



Feasibility of Innovative Smart Mobility Solutions: A Case Study for Vaasa

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Abstract: The global trend of urbanization and growing environmental awareness have risen concerns and demands to develop cities to become smarter. There is a grave need for ambitious sustainability strategies and projects, which can aid cities intelligently and comprehensively in this task. European Union (EU) launched 2014 the Horizon 2020 program (aka Horizon Europe), aiming to encourage the EU nations and their cities to take action to reach carbon neutrality through projects striving to smart city development. By promoting innovative, efficient, far-reaching, and replicable solutions, from the fields of smart energy production and consumption, traffic and mobility, digitalization and information communication technology, and citizen engagement, the objectives of the smart city strategies can be achieved. Horizon 2020 funded IRIS Smart Cities project was launched in 2017. One of the follower cities in the project has been the City of Vaasa in Finland. Vaasa's climate objective is to reach carbon neutrality by 2030. In order to achieve this goal, the city has taken several decisive measures to enhance de-carbonization during recent years. One essential target for de-carbonization activities has been traffic and mobility. The primary purpose of the research conducted was to study the smart mobility, vehicle-to-grid (V2G), and second life battery solutions in the IRIS Smart Cities project, demonstrated first by the Lighthouse cities and then to be replicated in the City of Vaasa. The aim was to study which importance and prioritization these particular integrated solutions would receive in the City of Vaasa's replication plan led by the City of Vaasa's IRIS project task team of 12 experts, with the contribution of the key partners and stakeholders. Additionally, the aim was to study the potential of the integrated solutions in question to be eventually implemented in the Vaasa environment, and the benefit for the city's ultimate strategy to reach carbon neutrality by 2030. The secondary object was to study the solutions' compatibility with the IRIS lighthouse cities' demonstrations and gathered joined experiences concerning the smart and sustainable mobility and vehicle-to-grid solutions, and utilization of 2nd life batteries. The results of the research indicated, that the innovative smart mobility solutions, including vehicle-to-grid and second life battery schemes, are highly relevant not only to the IRIS Lighthouse cities, but they also present good potential for the City of Vaasa in the long run, being compatible with the city's climate and de-carbonization goals.

Keywords: smart city; smart mobility; sustainability; second life battery; vehicle-to-grid; replication plan



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1. 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 (CO₂) 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.

Consequently, 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 (aka Horizon Europe), aiming to encourage the EU nations and their cities to take action to reach carbon neutrality through projects striving to smart city development. Once initiated, the Horizon 2020 program became the Europe 2020 strategy's flagship initiative with €77 billion budget. It is the biggest research and innovation program in the history of the EU, being the main instrument and setting the framework to enable the implementation of the EU's research and innovation undertaking.

Over the years 2014–2020, 17 different smart city projects received funding and were launched. Each project, with duration of five years, was led by 2–3 Lighthouse cities (LH) from various EU countries, which were then joined by 4–6 follower cities (FC). All of the Horizon 2020 smart city program's projects have shared similar goals, although the solutions and measures to achieve them may have altered between the cities. The main objective of each project has been to battle climate change by innovative, efficient, far-reaching, and replicable integrated solutions, from the fields of smart energy production and consumption, traffic and mobility, information communication technology (ICT), and citizen engagement. Each project's Lighthouse cities have been developing, testing and demonstrating various integrated, innovative, and market-orientable smart city solutions in the fields of sustainability, smart energy, and smart mobility. The LH cities have been acting as role models for the follower cities, which are obligated to replicate the LH cities' demonstrations. The follower cities are not expected to replicate every smart city solution demonstrated by the LH cities, since the variety of integrated solutions is vast. Eventually, each city's choice of selection of replicable integrated solutions depends on a city's ambitions, characteristics, geographical location, technological level, resources, administration, culture, and set goals and strategies in sustainability, smart city development and economic growth [1–6].

Although the Horizon 2020 program came to its initial end in the end of 2020, its funded projects have been carrying on their smart city strategies and development, and the Horizon 2020's legacy is fostered for the next decade and beyond. Horizon Europe continues Horizon 2020's work on smart city development. It is of highest importance for Horizon Europe, that each of its funded smart city project and all of the cities involved, continue to evolve towards ever smarter and more sustainable cities in the future, and while doing so, inspire other cities to follow their example of sustainability and low-carbon development [1,2,4,7].

Horizon 2020 funded IRIS Smart Cities project (*Integrated and Replicable solutions for co-creation in Sustainable cities*) was launched in 2017. The project's Lighthouse cities have been Gothenburg (Sweden), Nice Cote d'Azur (France), and Utrecht (The Netherlands). These cities have been acting as living laboratories for demonstrations, integrations and implementations of innovative energy efficient areas, flexible smart energy solutions and applications, as well as incrementing the utilization of renewable energy sources (RES) and smart energy storage solutions (ESS). Additionally, the LH cities have been striving for intelligent utilization 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, the LH cities have been cooperating actively with the follower cities. The FCs of the IRIS project are Alexandroupolis (Greece), Focsani (Romania), Santa Cruz de Tenerife (Spain), and Vaasa (Finland) [8–11].

