Nantes | Hamburg | Helsinki

Ref. Ares(2019)7391705 - 01/12/2019

Deliverable due date: M36 – November 2019

D3.8 Development of new Mobility Services and Intermodality Strategies

WP3, Task 3.7

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

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

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Project Acronym	mySMARTLife	
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**	
Project Duration	1st December 2016 – 30th November 2021 (60 Months)	
Deliverable	D3.8 Development of new Mobility Services and Intermodality Strategies	
Diss. Level	PU	
Status		Working
		Draft
	■	Final
Due date	30/11/2019	
Work Package	WP3,Task 3.7 (Subtasks 3.7.3, 3.7.4 and 3.7.5)	
Lead beneficiary	HAW	
Contributing beneficiary(ies)	HAM, VHH, SNH	
Task description	According to the Grant Agreement this deliverable aims at the investigation on innovative mobility services and report on the intermodality strategies implemented in the demonstration area. D3.8 is related to the following task and subtasks: **Task 3.7: Sustainable Mobility and Electrical Mobility - SMART MOBILITY** In this task it will be managed the large up-take of electric buses, and several mobility systems in Hamburg, together with the monitoring of the charging infrastructures. **Subtask 3.7.2: Logistics microhub**. HAM will design and develop a pilot logistics microhub to reduce traffic and CO_2 emissions of parcel distribution on the “last mile” within urban areas. **Subtask 3.7.3: Community Car-sharing**. Car-sharing concepts utilizing e-cars will be developed and implemented by HAM together with VHH. To test the acceptance and interest of citizens for community car-sharing, the residential buildings will be provided with e-cars based on a sharing business model. **Subtask 3.7.4: Innovative mobility services**. The electrification of local bus lines with 10 e-buses as well as charging points for e-busses will be implemented. Locally produced wind energy will be used to charge electrical buses. **Subtask 3.7.5: Intermodality strategies**. In this subtask HAM will foster intermodal traffic and will deploy 25 e-cars and 5 e-bikes in the public fleet. A local multi-modal-hub, with car-sharing and bike-sharing services, will be electrified. New bicycle and pedestrian connections will complement this task together with charging infrastructure for e-cars that will be provided for residential quarters. 10 charging points will be implemented in zone 3. A master-slave-system with intelligent charging points will be implemented.	

Date	Version	Author	Comment
06.09.2019	0.1	HAW	Doc setup and 1st draft for ToC
27.09.2019	0.2	VHH	Add first draft of chapter 3.1,3.2
24.10.2019	0.3	SNH	Add first draft of chapter 4.1,4.2, 5.4

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28.10.2019	0.4	HAW	Add first draft of chapter 4.3
12.11.2019	0.5	HAM	Add first draft of chapter 5.1, 5.3
12.11.2019	0.6	SNH	Changes 4.1, 4.2, 5.2, 5.4
15.11.2019	0.7	VHH, SNH	Changes Chapter 3.1, 3.2
15.11.2019	0.8	HAM	Changes in Chapter 5, Changes Chapter 3
16.11.2019	0.9	HAW	Finalization chapter 4.3, 3.3
16.11.2019	0.10	HAW	Layout harmonisation overall
16.11.2019	0.11	HAM	First draw Chapter 3.4, 5.1, 5,3
19.11.2019	0.12	VHH	Changes Chapter 3.1, 3.2
20.11.2019	0.13	SNH	Finilazation and Translation 4.1, 4.2, 5.2, 5.4
18.11.2019	0.14	HAM	Changes Chapter 3.4, 5.1, 5.3
19.11.2019	0.15	HAM	First Draw Chapter 6
20.11.2019	0.16	HAW	Chapter 1,2 and 7 Conclusions
20.11.2019	0.17	HAW	send to Review
21.11.2019	0.18	HAW, SNH, VHH, HAM	Small Changes after audio conference
25.11.2019	0.19	HAW	Annex, References
25.11.2019	0.20	HAM	Finilazation Chapter 3.4, 5.1, 5.3, 6
26.11.2019	0.21	All	Implementation after Review from Cartif review
27.11.2019	0.22	HAW	Proof reading
28.11.2019	0.23	HAW	Submisssion to Cartif for final review
30.11.2019	1.0	CAR	Final check

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Abbreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
B2B	Business to Business
B2C	Business to Consumer
C2X	Consumer to X
CI	Charging infrastructure
CP	Charging point
CPO	Charging Point Operator
EMP	Electric Mobility Provider
FHH	Freie und Hansestadt Hamburg (free and hanseatic City of Hamburg
GUI	Graphical User Interface
HHVA	Hamburger Verkehrsanlagen GmbH
HPC	High Power Chargers
PV	Photovoltaics
RE	Renewable Energy
RFID	Radio Frequency Identification
SMS	Short message Service
SOC	State of Charge

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1. Executive Summary

This deliverable is structured by the sections Urban Strategies for electric mobility (Section 3), Expansion of the e-mobility charging infrastructure (Section 4), Further inter- and multimodality strategies (Section 5) and New Logistic solutions (Section 6). In these chapters, the subprojects are described in detail, summarised under the respective focal points. Section 7 summarises the findings and results of each sub-project.

Hamburg's urban strategies for the electrification of existing fleets consist of the electrification of public transport, a concept for the direct supply of wind power, as well as the electrification of the service vehicles of the municipal authorities. The players are the bus transport company VHH, the distribution network operator Stromnetz Hamburg (SNH), the University of Applied Sciences (HAW) and the City of Hamburg (HAM).

In this deliverable they will show what efforts have been made in detail. First the initial situations are described and which concept was built on it. When describing the implementation, not only opportunities but also obstacles and setbacks are addressed. The individual sections are concluded with the key findings of the individual activities.

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2. Introduction

2.1 Purpose and target group

This deliverable is allocated within Task 3.7, which evaluates the sustainable and electrical mobility. It deals with actions in local public transport such as the switch to e-buses (3.1) and the necessary load management (3.2) and in individual transport such as the development of charging infrastructure (4.1) and load management (4.2). Work is also underway to create a direct connection to the nearby wind farm for charging the e-busses (3.3). This not only has the potential to reduce energy costs, but also to significantly increase the share of renewable electricity in charging the e-buses. But the area between public and individual transport is also being worked on. For example, the fleet of the Bergedorf district office will be expanded to include e-cars (3.4), Hamburg's multi-modal hubs will be further electrified and incentives for car-sharing with e-cars will be created. In this way, the contributions to climate protection made by each and every one of us, as well as those made by local authorities, cities and companies, will be promoted.

The deliverable is aimed at cities and municipalities that want to electrify their public transport systems. It is aimed at network operators and companies who want to set up charging infrastructure and operate load management, as well as at interested parties who want to get to know new concepts and their implementation and background.

2.2 Contributions of partners

Verkehrsbetriebe Hamburg-Holstein GmbH (VHH)

is the second largest public transport provider in northern Germany located in Hamburg. The VHH connects the surrounding municipalities with the city centre of Hamburg, providing high quality bus services both in urban, suburban as well as rural areas. The VHH headquarter is located in the Borough of Bergedorf directly within the mySMARTLife project area and the company is committed to only procuring electric vehicles for the city of Hamburg from 2020 onwards. The VHH owns around 550 busses and employs over 1.600 employees from more than 60 nationalities. The busses are stationed in 12 depots around the outskirts of Hamburg and VHH services 154 lines providing transport to approx. 106 Mio. customers each year.

Hamburg (HAM)

is a State (Land) in the Federal Republic of Germany, with a population of 1.8 million, making it the second largest city in Germany and seventh largest in Europe. The combination of a history of progressive policies and ambitious climate protection goals led to Hamburg being awarded the title European Green Capital 2011.

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Stromnetz Hamburg GmbH (SNH)

is owner and operator of the electricity grid within Hamburg and the corresponding cables, overheadlines, transformators and substations. 13 billion kilowatt hours of electricity run through the electricity grid in Hamburg in order to supply 1.1 million private and commercial customers. SNH acts as the central municipal actor of the city and is responsible as the city's contractor for the coordination, procurement, installation, operation and maintenance of the charging devices installed by the city – manufacturer-neutral and free of discrimination.

Hamburg University of Applied Sciences (HAW Hamburg)

is one of the largest of its kind in Germany and within its four faculties offers a wide range of Bachelor's and Master's programs in engineering, IT, life sciences, design and media as well as business and social sciences.

Table 1: Contribution of partners

Participant short name	Contributions
HAW	Overall lead and development of main structure of the deliverable. Writing of 3.3, 4.3, Summary, Introduction, Conclusion
HAM	Contribution to sections 3.4, 5.1, 5.3, 0
SNH	Contribution to sections 4.1, 4.2, 5.2, 5.4
VHH	Contribution to section 3.1, 3.2

2.3 Relation to other activities in the Project

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D3.7	Simulation of impact on electricity grid and environment
D3.9	Parking Space detection

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3. Urban strategies for electric mobility

3.1 E-busses at VHH

3.1.1 Project description

VHH is one of two major bus companies providing transport services in and around Hamburg with a fleet of over 550 busses. The VHH headquarter depot with a capacity of approx. 140 busses is situated directly within the project area of Bergedorf. Public transportation is to be playing an important role in Bergedorf's modal split, thus, it needs to be further developed sustainably. Therefore, ten new electric busses were to be deployed in Bergedorf. Moreover, as a part of the future development, it is already planned to buy 34 additional e-busses at the end of 2020 and more in the following years. At the final stage of expansion 134 e-busses can be based in the VHH bus depot at Bergedorf. Recharging will be at the depot during the night within a maximum of 5 hours (see Section 3.2). Moreover, fast charging stations will be implemented at Bergedorf's bus depot with a new design of shared power modules between charging points. Charging will use renewable energy only (wind & solar, hydro and others).

3.1.2 Initial situation

In two prior e-bus projects, the VHH had gained some experience with both a plug-in charging system (midi busses by Rampini, deployed on line 488 in Blankenese in the west of Hamburg), as well as an opportunity charging system (articulated busses by VanHool to service Metroline 3 running directly through the city centre). The opportunity charging system proved difficult in combination with the 16 km long distance to cover between charging points and complicating a reliable service when busses got delayed in heavy city traffic. The busses also suffered technical problems related to cold temperatures and ultimately could not provide the performance hoped for. In comparison, the handling of the plug-in charging system was familiar to the drivers as diesel systems already require a plug-in for pre-conditioning and parking space detection at most depots already. The market for electric busses in 2016 was dominated by smaller manufacturers providing individual solutions rather than standardized interoperable systems. The ISO 15118 standard had only been published for the first time in 2014 while a German DIN standard was still used widely by manufacturers and many proprietary solutions exited simultaneously as the bus companies had not adapted their designs yet. Together with the second bus company in Hamburg, the Hochbahn, and the largest bus company in Germany BVG from Berlin a strategic partnership was created to exert pressure on manufacturers and form a unified initiative defining the major necessities for electric busses as needed in major city public transport services. The initiative has grown to include more than 15 public transport suppliers throughout Germany and knowledge sharing workshops are taking place approx. every 6 months.

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3.1.3 Concept and realization

Within the mySMARTLife project VHH set out to procure 10 electric busses. This was a significant step up from individually trialling electric busses and the first steps to a proper fleet introduction for e-busses. The demands of running a fleet of e-busses necessitated a more in-depth look at the energy requirements of a large fleet of electric busses, scrutiny of the processes of the operations and how they needed to be adapted for the new technology as well as clearly defining the specifications of the vehicles themselves. Many activities focused on the preparation of a continuous change towards emission free services and how this can be achieved for the entire company. The transition was forecasted lately with an increase in services requested by the city of Hamburg to grow the fleet to over 650 e-vehicles in 2030 with a possible ~800 e-busses by 2035 if trends persist. It is anticipated that the EU Clean Vehicle Directive will also change the client body demands from the communities surrounding the City of Hamburg from 2024 onwards similarly towards an outright emission free scale up.

Figure 1: Forecasted scale-up of emission free vehicles at VHH (grey for diesel, orange for electrics) [source: VHH]

The aim within the project was to both guarantee a high usability of the e-busses in operations through the largest possible range as well as preparing for a complete fleet roll-out. Interoperability of all systems also across other public transport providers especially within Hamburg as well as independence from the manufacturers to guarantee best results in future tenders was essential to the VHH focus.

The VHH, as a public company of the city of Hamburg, participates in the energy contract procured for all public entities of the city. This contract stipulates green energy from renewable sources such as wind, hydropower etc., which, in turn, ensures that the e-bus fleet can provide a sustainable transport service.

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3.1.4 Vehicle specifications

With the experiences of the past e-bus projects in mind, VHH analysed the feasibility of using overnight plug-in charging as an option for the entire fleet. One of the major draw backs of electric busses and particularly pronounced in this charging solution is the range in relation to the battery weight. After analysing the bus runs for the city of Hamburg regarding their length and energy consumption, it was found that 250 km range would cover 50% of all current runs without loss of efficiency. With this requirement in mind, the fleet could continue to develop until around 2025 by which time improved battery systems might be available on the market with longer ranges or other technologies such as hydrogen might be further developed and could be explored as an option.

Thus, the key requirement for VHH e-busses was set at 250 km of range to be guaranteed by the manufacturers. After an initial round of talks with various bus manufacturing companies this appeared to be mostly unavailable on the market in 2017, so, for the tender, the specification was lowered to demanding more than 200 km as guaranteed range with additional points awarded for longer guaranteed distances. The tender returned interest from 5 different manufacturers but resulted in only one company meeting specifications and offering most of the requirements. VHH decided to place the order with Sileo e-bus manufacturers for delivery in February 2018 and set out on further technical talks for detailing the specifics of the busses.

Requirements of the VHH in the tender centred mostly on standardised systems such as a non-proprietary charging system in alignment with ISO 15118 and OCPP protocols, CCS 2 connections above the front axle on both sides of the vehicle to account for the space saving block parking necessities as well as VDV (German transport association) specified driver work space. This would prove to be a major stumbling stone with the bus manufacturer as it required major changes to their existing design.

3.1.5 Inspections and deliveries

It was planned that by the middle of 2018 all e-busses would be delivered and the first would start to be put into regular customer services. Unfortunately, the manufacturer suffered some delays through a fire burning down the factory hall at their production site in Germany. This necessitated an outsourcing of part of their production back to Turkey where the main body company producing the chassis was located. Additionally, to meet the VHH specifications, major changes in the design of the vehicle were required changing the entire front of the bus to accommodate the VDV driver space. Another major challenge was to change the proprietary charging system to the new ISO 15118 standard. These specifications were laid out from the start in the tender documents by VHH and rated crucial to both safety and ensuring the future scalability of the VHH public e-bus fleet so that only very few compromises were possible to be negotiated to help the manufacturer meet their target.

The first solo bus was presented with 6 months delay in August 2018 for pre-inspection. VHH submitted a lengthy list of open points to the manufacturer and a recurring process of inspections and remedial work

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on the open points ensued. Overall the Sileo e-busses were submitted a total of 17 times to the VHH for inspection (10 times for the solo e-bus and 7 times for the articulated e-bus) but mostly the manufacturers efforts to fulfil safety and interoperability measures failed to meet requirements.

One difficulty proved to be the homologation of the vehicle which could not be achieved as an overall type certification within Germany but was produced as a one-off registration in Ireland. The implementation of ISO 15118 charging standards and important safety issues with the internal wirings were regarded as critical issues for the deployment of these busses and were part of the objections raised by VHH.

The continuous delays and quality issues were addressed several times with the manufacturer in high level management talks and the VHH first reduced the number of e-busses to be procured from Sileo from 10 to 4 e-busses later that year.

Also in 2018, a new tender process was started initially intended for a further 10 e-busses with 2019 delivery. Considering the difficulties with the Sileo e-busses and with the other market options in mind, the range requirement was reduced to a more conservative 150 km guarantee by the manufacturers and a further concession was made that only a right-hand charging inlet was required. The ISO standard at the time had not caught up with this requirement by fleet operators regarding inlets on both sides of the busses to facilitate block parking as a necessary space saving measure in the depots. The changes will have a small impact in slightly complicating their use in daily operations. This tender for a further 10 e-busses included an optional component of 10 e-busses which could be called upon as desired. The tender was awarded early in 2019 to Evobus. At this stage VHH also placed an order for the additional 6 e-busses to replace the Sileo reduction and ordered 16 e-busses overall.

In June 2019, a fire afflicting a Sileo solo e-bus after an accident in southern Germany grounded the entire Sileo fleet Germany wide. Even though the origin of the fire is still to be analysed, the VHH concluded that with more than 16 months delay on the delivery and unanswered questions regarding the technical specifications and safety of the e-busses to completely withdraw from the contract and pursue the new order from EvoBus with full attention.

Talks with EvoBus developed smoothly and they subsequently submitted the first 12m e-bus for pre-inspection at the manufacturing site at the end of September 2019. Special measures to integrate VHH communications technology still need to be implemented and a further 4 e-busses have been delivered to the EvoBus service center located in Hamburg for fitting out with VHH communications equipment at this stage. 2 e-busses are now constantly on site at Bergedorf since the start of November 2019 for training of the driver and workshop force. All e-busses still need to undergo extensive testing but with the aim to introduce them fully into customer service at the beginning of 2020.

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Figure 2: EvoBus delivered to VHH in October 2019 [source: VHH]

To bring the total number of e-busses in the depot up to 20 as originally planned for the end of 2019, the remaining 4 e-busses will be added to the order once testing is successful and hopefully these will arrive later in 2020. All 2019 e-busses from EvoBus will be 12m solo e-busses. Two further tenders were awarded by VHH early in 2019 with 17 solo e-busses to be delivered by MAN and 17 articulated e-busses by EvoBus both towards the end of 2020. Specifications for these e-busses were raised again to require 200 km range and charging inlets on both sides.

At the end of mySMARTLife project in 2021 VHH hopes to be running a fleet of 44 e-busses from Bergedorf.

3.1.6 Adaptation of processes and knowledge building

Having decided on an overnight plug-in charging system for the e-busses meant that consequently the cleaning process and daily service of the busses needed to be adapted. The understanding was that interrupting the charging process could be undesirable for the health of batteries and it represents a further complication in the charging plan for energy optimization purposes on the depot. Thus, a new routine was defined which splits the cleaning into dry and wet cleaning with the wet cleaning and refilling of liquids taking part only every two days now and the dry cleaning being undertaken outside in the parking area while the e-busses can remain connected and charging.

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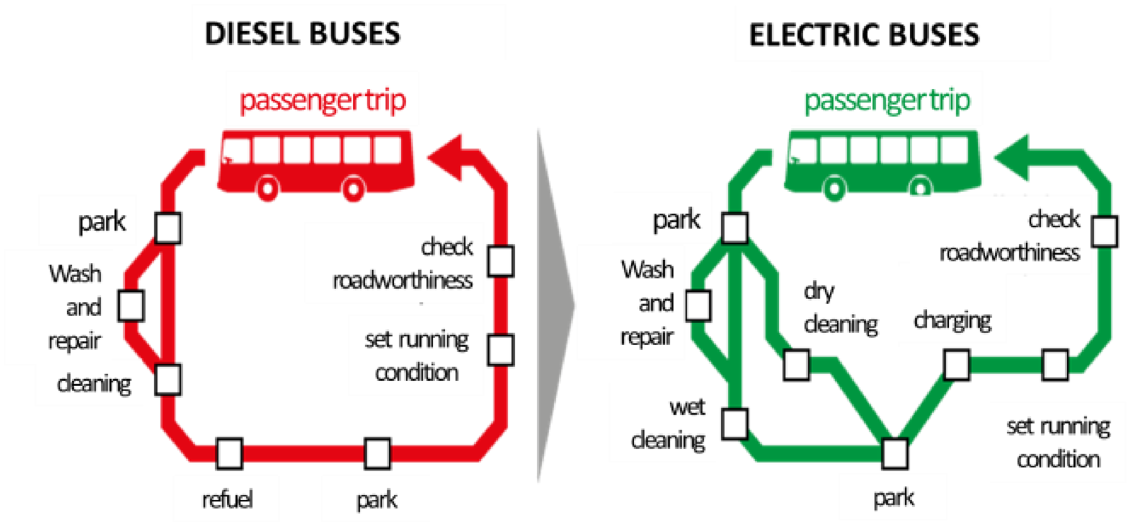

Figure 3: Process change for e-busses regarding services [source: VHH]

Further processes were identified in connection with the e-busses such as new personnel needed to look after charging points and diagnosis software to help them understand possible defects. The tools such as ITCS software, depot planning and route planning software or a load management for charging either needed new upgraded modules to account for e-bus needs or did not exist previously. The increased complexity added by the range restriction and charging time requires VHH to adapt the processes and evolve into a more digitalized company.

The workshop team in Bergedorf was successfully trained in High Voltage technology with high priority given to proper safety procedures. The new construction of the workshop was complemented with a second level work space to ensure proper access to the battery banks, which are commonly located on top of the e-busses as a roof installation. This type of fit out is not common in standard bus workshops and VHH has experienced a significant number of other public transport providers asking for advice on the implementation and coming for a site visit to help them with their own adaptation to e-mobility. The workshop was officially opened by the mayor of Hamburg in January 2019 underlining the importance of these significant efforts by the VHH to invest in a carbon neutral future.

