 0,5 % of the energy demand.

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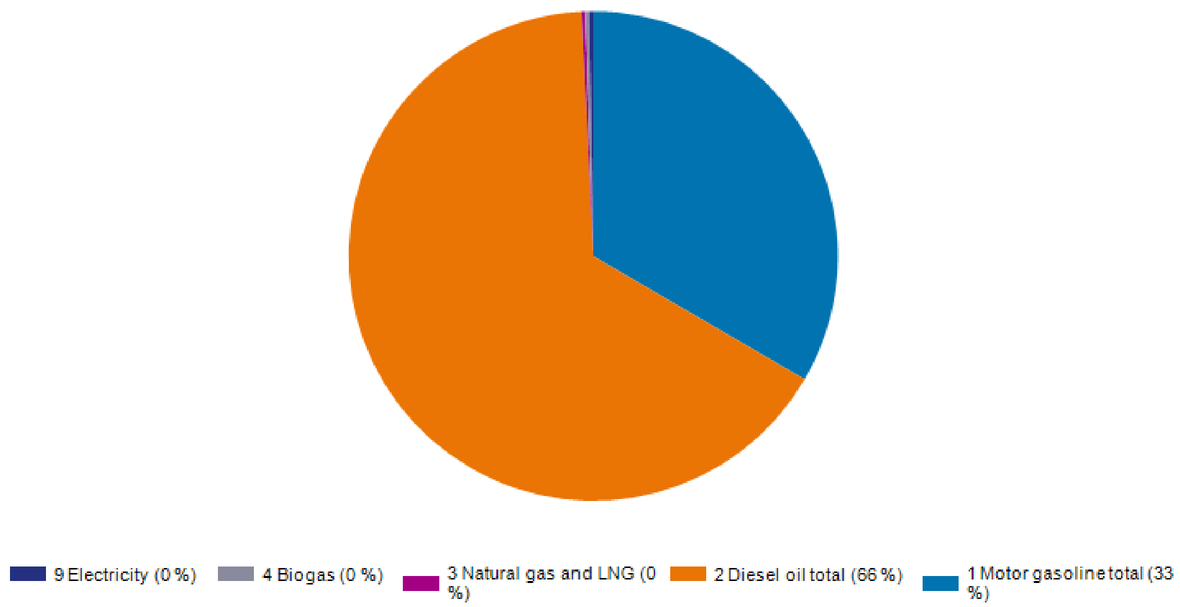

Figure 63. Source: Energy supply and consumption, Statistics Finland, whole Finland, statistics code: 008_12sz_2020 (Statistics Finland, 2022a)

In Table 10 one can see the distribution of the vehicle fleet registered in Espoo by type of vehicle. Passenger cars form the vast majority of the vehicle fleet, but vans, heavy duty vehicles and motorcycles are also not negligible.

Table 10. Vehicles registered in Espoo. Source: Statistics Finland, Espoo, in traffic, statistics code: 004_11ic_2020 (Statistics Finland, 2022b)

Vehicle type	Number of vehicles 2020
Passenger cars	123750
Vans	8270
Lorries, > 3.5 tonnes	1996
Buses, coaches	837
Special automobiles	30
Motor cycles	5046
Mopeds	3111
Snow mobiles	605
Tractors without road tractors	2750
Motor driven working machines	1099
Three-wheel vehicle or quadricycles	17
Light quadricycles	128
Quadricycles	195
Caravans	1063
Semitrailers	169
Other trailers total	22560

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From Table 11 we can observe different vehicle types and their average annual mileage (in km/year). While passenger cars and vans hover around 15 000 km/year, trucks reach over 30 000 km/year and buses are close to 50 000 km/year. This translates to 41, 82 and 136 daily km on average.

Table 11. Annual mileage for different types of vehicles during years 2015 - 2019 based on road statistics and the Karoliina project. (Pihlatie et al., 2021, p. 112)

	Source	2015	2016	2017	2018	2019
Cars	Statistics	17 945	15 320	15 104	14 971	14 838
	Karoliina	13 776	13 906	13 764	13 846	13 308
Vans	Statistics	12 698	17 610	17 546	17 443	17 239
	Karoliina	15 168	15 494	15 580	15 301	15 598
Trucks	Statistics	33 664	35 917	34 378	34 673	33 962
	Karoliina	33 610	32 606	32 159	32 145	31 544
Buses	Statistics	46 605	51 070	50 223	49 081	48 331
	Karoliina	47 684	47 434	47 141	47 740	45 355

Combining the data from Table 10 and Table 11 we can obtain the estimates of total mileage per each vehicle class in Espoo. Note that this is a very rough estimate since it does not consider that there might be different patterns for each part of Finland when it comes to average mileage. The resulting estimates are shown in Table 12.

Table 12. Estimated annual km per vehicle type

Vehicle type	2020 - number of vehicles	2019 - average yearly mileage (km)	Estimated total distance per year (10^6 km)
Passenger cars	123750	14838	1838
Vans	8270	17239	142
Lorries, > 3.5 tonnes	1996	33962	68
Buses, coaches	837	48331	40

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Table 13. Emissions by each sector of traffic in Espoo by HSL (HSY, 2021)

ESPOO	CO2 emissions 2020 (1000t CO2eq.)
Passenger cars	172
Vans	27
Buses	6
Lorries	73
Motorcycles	6
Ships and boats	6
Rail transport	3
ALL TRAFFIC	292
Road traffic	283
Public transport	10

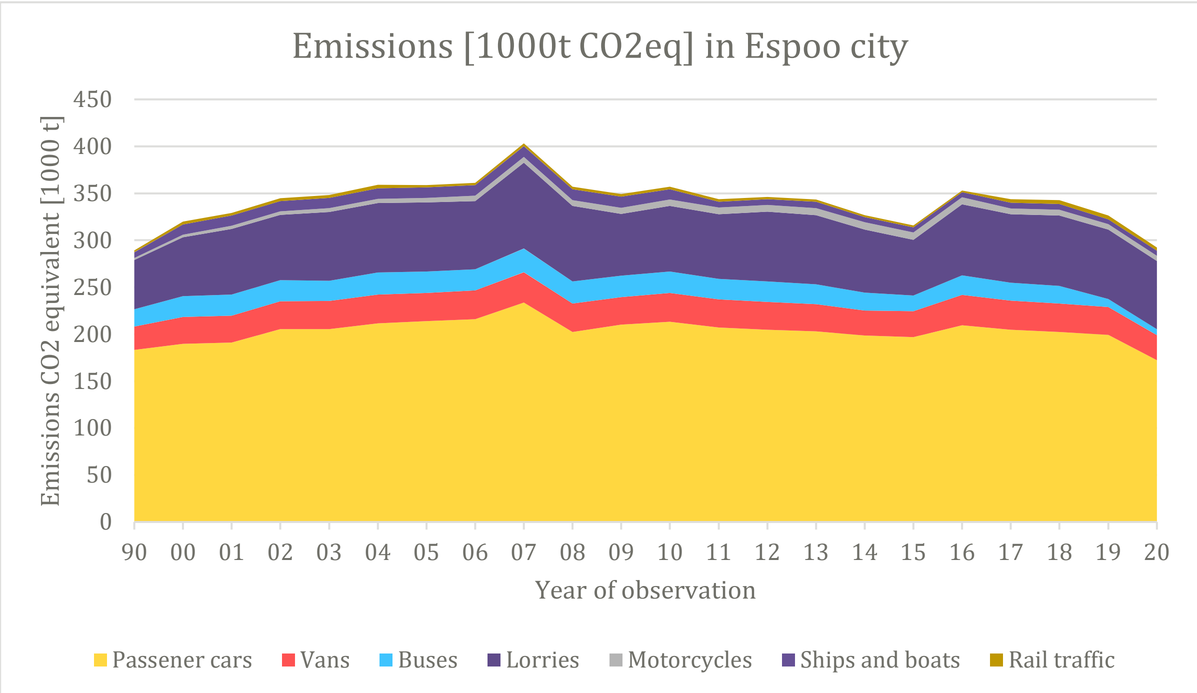

Figure 64. Change in emissions by type of vehicle in Espoo by HSY (HSY, 2021).

Based on data shown in Table 13 and Figure 64, we can see the emissions produced by each type of vehicle in Espoo as presented by HSY. Since there is a strong correlation between the emissions and future electricity demand if the transport sector is electrified, it should serve to validate our estimate for total energy consumption by mode as seen in Table 14. The estimates for consumptions are based on work in Karoliina project. (Pihlatie et al., 2021). The fact that the emissions do not correlate precisely with the estimated energy demand can be among others attributed to different factor of savings when converting each transport mode to electricity, for example some mode might consume 5x less in the electrified version while another one is only 3x more efficient.

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Table 14. Estimated energy need if full electrification is achieved.

Vehicle type	Estimated yearly distance (10^6 km)	2019-estimated average electricity consumption (kWh/km)	Estimated yearly energy consumption (GWh)
Passenger cars	1838	0,15	275
Vans	142	0,20	28,4
Lorries, > 3.5 tonnes	68	1,50	102
Buses, coaches	40	1,00	40

Summing the numbers up, we get a total demand of 445,4 GWh/year in maximum electrification scenario. That makes it about 51 MW of produced power on average. To validate this number further, we can take the total transport energy consumption from Figure 63 with the source (Statistics Finland, 2022a) citing 42 TWh consumed for 2020. Since the population of Espoo represents roughly 5 % of Finland's population and electric powertrain usually consumes only 20 % compared to internal combustion engine, we get a figure of 420 GWh/year, which is close to the 445,4 GWh/year number we calculated earlier.

5.2 Detailed 24-hour model

While we were able to obtain an estimate for annual consumption from the available statistics, we need to study daily patterns in order to understand when and where charging will most likely happen.

The methodology that has crystalized throughout the study can be broken down to following steps:

1. Establish Markov chain (see Section 3.3.3) with 10-min time step to represent activity for certain type of vehicle
2. Use the Markov chain to derive duty cycles for a number of vehicles
3. Optimize the charging pattern for the duty cycle given price curve and charging constraints
4. Aggregate the values for each scenario
5. Aggregate the vehicle scenarios into grid scenario

Since there is a need to study charging schemes, V2G and various modes of transport a total number of 4 Markov chains, about 400 duty cycles, 36 vehicle scenarios and several grid price scenarios were established, however not all the possibilities were processed further when compiling the final results.

Markov chains are a way of modelling certain time series data. Using Markov chains comprises of breaking up the time series into time windows and then predicting the status of each time window based on the status of the previous one. The prediction patterns are set in transition matrix and if the matrix changes based on time of the day we are talking about variable transition matrix.

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The way each Markov chain was constructed is different and is described separately in the following chapters. The reason for the difference is mostly various quality of data available for each subtype. Charging constraints and charging environment are also depending on the type of vehicle.

