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Feasibility of Innovative Smart Mobility Solutions for Vaasa – A Case Study of EU Horizon 2020 IRIS Project

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ABSTRACT:

The primary purpose of this thesis is to examine the innovative smart mobility, and second life battery solutions, represented in the City of Vaasa's Horizon 2020 IRIS Smart Cities Replication plan. The objective is to find certitude of the Lighthouse cities' demonstration validity and feasibility concerning the City of Vaasa's replication plan. Additionally, the aim is to study the solutions' potential to be implemented in Vaasa, and the benefit concerning the city's general plans to reach carbon neutrality by 2030. The secondary object is to examine the solutions' compatibility with the IRIS Lighthouse cities' demonstrations and gathered experiences, and with the recent plans and projects executed in Vaasa related to smart and sustainable mobility solutions. This thesis was commissioned by the City of Vaasa.

European Union launched 2014 the Horizon 2020 program, aiming to encourage EU nations and their cities to take steps to reach carbon neutrality via projects promoting Smart City development. Horizon 2020's aim is to battle climate change by encouraging cities to become more sustainable. By promoting innovative, efficient, far-reaching and replicable solutions, from the fields of smart energy production and consumption, traffic and mobility, information communication technology, and citizen engagement, the objective can be achieved. IRIS Smart City project (Integrated and Replicable solutions for co-creation in Sustainable cities) was launched in 2017. The project consists of three Lighthouse cities and four follower cities. Vaasa has been part of the project since 2017 as a follower city. The IRIS project's solutions are first to be studied and demonstrated by the Lighthouse cities and then to be replicated by the follower cities. A replication plan is required to examine and present the feasibility and validity of the integrated solutions, to secure their implementation process.

The results of this thesis indicate that the innovative smart mobility solutions, including V2G and 2nd life battery schemes presented in the City of Vaasa's replication plan, are relevant to the City of Vaasa, by being compatible with the city's climate and decarbonization goals and related sustainable mobility plans and projects executed in Vaasa in the past few years. These solutions play significant role in the Lighthouse cities' demonstrations, thus showing great potential for utilization in the City of Vaasa's infrastructure, mobility and smart grid development plans. The solutions can advance Mobility as a Service concept, electric vehicle utilization development, and aid in decarbonization, enhancing energy efficiency, creating new businesses and services, and improving the attractiveness of the city.

Keywords: Horizon 2020, IRIS, Smart City, Innovative mobility solutions, sustainability

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Abbreviations

BESS	Battery energy storage system
BEV	Battery electric vehicle
BIM	Building information model
BMS	Battery management system
CIM	City information model
CIP	City information platform
DER	Distributed energy resources
DG	Distributed energy generation
DMS	Demand side management
DSO	Distribution system operator
e-	Electric-
ESS	Energy storage system
EC2B	Easy-to-Be (Mobility as a Service model)
EMS	Energy management system
EU	European Union
EV	Electric vehicle
FC	Follower city
GHG	Greenhouse gas
G2V	Grid-to-Vehicle
HEV	Hybrid electric vehicle
IC	Internal combustion engine
IS	Integrated solution
LH	Lighthouse city
MaaS	Mobility as a Service
PHEV	Plug-in electric vehicle
PV	Photovoltaics
QoL	Quality of Life
RES	Renewable energy source
RESS	Remote energy storage system

SOC	State of charge
SOH	State of health
TSO	Transmission system operator
T.T.	Transition Track
V2G	Vehicle-to-Grid
VPP	Virtual power plant

Introduction

Climate change, global warming, rising emission levels, and increased energy consumption have led nations across the world to initiate decisive measures to restrain, control and turn the negative development concerning the climate, environment and ultimately the future of our planet. During the past three decades, several international climate agreements have been ratified to stop the global warming, and decrease the carbon dioxide (CO_2) levels produced mainly by energy production and consumption, traffic and agriculture. As governments have set goals for the next decades to reduce emissions, and strive to better energy efficiency, they are also facing considerable challenges. Large cities are expanding in size and inhabitants, due to the Earth's growing population and the trend of urbanization. Thus, pollution levels and emissions from energy production and consumption are increasing. Additionally, the urban traffic and the emissions caused by it are increasing. Cities are one of the key factors in the fight against climate change. Mitigating measures performed in the cities concerning energy production, consumption, traffic, and related emission, have a direct impact on the future of our planet.

European Union (EU) launched 2014, the Horizon 2020 program, aiming to encourage the EU nations and their cities to take action to reach carbon neutrality through projects striving to Smart City development. Over the next 7 years, 17 different Smart City project received funding and were launched. Each project was led by 2-3 Lighthouse cities (LH) from various EU countries, which were joined by 4-6 follower cities (FC). Every Horizon 2020 Smart City program's project share similar goals, although their solutions to achieve them may differ. The main objective of each project is to battle climate change by innovative, efficient, far-reaching and replicable solutions, from the fields of smart energy production and consumption, traffic and mobility, information communication technology (ICT), and citizen engagement. Horizon 2020 funded IRIS Smart City project (Integrated and Replicable solutions for co-creation in Sustainable cities) was launched in 2017. The Lighthouse cities in the five-year project are Utrecht (Netherlands), Gothenburg (Sweden) and Nice Côte d'Azur (France). The follower cities are Alexandroupolis (Creek), Santa Cruz de Tenerife (Spain), Focsani (Romania) and Vaasa (Finland).

The City of Vaasa's climate objective is to reach carbon neutrality by 2030. In order to achieve this goal, the city has taken several measures during the past decade. It has been involved with the EU's The Covenant of Mayors climate program since 2016. In addition, several projects and reports have been carried out concerning sustainable mobility and urban development, smart grid advancement, and citizen engagement. Furthermore, the City of Vaasa's infrastructure and traffic planning, construction and mobility design and activity, and energy consumption and production, are implemented in a sustainable manner, thus promoting decarbonization.

The City of Vaasa was accepted to the IRIS Smart City project in 2017. IRIS is constructed from five different Transition Tracks (T.T.), all including variety of integrated solutions (IS), measures by which the objectives set by the Horizon 2020 program can be achieved. IRIS consists of 16 solutions. First, they are to be researched and demonstrated by the Lighthouse cities, and afterwards replicated by the follower cities. However, in order to reach actual replication and implementation of the solutions, a thorough replication plan must be developed. In the starting stage of the IRIS project, the City of Vaasa expressed its interest in replicating all 16 of the replication plan's integrated solutions. However, some of the solutions have proven to be more feasible for the City of Vaasa to be replicated than others. Additionally, concerning some of these solutions, considerable measures have already been taken, e.g. in the development of the city's heat network, energy production, smart grid solutions, and various construction projects.

The IRIS projects' Transition Track #2 and #3 consist of solutions concerning innovative mobility services for the citizens, vehicle-to-grid (V2G) technology, and utilizing second life (2^{nd} life) batteries in large-scale storage schemes. These solutions are also of interest to the City of Vaasa. Smart e-mobility schemes and the development of Mobility as a Service (MaaS) concept present high potential for replication and final implementation. V2G solutions and utilizing 2^{nd} life batteries have also potential and significance, however, more in the future perspective. Yet, the replication plan examines them as well.

Currently, traffic represents approximately 30% of Vaasa's CO_2 emissions. This share is estimated to increase in the future. The IRIS project's measures targeted at innovative mobility solutions, and the Lighthouse cities' mobility, V2G and 2nd life battery solutions have to comply with the City of Vaasa's general decarbonization plans, and the designed infrastructure and traffic projects, in order to have significance and validity for the replication plan. In addition, the replication plan needs not only to find support and example from the Lighthouse cities' demonstrations and experiences. Additionally, it needs to find cohesion with the other mobility related plans and projects done in Vaasa in recent years. The findings and collective voice of these projects, and information about the importance of sustainable e-mobility, faster adoption of electric vehicles, and development charging infrastructure and mobility services, can aid the City of Vaasa's decision-making processes and carbon free development.

1. Horizon 2020

The 2008 financial crisis, and the necessity to cope with its impacts on the European economy, initiated several incentive programs and projects in the European Union. The most significant challenges were to find measures to stabilize the financial and economic system in short-term, as well as to protect and create new economic growth and opportunities for the future. The EU's economy, and competitiveness in global scale, needed thorough structural reformation and fiscal consolidation. Thus, research and innovation became top priorities in the new Europe 2020 strategy, receiving significant funding and investments. Based on the strategy, the European Union would strive to generate substantial amount of new smart technological and scientific breakthroughs, hence creating new business opportunities and jobs via innovative products and services. Fighting climate change and adapting to its impacts, reducing emission levels, reforming energy production and efficiency, and advancing sustainable and comprehensive economic growth, became the basis of the Europe 2020 strategy (European Commission, 2011 & 2017).

The EU ushers its member states to turn away from non-renewable, fossil-fuel based energy production, to sustainable and renewable energy, e.g. wind, solar, hydro, wave, geothermal energy and waste incinerated heat. The endeavors to achieve carbon neutral societies require various assertive actions, including developing cities to become more environmentally friendly, i.e. smart. Smart cities utilize innovatively both centralized and decentralized energy production with strong renewable energy sources (RES) involvement, and emphasizing energy efficiency and sustainability. Smart cities exploit smart grid and micro grid concepts, electrified transport, i.e. e-mobility, and robust information communication technology, to reduce their carbon footprint. Furthermore, new technologies and innovations provide tools for more efficient and encompassing energy services for these cities' citizens and businesses. In 2011, the EU's Head of State and Government, urged the European Commission to combine all of the existing EU's funding for research and innovation under one joint strategic framework. The extensive cooperation and consultation between the European Parliament and multiple key stakeholders lead to the design of the Horizon 2020 program, which was eventually launched in 2014 (European Commission, 2011 & 2016; Garrido-Marijuan et al., 2017; The IRIS Smart Cities Consortium, 2019).

The EU is committed to an ambitious decarbonization of its economy and environment. Diminishing harmful emissions, while constantly adapting to the growing climate and environmental pressure and urbanization, are vitally important measures in achieving this objective. Once initiated, the Horizon 2020 program became the Europe 2020 strategy's flagship initiative. The Horizon 2020 is the biggest research and innovation program in the history of the EU, being the main instrument and framework to enable the implementation of the EU's research and innovation undertaking. The program's architecture was deliberately designed to be simple, in order to avoid unnecessary bureaucracy, and to facilitate most effectively the access and launch of the participating projects. The Horizon 2020 incites market driven innovations and research projects, thus aiming at direct economic incentives (European Commission, 2011, 2017 & 2020).

By combining all existing EU research and innovation funding, the Horizon 2020's accumulated available funding when launched was €77 billion. This amount was to be addressed to various EU smart city projects to be initiated over the next seven years, 2014-2020, each to have a duration of five years. Thus, although the Horizon 2020 came to its end in 2020, its funded projects carry on their smart city development and the Horizon 2020's legacy to the next decade and beyond. It is also the highest aspiration of Horizon 2020, that each of its funded smart city project and each city involved, continue their work to evolve towards ever smarter and more sustainable city environments in the future, and to inspire other cities to follow their example of sustainability and low-carbon development (European Commission, 2011, 2017 & 2020).

The Horizon 2020's foundation and main objective is to promote sustainable development, which received nearly 60% of the program's preliminary budget. The rest of the 35% of the budget was designated to consolidated climate and environmental objectives. Principally, the Horizon 2020's main-focus areas receiving funding were:

- To build a low-carbon and climate resilient future.
- Encourage circular economy and connectivity in environmental and economic fields.
- Promote robust digitalization of European industry and services.
- Develop the adoption of electric vehicles and their penetration to automotive markets, next generation battery technologies, and schemes to advance the progress of carbon-free society.

The Horizon 2020 had several mutually reinforcing thematic sections to support its endeavors, including excellent science, industrial leadership, societal challenges, innovation in small and medium sized enterprises, access to venture capital, and spreading participation with excellence and knowhow. Thus the Horizon 2020, through funding for potential smart and sustainable projects, it aimed to ensure the EU's long-term competitiveness via state-of-the-art research and innovation activity. Moreover, the program strived to make the EU more profitable for investments and businesses related to smart technologies and innovations (European Commission, 2011, 2017 & 2020)

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By securing sufficient financing, the Horizon 2020 was able to maximize the growth potential of the European smart energy technology, research and innovation work, and sustainable development of businesses. In addition, the Horizon 2020 approached societal challenges by distributing funds to following focus points:

- All-embracing, innovative, digital, secure and well-being societies
- Climate action, resource efficiency and raw materials
- Smart, secure, clean and efficient energy
- Smart, green, electrified and integrated transport

(European Commission, 2011 & 2020)

2. Smart Cities

Currently, more than 50% of the world's population is concentrated in cities, or in their close proximity. It has been estimated, that by 2050 that share has risen by additional 20%. In 2016, there were 28 megacities in the world, with population more than 453 million combined. According to many estimations, the number of these megacities will be over 40 by 2030. Urbanization is a global megatrend, which has direct effects on climate change, rising emission and pollution levels, and the requirements of energy production, distribution and consumption. Additionally, urbanization's impacts on infrastructure requirements and land use, residential and transport requirements, and sustainability on all of its levels: environmental, economic, social and cultural (Sloman, 2017; Cassandras, 2016).

The accelerated urbanization and growing environmental awareness have risen concerns and demands to develop cities smarter, with the ability to be constantly evolving. There is a need for ambitious sustainability strategies, which aid cities intelligently and comprehensively by integrated technological solutions, and which can be demonstrated on a larger scale, to reach their smart city objectives. Smart city development promotes innovative energy solutions, smart grid and RES development, and strives to advance sustainable transport modes, thus affecting on economic and social levels, and enhancing quality of life (QoL). A smart city utilizes ICT to reach more efficient and intelligent standards in achieving carbon neutrality. It preserves natural resources, and reduces land use by mature and jointly executed coordination, planning of infrastructure and transport design. A smart city strives for implementation of green and innovative technical solutions, leading to savings in cost and energy, and promoting better service delivery (Cassandras C.G., 2016; IEC, 2014; Ferrer et al., 2017; The IRIS Smart Cities Consortium, 2019).

A city can evolve smarter by transforming the existing urban infrastructure gradually to meet the requirements of a smart city. In addition, a city can design and construct new city districts, infrastructure and environment by utilizing the smart city procedures and solutions. These districts will act as example areas, i.e. living labs, and consequently cause changes in adjacent city districts towards smart city development. The smart city advancement should have a holistic approach on sustainability. Measures to reduce a city's impact on environment and to expedite the integration of intelligent and efficient use of technologies with the urban infrastructure outright form the backbone of environmental sustainability. Economic sustainability signifies attempts to develop a city's economic potential, new financial and business models and innovations, and advance more efficient and annexed service and infrastructural solutions. A smart city's attractiveness for people, businesses and capital, improves the overall employment, business and service possibilities, when social sustainability is functioning properly. Thus, cost reductions, higher stability and security, and enhancement of quality of life can be achieved (IEC, 2014; Ferrer et al., 2017).

In order to plan, capitalize and implement the best operating smart city solutions, new methods, technologies and innovations are required. These include efficient and affordable energy production based on RES, and investing in the development of e-mobility solutions, smart charging and energy storage schemes, and advanced ICT solutions. Additionally, key stakeholder engagement is relevant, including political leaders, government and city officials, organizations, service operators and solution providers, investors and consumers. Furthermore, local level citizen engagement has a paramount role in smart city development. By these means, the continuance of the smart city development can be secured, including the optimal end-result of citizen-awareness and attractive city environment (IEC, 2014; Ferrer et al., 2017).

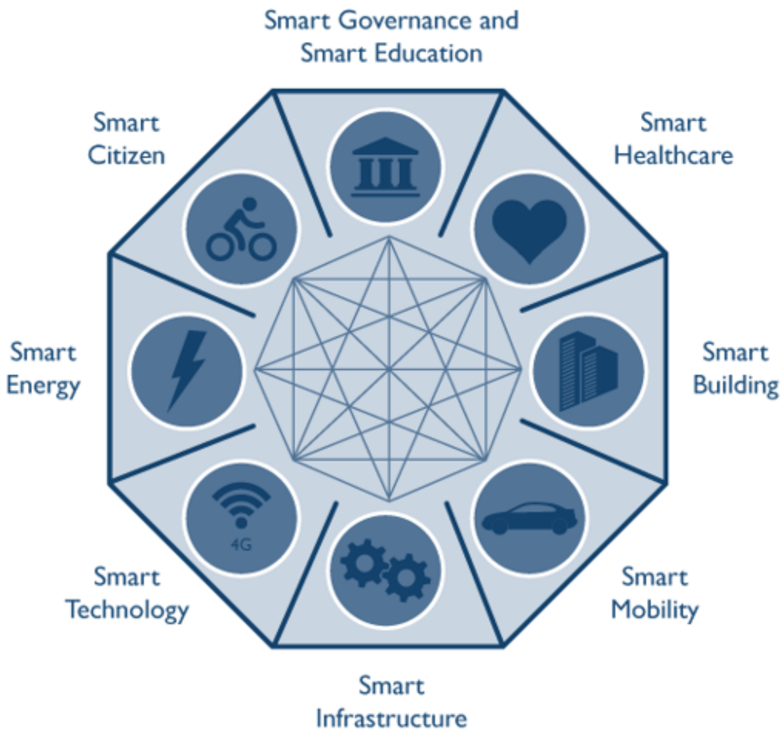

Figure 1. Smart city concept (Singh, 2014).

Smart city development can face challenges. They can be financial, technical, social or administrative. Collaboration between different stakeholders may prove to be problematic. Lasting and successful partnerships might be difficult to establish. Disagreements about planning, means, priorities and objectives might emerge. Capital may be insufficient, or the procurement rules are not appropriate or clear to everyone involved. There may be issues with insufficient standards, regulations, even laws. The required infrastructure may not be mature enough to hold the integration of a planned smart solution. Lack of required competence or deficiency of necessary local administrative capacity may hinder the development. Resistance to change might occur from any of the key stakeholder groups. Moreover, the successful development of a smart city solutions and technology, which are easily adoptable by the society, user-friendly and reliable, is not self-evident (Ferrer et al., 2017; Van Steen, 2019, IEC, 2014).

Designing the different sectors of a smart city, indicated in the Figure 1, and predicting the requirements, consequences and benefits of the smart transformation, can be challenging. In order to evade unnecessary hindering factors and challenges, well-designed and thoroughly carried out interoperability is vital, alongside with resorting to internationally agreed standards and technical specifications. Successful coalescence of smart infrastructure, technology and existing environment is imperative for value creation and in order to reach the objectives of a smart city's predesigned framework. By joining horizontal and vertical integration methods, better value, robust quality standards and interoperability can be obtained. Thus, the stakeholder involvement can be strengthen, necessary supply chains enhanced and bottlenecks avoided. This is also beneficial in order to keep the related costs under control, advance the efficiency of the measures required, and ultimately support and improve the smart energy technologies' business environment. By utilizing both bottom-up and top down strategies for knowledge, information and intelligence processing, a smart city's measures for sustainability, service development, data centricity and successful citizen engagement can be achieved more efficiently. Thereby, the smart city development benefits from immediate feedback from its environment and key stakeholders, all joining and being in contact with the smart city progress and inducements (IEC, 2014; Ferrer et al., 2017; Van Steen, 2019).

2.1. Smart Grid

The infrastructures of power systems, from electricity generation to utilization industrially, commercially and residentially, are currently in the state of significant change. The power systems, i.e. grids, are required to evolve, to become smarter. Today's power grid needs to be reliable and efficient, resilient and flexible, secure and technically advanced, controllable and customer friendly. The main drivers for these requirements are the rising global population, urbanization, and environmental issues, e.g. the climate change, global warming and increased emission levels. They all have an influence on international and national energy and environmental policies, laws and regulations around the world. Additionally, advances in technology, and increased utilization of renewable energy sources steer the development of the power systems towards a new age (Malik, 2013; Rodriquez-Molina et al., 2014; Varaiya et al., 2011).

The start of power systems dates back nearly 140 years. The first power station in the world, Edison Pearl Street Generation Station, located in lower Manhattan, New York, USA, and started its operation in 1882. Since then, power systems have developed into large central power generating stations, supplying electricity through high-voltage networks to local distribution systems, serving all levels of consumption: industrial, commercial and residential.

A traditional power grid uses large power plants to produce raw electricity. The power plants are directly connected to the high voltage (HV) networks through centralized synchronous generators with high inertia. The HV networks distribute power to medium voltage (MV) networks and industrial customers through HV/MV substations. MV/LV distribution substations conduct power to low voltage networks with commercial and domestic customers. Transmission system operators (TSO) provide the power grid infrastructure, covering long distances. TSOs are also in charge of the offer and demand balance of the grids. Distribution system operators (DSO) are responsible for the features related to end-user connectivity concerning the power network (Rodriquez-Molina et al., 2014; Malik, 2013; Varaiya et al., 2011; Ye, 2018).

A modern power system's ideal requirements are high reliability, quality, flexibility and efficiency in energy supply. Active monitoring and fast reaction to any changes in the power delivery system are also unconditional qualifications. Reliability is needed in balanced electricity supply, improved energy efficiency, and constant voltage and frequency control. Moreover, increased integration of renewable power generation, electricity storage systems, e.g. battery-energy storage solutions (BESS), and the rising number of EVs, set their own demands for power grids. Furthermore, digitalization and increased impact of new technology, wireless communication, and new generation security threats, raise the level of requirements for the functionality of current power systems even higher. Modern power grid is required to be self-healing in case of power disturbances, and resilient to stand all attacks, physical and cyber. Efficiency in providing local and system-wide technical services and endeavour to minimize network losses are essentials as well.

Unfortunately, the traditional electric power system infrastructure is not designed to meet these vast requirements. It is designed on the operating model, where electricity flows primary in one direction, from HV generation sources to MV and LV level consumption. It has limited cross-border interconnections, relying on centralized control. The traditional power systems are dependent on non-renewable energy sources (coal, gas, petroleum), which cause approximately 40% of the global carbon dioxide (CO_2) emissions, thus having severe negative impacts on the environment. Furthermore, traditional power systems are technically optimized for regional power adequacy, and are able only for limited automation and situation awareness. They lack customer-size data to manage and reduce energy use sufficiently for today's standards (Malik, 2013; Rodriquez-Molina et al., 2014; Isaacs, 2004; European Commission, 2006; Varaiya et al., 2011).