Figure 4: Second level roof workshop space within the e-bus workshop at VHH [source: VHH]

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The training of the drivers in Bergedorf was initially intended for their annual module training in 2018 but due to the delivery delays was amended to an introduction and overview of the e-mobility activities at VHH. The decision was taken to produce short explanatory videos once the e-busses from EvoBus were delivered which could be useable in the future electrification of the teams at other depots and retain the information for reviewing at any point for the drivers. The videos will be available from the VHH members' app any time a driver would like to review and update themselves with some of them being made available to the public for general information purposes as well. As some of the videos require filming with the actual e-busses the videos are anticipated for final approval around the beginning of 2020.

3.1.7 Technological Readiness Level

The ambitious approach VHH took towards a fleet procurement aimed mostly at e-busses of a Technological Readiness Level 8 (TRL8: System complete and qualified). As shown in the description above, the conclusion within the mySMARTLife project and especially in conjunction with the first attempt at procurement, this was not available on the market. Currently VHH would rate the TRL at 7 (System/Prototype demonstration in operational environment. With the second procurement it is anticipated that an improvement will be noticeable and a significant move towards TRL 8 can be shown within the monitoring phase of the project.

3.1.8 Key findings

With the mySMARTLife project, the VHH has taken important steps in laying out the company road map towards a more sustainable form of public transport by successfully procuring a first fleet of 16 e-busses for the depot in Bergedorf. But it is anticipated that continuous efforts in adapting and digitalising the processes are needed to meet the challenges adapting to this innovative new technology. These efforts will be important in integrating the further 34 e-busses that have already been ordered and will continue to pave the way on the path of transition to a more sustainable public transport service.

- Changing from singular e-mobility projects to a full fleet scale-up produced increased quality requirements and the need to ensure the purchased technology would be compatible with all company locations, not just the project area, as well as needing to be compatible with any future procurements. A strategic analysis is very helpful for weighing up the different options.
- When settling on an overnight charging technology, range in km vs. battery weight is the defining technical challenge. For optimal operations an improvement in this area will be essential in the future scale-up of the e-bus fleet.
- In new innovations not all customer requirements will be met right from the start. E.g. the requirement for charging inlets on both sides of the e-busses had been overlooked entirely by suppliers. The need for pre-conditioning of the e-busses (heating or cooling before service start, location detection) in the depot is still open in the standardisation and therefore not implemented by all manufacturers.

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- Ambitious requirements and an unclear standards landscape (ISO15118 vs. DIN SPEC 70121) led to a reduced number of participants in the first tender. Unique local requirements hampered the successful participation in EU wide tenders further for manufacturers unaccustomed to the local association standards and the tendering process itself posed difficulties for some suppliers.
- The increased number of participants in the second tender is a positive indication that the technology is advancing, and suppliers are responding to the increased demand as well as developing their products further to meet the operator requirements.
- It will be important that the increased competition on the e-bus market will lead to a decrease in prices. Currently the high costs of electric busses compared to the diesel equivalent is a deterrent to deployment in a competitive market setting making grant programmes essential at these early stages of transitioning this innovative technology towards regular operations.
- The continued support of the client body authorities will be key to achieving a completely carbon neutral public transport service in the future
- For the bus operator, the strategic change towards sustainable e-mobility requires significant efforts well beyond training the drivers and work shop members. Almost all processes are affected and the efforts to involve all company members and departments and include them in the process are easily underestimated.
- Digitalisation can significantly support the efforts of adapting to e-mobility but itself requires a very demanding implementation process.

3.2 Charging Infrastructure for electric busses

3.2.1 Project description

The VHH as one of two transport service providers in the Hamburg metropolitan area operates from 12 depots circling the perimeter of Hamburg north of the Elbe and delivering a key connection for commuters from the surrounding communities into the city centre as well as their local services. The depots vary greatly in size from small capacity locations with approximately 20-25 busses to the largest depot reaching a top capacity of more than 160 busses currently. Due to a forecasted increase in demand in public transport for the city of Hamburg, as well as the need to change to more sustainable forms of transport as stipulated by the city, the depots need to be equipped to accommodate the fleet of e-busses. To support the deployment of the 10 electric busses (see section 3.1) from the headquarters depot located directly within the project area of Bergedorf, a corresponding charging infrastructure for overnight charging e-busses needed was be implemented for mySMARTLife. The analysis showed that mostly the time in the depot at night allowed a maximum of 5 hours for charging. Moreover, the stations needed to have fast charging of up to 150 kW at times to accommodate the runs at Bergedorf's bus depot. To reduce the

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investment in power modules a new design of shared modules between charging points was implemented. The charging will use renewable energy only to ensure sustainability.

3.2.2 Initial situation

In two prior e-bus projects, the VHH had gained some experience with both a plug-in charging system (midi busses by Rampini, deployed on line 488 in Blankenese in the west of Hamburg) as well as an opportunity charging system (articulated e-busses by VanHool to service Metroline 3 running directly through the city centre). The opportunity charging system presented high challenges during the implementation in the public space. Additionally, the transport network covered by VHH busses mostly supplies links going outward from the city centre to the surrounding municipalities which presents much fewer intersecting points. With more than 154 lines to service and many more end stations where charging points would ultimately be needed, the decision was taken to implement a completely depot-based over-night charging system instead. The Rampini system of plug-in charging had proven very reliable, but for just two smaller vehicles no special measures had been necessary to facilitate the charging connections within the depot. For a fleet of 10 full sized 12m and 18 m e-busses, this was going to be much more of a challenge. The depot at Bergedorf is located directly within the mySMARTLife project area and has a capacity to be expanded to 134 e-busses eventually with approximately 82 vehicles providing the daily service. No e-busses had been stationed here previously and no charging infrastructure existed. The depot is ideally located right next to the Bergedorf electric power transformation substation. The original power connection consisted of a simple 630 kVA compact transformation station supplying the needs of the work shop and administration buildings.

3.2.3 Concept and realization

At the start of the mySMARTLife project an analysis was undertaken which examined the length of all runs providing services from the Bergedorf depot. It estimated the energy consumption per km to predict that each night an approx. 32 MWh would be needed for the 82 busses deployed daily once all services were changed to e-busses. As not all busses leave and return simultaneously there was reason to assume that the charging could be distributed over a far longer period than the 5 hours per bus. It was assumed that power modules of 50 kW would be available and could be combined to reach a top charging power of 150 kW and with such a distribution the max peak load would be around 4.35 MW around 2 am at night.

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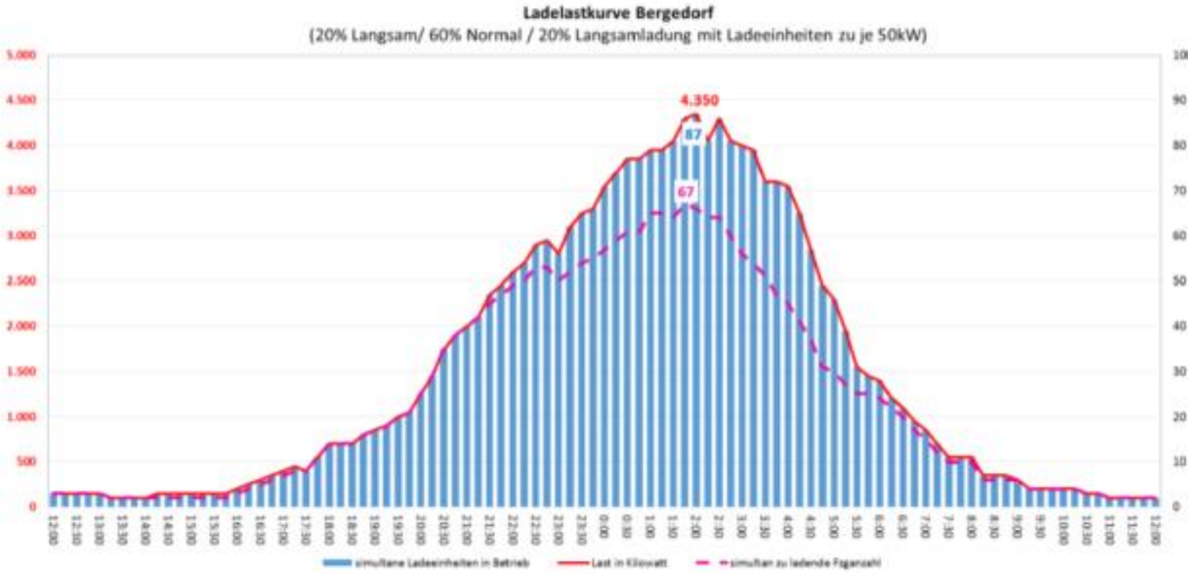

Figure 5: Load curve for Bergedorf depot, 67 busses charging simultaneously at peak time using 87 power modules of 50 kW each resulting in a forecasted 4,35 MW peak load [source: VHH]

Even the power demand of a smaller fleet of 10 e-vehicles was going to surpass the standard grid connection. Keeping future expansion in mind, the local depot grid was re-dimensioned completely to allow scaling up through successive installations of charging infrastructure until a fully electrified depot would be reached around 2030. The concept was to increase the grid connection to 5.5 MVA at the beginning and create a local area network of 10 kV distributing the power via two rings to safeguard against failure and increase the reliability of the overall system. To account for additional power demands for the workshop and administration as well as pre-conditioning of busses and in anticipation of hopefully increasing range for overnight charging e-busses, the ductwork for the cables was provided so that an increase in the grid connection to 11 MVA would be possible if needed and could be added later without the need for costly ground work again. Later up to 9 modular transformation stations could be added, each with the capacity to power smaller islands of up to 16 busses each. The tenders for these electrical installations were carried out and awarded towards the end of 2017. Simultaneously the specifications and tender for the charging points themselves was drawn up. The main aim was to procure charging infrastructure independent of any bus manufacturer that would allow any e-bus to charge. Concurrently to the e-bus specifications the infrastructure needed to use the ISO 15118 standard, OCPP communications protocols and CCS2 connections to provide interoperability.

3.2.4 Charging point specifications

The first and very noticeable challenge in creating the specifications for the charging infrastructure was the fact that no one had previously procured this type of charging infrastructure independently of the manufacturer before and no blue print requirements could be drawn upon. To alleviate this lack of expertise both a transport consulting company and Stromnetz Hamburg [SNH] were called upon to help

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detail the specifications. Besides including the important standards mentioned above, the focus was given to make less power modules work for more e-busses and requiring a flexible and modular system. Initially this was designed as a fully matrixed share of 4x 50 kW modules across three charging points in any possible combination. While a stack of power modules was generally used by manufacturers, the possibility of not allocating a full 150 kW per charging point each time but having less power overall and switching between the modules thus diverting spare energy to other points was an entirely new concept. SNH reviewed the documents and suggested that the complexity in the description could result in difficulties. One of their concerns was that this idea was so new and innovative to the market that it would force manufacturers to significantly deviate from their standard products and out of their comfort zone. The tender proved the SNH predictions to have been woefully prescient as the companies that had shown interest early in the process dropped out one by one which resulted in one final offer that, due to the high price and for lack of competition, could not be accepted; nor did it reflect the underlying idea of the matrix power switch. The necessity to review the specifications and start another EU tendering process meant the detailing of the transformation stations of the electric grid had to be delayed putting much of the infrastructure works on hold.

During the revision process of the specifications the adherence to a fully matrixed switch system was eased and substituted by a median use of power across groups of charging points. This allowed for more flexibility and gave room for different technical interpretation to the manufacturers. Like the rise in participation in the second e-bus tender, the new charging points tender attracted 4 serious offers with a variety of technical concepts, two of which were reflecting the nature of the shared power modules and in summer 2018 VHH awarded the Polish company EkoEnergetyka with the first contract for charging stations for the Bergedorf depot. The EkoEnergetyka charging technology would share 150 kW power between two charging points. One bus could draw the full 150 kW while the other charging point was not charging at all or two connected e-busses could charge with 75 kW each simultaneously.

With the tender successfully awarded, the detailing of the electrical connection to the areal grid could resume and a combined station was devised combining both the transformer as well as the inverter modules of EkoEnergetyka. This combined station would measure 2.5 m x 11.8 m thus taking up the equivalent space of one solo bus making the size entity easy to use in future depot planning.

During the time of the second tender and in a cooperation project between VHH, the Helmut-Schmidt-Universität Hamburg (HSU) and the second bus company in Hamburg the Hochbahn, it was scientifically analysed and shown by HSU that in a bus depot a curtailment of the available energy for charging could easily go up to c=0.68 before the energy supplied over time would fail to provide enough power for the transport services for the day. This proved the VHH hypothesis that sharing 150 kW between two points was more than sufficient for the e-bus depots.

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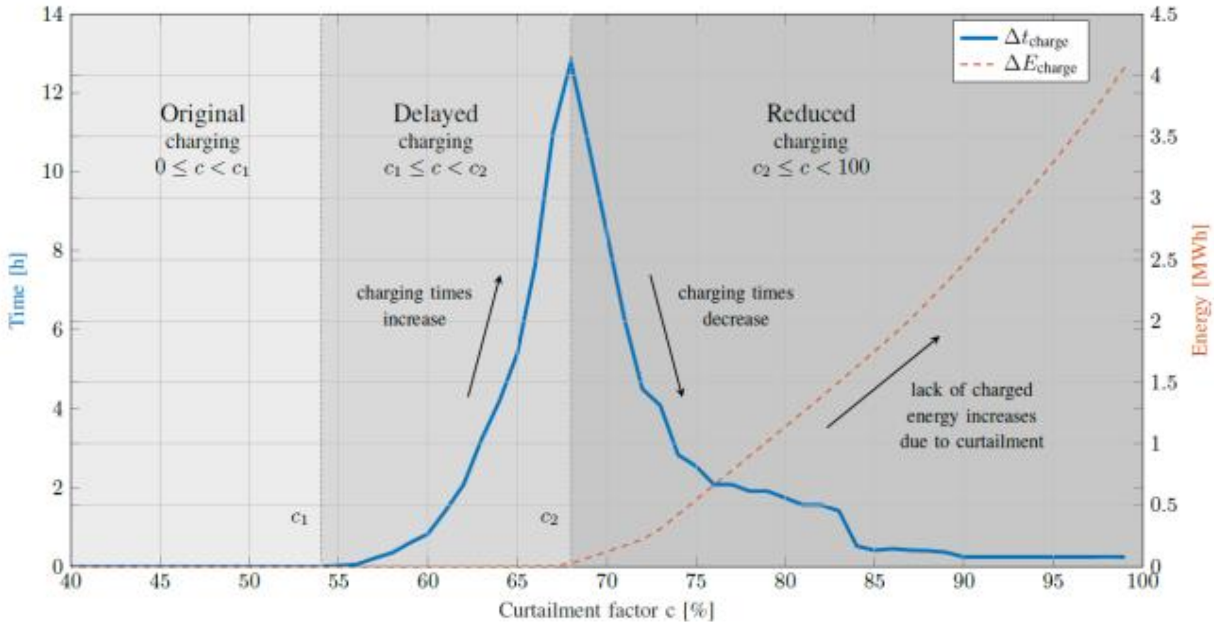

Figure 6: Bus depot BBD from Hochbahn, additional charging time and not charged energy for every bus in average over curtailment factor c; for every bus in average over curtailment factor c [source: "Evaluation of Modular Infrastructure Concepts for Large-Scaled Electric Bus Depots"; Laura Haffner, Marc Schumann, Detlef Schulz; Helmut-Schmidt-University Hamburg, Germany 2018]

In accordance with the EkoEnergetyka, setup of 150 kW power sharable between two charging points, the overall power provided by the transformation station needs to be 1200 kW and the transformer was specified to 1600 kVA. Some additional changes needed to be made to allow for the integration of the battery storage container from MAN. EkoEnergetyka submitted their inverter station and charging points for pre-inspection in February 2019 and the installation of the combined station took place in April 2019 with delivery of the battery storage following shortly in May 2019. Subsequently, the cables were installed for the charging points and the satellite connectors set up in the block parking area in the depot which was concluded in July 2019.

Figure 7: Battery storage container on the left, combined transformer and inverter station on the right [source: VHH]

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The charging infrastructure had now not only caught up to the timeline of the e-busses but was running ahead with the first EvoBus delivery not expected for another 2 or 3 months. Luckily, the second transport provider Hochbahn had purchased busses from both EvoBus as well as Solaris and provided a great opportunity for both running an early acceptance test on the charging points as well as a first true test of interoperability. The interface between e-bus and charging infrastructure could be monitored by a service provider company called Verisco who was invaluable in ironing out the first difficulties in communication regarding ISO 15118 standard. The standard includes some plug & charge options and is set up to check for certificates on the e-bus. This same certificate needs to be present and understood by the charging infrastructure and was swiftly implemented by EkoEnergetyka. It was also determined that the Solaris bus did in fact not follow the ISO 15118 protocol but utilised the old DIN SPEC 70121. The charging points however had no difficulty also accepting this type of communication. It brings up some questions how to ensure proper communication standards are adhered to, especially when in the future wider interoperability and true plug & charge capabilities will be integrated into underlying systems such as the load management and pre-conditioning controls.

The future challenge for VHH will be to maximise the usefulness of the shared charging infrastructure and a specialised load and charging management system is planned to be implemented soon. Stromnetz Hamburg GmbH (SNH) has been very supportive from the start and a decision was made early on by VHH to also use the SNH back-end solution, which runs on all public charging infrastructure points. This provides very positive synergies for the city of Hamburg and a bilateral project between SNH and VHH aims to develop the needed charging management system based on the load management already successfully implemented in the mySMARTLife (Action 30) at Kampweg for the local public authority fleet.

Figure 8: double charging points at VHH depot Bergedorf with 12m EvoBus connected for a first charge test [source: VHH]

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3.2.5 Adaptation of processes and knowledge building

VHH as a transport provider is focused exclusively on bus transport. Therefore, it was quickly apparent during the charging infrastructure project that no knowledge was present in the company from colleagues in the electrically powered transport fields such as underground or tram business. While drawing upon external expertise at the start was both useful and enlightening, the need to invest in personnel on the premise soon became clear. Not only will the transition towards e-mobility in the next years necessitate the development of more charging infrastructure at all depots; the charging infrastructure is an integral part of the sustainable transport service and the reliability of the system will directly influence the ability of the operator to provide the service. Thus, ensuring that responsible personnel are available and keeping the infrastructure in perfect running order is essential to the future business.

The aim for VHH is still to remain a lean company with many of the service specifics of the electrical equipment detailed in service agreements with manufacturers or other professional providers. But this type of infrastructure also stipulates that the operator must have a dedicated responsible person with electrical qualification on site to ensure safety and proper handling. Consequently, VHH has invested in the future of their operations and created a new team highly motivated professionals now taking on the new challenges and defining the processes connected to the charging operations.

3.2.6 Technological Readiness Level

In the mySMARTLife project VHH aimed at demonstrating that the e-bus and charging systems could be independently procured from each other. This inherently requires the system to have a technological readiness level beyond 7 (prototype) as interoperability of systems can only function based on standards that both parties adhere to.

A true evaluation of the charging infrastructure can not be made before extensive tests have been run with the e-busses. While anticipating some initial difficulties as can be expected in innovative projects, VHH is confident that during the monitoring phase of the next two years a TRL 8 can be achieved for the charging system.

3.2.7 Key findings

- To be able to develop a bus depot for e-mobility requires a forecast of predicted energy consumption of the stationed fleet as groundworks and all electrical equipment must be dimensioned correctly from the start to prevent costly changes during the later scale-up.
- The charging infrastructure proved to be a bigger challenge than the electric busses. As a bus operator there was reasonable experience in approaching bus specifications, quality checks etc. With the charging infrastructure and the electrical components there was very little previous experience available to be drawn upon especially for overnight charging depots; not only at VHH but overall in Europe.

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- The infrastructure consisted of various independently awarded tenders (grid connection point, ductwork and cables, transformer stations, inverter and charging points). This meant many intersecting areas and interfaces which caused an enormous amount of work in management and communication efforts.
- Maintenance and services of the new infrastructure will play in important roll in the reliability of the system and therefore to the ability of the operator to provide the transport services. The important efforts to define service levels and negotiate contracts should not be underestimated.
- To integrate the charging infrastructure fully into the operations and further optimize the available flexibility as well as controlling additional features such as load management and pre-conditioning the digitalisation of processes must be pursued further.
- The charging infrastructure for e-mobility requires a significant amount of space needed to be allocated per bus. This can cause major difficulties in certain depots and space in densely populated cities is already at a premium making this a stumbling stone in the scale up of this sustainable transport solution.