An example of how the Markov chain reflects the activity by time of the day can be seen in Figure 65, and aggregated duty cycles derived using it can be seen in Figure 66. As one can see, the patterns do not match 100 %, mostly due to high level of discretization (in this case only 25 vehicles were used), but also due to the fact that not all cycles could be finished by the standard configuration of electric vehicle. Such cycles are always a minority but are not included and the search process for a new duty cycle is initiated.

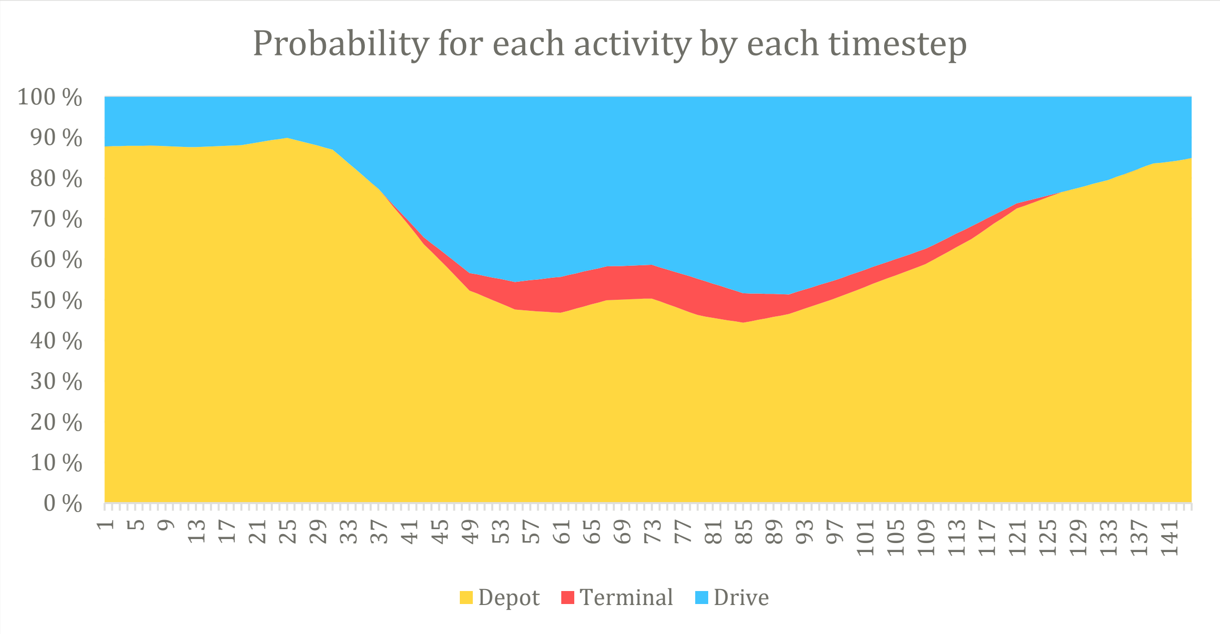

Figure 65. Example of probabilities for each activity and their dependence on time of the day before drawing the duty cycles. These probabilities serve to calibrate the Markov chain. Each 10-minute timestep starting from midnight is shown on the x-axis and the probability for an activity on the y-axis. For instance, most vehicles are parked during the night, hence, the depot probability is high in the beginning and the end.

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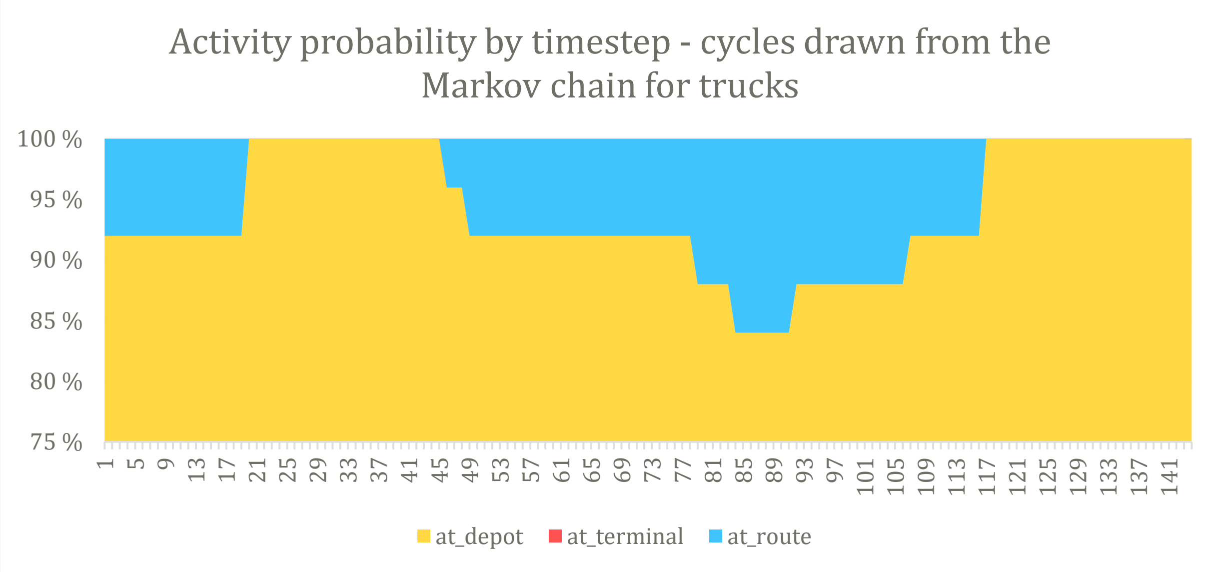

Figure 66. Example of summary of 25 duty cycles for trucks. These illustrate the actual simulated duty cycles.

5.2.1 Passenger cars

5.2.1.1 Duty cycles based on ABTM

Modelling the impact comes with its own difficulties. One needs to know a context for each vehicle to have a chance at predicting where the vehicle will charge. Due to its nature, Activity-Based Transport Models (ABTM) are very suitable for the task, since they map the daily routine of each passenger vehicle in detail. VTT already owns one of such models for the Capital Region of Finland introduced in (Hajduk, 2018). Therefore, it was natural to adapt the model for the new developments in Kera, Leppävaara and Lippulaiva (all of them in Espoo, Finland) and study the patterns obtained from the model. See Figure 67 for the newly added facilities.

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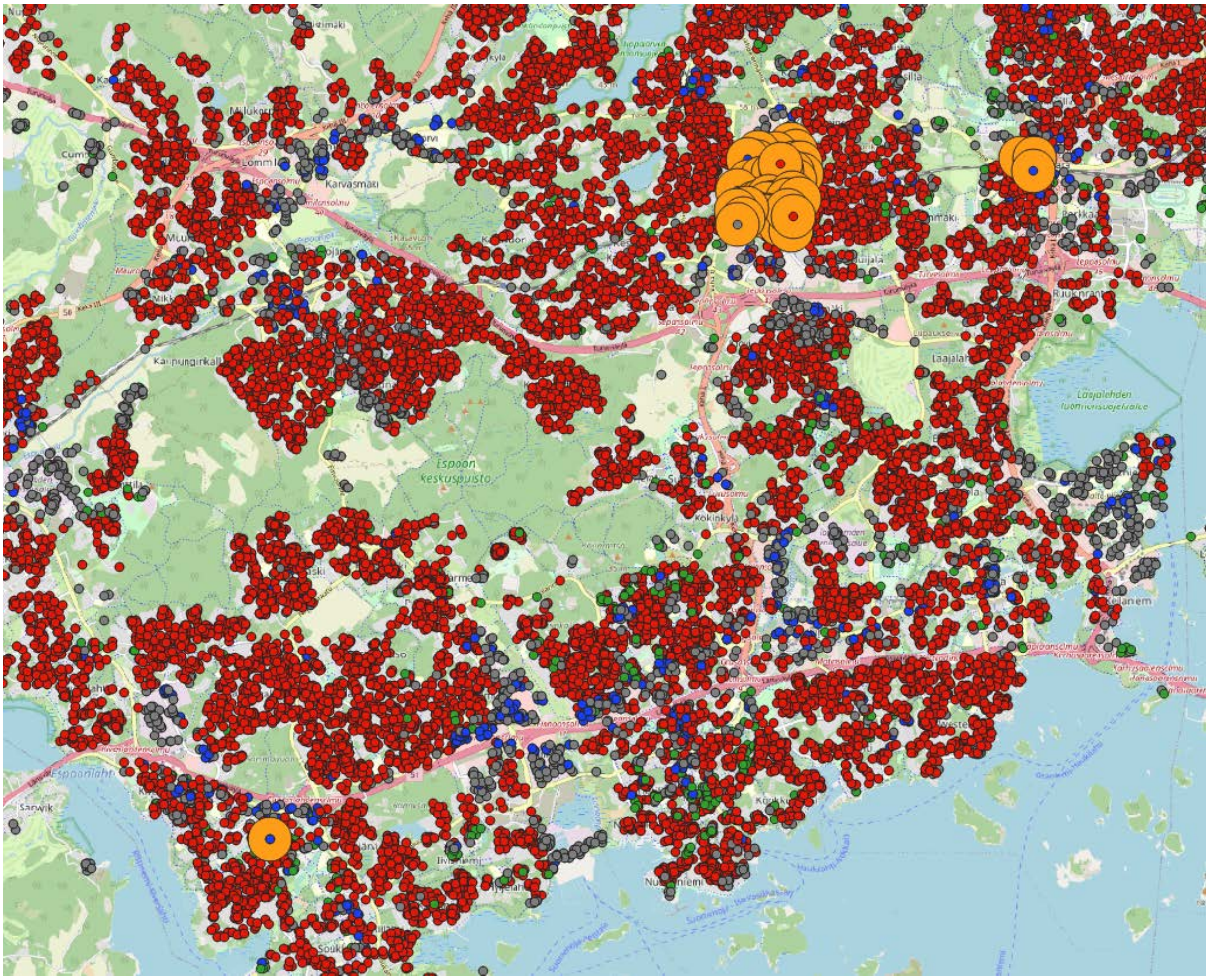

Figure 67 .Facilities in ABTM, newly added facilities for Sparcs in orange. Red=residential, grey=workplaces, green=leisure/sports, blue=services/shops. Source: VTT

ABT model has been deployed and adopted to study possible charging scenarios in passenger transport. The model itself maps all the schedules of all the residents of Capital region of Finland. The schedules were obtained through a custom methodology relying on Markov chains (different ones from the focus of this study). The description of the ABTM can be found in (Hajduk, 2018).

5.2.1.2 Charging availability pattern for cars

Following the obtained schedules, deriving the charging Markov chain helps to generalize the temporal patterns of driving during the day as well as map the availability of potential charging spots throughout the whole routine. In addition to that, it helps to synchronize the car schedules with schedules derived from other sources.

The derived charging pattern based on the Markov chain can be seen in Figure 68 and Figure 69, composing of the "status" part and the "transition" part. While the status part reflects the expected number of vehicles in each activity, the transition part reflects the probabilities to transition to the next activity.