The IRIS project consists of five Transitions Tracks (TT), which all include various integrated smart city solutions (IS). Once a Lighthouse city has successfully demonstrated an activity of an innovative smart city solution in their environment, a follower city is then

better able to create a *replication plan* for the integrated solutions they have chosen, and determine the schedule, resources, and partners for successful implementation [10,12,13].

The five IRIS project's transition tracks and the included integrated solutions are [10,12,13]:

Transition Track #1:

Smart Renewables and Closed-loop Energy Positive Districts:

- IS 1.1 Positive energy buildings
- IS 1.2 Near zero energy retrofit district
- IS 1.3 Symbiotic waste heat networks

Transition Track #2:

Smart Energy Management and Storage for Grid Flexibility:

- IS 2.1 Flexible electricity grid networks
- IS 2.2 Smart multi-sourced low temperature heat networks with innovative storage solutions
- IS 2.3 Utilizing 2nd life batteries for smart large-scale storage schemes

Transition Track #3:

Smart e-Mobility Sector:

- IS 3.1 Smart solar V2G EVs charging
- IS 3.2 Innovative mobility services for the citizens

Transition Track #4:

City Innovation Platform (CIP) Use Cases:

- IS 4.1 Services for urban monitoring
- IS 4.2 Services for city management and planning
- IS 4.3 Services for mobility
- IS 4.4 Services for grid flexibility

Transition Track #5:

Citizen Engagement & Co-creation:

- IS 5.1 Co-creating the energy transition in your everyday environment
- IS 5.2 Participating city modelling
- IS 5.3 Living labs
- IS 5.4 Apps and interfaces for energy efficient behavior

Vaasa is a medium size city on the west coast of Finland. Approximately 68,000 inhabitants live in the City's region, and 120,000 in total with its sub-regions. Vaasa is known as the Nordic Energy Capital, due to its unique and vigorous Energy Vaasa Cluster. The annual business turnover of the companies belonging to the Cluster, is around €5 billion euros. The export rate of Energy Vaasa Cluster is over 80%, representing 30% of Finland's total energy-technology export value.

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 to enhance de-carbonization during the past decade. Vaasa 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 by the city, the University of Vaasa and independent research companies.

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, and thus they have been prioritized. Additionally, concerning some of the prioritized 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 [14].

The IRIS projects' Transition Track #2 and #3 consist of solutions concerning innovative mobility services for the citizens, vehicle-to-grid technology, and utilizing second life (2nd

life) batteries in large-scale storage schemes. The conducted study concentrated on these solutions, which are of high importance for the IRIS LH cities smart city development. The aim was to study which importance and prioritization these particular integrated solutions would receive in the City of Vaasa's replication plan led by the City of Vaasa's IRIS project task team of 12 experts, with the contribution of the key partners and stakeholders. These integrated solutions are 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 2nd life batteries have also potential and significance, however, more in the future perspective, due to the relatively low adoption level of electric vehicles (EV) in the Vaasa region and under-developed EV charging infrastructure [14].

2. Literature Review: Smart Cities

Currently, more than 50% of the world's population is concentrated in large cities, or in their close proximity. It has been estimated, that by 2050 the amount of people living in these mega cities has risen by additional 20%. Urbanization is a global megatrend, which has direct effects on the climate change, rising emission and pollution levels, as well as on the energy production, distribution and consumption. Additionally, urbanization bears direct impacts on urban infrastructure requirements, land use, residential and transport requirements, and sustainability on all of its levels: environmental, economic, social, and cultural [15,16].

The accelerated urbanization and growing environmental awareness have risen concerns and demands to develop cities to *become smarter*, with the ability to be constantly evolving. There is a grave need for ambitious sustainability strategies and projects, which can aid cities intelligently and comprehensively in this task. 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 objectives of the strategies can be achieved [5,6].

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 and planning of infrastructure and transport design. A smart city strives for implementation of green and innovative technical solutions, leading to savings in costs and energy, and promoting better service delivery [5,6,13].

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 and cultural sustainability levels are functioning properly. Thus, cost reductions, higher stability and security, and enhancement of quality of life can be achieved [13,15,17].

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 promoting sustainable mobility solutions, smart charging and innovative 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. Indeed, local level citizen engagement has a paramount role in any smart city development strategy. 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 [5,6,17].

2.1. 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 the deployment of the 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 to advance information management and decision-making. Ultimately, the goal is more sustainable and well-functioning urban surroundings, with the ability to provide better QoL to the citizens by efficient, secure, and sustainable mobility, energy technology, digitalization, and ICT solutions. Smart transport, including individual mobility and public transport, seeks to support and exploit new ways of, e.g., e-mobility systems, self-driving vehicles (not part of the IRIS project), continuous mobility chains and mobility services, which are not only efficient and user-friendly, but cost-effective as well [18–21].

Private and public transport's transition from internal combustion engine (IC) vehicles to electric, gas and/or bio fuel vehicles helps to decrease fossil fuel consumption, hence aiding to achieve carbon neutrality in smart cities. Transmission from private car ownership towards car sharing, self-driving vehicles, and enhanced smart public transport services and increased connectivity, result in more sustainable transport in general, with decreased traffic volume and emission levels, being optimized to meet the demands and requirements of inter-modality. Smart public transport systems are highly flexible, providing consumers more versatility in transport modes, routes, schedules, service providers and payment systems [20,21].