European Commission's defines a Smart grid as *an electricity network that can cost efficiently integrate the behaviour and actions of all the users connected to it - generators, consumers and those that do both - in order to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety* (European Commission 2011).

Smart grids - provide enhancements and expansion to the traditional power grids, their maintenance and operations, by being flexible, optimal and bidirectional. As illustrated in the Figure 2, Smart power generation is coordinated, and locally managed, having full integration of distributed energy generation (DG) with RES (wind, solar (PV), hydro, wave, geothermal, bio and waste-energy), alongside with large-scale centralized power generation. Smart grids provide enhanced sensory and control capacity, designed to deliver and perform at high-speed, in near- or real-time, in order to adjust to integrated DG, RES, energy storage units, EVs, direct consumer participation in energy management (consumption and production), and efficient communication appliances. Smart systems aim to provide user specified secure, quality and reliable power supply for the digital age. The customers are provided with better tools to manage their energy consumption, not only to act as consumers but having the ability to perform as energy producers as well. With improved economic productivity, high-class demand side management (DMS) and customer-driven value-added services, consumers can benefit from cost savings and increment in quality of life.

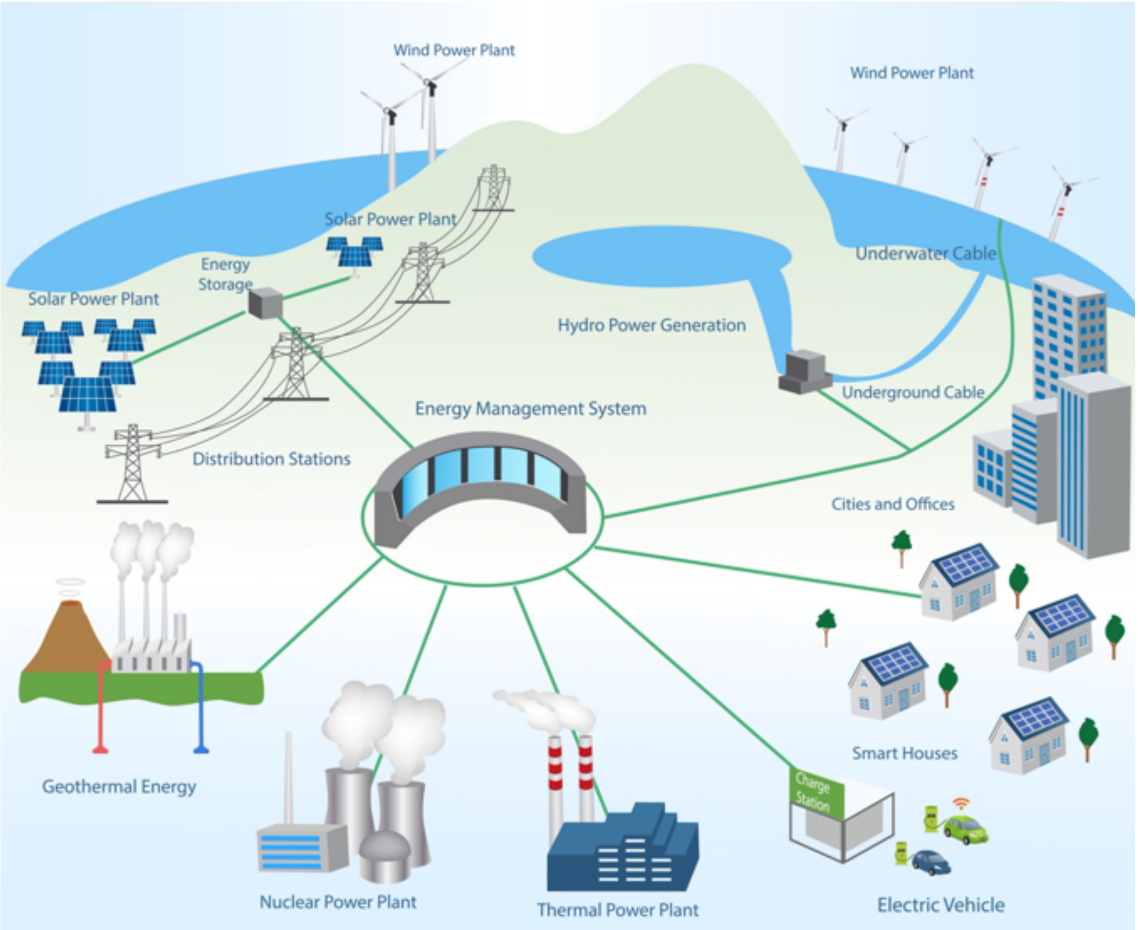

Figure 2. Smart grid components (Lohrmann, 2017).

Minimized environmental impact can be achieved by maximizing safety and sustainability. Smart grid's operation and technology are designed to meet the demands of modern cyber security, and to assure long-term operation of the whole power system. Latest advances in wireless communication technology and intelligent information management systems are utilized, in order to secure the most robust and dependable operation, control and monitoring (Malik, 2013; Rodriquez-Molina et.al, 2014; Isaacs, 2004; European Commission, 2006 & 2011).

Smart grid operating model includes also the concept and activity of microgrids and virtual power plants (VPP). Both have become more common by the development and decentralization of the power systems. A microgrid is a local cluster of electricity loads and sources, operating connected and synchronously with the actual wide area power system. A microgrid can be disconnect to "island mode" if necessary, thus functioning autonomously apart from the actual grid. Microgrids' features include heavy integration of DG sources and RES. Prevalence of microgrids has dramatically increased during the past 12 years when various communities, commercial buildings, public institutions, universities and military installations have started to utilize the opportunities of decentralization of power systems.

A virtual power plant is a coalition or system of suppliers, which generates power for independent consumption, and takes actively part in energy sales by utilizing RES, energy storage systems (ESS) and cloud-based technology. VPP acts as one large, virtual and controllable power plant, ensuring its suppliers an opportunity to operate as a unified and flexible resource in the energy market, simultaneously achieving energy self-sufficiency.

Microgrids and VPPs have in common their compilations and optimization of distributed energy resources. The biggest difference is that microgrids have a confined network boundary and ability to operate in island mode. Whereas, VPPs can stretch over much wider geography, being able to alter size depending upon real-time market conditions. The increasing number of microgrids and virtual power plants bring more flexibility to the power systems. The most relevant drivers for this development have been the evolution of the smart grid concept and its supporting technological innovations, including DER, reduction in costs of consumer sized solar energy and energy storage technology. In addition, efforts to cut down energy costs in general, and global policy efforts to reduce greenhouse gas emissions have contributed to the increment of microgrids (Hanna et al., 2017; Rodriquez-Molina et al., 2014; Ye, 2018; Bavrani et al., 2017).

The smart power systems allow the electricity markets to develop into platforms operated by large number of different market actors. The trend is moving away from the traditional wholesale market structure towards retail markets, including active consumers with energy production capabilities to act as producers. The level of competition increases, thus enabling better incentives for cost efficiency and enhance innovations. The consequences are extensive and require capability for greater flexibility in the interaction between demand and supply. A smart grid does not focus solely on the wholesale market, instead it includes all market segments, including trading. A smart power system takes into account the end-user behaviour, hence affecting the energy market as a whole. The positive outcomes include requirements for market operations' increased efficiency, reduction in energy costs, and the development of the future's decarbonized grid. Additionally, consumers gain the possibility by smart meters and two-way communication, to enhance their energy consumption management, cut costs and act as energy producers for the grid, with measures such as PV energy, separate energy storages and/or with EVs through their batteries (Greve, 2016; Green & Webb, 2016; Ye, 2018).

In smart grids both producers and consumers are making decisions concerning consumption, based on prices signalling timely the true marginal cost of changing energy demand, instead of having traditional flat-rate tariffs with no or little possibility to contribute to the energy costs. This dynamic and real-time pricing allows the energy markets to fully exploit and reward its generating capability, thus giving way for flexible and smart "energy-only" market, promoting new business models.

One possible model, which delivers more control and cost effectiveness to network providers and transparency of prices for consumers, connects these two operators in an evolved market infrastructure, focusing on the potential of trade of *energy service* rather than just simply *trading energy*. The network operators are able to trade more efficiently on multiple platforms, and with multiple operators: industrial, commercial, domestic, microgrids, VPPs, EVs etc. Additionally, technology companies can sell power alongside the meters and/or other devices controlling the consumption (Greve, 2016; Green, 2016; Ye, 2018).

2.2. Smart Transport

Some of the biggest transport related challenges in today's growing cities are congestion, pollution, accidents, noise and scarceness of public space. Enhancing the development of diverse transport systems and technology, require deployment of Mobility as a Service concept (MaaS), urban mobility governance, and real-time data collection and management. Thus, better traffic and infrastructural planning and management can be achieved. Additionally, there are matters of social nature to be considered, such as better ability to improve traffic safety, enhance environmental performance and attractiveness, and advance information management and decision-making. Ultimately, the goal is more sustainable and well-functioning urban surroundings, with the ability to provide better quality of life to the citizens by efficient, secure and sustainable mobility, energy technology and ICT solutions (Van Oers et al., 2020; Surdonja et al., 2020).

Through state-of-the-art energy technology, sustainable transport and ICT solutions, a smart city benefits from improved and precise quality and quantity measurements, aided by real-time big data management, analytics and modelling. Consequently, gained development in knowledge capacity building, transfer and lessons learned, enable and amplify the city's smart aspirations. Smart transport, both individual mobility and public transport, seek to support and exploit ways of e-mobility systems, continuous mobility chains and new mobility services, which are not only efficient and user-friendly, but cost-effective as well (Van Oers et al., 2020; Porru et al., 2020; Dudyck & Piatkowski, 2018).

Private and public transport's transition from internal combustion engine (IC) vehicles to electric, gas and bio fuel vehicles helps to decrease fossil fuel consumption, hence helping to achieve carbon neutrality in smart cities. Transmission from private car ownership towards car sharing, i.e. car-pooling, and enhanced smart public transport services and increased connectivity, result in more sustainable transport in general, with decreased volume and emission levels, optimized to meet the demands and requirements of inter-modality. Smart public transport systems is highly flexible, providing consumers more versatility in transport modes, routes, schedules, service providers and payment systems (Van Oens. et al., 2020; Porru et al., 2020; Dudyck & Piatkowski, 2018).

Utilization of advanced EV technology and related solutions, e.g. smart charging and V2G schemes, with option of combining RES and/or remote energy storage systems, are all part of a smart mobility's structure and integrative solutions. Functioning MaaS concept provides attractive and sustainable alternative for private transport and vehicle ownership. It avails of intelligent mobility systems, e.g. data management, ICT and real-time information access. Costs concerning traffic and travel can decreased, congestions be mitigated, and time used in travelling reduced. Additionally, the safety factors of traffic can be enhanced, and pollution and noise levels reduced. Furthermore, smart mobility contributes to the overall design of smart cities by transport network's efficiency, better management of parking spaces, and advancing public transport's usage rate and its supporting policies (Van Oers et al., 2020; Surdonja et al., 2020; Dudyck & Piatkowski, 2018; Barone et al., 2014).

2.3. Electric vehicles and e-mobility

Electric vehicle (EV) was invented already in the early 1830's, decades before the first IC engine vehicle invention, taking place later that same century. Electric vehicles were common until the 1930's, when their share out of the automotives started to diminish, due to their insufficient driving power, overall slowness, short driving range and high price. The IC vehicles had reached much higher popularity during the 1920's, because of better performance factors, affordability, and invention of mass-production. It was not before the early 1990's, after sufficient advancements in power electronics and microelectronics technologies, when the hybrid EV production could start in the United States (Sharma et al., 2020; Pavic et al., 2020; Mullan et al., 2012; Matulka, 2014).

During the first two decades of the 21st century, the demand for EVs has increased steadily. The main reasons for this development have been general increment in environmental awareness, EVs' much lower carbon emission and air pollution levels, considerably lower oil use, reductions in model prices, and improvements concerning power performance, driving range, charging and safety. Additionally, external factors such as fuel prices, availability of charging stations and development in consumer characteristics have improved the advancement of EVs adoption and penetration into automotive markets around the world. Moreover, the political, economic and environmental accord over the risks of transport systems' dependency on petroleum-based fuels has contributed to firming the foundation for EVs' ascent (Sharma et al., 2020; Pavic et al., 2020; Mullan et al. 2012; Matulka, 2014).

There are three types of electric vehicles.

2.3.1 Hybrid electric vehicles (HEVs)

HEVs represent the most proven and market established EV type. A HEV is powered by an IC engine, which receives additional power from an electric motor. The utilized electricity is produced either by the IC motor running an electric generator, or from kinetic energy, which is harnessed via regenerative breaking, and consequently transformed into electricity. HEVs are further divided into three subtypes.

- Series HEV: a combustion engine drives an electric generator, which charges a battery, providing power to the electric motor. Only the electric motor supplies power to the wheels. No mechanical connection between the IC engine and the transmission exists, thus making it possible for the IC engine to operate at maximum efficiency.
- Parallel HEV: an IC engine and an electric motor are connected parallel for mechanic connection. The IC engine is the primary power source and the electric motor operates as a backup power source or for extra torque.

- Series-parallel aka combined hybrid HEV: has features from series and parallel HEV types. Series-parallel is the most complex and expensive system of the three HEV types (Pavic et al., 2020; Quinn et al., 2010; Habib et al., 2015).

2.3.2 Plug-in hybrid electric vehicles (PHEVs)

PHEVs have the capability to run on gasoline or electricity. The ability to use batteries to power an electric motor, which can operate as an alternative power source and independently from IC engine for the vehicle, result in petroleum usage reduction and decreases in CO_2 emissions. A PHEV has to be plugged into the power grid for charging. Thus, it possesses the ability to operate in V2G mode, after required modifications have been done for the vehicle.

2.3.3 Battery electric vehicles (BEVs)

The most advanced electric vehicle type is the battery electric vehicle (BEV), i.e. pure electric vehicle. BEVs use solely batteries and electric motor to run and have no IC motor. BEVs have to be charged as PHEVs. Some of the newest BEV models have the ability to operate in V2G mode, and the others can be modified for the ability. BEVs have more limited driving range than PHEVs (Pavic et al., 2020; Quinn et al., 2010).

PHEVs' and BEVs' technologies are designed to enable unidirectional charging from the grid, i.e. grid-to-vehicle (G2V). However, both of these EV types can be designed to enable bidirectional charging, i.e. vehicle-to-grid (V2G) mode, thus been able to supply power from the batteries to the grid. Thus, EVs with V2G capability can be utilized to support the power grid as distributed power storage and supply, and in various ancillary services, e.g. voltage and frequency control, and load following (Drude et al., 2014; Sharma et al., 2020).

Batteries are the most significant and expensive components of PHEVs and BEVs, concerning their competitiveness. Issues such as cost and climate conditions are of concern with batteries, as well as energy density and power density, since they affect the allowed driving range. BEVs' driving range can vary from 100 km to 500 km, depending on the battery capacity. Additionally, the utilized battery technology affects a battery's cycle life. Lithium-ion based batteries are best suitable for EVs purposes (Lithium-ion aka Li-ion or LIB), particularly Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)

and Lithium Titanate aka LTO (Li_2TiO_3) batteries. Other lithium based battery technologies include Lithium-iron phosphate aka LFP ($LiFePO_4$), Lithium-Sulfur (Li-S) and Lithium-air (Li-O2) batteries. Although these lithium battery models are also suitable for EV use, they are more advanced and expensive than common Li-ion batteries, and still in the research stage (Sharma et al., 2020; Pavic et al., 2020; Battery University, 2021).

Since there are various different sizes and model types of EVs, various different battery models exist as well. The most notable feature of a battery is the power it can provide. Demanding operating temperatures, i.e. extreme hot or cold, have the effect to degrade a battery, thus accelerating the loss of its capacity and reducing its cycle life. Heat has an impact on the battery by reducing its life, and cold decreases its performance temporarily. The most important EV battery qualities are trip-length capability, amount of peak power delivered during acceleration, and energy harnessed during breaking. EV's battery management system (BMS) has multiple tasks to manage. BMS estimates the battery's state of charge (SOC) and state of health (SOH) conditions, and monitors and balances the battery's cell activity. In addition, the BMS manages the battery's thermal condition, safety and protection. Moreover, the BMS is the interacting component to the charging station, implementing an optimal charging profile for the battery (Battery University, 2021; Baronti et al., 2016; Sharma et al., 2020).

A small electric vehicle is usually equipped with a 12–18kWh battery. A mid-sized family sedan battery has 22–32kWh of power. The most powerful EV models are equipped with large-size battery, capable of producing 60–100kWh, providing extended driving range and higher performance. Most EV batteries are guaranteed to have a life span of 8-10 years or approximately 160 000 km.

Development in batteries' cost, lifespan, reliability, sustainability, safety, usability and capacity, are all factors determining EVs' overall success and advancement in automotive markets globally. Additionally, improvements and design of new battery material and chemistry solutions play a crucial role. For example, designs of battery packs, advancements in lithium-ion and nickel metal hydride (NiMH) technologies and manufacturing processes, and batteries' recyclability and end-of-life solutions (e.g. second-life battery schemes), will have significant impact on EVs' future evolvement and success trajectory (Pavic et al., 2020; Baronti et al., 2016; Battery University, 2021).

2.4. Smart charging

The fast rising number of EVs require wider, reliable and more comprehensive charging infrastructure. As the number of EVs increases, their potential impacts on power grids ascends as well. Hence, efficient smart charging schemes and management become essential. In smart charging, an EV and a charging device are in data connection. This connection is further connected with a charging operator via the charging device. The charging operator/the owner of the charging device is able to monitor, control and restrict the charging remotely, thus optimizing the energy consumption effect to the grid. If charging is not managed controllably, a large number of EVs can cause severe peak loads to the power grid by increased power and energy demand, hence having significant impact on the power quality. Other potential effects to the power grid are possible negative impacts on the various system components, e.g. transformers. Without regulation and control, charging simultaneously a large number of EVs, i.e. fleets, can cause disruption to the stability of the whole power system. The rising demand of electricity requires enhanced control of DMS, having the capability and tools to utilize the capacity harnessed from EVs, their ability of acting as distributed energy storages and power generation units for the grid (Baronti et al., 2016; Mullan et al., 2012; Habib et al., 2015; Sharma et al., 2020).

Different EV charging technologies are:

- Unidirectional vs. bidirectional:

The charging of EVs can either be unidirectional or bidirectional. In the first model, aka grid-to-vehicle (G2V) solution, an EV uses the power grid to charge its battery. In the later model, the EV battery can also be used to supply power to the grid, i.e. V2G solution.

- On-board vs. off-board chargers:

When an EV is equipped with an on-board charger, it can be charged anywhere, where a power outlet (plug-in) exists. On-board charger adds more weight to an EV. Whereas, an off-board charger requires a charging point or a station with power rating of approximately 50kW to charge the battery of an EV.

- Integrated chargers:

An EV's electric drive system components take part in charging, which reduces the size of an on-board charger, or it is not required at all. Thus, reductions in cost, weight and space usage can be achieved.

- Wireless aka dynamic charging:

Electric power is transferred wirelessly to an EV through a power field. The system requires a large size antenna array, which can be supported by inductive or magnetic resonance coupling, microwaves, or laser radiation. However, wireless charging is still in the research stage, and its expenditures are high. Yet, once operational and widely available, it has the potential to revolutionize the whole transportation system (Baronti et al., 2016; Sharma et al., 2020).

In charging, the current and voltage needs to be constantly controlled. This can be best achieved by either keeping the current or voltage constant. Additionally, different levels of charging exist. Level 1 charging or slow charging is designed for residential outlets, for on-board charger models with 120V AC outtake. Level 2 aka semi-fast charging is suitable for charging stations, and are capable for five times faster charging than the level 1, thus being able to fully charge an EV in 5-7 hours. Level 3 aka fast charging uses DC power with constant current and voltage. Its charging power exceeds 100kW, requiring charging technology of considerable size, thus being suitable only for off-board charging. Fast charging is optimal, e.g. in public transport and commercial logistics usage, where battery charging should not last more than 30-60 minutes (Sharma et al., 2020).

However, smart charging solutions require new kind of charging schemes:

- Uncontrolled, time-of-use smart charging:

Smart charging based on optimization of time-of-use is the simplest form of smart charging. It incites the end-users to utilize off-peak periods for charging from peak times. Additionally, it is relatively straightforward to implement time-of-use charging, since its external stakeholder control does not exist. Time-of-use charging has proven its effectiveness in delaying EV charging until off-peak periods at low EV penetration levels (Paulraj, 2019; Virta, 2021).

- Unidirectional controlled charging (V1G):

Either EVs or the charging infrastructure can adjust their charging rate in unidirectional controlled charging. The grid operator oversees the charging process via controlling signals. Daily estimation of the local available charging capacity is provided by Open Smart Charging Protocol (OSCP), and Open Charging Point Protocol (OCPP) to the Charge Point/Spot Operator (CPO), which adjusts EVs' charging profiles to the available charging capacity.

- Bidirectional V2H / V2B / V2X smart charging:

Smart charging scheme, which provides an EV battery's power supply to be connected to its close surroundings, performing as a back-up power source increasing self-consumption. Hence, it does not stress the actual power grid but functions as an alternative power source. This scheme can add flexibility and reliability to, e.g. homes (V2H), buildings (V2B) or some other objects', e.g. facility, appliances, lighting etc., electricity consumption (Paulraj, 2019; Virta, 2021).

- Bidirectional Vehicle-to-grid (V2G):

With V2G solution, an EVs can be utilized as a distributed power source and storage for the grid. Thus, it is more evolved smart charging method than controlled V1G or bidirectional charging for self-consumption. Furthermore, in V2G smart charging/discharging, EVs' batteries can be utilized in ancillary services, including voltage support and frequency control, load following and functioning as secondary reserve for grid flexibility and reliability. In V2G smart charging, the TSO is capable of purchasing energy from EV owners if the peak demand requires it. Hence, V2G has higher commercial value, which can encourage consumers to acquire an EV (Paulraj, 2019; Virta, 2021; Habib et al., 2015).