Along the road mapping out the VHH path towards more sustainable public transport the first successful implementation of 16 charging points and electrical infrastructure to support the new fleet of e-busses is an important milestone achieved through mySMARTLife. While first tests in real operational conditions are yet to come, the scale-up at the Bergedorf depot has already continued. A new combined station of transformer and inverters was delivered in November 2019 and installation of the16 charging points is already under way. The bigger challenge however will be further developing additional depots with more severe space constraints and finding new depot spaces to provide for the forecast increased demand in sustainable public transport within the city overall.

3.3 Green integrated Energy at VHH

3.3.1 Project background

The energy sector changes because of the energy system transformation. The use of primary energy sources like coal decline in contrast the use of CO2-neutral renewables (e.g. wind energy) increase. Therefore, electricity production is moving away from centrally located large-scale power plants. There will be millions of decentralised lower capacity renewable energy (RE) power plants in the electricity grid. (Schwab 2017) The renewable Energies act (EEG) requires that the electricity generated from renewable energy sources must be primarily purchased by grid operators. For this reason, conventional power plants only cover the difference between the current RE generation capacity and the grid load (residual load). This coverage becomes difficult with an increasing percentage of renewables, because in some cases more electricity is offered from renewables than require by the grid load. This leads to common regulation or forced shutdown of wind power and PV systems. Also the fluctuated RE production complicates to

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reach a stable supply. For that reason, expansion of power grids and smart grids are needed. Energy storage combined with flexible grids can regulate renewable energy excess (Schwab 2017). Such regulations are avoided if in case of bottlenecks, the generated clean energy is used otherwise until a feed-in into the grid is possible. An option is to regulate the system at the grid connection point. For example, the electricity can be supplied to a consumer or storage via direct line. Here is the deployment of sector coupling, for example with mobility, useful (IKEM 2018).

The transport sector should also become more sustainable, because in a globalised world transport has become essential. However, the mobility all over the world is currently based on the consumption of fossil fuels and the number of vehicles on the road is growing. In Germany alone, the energy consumption of transport has more than tripled since 1960 (BMU 2016). This has significant consequences for climate change and air pollution. Alternative engines like electro mobility link to renewable energy are a more sustainable solution. That means the transition to sustainable energy and mobility requires not only grid expansion but also merging of sectors. In this way the sector coupling contribute to achieving the political climate change targets with regard to decarbonisation of the energy supply. In addition, their implementation could make advantageous (e.g. acceptance-generating) for local developments (IKEM 2018). With sector coupling RE can be used directly or indirectly. Disadvantage by indirect use is conversion losses and lower efficiency, for example in hydrogen applications. A direct line from wind turbines (as in this case) to the consumer supplies electricity from RE without these losses and higher efficiency. Furthermore, the characteristics of clean energy remain, because the generated energy does not mix with fossil energy in the grid (grey energy). Certificates of source according to §§ 78 et seq. EEG 2017, 42 EnWG are only for marketing purposes usable. The green energy characterise is lost, if electricity is obtaining from the public grid (IKEM 2018). It is prescribed that owner of electric charging stations prove the origin of clean energy. They can conclude a certified green energy supply contract in accordance to § 79 EEG (hamburg.de, Elektromobilität). Another opportunity is the direct link to wind turbines. It not only fulfils the condition but supplies also green energy. The buses drive with local generated clean energy and produce no CO_2 emissions. Climate protection goals are achieved by it: Hamburg plants to reduce CO_2 emissions by 80 % until 2050 (compare with the year 1990) (hamburg.de, Koaliationsvertag).

Another important aspect is the sale of generated electricity, in this case the wind energy. Operator from renewables systems allocate a contract accordance to § 21 b I EEG. It allows to switch between the following option of sale: market premium, feed-in tariff, tenant electricity surcharge and other direct marketing. But the use of multiple sales for electricity at the same time is forbidden accordance to § 80 EEG. With a direct link from wind turbines to the charging bus station, the wind park operator can sale the generated energy directly to the customer VHH.

The complete energy system is stable if feeding and removal is in balance. When too much electricity is produced e.g. by wind power, the consequence are negative electricity prices on stock exchange. Majority

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of RE operators sell the generated electricity by receiving EEG payments by market premium. This option does not compensate all costs by far. The turbines get no payment, if the negative prices last over six hours. That leads to switch off the wind turbines immediately. (BMWi 2019) VHH can counteract this as a constant customer. Due to the battery storage on the VHH side, the wind power is taken at any time. If necessary, the electricity is forwarded to the bus charging station.

One approach for the direct sale of the wind power is the Power Purchase Agreement (PPA), an electricity supply contract between two parties. The wind park operator and the consumer regulate different conditions like delivery volume, price, accounting treatment and consequences for nonfulfillment. Thereby, Energy can be supplied physically or through balance sheet. Due to the geographical proximity to bus charging stations the “On-Site PPA” is possible. Wind power can be supplied direct physically. The dimensioning of the system with PPA is usually based on consumption profile of the wind turbines. The VHH energy storage flexibles the consumption profile. Wind energy can be obtained at any time provided the capacity of the storage is enough. Otherwise, charging management should be taken into consideration supplementary. PPA contract includes the grid operator in case of residual electricity. The residual power can then be fed into the grid, so that wind turbines do not have to be switches off. PPA has some advantages such as long-term price security, opportunities to finance investments in RE, or the reduction of risks related with electricity sales and purchases. In addition, physical supply of green local generated energy takes place. The flexible contract enables to reflect the individual preferences of wind turbine operators and consumers. Another point is that PPAs can be concluded at fix prices and allow greater participation in market risks and opportunities. Detriment is that the contracts require a lot of time and agreement. Also both parties are bound by long-terms contracts. This can lead to disadvantages if price for one of the parties develop negatively. Furthermore, electricity production from wind is fluctuating. If the agreed volume of energy is not available, the wind park operator must be able to compensate these physically or financially (Next Kraftwerke, PPA 2019).

Charges such as grid fees for the wind energy can be waived or reduced. The conditions for it are regulated by law. § 3 No. 12 EnWG differ between two direct connections. The first one describes the case from wind energy to bus charging station and storage of VHH. Intended is a direct line which accesses the consumer with green energy. Through that the current is not applicable accordance to § 9 Abs.1 No.1 StromStG. In addition, the EEG levy reduce to 40 percent if in the year exclusively green energy are utilised by § 61b EEG. Still is possible to reduce the EEG levy to zero percent with the condition that the green energy is used by the final consumer and the electricity is not transmitted through a grid accordance to § 61e Abs. 1 No. 2, 3 EEG 2017.

3.3.2 Project description

A direct link between the local windfarm (see D3.4 chp. 4) and the VHH bus depot makes it possible to load their new ebusses (see chp. 3.1) with green energy. The main target is to charge VHH electrical buses with local renewable energy. Moreover, instead of just using grid electricity and balance renewable

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electricity mathematically, it is planned to enhance the project concept by directly using locally produced wind power from the “Wind Park Curslack” (see D3.4 chp. 4), placed approx. 1 km away from the bus depot with 5 wind turbines and a nominal capacity of 13 MW. The wind park is part of the “Energy-Campus Bergedorf” where the Competence Center for Renewable Energy and Energy Efficiency (CC4E) of the University of Applied Sciences Hamburg (HAW Hamburg) is running multiple projects in the area of renewable energy, smart grids and integrated energy concepts. (e.g. hydrogen for heating (D.3.3), local Windfarm (D3.2), impact of growing number of charging statation on the grid (D3.7) and clean energy chargingstation Section 4.3). Figure 9 gives an overview over the local conditions in the project (The course of the cable is still being planned).

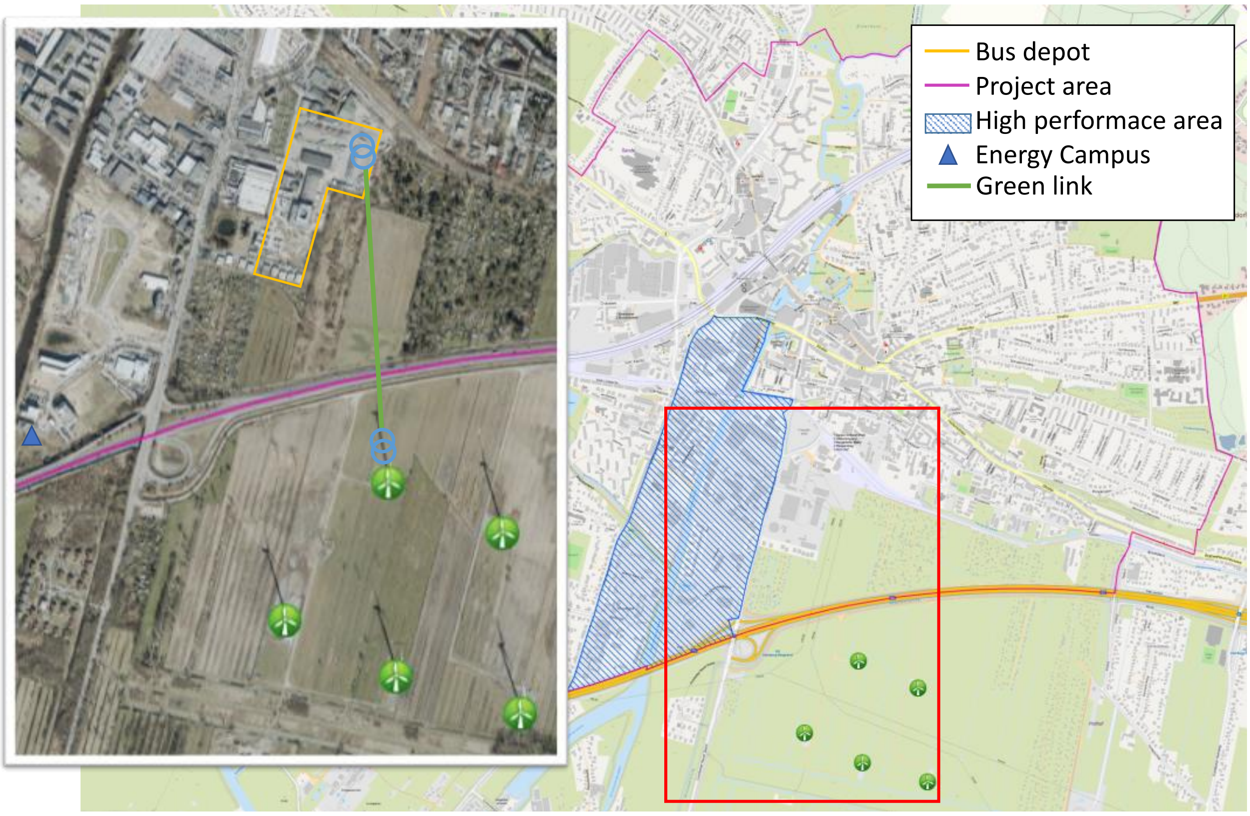

Figure 9: Green link in project area [map: Hamburg, editing: HAW]

VHH already plans to integrate battery storage at the charging infrastructure at the bus depot in 2019. The charging of the buses will mainly be done at night. At first, this battery will be used for peak shaving, hence to reduce the maximum electricity demand during the charging process of multiple busses (see also Section 3.2). In the wind park Curslack another battery system was installed in summer 2018 (capacity 792 kWh / power 720 kW, see D3.2). The basic idea of this action is to physically connect the wind farm with the VHH bus depot and the charging infrastructure. The concept of a joined areal network should enable the synergetic use of the different system components like the two battery systems (VHH battery

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and battery in the Wind Farm) and Wind Farm Hamburg Curslack to charge the buses with local green energy.

Due to the legal and technical complexity, legal and technical feasibility studies are initially carried out. These studies should show which framework the legal conditions set, which contractual relationships are adapted and which business cases are possible. In addition, it will be examined how the physical connection can be built later. This includes route planning and planning of connection points on both sides.

Following the feasibility studies, the proposed measures will be implemented after a review. At the beginning, the design phase was divided into three milestones:

- Basic Concept with feasibility study
- Legal Framework
- Planning and Construction (This milestone marks the transition to the project phase of planning)

3.3.3 Initial Situation

The bus transport company Verkehrsverbund Hamburg Holstein (VHH) acquires the first e-buses as part of mySMARTLife. The challenges and opportunities the VHH is facing are described in Chp. 3.1. In order to increase the use of green electricity but also to identify economic opportunities, mySMARTLife also aims to create the possibility of charging the new e-buses with electricity from the wind farm. The VHH already has part of the necessary infrastructure to receive and distribute the necessary quantities of electricity.

The wind farm already operates a storage facility (D3.4 chp. 4). Due to the short distance between the wind farm and the VHH, the possibility of a physical connection for the transmission of electrical energy should be explored. The VHH expects to be able to reduce its electricity costs in this way. For the wind farm operator, this results in a fixed customer for part of the electricity produced, which no longer has to be marketed.

How the implementation will continue will now depend on the results of the feasibility studies expected in late 2019/early 2020. These will show which business cases are feasible after which adjustments. They will provide a first draft for the technical and structural execution. The planning and implementation phase can then begin with these findings.

3.3.1 Key findings

- The transport sector will become more sustainable if e-busses charge green energy form wind turbines. In long term political climate changes targets can be achieved.
- Direct use of wind energy for charging stations means lower losses and higher efficiency than indirect use, e.g. hydrogen power.

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- Sector coupling with regional produced wind energy, could generate more acceptance for the energy transition.
- Energy storage can balance the network load. Too high load peaks are avoided and the grid is not overloaded.
- Wind turbines do not need to shut off if too much electricity is produced, because the storage absorbs these wind energies. Wind power operators benefit from direct energy sale.
- The cable need to be installed. Investment cost for the development should amortize.
- Legal and economic frameworks should be clarified.

3.4 Electrification of public fleet

The following chapter descripes the electrification of the public vehicle fleet as a part of the strategy to foster electric mobility in Hamburg. In the Borough of Hamburg-Bergedorf, where the mySMARTLife project area is located, the fleet of the municipality of the borough and the fleet of the public transportation provider VHH are the largest public fleets. Therefore, the project focuses on the electrification of these two fleets. These can be used as a good example for the electrification of further public fleets in the City of Hamburg. The implementation of this task is closely linked to the local procurement rules for passenger cars for public fleets. For this reason, a brief overview of the applicable Hamburg procurement rules is given below.

3.4.1 Initial Situation

In order to guarantee fair, efficient, and sustainable public procurement contracts the German laws for procurement regulate the corresponding processes. Different legal norms provide detailed provisions on how public principals may proceed when awarding procurements. The Free and Hanseatic City of Hamburg has implemented the need for sustainability in public procurement in various ways: Since 2016 there are general guidelines for “Green Procurement” that aims at supporting the responsible local authorities in considering ecological aspects in public procurement (FHH, 2019). In the field of procurement of new public vehicles regulations consider the purchase of cars with low levels of $CO2$ and pollutant emissions (Umweltbundesamt, 2014). In case of the replacement of vehicles, electric cars have priority over conventional cars with combustion engines. Therefore, a change in the reverse onus clause (German: “Beweislastumkehr”) was implemented in 2014. In a procurement process the public consumers no longer have to justify why an e-car should be purchased but why exceptionally no e-car is considered. With a number of more than 300 e-cars in the public sector Hamburg ranks among the leading European cities in this field (FHH, 2014).

In the City of Hamburg, the administration of the borough performs the duties of the local government. This also includes the maintenance of the district roads, the roadside areas, the green areas and parks

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and, especially in Bergedorf, the maintenance of the watercourses in the marshes and the dikes along the river Elbe.

For this purpose, the borough owns and manages a large fleet of cars, trucks and auxiliary vehicles, which offers a considerable potential for reducing emissions. The following table provides a brief overview of the borough's vehicle fleet. Most of the vehicles are located at a depot of the department for Management of Public Space. Overall, this is a very typical situation, which is similar in the other districts of Hamburg.

Table 3: Overview about the public fleet of the Borough (source: Borough of Hamburg-Bergedorf, own source)

Vehicle class	Number	Electric drive	Electrification quote (incl. hydrogen)
Passenger cars	23	17 (+1 hydrogen)	78%
Caddys / Minivans	3	0	0
Buses / Vans	9	0	0
Tractors all sizes	11	0	0
Trucks (up to 12t)	26	2 (small platform trucks at a cementery)	1%

Another larger public fleet of cars is operated by the public transport company VHH. Here smaller cars are used for transportation for staff members, i.e. with these cars the bus drivers are brought to their buses at the beginning and end of their shifts. Usually this is the central bus station at the Bergedorf railway station, for some lines, however, this can also be terminal stations. These cars travel on average workindays about 20-30 kilometres, depending on there deployment location. Due to this regular usage profile, this fleet is also very well suited for electrification - a total of 10 cars are involved here.

Table 4: Overview of the public fleet of the VHH (source: Borough of Bergedorf based on data from VHH)

Vehicle class	Number	Electric drive	Electrification quote
Passenger cars	34	10	29,5%
Caddys / Minivans	2	0	0
Buses / Vans	2	0	0

3.4.2 Implementation 1: Procurement of e-cars

At the beginning of the mySMARTLife project, the Borough of Hamburg-Bergedorf generated an overview of the vehicles and their locations. It became evident that most of the vehicles of the Borough are used at the department of the Management of Public Space.

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At the same time, other public fleets were examined as well and it was recognised that the bus operator VHH also has several passenger cars and that the simultaneous electrification of the bus depot (see Sections 3.1 and 3.2) could result in synergy effects.

As a first step, the responsible persons at the department of Management of Public Space were contacted. This had to be done particularly early, as the old leasing contracts for the conventionally fuelled cars expired and a new procurement was pending. At the same time, SNH provided advice on the electrical charging infrastructure. The vehicles used for the regular control of the district roads, for the green and forest areas, as well as the vehicles for the control of the water ditches in the marshes and the dikes at the Elbe were considered here above all. It turned out that on an average day usually not more than appr. 115 km are driven, which makes these vehicles especially suitable for replacement by e-vehicles. However, in the event of a flood on the Elbe (a regular event in spring and autumn), the Borough assumes the tasks of disaster control and dike defence. In these cases, vehicles with a sufficient range must be available.

Furthermore, it became apparent that the electricity connection of the depot was close to the limit and could only accommodate a limited number of vehicles. SNH analysed the situation and developed and installed a special load management. This management allowed to optimise both, the adequate power supply at the electricity connection and the availability of a sufficient number of cars that is fully charged for cases of emergency. Thanks to the intelligent charge control, two e-cars are now always charged particularly quickly and 10 new charging points with 44 kW capacity have been implemented. This way, worries about a limited range due to incompletely charged cars in cases of emergencies, such as the described flood situations are not necessary (see Section 4.2: Load Management).

Due to the favourable framework conditions, which provide for a compulsory procurement of electric vehicles in Hamburg and due to the technical solutions of SNH, it was possible to quickly agree on an exchange of initially 10 passenger cars by electric vehicles, Renault Zoe's. During the project further 2 (Renault Zoe) passenger cars were purchased additionally at this location and 2 small electric platform trucks (Goupil G4) with a load capacity of 1,2 t were purchased to be used for the gardening at a cemetery. Moreover, the official car of the Head of the Borough was replaced by one hydrogen fuelled car, a Toyota Mirai.

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Figure 10: The passenger cars and charging stations at the department for public space (source: Borough of Bergedorf)

As public enterprise the VHH is also committed to the procurement regulations set by the City of Hamburg, which requires the procurement of non-fossil emission free vehicles. For this reason, at the VHH as well, the electrification can be initiated easily. Directly after the electrification of the public fleet of the Borough of Bergedorf, the project mySMARTLife analysed the use of e-cars at the VHH. Because leasing contracts expired here as well, it was right away possible to purchase e-cars (VW e-up!). Additionally to the cars, wall boxes for the charging of the cars were purchased. Due to the profile of use a specific load management was not needed.

Figure 11: The passenger cars at the depot of the VHH (source: VHH)

3.4.3 Implementation 2: Procurement of e-bikes

In contrast to the procurement of e-cars, the procurement of e-bikes was much more difficult, because there was no experience and there were no established use-cases. The financial administration of the borough demanded an application case that complies with the tasks of the municipality before the procurement of a relatively expensive e-bike.

After the start of the electrification of the public car fleet, the project mySMARTLife analysed the tasks of the different departments of the municipality in Bergedorf. The aim was to identify tasks which could be supported or carried out more effectively by the use of e-bikes. Additionally, it was analysed if the number of car trips could be reduced by the utilization of e-bikes.

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Thus, for the first step an online survey among the employees of the authorities in Hamburg-Bergedorf was conducted. 98 of around 580 employers took part in the survey. Questions about the characteristic of business trips, the amount of trips, the main mode chosen for the trips, the average distance of the trips, the main advantages/potential of e-bike and more were asked. The survey was proceeding with an online-tool and every employee could take part voluntarily. The results of the survey were analysed and aggregated in excel sheets and a presentation. Overall, the survey has shown that many business trips are done by car, often even with the private cars of the employees, which is officially not desired, because of insurance reasons. Several trips could be replaced by e-bikes, especially trips within the inner city of Hamburg-Bergedorf. In a free comments box the employees could additionally insert their opinions and conditions under which they would use e-bikes in their daily work. Most comments were related to the desire for flexible and easily accessible rental opportunities.