Utilization of advanced EV technology and related solutions, e.g., smart charging and V2G schemes, with option of combining RES and ESS, 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 be decreased, congestions be mitigated, and time used in travelling reduced. Additionally, the safety factors of traffic can be enhanced, and pollution and noise levels mitigated. 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 [18,19,21,22].

2.2. Smart Charging

The fast rising number of EVs require wider, reliable and more comprehensive charging infrastructure. As the number of EVs increases, the potential impacts of EV fleets 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 can cause disruption to the stability of the whole power system. The rising demand of electricity requires enhanced control of distribution management system (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 [23–26].

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 50 kW 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 still very high. Once operational and widely available, it has the potential to revolutionize the whole transportation system in smart cities [23,26].

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 [27,28].
- 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 of the area in question.
- 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 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 [27,28].
- Bidirectional Vehicle-to-grid (V2G): With V2G solution, an EV 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, an EV's battery 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 transmission system operator (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 [24,27,28].

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 CO₂ 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 have already been purchased for the EVs' preliminary use [24,25,29].

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. 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 all parties involved: the electricity system operators (SO), aggregators, electricity retailers, and the EV owners [24,25,29].

2.3. 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", i.e., 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. Finding a "second life" for the used EV batteries is receiving wide attention globally. EV batteries' 2nd life could benefit the batteries' manufacturers, user and potentially create new businesses and revenue streams. Thus, granting a battery a 2nd would have positive environmental and economic effects. As transportation steadily transforms from IC powered vehicles to EVs, the number of lithium-ion batteries in and out of use rises considerably [30,31].

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. Hence, three end-of-life options exist: disposal, recycling or continuance of utilization in a less demanding battery application, i.e., gaining 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 still more expensive to recycle a battery than it is to mine new lithium. Because reclaiming lithium is costly, less than 10% of all used EV batteries' lithium is recycled, and vast amount is 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 fully [32,33].

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 somewhere between 3.6–17.6 GWh. Some sources estimate this amount to be even as high as 200 GMh. In 2063, the amount could be five times that. This development will have a descending reflection on new lithium-ion battery prices, which are already declining due to their own market development, caused by the rising number of EVs sold worldwide. 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 challenges [33–35].

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. They can also be exploited to operate interconnected with PV as storage use in microgrid purposes for various premises, municipalities and neighborhoods, or even in small town scale. 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. Additionally, they can function as electrical appliances for water and living-space heating, and as a reserve storage in the case of localized blackouts. 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 [36–39].

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. They 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. Moreover, they can have a significant part in maintaining utilities power reliability at lower cost, than what would be possible with new battery storage units [30,38,40].

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, bikes, and even ferries. Additionally, second life batteries can be used to form a basis of vehicle leasing businesses, such as tax services and delivery firms [36–38,41].

2.4. Mobility as a Service (MaaS)

Concerns over urbanization and climate change, increased environmental awareness, and latest advancements in digitalization, vehicle, internet, and ICT, 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 [42,43].

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, self-driving vehicles 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 [42–45].

Successful and well-functioning MaaS does more than just develop 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 [46,47].

3. Materials and Methods: Transition Track #2 and #3 Activities in the IRIS Lighthouse Cities

One of the IRIS LH cities' goals 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 in EVs' charging, V2G, and ESS solutions, including 2nd life batteries, play significant role in the IRIS LH cities' demonstrations [11,48].

The IRIS project's Transition Track (TT) #2, Smart Energy Management and Storage for Grid Flexibility includes three integrated solutions (IS) that can be demonstrated by the LH cities and replicated by the FC. The IRIS LH cities demonstrations and results on TT #2's third IS, utilizing 2nd life batteries for smart large-scale storage schemes, were examined in the study from the LH cities various demonstration deliverables/reports by meticulous qualitative analysis used as a research method. Additionally, TT #3's Smart e-Mobility Sector, containing integrated solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens were studied. Both of these solutions have a significant importance in the LH cities demonstrations and deliverables, thus reflecting greatly on the City of Vaasa's replication plan.

The later TT, #3, consists of 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 and car sharing services [11,48].

4. Results

4.1. Gothenburg, Sweden—Transition Track #2: Utilizing 2nd Life Batteries for Smart Large Scale Storage Schemes

- Demonstration and study of a 350 V DC building microgrid utilizing 140 kW rooftop PV installations with a 200 kWh 2nd battery storage:

Gothenburg's Akademiska building, took part in the IRIS project by demonstrating how DC system is able to provide advantages when local microgrid level electricity is produced with solar panels and stored in 2nd life battery system. The study 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. The DC system provided secure supply and enhanced energy efficiency [49,50].

Gothenburg's demonstrations and results on Utilizing 2nd life batteries for smart large-scale storage schemes, indicated both matters of potential and challenging aspects, as clarified in Table 1.

Table 1. Matters of potential and challenging aspects of Gothenburg’s demonstration of the solution, Utilizing 2nd life batteries for smart large-scale storage schemes [49,50].