2.5. Vehicle-to-grid solutions

Through V2G, EVs can be utilized as an additional power source to the grid. With great number of EVs, i.e. fleets, V2G operating model reduces the dependency on oil, and lowers CO_2 emissions. Additionally, V2G has the capability to enhance stability, reliability, efficiency, and generation dispatch of a distributed network, thus increasing the entire power grids' performance. Majority of the EVs are not utilized in traffic all the time. Instead, they spend vast amounts of time parked, where they could be connected to the grid. Once stationary, the batteries of EVs are not utilized for driving, thus forming an enormous source of distributed energy storage, which could be used as an extension and support to the electricity supply system, in smaller or larger scale. The batteries represent zero-cost energy storage for the grid use, since they already have been purchased for the EVs' use (Mullan et al., 2012; Habib et al., 2015; Quinn et al., 2010).

V2G concept has major benefits. Large amount of EV batteries have the capacity to store excess electricity during low-demand hours, and release it back to the grid when the energy demand is at its highest, as illustrated in the Figure 3. EV batteries have rapid response time for storing energy, and they are capable of providing low-cost aid through various ancillary services, e.g. voltage support, frequency regulation, load following and aiding in black starts. In addition, EV batteries are able to increase and enhance renewable energy generation to the grid, e.g. by interconnection with smart homes' photovoltaic (PV) panels in urban areas, thus balancing and adding stability to the power system. By and large, V2G solution can also generate revenue for the all parties involved: the electricity system operator (SO), aggregators, electricity retailers and the EV owners (Mullan et al., 2012; Habib et al., 2015; Quinn et al., 2010).

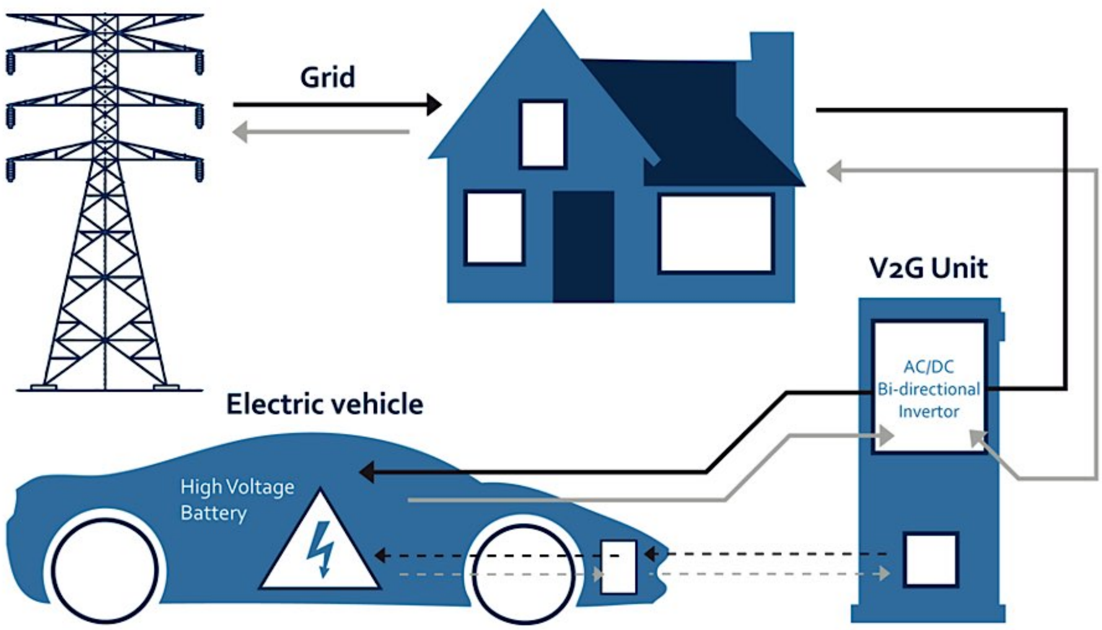

Figure 3. Vehicle-to-grid (V2G) operating model (EVConsult, 2021).

2.6. Second life batteries

EV batteries' end-of-life purpose raises many questions and concerns. Should the batteries be disposed or recycled, or could their purpose be prolonged? Is a battery still usable and does it have any value, after its capacity and performance levels have declined, i.e. the battery has reached the end of its "first life", its original purpose? Nowadays, when circular economy's procedures and values are common concepts, the matter of EV batteries' end-of-life has become more important as well. Finding a "second life" (2nd life) for the used EV batteries is receiving wide attention globally. EV batteries' second life could benefit the batteries' manufacturers, user and potentially create new businesses and revenue streams. Thus, granting a battery a second life would have positive environmental and economic effects. As transportation steadily transforms from IC powered vehicles to electric vehicles, the number of lithium-ion batteries in and out of use rises considerably (IEA 2019; Engel et al., 2019).

Normally, an EV lithium-ion battery's first life lasts approximately 8-10 years, after which it is no longer suitable to function as a battery in regular EV usage. However, the battery still has 70-80% of its capacity left. Then, three end-of-life options exist: disposal, recycling or continuance of utilization in a less demanding battery application, e.g. having a 2nd life. Disposal of an EV battery possesses environmental concerns to be taken into account, the reason why it is a best option only for damaged batteries. Moreover, disposal without recycling is not economically sensible. Recycling, i.e. collecting the battery's valuable metals is an expensive procedure. With lithium-ion batteries, it is more expensive to recycle a battery than it is to mine new lithium. The cost of recycling a battery is approximately €/kg (10€/kWh), which is three times higher than can be expected from selling the used battery on the market. Because reclaiming lithium is so costly, less than 10% of all used EV batteries' lithium are recycled, and vast numbers are been disposed, resulting great losses in the batteries' still existing value. By reusing the battery and harnessing its 2nd life potential, its lifespan's total use and value can be captured (Jiao, 2016 & 2020; Desarnaud, 2019).

In 2019, the global amount of sold electric vehicles (PHEV & BEV) was over 2 million units, raising the total global number of EVs in use to 7.2 million. According to estimations, in the year 2025 the total number of EVs in the world will reach 100 million, with 25% market share of all cars sold globally in each year. In 2030, over 250 million EVs are expected to exist in use, and approximately 45 million new ones to be sold every year. The ascending development of EV industry will increase the number of out-of-use lithium-ion batteries drastically (IEA 2020; Hossain, at al., 2019, Desarnaud, 2019; Engel et al., 2019; Jiao, 2020; Van Troeye, 2019).

According to estimations, in 2030 the accumulated amount of energy generated by the EVs' lithium-ion batteries in global scale, counting both new batteries and those taken out of use, will be 3.6-17.6GWh. Some estimate this amount to be even as high as 200GMh. In 2063, the amount will be anything between 32.3-1010GWh, according to the lowest and most optimistic evaluations. This development has a descending reflection on new lithium-ion battery prices, which are dropping already regardless this factor, due to their own market development. Currently the price of a new lithium-ion battery is around $200-300/kWh, whereas in 2025 the price is estimated to be

$90-100/kWh. The decrease in prices is due to the increase of number of EVs sold in the markets.

A great potential exist for 2nd life batteries in stationary energy-storage applications, which require less frequent battery cycling (100-300 cycles/year). If a new EV battery has 22kWh energy, after its first life it still holds 15-17kWh, which can enable a second life of 10 more years, if utilized shrewdly (IEA 2020; Hossain, at al., 2019, Desarnaud, 2019; Engel et al., 2019; Jiao, 2020; Van Troeye, 2019).

By fully utilizing the growing number of 2nd life batteries, the need for new batteries would be lesser, resulting in reduction of natural resources' exploitation. Second life batteries present no added burden on the environment. Instead, they enable an affordable energy storage solution, able to operate in various stationary energy-storage applications, and enhance smart grid and renewable energy development. Utilizing 2nd life batteries is scalable, affordable and sustainable. However, for safety reasons, 2nd life batteries require testing before they can be utilized. However, thereafter they are a vital mean tackling the growing energy consumption issues (Colthorpe, 2019; Jiao, 2016 & 2020).

Second life batteries can perform as stationary primary energy storages in smaller scale, or as back-up storages in more demanding usage. In peak demand, 2nd life batteries can aid in ancillary services such as voltage support, frequency regulation, black start and load following, as indicated in the Table 1. They can also be exploited to operate with PV as storage use in microgrid purposes for various premises, municipalities and neighborhoods, or even in small town scale, functioning for the local smart grid. In transmission-deferral application, 2nd life batteries can provide power support to a neighborhood grid transformer, when the energy demand is higher than the transformer's capacity. 2nd life batteries charge during off-peak periods and are ready to inject the power back to the grid when needed. Second life batteries can also function as electrical appliances for water and living-space heating, and as a reserve storage in the case of localized blackouts (Table 1). 2nd life batteries participation in electricity supply in residential applications is best utilized for private usage, e.g. for common electricity management, to share locally produced green energy, or to reduce energy bills and environmental energy production and consumption impacts (Hossain et al., 2013; Van Troeye, 2019; Bobba et al., 2018; Casals et al., 2019).

In commercial applications electricity demand is higher, thus the need for higher number of batteries is necessary. Second life batteries can be used in load following, i.e. aiding in balancing the generation of electricity and the load. Additional commercial applications for 2nd life batteries include acting as reserve for localized blackouts and emergencies. Second life batteries can also replace, at least partially, the much more expensive first life batteries in the applications.

The power demand is the highest in industrial applications, where 2nd life batteries can function as storage and backup for RES, and in ancillary services, such as voltage support, frequency regulation and load following. 2nd life batteries can also have a significant part in maintaining utilities power reliability at lower cost, than what would be possible with new battery storage units. (Hossain et al., 2013; Engel, H. et al., 2019; Palizban & Kauhaniemi, 2016).

Table 1. The suitable applications for Lithium-ion batteries (Palizban & Kauhaniemi, 2016).

			Electrochemical			
			Lead-acid	Lithium-ion	NaS	Vanadium redox
Bulk Energy	Energy arbitrage		Red	Red	Red	Red
	Peak shaving		Red	Red	Yellow	Yellow
Ancillary Service	Load following		Green	Yellow	Green	Green
	Spinning reserve		Yellow	Red	Yellow	Red
	Voltage support		Green	Green	Green	Yellow
	Black start		Green	Green	Green	Green
	Frequency regulation	Primary	Green	Green	Green	Green
		Secondary	Green	Green	Green	Green
		Tertiary	Green	Green	Green	Yellow
Customer Energy Management		Power quality	Green	Yellow	Yellow	Yellow
		Power reliability	Green	Green	Green	Green
Renewable energy Integration		Time shift	Yellow	Yellow	Yellow	Yellow
		Capacity firming	Yellow	Yellow	Yellow	Yellow

In transport applications, 2nd life batteries can be utilized in EV charging stations, for fast charging without overloading the local energy supply. They can even serve as distributed storage units for citywide tram networks. Although 2nd life batteries are not able to function as well and reliably as a new batteries for everyday EV usage, the 70-80% capacity they possess can power a vehicle for short range mobility needs, e.g. for local traveling and commuting, and powering city shuttles, school buses, fork lifts, e-scooters and bikes, and even ferries. Additionally, second life batteries can be used to form a basis of vehicle leasing businesses, such as tax services, delivery firms etc. They can be utilized for V2G applications, and telecom base stations and data centers as backup power sources (Hossain et al., 2013; Melin, 2018; Bobba et al., 2018; Casals et al., 2019).

2.7. Mobility as a Service (MaaS)

Concerns over urbanization and climate change, increased environmental awareness, and latest advancements in digitalization, vehicle, internet, and information communication technologies, have affected strongly to transport and mobility markets. Mobility as a Service (MaaS) concept aims to transform the purely operational transport model to comprehensive, sustainable and user focused mobility service assortment, resorting to modern bottom-up approach instead of traditional top to bottom. The objective is to provide all MaaS users an unbreakable mobility chain possibility, enabling one-step mobility within a MaaS' region, i.e. a city (Yellowlees, 2017; Stopka et al., 2018).

The main objective of MaaS is to advance the energy efficiency and fluency of urban transport and mobility, prioritizing constantly the end-users benefit. MaaS joins the public and business sectors with the users, striving to increase the attractiveness of public transport and enhancing the operability of unbreakable mobility chains. It promotes cycling and walking as an alternative-choice of mobility to vehicle ownership. In addition, the development and utilizing innovative mobility solutions are part of MaaS, e.g. car sharing, and utilizing EV fleets' power supply potential in V2G solutions and smart charging schemes. Furthermore, the concept can aid in traffic congestion mitigation, and reduce the need for parking spaces, thus affecting to urban attractiveness and land use. Moreover, organizations can benefit from MaaS by being able to improve their logistical services more efficiently (The Finnish Government, 2016; The Ministry of Environment, Finland, 2017; Yellowlees, 2017; Stopka et al., 2018).

Successful and well-functioning Mobility as a Service does more than just develops transport and mobility. It has wide economic and environmental scopes. By enhancing the utilization of digitalization and ICT, collaboration of its stakeholders, and dismantling unnecessary regulations and bureaucracy, MaaS improves the compatibility of all different actors being part of its operating model. Hence, it aids new business models to break into markets, and improves the service environment. The main objective is to develop user friendly, market oriented and high quality mobility services, which operate seamlessly as one economically and environmentally sustainable, digital and constantly evolving system. (The Finnish Government, 2016; The Ministry of Environment, Finland, 2017).

3. Horizon 2020 Lighthouse projects

The European Union's Horizon 2020 program includes several individual smart city projects, which are based on Lighthouse (LH) and follower cities (FC) concept. Each individual project is built around three Lighthouse cities and minimum of three follower cities, located in different EU states. The Lighthouse cities develop, test and demonstrate different integrated, innovative, and market-orientable solutions in the fields of sustainability, smart energy and smart city solutions. The LH cities act as role models for the follower cities, which are obligated to replicate the LH cities' demonstrations.

It is essential for each project's success, that the demonstrated LH solutions are replicable for the follower cities, either as an independent project, or on city district level. The follower cities are not expected to replicate every solution demonstrated by the LH cities. However, the variety of integrated solutions is vast, and each city's choice of selection depends on the city's ambitions, characteristics, geographical location, technical level, resources, administration, culture, and set goals in sustainability and economic growth (European Commission, 2016 & 2017; Ferrer et al., 2017).

Matters concerning a city's capability to be accepted in a smart city project, and determining how advanced its smart city level is, depend on how advanced the city is in the following:

- State of Sustainable Energy and Action Plan (SEAP)
- The level of smart grid solutions in general
- The utilization of RES
- Adoption of EVs and related technologies, i.e. innovative smart charging infrastructure
- State of sustainable mobility and Mobility as a Service concept
- Utilization of 1st and 2nd life BESS
- Sustainable buildings and construction solutions
- Level of state-of-the-art ICT solutions

(European Commission, 2016 & 2017; Ferrer at al., 2017)

A Lighthouse city's goal is to achieve significant improvements in energy sufficiency, with encompassing utilization of various RES: wind, solar, hydro, wave, and geothermal energy, waste incinerated heat and energy storages. A LH city's integrated electricity solutions should be able to support the invocation of V2G, smart charging, and EV fleet solutions. State-of-the-art ICT solutions are vital for improved planning, management, control and maintenance of smart applications and actions. By guaranteeing successful implementation of robust ICT solutions with smart energy and transport solutions, physical urban infrastructure and operational technologies in buildings, the adoption of MaaS can be enhanced, and citizen/user engagement executed successfully (European Commission, 2016 & 2017; Ferrer at al., 2017).

The concept of Smart Cities and Communities (SCC) is a network of Horizon 2020 funded Smart City projects. The various projects may have different characteristics. However, they share a common goal: to achieve a sustainable, carbon neutral and environmentally friendly smart city operating model, driven by replicable smart energy innovations and technologies. Each Horizon 2020 smart city project has a duration of five years, in which it is required to gain results. That is to say, the FC cities are required to demonstrate smart city solutions, and their follower cities are to replicate them or at least design a valid replication plan to implement the smart city solutions (European Commission, 2017).

The Horizon 2020 Smart Cities network consists of the following smart city projects, with mentioned LH cities, number of follower cities, and project start dates:

- Atelie (Amsterdam & Bilbao, 6 FCs, 2019)
- Poctyf (Alkmaa &, Evora, 6 FCs, 2019)
- Sparcs (Espoo & Leipzig, 5 FCs, 2019)
- CityXchange (Limerick & Trondheim, 5 FCs, 2018)
- Making City (Groningen & Oulu, 6 FCs, 2018)
- **IRIS (Gothenburg, Nice Cote e d'Azur & Utrecht, 3 FCs, 2017)**
- MatchUP (Antalya & Dresden, 4 FCs, 2017)
- Stardust (Pamplona, Tampere & Trento, 4 FCs, 2017)

- mySMARTlife (Hamburg, Helsinki & Nantes, 3 FCs, 2016)
- Ruggedised (Glasgow, Rotterdam & Umeå, 3 FCs, 2016)
- GrowSmarter (Barcelona, Cologne & Stockholm, 5 FCs, 2015)
- Remourban (Nottingham, Tepebasi/Eskisehir & Valladolid, 2 FCs, 2015)
- Replicate (Bristol, Florence & San Sebastian, 3 FCs, 2015)
- Sharing Cities (Lisbon, London & Milan, 3 FCs, 2015)
- SmartEnCity (Tartu, Souderborg & Vitoria-Gasteiz, 2 FCs, 2015)
- Smarter Together (Lyon, Munich & Vienna, 3 FCs, 2015)
- Triangulum (Eindhoven, Manchester, Stavanger, 3 FCs, 2015)

(EU Smart Cities Information System, 2020)

For each participating city, it is essential that the planning of smart cities' infrastructures and processes can be integrated seamlessly with related existing national policies and regulations. Functioning and successful business models, as well as finance and procurement processes are important for a smart city projects advancement and success. Active engagement of citizens and key stakeholders enhances wider perspective planning and more thorough decision-making processes. The district level integration of smart homes and buildings, use of RES, smart mobility and energy storage solutions, and exploiting smart management systems with integration of reliable ICT solutions, resonate a strong positive example for other city districts to follow. The end-result is more sustainable, energy efficient and holistic smart city development, which can be imitated by cities not yet part of the SCC (The IRIS Smart Cities Consortium, 2017; Massink, 2019).

4. IRIS - Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

IRIS smart city project was initiated in 2017. The project is funded by the European Union’s Horizon 2020 program, with duration of five years (2017-2021). IRIS Lighthouse cities are Gothenburg (Sweden), Nice Cote d’Azur (France), and Utrecht (Netherlands). These cities act as living laboratories for demonstration, integration and implementation of innovative energy efficient areas, flexible smart energy solutions and applications, incrementing the utilization of RES and ESS, e.g. battery-energy storage solutions with first and 2nd life batteries, heat energy storages, and EVs’ energy storage capacity via V2G and PV integrated systems. Additionally, the LH cities strive for intelligent use of state-of-the-art ICT solutions, sustainable mobility schemes and services, and interactive citizen engagement. The paramount goal is to improve the urban life, and to ensure sustainable, secure and affordable energy for living and mobility for all citizens and businesses. To achieve this, coalition of universities, research organizations, innovation agencies, local authorities and private expertise have joined forces in collaboration. To enforce this, the LH cities cooperate actively with the follower cities; Alexandroupolis (Greece), Focsani (Romania), Santa Cruz de Tenerife (Spain) and Vaasa (Finland) (Massink, 2019; Angelakoglou et al., 2019; Nikolopoulos et al., 2018; Crombie et al., 2018).

The IRIS project consists of five Transitions Tracks, which all include various integrated smart city solutions. Once a Lighthouse city has successfully demonstrated an activity of an innovative smart city solution in their environment, a follower city is able to create a replication plan for the chosen integrated solutions, and determine their schedule, resources, partners, which are the requirements for successful implementation. Not all of the solutions demonstrated by the LH cities’ are required, or can be replicated by the follower cities. Each participating city, a follower and a Lighthouse, has its own baseline, needs, framework and goals when starting the IRIS Smart City endeavor, determining which integrated solutions form its replication plan (The Smart Cities Consortium, 2017; IMCG, 2020; Massink, 2019).

The five IRIS project's transition tracks and their integrated solutions, shown in the Figure 4, are:

Transition Track #1:

Smart Renewables and Closed-loop Energy Positive Districts:

- Positive energy buildings
- Near zero energy retrofit district
- Symbiotic waste heat networks

Transition Track #2:

Smart Energy Management and Storage for Grid Flexibility:

- Flexible electricity grid networks
- Smart multi-sourced low temperature heat networks with innovative storage solutions
- Utilizing 2nd life batteries for smart large-scale storage schemes

Transition Track #3:

Smart e-Mobility Sector:

- Smart solar V2G EVs charging
- Innovative mobility services for the citizens

Transition Track #4:

City Innovation Platform (CIP) Use Cases

- Services for urban monitoring
- Services for city management and planning
- Services for mobility
- Services for grid flexibility

Transition Track #5:

Citizen Engagement & Co-creation:

- Co-creating the energy transition in your everyday environment
- Participating city modelling

- Living labs
- Apps and interfaces for energy efficient behavior

(The Smart Cities Consortium, 2017; IMCG, 2020; Massink, 2019)

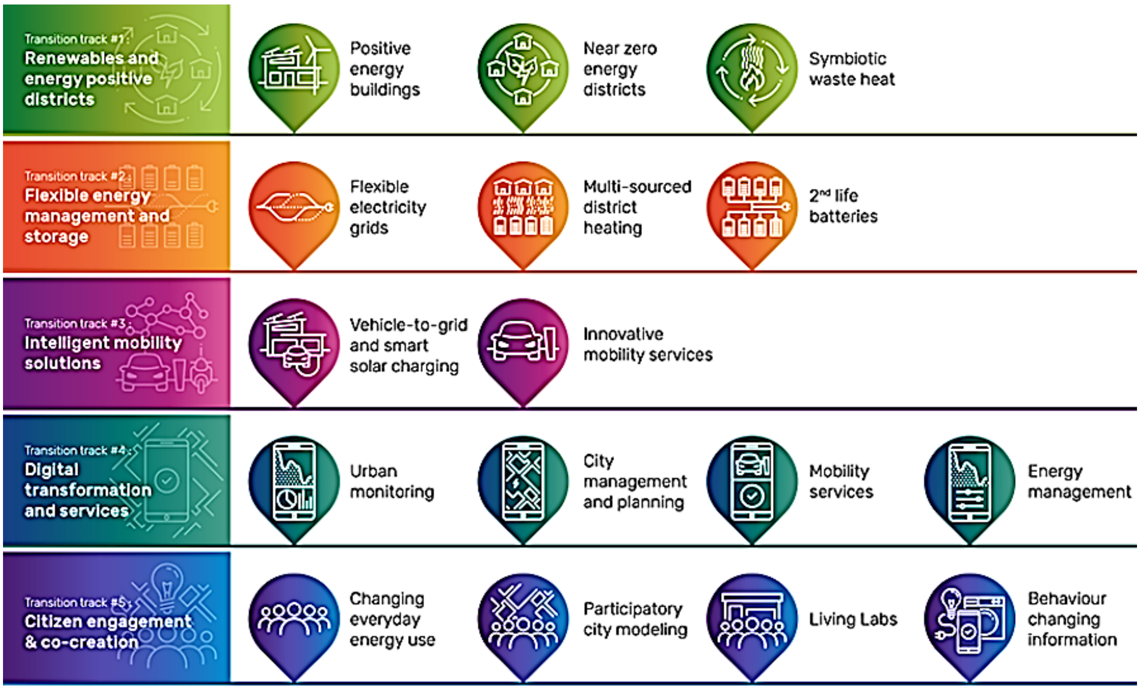

Figure 4. IRIS Transition Tracks and the integrated solutions (The Smart Cities Consortium, 2017; IMCG, 2020).