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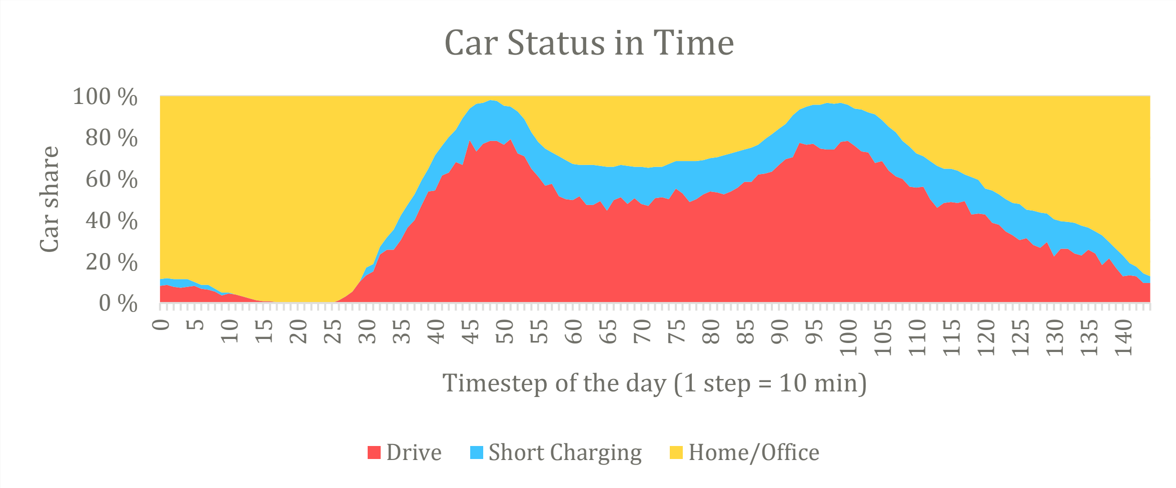

Figure 68. Markov chain for cars - activity probabilities

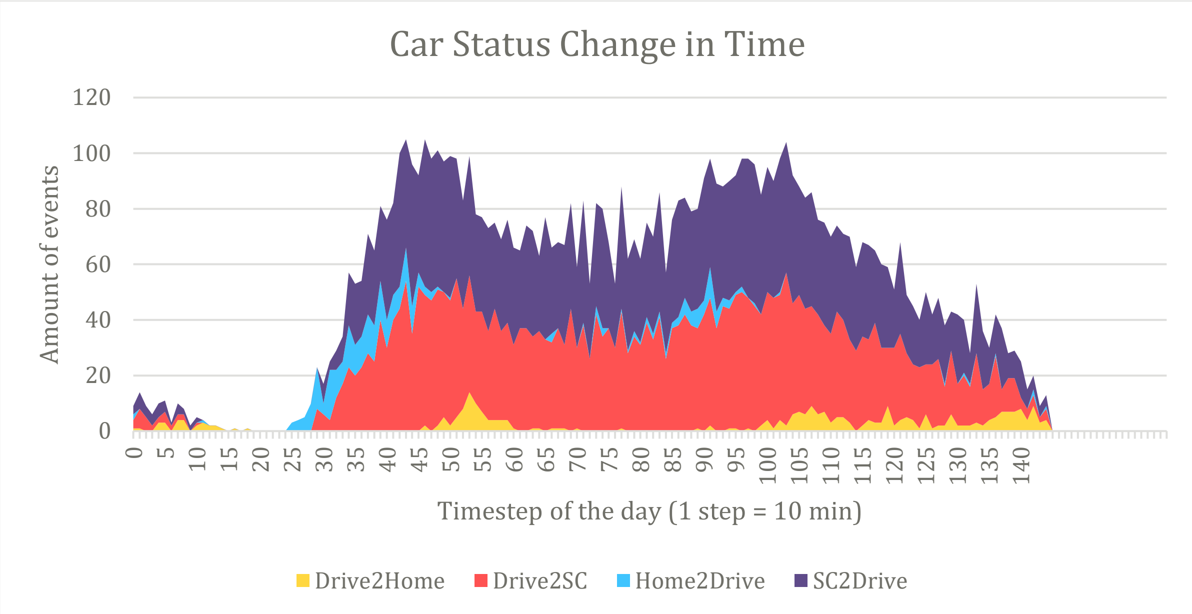

Figure 69. Markov chain for cars - transition matrix

When the future is uncertain, it usually better to study it through the optics of scenarios. In our case we will study the combinations outlined in Table 15 for cars. For the battery, we assume useful capacity of 60 kWh for the BEV and the ability to DC fast charge at 100 kW, slow charging is set to 11 kW. Fast charging scenario had to use bigger battery up to 100 kWh to make significant number of cycles feasible.

Table 15. Car scenario names

Scenario name	Constant price	Spot pricing	V2G
Slow charging	P1a	P1b	P1c
Mixed charging	P2a	P2b	P2c
Fast charging*	P3a	P3b	P3c

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*Despite various tests, the Fast-charging scenarios were always hard to execute successfully. That hints at the possibility that too many cars would fail to replenish their charge within a day if there were zero home/street charging possibilities.

The following facts are part of the default settings:

1) 100 % electrification scenario (no hand-picking of cycles, however impossible cycles due to insufficient amount of charging possibilities are skipped)
2) If too many cycles are skipped the scenario is seen as not feasible
3) Drive cycles more or less consistent, same energy for driving within the vehicle segment when combining scenarios together
4) Keep battery SOC up if possible, SOC start and end at 99 %, in some specific cases different start and end SOC are used (fast charging scenario, long-distance logistics).

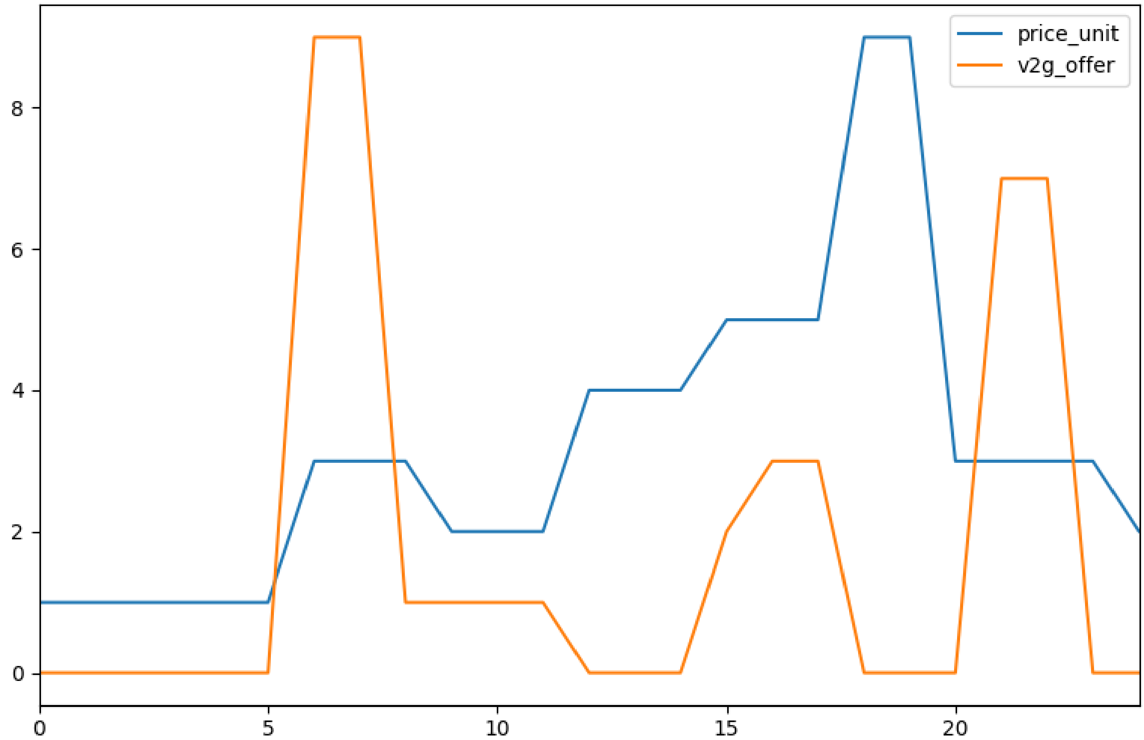

Figure 70. Price signal (price_unit) and V2G offer (v2g_offer) in tens of eurocents/kWh. V2G curve being higher than the spot price is assumed to be necessary to increase incentive for drivers to participate in the scheme.

In Figure 71 we can observe the total charging powers for the fleet of 100 vehicles across different scenarios. In Figure 72 we observe the difference between scenarios in terms of diurnal varieties in stored energy. Table 16 serves for summarizing the maximum load on the grid in each scenario (in Table 15) and Table 17 shows the same data adjusted for the differences in driving energies since especially fast-charging scenario might or might not affect the mobility behavior of the drivers. Fast-charging scenario can also be acting as filter for which cycles can be electrified, and thus it could be realistic that more energy is spent per vehicle (low-mileage vehicles would then remain hybrids or not electrified). The normalized table however shows what would happen if for example those drivers

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whose cycles did not currently work in fast-charging scenario would make an extra detour with charging stop.

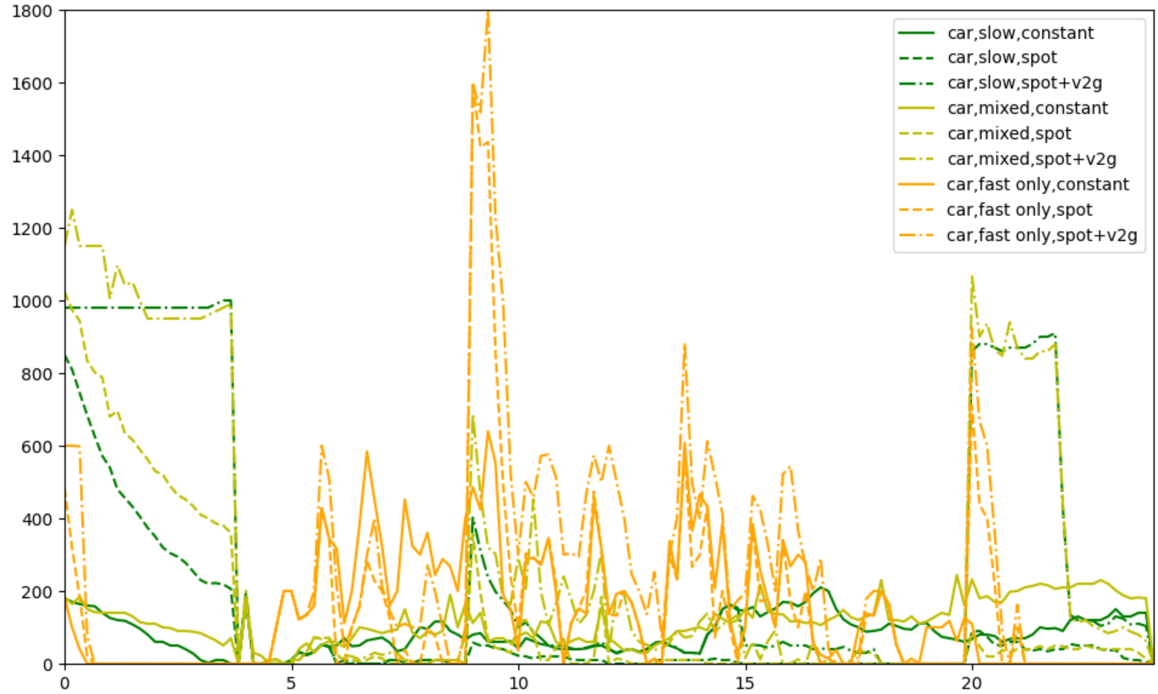

Figure 71. Charging powers in kW (y-axis) versus the time of the day on x-axis.