Figure 12: e-bike ride event with the employees of the municipality of the borough (source: Borough of Bergedorf)

Further, to raise the acceptance of e-bikes and to give every employee a chance to get in touch with this new mobility form and reduce concerns, trial sessions for e-bikes were held in three different locations. These were organized at the Bergedorf town hall, the main facility of the Bergedorf authorities, at the mySMARTLife-office and at the department for management of public space. The Volkswagen AG provided three e-bikes and the HAW one cargo e-bike. Employees of the authorities and also pedestrians could try the e-bikes to get a feeling for these. At the same time, these sessions should help to raise the motivation of the employees to use such bikes for business trips.

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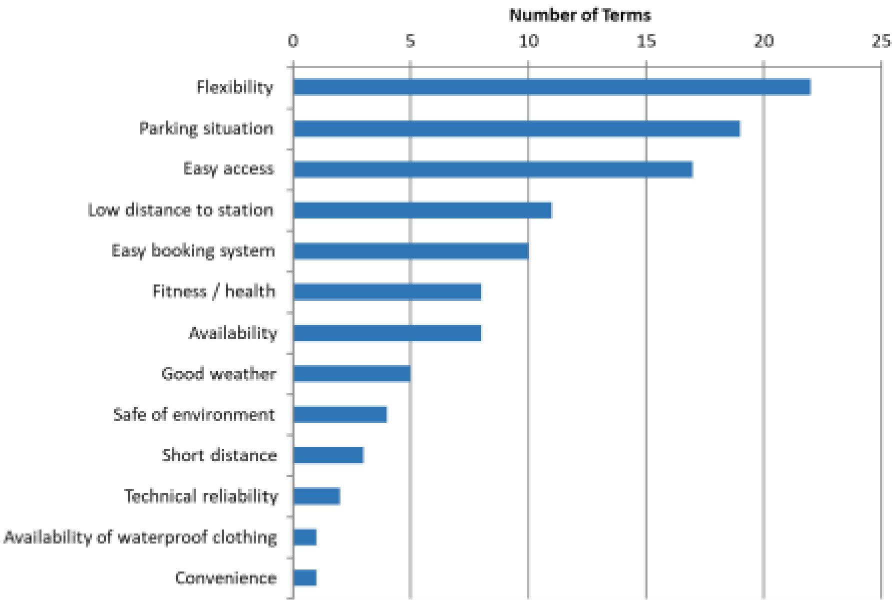

Figure 13: Number of Terms - Most mentioned motivational aspects to use an e-bike in the daily duty of the employees in the Borough of Bergedorf (source: Borough of Bergedorf, own source)

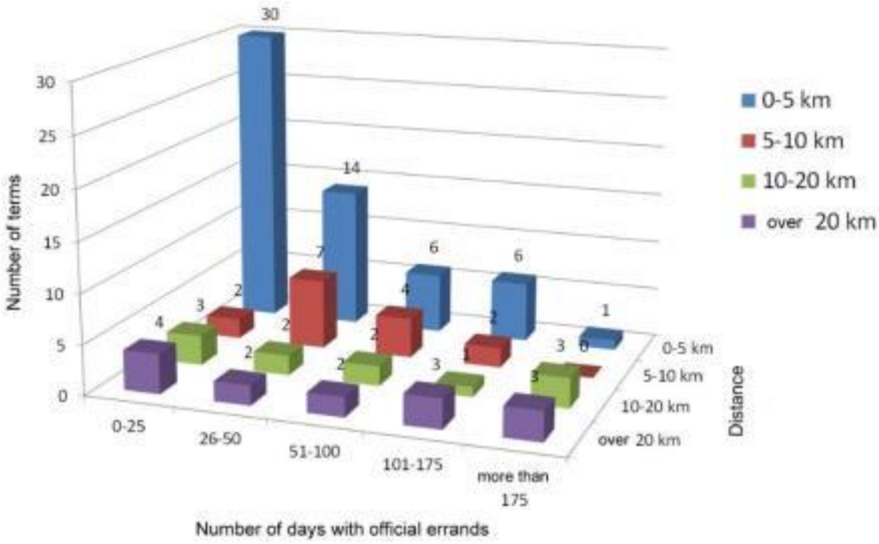

Figure 14: Destribution of Trips in the chart above the absolute number of trips (Y-axis) per department (X-axis) is classified into distances of the trips. While some few departments have many long trips, it can be seen that most departments have mainly short trips of 0-5 km which could be done with normal bikes, the main potential for e-bikes has been seen in the distance between 5-10 kilometers (source: Borough of Bergedorf, own source)

The general feedback of the survey and the e-bike events was very positive. Especially the employees at the department for Management of Public Space were very interested in the use of e-bikes or cargo e-bikes. Most of the people, who tested the e-bikes for the first time, were pleasantly surprised and in favour of getting e-bikes for business trips for the department.

THIS DELIVERABLE HAS NOT YET BEEN APPROVED BY THE EC

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Yet, the main barriers for the purchase of e-bikes, as a new element of the public fleet, are the high cost of the bikes and the additional costs for the installation of parking boxes. Also, the e-bike events have shown that the wide range of the height of the employees is a problem. At last two different bicycle sizes at one location would be needed in order to take account of the needs of the employees. It was calculated that a robust e-bike together with the installation and bike helmets would cost between appr. 3,000 to 4,000 € each.

Another barrier is that at the most promising location for e-bikes, the agency for public spaces, already several conventional bikes for short trips are offered and several e-cars for long distance trips. The good equipment with different available climate friendly vehicles for different distances at that location reduces the demand for further vehicles. Eventually, the costs for e-bikes need to be considered as too high to justify the investment, as long as possible use cases in Bergedorf can be handled with other vehicles. However, at the public order office, new tasks in the inner city have increased and at the moment the procurement of 3 e-bikes to nadle these taks has started at the Department for Public Space. Also the request for e-bikes among the employees is constantly increasing. These developments might lead to the purchase of further e-bikes within the duration of mySMARTLife.

3.4.4 Key findings

It has shown that authorities and operators of other public fleets are subject to strict regulations when it comes to the procuring of cars. These are, firstly, the described procurement rules that must be observed and, secondly, the circumstance that public authorities always need specific reasons for procuring vehicles and bicycles that meet the needs in the fulfilment of the tasks of a public authority.

In general, public fleets are very well suited for electrification due to their defined usage behaviour and (at least in urban areas) their limited driving performance during a working day. The use profiles of vehicles in public fleets are often steady over a long period of time. Additionally, distances driven per day are usually within the range of electric vehicles. In the combination of a charging management, e-cars can be introduced easily into a public fleet.

While almost 78% of the passenger car fleet in the district is electrified and 29.5 % of the VHH, there is still great potential in the fleet of special vehicles such as trucks or tractors. The first steps have already been taken in the project with the procurement of 2 smaller e-transporters at a cementery. At the moment, however, the market not yet offers suitable electric vehicles with larger load capacities, such as larger trucks (7.5t - 12t) or other utility vehicles, which could be a comprehensive replacement for fossil fuelled vehicles.

It has shown that new procurement regulations can foster the electrification of public fleets when these regulations demand the procurement of electric vehicles. In Hamburg, the existing framework conditions, which demand a preferential procurement of e-cars are clearly benefit the electrification of public car

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fleets. This has proven to be true in the comparison of the electrification of the car fleet of the Borough of Bergedorf and the introduction of e-bikes into the same fleet.

The e-bike event in mySMARTLife has turned out, that the majority of employees are interested in e-bikes and new mobility solutions. The events were very well attended and a lot of people showed up to test an e-bike for the first time in their life, to find out, if an e-bike could be a solution for their private life or a new possibility to get to work. Here, the practice experience was a very good situation to get a direct feedback from the employees. But the main barrier in the implementation of e-bikes is the high cost and the "sandwich position" between cheaper conventional bikes and e-cars for long distance trips. To overcome this impediment, a very clear use case needs to be defined, e.g. use in steep terrain. But with the purcheasement of 3 e-bikes for the order office, mySMARTLife could implement a new mobility solution to the public fleet, because a very clear use case could be defined.

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4. Expansion of the e-mobility charging infractructure

4.1 Fast charging stations

4.1.1 Project description

Today's fast-charging infrastructure in Europe generally offers an output of 20 kW or 50 kW per charging station. However, it should be recognised that charging infrastructures are delivering ever-higher outputs. These high-power chargers (HPC) are used in particular along corridors to allow longer distances for electric vehicles. These are increasingly being set up in the form of charging stations. In a metropolis like Hamburg, the development of fast charging infrastructure has to be considered differently, as the focus here is particularly on the charging needs of residents and inner-city traffic.

This action is dedicated to the development of fast charging infrastructure in the project area of the Bergedorf district. Five DC fast charging stations with up to 50 kW and one DC high-power charging station with up to 150 kW are to be installed, of which one DC fast charger has so far been realised in the project area, but 64 DC fast chargers in the entire city of Hamburg.

The five DC chargers are to be set up as part of the Hamburg (fast) charging concept. Thus, relevant charging standards should also be supported in Hamburg-Bergedorf. These fast charging stations are so-called triple chargers, i.e. combined charging stations with three plugs and fast charging cables. This design supports all relevant connector types: DC CCS, DC CHAdeMO and type 2 in the AC range. Current electric vehicles have to charge for about 30 minutes to reach up to 80% of their battery capacity (HMWEVW, 2017). A further significant reduction in charging time can be achieved by increasing the charging output, e.g. to 150 kW per charging station or charging point. These high-performance devices are comparatively new and in recent years, new products have been launched on this young market. A fast charging concept of this kind was also foreseen in the project area in Hamburg-Bergedorf and was closely examined within the scope of the project, but unfortunately, it could not be realised during the course of the project.

The minimum technical requirements for charging stations are defined in EU Directive 2014/94/EU (EU, 2014), which stipulates certain plugs as standard, e.g. for reasons of interoperability. Other requirements that apply only in Hamburg, such as accessibility and design requirements, are embedded in the master plan. The e-mobile parking spaces in the city of Hamburg are marked by special signs. A license plate for electric vehicles is required to use an e-mobile parking space. This license plate can be obtained from the registration authority. In addition, the maximum parking time must be observed during operation and a parking disc must be stored in the vehicle (LBV, 2018). Finally, it should be mentioned that the Hamburg infrastructure of course also meets the requirements of the national charging station regulation (BMWi, 2016).

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The following table shows the various charging technologies being set up in Hamburg:

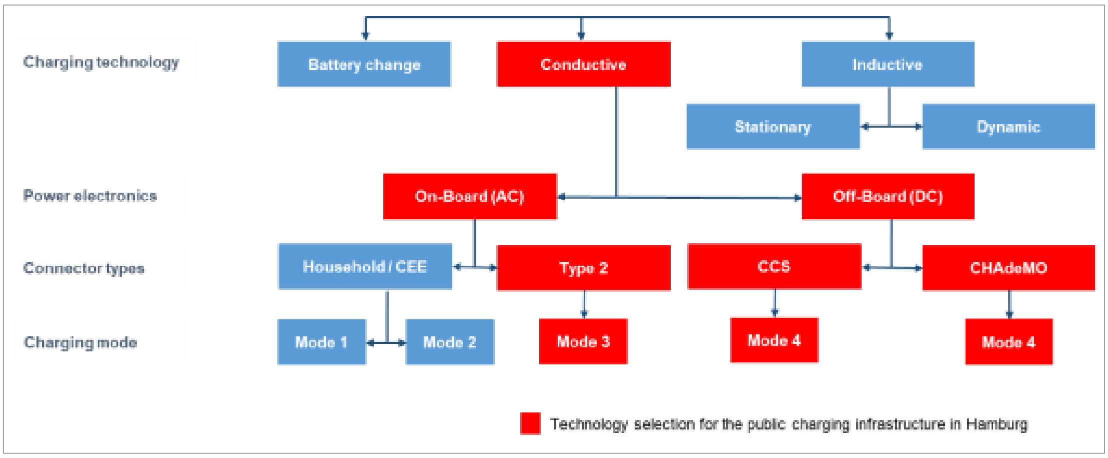

Figure 15: Charging technology in Hamburg (Source: SNH)

In connection with the desired buildup of a high-power charger, it makes sense to differentiate between the vehicle ramp-up according to the appropriate charging technology. Market development in the segment of corresponding fast-charging vehicle models plays a central role here. When initiating the Hamburg Master Plan FHH (2013) for the development of public charging infrastructure, it was assumed that in view of the market supply of production vehicles, in particular from German, French and Japanese production, approx. 40% of the electric vehicles in Hamburg would be capable of DC fast charging by mid-2016. And as a result that increasingly higher charging capacities would then be introduced into production vehicles. The demand-oriented expansion of the city's charging infrastructure is thus directly related to vehicle technology and the proportion of electrification of vehicles on Hamburg's roads.

The central challenge of this work package was therefore to derive the required quantity and technology of the charging infrastructure to be built in the Hamburg project area. It should always be borne in mind that normal charging infrastructure is generally set up across the board, as this infrastructure has a much higher network density in terms of location and costs.

Figure 16: The first DC triple charger in Hamburg-Bergedorf (Source: Bezirk Bergedorf)

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4.1.2 Baseline situation

The Free and Hanseatic City of Hamburg is a growing metropolis and a major northern European transport hub. As a former European Green Capital, Hamburg is particularly committed to the principle of sustainability and is continuously working to improve the social, economic and environmental conditions of the city's citizens - in line with the urban development strategy "Green, fair, growing city by the water" by 2030 (FHH, 2014).

The consistent promotion of electric vehicles is a decisive step in this direction. The resulting reduction in pollutant and noise emissions is aimed directly at improving air quality and offers clear potential for improving Hamburg's attractiveness as a location for citizens and businesses alike.

With the master plan adopted in 2014 for the expansion of the publicly accessible charging infrastructure, the Hamburg Senate has substantiated the demand-driven expansion of the charging infrastructure for electric vehicles and the promotion of electromobility in Hamburg. The timeline gives an overview of the history of the public charging infrastructure in Hamburg

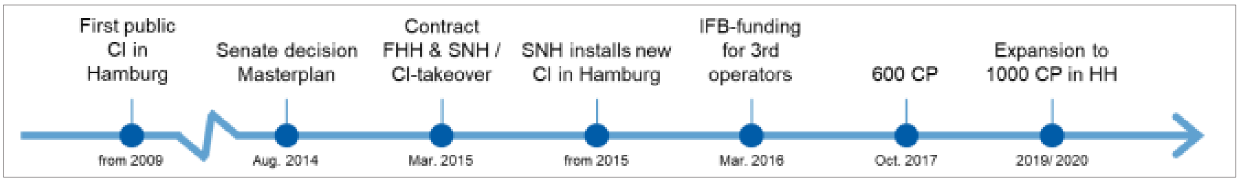

Figure 17: Roadmap of the public charging infrastructure in Hamburg (Source: SNH)

Currently, around 951 publicly accessible charging points (441 locations) are already available in Hamburg (as of 31.09.2019); these are almost entirely operated by the municipal subsidiary Stromnetz Hamburg GmbH. The charging infrastructure is divided into AC (alternating current) and DC (direct current) technology: There are currently 887 AC normal charging points at 410 locations and 64 DC rapid charging points or locations.

The previous evaluations regarding charging processes and capacity utilisation show an increasing use and thus a clear need for charging in the central inner city area. The indicator for this is the significant increase in the number of charging operations to over 17,000 per month in the city of Hamburg. Experience from other European cities such as Copenhagen or London shows that the market launch of vehicles is much faster if a dense network of adequate charging infrastructure is available in the central inner city area.

In order to support a corresponding system change even more consistently, the existing network of municipal charging infrastructure in Hamburg will be further expanded. In line with the charging processes that occur, the development focuses on the inner city area. Considerable compaction has been achieved here, and strongly increasing use has been recognised. A further goal is to establish a comprehensive charging network and thus to include all Hamburg districts. It can be seen that the focus in the distribution

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of the charging infrastructure was on the city centre (SNH, 2019), i.e. on the districts of Altona, Eimsbüttel, Mitte, Nord and also Wandsbek. In the districts of Harburg (south of the Elbe) and Bergedorf (outside, to the east) a much slower expansion can be expected due to reduced demand. This reflects the fact that highly frequented locations are first equipped with charging infrastructure before residual areas are developed. In the following, the current status of the structure is visualised.

The image below illustrates the current status of the development of public charging infrastructure in Hamburg by district. Here it becomes clear that the criteria-based structure (especially as far as DC is concerned) takes place in the heart in the inner city area. There is currently one DC charging station (= one DC charging point) set up in Hamburg Bergedorf. This would correspond to approx. 2% of all DC charging points available in Hamburg.

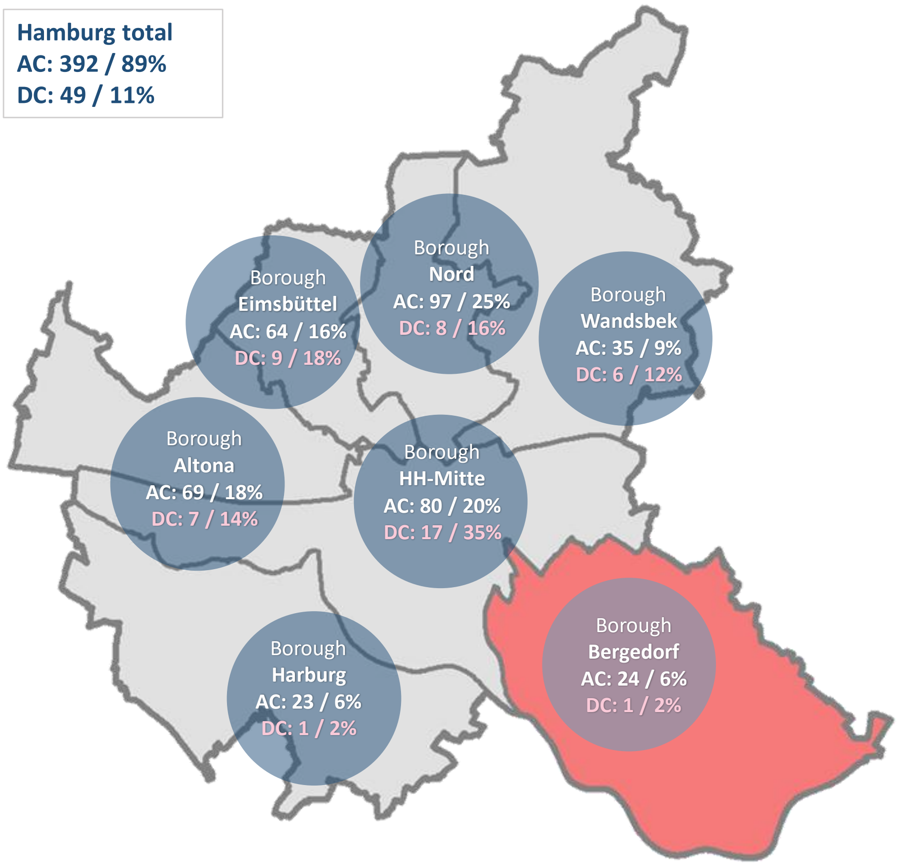

Figure 18: Distribution of public charging stations (AC/DC) in Hamburg (Source: SNH)

It is planned to create 1000 public charging points operated by the SNH by the beginning of the year. A key question for a demand-driven development is, on the one hand, location and, on the other hand, the type of charging infrastructure to be set up. A distinction is made here between normal charging infrastructure and fast charging infrastructure. In connection with the construction, the construction of fast-charging infrastructure is particularly sensitive, as it is very cost-intensive. It is therefore very important to

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install this DC technology in line with its actual use. The following illustrations show the development of the structure and use of the public charging infrastructure in Hamburg. Here, it becomes clear that the increase in the number of charging points is always accompanied by an increase in use. The development of the charging infrastructure thus supports the increasing electrification of mobility in Hamburg.