5. Transition Track #2 & #3 activities in the IRIS Lighthouse cities

The trend of increasing urbanization adds pressure on well-functioning traffic, its requirements, applications and services. IRIS LH cities' goal is to reduce carbon emissions and pollution levels from traffic, and raise the level of sustainable transport by e-mobility solutions, utilizing the MaaS concept, and investing in sustainable public transport. Additionally, integrating smart management and control to EV charging infrastructure, the possibility of utilizing photovoltaic (PV) solar panels with EVs' charging, V2G, and RESS, including 2nd life batteries, play significant role in IRIS LH cities' demonstrations (Nikolopoulos & Pramangioulis et al., 2018; Nikolopoulos & Tryferidis et al., 2018).

The development of sustainable urban transport calls for solutions evolving its technology, infrastructure and services towards *green* direction, by encouraging citizens to promote public transport, e-mobility solutions and vehicle sharing. Smart transport's requirements are accessibility, reliability, flexibility and cost-effectiveness. State-of-the-art technologies, digitalization, ICT solutions, and open data access for consumers are part smart transport. Mobility as a Service and multimodality are concepts, which aim to provide integrated, versatile and efficient transport system, which advances sustainable mobility based (gas and/or e-buses, modes of cycling, walking) door-to-door services, promoting mode-independent connection service, thus reducing private car ownership (Nikolopoulos & Pramangioulis et al., 2018; Nikolopoulos & Tryferidis et al., 2018).

As EVs become more popular, eventually taking over the global automobile stock during the next few decades, various positive impacts as well as challenges will emerge. The development can affect favorably on countries' environments, energy productions, efficiencies and economies. However, while integrating large EV fleets with an energy grid may have great advantages, it might result unpredictable energy flows as well, if not managed properly. Successful integration of RES with e-mobility solutions, and fleets of private and shared EVs and e-buses, require sophisticated smart charging infrastructure, management and control. Charging a large number of EVs simultaneously, should not be able to put uncontrollable amount of added stress on a power grid. Additionally, charging should not only be well designed, it needs to be well scheduled, and offer vehicle-to-grid (V2G) possibility. Thus, EV owners are able to switch from being just electricity consumers to take part of producing energy and selling it to the grid, i.e. to become prosumers. Integrating RES and smart charging not only maximizes the profits of RES, but by allowing high level of self-consumption and -sufficiency to EV owners, it reduces grid stress and possible EV charging power peaks. Hence, RES combined with smart charging enhances the financial value of grid flexibility (Nikolopoulos & Pramangioulis et al., 2018; Nikolopoulos & Tryferidis et al., 2018).

IRIS project's Transition Track #2, *Smart Energy Management and Storage for Grid Flexibility* includes three integrated solutions that can be demonstrated by the LH cities and replicated by the FC. The T.T. #2's third solution, *Utilizing 2nd life batteries for smart large- scale storage schemes* is examined in this thesis. Additionally, this thesis concentrates on IRIS Transition Track #3's Smart e-Mobility Sector, containing integrated solutions, *Smart solar V2G EVs charging*, and *Innovative mobility services for the citizens.* The later solution consists e-mobility, car sharing, and MaaS concept, prioritizing in public transport, and other sustainable mobility applications. These subcategories aim at increasing the deployment of EVs in private and public transport. Additionally they strive to enhance EV fleet management schemes to the end-users, and MaaS services to reduce number of private vehicles by increasing public transport, car sharing systems and services. Moreover, the use of RES in the mobility applications and services is essential feature for the solutions (Nikolopoulos & Pramangioulis et al., 2018; Nikolopoulos & Tryferidis et al., 2018).

The manner by which the Transition Track #3 solutions and the T.T. #2's solution, Utilizing 2nd life batteries for smart large scale storage schemes, are demonstrated in the IRIS Lighthouse cities differ somewhat from each other. Although Utrecht, Gothenburg and Nice all have some similarities in their chosen solutions, they also have several independent fields of interest in the 2nd life battery, and intelligent mobility solutions. The City of Vaasa, as a follower city, strives to find the most suitable integrated solutions, concerning 2nd life batteries and Smart e-Mobility, to be assessed and replicated in its own environment. However, before Vaasa's replication can be analyzed, the demonstrations of the Lighthouse cities need to be examined. These demonstrations are continuing.

5.1. Gothenburg, Sweden – T.T. #2 and T.T. #3 solutions and demonstrations

1. Transition Track #2: Utilizing 2nd life batteries for smart large scale storage schemes:

- Demonstration and study of a 350V DC building microgrid utilizing 140kW rooftop PV installations with a 200kWh 2nd battery storage:
  Gothenburg's *Akademiska hus*, took part in the IRIS project, and has demonstrated how DC system is able to provide advantages when local microgrid level electricity is produced with solar panels and stored in 2nd battery system. The study has explored the re-usefulness of EV batteries in stationary energy storage applications. The batteries were primary expected to provide aid in peak power shaving, as well as storing locally produced PV electricity for later use. Secondarily, the constructed system enables Akademiska hus to buy and store electricity from the grid at off-peak periods, for later peak-period consumption or sales. The DC system has provided secure supply and enhanced energy efficiency (Löveryd et al., 2020; Pavic et al., 2018).

  Gothenburg's demonstrations, concerning the integrated solution, Utilizing 2nd life batteries for smart large-scale storage schemes, has indicated both matters of potential and challenging aspects, as clarified in the Table 2.

Table 2. Matters of potential and challenging aspects of Gothenburg's demonstration of the solution, Utilizing 2nd life batteries for smart large-scale storage schemes (Löveryd et al., 2020; Pavic et al., 2018).

Matters of potential:	**Challenges:**
Sweden possesses a strong unified political determination that the reduction of CO_2 and GHG emissions must proceed swiftly. Initiatives and innovations striving to achieve this goal receive a strong political support.	Subsidies are mandatory in the introduction phase of 2nd life battery solutions. However, this makes the topic a subject of a lengthy political debate, hindering the development of business models and market introduction.
2nd life batteries can act as energy storage units for various size solutions and demands, and provide capacity to aid in grid flexibility and reliability through various ancillary services, e.g. load following, frequency regulation, voltage support and aiding in the case of local black outs.	Management of the collection, storing and ownership or the received data, and financial profit from the 2nd life battery solutions are not clear. Particularly, interfaces concerning the batteries' ownership due to their prolonged life, present a challenge.
2nd life batteries can advance and enhance the utilization and development of RES.	Uncertainty and utilization of "old batteries" may cause opposition. Hence, citizen engagement and guidance are vital, as are "change agents" – people and organizations acting as early adaptors in utilizing 2nd life batteries.
Fast moving technological development and emerging smart energy innovations push forward the utilization of 2nd life batteries.	Batteries and large-scale storage solutions require large investments and have long payback periods.
	Fire safety regulations have to examined and secured, concerning 2nd life battery utilization in building applications.

2. Transition Track #3: Smart e-Mobility Sector:

From the T.T. #3's two solutions, Smart solar V2G EVs charging and Innovative mobility services for the citizens, Gothenburg concentrates on the latter, since the city's EV charging infrastructure and EV pool size is not yet comprehensive enough for large scale V2G solutions.

Gothenburg's innovative smart mobility solution is called EC2B, i.e. Easy to Be. EC2B is built on Mobility as a Service concept, aiming to combine seamlessly the use of private vehicles, shared vehicles, bicycles and public transport, in order to be able to provide functioning and user-oriented services and unbreakable mobility chain. The emphasis is on e-mobility - EVs, e-buses and e-bikes. EC2B strives to utilize mobility management elements, supported by enhanced ICT solutions. Information services from service provides to end-users is a precondition to EC2B. Gothenburg's primary objective is to reduce CO_2 emissions by 80-90% by 2035, and to have the city's traffic totally electrified by 2030, private and public. To succeed in achieving this ambitious goal, Gothenburg relies on EC2B solution, invests heavily in high-performance e-bus fleet, and plans to encourage the EV adoption through developing charging infrastructure (Lund, 2020; Pavic et al., 2018).

EC2B aims to reduce private car ownership by offering a new mobility concept to citizens, through a versatile and attractive alternative to car ownership. By increasing the number of EVs, EC2B helps to reduce CO_2 emissions, as well as air pollution and noise levels. By providing an easy access and continuous mobility chains, by utilizing variety of transport modes, users are encouraged to exercise more sustainable travel habits. Furthermore, EC2B aims to promote vehicle sharing community approach. With car sharing, less vehicles are present in the traffic, thus congestions can be mitigated. Car sharing reduces the need of parking spaces, being a positive matter for property owners, since parking spaces and underground garages are expensive. Thus, EC2B possesses the ability to optimize land use (Lund, 2020; Pavic et al., 2018).

Despite its many positive features, EC2B does face challenges as well. The transformation from private car ownership to public transport or shared mobility can raise opposition. Mobility as a Service is not a familiar concept to public in general, requiring new ways to engage the citizens. The existence of viable business models for all service providers involved in EC2B presents challenges. Additionally, standardization requires more clarity (Lund, 2020; Pavic et al., 2018).

Gothenburg's Smart e-Mobility demonstrations are:

- EC2B for tenants in Brf Viva:

  EC2B provides users alternative to car ownership, allowing easy access to a variety of transport modes, e.g. e-cars, e-bikes or public e-transport. The objective is to enable an easy access service of continuous mobility chain in the city, regardless where end-users live, work or spend their leisure activities. In this demonstration, EC2B was implemented for tenants of 132 apartments in Brf Viva building in Gothenburg, where no private car parking is available. Versatile mobility services and limiting car parking encourages tenants to favor more sustainable transport habits, and to use own cars only when it is necessary.

- EC2B for employees on Campus Johanneberg:

  The EC2B concept was adjusted to meet the demands of the employees in the campus area of Johanneberg, Gothenburg. In addition, by providing an easy access to a wide range of transport options, a new function was developed within the EC2B mobile application for the employees, allowing them to send receipts of their travel expenses, e.g. car rental fees or public transport tickets, directly from the application to their employer's financial department, in order to reduce administrative procedures. Thus, through offering attractive options for local business travel and commuting, employees can be less dependent on driving their own cars to work or resorting to private cars on business trips. Hence, more sustainable transport habits can be promoted, and traffic can be reduced in the campus area (Lund, 2020; Pavic et al., 2018).

Gothenburg's demonstrations, concerning the integrated solution, Innovative mobility services for the citizens, has indicated both matters of potential and challenging aspects, as clarified in the Table 3.

Table 3. Matters of potential and challenging aspects of Gothenburg's demonstrations of the solution, Innovative mobility services for the citizens (Lund, 2020; Pavic et al., 2018).

Matters of potential:	**Challenges:**
The developing digitalization advances EC2B, e-mobility, and the required infrastructure.	MaaS is a new phenomenon for consumers and service providers, which can cause challenges.
MaaS can aid in the need to reduce parking slots and volume of city's traffic. Property developers/owners can cut costs on parking places, improve their real estates' value, or develop their land use.	The role of public transport in MaaS is still unclear in Swedish legislation, thus hindering the joining of public transport authorities in MaaS.
MaaS can enable new business models, opens new revenue streams and creates new jobs.	To find a business model, which would work for all the parties involved in the MaaS solution is a challenge. Lucrative financial end-result for all parties requires collaborated, well-planned and thoroughly executed service.
More and more people are concerned about the environment, and doing their part for sustainability and utilizing green solutions. EC2B enables an easy way to be environmentally friendly. In addition, MaaS has great environmental impacts. It reduces CO2 emissions, decreases the traffic, and improves the attractiveness and safety of the city.	Private car ownership and clinging attitudes for the issue, require time and patience to change. Citizen engagement, functioning EC2B MaaS model and change agents can have an encouraging effect.
MaaS and alternative ways of mobility reduce individuals costs, concerning own an own car.	

5.2. Nice, France – T.T. #2 and T.T. #3 Solutions and Demonstrations

1. Transition Track #2: Utilizing 2nd life batteries for smart large scale storage schemes:

- Flexible electricity grid networks, including PV, 2nd life batteries and lighting network:

The demonstration integrates local RES with decentralized battery storage (1st and 2nd life batteries) and EV charging infrastructure (both public and private) under a common Local Energy Management System. Objective has been to test different operation strategies of such connected assets, focusing on the delivery of flexibility services to the power grid. The demonstration is organized by various service providers, from the management of a single asset to the whole district scale, in order to achieve functioning and reliable interface with energy service markets via aggregation. The demonstration performs as a pilot for the electricity industry, serving as a model for further development and replications. Considerable amount of knowledge has been gained from the research, which has been shared with the key stakeholders to further the multifaceted debate concerning smart local energy management systems, and enhancing the dissemination, communication and replication activities (Keim et al., 2019; Attour et al., 2019; Barre et al., 2018).

- Utilizing 2nd life batteries for smart large-scale storage schemes, including PV, EVs and V2G):

The objective has been to cross-compare the performance of 1st and 2nd life BESS for similar applications within the building sector. Both battery types, 1st life BESS of the EVs via V2G charging poles, and the 2nd life BESS stack, has been used to provide stationary BESS based energy services within the IMREDD smart building block and in Nice Méridia's Palazzo Meridia positive energy buildings. By using similar BESS capacities, batteries' performance and behavior has become more easily comparable.

IMREDD and Palazzo Meridia have demonstrated collective self-consumption at building scale, which is a new concept for commercial and residential customers in France. Part of the buildings' energy efficiency strategies have been to utilize RES integrated to 2nd life batteries. The demonstration of the performances of mentioned BESS technology, in providing building and grid ancillary services, e.g. in optimizing self-consumption and enhancing PV's efficiency. The positive results from Palazzo Meridia and IMREDD has provided a better assessment of BESS' integration possibilities into the energy system (Keim et al., 2019; Attour et al., 2019; Barre et al., 2018).

Nice's demonstrations, concerning the integrated solution, Utilization of 2nd life batteries for smart large scale storage schemes, indicated both matters of potential and challenging aspects, as clarified in the Table 4.

Table 4. Matters of potential and challenging aspects of Nice's demonstrations of the solution, Utilizing 2nd life batteries for smart large-scale storage schemes (Keim et al., 2019; Attour et al., 2019; Barre et al., 2018).

Matters of potential:	**Challenges:**
The technology for utilizing 2nd life batteries is available. Additionally, ICT required hardware and software is available for high performance monitoring and control activities.	Currently, too many protocols and standards hinder the forming of a uniform operating model between different actors, making management and control of platforms is difficult. In addition, regulation on BESS and the utilization of 2nd life batteries is not on mature level yet.
Several EU driven policies and reforms and the French law promote advancement of decentralized energy systems and increased utilization of RES. Additionally, the development of BESS is considered important, thus 2nd life battery utilization as part of it.	Currently, fully operating V2G model is not allowed in France's Public Distribution Grid. It is only allowed when operating behind private property, and as defined by French grid code. Hence, the development of pervasive V2G utilization presents challenges for both French public and private e-mobility services, limiting also the utilization of 2nd life batteries in V2G solution.
The RES related projects among neighborhoods are considered to improve the approval of RES utilization and related technologies, including 2nd life batteries.	France's energy market design, and taxing of grid transport and distribution, does not favor consumers for becoming prosumers. Currently, the minimal energy bid size is 1MW, preventing smaller players and consumers entering the e-market.

There is high potential and anticipation for various new business models and markets, concerning RES, BESS (including 2nd life batteries) and V2G.	It is somewhat unclear by the French law, that what does the concept "energy self-consumption" consist of? Including also EVs' V2G operating model, and usage of BESS.
RES, BESS and EV technologies utilization aid in carbon footprint reduction, and raising energy efficiency and grid flexibility.	There are various contractual and financial issues to be sorted out between all parties involved. Commercialization and financial viability are not yet on mature level for the utilization of 2nd life batteries.
	Non-renewable energy sources are still too lucrative option for the energy market. Carbon taxes need to be on a higher level, other tradable carbon bonds must become more effective and promotion of RES has to increase.

2. Transition Track #3: Smart e-Mobility Sector:

- Smart solar V2G EVs charging:

  The solution relies in strong smart charging infrastructure development. Smart charging integrates EVs, charging stations, intelligent charging solutions, and charging operators' share data connections. Smart charging monitors and manages the use of the charging devices, to optimize electricity's consumption and flow direction (V2G). By monitoring a large pool of charging stations equipped with fast charging points, which can belong either to public or private networks, more flexibility can be provided to the public electricity grid. This can happen by implementing power shaving and shifting through unidirectional controlled charging (V1G), or by other energy services such as using EVs' batteries as energy reserves for grid flexibility. The integration of such strategies can result in the optimization of the total energy consumption, and possibly generate a new revenue stream for EV charging infrastructure (EVCI) operators and owners (Keim & Tawil-Jamault et al., 2019; Attour et al., 2019; Barre et al., 2018).

- Innovative mobility services for the citizens:

The aim has been to optimize the operation of a fleet of shared EVs by coupling the booking, and forecasting the utilization of the EVs to the smart charging management of the EVCI. This has resulted in higher utilization rate of the shared EVs, hence increasing the turnover received from the vehicles. Additionally, it has increasing the efficiency ratio between the charging stations and the fleet of EVs. The demonstration has indicated that optimizing the use of shared vehicles can have a favorable effect on the reliability and efficiency of the implementation of smart charging services (Keim & Tawil-Jamault et al., 2019; Attour et al., 2019; Barre et al., 2018).

Nice's demonstrations, concerning the integrated solutions, Smart solar V2G EVs charging, and Innovative mobility services for citizens, indicated both matters of potential and challenging aspects, as clarified in the Table 5.

Table 5. Matters of potential and challenges of Nice's demonstrations of the solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens (Keim & Tawil-Jamault et al., 2019; Attour et al., 2019; Barre et al., 2018).

Matters of potential:	**Challenges:**
The technology for the solutions is available. Multiple of EV and charging infrastructure and solution providers exist, and ICT solutions are on mature level.	Monitoring and control aspects of charging need to be investigated and tested fully for the services' utmost reliability and attractiveness.
Based on the previous point, smart charging services can proceed to further development, initiation of services, and eventually to commercial exploitation.	EVs booking prediction (where and when), and free-floating operation (EV chargeable both in public and private charging stations anywhere in the city) are not mature yet and need to be tested further. Additionally, regulations for free-floating charging require thorough examination and work between key stakeholders.
The French law supports the development of e-mobility and its related technologies to be exploited, in order to reduce emission and pollution levels, and promote higher environmental, economic and social sustainability.	V2G operating model is not allowed currently on the Public Distribution Grid, only when operating behind private property, and as defined by French grid code. Hence, the development of V2G utilization is very challenging for both French public and private e-mobility services.
Smart charging technologies promote various charging schemes: standard, semi-fast and fast charging, providing different residential areas or property-owners options to find optimal charging solution.	The energy market design, and taxing of grid transport and distribution do not favor consumers becoming a prosumers. Currently, the minimal energy bid size is 1MW, preventing smaller players entering the e-market.

Better and wider charging infrastructure network reduces the hindering factors for EVs' adoption.	User acceptance may be low for share-able EVs, and particularly for V2G solutions, which technology and charging schemes may not only be challenging for consumers but also for service providers.
Carbon footprint and pollution reduction, lower noise levels.	More incentives related to EV pricing, V2G schemes, and shared EVs operating models, (e.g. prices, taxing, tariffs) are needed for consumers to start purchasing EVs instead of IC engine cars, or resort to car sharing.
EV batteries enable V2G operating model, enabling new business and revenue generation models. V2G schemes aid power systems through distributed energy storage capabilities, and via capability to participate in enhancing a grid's flexibility and reliability through ancillary services.	Energy market still favors cheaper non-renewable energy sources. Carbon taxes need to be on a higher level, other tradable carbon bonds must become more effective, and promotion of RES has to increase.

5.3. Utrecht, Netherlands – T.T. #2 and T.T. #3 Solutions and Demonstrations

1. Transition Track #2: Utilizing 2nd life batteries for smart large scale storage schemes:

- Solar V2G charging points for EVs, utilizing 2nd life batteries:
  The City of Utrecht has utilized 18 smart solar V2G charging stations for EVs in its demonstration district. The charging points are interconnected with PV-systems. These bi-directional charging stations provide the infrastructure both motivation and financial interest in integration of smart energy management. The demon-

stration are carried out by combining sustainable transport, and maximizing self-consumption, thus enabling grid stress reduction, and unlocking the financial potential of grid flexibility. By combining the EVs' and e-buses' V2G capabilities with stationary 2^{nd} life batteries, and receiving support by open ICT for interconnection, performance monitoring and new information services for aggregators, grid operators, municipality and citizens, the demonstration in the selected areas of Utrecht has been successful (Van der Ree et al., 2019; Harmelink et al., 2019; Peekel et al., 2018).

- Solar V2G charging points for e-buses, utilizing 2^{nd} life batteries:

  The City of Utrecht has utilized 10 smart solar/wind V2G charging stations for e-buses in the demonstration district of Westraven. The e-bus charging stations provide valuable monitoring and research data for the ambition to integrate smart energy management, thus being a reliable test bed of how large charging powers can be connected to the grid most optimally (Van der Ree et al., 2019; Harmelink et al., 2019; Peekel et al., 2018).