Matters of Potential	Challenges
Sweden possesses a strong unified political determination about the swift reduction of CO ₂ and GHG emissions. 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.
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.	Issues concerning the collection, storing and ownership or the received data, and financial profit from the 2nd life battery solutions need further investigation.
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.	Fire safety regulations have to be examined and secured, concerning 2nd life battery utilization in building applications.

4.2. Gothenburg, Sweden—Transition Track #3: Smart e-Mobility Sector

From the TT #3’s two integrated solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens, Gothenburg concentrated on the latter, since the city’s EV charging infrastructure and EV pool size was not yet comprehensive enough for large scale V2G solutions.

Gothenburg’s innovative smart mobility solution is called EC2B. This ongoing and developing MaaS model aims 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 chains. 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 providers to end-users is a precondition for EC2B. Gothenburg’s primary objective is to reduce CO₂ 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 in its high-performance e-bus fleet, and plans to encourage the EV adoption through developing charging infrastructure [50,51].

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 altogether familiar concept to public, thus 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 [50,51].

Gothenburg’s Smart e-Mobility demonstrations are:

- EC2B for tenants in Brf Viva demonstration area:

EC2B provided 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 was to enable an easy access service of continuous mobility chain in the city, regardless where end-users lived, worked or spent their leisure activities. In this demonstration, EC2B was implemented for the tenants of 132 apartments in Brf Viva building in Gothenburg, where no private car parking was available.

- 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. Thus, through offering attractive options for local

business travel and commuting, employees could be less dependent on driving their own cars to work or resorting to private cars on business trips [50,51].

Gothenburg's demonstrations and results, concerning the integrated solution of Innovative mobility services for the citizens, indicated both matters of potential and challenging aspects, as clarified in Table 2.

Table 2. Matters of potential and challenging aspects of Gothenburg's demonstrations of the solution, innovative mobility services for the citizens [50,51].

Matters of Potential	Challenges
The developing digitalization advances EC2B, e-mobility, and the required infrastructure.	MaaS is a new concept for consumers and service providers, which can cause challenges.
MaaS can aid in mitigating traffic in the city, thus reducing the need of parking places. Property developers/owners can cut costs on parking places, improve their real estates' value, or develop their land use.	To find a business model, which would work for all the parties involved in the MaaS solution is challenging. Lucrative financial end-result for all parties requires collaborated and well-planned service.
MaaS can enable new business models, opens new revenue streams and create new jobs.	Private car ownership and clinging attitudes for the issue, require time and patience to change. Citizen engagement and functioning EC2B MaaS model are required.
More and more people are concerned about the environment, and doing their part for sustainability and de-carbonization. EC2B enables an easy way to be environmentally friendly.	
MaaS and alternative ways of mobility reduce individual costs, concerning car ownership.	

4.3. Nice, France—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. The 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 has been organized by various service providers. The demonstration has acted as a pilot for the electricity industry, serving as a model for further development and replications [52–54].

- 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 battery energy storage solutions (BESS) for similar applications within the building sector. Both battery types, 1st life BESS of EVs via V2G charging poles and a 2nd life BESS stack, have 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. Part of the buildings' energy efficiency strategies have included the utilization of 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, have provided encouraging results both from Palazzo Meridia and IMREDD [52–54].

Nice's demonstrations and results, concerning the integrated solution of utilization of 2nd life batteries for smart large scale storage schemes, indicated both matters of potential and challenging aspects, as clarified in Table 3.

Table 3. Matters of potential and challenging aspects of nice’s demonstrations of the solution, utilizing 2nd life batteries for smart large-scale storage schemes [52–54].

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, utilization of 2nd life batteries requires further research and testing.
Several EU driven policies and the French law promote advancement of decentralized energy systems and increased utilization of RES and BESS, including 2nd life battery utilization.	Fully operating V2G model is not currently possible 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, also limiting 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.
There is high potential and anticipation for various new business models and markets, concerning RES, BESS, and V2G.	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.
RES, BESS, and EV technologies utilization aid in de-carbonization, raising energy efficiency and in grid flexibility.	

4.4. Nice, France—Transition Track #3: Smart e-Mobility Sector

- Smart solar V2G EVs charging:

This ongoing IS relies in strong smart charging infrastructure development in the demonstration areas. 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) [52–54].

- 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 electric vehicle charging infrastructure (EVCI). This has resulted in higher utilization rate of the shared EVs, hence increasing the turnover received from the vehicles. Additionally, it has increased the efficiency ratio between the charging stations and the fleet of EVs available. 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 [52–54].

Nice’s demonstrations and results, concerning the integrated solutions of Smart solar V2G EVs charging, and Innovative mobility services for citizens, has indicated both matters of potential and challenging aspects, as clarified in Table 4.

Table 4. Matters of potential and challenges of nice's demonstrations of the solutions, smart solar V2G EVs charging, and innovative mobility services for the citizens [52–54].