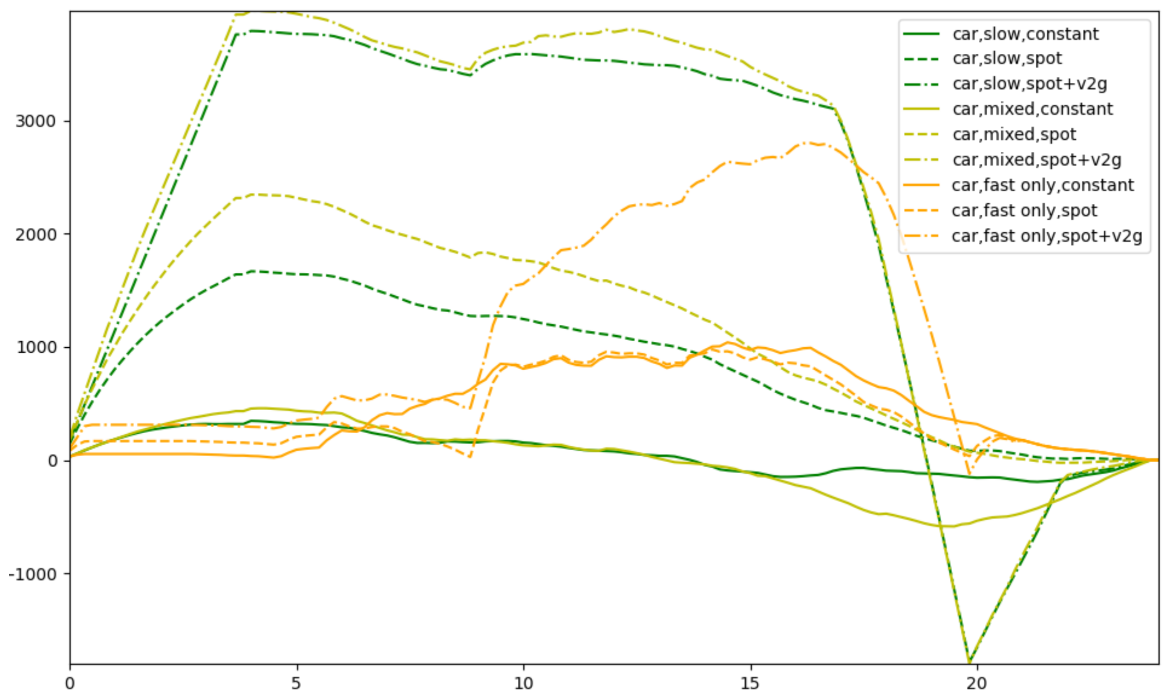

Figure 72. Energy in kWh stored in battery, start and end at 4 AM at 99 % SOC (except for fast-charging scenatios), x-axis for time, y-axis for stored energy in batteries. The energy at midnight is set to zero.

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Table 16. Maximum charging power (kW) for each scenario during the day

	Constant price	Spot price	V2G
Slow	210	850	1000
Mixed	244	1024	1250
Fast only	640	1600	1800

Table 17. Maximum charging power (kW) weighted by driving energy (e.g. energy spent for driving is the same for each scenario)

	Constant price	Spot price	V2G
Slow	210	850	1000
Mixed	174	720	878
Fast only	374	934	1051

5.2.2 Buses

Regarding the studied areas, long-distance buses are not expected to have any impact since the areas are rarely starting point of a long-distance bus routes. There are some routes going through Espoo with stops in those areas, but it would likely not make sense to install any fast-charging equipment to those.

City buses are mostly represented by HSL and each study area has either a terminal or significant presence of public transport. In Kera, no bus terminal is expected to be built, but a tram line is planned for the future. The amount of electricity needed for the tram is not included in this study.

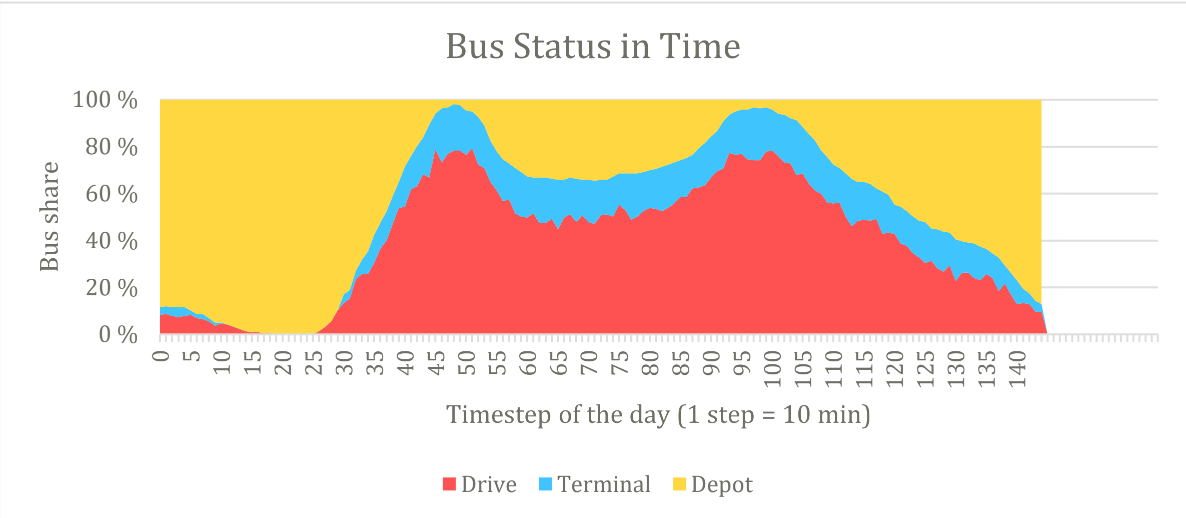

Figure 73. Location pattern for the bus segment of traffic

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The bus terminal charging impact is also studied in section 3.3. For the purpose of the city-wide simulation, similar scenarios were run also for the bus traffic. Bus charging was assumed 50 kW in depot, 300 kW while battery capacity has been set to 300 kWh. The resulting charging curves for different scenarios can be observed in Figure 74.

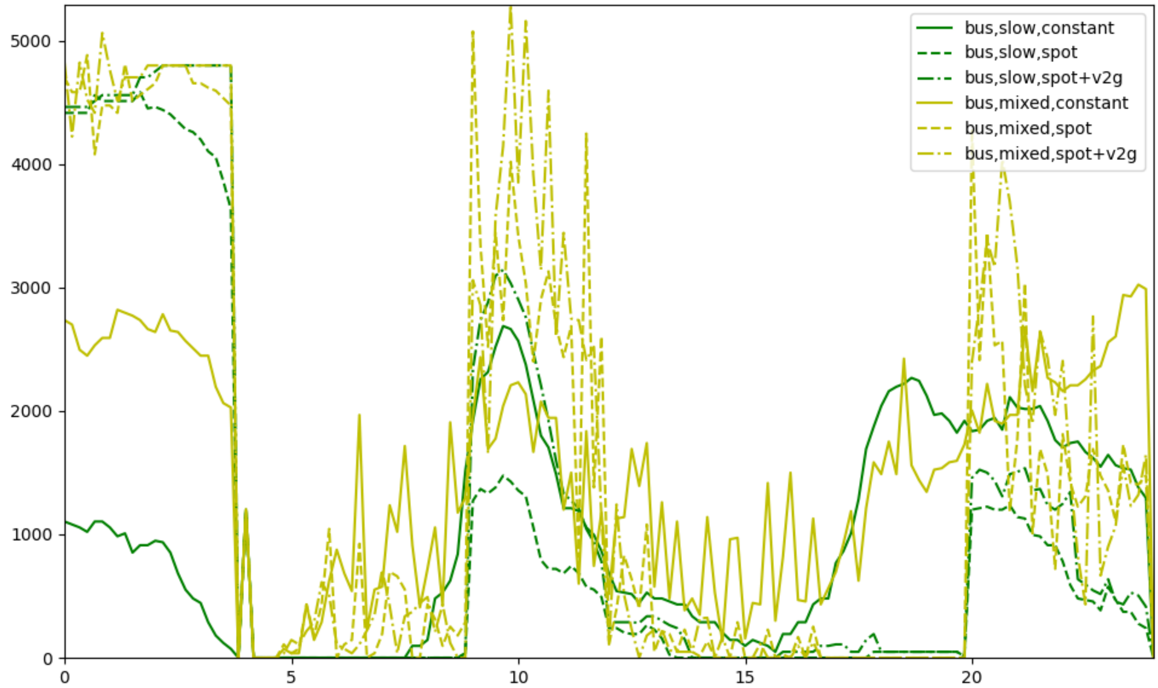

Figure 74. Results from charging scenarios for buses, x-axis shows time, y-axis shows kW

5.2.3 Delivery Traffic

Delivery traffic is a significant contributor to overall traffic volumes. Delivery or distribution traffic is characterized mostly by duty cycles located within urban context with many stops in their schedule.

Similarly to the following logistics case, the patterns for the daily distribution of delivery traffic have been obtained on the basis of LAM points data - automated traffic counting stations (Finnish Transport Agency, 2021), check Figure 75 to see how the delivery traffic behaves on different days of observation. However, no dataset was found to identify the time for the pauses of the delivery traffic vehicles, therefore some very simple estimate has been used there. The resulting patterns are shown in Figure 76.

Utilizing these patterns, the scenarios except for fast charging only were simulated for the delivery traffic use case. The results of that can be seen in Figure 77.