- Stationary storage in apartment buildings:

  The City of Utrecht has demonstrated district-wide additional stationary storage in 12 apartment buildings. The storage consists of 2^{nd} life batteries, which are interconnected to primary V2G-storage and PV-systems by ICT. The 2^{nd} life batteries are able to provide a significant contribution, by making the grid more stable and resilient. In addition, the system has provided an important component for the city-wide virtual power & storage plant, which can provide sustainable energy and promote e-mobility, thus causing notable reductions in CO_2 emissions, and enhance flexibility services on low and medium tension levels (Van der Ree et al., 2019; Harmelink et al., 2019; Peekel et al., 2018).

- Smart energy management system:

  The demonstration district's energy management system (EMS), with the district's ICT platform have been able to prove interconnection and monitoring at district scale, thus allowing the deployment of the Universal Smart Energy

Framework (USEF), i.e. the business model concerning the value of flexibility. The USEF smart EMS has been able to assess the value of the flexibility delivered at low and medium tension grids levels, to the transmission system operator (TSO) and to the distribution system operator (DSO) (Van der Ree et al., 2019; Harmelink et al., 2019; Peekel et al., 2018).

Utrecht's demonstrations concerning the integrated solution, Utilizing 2nd life batteries for smart large-scale storage schemes, indicated both matters of potential and challenging aspects, as clarified in the Table 6.

Table 6. Matters of potential and challenges of Utrecht's demonstrations of the solution, Utilizing 2nd life batteries for smart-large scale storage schemes (Van der Ree et al., 2019; Harmelink et al., 2019; Peekel et al., 2018).

Matters of potential:	**Challenges:**
The utilization of 2nd life batteries can extend the batteries lifetime with additional 10 years, thus delaying the need for recycling or disposal, thus opening possible new venues for revenue generation.	Business models and investments for 2nd life battery applications are not yet economically viable.
Longer life for EV batteries, with their first and 2nd life, will force the price of new batteries to decrease.	More knowledge and research is required about the utilization of 2nd life batteries, potential solutions and monitoring tactics.
Circular economy is a priority matter for the EU, and 2nd life battery utilization and the possible benefit that can be gained from them, can enhance the circular economy's success.	More knowledge about regulations, incentives, taxing and management is required.
The utilization of 2nd life batteries can aid in reduction of CO_2 emissions, and help to increase the use of RES with greater efficiency, thus helping in better grid flexibility and reliability.	Utilizing *used* batteries can face opposition, e.g. due to safety issues and issues concerning attitudes. Guidance and end-user engagement is required.

2. Transition Track #3: Smart e-Mobility Sector:

- V2G EVs:

  Utrecht's car sharing system *We Drive Solar* has been demonstrated in the city's demonstration district. Fourteen solar powered V2G EVs are in use. Additionally, the city's demonstration site, apartment building block Bo-Ex, purchased four e-vans for maintenance and service use. By and large Utrecht's IRIS demonstrations has served as a living lab and a catalyst for fast upscaling of smart energy and mobility management for the whole city of Utrecht. Bidirectional charging infrastructure's development for the whole city has started. Once ready, it will enable large-scale V2G smart charging. We Drive Solar is able to provide a sustainable alternative mode of transport for the IRIS district residence. Additionally, it aids in NOx, fine particular matter, CO and CO_2 emissions reduction. Moreover, the batteries of the shared EVs contribute to smart energy management, combining sustainable transport with optimal self-consumption, thus reducing grid stress, and unlocking the financial value of grid flexibility (Van der Ree et al., 2020; Harmelink et al., 2019; Peekel et al., 2018).

- V2G e-buses:

  The City of Utrecht utilizes 10 smart solar V2G e-buses. The e-buses and their charging stations will provide a green mode of public transport for the IRIS district residents, and reduce emissions. In addition, the e-buses have generated large amounts of research data for the ambition to integrate smart energy management, and enabled testing of how large charging powers can be best operated with the grid (Van der Ree et al., 2020; Harmelink et al., 2019; Peekel et al., 2018).

Utrecht's demonstrations concerning the integrated solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens, indicated both matters of potential and challenging aspects, as clarified in the Table 7.

Table 7. Matters of potential and challenges of Utrecht's demonstrations of the solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens (Van der Ree et al., 2020; Harmelink et al., 2019; Peekel et al., 2018).

Matters of potential:	**Challenges:**
Increasing number of EVs in the traffic will reduce CO_2 emissions, improve local air quality and decrease noise levels.	To engage citizens to use We Drive Solar service requires guidance and active engagement. It can be a challenge trying to change one's habit away from car ownership, to start promoting car sharing and public transport instead.
Car sharing enables the City of Utrecht to develop low-traffic districts.	The education and income level of the population has an effect. More highly educated and with higher income individuals are prone to be more environmentally aware, than individuals with lower income and educational levels.
EV batteries enable V2G operating model, which can aid power systems through distributed energy storage capability, and via participating in grid enhancing flexibility and reliability services such as peak shaving, load shifting etc. Thus, new business and revenue generation models can emerge.	V2G operating model needs to be studied thoroughly and piloted properly before successful, safe and profitable service can be initiated. Wide stakeholder involvement is required.
The City of Utrecht provides various incentives to promote car sharing systems, e.g. attractive parking licenses, lower parking norms and continuously developing the MaaS concept for higher quality.	

6. Finland's National Climate and Sustainable Mobility Goals

In 1994, Finland signed the United Nation's agreement on necessary actions to be taken against climate change. Three years later the Kyoto protocol, i.e. United Nations' Framework Convention on Climate Change, was ratified. Its goal was to pledge the industrialized countries and their economies in the transition to restrain and demote greenhouse gas (GHG) emissions, honoring the agreed individual climate targets.

In 2015, Finland signed the Paris Agreement, which strives to enhance the measures taken globally against climate change, in order to prevent the global temperature rising over 1.5 - 2 Celsius degrees in the 21st century. In 2016, the Government of Finland set the national energy and climate strategy for 2030, which is regulated by the Ministry of Environment. The strategy has to meet the set goals and requirements of the Finnish Government's energy and transport policy. The policy's main objective is to reduce the GHG emissions by 40% by 2030, and 80% by 2050 from the 1990 level. The share of RES out of the nation's energy production is aimed to be increased by 27% before 2030. In 2005, Finland's total carbon footprint was 33,7Mt CO_2. The new aim set in 2016 determined 2030's carbon footprint to be 20,6Mt CO_2 (The Government of Finland, 2016; Ministry of the Environment, 2017).

The Government of Finland has set decisive national goals to reduce traffic caused emissions by 50% by 2030 from the 2005 level. Additionally, the goal to increase RES' share of transport's total energy consumption has been set at 20%. To achieve these goals, the emissions from traffic need to be reduced by 50% by 2030, signifying a total effect of 3,1Mt CO_2. Currently utilized transport fuels need to be replaced with less pollutant renewable options, e.g. hydrogen, biofuels and synthetic fuels, or by heavily increasing alternative power mean vehicles', i.e. EVs, share compared to internal combustion engine powered vehicles. Finland's aim is to have minimum of 250.000 EVs in traffic by 2030 (The Government of Finland, 2016; Ministry of the Environment, 2017; Pastinen & Vallenius, 2018).

Regardless the number of EVs in traffic, vehicles and the whole transport system needs to improve their energy efficiency. The transport system needs to go through transformation by inventing new services and ways of mobility, and by utilizing digitalization and ICT. This includes Mobility as a Service concept, developing infrastructural endeavors jointly with traffic, and investing extensively in sustainable mobility: public transport, cycling and walking. Additionally, the energy efficiency of mobility needs to evolve, so it is able to reach the national goals. Hence, adopting new motor and power technologies, and reducing the weight of the vehicles, are essential measures to be taken in account (The Government of Finland, 2016; Ministry of the Environment, 2017; Enell-Nilsson et al., 2019; Kiiskilä & Ristamäki, 2019; Pastinen & Vallenius, 2018).

In Finland, approximately 60% out of all ground traveling takes place by utilizing a private car. Bus transportation constitutes of 5%, and all rail traffic (trains, trams) only 2%. In comparison, 22% of the Finnish people prefer walking to motor transport, and 8% of people like to travel by a bicycle. As for the purposes of using different means of ground travelling, 25% takes place for occupational purposes, 35% for leisure activities, 30% for shopping and errands, and 10% for acting as a driver for someone else. The share of sustainable mobility (walking, bicycling, public transport) trips out of all ground travel trips is 15%, and from ground travelling in general 37%. Approximately 3% out of all public transport trips are connected trips (Pastinen & Vallenius, 2018).

The most relevant Finnish laws ruling over transport and mobility, and their effects on environment, are the climate law (609/2015), the environmental protection law (527/2014), the vehicle law (1090/2002) and the public transport law (869/2017). With these laws, the Finning Government aims to secure sustainable and environmentally aware development of transport and mobility, and the technology and services involved. Additionally, the laws strive to ensure the ability to reach the climate goals set by the EU and the Finnish Government. Furthermore, they aid to fight against climate change, reduce emission levels, and to advance the utilization of new technologies of private motoring and public transport (Ministry of the Environment, 2014 & 2015; Ministry of Transport and Communications, 2003 & 2017).

7. Vaasa's Decarbonization and Sustainable Mobility Goals

Vaasa has committed steadfast to the climate work and the Government of Finland's set decarbonization goals. Vaasa's City Council set a target for the city in December 2019, to achieve carbon neutrality by 2030. Other objectives in Vaasa's Energy and Climate Program 2019 are:

- Improving energy efficiency by saving energy and intensifying its use.
- Increasing the use of renewable energy sources.
- Developing efficient energy services for neighbourhoods, constructors and renovators.
- Buying only green electricity for public buildings.

Sustainability and energy efficiency form the framework for Vaasa's environmental and mobility goals. Smart mobility has high importance in Vaasa's city planning and future goals, since it aids to advance the wellbeing of the citizens, population growth, employment, and economic growth. The transition process to reach carbon neutrality by 2030 requires fast and decisive measures, without forgetting to secure the future for Vaasa's citizens, industry and services. Hence, innovations, research and development, new business concepts, and collaboration between key stakeholders are required.

In addition, energy efficiency and becoming energy self-sufficient are in the City of Vaasa's interest. To accomplish these goals, the use of renewable energy sources (wind, solar, waste and thermal heat) is planned to be increased, and Vaasa's residential areas' energy consumption to be reduced. By doing so, the GHG emissions can be cut down by 70**%** before 2030. Currently the biggest causes of CO_2 emissions in Vaasa are the district heating (DH) 31%, traffic 29%, separate heating 17%, and the energy consumption of the inhabitants 13% (The City of Vaasa, 2016 & 2019; Enell-Nilsson et al., 2019; Siirilä, 2019; Sweco ympäristö Oy, 2014).

Substantial cut downs to the emissions caused by the traffic, presents a challenge for Vaasa, since private car ownership level is very high in the city's region. Most of Vaasa's inhabitants commute, shop and go to their leisure time activities by driving an own car. Moreover, public transport needs further development from its current level. Shifting to use solely public transport or other means of sustainable mobility, are influenced by encouragement to change one's habits and attitudes, providing an easy access to relevant information concerning mobility, and improvements done to the public transport services and mobility chains. In fully functioning mobility chain, a person is able to travel any distance in a city by using public transport with e.g. bicycles, buses, e-scooters and rental EVs, without having to spend excess time of searching next mean of transport (The City of Vaasa, 2016 & 2019; Enell-Nilsson et al., 2019; Siirilä, 2019).

The emissions from the traffic are planned to be reduced by 90% by 2030. Hence, the development and utilization of public transport has to be improved considerably, with heavier investments in sustainable bus alternatives - electric and bio. Additionally, the bus routes need development, in order to meet efficiently Vaasa's mobility needs and citizens' requirements for public transport services. In 2017 there were 1.2 million travels done by public transport in Vaasa. The goal is to quadruple the number of travels to 4.8 million travels by 2035. Furthermore, Vaasa is developing its cycling infrastructure and services with specialized bicycle routes and lanes, city bike services, and ensuring the cycling routes are safe and cleared of snow during winter months (Enell-Nilsson et al., 2019; Siirilä, 2019; Lindeqvist et al., 2020).

Sustainability and carbon footprint reduction are not only the city's goals. The organizations need to do their own share by encouraging their employees to commute by using sustainable mobility forms: public transport, cycling, walking, and car sharing. The climate actions and achieving the set goals require planning, coordination and cooperation between the City of Vaasa, the local organizations and institutions, and citizens of Vaasa.

The biggest drivers for Vaasa's sustainable transport and smart mobility development are based on its vast energy technology expertise, urbanization trend and new possibilities provided by new technologies. New technical solutions and appliances, digitalization, ICT and data analytics can reduce traffic congestions, thus causing fewer accidents and reducing emissions. As a result, the environment becomes cleaner, and the general health of the people improves. Sustainability, new technologies of energy production, RES and mobility solutions require heavy investments and commitment in decision-making. Cooperation and clear roles in economy and policies need to be drawn. Required technologies are available, the biggest challenge is how to implement new technologies most efficiently to already existing system, or how to construct a completely new system, e.g. new smart city district, and connect it to old city infrastructure (Enell-Nilsson et al., 2019; Siirilä, 2019; The City of Vaasa, 2016 & 2019; Sweco ympäristö Oy, 2014).

Vaasa attempts to develop its mobility jointly with its infrastructure development. Hence, the results can be expected to be the most robust and enduring, and being able to stand future development endeavors. Currently there are several large-scale ongoing or near-future planned infrastructure constructions, which require major changes in existing transportation system, and in the design of completely new transport solutions. Vaskiluoto district's reconstruction with construction of a local energy company's new facilities and Vaasa harbor's enlargement are undertakings, which will take several years and modify the districts transportation requirements and infrastructure anew. Similar kind of large construction, where newly planned city districts' construction takes place jointly with designing and constructing the transportation system, is the district of Ravilaakso. Low energy district Ravilaakso will be constructed in 3-4 phases, starting in 2022, providing significantly lower energy consumption housing solutions and district energy storage system, which helps to achieve higher energy efficiency. Additionally, the Ravilaakso district will have readiness for e-mobility, with adequate charging infrastructure and incentives for car sharing (The City of Vaasa, 2016; Sweco ympäristö Oy, 2014; Tenho et al., 2018; Kurikka-Oja & Kumpula, 2015).

7.1. The Covenant of Mayors

In 2016, Vaasa was accepted in the EU's The Covenant of Mayors for Climate and Energy program. The program aims to gather together thousands of local governments around the European Union states and outside Europe, which are committed to implementing the EU's climate and energy objectives. The program was initiated in 2008, and over the years, the Covenant of Mayors has grown to be a global program. Thus far, over nine thousand local and regional authorities from 53 countries around the world have gotten involved. The Global Covenant of Mayors exploits the experience gained over the past eight years in Europe, and is building on the key success factors of the initiative: the bottom-up governance, the multi-level cooperation model, and the context-driven framework for action. The Covenant of Mayors program is directly linked to the EU's climate and energy policy framework (The Covenant of Mayors, 2020).

Each Covenant member has to commit to a Sustainable Energy and Action Plan (SEAP) to be involved in the program. The essence of SEAP are the Baseline Emission Inventory, and the Climate Risks & Vulnerability Assessment, which aid in monitoring and steering the actions of sustainability for reducing the carbon footprint. SEAP's primary objectives by 2050 are intense carbon footprint reduction, enhancing the capability to adapt to the climate change's impacts, and securing people's access to reliable, affordable and sustainable energy. (The Covenant of Mayors, 2020).

7.2. Sustainable mobility plan, MoveIT project, and BothniaTM project

The Finnish government has set a national target to reduce emissions from traffic by 50% before 2030 from the 2005's level. Based on national policies, the City of Vaasa decided on Sustainable Mobility Plan in 2019. The plan, implemented together with Traficom and WSP Finland Oy, reviews Vaasa's strategies related to transport, mobility and related infrastructure. It aims to develop guidelines and solutions for means of daily sustainable transport in the city, and clarify the measures to be taken with traffic, so that Vaasa can achieve carbon neutrality before 2030. The Sustainable Mobility Plan (2019) defines the vision, objectives, interventions and reporting system for mobility in Vaasa, thus providing vital information about how and when the IRIS solutions could be replicated in Vaasa. In addition, the program has strong focus on citizen engagement (Enell-Nilsson et al., 2019; The City of Vaasa, 2019; Siirilä, 2019).

However, the development of the Sustainable Mobility Plan was preceded by "Vaasa Arena for Change" workshop, both illustrated in the Figure 5 with other related projects connected to sustainable transport in Vaasa. The workshop was part of by BothniaTM project, funded by the European Regional Development Fund (ERDF), the City of Vaasa and the University of Vaasa. One main objective of the BothniaTM project was to identify stakeholder and citizen engagement's importance for the community's sustainability development. Additionally, the project concentrated on involvement and influence of *change agents* for a community, in achieving the sustainability goals. This activity can be referred to the IRIS integrated solution *Community Building by Change Agents* demonstrated in Utrecht (The City of Vaasa, 2019; Enell-Nilsson et al., 2019).

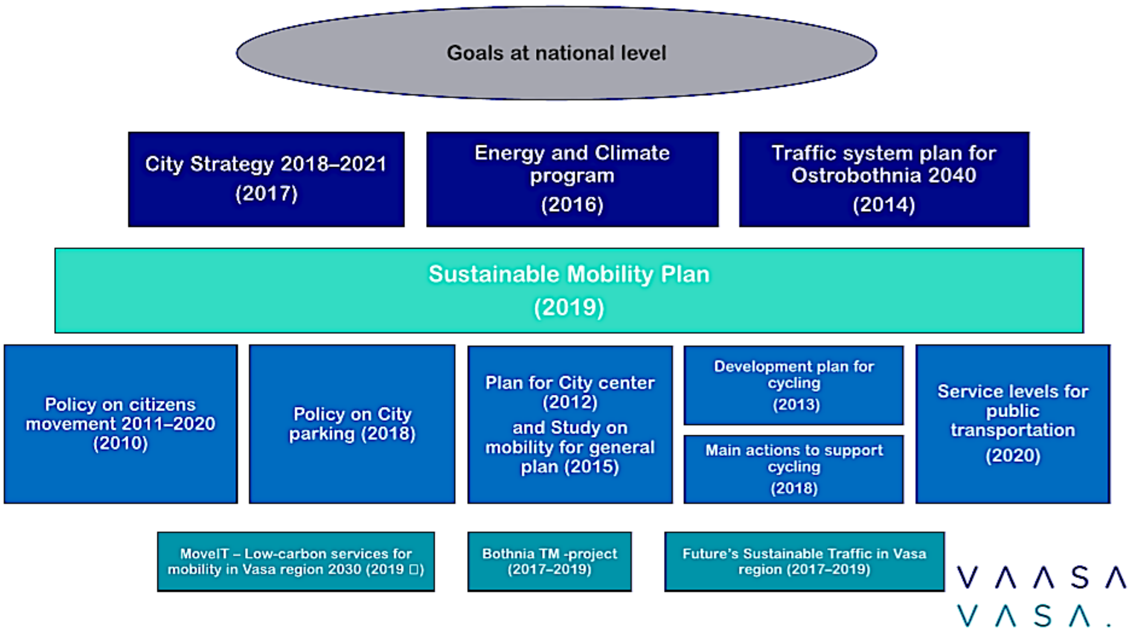

Figure 5. Vaasa's strategies, policies, plans and programs related to carbon neutrality goals and sustainable transport (Onkalo et al., 2021).

The Vaasa Arena for Change workshop generated the following key notifications about the mobility objectives best serving the citizen's desires:

- Public transport usage to be quadrupled by 2035.
- The cycling modal share to be tripled by 2035.
- Traffic emissions to be reduced by 90% by 2035.
- Reduce CO_2 emissions.

- Low-carbon solutions should receive the highest priority in infrastructure development.
- Increase the utilization rate of a shared cars and public transport, and increase their revenues.
- Reduce the number of cars in public spaces.
- Reduce the need to build expensive underground parking spaces and street level parking.
- Coordination of planning to be enhanced considerably.
- Sustainable commuting/mobility to be placed on organizations' agenda.
  (Enell-Nilsson et al., 2019)

Additionally, the Sustainable Mobility Plan includes several measures for years 2019-2022, indicated in the Table 8, to improve services and infrastructures for cyclist and pedestrians, which are outside the IRIS implementation and replication model. However, there are several plans to improve the services, technologies, infrastructure, and mobility solutions, which can be linked directly to the IRIS T.T. #3 integrated solutions, enabling lessons learned from the LH cities' demonstrations, and replication in Vaasa's environment, clarified in the Table 8. Some of the Sustainable Mobility Plan's activities have indirect IRIS replication plan connections, since those activities support or enhance Vaasa's replication plan's integrated solutions.

Table 8. Planned activities of Sustainable Mobility Plan, which have either direct or indirect link to the IRIS replication plan (Enell-Nilsson et al., 2019; Onkalo et al., 2021).