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.	Monitor 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 on mature level yet and need to be tested and developed further.
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 currently fully possible on the Public Distribution Grid, only when operating behind private property, and as defined by French grid code.
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.	Currently, the energy market design, and taxing of grid transport and distribution do not favor consumers becoming a prosumers.
Better and wider charging infrastructure network reduces the hindering factors for EVs' adoption.	User acceptance may prove to be challenging for shareable EVs, and for V2G solutions.
Carbon footprint and pollution reduction, lower noise levels. 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.	More incentives related to EV pricing, V2G schemes, and shared EVs operating issues, (e.g., prices, taxing, tariffs) are required to improve.
V2G operating model enables new business and revenue generation models.	

4.5. Utrecht, Netherlands—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 utilized 18 smart solar V2G charging stations for EVs in its demonstration district initially. The charging points were interconnected with PV-systems. These bi-directional charging stations provided the infrastructure both motivation and financial interest in integration of smart energy management. The demonstration was 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 2nd life batteries and receiving support by open ICT for interconnection and performance monitoring, providing information services for aggregators, grid operators, municipality, and citizens could be achieved. The demonstration in the selected areas of Utrecht has been successful and developed further [55–57].

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

The City of Utrecht has been utilizing 10 smart solar/wind V2G charging stations for e-buses in the demonstration district of Westraven. The e-bus charging stations have provided valuable monitoring and research data on how e-bus charging powers can be connected to the grid most optimally.

- Stationary storage in apartment buildings:

The City of Utrecht has been demonstrating district-wide additional stationary storage in 12 apartment buildings. The storage has consisted of 2nd life batteries, being interconnected to primary V2G-storage and PV-systems by ICT. The 2nd life batteries have provided a significant contribution, by making the grid more stable and resilient.

- 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) [55–57].

Utrecht's demonstrations and results concerning the integrated solution of Utilizing 2nd life batteries for smart large-scale storage schemes, have indicated both matters of potential and challenging aspects, as clarified in Table 5.

Table 5. Matters of potential and challenges of Utrecht's demonstrations of the solution, utilizing 2nd life batteries for smart-large scale storage schemes [55–57].

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 fully economically viable yet.
Longer life for EV batteries, with their first and 2nd life, will decrease the price of new batteries.	More knowledge and research are required about the utilization of 2nd life batteries, potential solutions, and monitoring tactics.
Circular economy is a priority matter for the EU, thus 2nd life battery utilization is vital.	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 and 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.

4.6. Utrecht, Netherlands—Transition Track #3: Smart e-Mobility Sector

- V2G EVs:

Utrecht's ongoing car sharing system *We Drive Solar* was initially demonstrated in the city's demonstration district. Fourteen solar powered V2G EVs were 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 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.

- V2G e-buses:

The City of Utrecht have been utilizing 10 smart solar V2G e-buses. The e-buses and their charging stations will continue providing sustainable mobility mode 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 [35].

Utrecht's demonstrations and results concerning the integrated solutions of Smart solar V2G EVs charging, and Innovative mobility services for the citizens, have indicated both matters of potential and challenging aspects, as clarified in Table 6.

Table 6. Matters of potential and challenges of Utrecht’s demonstrations of the solutions, Smart solar V2G EVs charging, and Innovative mobility services for the citizens [55–57].

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. Utilizing public transport or car sharing versus car ownership, raise challenges.
Car sharing enables the City of Utrecht to develop low-traffic districts. The city 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.	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 from levels of lower income and education.
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. 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.

4.7. Results: Transition Track #2 and #3 in Vaasa

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 °C 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 [46,47].

The Government of Finland has set decisive national goals to reduce traffic caused emissions by 50% by 2030 from the 2005 level. 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 source vehicles’ (i.e., EVs) share compared to IC powered vehicles [46,47,58].

The Finnish transport system needs to go through transformation by inventing new services and ways of mobility, and by utilizing digitalization and ICT. This includes introducing MaaS concepts, 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, thus being able to reach the national goals [47,59,60].

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, cycling, public transport) trips out of all ground travel trips is 15%, and from ground travelling in general 37% [58].

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 advancement. The transition process to reach carbon neutrality by 2030 requires fast and decisive measures from the city, organizations, and institutions. Hence, innovations, research and development, new business concepts, and collaboration between key stakeholders are required.

Substantial cut downs to the emissions caused by the traffic, present 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 their 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 [59,61–65].

Traffic consists of 30% of all the CO₂ emissions in Vaasa, and is planned to be reduced by 90% by 2030 according to the city's de-carbonization strategy. Hence, the development and utilization of public transport needs to be improved considerably, with heavier investments in sustainable bus alternatives-electric and/or 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 [59,61,66].

4.7.1. Utilizing 2nd Life Batteries for Smart Large-Scale Storage Schemes

Currently, there are no energy storage solutions in Vaasa applying 2nd life batteries. While applications 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 relatively low level of adoption of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in Vaasa, and in Finland in general. In the end of 2020, there were approximately 46,000 PHEVs and approximately 10,000 BEVs in use in Finland. On the national level, the adoption of hybrid electric vehicles (HEVs) 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 to be utilized in traffic. 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 concepts. In addition, the scarceness of smart charging, charging infrastructure in larger scale, 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 [14].

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 Table 7 [14].

Table 7. The matters of potential and challenges of utilizing 2nd life batteries in Vaasa.