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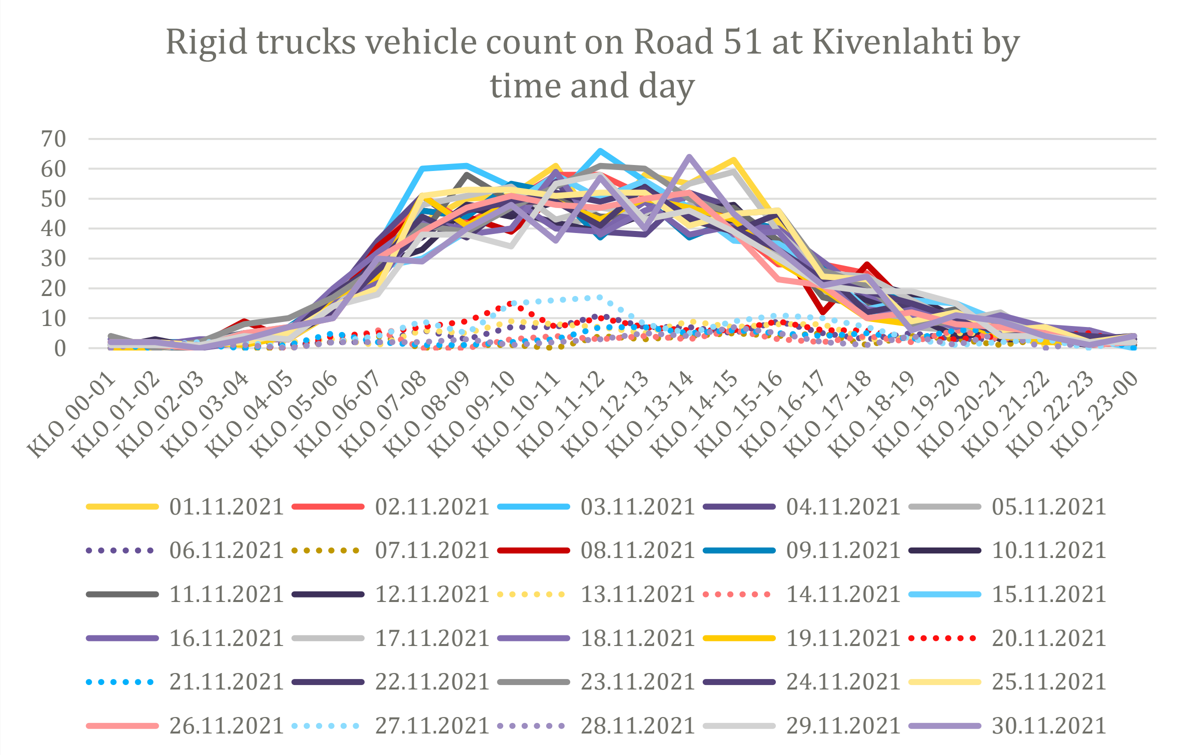

Figure 75. Observations from Kivenlahti, dashed days fall to weekend, source LAM points

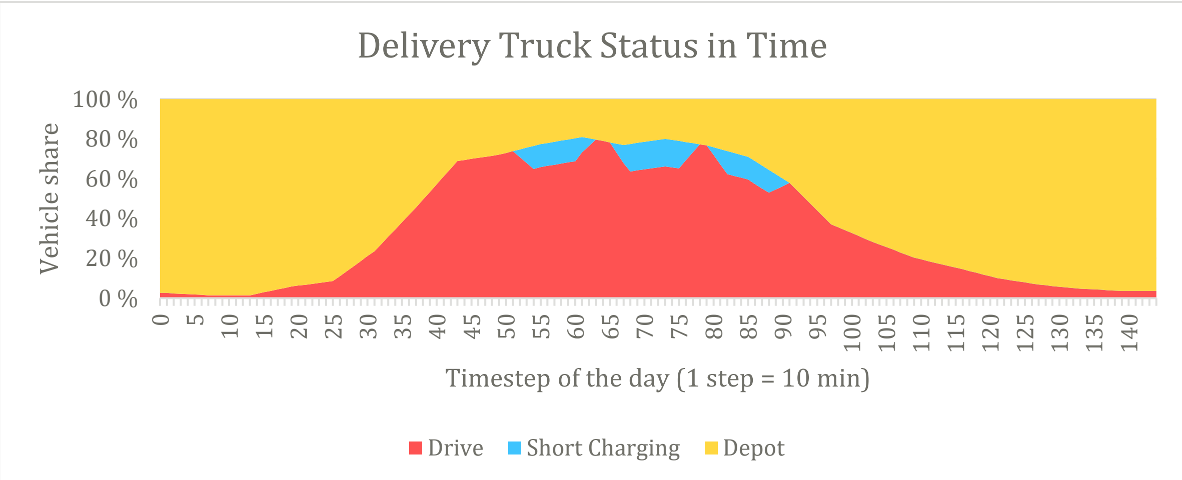

Figure 76. Hypothetical location pattern for the delivery truck segment of traffic

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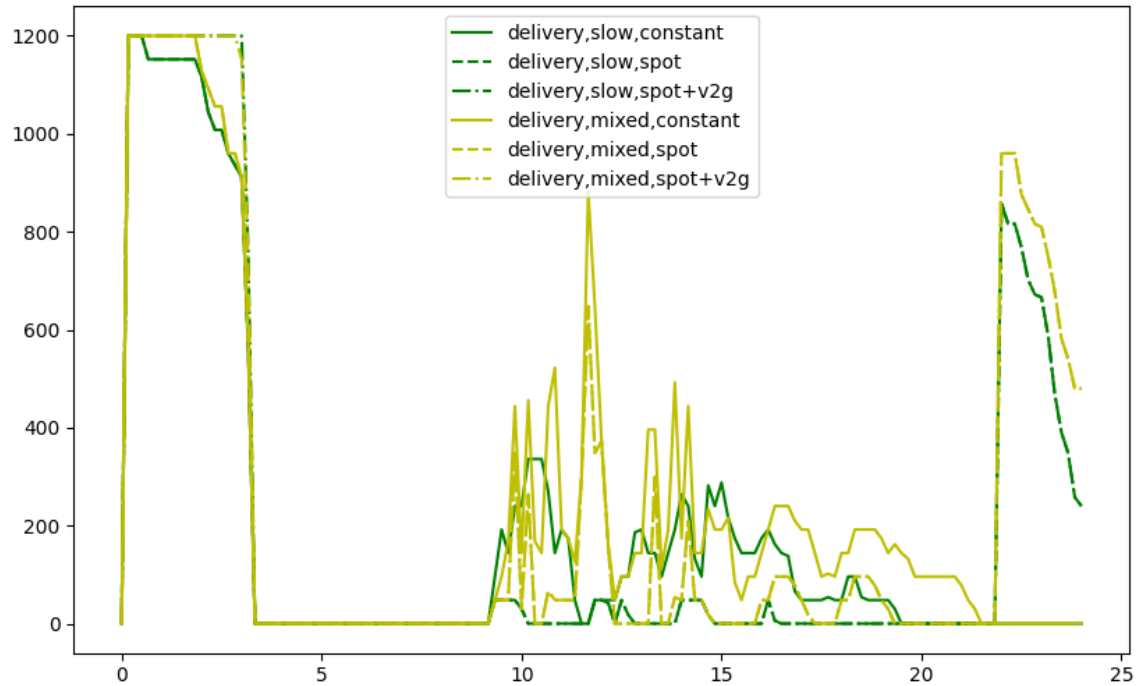

Figure 77. Results from charging scenarios for delivery traffic, x-axis shows time, y-axis shows kW

5.2.4 Long-distance Logistics (Semis)

Similarly to the delivery use case, traffic counts have offered probably the most valuable insight into the temporal patterns of long-distance vehicles. Open data for hundreds of measurement points around Finland are available from (Finnish Transport Agency, 2021). The data was filtered for southern Finland, in particular Uusimaa province. An example of the data can be seen in Figure 78.

Continuing from the processed data, a location pattern has been established for long-distance logistics as in Figure 79. Here the depot location should be interpreted as long-term stop, while terminal is a short-term stop, typically when loading and unloading goods.

Finally, in Figure 80 we can observe the difference between the simulated charging curves of each scenario. The fast-charging only scenario has been skipped as it is nearly impossible for most of the duty cycles. In the mixed scenario (both depot and terminal charging) the battery size has been reduced to 400 kWh, in depot only scenario the battery size amounts to 500 kWh.

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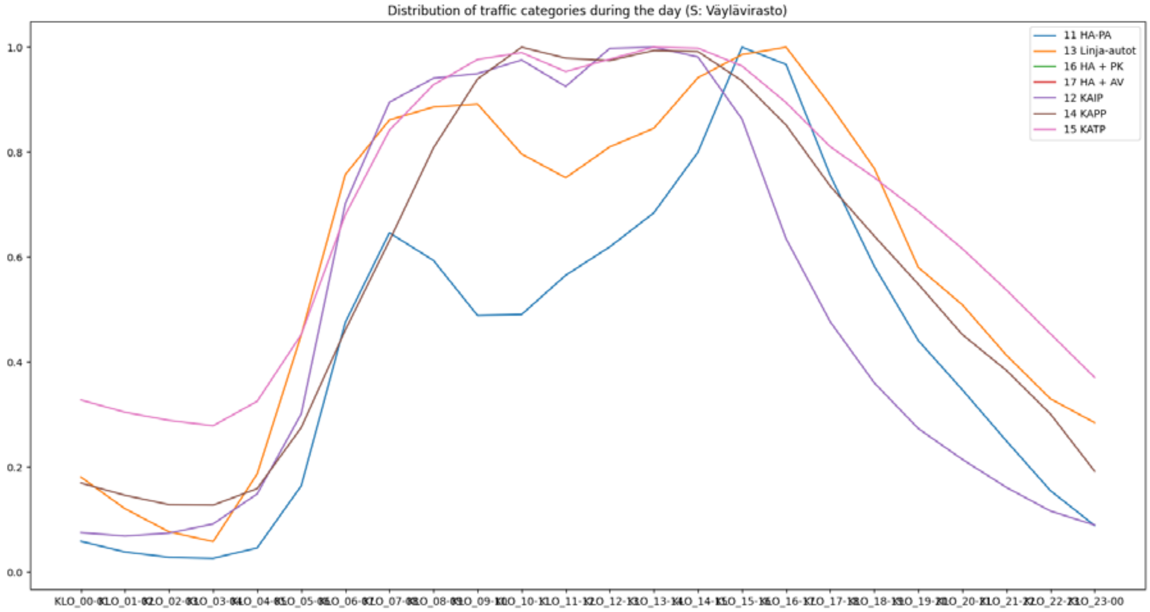

Figure 78. LAM data from (Finnish Transport Agency, 2021) showing traffic volumes distribution throughout the day for different categories of vehicles. Categories 12,14 and 15 relate to heavy duty vehicles, 13 refers to buses, the rest belongs to cars and vans.