Sustainable Mobility Plan Activity	Implementation planned	Description	INDIRECT IRIS replication possibility
Development of the city centre for pedestrians	2019-2021	Support innovative initiatives. Increasing pedestrian zones in the city centre	T.T. #3, IS 3.2 MaaS
Development of safety, accessibility and quality related to pedestrian zones and cycling paths	2022	Functioning network including green zones	T.T. #3, IS 3.2 MaaS
Project to improve existing cycling paths	2020-2030	Improvement of existing cycling paths	T.T. #3, IS 3.2 MaaS
Planning of new cycling routes and priorities	2021 - 2022	Update the city centre plan, pilot for new cycling path in the city centre etc.	T.T. #3, IS 3.2 MaaS & Citizen engagement T.T. #5
Specific budget for cycling	2020	Financing plan mobility	T.T. #3, IS 3.2 MaaS & mobility chains
Development of parking facility plan for cycling	2020-2021	Plan on parking facilities	T.T. #3, IS 3.2 MaaS & mobility chains
Improve conditions during winter season for light traffic	2020-2021	Service levels and main network for cycling and pedestrians	T.T. #3, IS 3.2 MaaS & mobility chains
Sustainable Mobility Plan Activity	**Implementation planned**	**Description**	**DIRECT IRIS replication possibility**
Sustainable Mobility Plan	2019	Strategic document based on the City Strategy	T.T. #3, IS 3.2 MaaS
Annual plan for communication on sustainable mobility	2020	Plan for communication, goals, stakeholders, budget	Co-creation and citizen engagement T.T. #5 & T.T. #3, IS 3.2 MaaS

Development of public transport	2021	Improve services, routes, smart solutions, connections etc.	T.T. #3, IS 3.2 MaaS
Procurement or subsidies to e- or biogas buses	2021	Implement EU decisions on procurement	T.T. #3, IS 3.1 e-buses and charging systems & T.T. #3, IS 3.2
Improving public image of public transport	2020	Co-creation with citizens, service provides	Co-creation and citizen engagement T.T. #3, IS 3.2 MaaS & T.T. #5 Citizen engagement
Digital services for mobility	2020-2021	Real time service on public transport, piloting platform for different applications, payment systems and services related to mobility	Services for smart mobility T.T. #3, IS 3.2 MaaS, Data platform T.T. #4, IS 4.3 Services for Mobility
Plan to develop mobility hubs	2019-2020	Development of hub for mobility services and connections to districts	T.T. #3, IS 3.2
Raising awareness of employers and private enterprises about sustainable mobility	2022	Awareness, co-creation and engagement to facilitate mobility plans for private sector employers	Citizen engagement T.T. #3, IS 3.2 & T.T. #5
Raising awareness of smart energy and mobility solutions	2022	Subsidies and guidance to housing associations for sustainable mobility and energy efficiency (EVs, charging infrastructure, shared vehicles, e-bikes, mobility services)	Services for smart mobility, and citizen engagement T.T. #4, IS 4.3 & T.T. #3, IS 3.1 & 3.2
Data collection	2019	Data collection and system available on city web-site	Data platform, and smart charging T.T. #4, IS 4.3 & T.T. #3

Pilot on public-private partnership in new housing construction projects	2022-2027	Improve quality of housing areas and related outdoor spaces, EVs, shared vehicles, e-bikes, charging, mobility services. Model to measure benefits	T.T. #2, T.T. #3, IS 3.1 & 3.2 , T.T. #5
More efficient and flexible use of public spaces	2020	Co-operation and easy access to public spaces. Shared parking places	T.T. #3, IS 3.2 & Citizen engagement T.T. #5
Participatory planning and budgeting	2021-2022	Co-creation and engagement of citizens for planning and budgeting	Citizen engagement T.T. #3 & T.T. #5

In addition, the City of Vaasa, in collaboration with Vaasa Region Development Company VASEK, the University of Vaasa, and the Center for Economic Development, Transport and the Environment (ELY), implemented *MoveIT - Low Carbon Dioxide Transport Services in the Vaasa Region by 2030* project in 2019. The project was funded by *Pohjanmaan liitto* through European Regional Development Fund (EAKR), together with local ELY, the City of Vaasa and the Municipality of Mustasaari. MoveIT prepared an analysis of the current situation, and vision for the public transport and other mobility solutions in Vaasa region. The focus of the project report is Mobility as a Service, and the development of the mobility chains in the Vaasa region. Thus, the report provides a baseline for most of the issues related to mobility in IRIS Transition Track 3, Smart e-Mobility sector (Siirilä, 2019).

The key subjects of the MovilT project concerning Vaasa were:

- Sustainable mobility and reduction of traffic.
- Enhance cycling and walking possibilities in the city’s center and region.
- Changes in mobility’s services, digitalization and user behavior.
- Zero and low-carbon vehicles and fuels.

8. Vaasa's IRIS replication plan

T.T. #1: Smart Renewables and Closed-loop Energy Positive Districts			
Integrated solution	**Project name**	**Partners**	**Estimated period**
✅**IS-1.1: Positive energy buildings** (Nice: Palazzo Meridia (self-consumption, RES, BESS) & IMREDD + Gothenburg: Brf Viva (PV, BIPV, local ESS, 2nd life batteries) + Utrecht: Bo-Ex (RES, Smart metering)	New energy positive community building in the city cente	The City of Vaasa, local energy distribution system operator (DSO) Vaasan Sähköverkko Oy, local electricity company Vaasan Sähkö Oy, constructor etc.	TBA
IS-1.2: **Near zero energy retrofit district** (Utrecht: Bo-Ex)	Olympia block, Ristinummi district etc.	The City of Vaasa, Oy Pikipruukki Fastighets Ab, VOAS	TBA
✅**IS-1.3: Symbotic waste heat networks**	Vaskiluoto heat storage	Vaasan sähkö Oy, waste incinerator plant owner	TBA

T.T. #2: Smart Energy Management and Storage for Grid Flexibility			
Integrated solution	**Project name**	**Partners**	**Estimated period**
✅**IS-2.1:** **Flexible electricity grid networks**	Smart Grid (previous project: Sundom Smart Grid)	Vaasan Sähkö Oy, Vaasan Sähköverkko Oy, The University of Vaasa	TBA
✅**IS-2.2: Smart multi-source low temperature district heating with innovative storage solutions** (Gothenburg: 350 V DC building microgrid utilizing 140kW rooftop PV installations, 200kWh BESS + Nice: Flexible electricity grid networks + Utrecht: V2G, smart charging, BESS)	Suvilahti self-sufficient district &Ravilaakso low-temperature DH	The City of Vaasa, Vaasan Sähkö Oy, Westenergy Oy	TBA
IS-2.3: Utilizing 2nd life batteries for smart large scale storage scheme s (e.g., Nice: IMREDD (RES, BESS) + Utrecht: apart ment buildings and V2G storage schemes, e-buses, smart charging + Gothenburg: low temperature DH 45/30 system & cooling)	TBA	The City of Vaasa, Vaasan sähkö Oy, Vaasan sähköverkko Oy e-vehicle manufacturer/-s	TBA

T.T. #3: Smart e-Mobility Sector			
Integrated solution	**Project name**	**Partners**	**Estimated period**
IS-3.1: Smart solar V2G EVs charging (Utrecht: We Drive Solar + Gothenburg: EC2B + Nice: Smart-Solar V2G)	TBA	Vaasan sähkö Oy, Vaasan sähköverkko Oy, The City of Vaasa	TBA
✅ **IS-3.2: Innovative mobility services for the citizens** (Gothenburg: EC2B Viva & Campus, MaaS + Nice: Innovative Mobility Services, EV fleet + Utrecht: WeDriveSolar)	EC2B Ravilaakso: EVs (fleets), car sharing, smart charging schemes, Sustainable mobility, cycling, public transport development	Construction company, The City of Vaasa, a vehicle provider (TBA)	2022-2025

T.T. #4: City Innovation Platform (CIP)			
Integrated solution	**Project name**	**Partners**	**Estimated period**
IS-4.1: Services for urban monitoring (Nice: Sensors data collection in air quality + Gothenburg: CIM pilot + Utrecht: Monitoring E-Mobility, Smart Street Lighting with multi-sensoring)	TBA	Vaasan sähkö Oy, The City of Vaasa	TBA
IS-4.2: Services for city management and planning (Nice: BIM/CIM data display + Gothenburg: CIM platform + Utrecht: 3D City Innovation Model)	TBA	The City of Vaasa	TBA
IS-4.3: Services for Mobility (Nice: Data control and monitoring for Smart e-mobility + Utrecht: Monitoring E-Mobility)	TBA	The City of Vaasa	TBA
IS-4.4: Services for Grid Flexibility (Nice: Data interoperability with energy cloud + Gothenburg: The City Information Platform + Utrecht: Monitoring Grid Flexibility)	Connection to IS 1.1, 1.2, 2.1, 2.3, 3.1 & 3.2	The City of Vaasa, Vaasan sähkö Oy	TBA

T.T. #5: Citizen Engagement			
Integrated solution	**Project name**	**Partners/Engagement**	**Estimated period**
✅**IS-5.1:** **Changing everyday energy use** (Utrecht: Community building by change agents)	TBA (relation to TT#1 & TT#3 activities) Ristinummi district, The Olympia-block (TBA)	The City of Vaasa, the University of Vaasa, Novia, Ristinummi district and The Olympia-block citizens, residents associations, district councils, Vaasa S etlementti Association	TBA
IS-5.2: **Participatory city modelling**	TBA	The City of Vaasa, citizens	TBA
✅**IS-5.3: Living labs** (Utrecht: Co-creation in Local Innovation Hub)	LähiöInno (Ristin ummi district, The Olympia-block)	The City of Vaasa, The University of Vaasa, NOVIA, Ristinummi district and The Olympia-block citizens, resident associations, district councils, Vaasa Setlementti Association	2020-
✅**IS-5.4: Behaviour changing Information** (Nice: Public awareness campaign Energy – School & Collège; Youth & Family + Utrecht: Campaign District School Involvement)	Energy Education Path	The City of Vaasa, pupils and students in Vaasa and their families, teachers and schools' staff	2017-

Table 9. Vaasa's replication plan in full (Onkalo et al., 2021).

From the Table 9, presenting Vaasa's replication plan, one should first notice the five different Transition Tracks, and how they are further divided into 16 integrated solutions in total. From these solutions, the ones the City of Vaasa is planning to implement, or is already utilizing, are specifically marked. In addition is indicated, which LH cities' demonstrations are behind Vaasa's replication plans. The second column is reserved for Vaasa's planned replication project in specific. The key project partners and tentative schedule are shown in columns three and four, respectively.

T.T. #5 deals with various aspects of citizen engagement. However, citizen engagement as an activity is considered very important aspect in the IRIS project, and therefore it must be included in every single Transition Track's integrated solution. Concerning Transition Track #2's integrated solution 2.3 Utilizing 2nd life batteries for smart large-scale storage schemes, no designated project is visible in the Table 9. This indicates that the City of Vaasa does not currently have plans to replicate this solution, which still requires further investigation. Still and all, this solution will be addressed more thoroughly later on in this thesis.

As for Transition Track #3, the integrated solutions 3.1 Smart solar V2G EVs charging, and 3.2 Innovative mobility services for the citizens, both are of interest for the City of Vaasa. Particularly for the IS 3.2, the City of Vaasa has various plans for replication activities. Additionally, the IS 3.1 is of interest, although not yet feasible for replication. However, the solution has great potential in the future, benefiting from growing EV stock, enhancing local smart grid development, and advancing certain IRIS integrated solutions' development, e.g. IS 2.1, 2.3, 3.2 and 4.4 (Onkalo et al., 2021).

9. IRIS - Replication Activities of Transition Track #2 and #3 in Vaasa

The City of Vaasa's strategy to achieve carbon neutrality by 2030, and the city's Sustainable Mobility plan, both have ambitions to increase sustainable models of mobility, e.g. public transport, e-mobility and Mobility as a Service concept. These ambitions can also be found from the T.T. #2's IS 2.3, and the T.T. #3's IS 3.1. and 3.2 of the Vaasa replication plan.

9.1. Utilizing 2nd life batteries for smart large-scale storage schemes

Currently, there are no energy storage solutions in Vaasa applying 2nd life batteries. While the application of 2nd life Li-ion batteries for energy storage solutions is an interesting and potential concept in terms of future's energy solutions in Vaasa area, the limiting factor currently is the extremely low level of adoption of PHEVs and BEVs in Vaasa, and in Finland in general. In the end of 2020, there were little over 45.000 PHEVs and approximately 9.700 BEVs in use in Finland, as shown in the Figure 6. On the national level, the adoption of hybrid electric vehicles (HEV) is still far greater than PHEVs and BEVs.

The utilization of 2nd life batteries and their development into a viable market in Finland, requires strong progressive development of e-cars and e-buses sold for private and public sector, and utilization in traffic among all vehicles. Thus, eventually the stock of 2nd life batteries will grow, and the development of their utilization can start. Other affecting factors to non-existing utilization of 2nd life batteries are the relatively weak development of MaaS concept and its sustainable mobility solutions and e-mobility in general. In addition, the scarceness of smart charging, charging infrastructure, and innovative solutions to exploit 2nd life batteries in smart energy solutions, e.g. interconnection with RES, and battery energy storage solutions acting as energy storages for buildings, hinder the utilization of the 2nd life batteries (Onkalo et al., 2021).

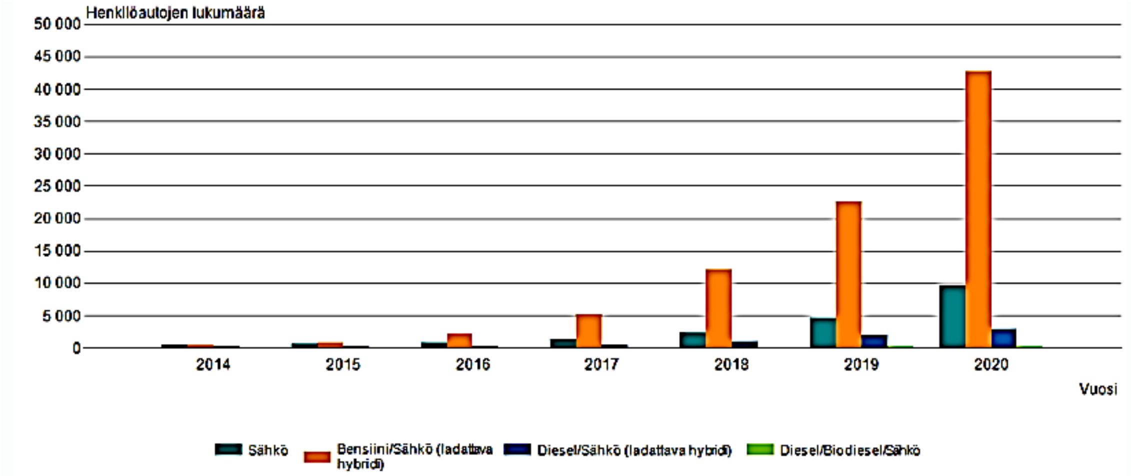

Figure 6. PHEVs (orange & blue) and BEVs (green) in traffic in Finland 31.12.2020 (Traficom, 2020).

Although 2nd life batteries for stationary applications are not applicable currently, nor in the near future, for the City of Vaasa, such energy storage solutions do represent possibilities for Vaasa region subsequently, as indicated in the Table 10. However, currently no plans exist to replicate second-life battery demonstrations as done in Utrecht, Nice and Gothenburg. As the number of battery electric vehicles grows, and the supply of 2nd life batteries will increase substantially from the current level, then an implementation plan will be called for. More investigation on the subject is required, in order the matter of utilizing 2nd life batteries to become well-grounded (Onkalo et al., 2021).

Table 10. The matters of potential and challenges of utilizing 2nd life batteries in Vaasa (Onkalo et al., 2021).

Matters of potential:	**Challenges:**
National and regional policies and goals support measures striving for energy efficiency, use of sustainable energy sources and solutions of energy storing.	Investments in 2nd life batteries are not yet economically viable. Without subsidies, it is very challenging for new business models for 2nd life battery solutions to emerge. Legal and financial circumstances need to be changed as well.
Many of the international studies indicate that the utilization of 2nd life batteries is cheap. The expenses of the batteries largely concern the batteries' "first life".	Knowledge of the utilization of 2nd life batteries is limited and may cause prejudice.
The technology for the utilization of 2nd life batteries is available. However, certain solutions may require more examination and research, depending on the case.	Security issues, e.g. fire safety, concerning the utilization of 2nd life batteries is of serious concern, and require further investigation.
2nd life batteries have 8-10 years of capacity left, and are environmentally safe and sustainable energy storage/source, if examined properly and handled correctly. Recycling a battery after its first life is more expensive, and disposal may possess environmentally dangerous issues.	More regulatory framework is needed in the utilization and trade of 2nd life batteries, not only in national level but internationally as well. Existing regulation does not support enough the commercialization of 2nd life batteries in wider perspective.
There are several potential and researched ways of utilizing 2nd life batteries: in buildings, e-mobility, MaaS and ancillary services for the local power grid.	The market is not mature yet for 2nd life batteries' usage in most countries. More time has to pass for EVs to increase their share of vehicles in use.

The utilization of the 2nd life batteries adds more length and value for the life cycle of a battery, which can benefit the battery manufacturer, grid operator and the battery owner.	The biggest hindering factors learned from the LH cities demonstrations were surprising. The price of the utilized 2nd life batteries was high. Additionally, in order to build a sufficient battery pack inside an apartment building for its energy use, substantial amount of work and investment was required, and the feedback from the inhabitants was not positive. The conclusion is that the market needs to mature and more research and pilot testing is necessary.

9.2. Transition track #3: Smart e-Mobility sector

Transition Track #3's integrated solutions are studied based on their replication possibilities in Vaasa's new Ravilaakso district, illustrated in the Figure 7. The main stakeholders for the IS 3.1 Smart solar V2G EV charging, are the DSO, being responsible for the technical infrastructure and services related to possible V2G solutions, with a company providing the shared EVs, and the constructor companies responsible for building district's houses.

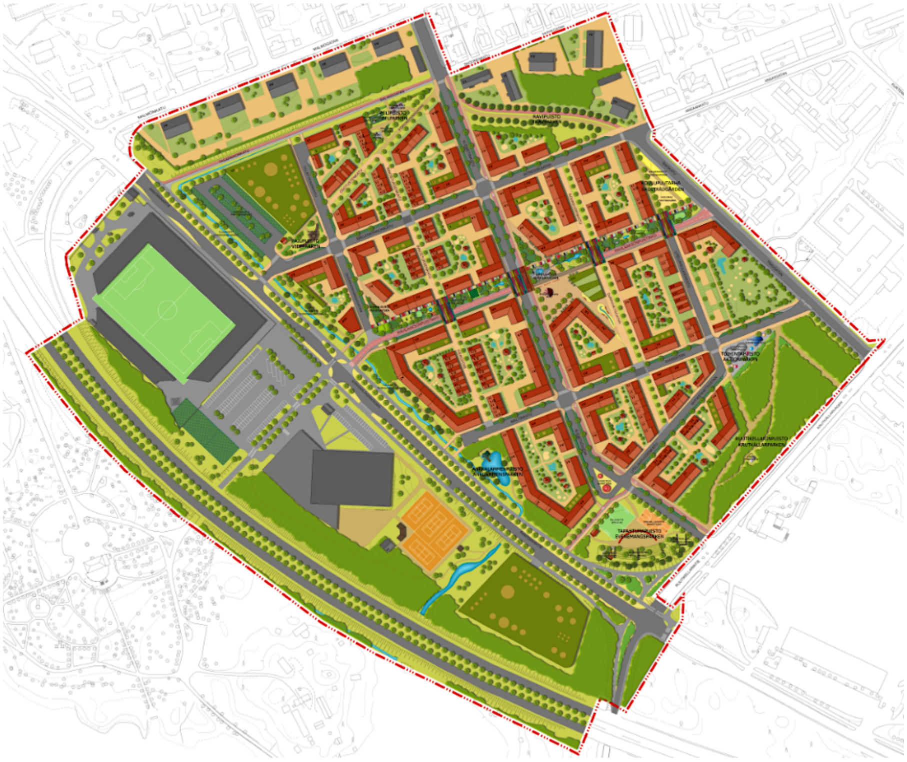

Figure 7. Ravilaakso replication area shown in red (Onkalo et al., 202).

IS 3.1's biggest challenges are the lack of knowledge related to consumer behavior, and the sustainability and economic feasibility of the solutions. Currently, it is highly difficult to identify the available EV stock in the Vaasa region. Thus, it is very challenging to, reliably identify the exact number of EV owners capable of utilizing V2G service, if such a service would exist. Additionally, currently only a few vehicle manufacturers allow V2G application, why small number of V2G enabled EVs are sold in all together in Finland. However, growing number of EV manufacturers are constantly developing V2G enabled EVs, and rising number of such models are being introduced to the automotive markets at growing rate (Onkalo et al., 2021).

Moreover, is it very challenging to draw exact conclusions on what extend the local power grid would benefit from the possible local V2G charging infrastructure, or what kind of impact would the solution have on the durability of the EV batteries. Additionally, not enough knowledge exists on what would be the true economic benefits for the EV owners. For the IS 3.1, there is a need to improve the knowledge of the development of the V2G solutions and services, and what are the financing options for developing such services for a city such as Vaasa, where customer base is minimal compared to the charging infrastructure required. There is also need to gain more knowledge about customer behavior concerning V2G solutions.

The stakeholders of IS 3.2 Innovative mobility services for the citizens, were identified during the Transition Arena workshop, with participants from the City of Vaasa (civil servants and board members), the University of Vaasa, NOVIA University of Applied Sciences, Regional Development Company VASEK, and Technology Centre Merinova. Smart Mobility Services are considered as an opportunity to develop new concepts, especially in densely populated urban areas, and the development needs to involve organizations, citizens and service providers.

For Vaasa's plan to replicate Gothenburg's EC2B demonstration, the main challenges are related to the sustainability of business models, and the uncertainty of human behavior. EC2B is based on complex agreements between different third parties, housing developers, a platform developer and an EV provider. For EC2B in Gothenburg, the Lighthouse partner was a company, which took an active role in supplying the shareable EVs. The company in question may provide knowledge and technology to possible replication partners in Vaasa (Onkalo et al., 2021).

9.2.1. Smart solar V2G EVs charging

V2G and Smart solar charging solutions are closely linked to Transition Track #2 Smart Energy Management and Storage for Grid Flexibility, to its both integrated solutions 2.1, Flexible electricity grid networks, and 2.2, Utilizing 2nd life batteries for smart large-scale storage schemes. In addition, the IS, Smart solar V2G EV's charging, is connected to Transition Track #4's IS 4.4, Services for grid flexibility.

Currently, there are approximately 25 public e-charging stations in Vaasa region, illustrated in the Figure 8. Several operators exist, and can be expected, that in the future the number of charging stations will mainly raise by private operators. Currently, there are no activities related to V2G solutions in Vaasa (Onkalo et al., 2021).