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.	Market situation and 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.
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 raises 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.	More regulatory framework is needed in the utilization and trade of 2nd life batteries, not only in national level but internationally as well.
There are several potential and researched ways of utilizing 2nd life batteries in storage purposes, e.g., in buildings, e-mobility, and MaaS, and for ancillary services for the local power grid.	
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.	

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

Transition Track #3's integrated solutions were studied based on their replication possibilities in Vaasa's new *Ravilaakso* district. The main stakeholders for the IS 3.1 Smart solar V2G EV charging, are the district system operator (DSO), being responsible for the technical infrastructure and services related to possible V2G solutions, with an undefined company/-ies providing the shared EVs, and the constructor companies responsible for building district's houses. 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.

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 service provider/-s [14].

4.7.3. Smart Solar V2G EVs Charging

V2G and Smart solar charging solutions are closely linked to TT #2 Smart Energy Management and Storage for Grid Flexibility, to its both IS 2.1, Flexible electricity grid networks, and IS 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 TT #4's IS 4.4, Services for grid flexibility.

The City of Vaasa has planned for the new carbon neutral district *Ravilaakso* a fleet of vehicles for sharable use. It has been calculated that a shared car can replace 8–20 personal cars depending on the case. In *Ravilaakso* the city of Vaasa has planned 2 sharable EVs per a city block, altogether approximately 20 shareable EV for the whole district.

Ravilaakso is a new residential area of 83 apartment buildings and 45 townhouses, which will be inhabited by approximately 2500 people. The district's construction is planned to start in the beginning of 2022. Once finished the total living area of the *Ravilaakso* district will be approximately 135,000 m². 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 in the planning of the energy and mobility solutions for the district [14].

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 Table 8), the planning of implementing the IS can continue [14].

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 utilizing 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 IRIS Transition Track 5's integrated solution 5.1, *Changing everyday energy use*, which concentrates on citizen engagement, and affecting to individuals' energy behavior.

EVs and MaaS 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 [14].

Table 8. The matters of potential and challenges of utilizing V2G schemes in Vaasa.

Matters 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 is in full extent.	In order to utilize EVs' batteries in the existing energy system, a new implementable and lucrative business models have 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.
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. End-user knowledge of V2G service, in its full potential and its requirements, can require time to adapt and increase.
The contribution EVs have to the reduction of air-pollution might convince citizens to favor the adoption of e-mobility and shared transport modes, such as shared EVs.	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 operating model enables EVs to be utilized as distributed storage system for the grid, and in various ancillary services, providing more grid flexibility.	As the number of EVs increases, it is important that the charging activity and infrastructure are planned and managed intelligently, to avoid power peaks, and the need for additional power caused by charging.
V2G enables attractive mean for economical profitability, concerning the DSO, aggregators, service operators, and the EV owners.	More defined, detailed and well-constructed regulatory framework is required as V2G schemes become more current.

4.7.4. Innovative Mobility Services for the Citizens

Traffic is the second biggest source of CO₂ emissions in Vaasa, consisting of approximately 30% of emissions outside the trading sector. The other CO₂ sources are district heating 50%, consumer energy consumption 13%, agriculture 4%, and waste management 3%. To achieve a dramatic reduction of traffic related CO₂ emissions, various new methods of technology and emission mitigation are required. One of Vaasa's challenges concerning traffic is 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 to regular fuel 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 additionally purchased 12 biogas buses for the city's internal transport service. Additionally, new bus routes have been developed. Furthermore, citizens' opinions and wishes have been heard, e.g., through the city's webpage and previous projects [59,61,67].

Organizing a market based public transport in Finland is challenging, due to vast rural areas, 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 ICT system

monitoring on data, and the 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 transport plan. Well-planned and -executed public transport, increments in schedule, and efficient routing aid in the management of traffic congestion and attract the citizens of Vaasa to use public transport more. In addition, the aim to achieve carbon neutrality becomes more feasible [59,61].

Replication of LH city Gothenburg's VivaBf/EC2B demonstration is under more detailed scrutiny, in order to be utilized in Ravilaakso district. The EC2B's platform model could also be used in other district construction projects (indicated in Table 9), in the future [14].

Table 9. The matters of potential and challenges of Innovative mobility services for the citizens, in Vaasa.

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 which requires measures to be taken concerning traffic as well.	Curtailling 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 spaces 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 generate new business.	To stimulate citizens to change their habits of using private cars, and start actively promoting and utilizing car sharing system or public transport instead can be challenging.
Technology is already available. Can in itself advance V2G schemes.	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 economic 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.	Decision-making involves different stakeholders, public and private actors. To find common vision of goals and priorities may be challenging at times.
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 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. In Ravilaakso district, due to planned car sharing, fewer parking places are needed to be built than normally required by the building regulation, thus saving considerably in expenditures. On 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. The planning of Ravilaakso district's MaaS model involves several actors: end-users, various service providers, housing foundations, construction companies, different technical departments

from the city, DSO etc., aiming to develop high quality, attractive and sustainable mobility services [14,68].

4.7.5. Conclusions on Ambitions and Planning Concerning Activities for the T.T. #3 Smart e-Mobility Sector

The City of Vaasa's Sustainable Mobility Plan, conducted in 2019, approaches the activities described in the IRIS replication plan's TT #3, with wide perspective, including 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 to challenge.