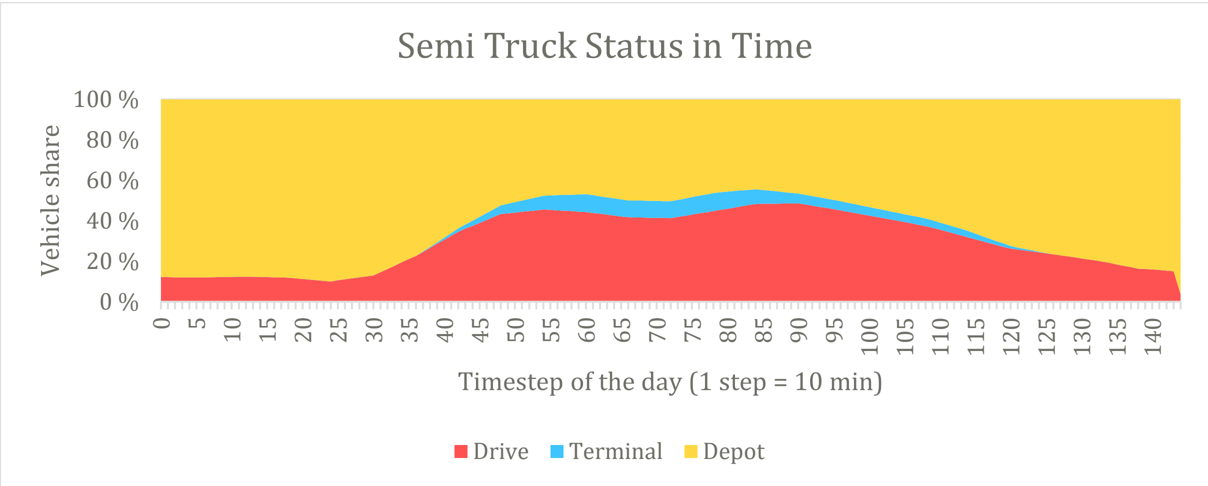

Figure 79. Hypothetical location pattern for the long-distance truck segment of traffic.

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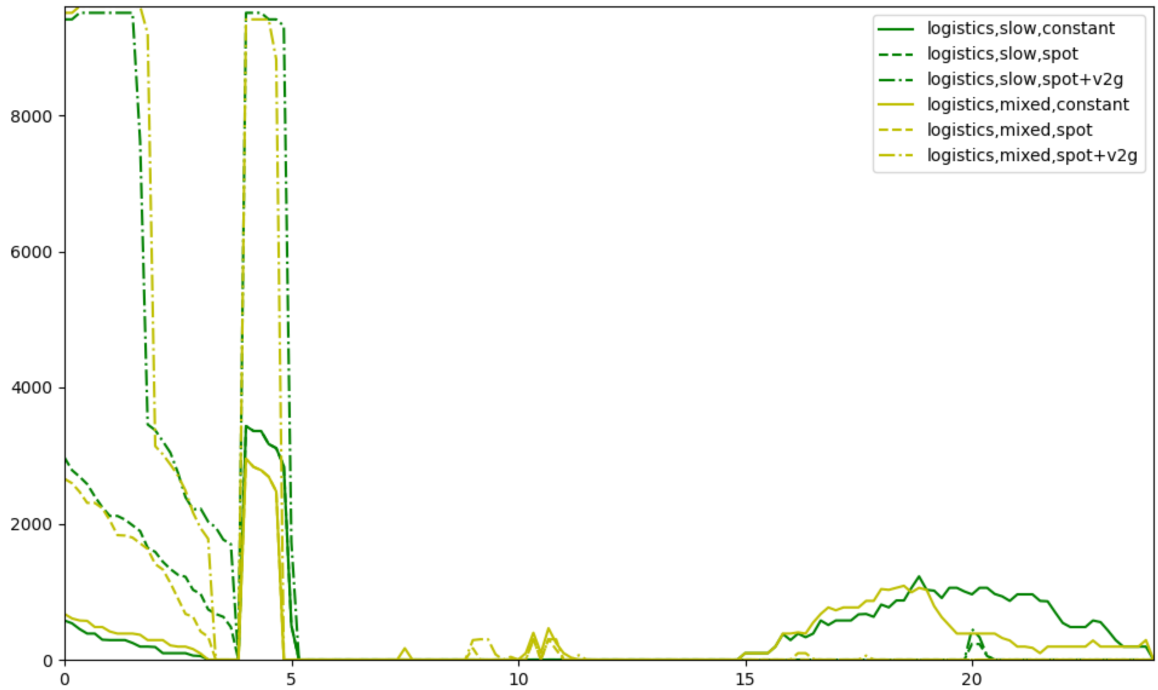

Figure 80. Charging curve for logistics cases, x-axis shows time, y-axis shows kW.

5.2.5 Charging Scenarios

5.2.5.1 Combined impacts

For combined impact only the mixed scenarios with charging available both at home/depot (slower) and commercial facilities (faster) are studied. The scenarios limited to domestic/depot charging are not likely to reflect the future situation, since if charging outside home is cheap, it would encourage charging outside home as well. On the other hand, charging only outside means missing out on cheap charging tariffs and would make electromobility much less attractive. New charging solutions keep emerging such as charging from streetlamps (Hall & Lutsey, 2020) or inductive charging making it possible to charge even when parked on the street side. In addition to that, many challenging driving cycles did not have a solution for simulations with economic size of battery storage.

In Figure 81 we observe that constant prices scenario projects into relatively stable charging power throughout the day, mostly fitting under 100 MW for the whole city of Espoo. While this might look positive, there is little cooperation with the grid as the typical times when the grid is stressed the most (evening from about 4 to 7 PM) coincides with the peak in charging demand.

In Figure 82 where spot pricing is used, we observe much higher levels of interaction with the grid. In the morning and evening peak, the charging demand is heavily reduced as people and companies are monetarily incentivized to charged outside of these times. The charging peak then reaches up to 200 MW in the night, but that is because the grid usually has reserves at that time and thus the spot price is rather cheap. Thanks to the high share

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of nuclear and wind power in the Finnish grid, this is expected to hold true in the future as well.

In Figure 83 we expect the people and companies to participate in the V2G scheme while following spot prices for charging. The hypothetical price curves were shown earlier in Figure 70. Somewhat interestingly, the charging powers are much higher than in the previous scenarios. This has however a logical explanation, as all the energy returned to the grid at critical times has to be charged from the grid at some other time of the day. While semis (long-distance trucks) are charging mostly after midnight as in this scenario they have more powerful depot charging equipment, passenger cars start to charge much earlier. At least part of it could be explained by slower home charging for the cars as they do not have the luxury to wait for the cheapest price in the late night. More powerful charging capacity at home would likely switch the charging later into the night.

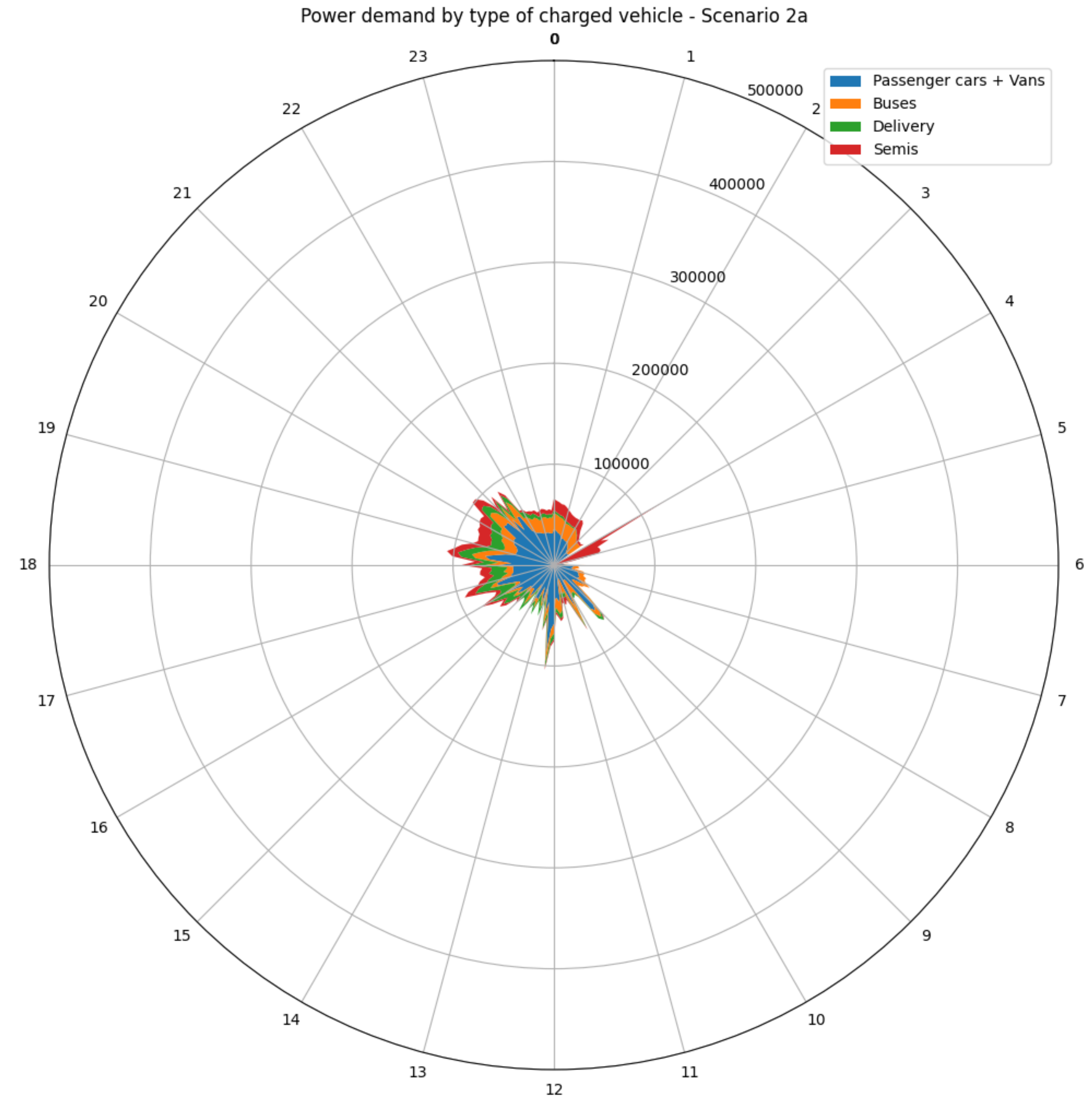

Figure 81. The charging power usage of the different vehicle segments during a 24-hour period in the combined scenario 2a. Source: VTT