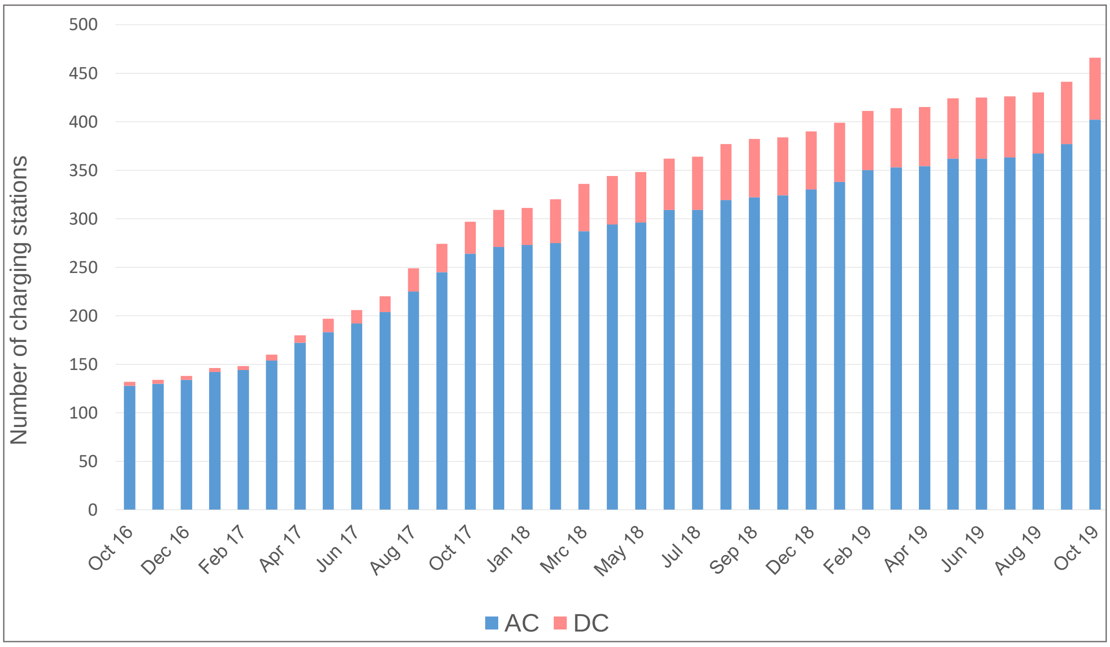

Figure 19: Expansion of public charging infrastructure (Source: SNH)

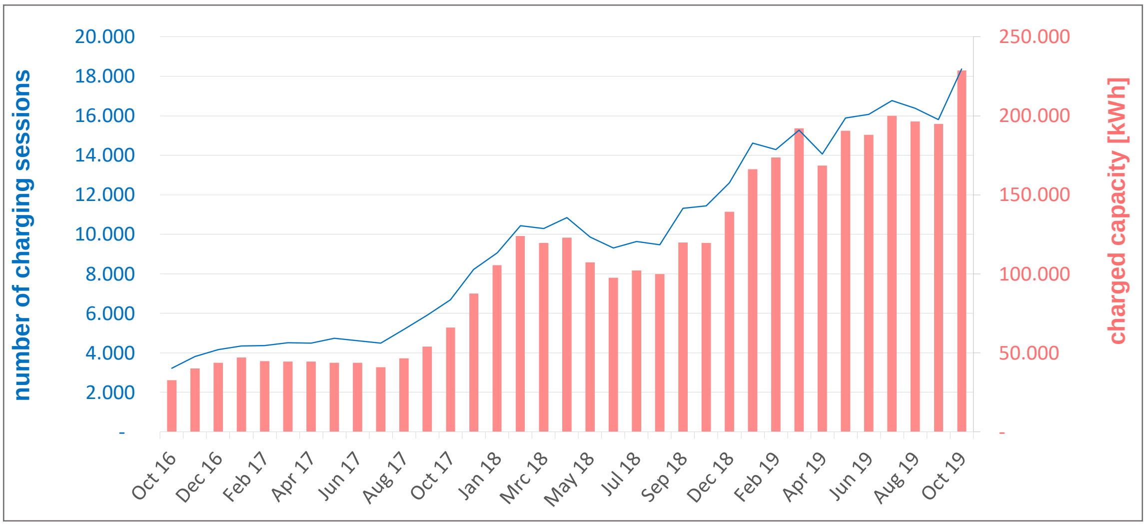

Figure 20: Utilisation of public charging infrastructure (Source: SNH)

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4.1.3 Concept/realisation

Hamburg is one of the first German cities to embark on a structured, concept-based and demand-oriented expansion of public charging infrastructure. In recent years, the processes for setting up the charging infrastructure have been greatly optimised. The cooperation of the various partners involved has thus been improved and the set-up time compressed. The basic process steps and tasks of the partners involved are described below:

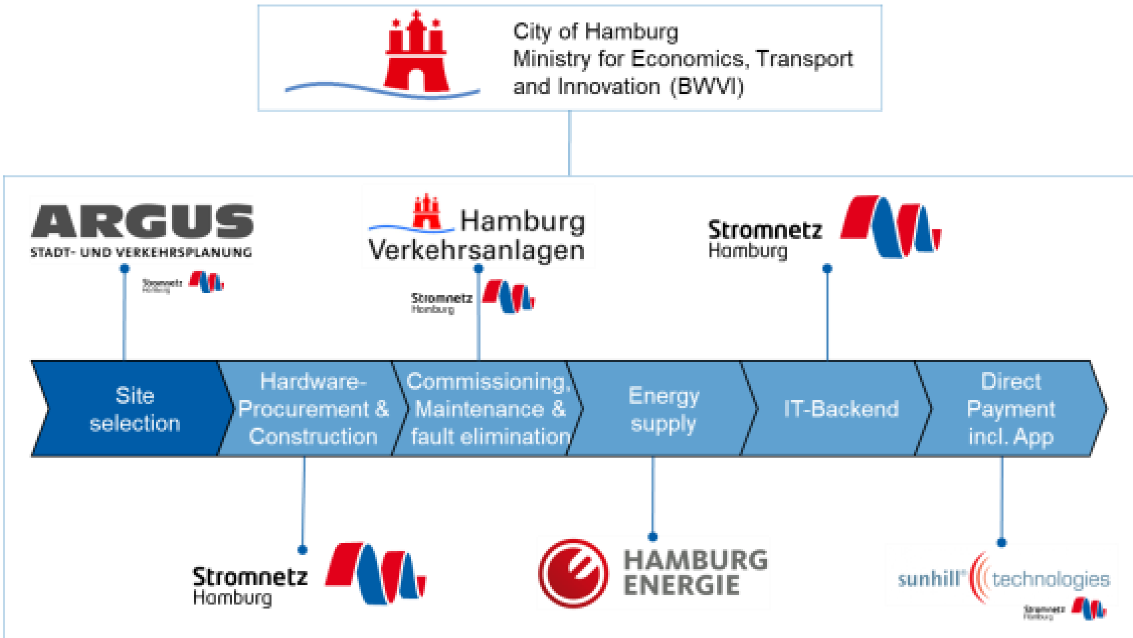

Figure 21: Role model of the parties involved in the development of public charging infrastructure in Hamburg (Source: SNH)

The starting point for setting up a public network of charging infrastructure should always be a comprehensive concept: in Hamburg, the master plan mentioned above. The diagram above shows the other partners involved in the expansion and operation of the charging points.

The first step in the implementation of charging infrastructure is to find a suitable location. The choice of location for the charging stations is coordinated by the Ministry of Economics, Transport and Innovation (BWVI). It is supported by the project control centre for electro mobility in Hamburg, hySOLUTIONS GmbH, and the urban planning office ARGUS. Site assessments are prepared and suitable sites are forwarded to SNH. SNH then applies to the FHH districts for permission to make special use of public roads. If the site is located on private property, a licence agreement is concluded with the owner or tenant. Once the charging site has been approved, SNH will commission the installation. Mains connection, foundations and construction of the charging station are carried out by an external technical service provider. The commissioning will be carried out by another technical service provider, Hamburger Verkehrsanlagen (HHVA). After commissioning, charging can take place at the charging stations. Maintenance and repair are also carried out by HHVA. The charge point operator (CPO) is responsible for

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the operational business. The CPO in the Hamburg model is SNH. It is the owner of the charging facilities and monitors and controls the operation by connecting the charging stations to its own IT backend. The electricity supply at the charging stations has been awarded to the electricity distribution of an energy supplier because SNH, in its role as grid operator, is not responsible for the electricity supply at the charging stations or is not allowed to carry out these and all directly connected activities due to legal requirements (BNetzA, 2019). The central electricity supplier is currently Hamburg Energie. Electric mobility providers (EMPs) can conclude electricity supply contracts with Hamburg Energie so that EMP customers can charge their electric vehicles at the charging stations. The billing data is provided by the SNH IT backend and delivered to Hamburg Energie via an interface. This means that the charging processes are billed to the EMPs or their end customers. An EMP offers its customers the opportunity to gain access to the Hamburg charging infrastructure and to charge their electric vehicles. To do this, the EMP must conclude a corresponding access agreement with SNH and provide SNH with an encrypted list, a so-called white list, for customer identification (SNH, 2019).

In connection with this action, the site selection represents the relevant process step in the construction of public charging infrastructure. This step was the biggest challenge and at the same time the reason why the objectives in this work package were not achieved. The process of site selection in Hamburg can again be divided into five steps. These are shown below.

Step 1: Allocation plan

Within the framework of allocation planning, the locations of the charging stations are evaluated and selected on the basis of a two perspectives: macro perspective and micro perspective.

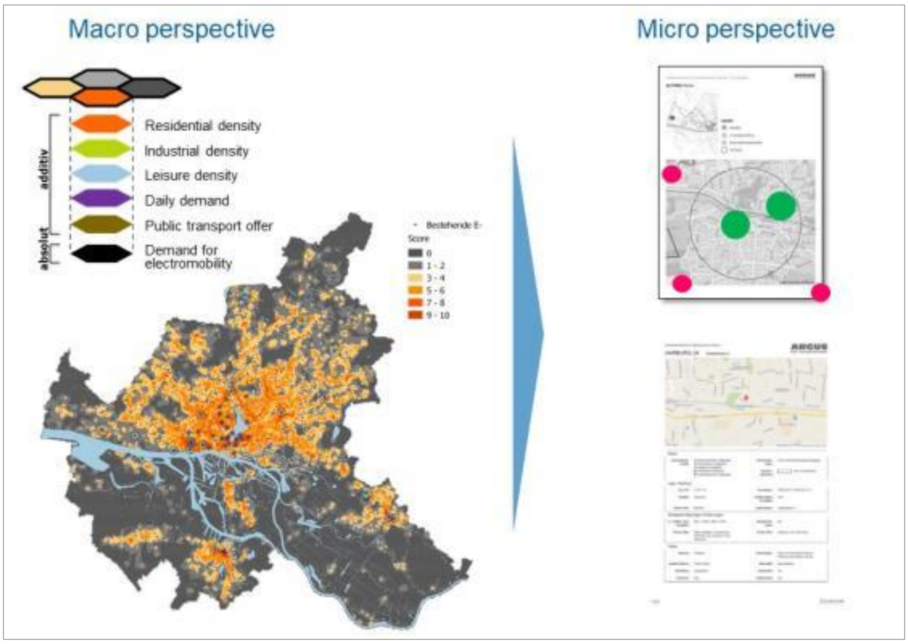

Figure 22: Allocation planning perspective (Source: ARGUS, 2018)

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Step 2: Site evaluation and prioritization

Location proposals (e.g. by PMO, by traffic planning office, by users, by districts) are evaluated and prioritized. The process is based on the established criteria (e.g. proximity to POI, public transport, parking pressure).

Step 3: Cost indication

For each location proposal connection costs are calculated by SNH.

Step 4: Selection of locations

On the basis of the present cost and benefit assessment, the decision for the selection of a location is made. If necessary, potential locations will be discussed in meetings with the responsible districts. Selected locations have to be applied as „special use locations“ by the districts administration.

Step 5: Implementation

As soon as the permits are available, the implementations start.

The following figure shows the location situation in Bergedorf. Two facts become clear. Firstly, there are few search spaces for the establishment of DC in Bergedorf, and secondly that a large number of locations must be considered in order to find a location for implementation. Search spaces refer to the macro perspective and define the spaces where you can search for DC location. As it may be seen, a large numer of non green dots in the figure below, a large number of locations must be "entered into the race" in order to set up a charging facility. Unfortunately, only one DC location could be implemented in the search spaces shown. Hamburg is currently striving for a scientifically sound evaluation of the location-finding process in order to make the further consolidation even more supported by criteria.

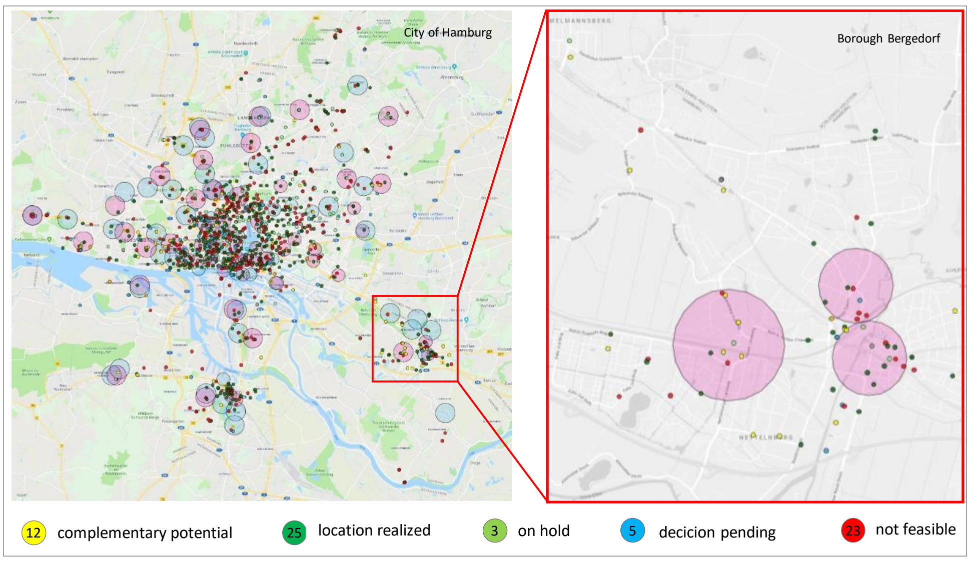

Figure 23: Examined locations in Hamburg-Bergedorf (Source: SNH’s own representation)

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4.1.4 Findings

The objectives described above for the construction of five DC fast charging stations and one high-power charging station could not be achieved in the project area in the Bergedorf district. But 64 DC Charge could be built up within the implementation phasis in Hamburg total. In essence, the aim is to pursue development that meets criteria and needs. This leads to development in the areas and at the microlocations that can be determined (and then also implemented) by the model used. As in many places (and especially in Germany), the speed of the development of electromobility was overestimated in the period before the current project. In reality, there has been a slowdown in electrification. This goes hand in hand with the strong realisation that in a city like Hamburg there are very different needs for charging infrastructure and for charging electric vehicles in public spaces.

When planning the content for the mySMARTLife project, it was assumed that, given the large number of planned charging points, the number of five DC charging points in Hamburg-Bergedorf would represent a realistic target value. As part of the comprehensive concept-based site inspections, only one DC charging station of the 64 successfully installed DC charging stations in the entire urban area could be set up. The charging requirements in a metropolis like Hamburg are very different. In particular, the need for rapid charging infrastructure is still low in peripheral areas (see Bergedorf). It can be assumed that in the context of the increasing number of electric vehicles in Hamburg in combination with the current rapid development of the Hamburg district of Bergedorf, further DC charging stations can be erected in the future.

The construction of charging infrastructure and, in particular, densification change with different drive technologies must be realised based on requirements and criteria. Allocation models make it possible to coordinate the construction and expansion of charging infrastructure and to communicate this clearly to other actors. With regard to the planned HPC infrastructure, the development in the vehicle sector was overestimated. To date, no market offer of HPC chargeable vehicles has developed. The vehicles are simply not yet available (with a few exceptions in the premium segment, such as the Porsche Taycan). Thus, no use case could be identified. As soon as the range of corresponding vehicles has been launched on the market, Hamburg will initiate the construction of the first HPC.

In an exchange with the partners involved in the development and in particular the engineering office ARGUS, the following four key findings from previous years were identified by the engineering office. (ARGUS, 2018)

- The densification patterns change with different drive technologies. Overnight and opportunity charging entail different requirements for the charging infrastructure environment: Places of interest, tourist attractions, densely populated residential areas etc. The use of the charging

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infrastructures should be consulted in an evaluation process to validate and optimise the location model.

- An E-Charging infrastructure strategy/ allocation models help to communicate transparently and support investment decisions. Many players know "the right" place for charging the infrastructure. The user-friendliness is good, but it should be placed in a broad context. Allocation models make it possible to coordinate expansion and communicate clearly with other players.
- Geoinformation is available almost everywhere in Europe and these GIS can help to easily understand complex geographic systems. There is an enormous potential to identify the ideal e-charging infrastructure and to keep track of the search process with suitable online tools.
- Strategies should adapt to change: Each city (city structure and fleet) is different - so there is no overarching network strategy. Chargeable network operators should use the results of the assessment to make changes to the charging patterns.

4.2 Load Management

4.2.1 Project description

In connection with the rapidly rising number of electric vehicles and the simultaneous growth in the number of charging stations, site-specific grid connection capacities are becoming increasingly important. The electrification of (public) fleets often shows that the existing grid capacities are not sufficient. The necessary expansion is usually cost-intensive. An intelligent charging technology, a so-called intelligent load management, provides a solution here.

In the mySMARTlife project, SNH was able to further develop the company's own IT backend with regard to intelligent load management and successfully demonstrate the functionality and suitability for everyday use of such a load control system.

4.2.2 Baseline situation

The Hamburg Senate is actively and steadily driving forward the expansion of electric mobility in Hamburg. In addition to the expansion of the publicly accessible charging infrastructure, the city's vehicle fleets are also to be electrified to an increasing extent. This electrification affects all vehicles of the core administration (e.g. authorities or senate), the state enterprises, the special vehicle fleets and the public enterprises of the Free and Hanseatic City of Hamburg (FHH). In this context, concrete targets for the proportion of battery electric vehicles have been developed (FHH, 2015). In the course of this conversion of Hamburgs conventional fleets to electric fleets of vehicles, the complementary construction and expansion of charging facilities for the various applications will be successively implemented over the coming years. These charging facilities can be located both in public spaces and in private commercial areas. The electrification of the vehicle fleet of the public space management department and the depot in Bergedorf shows the consistent implementation of the city of Hamburg based on the Bergedorf district.

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Stromnetz Hamburg GmbH (SNH) plays a central role in the expansion of the charging infrastructure in the procurement, installation and operation of the charging infrastructure. SNH acts as a central procurement agency (FHH, 2017) for charging infrastructure and provides framework agreements for charging infrastructure hardware upon which both SNH and municipal consumers can call for services. SNH advises the municipal partners and supports them with its expertise in the field of electro mobility, which has been built up over many years.

4.2.3 Concept/realisation

Step 1: Information technology basis

SNH always works on open source protocols and implements the current IT backend communication protocol OCPP v1.6. This protocol ensures the backend to charging infrastructure communication. In version 1.6 an optimised load management module is available, which provides the necessary functionalities. This OCPP version and in particular the ‘Smart Charging Module’ are necessary to ensure the load management functionality of the charging infrastructure. (OCA, 2019) All necessary testing procedures and software implementation tests have been properly performed.

The result step one: IT backend upgrade completed. The backend is prepared on the software side for piloting.

Step 2: Identification Usecase (pilot environment)

As part of the mySMARTLife project, the Bergedorf district is electrifying its vehicle fleet (see Section 5.4). It was decided that ten electric vehicles are to be used by the Bergedorf district. In particular, the use of the selected ten Renault ZOE cars provides a good basis for demonstrating load management functionalities. The following framework conditions lead to a selection of the site as a demonstration site:

- the grid connection capacities are limited, load management is necessary
- the electric fleet procured by HAM has a relevant size
- the charging infrastructure hardware used has not been selected, procured or installed and can therefore be tailored precisely to the vehicle fleet.

The result step two: the location was selected as a pilot.

Step 3: Hardware installation and backend connection

After SNH had designed the charging infrastructure and accompanied and supported those responsible in the Bergedorf district with hardware procurement and installation, the charging stations were installed and connected to the SNH IT backend (Schulz, 2019). The implementation at the demonstration site has the following characteristics.

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Function of load management: If the sum of the charging currents of all parallel charging processes exceeds the maximum charge, the previously installed charging management intervenes. This works on the basis of load distribution through prioritisation. Load management reduces the charging currents at the charging points with lower priority. If charging of a vehicle is paused or discontinued, this power is also distributed or forwarded to the other or prioritised vehicles.

Charging point gateway: The charging point management can be individually controlled by the e-Mobility Gateway. The result is a network that guarantees maximum connectivity with up to 16 satellites. The gateway can be subsequently integrated into the overall system of the smart charging points, but the gateway can also be taken into account during planning from the outset – as here in Bergedorf. A wallbox acts as a master and controls and manages the load flow and power distribution. This is not the only task of the Master. It also manages users and the corresponding access keys – in this instance, the RFID cards (numbers). Via the backend connection, the user can access each charging point and individually control and assign the priorities. Prioritised users can be defined. The system is designed to create an optimal charging solution, especially for fleets used for operational purposes.

Gateway - Backend: Communication between the operator and the stations with the gateway takes place via the Open Charge Point Protocol (OCPP). OCPP is a protocol that can change and save previously defined parameters (see above). Thus, all relevant data can be accessed via a web frontend. With the help of the web interface, monitoring functions for charging capacities, charging performances, uses, faults, etc. can be created. Permissions management is also possible here. Configuration of the load management functionalities is ensured.

The result of step three: the charging infrastructure hardware is ready for use.