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 chains [14].

5. Discussion

After the City of Vaasa has concluded its IRIS replication plan, the actual execution and further development of the integrated solutions, and the implementation of technologies, solutions, and services based on the LH cities demonstrations can start. This stage will require wide stakeholder involvement. Additionally, 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 are necessary.

When planning the replication activities of the TT #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 a paramount importance. Thus, the replication plan and future activities can become successful, and find congruence between the IRIS project's objectives and enhance the City of Vaasa's strategies, decision-making processes, and stakeholder engagement.

Figure 1 indicates that the joined positive experiences and results the LH cities all shared about the utilization possibilities of 2nd life batteries, consists mainly of environmental effects, RES and grid support possibilities, and new business opportunities. 2nd life batteries are considered to be a great asset in the future's smart grid operations, supporting 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 Figure 2, 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. Nevertheless, Vaasa is slightly more skeptical towards this IS.

Figure 3 indicates that the LH cities' positive experiences and results 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., as 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.

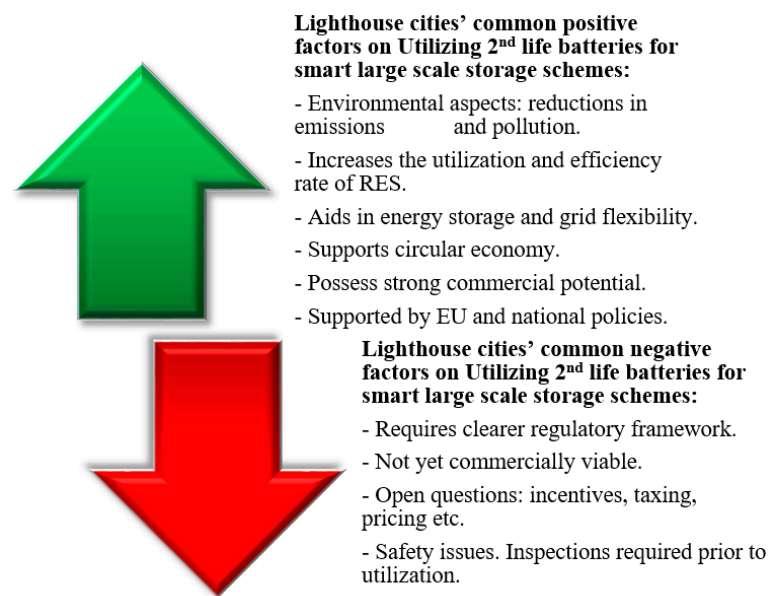


Figure 1. Lighthouse cities' common positive and negative factors on utilizing 2nd life batteries for large smart scale storage schemes.

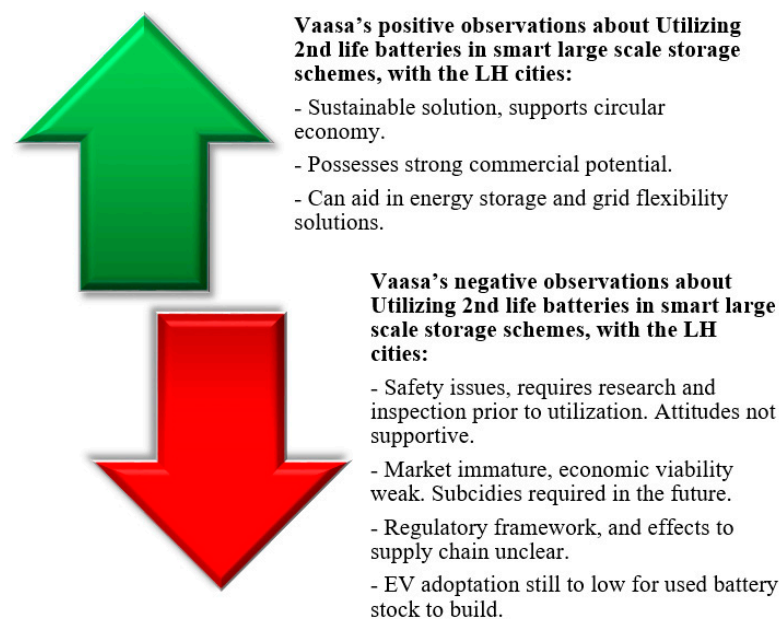


Figure 2. Vaasa's positive and negative similarities on utilizing 2nd life batteries for smart large-scale storage schemes with the LH cities.

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 Figure 4. 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 the LH cities, 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 them but also a great demand in wider scale.

In Vaasa and in Finland in general, EV adoption is still relatively low and wide EV charging infrastructure is scarce, although both factors 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 of MaaS and V2G schemes in particular.