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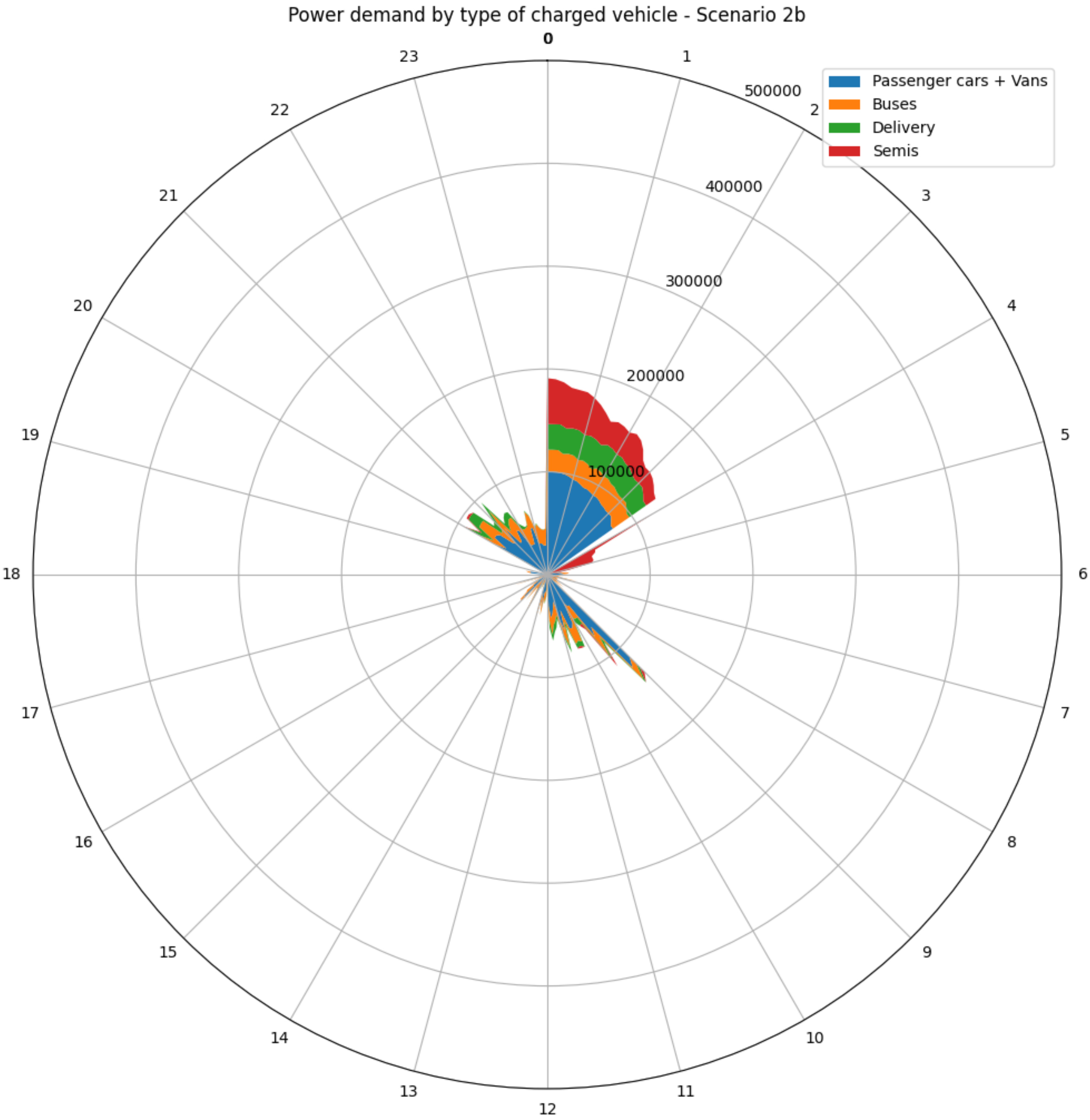

Figure 82. The charging power usage of the different vehicle segments during a 24-hour period in the scenario 2b. Source: VTT

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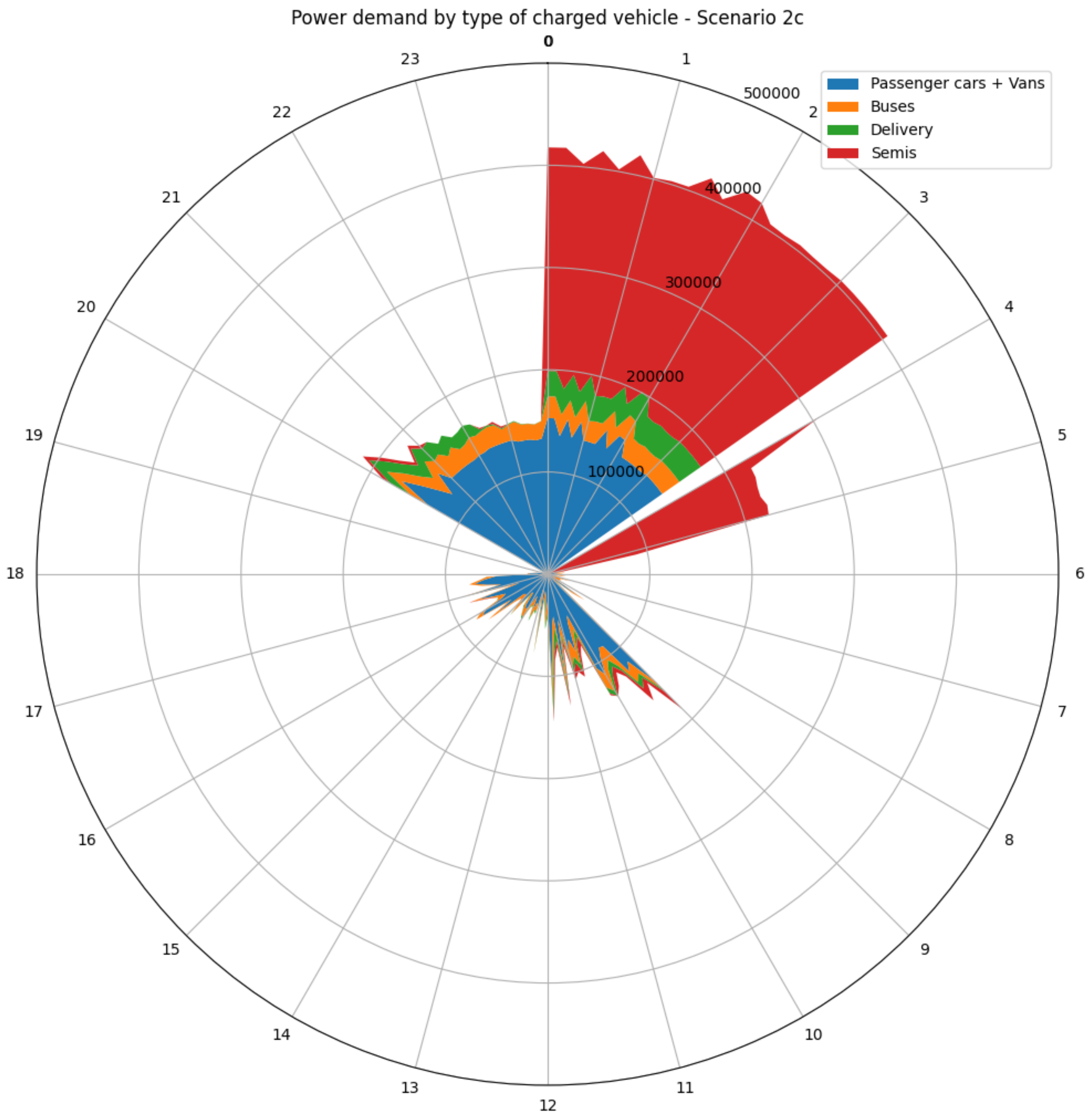

Figure 83. The charging power usage of the different vehicle segments during a 24-hour period in scenario 2c. Source: VTT

5.2.5.2 Likelihood of scenarios

In order to reduce the grid load in critical times, it is quite likely that some sort of smart pricing might be needed to motivate people to charge in more suitable time. On the other hand, since smart pricing itself (Scenario 2b) already greatly reduces the demands on the grid in critical times, the extra expenses on V2G will need to be well justified and the customers would need to be persuaded that the participation benefits overweigh the potential loss in the lifespan of the battery.

5.2.6 Planning Recommendations Based on the Models

We conclude that this study underlines the necessity of being able to charge as flexibly as possible with slow charging being more important than fast charging options. First of all,

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both household and commercial chargers are essential to support the existence of electric mobility. As supported by the work with the scenarios, availability of domestic charging means that charging can happen at more preferable times from the perspective of the grid operation, see example of grid load in Figure 84.

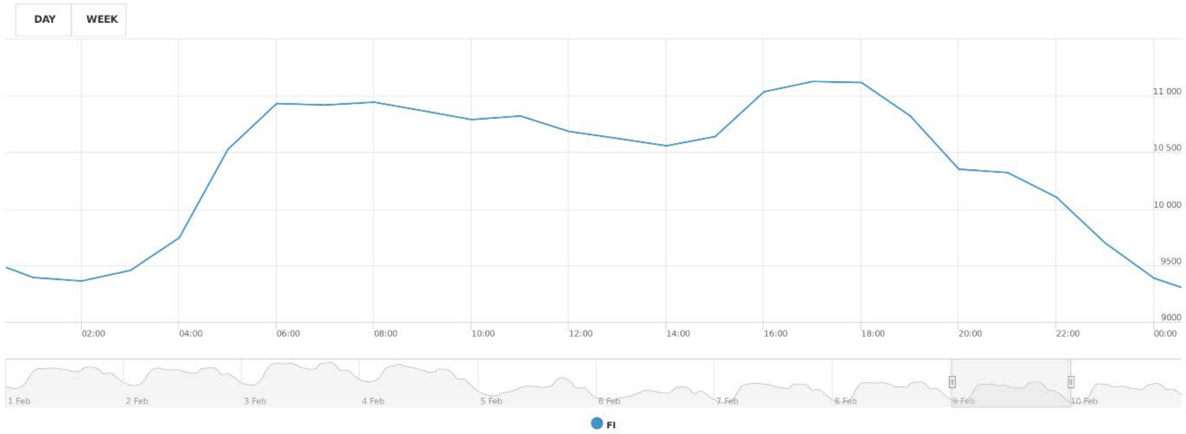

Figure 84. An example of a more pronounced afternoon peak from 5th February of 2022. However, not always the afternoon peak is that visible. Source: https://www.nordpoolgroup.com/

The main recommendations thus are:

1) Enable slow charging at home whenever possible. All new residential developments should be EV-ready.
2) Depots for heavy duty vehicles should be dimensioned to enable night charging at higher speeds, vehicles that would participate in V2G scheme will need higher installed capacity
3) Charging at commercial facilities (shopping, offices) is essential for enabling electrification of challenging duty cycles

5.2.6.1 Impact Evaluation

During this study we conclude that the electricity needed to power full electromobility for Espoo is in the area of 1 GWh/day. This, surprisingly, is not an impossible figure, given that it only represents roughly 5 kWh per inhabitant and day. Depending on the pricing scheme and the ability of V2G, different maximum charging power is achieved. Somewhat surprisingly, flat pricing seems to lead to the lowest maximum power of only about 100 MW, while smart pricing raises that to 200 MW and V2G further increases the amount to about 400 MW in a city-wide context. It should be noted that these power levels only indicate the power used for charging of vehicles. If the entire electricity demand would be taken into account, the smart pricing scheme would lower the power fluctuations as the vehicles are charged mostly when the overall energy demand is at lowest. Somewhat unsurprisingly, the reason why V2G needs higher maximum capacity is because it not only needs energy for powering the vehicle, but also for storing of the grid's energy.