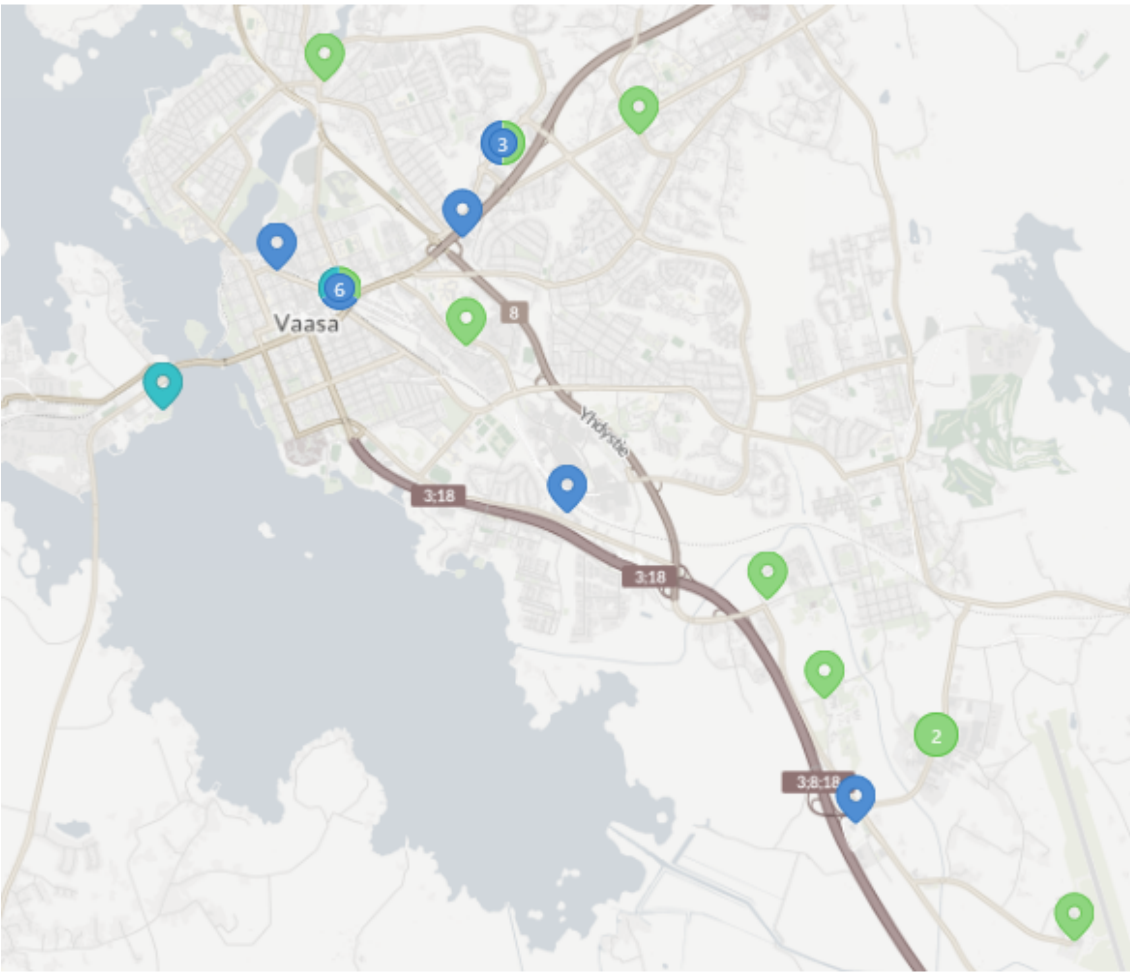

Figure 8. Location of e-charging stations in Vaasa. Additional three stations are located further out of the center of the city (latauskartta.fi, 2020).

The City of Vaasa has planned for the new near-zero energy district Ravilaakso, a small fleet of vehicles for sharable use. It has been calculated, that a shared car in the district would replace six personal cars. It is yet uncertain, whether the vehicles will be EVs. Tentative planning is that they will be.

Ravilaakso is a new residential area of 83 apartment buildings and 45 townhouses in Vaasa, which will be inhabited by approximately 2500 people. The district's area was used as a horse race track before it was decommissioned in 2016. Civil engineering work began in 2019, and the construction of buildings is planned to begin in 2022. Once finished the total living area of the Ravilaakso district will be approximately 135 000 m^2. In the developed Ravilaakso district, the aim is to achieve the highest possible level of energy independence and sustainability. One of the most important environmental goals of the City of Vaasa is to reduce the city's carbon footprint. This has been taken into account, when planning the energy and mobility solutions for Ravilaakso (Onkalo et al., 2021).

Smart charging and interconnection with PV are expected to play a major role in the future's smart grid operations. When the EV penetration rate will reach the level, where the DSO and the flexibility of its operations will need the adoption of additional smart energy technologies, e.g. involvement of RES, V2G and RESS, V2G presents high potential for ancillary services. Through large number of EVs, smart charging and management, providing extra electricity to the system when needed is possible. Moreover, V2G can function as a distributed energy storage, or a storage network, not only on regional but on national level as well.

Currently the City of Vaasa has no intent to replicate the IS 3.1, due to the fact, that the demand for smart solar V2G EVs' charging is negligible in Finland in general, i.e. there is no V2G service available and smart charging infrastructure is yet to be developed. However, when EVs become increasingly popular, and viable business model/-s for V2G solutions and services shall eventually emerge (indicated in the Table 11), planning of the replication can continue. The demonstration conducted in the LH city Gothenburg, related to e-buses and their charging system (V2G), could be replicated later after the project period, if the City of Vaasa will invest in e-buses (Onkalo et al., 2021).

Table 11. The maters of potential and challenges of utilizing V2G schemes in Vaasa (Onkalo et al., 2021).

Maters of potential:	**Challenges:**
EU expresses a strong political commitment towards e-transport and MaaS concept.	The City of Vaasa has already made an investment in biogas buses, and required infrastructure for local bio fuel production. Transferring to e-transport requires a new investment plan.
The investment cost of a bidirectional adjustable charging system is higher than in G2V system. However, it is the most cost-effective and economically profitable alternative once utilizing V2G in full extent becomes widespread.	In order to utilize EVs' batteries in the existing energy system, a new implementable and lucrative business model has to emerge.
The required technology is already available.	EVs are more expensive than IC powered vehicles. E-buses demand charging infrastructure, for example fast charging stations at each endpoints of the route. These stations can be very expensive. Well-functioning, effective and full electrification of the city's bus fleet requires fast charging infrastructure capacity, manageable in size as well.
The rising number of EVs and reduction of fossil fuel driven cars in traffic, will lead to reduction of CO_2 emissions, improvement of air quality, and reduction of noise levels.	User acceptance of smart charging can prove to be a barrier for quite some time. For many of the end-users such a service, and their awareness of its full potential, requirements and effects, can be relatively limited.

The contribution EVs have to the reduction of air-pollution might convince citizens to favour the adoption of e-mobility and shared transportation, such as shared EVs.	However, for V2G solutions, only a few vehicle manufacturers exist currently, who allow the use of EV batteries in the V2G operating model. Many of the available EV models, and charging infrastructure models, have too low technical performance and capacity, to manage detailed V2G schemes.
V2G operating model enables EVs to be utilized as distributed storage system for the grid, and in various ancillary services, providing more grid flexibility.	The main identified technical barriers related to the power infrastructure and e-charging stations are the compatibility of the charging stations with the local power network, and availability of power of the local network.
V2G enables attractive mean for economical profitability, concerning the DSO, aggregators, service operators, and the EV owner.	As the number of EVs increases, it is important that the charging activity and infrastructure are managed intelligently, to avoid power peaks, and the need for additional power caused by charging. Components for implementing smart charging at the property level already exist, but only at the higher grid network levels.
	More defined, detailed and well-constructed regulatory framework is required as V2G schemes become more current.
	Lack of wide smart charging infrastructure network.

A considerable challenge is to stimulate citizens to change their habits of using private cars, and start actively promoting and utilizing more sustainable mobility alternatives, such as public transport, resorting to car sharing, and buying EVs instead of cars ran by fuel. Private car ownership and private car commuting are very common in Vaasa. Therefore, increasing the utilization of public transport and car sharing are challenging issues. The replication of integrated solution 3.2 should be combined with the replication of integrated solution 5.1, *Changing everyday energy use*, which concentrates on citizen engagement, and affecting to the energy behaviour.

EVs and Mobility as a Service reduce consumers' carbon footprint and open new types of business opportunities. The energy storage potential provided by e-cars and e-buses via V2G solution, combined with smart energy and charging management, have the potential to aid, or even optimize the energy self-consumption of buildings, reduce grid stress, and unlock the financial value of grid flexibility. After the development of more advanced V2G systems takes place, and enough information about suitable business models and technical requirements are available, the City of Vaasa can investigate the solution's potential anew, and make decisions for further V2G schemes. Prior to that, local pilot project should be carried out, since more research is required on the subject (Onkalo et al., 2021).

9.2.2. Innovative Mobility services for the Citizens

Traffic is the second biggest source of CO_2 emissions in Vaasa, consisting of 29% of emissions outside the trading sector. The other CO_2 sources are district heating 50%, consumer energy consumption 13%, agriculture 4% and waste management 3%. In the close future, traffic will raise to be the biggest source for CO_2 emissions, when the political decision to ban fossil fuels in heating will come into full effect, and the energy efficiency of living will increase. To achieve a dramatic reduction of traffic related CO_2 emissions, various new methods of technology and emission mitigation are required (Liljeström et al., 2019).

Some of Vaasa's challenges are that the number of vehicles per person is high (630 vehicles per 1000 persons) and the share of vehicles using alternative fuels or powering technology is low. However, several positive steps have been taken. New biogas buses have been added to the city's bus fleet. The City of Vaasa has built a system for local biogas production and purchased 12 biogas buses for the city's internal transport service. Additionally, new bus routes have been developed, in collaboration with Vaasa region's biggest employing companies. Additionally, citizen's opinions and wishes have been heard, e.g. through the city's webpage and in BothniaTM project. Currently, approximately 1.2 million trips are done in Vaasa by public transport annually. Based on the BothniaTM project, this amount is planned to be doubled by 2025 and quadrupled by 2035 (Enell-Nilsson et al., 2019; Siirilä, 2019; Lehtomaa et al., 2012).

Organizing a market based public transport in Finland is challenging, due to long distances and the difference in the sizes of the cities. Smart mobility services are considered as an opportunity to develop new concepts of sustainability, especially in densely populated urban areas. Vaasa is aiming to improve the service level in the mobility sector, mainly in public transport, improving the cost and resource efficiency. The target is to receive cheaper unit cost for the services and better utilization level.

One of the main objectives is fully functioning shared transport system, which would include cars, bicycles and e-scooters. For shared transport system, the main tool is system monitoring on data, and devices connected to the transport service system. Further development of e-mobility and the use of biogas and/or e-buses in Vaasa's transport, are also main objectives for the Vaasa´s logistic plan. Well planned and executed public transport, increments in schedule and efficient routing, aid in the management of traffic congestion and achieving carbon neutrality (Enell-Nilsson et al., 2019; Siirilä, 2019).

The share of cycling in Vaasa is 12%, presenting good potential for growth. Distances in the city are short, the terrain is relatively flat, and the number of students, who utilize bicycles a lot, is approximately 13 000. Nearly 80% of the citizens of Vaasa live within cycling distance from the city's center, which is maximum of 5 km. In 2018, a bike sharing system was tested in the city center and in the Vaasa University's campus area with positive results. Additionally, renting an electric scooter is possible in Vaasa. This service was introduced in 2020, and it has quickly gained popularity.

Still and all, as indicated previously in the Table 8, improving services and infrastructure for cycling and pedestrians is not directly involved with IRIS Transition Track solutions. However, well-functioning services, technologies, solutions and infrastructure concerning the T.T. #3's Mobility as a Service concept: public transport, e-mobility, functioning mobility chains, utilizing digitalization, smart charging and monitoring, are at least indirectly linked to light traffic. Additionally, the T.T. #4's Services for mobility and the T.T. #5 Citizen engagement, possess indirect linkage to improving the environment, services and infrastructure of light traffic in connection to the T.T. #3. Moreover, citizen engagement as an activity has to be part of every IRIS integrated solution, regardless, which Transition Track is in question.

Replication of LH city Gothenburg's VivaBf/EC2B demonstration is under more detailed scrutiny, in order to be utilized in Ravilaakso district. This planned project is part of activity described in the Sustainable Mobility Plan's *Pilot on public-private partnership in new housing construction projects*. The EC2B's platform model could also be used in other new housing construction projects, as well as in other housing associations and public housing companies (Onkalo et al., 2021).

Table 12. The matters of potential and challenges of Innovative mobility services for the citizens, in Vaasa (Onkalo et al., 2021).

Matters of potential:	**Challenges:**
There is a strong national and local political commitment to achieve sustainable mobility. The City of Vaasa is committed to reach carbon neutrality by 2030. Vaasa's population is growing steadily, setting high requirements for the city's accommodation needs. Large part of this growth needs to be accommodated within the current city boundaries. This will be carried out through more compact building, increasing the number of homes per km^2. Simultaneously, the city center has to remain attractive and approachable, and capable to meet the needs of the growing number of citizens.	Curtailing private car ownership, or private car mobility, can be sensitive political issues. Hence, delays or avoidance of making such potentially unpopular decisions may occur.
The City of Vaasa is working proactively to promote the development of MaaS concept. By promoting public transport, e-mobility and related services, digitalization and ICT in transport services, car sharing and smart charging, the city's mobility objectives can be achieved.	It can be challenging to find a business model viable for all actors involved in MaaS solution. Developing and maintaining the digital platform requires investments and capital. For some mobility-service providers it may be challenging to find sufficient amount of funding for planned sturdy MaaS solution on all levels.

MaaS connected to accommodation can reduce costs for property developers, as it might reduce the number of parking lots needed, or building expensive underground parking garages. It can also lower mobility costs for users, if ownership of a car becomes unnecessary. For mobility service providers, it might attract new customers.	To stimulate citizens to change their habits of using private cars, and start actively promoting and utilizing car sharing system or public transport instead, or switching from IC powered cars to EVs, can be challenging. Private car ownership is an individual right and matter of choice.
Technology is already available.	As the service to be developed in this case (Maas/EC2B) is primarily targeted at newly built housing projects, it is mainly available for people with good economical status.
For new construction areas, the City of Vaasa can apply lower parking norm, e.g. parking spaces that need to be reserved per dwelling. The city is preparing pilots projects on how to actively stimulate the development of MaaS concepts, by reducing parking places, which can be required if MaaS concept is utilized. However, the urban plans and building regulations define how many parking lots are required in different buildings areas. Any exceptions are decided during the permitting process.	Decision-making involves different stakeholders, public and private actors. To find common vision of goals and priorities may be challenging.

Improved services should lead to reduction of the CO_2 emissions, improvement of local air quality and reduction of noise levels. Additionally the volume of traffic should reduce.	More clarity to regulatory and legislative framework, incentives, tariffs, prices for consumers and service providers are needed.
The City of Vaasa can apply lower parking norm in new development areas, where property developers are able to make new arrangements for mobility services, such as vehicle and bike sharing.	
Can advance V2G schemes.	

The new Ravilaakso district is planned to have a *Well-being city block*, financed by a social services foundation (2 apartment buildings) for seniors. Car sharing is part of the plan, and the Foundation is planning 1-2 EVs for the block. The Foundation will be the owner of the housing block, consisting of total 103 apartments, thus guaranteeing good conditions for shared vehicle use. Additionally, the Foundation will provide a number of e-bikes for its block. Ravilaakso district has big ambitions for car sharing in general. Moreover, the City of Vaasa has negotiated with a constructor and a construction project developer about another block in Ravilaakso, which also intends to acquire a few shareable cars for the area.

In order to replicate Gothenburg EC2B demonstration, the Foundation responsible for the Well-being block in Ravilaakso, will engage its residents in an early stage via marketing and advising the use of services available when new residents are in the process of moving into the district. The replication of integrated solution 3.2 Innovative Mobility services for the Citizens, should be replicated jointly with the integrated solution 5.1 Changing everyday energy use for best possible end-result (Onkalo et al., 2021).

The business model for EC2B model operating in Ravilaakso has not yet been decided in detail. However, as a business concept, MaaS has several potential aspects, enabling new services and businesses, as indicated in the Table 12. For the Foundation responsible for the Well-being block in Ravilaakso district, due to car sharing, less parking places are needed to be built than normally required by the building regulation, thus saving considerably in expenditures. In average, one parking place can cost from several thousands to tens of thousands of euros. In addition, the inhabitants can get more services related to developed sharing concept, e.g. e-bikes, e-scooters and a phone application. This application can also be used for managing and booking other shared resources. The application and digital platform developer will get access to new markets for its products, and possibility to further develop its business in Vaasa.

Additionally, Ravilaakso district's mobility plan requires providing shared vehicles, e.g. cars, bikes, e-scooters etc., generating profit for the service providers. Moreover, the City of Vaasa will benefit financially from the increased utilization of the public transport, from the ticket sales. Most of the other possible replication activities related to the Sustainable Mobility Plan are done by the City of Vaasa, and are dependent on the city's budget. The project is based on EC2B service, which involves several actors: end-users, various service providers, housing foundations etc., aiming to develop high quality, attractive and sustainable mobility services, shown in the Figure 9 (Onkalo et al., 2021; Lättilä, 2015).

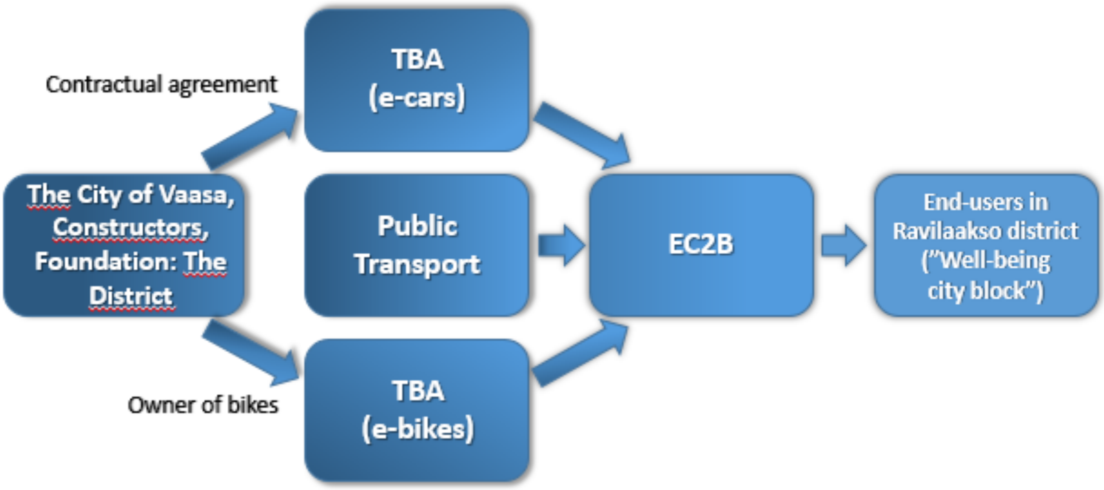

Figure 9. EC2B governance model for Ravilaakso district (Onkalo et al., 2021).

EC2B enables housing development, where one does not have to take into account the aspect of vehicle ownership. This is managed through packaging flexible mobility services, counselling and *community for sharing*- concept. EC2B aids real estate developers, who want to offer the market a modern and urban housing concept, with lesser number of cars in the district. This can be achieved through a package solution of sustainable and flexible mobility, which is attractive to both customers or residents and authorities. EC2B benefits mobility service providers, who want to reach large and affluent market for their sustainable mobility services. It will form a functioning part of a comprehensive service for sustainable mobility, easily accessible. EC2B advances Vaasa's aspirations to create a more attractive urban environment and sustainable development with fewer cars and a significantly more efficient land use (Onkalo et al., 2021).

The implementation of EC2B's replication for Ravilaakso district will proceed as follows:

1. **Evaluation** of Gothenburg's demonstration in collaboration with the Foundation, EV provider-company, and the City of Vaasa.
2. **Feasibility study** of the EC2B will be developed. Identification of providers of shared resources and content of the platform, and services need to be identified.
3. **Risk analysis** includes risk identification and description of risk mitigation activities.
4. **Financial analysis** includes the investigation of financing schemes and funding from each partners' business case. Several national and EU funding sources exist. At this stage, the City of Vaasa should to decide, how it should act to referred required parking norm and number of used shared vehicles.
5. **Detailed design documents**. The Foundation of Well-being city block and main stakeholders will develop the technical documents required for implementation.
6. **Agreements**. Depending on the project definition, agreements between different partners of the implementation have to be formed, to define re-

sponsibilities and business models. If part of the implementation is outsourced, the public procurement will be carried out according to the national legislation.

7. **Project implementation.** The development of required services and applications for the platform, and construction phase of required infrastructure, including construction works, equipment installation etc.
8. **Commissioning**. Before operation, the commissioning step is recognized as of high importance, due to the innovative and complex nature of the designed measures (Onkalo et al., 2021).

National funding sources include:

- The Government of Finland
- The Finnish Innovation Fund SITRA
- Motiva Ltd. - Sustainable Development Company
- Business Finland for public and private projects
- Regional level funding sources, e.g. *Pohjanmaan liitto*

(Onkalo et al., 2021).

Table 13. EU financial instrument for Transition Track #3 (Nikolopoulos et al., 2018).

Transition track #3 Intelligent mobility solutions — Vehicle-to-grid and smart solar charging — Innovative mobility services

Transition Track est. relevance		Project Size	Risk	Time-span	Info
EIB 4.1 European Investment Bank	Medium	Medium to large	Low risk	Long to mid term	Applicants/partners will undergo the EIB Due-Diligence process
EIF 4.2 European Investment Fund	Medium	Large and mid sized	Low to medium	Long to mid term	Applicants/partners will undergo the EIB Due-Diligence process with EIF or Intermediary partner
GB/CAB 4.3 Green /Clim. Awareness/ Bonds	High	Small to large projects.	Low risk	Long to mid-term	financing for sustainable projects and activities that promote transition to climate resilient growth.
PPP 4.4 Public Private Partnership	High	Medium to large	Risk-sharing managed in PA	Long to very long	Initiated to enable private capital in infra-structural city investments
4P 4.5 Public Private People Partnership	High	Medium to large	Risk-sharing managed in PA	Long to very long	Enabling citizen participation and public/ private cooperation in development projects
PF4EE 4.6 Priv. Finance for En. Efficiency	High	Large and mid-sized	Low to medium risk	Medium to long	Facilitating access to affordable financing for investments with strong energy-efficiency focus
EEEF 4.7 European Energy Efficiency Fund	High	Medium	Low to medium risk	Medium to long	Initiated to bring public and private partner-ship capital into climate change mitigation
EFSI 4.8 European Fund for Strategic Inv	High	Micro, small and mid size	Medium to high risk	Medium to long	Launched to help overcome the current investment gap in the EU
CF 4.9 Crowd Funding	Medium	Small projects	Medium to high risk	Short to mid-term	By EU-commission described as an under-developed source of funding and financing

9.2.3. Conclusions on ambitions and planning concerning activities for the T.T. #3 Smart e-Mobility Sector

The City of Vaasa's Sustainable Mobility Plan approaches the activities described in the IRIS replication plan's T.T. #3 with wide perspective, including e.g., biogas buses, cycling, pedestrian areas, and route planning. Simply waiting for EVs to become more popular, or car sharing becoming commonly used mean of mobility, the basic problems caused by high level of private car ownership, and increments in traffic flows and congestion, continue. Any incentives promoting EV growth should not conflict with the objectives of public transport development, they can both aid to achieve the carbon neutrality goals.