Figure 24: Visualisation of the hardware installation at the demonstration site Kampweg (Source: SNH)

Step 4: Load management

In agreement with the Bergedorf district, the following steps were taken. The parameters of vehicle prioritisation on the user side were recorded and the necessary distribution of the available grid connection capacity was carried out.

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Figure 25: Setup of the demonstration site (Source: SNH)

Framework

- Limited connection capacity
- Different prioritisation based on the priority user profile: Two prioritised and further charging bays
- In bottleneck situations, the three defined charging bays are served at full capacity. The remaining power is divided equally among the remaining charging points. In this way, important vehicles, such as emergency service vehicles, can be secured

The result of step four: the vehicles, the optimised charging infrastructure and the load management were put into operation.

Step 5: Workshop

SNH is conducting a user workshop so that the municipal users of the charging processing can monitor and analyse themselves via the backend. Moreover, SNH is developing a simple software tool to support evaluation and to prepare the data.

The result of step five: The planned activities in the project have been completed. The goals have been met and the vehicles are in service. SNH will continue to support HAM and provide new generations of load management software and functions.

4.2.4 Findings

The sub-project can be regarded as a complete success. This is also reflected in the central data on the use of the charging infrastructure. The reported data refers to the period 04/2017 to 09/2019 and therefore represents the complete conversion phase. In principle, it can be stated that the vehicles are used to full capacity and in continuous use. In recent years, SNH has been able to support many Hamburg sister companies in the early stages of electrifying their fleets. In the first phases of electrification of urban fleets, we discovered that most electric vehicles only function as back-ups. This means that it is lesser-used vehicles that were more likely to be substituted and therefore travelled only a few kilometres and had to be charged relatively little or rarely. This was not the case during the pilot in the Bergedorf district. Immediately after integration into the fleet, the vehicles are in almost daily use and travel relevant distances. Here are the highlights:

- 10 charging points were connected to the vehicles for a total of 99,855 hours (5,991,273 minutes)
- On average, the vehicles were connected to the charging infrastructure for 15 hours a day
- 4873 charging operations were carried out in the project

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- 47,970 kWh were charged, which corresponds to the amount of energy required to fully charge the 22 kWh vehicle batteries of the Renault ZOE used over 2,100 times.

After evaluating the RFID card usage at the corresponding charging points, it becomes clear that the RFID cards are permanently assigned to the cars and charge the vehicles at assigned places. Only in rare cases are the existing RFID cards used at different charging points. The respective "main use" is shown in the graphic by a green marking. A total of 15 RFID cards are intended for use at the Bergedorf District Office in Hamburg, whereby one card serves only as a backup and has not yet been used. The following table shows the number of RFID cards used at the specific charging points. Here, the accumulation of charging processes in the fields with the green markings clearly shows that there is almost a one-to-one relationship between charging card/vehicle. The charging points are thus assigned to the vehicles. Here it becomes clear that the vehicles are assigned to a certain purpose. For details on the use of the vehicles, see section 3.4.

Table 5: Overview of RFID card usage (Source: SNH)

		RFID Card														
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	total
charging point	#1	1	1		480		1			1		1		2	440	927
	#2	1			1		1	1						319	8	331
	#3	2	7			8	1		1		626			4		649
	#4	1	2			663	2	1			9				1	679
	#5	1	1				3	600			5					610
	#6	1	488			1					8	1	1			500
	#7	1	1				1		226				1			230
	#8	1	3	5			38						179			226
	#9	1					268						30			299
	#10	1	3				2					413	3			422
	total	11	506	5	481	672	317	602	227	1	648	415	214	325	449	4.873

Table 6: Demonstration Kampweg - sessions, duration and consumption (Source: SNH)

Number of charging sessions				
Charging station	2.017	2.018	2.019	total
#1	121	472	334	927
#2	130	127	74	331
#3	253	235	161	649
#4	219	260	200	679
#5	188	248	174	610
#6	182	195	123	500
#7	104	83	43	230
#8	69	87	70	226
#9	79	138	82	299
#10	83	199	140	422
total	1.428	2.044	1.401	4.873

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Connection duration [h]				
Charging station	**2017**	**2018**	**2019**	**total**
#1	565	3.099	2.252	**5.917**
#2	2.978	4.651	2.732	**10.361**
#3	2.892	4.353	2.933	**10.178**
#4	3.696	4.530	3.008	**11.234**
#5	3.703	4.534	2.475	**10.712**
#6	3.165	3.955	2.699	**9.819**
#7	3.914	2.739	2.289	**8.941**
#8	3.456	3.263	2.084	**8.804**
#9	2.603	3.918	2.667	**9.188**
#10	3.512	6.377	4.812	**14.702**
total	**30.485**	**41.418**	**27.951**	**99.855**

energy consumption [kWh]				
Charging station	**2.017**	**2.018**	**2.019**	**total**
#1	362	3.869	2.619	**6.850**
#2	1.215	1.176	706	**3.097**
#3	2.154	2.537	1.766	**6.458**
#4	2.546	3.188	2.248	**7.982**
#5	1.790	2.420	1.706	**5.916**
#6	1.668	1.978	1.383	**5.029**
#7	1.507	995	516	**3.018**
#8	692	1.174	837	**2.703**
#9	741	1.387	943	**3.071**
#10	719	1.788	1.340	**3.847**
total	**13.393**	**20.514**	**14.063**	**47.970**

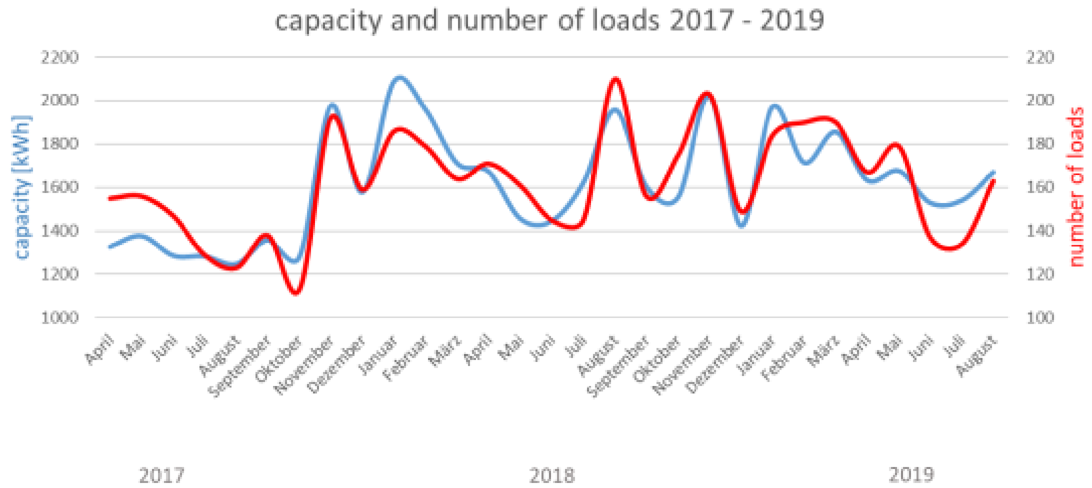

Figure 27: Graph of capacity and number of loads 2017 – 2019 (Source: SNH)

Let us now consider the number of charging processes and the amount of energy released over time. The high power charging stations are complete and qualified and have a Technology RL 8. Until now, no use case for an HPC has been identified in Hamburg. It is expected that there will be a use case for HPC so a TRL of 9 should be reached in the last year of the project.

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Lesson Learned

- The Hamburg Senate is actively and steadily driving forward the expansion of electric mobility in Hamburg. In addition to the expansion of the publicly accessible charging infrastructure, municipal vehicle fleets are also to be increasingly and promptly converted to battery electric drives.
- Location-based grid connection capacities play an important role in connection with the rapidly increasing number of electric vehicles and the associated increase in the number and performance of necessary charging stations. The electrification of (public) fleets in Hamburg shows that the existing network capacities in many places are not sufficient.
- The necessary expansion of connection capacities is usually cost-intensive and requires an expansion of the public network. This can be remedied by intelligent charging technology, so-called intelligent load management, and the use of an IT backend that uses open protocols to control charging processes and loads.

4.3 Clean energy charging stations connected to Energy Campus

4.3.1 Action Description

All implemented charging stations are supposed to be supplied with renewable energy. As far as possible the charging stations will be connected to the same grid connection as existing renewable energy sources of the Energy Campus of HAW. Together with a small scale load management and intelligent charging infrastructure the share of renewable energy consumption by electric vehicles will be raised. The achieved technology readiness level (TRL) is TRL 8, which means system complete and qualified. It will reach TRL 9 (actual system proven in operational environment) within the next month while monitoring phase is running.

4.3.2 Project description

The charging management flexibilize the charging processes of battery electric vehicles (BEV) at the technology centre Energy Campus of the HAW Hamburg. In this way, the share of renewable energy for charging processes can be increased.

The charging management is integrated into the existing building management system at the Energy Campus and is able to communicate with the charge controller of the wall box. It can initialize charging processes and vary the charging power.

By controlling the period of charging and the charging power, charging processes can be flexibly adapted to the supply of local renewable energies (e.g. wind energy). For this purpose, an optimization algorithm creates timetables for the charging processes, which represents the optimized charging power over time.

The timetables are generated based on the following points:

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- Input of the driver into the interface: The driver can communicate with the charging management, using a GUI (graphical user interface). The interface is realized with a tablet, which is mounted near the wall box itself. The interface asks the driver at what time the vehicle should be fully loaded. In addition, it still offers the option to initialize charging processes without flexibilization (that means the charging process starts immediately and with maximum charging power).
- Forecasts of the feed-in power of renewable energy sources into the public grid. The charging management has the ability to get up-to-date sources into the public grid from the internet. The data is provided by Stromnetz Hamburg on their homepage.
- SOC (state of charge, battery level) before charging: The SOC must be communicated to the load management so that the optimization algorithm can determine the required amount of electrical energy by taking into account the battery capacity of the vehicle and the charging power losses. The SOC is also given as an input into the GUI by the driver.

The GUI is accessible via web browser, so that the interface can also be displayed on other devices next to the tablet (e.g. on a smartphone).

4.3.2.1 Charging facility at the Energie-Campus

The charging station at the Energie-Campus is the wall charging station "wallb-e Home 22 kW" by wallbe GmbH. The charge controller is connected to the building network via an Ethernet connection. Communication with the charge controller can be realised using Modbus TCP. The wall box offers the possibility to regulate the charging power by regulating the charging current.

Figure 28: Wall box wallb-e [source: HAW]

The Multi-function meter shown on Figure 29 compensates for the wall box's inability to measure the charging power. The meter is integrated into the building management system and can be accessed by the charge management.

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Figure 29: Multifunctional meter “Sentron PAC 3200” [Source: HAW]

4.3.2.2 Forecast data

Stromnetz Hamburg GmbH is the distribution network operator for the electricity grid in Hamburg and provides a so-called "energy portal" online. The energy portal shows a range of information about the Hamburg electricity infrastructure. Among other things, data concerning the electrical load and generation (of the individual districts) and the transformer capacities of the substations are displayed (Stromnetz Hamburg GmbH, 2018a). In addition, under the category "Electricity Weather" forecast data regarding the feed-in power of wind and PV systems in the Hamburg power grid are displayed as figures (see Figure 30) and can be retrieved. The forecast data is given for every full hour and can be retrieved up to six days in advance (Stromnetz Hamburg GmbH, 2018b). Stromnetz Hamburg provides the actual feed-in power from wind turbines and PV systems on the following day.

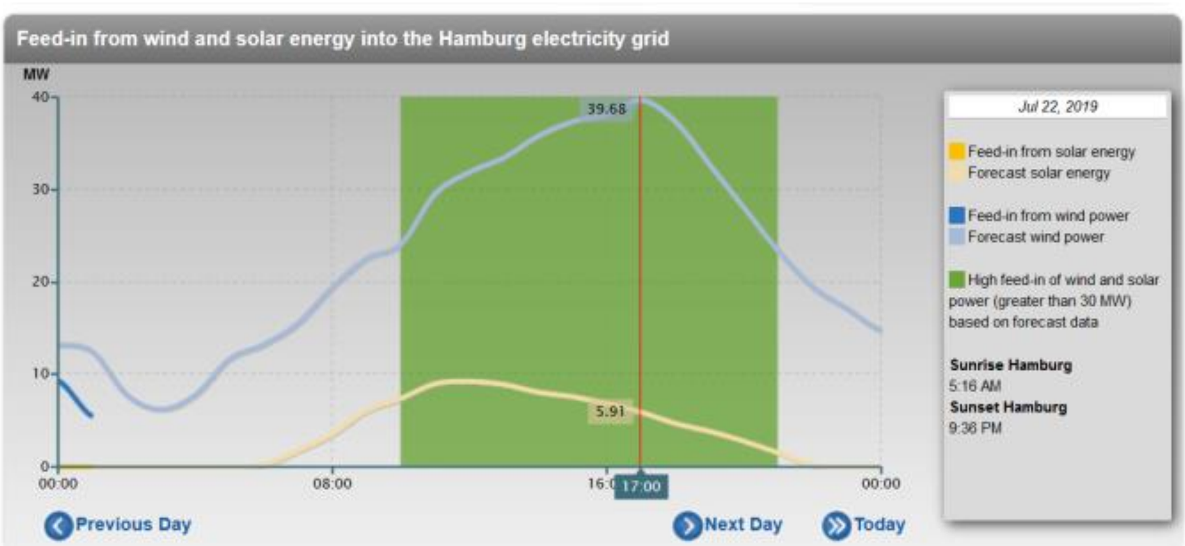

Figure 30: Forecast values regarding the feed-in power of wind and PV systems in the Hamburg power grid, shown in the energy portal of Stromnetz Hamburg

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4.3.3 Concept and Realization

Figure 31 shows how the components can be assigned to two different domains: The field domain (red box) and the management domain (blue box). The field domain includes the wall box, the Sentron PAC 3200 multi-function meter and the electric vehicle. The management domain consists of the load management including the GUI (incl. tablet) and a time series database (InfluxDB). The charging management itself and the GUI offer the user two different load options to choose from:

1) Environmental mode: The optimization algorithm calculates an optimal charging timetable based on user inputs and forecasting data.

2) Fast charging: The vehicle is charged with maximum charging power and immediately. This charging strategy corresponds to a charging process without the regulation of the charging management.

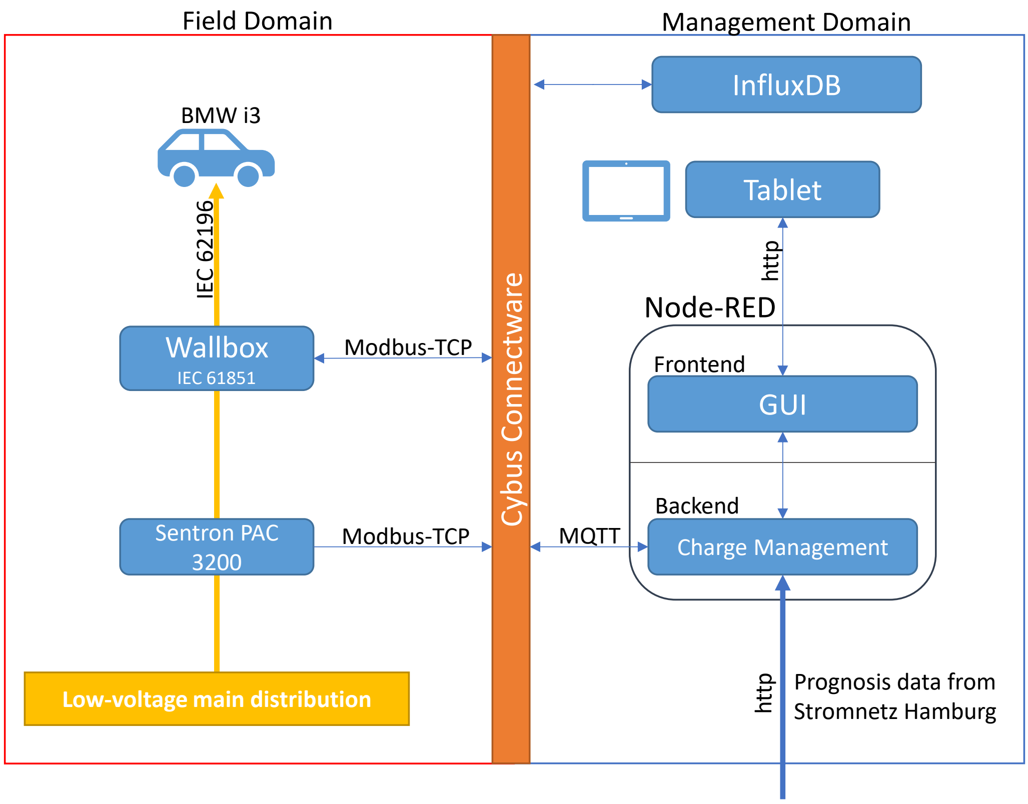

Figure 31: Design of the charge management with all components [source: HAW]

The communication between the electric vehicles and the wall box works according to IEC 62196. There is no possibility for the vehicle to transmit the SOC (state of charge) directly to the wall box. For this reason, the user is requested to manually enter the SOC into the GUI before charging. This is not necessary, if the BMW i3 from the Energy Campus is used, since the charge management can retrieve the SOC automatically from the online client portal of BMW (the BMW i3 is connected via sim card with

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the internet und sends vehicle information to BMW). Figure **32** shows a screenshot of the GUI for setting a charging process in the environmental mode.

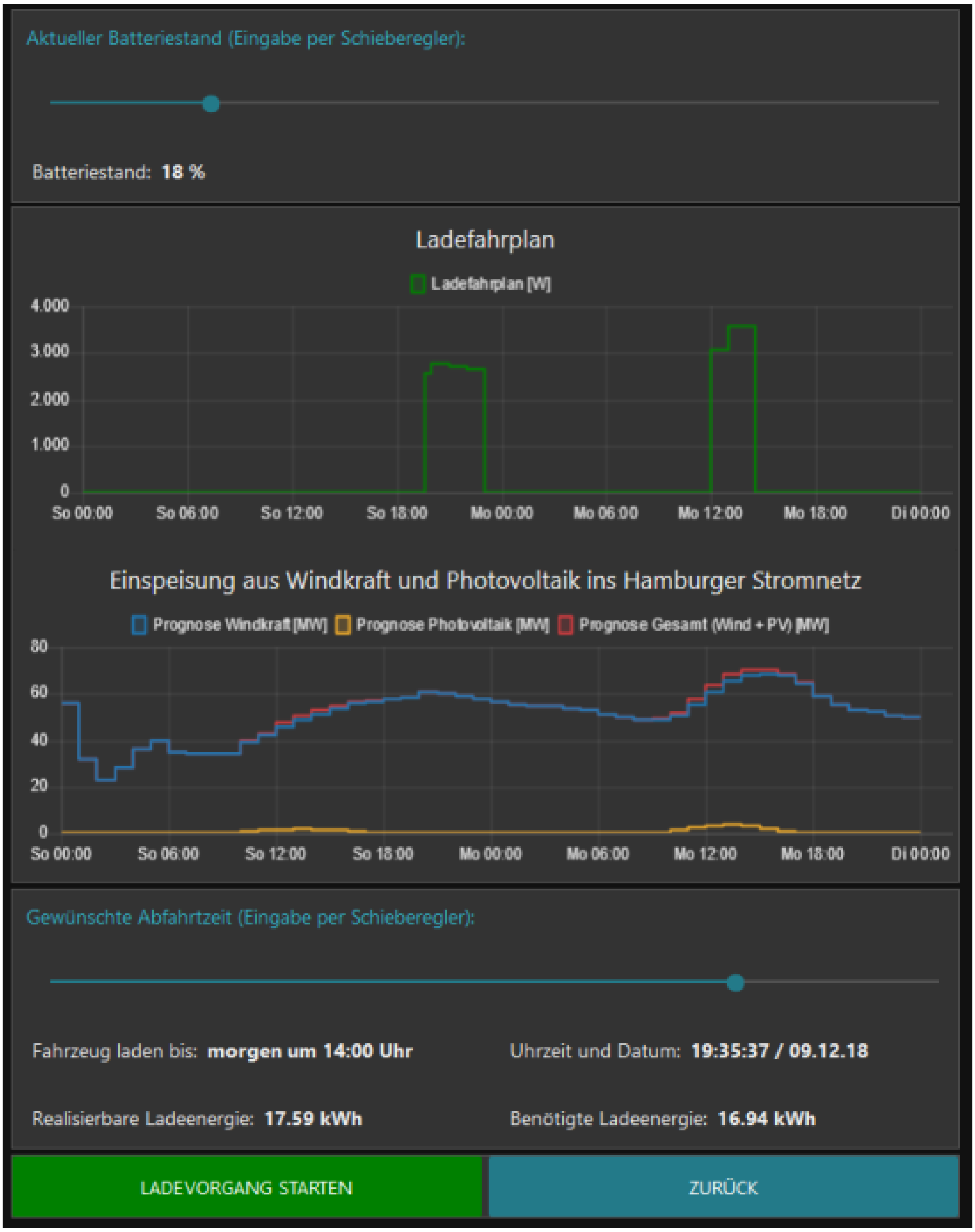

Figure 32: GUI for setting a charging process in environmental mode – The slider on the top enables the user to enter the current SOC – The diagram “Ladefahrplan” shows the optimized charging schedule – The diagram “Einspeisung aus Windkraft und Photovoltaik ins Hamburger Stormnetz” shows the prognosis data of Stromnetz Hamburg regarding the feed in power of renewables (blue: Wind power; yellow: Photovoltaics; red: Wind power + photovoltaics) – The slider on the button enables the user to enter the desired departure time (source: HAW)

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4.3.4 Optimization algorithm

The optimization algorithm creates a loading schedule to maximize the share of renewable energy during charging processes. Figure 33 describes the functional principle of the algorithm. The charging timetable is calculated based on various parameters (blue arrows). The parameters consist of the forecast data of Stromnetz Hamburg, the state of charge before loading (SOC_0), the current time (t_0) - which represents the earliest possible charging start - and the next departure time (t_n). Charging is therefore only permitted in a period between t_0 and t_n.