5.2.6.2 Mitigation of Impacts

While flat pricing led to the lowest maximum charging power, it has one disadvantage. The peak occurs at 6:30 PM, the time when there is greatest for electricity for other uses

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as well, especially within households. This is not optimal, and would mean that many charging stations would become less profitable and more of a burden and the overall installed capacity of the grid's power plants would need to increase (or another stationary storage would need to be introduced). In order to mitigate the issue, smart pricing shifts the load efficiently, given that people know how to work with the system. The V2G option then goes one level further and actively helps to reduce the load on the grid during the peak time.

5.2.7 Conclusions

We have studied the impact of electric mobility on the grid in the city of Espoo with focus on the most extreme case - full electrification of its road transportation. The study assumes that people are sensitive to the prices of electricity and would adapt their charging behavior within their given comfort range. Usually we assume that this comfort range is between 20 to 80 % SOC for the battery. Daily mobility patterns of different types of vehicles in Espoo are examined in detail with all the available resources. This leads to the development of a Markov chain that is able to reproduce most of the patterns while keeping the computational intensity relatively low. Each mobility pattern is then studied through the perspective of optimizing the charging pattern to minimize the cost of charging (while staying within the given range and not changing the mobility pattern).

For the purpose of studying the future options we propose a variety of charging scenarios reflecting different charging options and pricing frameworks. While domestic/depot charging enables most of the mobility patterns to electrify, some commercial chargers are essential as well. On the other hand, surviving only on commercial chargers was found to be problematic for most of the mobility patterns.

When combining the charging scenarios for each type of vehicle together, we found the combined impact of the whole electrified traffic in Espoo. The total charging powers were within the realm of hundreds of MW with the total need for electricity hovering above 1 GWh per day. Such numbers should not present a huge challenge for the future of electric grid in Espoo, but synergies can be gained by thinking about the systems' interaction way ahead.

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6. CONCLUSIONS

The overall target of the mobility related actions in SPARCS was to boost the uptake of e-mobility solutions. Diverse activities have been carried out in order to reach this target: charging infrastructure has been implemented, workshops and discussions with stakeholders and citizens have been organized, literature studies have been carried out as well as simulation studies of the impact of e-mobility. The activities have increased the understanding of the characteristics of new mobility solutions among the project partners and valuable learnings to be shared for future needs have been gained.

The Actions have examined the development of e-mobility solutions in various kinds of areas that are in different stages of urban development processes, providing valuable insight to how the solutions can be utilized in different, both spatial and temporal, contexts. The new Lippulaiva blocks in Espoonlahti have been extensively re-developed during the past few years, and continue to form into a new centre for the area in the upcoming years; Sello blocks in Leppävaara are located in an already densely built area, where infill and small scale redevelopment can take place to enhance the already central hub area ; Kera area will only begin construction in the upcoming years, with the goal of creaeting (almost) a fully new urban district to the area.

6.1 Summary of achievements

During the project, EV charging points and facilities for bikes (normal and e-bikes) were implemented in the Lippulaiva blocks, Espoonlahti. These solutions are well aligned with Citycon's sustainability strategy and its targets. The desire of Citycon is to promote the sustainable ways of getting around the city and one of the sustainability goals is to offer electrical vehicle charging possibility for cars and bikes in all Citycon's assets.

Almost all the e-mobility solutions in Lippulaiva have been in use since the opening of Lippulaiva in March 2022. Only the charging cabinets for batteries of e-bikes are still expected to be delivered. Based on the experience of 6 months, the solutions seem to be very successful. EV charging points are continuously used and there is clearly a need for charging stations for electric cars in the Espoonlahti region. Up to this point, the number of charging stations installed has been sufficient and the availability of the charging infrastructure has remained on a good level.

There are plenty of bicycle parking spots in the Lippulaiva blocks. Presumably the number of users of these parking facilities for bikes will increase when the upcoming metro extension line starts to operate in 2023. In the future, the usage of the parking facilities for bikes and e.g services for cyclist could be assessed to provide insights for further improvements and replication potential in other locations.

Large scale charging systems, shared chargers and optimized charging strategies were examined in Leppävaara area during this project. PIT implemented a 3000 kVA bus charging system, which has found to be successful in every way. It has shown that 99 % uptime is possible for a large charging system and has been an innovative solution for replication. This charging system is also designed so it could be shared with different electric fleets.

The integration between an energy management system and charging system has also been examined. Siemens has integrated AC chargers into Sello local building

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managements system, and PIT has integrated a charging system into energy management system / VPP in Ilmatar Areena. This has been an interesting integration, and makes it possible to control even bigger electrical systems as a whole. This kind of implementations will become more common in the future, and these are good demonstrations for development and replication.

VTT and PIT also created a simulation for charging strategies. This simulation was done for Leppävaara area, and it investigated current and future states in the area. Multiple simulation scenarios were run, and charging strategy, peak shaving and grid connection were optimized. V2G and electric price curves were also researched during the process. This kind of simulations could be used to plan large scale charging system and have an optimal usage and smallest impact for the grid.

Kera area is in the phase of planning and development, which provides a unique possibility to incorporate the technical, and practice and behaviour related insights gained from the SPARCS activities already in the first stages of (re-)development of the current brownfield area into a new city district. Developing a 'new' district and urban environment also means that new ways of doing things and processes have to be created. As the various insights gained from workshops on sustainable mobility modes and mobility hubs have shown that active development, decision-making and practical work is required to support and boost sustainable mobility modes and e-mobility in the area in all stages of the development of an area. This development does not happen idiomatically but needs active efforts, investments, adaptation strategies, and information sharing processes to succeed. The inclusion of such novel solutions, and developing and co-creating them together with different stakeholders, should be done already in the planning and design phase of an urban district. The upcoming years and decades in Kera area development will show how and which of these learnings can best support the area's transformation into a walking, bicycling and public transportation reliant urban district. SPARCS has provided some key tools to support this development.

The Kera station area will play an important role in the development of the area's local sustainable mobility system, and new solutions - technical, practice-based, behaviour-based, spatial & architectural solutions - are required to support the transition towards shared and carbon-free mobility and multi-modality, as envisioned for the district. The station area forms not only a transportation-related hub but also a hub of activity in a more general sense, including the social, cultural and practical uses of the shared public space and the social interaction taking place there. The transportation station area is simultaneously the heart of the local community as it brings people naturally together again and again. The solutions developed in Kera and in the station area also need to support these functions that go beyond the strictly transportation related issues. The conceptual insights and possibilities gained through SPARCS can support the development of such future e-mobility hubs that are accessible to all. Following the tradition of pop-up activities, piloting and testing, and temporary uses, as found in the Kera Halls, the station area could be development as a testbed for new solutions, practices, and modes of interaction.

One of the focus points of the e-mobility actions in SPARCS has been the development of e-mobility hubs. The e-mobility hub is a connection point of multiple mobility modes such as public transport, shared cars, and bikes. As the name implies, an e-mobility hub is able to serve the energy needs of electric vehicles besides serving the mobility needs of the

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users and inhabitants in the community. The share of electric vehicles is still low despite continuously rising sales figures, hence, the data on charging needs for vehicles is scarce. In order to analyze the impact of electric mobility on the electricity network, a simulation method was developed. The estimation of the charging need at a certain location requires data on the travelling needs and energy consumption, as well as assumptions regarding the charging preferences. The travelling needs for each and every vehicle cannot be precisely known, instead the analysis relies on the probabilities of vehicles either driving or being parked. These probabilities were extracted from previously developed activity-based transport models and openly available statistics depending on the vehicle category. A period of 24 hours was simulated and various pricing schemes were applied. The charging preference was assumed to depend on the battery state of charge and the price of charging.

The overall power demand varied greatly depending on the pricing scheme applied. With constant charging prices, a great deal of the charging occurred during the afternoon. When a variable price was applied, the variation in the charging power increased and the power peaks were higher than in the case of constant prices. The results need to be understood in the context of the entire electricity distribution system; the price curve applied is directing the charging towards periods when the power demand is lower. Hence, if the electricity demand of other sectors would be included in the model, the power peaks would be lower in the case of varying charging prices. This result is in line with findings from the literature, stating that smart charging of vehicles is essential in reducing the stress on the grid. The analysis shown here is based on an example of the electricity spot price. The charging demand could be analyzed further utilizing a variety of price curves. The electricity prices have lately been characterized by extreme volatility and the future prices are quite uncertain. Renewable energy production, such as wind and solar power, cannot be controlled to the same extent as conventional production. The need for demand response and electricity storage will likely increase in the future.

6.2 Other conclusions and lessons learnt

The share of electric vehicles is currently increasing rapidly; the sales of EVs are continuously rising and the share of electric city buses have increased at a rate even higher than initially expected. Investments in new rail infrastructure in Espoo improves the competitiveness of public transport, and higher passenger numbers are expected as the society gradually normalizes after the COVID-19 pandemic. The majority of delivery vehicles still use fossil fuels. Electric trucks are well suited for the relatively short distances in city logistics, and the share of electric trucks might increase very fast as more options become available on the market. Electrification activities related to mobile machinery and service vehicles, e.g. refuse trucks are also constantly progressing. Whether or not to electrify mobility solutions is no longer a question; the challenge is rather how to manage the energy supply to the vehicles in an optimal manner. Smart and efficient usage of energy is a topic hotter than ever before, and even though the political and economic situation will normalize, the importance of efficient energy use will not disappear. The mobility activities carried out within the SPARCS project have created a good ground for further work. Extending and developing smart charging infrastructure has great potential to support the energy system in the transition from fossil energy sources to renewable sources. The engagement of citizens, which has been a substantial part of actions described in this report, should not be forgotten in the process of

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transition, as studies have shown that pitfalls do not lie in technology alone. The awareness of novel solutions has to be raised in order to achieve acceptance among the public. And of course, the primary purpose of all mobility solutions is to provide seamless and smooth transportation options for participation in society for all. This cannot be done without keeping the user's point of view in mind.

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7. ACRONYMS AND TERMS

Acronym / Term	Description
ABTM	Activity based transport model
AC	Alternating current
BEV	Battery electric vehicle
CaaS	Charging as a service
CCS	Combined charging system
CPP	Critical peak pricing
DC	Direct current
EV	Electric vehicle
EVCS	Electric vehicle charging station
GB/T	Chinese charging standard
HEV	Hybrid electric vehicle
HSL	Helsinki region transport authority
HSY	Helsinki region environmental services authority
KPI	Key performance indicator
LAM	Automated traffic counting station (orig. in Finnish)
LAN	Local area network
MaaS	Mobility as a service
PED	Positive energy district
PHEV	Plug-in hybrid electric vehicle
PTR	Peak time rebates
PV	Photovoltaic
RES	Renewable energy source
RFID	Radio frequency identification
RTP	Real time pricing
SDG	Sustainable development goal
SOC	State of charge
SWOT	Strengths, weaknesses, opportunities, threats
TOD	Transit oriented development
ToU	Time of use
V2G	Vehicle-to-grid

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