Vaasa's firm ambition is to achieve functional and economically viable public transport system that will be smart and include combination of different services and means of mobility. Smart mobility can function as an opportunity to develop new market-based mobility services in an urban area, to complement public transport and the sustainable mobility chain (Onkalo et al., 2021).

10. The development of the T.T. #2 and #3 replication activities in Vaasa

After the City of Vaasa has concluded its IRIS replication plan, the actual execution and further development of the integrated solutions, the implementation of technologies, solutions and services, based on the LH cities demonstration and the replication plans can start. This stage will require the involvement of various stakeholders and third party solution and service providers, contractors etc. However, in order to take the right actions in the future, concerning 2nd life batteries, V2G, and Smart e-mobility solutions, and to build a stable and lasting model for the utilization of these solutions in Vaasa, foresight and knowledge sharing is necessary.

When planning the replication activities of the T.T. #2 and #3 solutions, one should take into account, as lessons-learned, the LH cities' positive and negative experiences about the solutions. In addition, the City of Vaasa's policies, goals and ambitions to reach carbon neutrality before 2030, has paramount importance. Furthermore, the previous projects and studies conducted in Vaasa, i.e. Sustainable Mobility Plan, BothniaTM project, and MoveIT project, about decarbonization, sustainability, and improvements concerning energy efficiency, traffic and mobility, should be paid attention to. Thus, the replication plan and future activities can become successful, and find congruence between the IRIS project's objectives and the goals of the various previous projects, and enhancing the City of Vaasa's ambitions, decision-making processes and stakeholder engagement. The later objective aims to secure wider acceptance for the replicable solutions, being in align with plans and projects already done.

The Figure 10 indicates that the joined positive experiences the LH cities shared about the utilization possibilities of 2nd life batteries, consists mainly of environmental effects, RES and grid support possibilities, and new business opportunities. The 2nd life batteries are considered to be a great asset in the future's smart grid operations, and supporting factor in e-mobility as well. The negative experiences consist of challenges concerning immature regulatory circumstances, business models and support systems, and safety issues to be further developed. Vaasa's observations, shown in the Figure 11, are in align with the LH cities experiences concerning the utilization of 2nd life batteries, although Vaasa has no immediate plans to replicate 2nd life battery solutions. Thus, Vaasa has fewer positive factors to represent concerning the utilization of 2nd life batteries.

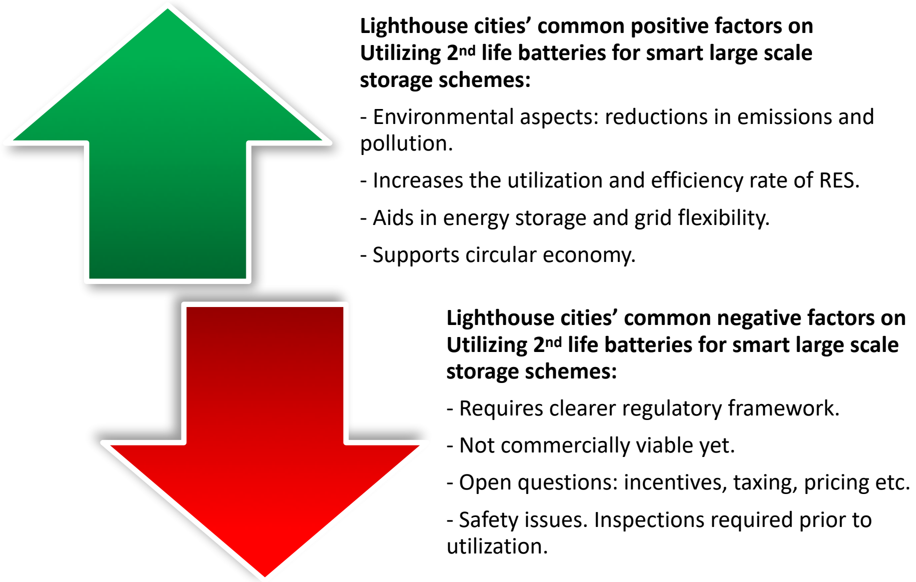

Figure 10. Lighthouse cities' common positive and negative factors on Utilizing 2nd life batteries for large smart scale storage schemes.

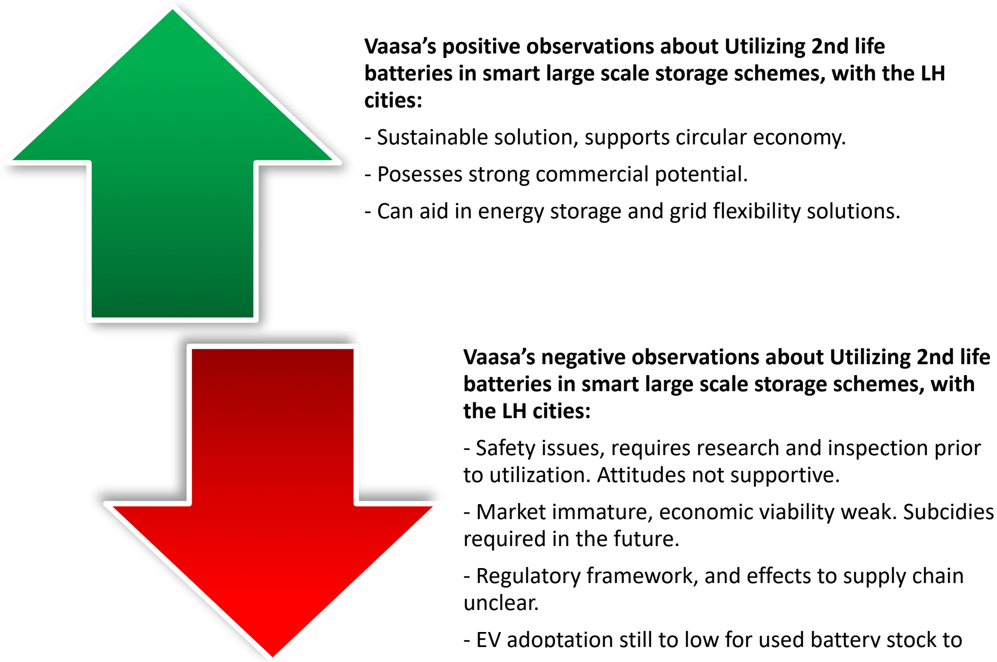

Figure 11. Vaasa's positive and negative similarities on Utilizing 2nd life batteries for smart large-scale storage schemes with the LH cities.

The Figure 12 indicates, that the LH cities' positive experiences and reactions concerning V2G and Smart e-Mobility solutions, consist of environmental aspects, but even more so of opportunities in potential new business and service models, via exploiting MaaS and V2G schemes. In Utrech, Nice and Gothenburg the MaaS concept and V2G are strongly considered as possible *game changers* in mobility, i.e. inter-connectable solutions, which will, when developed further, provide substantial economic and social value, and transform mobility and EV charging/discharging activity in the process.

For Vaasa, both MaaS, and V2G in particular, are concepts of the future. Their potential value is recognized, although not as strongly as in the LH cities, as indicated in the Figure 13. This prudence is due to the fact, that in the LH cities MaaS and V2G are considered to be solutions soon ready to advance to larger scale implementation. In these cities and countries they represent, as in more vastly populated Central-Europe in general, EV charging network development, as well as e-car and e-bus adoption, are more advanced than in Finland. Moreover, car sharing and MaaS concepts, although still to be developed further, are *de facto* phenomena set to succeed in the IRIS LH cities, there is not only a strong interest towards it but also a great demand. In Vaasa and in

Finland in general, EV adoption is still relatively low and wide EV charging infrastructure is scarce, although both expected to improve considerably in next few years. Additionally, lack of encompassing and clear policy and market framework concerning V2G is a challenge, whereas Mobility as a Service concept has a strong political and regulatory support in Finland.

The LH cities' joined negative factors are to do with issues hampering the opportunities, e.g. under-developed market and particularly the regulatory basis, and issues concerning new business models. In addition, opposing consumer attitudes, and required further testing and research required, are seen as barriers, since they obstruct the development MaaS and V2G schemes in particular.

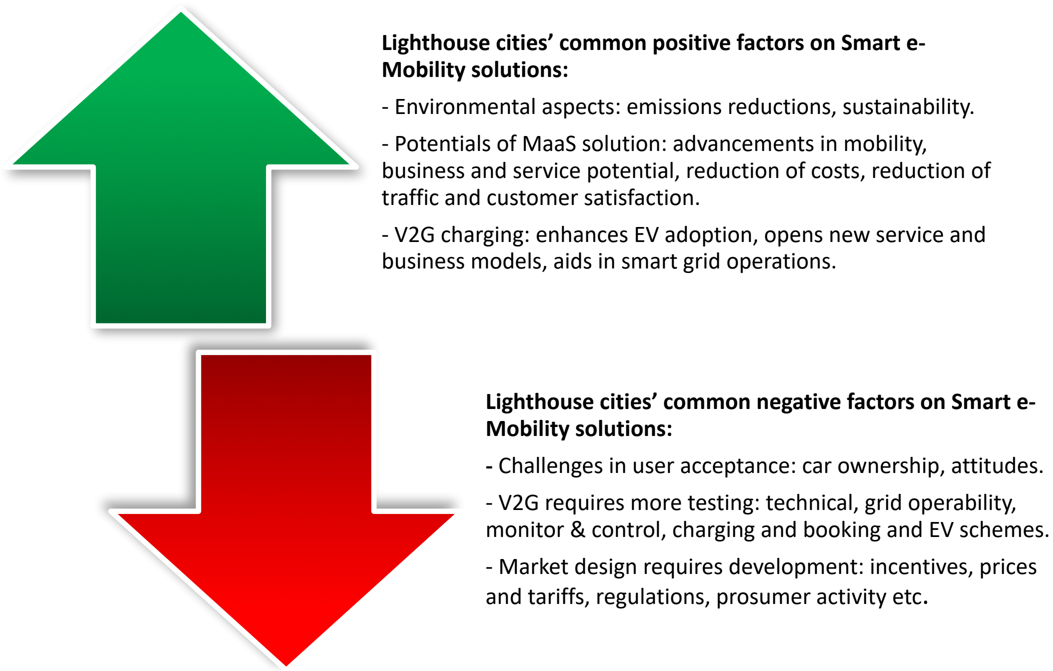

Figure 12. Lighthouse cities' common positive and negative factors on V2G and Smart e-Mobility solutions.

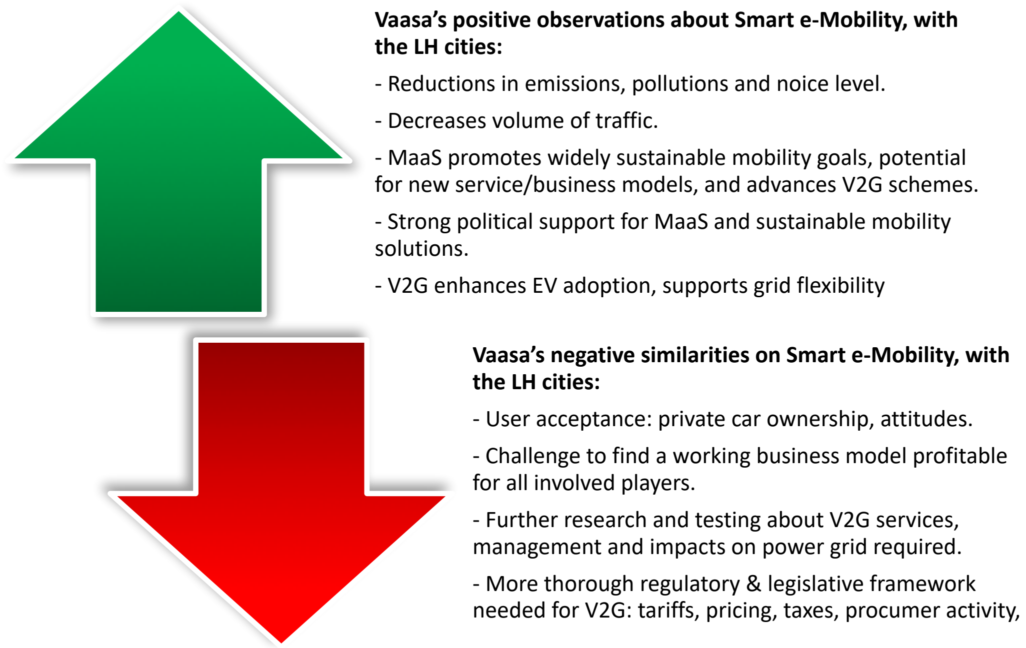

Figure 13. Vaasa's positive and negative observations about Smart e-Mobility with the LH cities.

When comparing matters concerning Vaasa's IRIS replication plan T.T. #2 and #3, to other Vaasa's decarbonization, sustainability and mobility projects and plans, it is for the benefit to analyze the similarities and try to find the common objectives within these projects. Although, Vaasa's Sustainable Mobility Plan, Bothnia TM project, and MoveIT project have differences in focuses and approaches, they share many common factors as well. By listing these common factors, it is possible to analyze whether Vaasa's IRIS replication plan's T.T. #2 and #3 solutions follow the most joined and mutual view of how Vaasa can achieve its carbon neutrality goal by 2030.

Table 14. The common objectives between Sustainable Mobility Plan, Bothnia TM and MoveIT projects, and their connection to the City of Vaasa's IRIS replications plan's 2nd life battery, and Smart e-Mobility solutions.

Previous plans and projects:	**IRIS:**
Increase sustainable services	Mobility as a Service (MaaS)
Enhance public transport	MaaS
Start utilizing e-buses	MaaS, V2G, 2nd life batteries
Advance zero & low carbon mobility	MaaS, V2G, 2nd life batteries
Reduce emissions from traffic	MaaS, V2G, 2nd life batteries
Introduce car sharing	MaaS
Increase the number of EVs and charging infrastructure	MaaS, V2G, 2nd life batteries

As the Table 14 indicates, Vaasa's IRIS replication plan's T.T. #2's integrated solution Utilizing 2nd life batteries for smart large scale storage schemes, and T.T. #3 in general, i.e. Smart e-Mobility Sector, are in align with the previous plans set, and projects done in Vaasa, concerning sustainable mobility, and goals to reach carbon neutrality by 2030. Although the replication plan's integrated solutions concerning 2nd life batteries and smart e-mobility schemes, possess many new features, technologies and measures not necessary as widely addressed in the previous projects, the replication plan and the previous plans strive for a common goal: more sustainable and carbon neutral mobility in Vaasa. Moreover, it is noteworthy that the IRIS replication plan supports the objectives of the previous plans and projects.

11. Conclusions

The City of Vaasa's goal is to become a carbon neutral city by 2030. In order to achieve this objective the city's plans and measures concerning energy production and consumption, infrastructure, construction, mobility and citizen engagement need to support each other for the common goal. In 2016, the City of Vaasa was accepted to the EU's Covenant of Mayors project, and in 2017 to the EU's Horizon 2020 program, to be part of its IRIS Smart City project. IRIS (Integrated and Replicable solutions for co-creation in Sustainable cities) consists of three Lighthouse cities and four follower cities. Horizon 2020 aim is to battle climate change and aid to achieve carbon neutrality by developing cities to become smarter, and promote innovative, efficient, far-reaching and replicable solutions, from the fields of smart energy production and consumption, traffic and mobility, ICT and citizen engagement. First, IRIS project's solutions are to be studied and demonstrated by Lighthouse cities, and then replicated by the follower cities. Replication plan is required to examine and present the feasibility and validity of the solutions.

IRIS project is composed of five Transitions Tracks, which all consist several different integrated solutions. IRIS' Transition Track #3, Smart e-Mobility Sector, consists of two solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens. The study of these two solutions; their feasibility for the City of Vaasa in correlation with the Lighthouse cities demonstrations and experiences, the City of Vaasa's carbon neutrality plans, and the previous projects and plans executed in Vaasa concerning mobility, is the objective of this thesis. Furthermore, the IRIS's Transition Track #2 solution, Utilizing 2nd life batteries for smart large scale storage schemes is studied, since it is closely related to the Transition Track #3's solutions in the Lighthouse cities, bearing a direct connection to EV, e-mobility (e-buses), V2G and Mobility as a Service solutions.

The Lighthouse cities' demonstrations indicate that the Smart e-Mobility Sector, and 2nd life battery solutions have significant potential and importance for developing smart and innovative e-mobility and EV charging solutions, Mobility as a Service concept, and battery storage schemes. The demonstrations promote the development of smart charging, utilization of V2G model, introduction of innovative e-mobility solutions, and exploitation of 2nd life batteries. In addition, the demonstrations are able express that the solutions mentioned do have the potential to create substantial financial value from creating new business opportunities, while promoting sustainable carbon neutral development.

Nevertheless, it is important to express that the LH cities are better capable to implement these solutions into their environment than the follower cities. The LH cities are bigger and located in countries and highly populated areas where related technologies' adoption is higher. The number of EVs is higher in LH cities, the charging infrastructure is more developed, the state of public transport, particularly e-transport, is more advanced, and the cities' environment, resources and related market development are more mature and more ready for the solutions. In all of the IRIS LH cities, the MaaS concept design is relatively mature with strong emphasis on e-public transport, car sharing, continuing mobility chains, strong utilization of digitalization and ICT solutions, and innovative mobility services.

Due to more developed EV stock and e-mobility, the LH cities are better capable to study and develop V2G and 2nd life battery solutions. In order to enhance V2G operating model, e.g. the LH cities Utrecht in Netherlands and Nice in France, are working in close collaboration with car manufacturer Renault and the local DSOs. In order to utilize 2nd life batteries, the LH cities have collaborated with local housing cooperatives, and found use for the used batteries in energy storage applications in apartment buildings, instead of recycling or disposing them. However, in order to have access to a sufficient number of used batteries required the applications, high enough adoption of EVs, and well-established and developed public e-transport is required. Hence, there will be enough 2nd life batteries available. In the LH cities, e-buses have been in use for several years. During the past couple of years, the batteries of these buses have reached the end of their first life, thus been ready to take on the role of the 2nd life.

The integrated solutions belonging to the IRIS Transition Track #3, Smart e-Mobility, are considered valuable in Vaasa's IRIS replication plan, and in other mobility related projects done in Vaasa is recent years. These solutions are considered important factors to support Vaasa's strategy to achieve carbon neutrality by 2030. The IS, Innovative mobility services for the citizens, possesses the highest potential value, including Mobility as a Service concept, enhancing sustainable public transport and car sharing, and development of continuous mobility chains. Moreover, the development of cycling and walking infrastructure are part of MaaS concept in broader sense, although these ways of mobility are not part of IRIS replication plan.

Traffic consists of nearly 30% of Vaasa's current CO_2 emissions. This percentage will rise, since the share of CO_2 produced by energy production and consumption is decreasing due to mitigating actions taken and affecting in these sectors. In addition, a challenging factor in Vaasa is that private car ownership is very high, and the level of the public transport does not currently promote enough higher usage level of public transport. Thus, the public transport's effect on decreasing the carbon footprint from the traffic is not substantial enough.

In Vaasa, in order to decrease the emissions from the traffic drastically, significant changes should be made concerning the public transport. Possible measures are to increase the number of buses (e-buses or gas) in use. Additionally, new bus routes may be needed, e.g. to have more main routes, and these routes to be supported by feeder routes operating in the districts, connecting and collecting passengers for the main routes. Furthermore, the schedules of the routes should be efficient, based on reliable regularity, covering districts later in the evening hours and operating regularly and longer in the weekends as well. With measures such as these, the service level and usage of the public transport can be increased, the level of private car utilization can be decreased, the development of the MaaS concept can gain the robust basis it requires, and the emissions from the traffic can be lowered in Vaasa. Furthermore, an advanced MaaS concept can promote new services and businesses, citizens' satisfaction and well-being, and the City's attractiveness. The utilization of e-buses can also, in time, introduce the possibility of utilization of 2nd life batteries, for example in storage solutions for apartment buildings.

In addition, V2G solution's potential for Vaasa is notable. However, it requires higher national and local EV adoption at first, smart charging infrastructure and smart grid development, and pilot testing. Although, the level of EV adoption is lower in Finland than it is in the IRIS LH cities' countries, the annual number of sold EVs in Finland is growing steadily, hence increasing the nation's EV adoption strongly in the next 5-10 years. Utilization of solutions such as V2G and 2nd life batteries can really start to develop strongly and reach their true validity after that.

The City of Vaasa's IRIS replication plan has strong compatibility with the previous projects, plans and workshops done in Vaasa, i.e. MoveIT, BothniaTM and Sustainable Mobility Plan. Although, each of these projects approaches the themes of sustainable mobility and traffic emissions' reduction with an individual emphasis, a unifying message and goal can be found: promotion and enhancement of sustainable mobility, public transport, e-mobility, MaaS and car sharing. V2G and 2nd life battery solutions support these goals. Thus, a very adamant and clear aspiration exists in Vaasa concerning the development of mobility. The same aspiration is strong and visible in the City of Vaasa's replication plan's solutions, concerning Innovative mobility, V2G and 2nd life battery solutions.

To work with this study was a strong and rich learning experience and rewarding process. It required collecting and studying vast amounts of background data, which was found from numerous reports, articles and websites. However, the biggest learning experience took place when I was offered an opportunity to join The City of Vaasa's IRIS replication plans' task team in the October 2020. The work required collaborating with various stakeholders and experts linked to the project and being accepted to IRIS teams-meetings, webinars and correspondence with the Lighthouse and other follower cities about the progress and solutions of the replication plans. Additionally, I was able to obtain exceptionally deep, multi-level and privileged insight not only to Vaasa's replication plan process and the City's decarbonization goals, but also to the Horizon 2020 IRIS project as a whole.

This thesis leaves the door open for new studies about the actual IRIS replication activities done in Vaasa, whenever they will take place. For example, a targeted research about the development and measures concerning Mobility as a Service concept in Vaasa, or about the new Ravilaakso district have validity and importance for further studies. The Ravilaakso district, in its development and construction stage, and later on when it is finished, enables highly attractive research ground for new studies, varying from e-mobility, car sharing and smart charging to low-temperature heat networks, smart houses and citizen engagement.

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