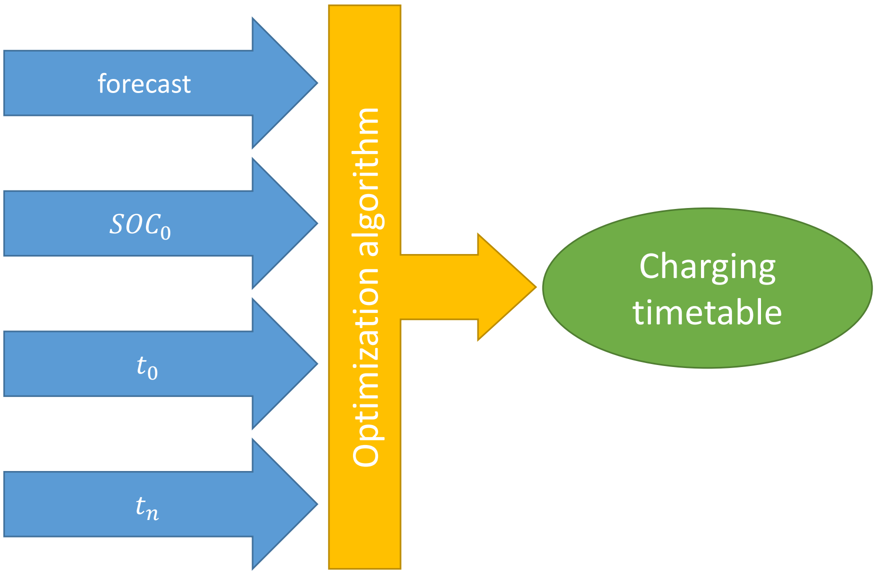

Figure 33: Functional principle of the optimizer (source: HAW)

In the following, the logic of the optimization algorithm is described based on two objectives and one constraint.

Objective

At the end of the charging process the SOC shall be 100%. For this purpose, the charged energy must correspond to the required charging energy. In order to determine the required charging energy, the efficiency of the charging process must also be considered.

When charging, the highest possible share of renewable energy should be used. Therefore, the algorithm is based on an internal cost function (which is not related to electricity prices etc.). At the end of the optimization process, the result of the cost function shall be as small as possible. The lower the result of the cost function is, the higher the share of renewable energies during the scheduled charging process. Therefore, the goal of the optimization algorithm is to keep the result of the cost function as small as possible.

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4.3.5 Conclusion

The project shows that charging processes of battery electric vehicles can be flexibly adapted by a charge management in order to significantly increase the share of renewable energies in charging processes. Crucial are free available prognosis data regarding the feed-in of renewable energy into the grid. The loading algorithm could only be realized on the basis of forecast data, which are openly available on the Internet. The higher the quality of the forecast, the better the solutions which can be created to intelligently adapt charging processes to the supply of renewable energy.

- During the testing phase of the charge management, the share of renewable for charging processes could be increased between 26% and 89%. For the evaluation, actual data for the feed-in power and residual load of Hamburg-Bergedorf was used.
- During the monitoring phase, the charge management is validated in daily use. The increase of the share of renewable energies depends on the potential during the existing charging time window.
- Another aspect that will be examined during the monitoring phase is the change in the target value (instead of the share of renewable energies). With regard to network supportiv operation, it may be useful to optimize for different parameters.

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5. Further inter- and multimodality strategies

This chapter describes approaches and strategies to foster inter- and multimodality in Hamburg in the context of the project mySMARTLife. The implemented approaches within mySMARTLife consider the fact that the project area in Hamburg-Bergedorf is located in the outskirts of the city. The outlying location is relevant for inter- and multimodality strategies, whereas most companies that offer such service focus the inner city areas and not the outskirts. In mySMARTLife, financial self-sustaining mobility concepts could be established, which are designed to remain in operation beyond the end of the project. For one thing, a community car-sharing is implemented in a housing quarter and for the other, the existing multy modality platform in Hamburg called "switchh" is to be further developed, in order to be realized in Hamburg-Bergedorf. Both approaches are supplemented with specialised charging infrastructure concepts, developed by SNH during the project. Since car, bike and ride sharing concepts are the basic corner stones of multimodality in Hamburg and the usage numbers have increased sharply in the last years, the chapter starts with a short overview about the different car-sharing services in Hamburg.

5.1 Car-sharing in Hamburg

The following chapter provides a short overview about Car-Sharing in Hamburg, an introduction of the realised community car-sharing concept in mySMARTLife and in the end a concept for a charging infrastructure solution adapted to the requirements of community car-sharing is described.

5.1.1 Overview of car-sharing services in Hamburg

The use of car-sharing services has increasingly become a popular form of transport in recent years. Especially in larger cities, there is a wide range of car-sharing companies, which favor the goal of reducing the number of cars per person in the city. The flexible lifestyle and the inner-city parking shortage increase the attractiveness of this form of mobility.

In Hamburg there are about 1,700 vehicles of the classic car-sharing options, which are distributed among 11 different providers (Scherler N., 2019). This puts the city in 10^{th} place among German cities in terms of the ratio of car-sharing vehicles to people.

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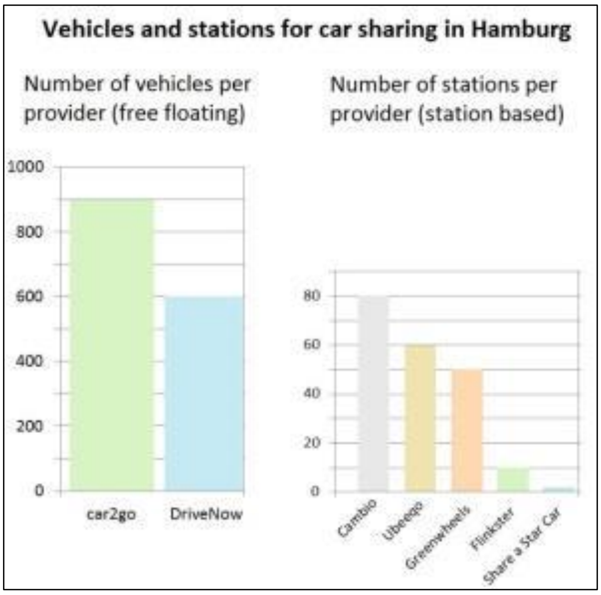

Figure 34: Vehicles and stations for car-sharing in Hamburg (based on Scherler N., 2019)

There are different types of car-sharing. In Hamburg, station based and free floating are the classic options. The traditional approach - station based - means that the cars are coupled to a fixed station and usually have to be reserved with a longer lead time. Free floating car-sharing vehicles, on the other hand, can be borrowed and parked anywhere within a defined business area, which results in greater flexibility. These cars also do not need to be reserved beforehand. Another method is private car-sharing, also known as share-economy. Private individuals offer their own vehicle for rental (Bach M., 2019). Mobility forms, such as ride-sharing or ride-pooling prevent people who have combinable start and destination points from travelling the distances individually. With ride-sharing, private individuals can take passengers with them in their car for a fee (Universität Mannheim, n.d.). Ride pooling is carried out by companies that use a matching technique in which different people with similar destinations are transported in one vehicle. The use of the offers is uncomplicated; reservations are mainly made via smartphone apps, while payment is automatically debited from the credit card.

Cambio, Citeecar, Flinkster, Greenwheels, Oply, Share a Starcar and Ubeeqo are the providers in Hamburg for station-based car-sharing. The most common free floating providers in Hamburg are car2go, DriveNow, Miles and Sixt share. Drivy and Snappcar are private car-sharing services. The best-known organization that forms networks for ride-sharing is BlaBlaCar. Ride-pooling providers in Hamburg are Clevershuttle, FreenNow Ride, Ioki and Moia (Scherler N., 2019). Clevershuttle, who used solely fuel cell and battery electric vehicles recently discontinued their operation in Hamburg since their main competitor Moia substantially expanded their services.

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The concept switchh, which was developed by Hamburger Verkehrsbetriebe HVV, consists of a network of Car2Go, DriveNow, cambio and StadtRAD with public transport. After the registration the user has price advantages and can prospectively, book with one app a vehicle of any offeror (Hochbahn, n.d.).

5.1.2 Advantages and disadvantages of different types of car-sharing

In the following, the advantages and disadvantages of different car-sharing types are highlighted. The approach of station based car-sharing can be seen as a suitable option for longer distances. However, a rather spontaneous use is difficult. Free floating car-sharing, on the other hand, can only be used for shorter distances because a fixed business area is defined. A clear advantage of free floating car-sharing is the high degree of flexibility. These two classic variants of car-sharing include the parking costs; in some cases there are even reserved parking spaces for those vehicles. These conditions contribute to the fact that the classic types of car-sharing are very user-friendly and show clear advantages in this respect compared to the use of a private car. What makes dealing with the sharing economy less attractive, is dealing with private property. However, owners have the possibility to earn some extra money while their car is no longer parked and not being used (Ludowig C., n.d.). In respect to environmental aspects, ride-sharing and ride-pooling generate a higher utilization of available space and seats in vehicles. Thus, the number of individual cars and, consequently, emissions can be reduced. From the user perspective, it is a further advantage that travel costs are shared and also social contacts can be made during the ride.

It can be said that the basic intention of car-sharing systems is to reduce private ownership of cars. However, the availability of car-sharing options can also be seen as factor generating additional car traffic as this form of mobility is in some regards an attractive alternative for public transport systems users or bike riding. Accordingly, car-sharing can compete with the car industry, railway companies and public transport. A further positive fact of car-sharing is the marketing and advertisement of e-mobility, as many companies offer e-cars.

In order to relieve the public space of residential quarters, more and more cities are starting the so-called community car-sharing, at best with electric cars. Station based car-sharing services are bundled in the neighborhood with the aim to promote the electrification of neighborhood mobility. In Hamburg, the e-Quartier project investigated the shared use of vehicles by up to 400 users at a total of 14 locations (Bönninghausen D., 2017). The idea behind this approach is to make the space that is usually occupied by parked cars available again for the people once the number of private cars is minimized. Private cars require a relevant large amount of space and most of the day they are not in use but parked alongside the streets. It has been shown that one car-sharing vehicle can replace up to 20 private vehicles. The availability of car-sharing cars in their neighborhoods persuaded many residents to sell their cars, whereas car-sharing turned out to be more cost-effective for them (Bundesverband Car-sharing, 2016).

Since there are a number of positive aspects of car-sharing, it can be expected that these services will be further expanded in the future. Especially in larger urban areas, the car-sharing vehicles have a high

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utilization rate, especially in the age group from 18 to 45 years. Respondents perceive car-sharing as very positive and for 50 percent of them it is an alternative to owning a private car (Automotive Institute for Management, 2012).

5.1.3 Community Car-sharing in mySMARTLife

As described in the previous section, car-sharing is expected to reduce the number of cars on the road by up to 20 cars per car-sharing car (Bundesverband Car-sharing, 2016). In residential areas, this has a particularly positive effect on stationary traffic, as many residential areas in Hamburg are now experiencing a considerable reduction of public spaces due to the increasing density of residential areas. With the reduction of cars and their parking areas and the simultaneous development of car-sharing stations in residential areas, the City of Hamburg intends to reduce traffic, pollutants and recover public space.

One larger problem, however, is that the car-sharing and ride sharing companies are mainly located in the centre of Hamburg, as this is the catchment area with the most customer potential. In this area the companies are in fierce competition with each other and partly also with public transport, which also generates its turnover primarily in this area. In some urban areas, already a congestion of free floating car-sharing services can be seen. In order to meet these problems and link the public transportation with car-sharing services, the Hamburg local transport company Hochbahn has developed the multi-modal concept “switchh”. “switchh” is not only visible at central railway stations in form of multi-modal switching points where users can switch between different modes of transport, it is also a system than soon will offer routing services that acknowledge and combine different forms of mobility in an easy accessible form (see Chapter 5.3.3).

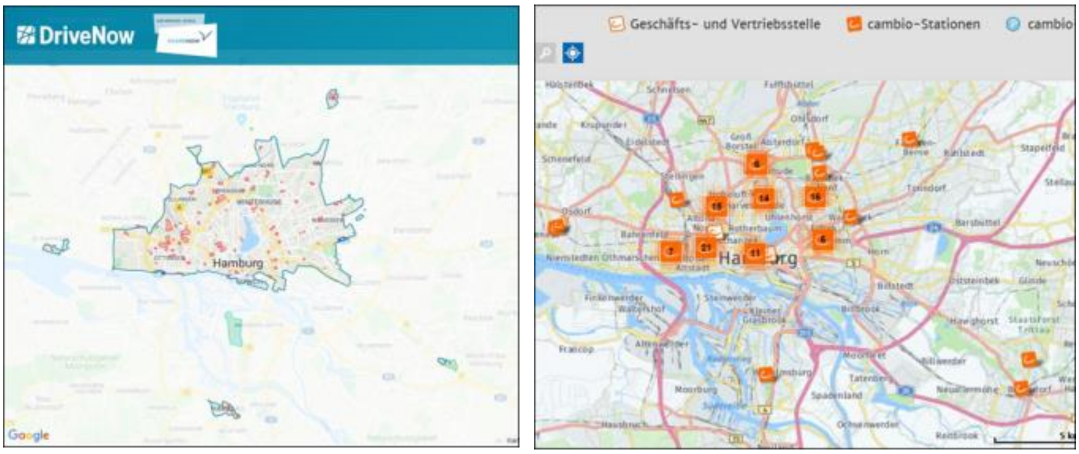

Figure 35: Two screenshots of booking portals. The left shows the business area of the free floating car-sharing provider drive now, and the right one shows the stations of the stationary car-sharing provider cambio. Both show the typical concentration of car-sharing operaters on the inner city areas (source left: DriveNow, 2019; source right: cambio Car-sharing 2019)

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In a similar way, the community car-sharing approach in mySMARTLife in Hamburg-Bergedorf attempts to solve the problem of over-concentration of car-sharing companies in the lucrative inner city and increasing space usage of parked cars. Community car-sharing is an attempt to offer car-sharing directly in a residential area, with a permanent community of residents and users. To this end, the Borough of Bergedorf approached several players in the housing industry and also car-sharing companies and developed a pilot project together with the project partners VHH and SNH. Especially the collaboration with VHH in this concept should be a new approach, whereas VHH is a municipal bus operator and was not involved in any car-sharing services before. This collaboration could become a new area of business for the VHH, with this intention; the established service should remain in operation after the mySMARTLife project. In addition to the development of a new operator model, it is the aim, to offer e-cars and charging infrastructure for the car-sharing, to promote e-mobility and save further emissions.

5.1.3.1 Procedure for implementation of the community car-sharing in the project

The implementation of community car-sharing in mySMARTLife can be divided into two different approaches. At the beginning of the project, the former project partner VW was still responsible for the implementation and the Borough of Bergedorf supported the project partner. The focus was here clearly on the implementation of an e-car fleet together with a software solution for car-sharing from VW. The goal was that VW provides the cars and the software and a housing company or a community of residents should then operate the car-sharing independently. The Borough of Hamburg-Bergedorf organised a workshop between a larger housing cooperative, the Bergedorf Bille gGmbH, and VW. In addition, Stromnetz Hamburg was involved as an expert for charging infrastructure. It quickly became clear that a housing company is usually not interested in operating its own car-sharing system or maintaining a car-sharing fleet.

After VW left the project, the Borough took over this action and developed a new approach. This approach seeks to establish community car-sharing in a peripheral residential area, by involving different partners with their specialised competences. This should reduce the economic risk for the prospective operator. This would be necessary, because the location that was chosen for this concept differs largely from areas, where car-sharing companies are usually operating, since the Borough of Bergedorf is located considerably far away from the usual business areas of most car-sharing operators. Participants in this approach are: the Borough of Hamburg-Bergedorf as initiator, the Bergedorf Bille housing cooperative, which establishes contacts with its cooperative members, the VHH for vehicle service and as marketing organiser, and cambio Car-sharing as the actual car-sharing operator. The exact tasks of the individual partners are explained in more detail below.

5.1.3.2 The roles of the involved partners

Bergedorf Bille Wohnungsbaugenossenschaft

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Bergedorf Bille is an established housing cooperative in Hamburg, with a housing stock of around 9,000 apartments, predominantly in the Borough of Hamburg-Bergedorf. On the one hand, the housing cooperative provides important access to its cooperative members. This will enable the VHH and cambio to promote the car-sharing service directly, e.g. directly at members' meetings or in the cooperative magazine. Through the support of the cooperative, possible inhibitions in the use of cambio Car-sharing should also be reduced. On the other hand, the housing cooperative is the owner of the parking spaces and will become the owner of the charging infrastructure for the e-cars. At the same time, Bergedorf Bille helped to find the right location with its specialized knowledge of its tenant structure.

cambio Car-sharing

The company cambio Car-sharing is an established car-sharing operator for stationary car-sharing. It operates more than 80 stations in Hamburg, some of them are already located in residential areas. In Hamburg-Bergedorf cambio is so far only represented at the “switchh” location at the Bergedorf railway station (see chapter 5.3.1). As part of the community car-sharing in mySMARTLife. Cambio advised on the choice of location from the economic perspective of a car-sharing operator. Additionally to the operation of the vehicles, cambio also offers the booking platform for the vehicles and assumes the customer service.

VHH

The public transport operator VHH and cambio are together responsible for the marketing of the station and establishment of a user community, which will go well beyond the monitoring phase to ensure successful operation of the car-sharing station after the project. Therefore, it will be possible to register for the car-sharing in the main info shop at the bus platform of the Bergedorf railway station. For the registration the users need to complete a form and verify their identity with a valid driver's license. In addition, the VHH will clean and maintain the vehicles at regular intervals. For this a corresponding agreement will be concluded between cambio and VHH.

Stromnetz Hamburg GmbH

In the beginning of this task, the beneficiary Stromnetz Hamburg GmbH (SNH) intended to provide the required charging infrastructure. This system would have a back-end connection other charging stations from SNH have as well, which would have among other services allowed the direct collection of data from this station. After a number of consultations by SNH on available charging infrastructure, Bergedorf Bille, however, decided to use a system that is not supported by SNH. Yet, together with cambio SNH advised Bergedorf Bille on the procurement of the charging infrastructure.

Borough of Hamburg-Bergedorf

The district of Hamburg-Bergedorf was able to bring the partners together, due to its knowledge of local players and moderated the development process. After an initial start-up phase, when the business

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relations are established, the Borough of Bergedorf will no longer play a role in this action. Eventually, it is planned that the partners will continue this action without further coordination by the Borough.

5.1.3.3 Standortauswahl und Stand der Umsetzung

In the course of implementation, several sites in Hamburg Bergedorf were investigated. The main criteria were that the amount of potential users had to be large enough to carry on this station beyond the project duration. The search was quickly narrowed down to the Bergedorf district of Lohbrügge, as the housing cooperative Bergedorf Bille owns there a large number of apartments.

Within this urban district, a parking lot in “Gördeler Straße” was examined first as a possible location. Initially, this location appeared to be suitable, but it turned out, that new buildings will be buildt here in the medium termand, and it was feared, that the construction site would have a negative effect on the use of the station especially. The final location that was chosen is only one street away from the previously examined location. It is on a tenant parking lot of Bergedorf Bille at the street Binnenfeldredder. The location is located at a main road what makes it clearly visible and easily accessible for tenants. In addition, three bus lines stop in the immediate surrounding and a “StadtRad” bike-sharing station is being built in the immediate vicinity. This allows for an easy change between the different mobility services.