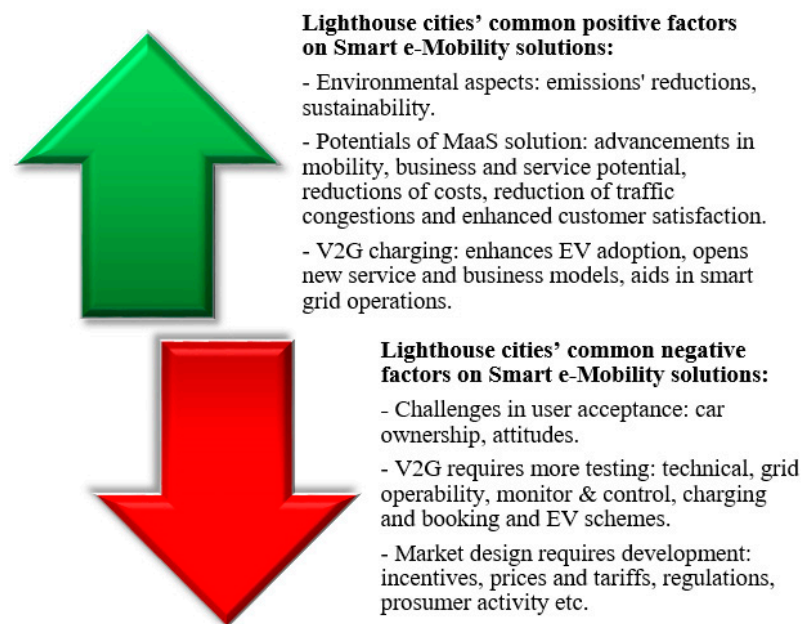


Figure 3. Lighthouse cities' common positive and negative factors on V2G and Smart e-Mobility solutions.

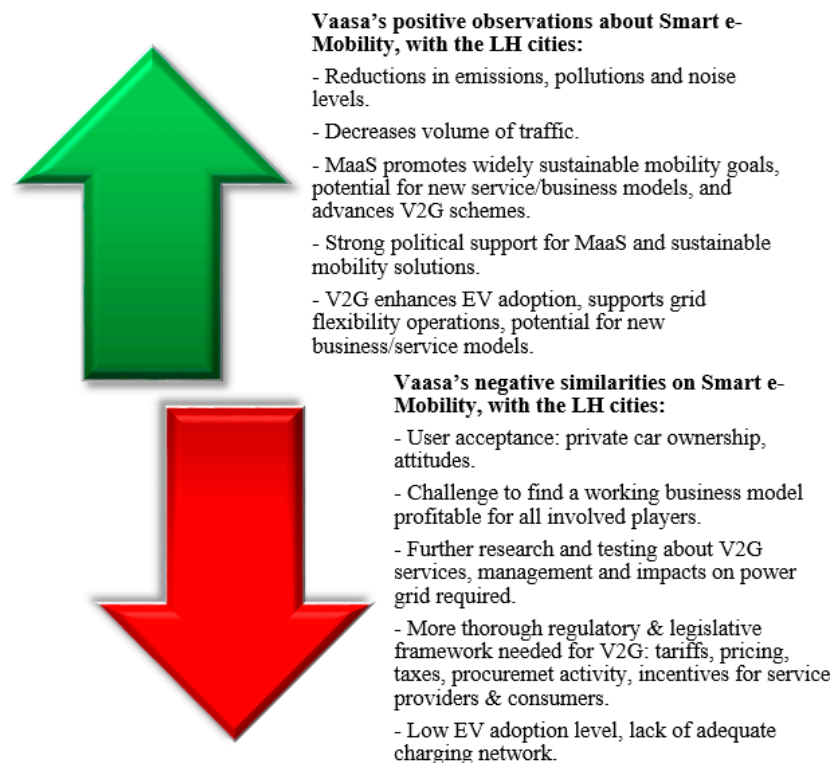


Figure 4. Vaasa's positive and negative observations about smart e-mobility with the lighthouse cities.

6. Conclusions

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.

IRIS Smart Cities project is composed of five Transitions Tracks, which all consist several different integrated solutions. IRIS' TT #3, Smart e-Mobility Sector, consists of two IS, 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, and the City of Vaasa's carbon neutrality plans, was the objective of the done research. Furthermore, the IRIS's TT #2 IS, utilizing 2nd life batteries for smart large scale storage schemes, was studied, since it is closely related to the TT #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, MaaS 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 to 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 in size and population, and located in countries 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 capable to adapt to the solutions' requirements presented in the research. 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. For example, in order to enhance V2G operating model, 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 for the applications, high enough adoption level of EVs and well-established and developed public e-transport are required. 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 IS belonging to the IRIS TT #3, Smart e-Mobility, are considered valuable in Vaasa's IRIS replication plan. 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 MaaS 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 were not directly part of IRIS replication plan.

Traffic consists of nearly 30% of Vaasa's current CO₂ emissions. This percentage will rise, since the share of CO₂ 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 well enough its higher user rate. 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, which is not the current situation. With measures such as these, the service level and usage of the public transport can be increased, the level of private car utilization decreased, the development of the MaaS concept can gain the robust basis it requires, and the emissions from the traffic can be lowered. In addition, it is worth to mention that public transport benefits from well-functioning car sharing system and vice versa. 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 currently 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 significantly 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.

This study leaves the door open for new studies about the actual IRIS replication activities done not only in Vaasa, but in other Lighthouse and Follower cities of the IRIS Smart Cities project. For Vaasa, targeted research about the development and measures concerning MaaS, or about the new Ravilaakso district's innovative mobility services, possess strong validity and importance.

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