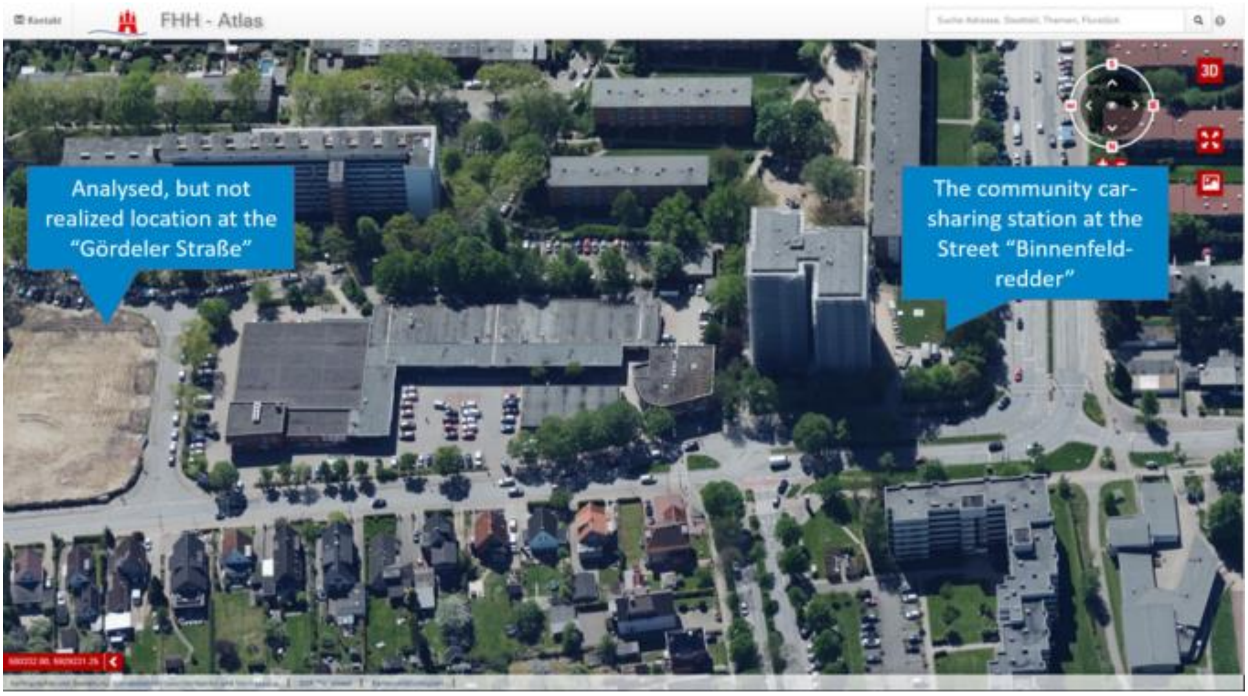

Figure 36: Arial view of the car-sharing location (source: Borough of Bergedorf, Aerial Picture: Landesbetrieb Geoinformation und Vermessung Hamburg, FHH – Atlas)

The station was solemnly opened during a neighbourhood party as part of the marketing campaign. For the start, one passenger car with a combustion engine is available at this station. The start with a non-electric vehicle should help to reduce first fears of contact with this new mobility service among the

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residents. At the beginning of 2020, an e-car including charging station will be installed there and another non-electric car, a small van, should follow to complete the available range of vehicles at this community car-sharing station.

Figure 37: Opening of the community car-sharing station October 2019 (source: VHH, Jacob)

The VHH has started a marketing campaign to make the station present among the residents and to promote it during the difficult start-up period. Cooperative members will be able to register at cambio free of charge and it is planned that they will be able to register directly at a central VHH information point at the Bergedorf railway station. Furthermore, the station will also be advertised at tenant events and in the member newspaper of the cooperative. Afterwards the station is to be advertised by a longer-term marketing campaign beyond the start phase. This is regarded as an important point for establishing this community car-sharing station beyond the mySMARTLife project.

5.1.4 Key findings

In Hamburg, a large number of car-, bike- and ride-sharing companies have already established themselves. The City of Hamburg regards car-sharing as an important approach to reduce individual car traffic. This accounts especially for the reduction of less frequently used vehicles, which at the same time occupy a lot of parking space in residential areas.

However, most car-sharing companies are concentrated in the Hamburg city centre, as this is the area, with the greatest customer potential and a spatially concentrated range of station services is easier to maintain for the companies. In order to reduce commuter traffic, however, car-sharing must also be offered in residential areas in the outskirts of the city.

The biggest challenge in the development of car-sharing stations in residential areas is the start-up phase. A permanent user community needs to be developed as quickly as possible around the station, so that the station is economically viable. For this purpose, the station must be positioned as visibly and easily accessible as possible. Moreover, the residents must be addressed directly and simply several times by reliable project partners. It should also be as easy as possible to register and to book the car-sharing services.

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The concept developed in mySMARTLife distributes clear roles and tasks. The partners contribute their strengths and were able to develop new business models. The public transport company VHH, for example, is able to increase the capacity of its workshops by maintaining the community car-sharing cars, and the existing public transport network with buses will be supplemented and consolidated. Bergedorf Bille can offer its cooperative members a new attractive service and benefits from a reduction of occupied parking spaces in the residential areas. For the car-sharing operator cambio, the cooperation reduces the economic risk in the start-up phase of the new station and enables the company to promote the station more specifically within the local community. The tenants of the cooperative Bergedorf Bille, as the actual community, regain space by reducing the number of parked cars in residential areas without having to give up individual mobility by car. The gained space can in turn be used for green areas or open spaces.

The Borough of Hamburg-Bergedorf also benefits from an expansion of the mobility offer in the district while at the same time reducing traffic. Since in the growing city of Hamburg there is only very limited space available, new forms of mobility and community car-sharing stations should be taken into account during the planning phase of new residential areas.

5.2 Charging infrastructure solution for communtiy car-sharing

5.2.1 Project description

The activities in this action can be divided into two separate approaches. There was also an adjustment due to the recently approved amendment. In principle, the overriding goal is to electrify the real estate sector in order to enable residents to switch over to electric mobility or to make the transition to it. In order to use the given connection capacities efficiently (especially in the case of a further future ramp-up), load management is often necessary here. Thus, the "intelligence" on the part of the hardware and backend functionalities used plays an important role.

SNH intends to develop charging infrastructure solutions that meet the special requirements of urban residential areas, e.g. with regard to

- limited connection capacities of buildings
- the design and choice of charging infrastructure
- the definition of necessary backend functionalities
- billing procedures for residents and mobility providers.

In the following, the different approaches of this action will be examined in more detail.

5.2.2 Baseline situation

One of the central challenges in connection with urban development, urban redevelopment and the ongoing implementation of the Hamburg Housing Programme is the question of how housing and mobility can be linked as intelligently and sustainably as possible in the future. In the fields of both housing and

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mobility, Hamburg is continuously developing its strategic approaches and the implementation concepts derived from them. An important element here is the expansion of electric mobility (FHH, 2015). This is not only expressed in the growing number of low-emission battery electric vehicles and the corresponding charging infrastructure, but also plays an increasingly important role in the implementation of intermodal, i.e. cross-modal, mobility concepts and in the integration into urban district development, both in new and existing buildings.

5.2.3 Concept/realisation

Approach 1: Charging infrastructure for private electric vehicles of local residents

The aim of the action is, together with the housing industry, to create charging facilities for residents of a neighbourhood in order to demonstrate a further approach to switching from private mobility to electric vehicles. To achieve this goal, SNH has conducted a series of extensive but unfortunately unsuccessful workshops with representatives of the real estate industry. These discussions have shown that there is pronounced cost sensitivity.

The experience from the various efforts together with the housing industry to design the electrification can be summarised as follows:

- Companies in the real estate industry have a wait-and-see attitude towards electro mobility (and car-sharing) and are not yet prepared to make substantial financial investments. The role of the housing industry actors in project implementation is often determined by the structural context.
- For projects in the new-build sector, the role of the project executing agency and developer is defined first and foremost as securing the technical prerequisites and providing the technical infrastructure up to the transfer point of the charging equipment.
- In the case of projects in the portfolio, the role of the portfolio owner or the actors from the real estate industry is often merely perceived as involvement in the implementation of technical requirements. In most cases, however, it does not cover joint expenditure on local infrastructure. Accordingly, electric mobility in the area of charging infrastructure is still in its infancy in the housing sector. Here a change is only gradually taking place. A further barrier to the implementation of the initially pan-European objectives within the remaining project period was the lack of relevant new construction projects in the implementation area.

Approach 2: Neighbourhood car-sharing concept

Since it was not possible to set up a private charging infrastructure together with the housing industry, the focus was on mobility concepts. Car-sharing vehicles are to be made available to the residents. The use of these vehicles is intended to replace private vehicles with internal combustion engines. As a result of the situation described above, an alternative implementation was initiated with the partners Volkswagen, Verkehrsbetriebe Hamburg-Holstein and the real estate partner Baugenossenschaft Bergedorf Bille: a

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Volkswagen car-sharing concept created specifically for the housing industry, a so-called "car-on-demand concept" with electric vehicles, which will be implemented in a residential building of the partner in Bergedorf Bille. After Volkswagen left the consortium the approach was continued, but a different partner setting was found. A new experienced partner from the field of car-sharing was successfully convinced to join the programme: Cambio Car-sharing. This partner already has a wealth of experience in the field of car-sharing in Hamburg.

5.2.4 Findings

In the course of advising and supporting the project, Stromnetz Hamburg elaborated on the central technical hardware and software requirements for the required charging infrastructure in detail and made them available to the implementing project partners (Cambio and Wohnungsbaugenossenschaft Bergedorf-Bille).

The following central points were defined:

- **Data communication**

OCPP 1.6 all profiles – particularly important for charging and load management as well as other topics such as car park detection etc.

- **Communication in general**

Communication must take place via GSM/GPRS/UMTS/LTE network as well as via cable connection (broadband) and WLAN in the current standard. Communication via cable must be possible in addition to the other listed communication channels (cost advantage). It must be possible to set up an own VPN to the backend server landscape.

- **Direct data communication**

There are many manufacturers that permanently connect hardware to their (proprietary) backend. This is especially important for further scaling, as they are able to integrate charging infrastructure products from different manufacturers. It should be possible to connect and control this LI via an IT system. You therefore need 100% access rights to the charging infrastructure.

- **Configuration interface of the charging infrastructure:**

If you cannot configure the charging station, then you are not flexible at the backend. The requirement is, therefore, that the service interface B is in place.

- **Updates and control**

Remote access (from afar) and without a maintenance/update contract must be in place. We handle this in such a way that we check the updates and then make them available to our partners in the system – you

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can then accept the already tested update and your infrastructure will be updated. The update then takes place automatically at non-productive times.

Lessons learned

- The companies in the real estate industry have a wait-and-see approach to electric mobility (and car-sharing) and are not yet prepared to make necessary investments or take equity stakes.
- Apartment buildings and apartment owners in particular face legal obstacles: often tenants do not yet have the option to install their own private charging station at their parking space.
- Car-sharing can make a substantial contribution to reducing the number of vehicles in a city such as Hamburg and to the targeted use of electric vehicles.

5.3 Development of multi modal hubs in Hamburg

The following chapter gives an overview of the existing multi-modality platform in Hamburg, called "switchh", and its further development in the mySMARTLife project. In the following, a concept for a charging infrastructure solution adapted to the requirements of multi-modality is described.

5.3.1 Initial situation: The transportation hub at the Bergedorf station

Already at the beginning of the project, it became clear, that in the Hamburg project area, the railway station and its surroundings in the Bergedorf district, is by far the most important local transport huband therefore also the central location with the highest potential for a multi modal hub in the Borough of Hamburg-Bergedorf.

This main transportation hub in the east of the City of Hamburg is a combined railway and rapid transit station, which provides daily connections to regional and interregional destinations (including Rostock, Schwerin) and rapid transit connections in the direction of the Hamburg city centre and other destinations in the surrounding area.

Part of this hub is also the central bus station, from which buses of 27 bus-lines travel through the Bergedorf city centre, the rural area “Vier- and Marschlande”, the southern outskirts of the borough, as well as other municipalities of the Metropolitan Area of Hamburg. This traffic hub is supplemented by three garages; two of them are reserved for commuters (Park&Ride) with together 548 parking spaces and one public garage with 430 parking spaces. Regarding bicycles, there is one bicycle garage (Bike&Ride) with 214 parking spaces, 50 lockable bicycle boxes and a bicycle station from a local company (bicycle garage and workshop) with additional 500 parking spaces. Furthermore, this transportation hub is complemented by a station of the Hamburg bike sharing service “StadtRad” and a station of the Hamburg multimodal mobilityplatform called “switchh”.

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Figure 38: Aerial view of the transportation hub at the Bergedorf station (source: Borough of Hamburg Bergedorf, own source, Background picture: Landesbetrieb Geoinformation und Vermessung Hamburg – FHH Atlas)

5.3.2 Description of the approach in mySMARTLife

The further development of the transport hub at the Bergedorf railway station in the mySMARTLife project to a multi-modal hub is divided into two phases. At first, an attempt was made, together with the former project partner VWG, to develop one of the multi-storey car parks into a so-called "Mobility Warehouse". Various discussions were held with the Hamburg Park&Ride company, as well as with the operator of the multi-storey car park of a nearby shopping centre. VWG's aim was, to offer a comprehensive range of mobility services for citizens. This should have included the implementation of charging stations, the provision of rentable e-bikes and electric scooters, so-called last mile people movers, from the VW brand, as well as the integration of these services into a proprietary VW App. The Borough of Bergedorf supported the partner VWG in the talks with the car park owners, Stromnetz Hamburg advised on the necessary charging infrastructure. In particular, the construction of optimised commuter charging stations in the Park&Ride multi-storey car park (see chapter 5.4.3) and the integration of the Bergedorf city centre into the new VW Park App WePark were examined. However, VW's other products proved to be not yet fully developed, e.g. the last-mile-people-mover or a parking app with a gamification approach. In addition to this, VW's financing of the commuter charging stations was not secured either.

After the withdrawal of VWG from the project, the remaining partners are now pursuing a new approach that focuses on the existing multi-modality mobility service “switchh” run by the public transport operator “Hochbahn”. The switchh point at the Bergedorf station offers parking spaces for different bike-sharing and car-sharing providers. Three fixed parking spaces are reserved for stationary car-sharing cars from

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cambio and eight further marked parking spaces, which are marked green, are reserved for cars from the free floating car-sharing providers DriveNow and car2go, which are now part of the joint venture SHARE NOW. With this new approach, the development of a Multi Modal Hub and integration in a common mobility app, the project partner HAM is pushing the integration of the different mobility forward. Simultaneously, the project partner SNH is developing concepts for the electrification of the switchh throughout the Hamburg city area (see loading concept switch Section 5.3.3).

5.3.3 switchh as Hamburg’s multi modality platform

As mentioned above, the multi-modal mobility platform "switchh" is operated by the public transport operator “Hochbahn” within the Hamburg Transport Association (HVV). "switchh" connects the HVV's public transport services with supplementary mobility services such as car-sharing and bike-sharing. The aim is to enable access and use of the various mobility services particularly in an easy and convenient fashion in order to offer (city) residents an attractive alternative to owning a car. Through the connection of public transport with bike- and car- sharing providers, it is intended to provide more individualized mobility services and ensure mobility options for use cases that public transport cannot cover. The combined offer of switch improves users’ overall public transport experience, since bike- and car-sharing services offer an especially adept solution for the first and last mile.

The objective is to provide an attractive and convenient alternative to the use of private or company cars in a user-friendly way and to facilitate switch to public transport in combination with sharing offers and thus reduce the number of inner-city cars.

“switch” initially started as a 2-year pilot project in 2013, with the first pilot phase being carried out with one free-floating car-sharing provider and a rental car provider as partners. The first “switch” points initially concentrated on the large transfer stations in Hamburg. In 2015, after the pilot phase, the concept was also opened for stationary car-sharing services. "cambio Car-sharing" successfully asserted itself here and became a switchh partner. At the beginning of 2016, eight switchh points were in operation. Over the following years, the number has increased significantly. In 2018 alone 30 decentralised switchh points were set up in the high density residential areas of the inner city. In October 2019, 72 switchh points are in operation; a distinction is made between regular switchh points, recognisable by a green mark on the ground at the transfer stations, and between so-called "micro switchh points", which are located in the streets of the densely populated Hamburg city centre. The current partners are:

- Hamburger Hochbahn as the central operator of the app and the stations
- FreeFloating Car-sharing: SHARE NOW with car2go and DriveNow
- Cambio Car-sharing with stationary car-sharing services
- The public bicycle sharing provider in Hamburg StadtRAD

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These partners are allowed to use the green marked areas for parking and can also be found in the Hamburg Mobility App, the HVV App.

5.3.4 The three components of switchh

Overall, the switchh platform consists of three pillars: firstly, a spatial connection and visual bundling of offers, secondly, one price model and thirdly, a joint app. These modules are presented in the following section.

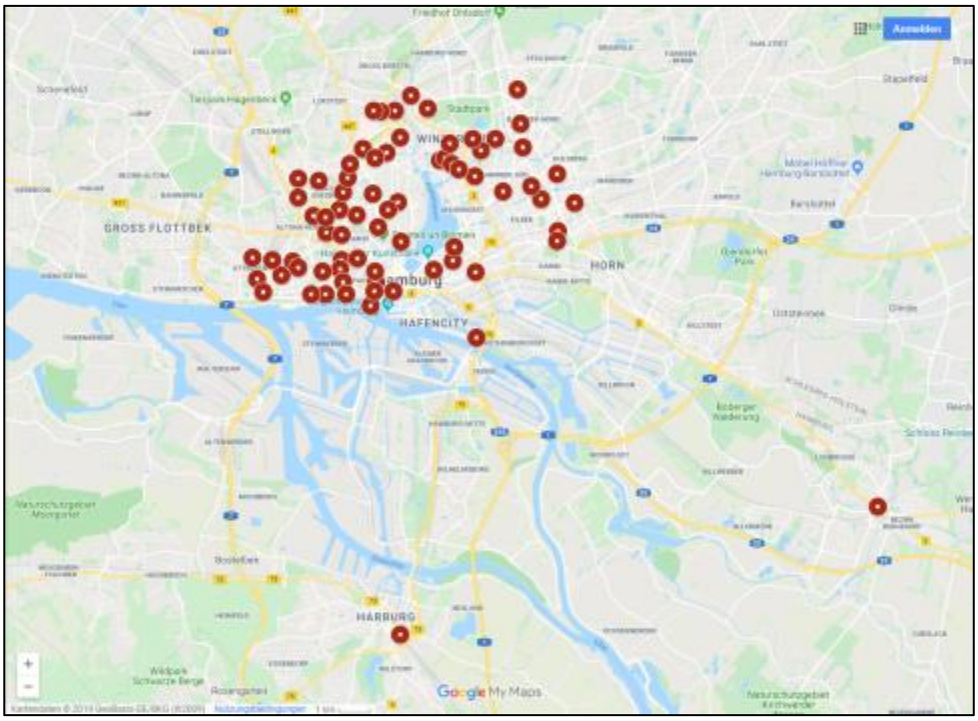

Figure 39: The switchh points in Hamburg. The map shows, that they follow the typical pattern of car-sharing providers, whereas they are primarily located in the densely populated and frequented inner-city areas (source: google.com, 2019)

1 Spatial connection and visual bundling of offers at switchh points

The two main aspects of the combination of several mobility services in one place are, that the respective offers are to be presented visually consistent to potential customers (marketing) and, at the same time, a simple change between the systems, for example from the train to the rental bicycle, is possible. Whereas the stationary car-sharing cars are often parked in parking garages or backyards of neighbourhoods, the cars of the free-floating car-sharing can be parked anywhere in the service areas. Here the reserved and marked areas for the cars at the switchh stations offer a visible point of contact for the customers. On the one hand, switchh points help to find available car-sharing cars and on the other hand, they considerably facilitate the search for parking space in Hamburg's city centre.

There are currently 72 switchh points in Hamburg, which are divided into central switchh points at Underground & Rapid transit stops, indicated by the green floor markings, and so-called micro switchh

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points in densely populated residential areas. It can be clearly seen that the switchh points also follow the typical pattern of car-sharing providers, whereas they are primarily located in the densely populated and frequented inner-city areas. Only the switchh points in Hamburg-Bergedorf in the east and Hamburg-Harburg in the south are located in peripheral locations.

Figure 40: Model of a comprehensive switchh station (source: Hochbahn, 2019)

2 A common pricing model with a discount access for the customer

The second pillar of switchh is a common pricing model for the individual partners. By means of a tariff agreed with the car-sharing operators, registration with switchh enables discounted access to car-sharing vehicles.

For 8.90 € per month, users receive a credit of 20 free minutes per month for the car-sharing providers car2go and DriveNow. Additionally, the registration is free at all participating partners and starting credits are offered. These range from 5 € for the rental bikes of StadtRAD Hamburg to 10 € for car2go and DriveNow and 15 € for cambio. The one-off registration can be made at switchh info points for all partners. After the use of the free minutes the regular tariffs of the partners apply.

3 The switchh App

The third pillar of switchh is the integration of all participating partners into a common app. Yet, this pillar is still under construction. So far there has been a rather rudimentary solution, where all switchh locations as well as all vehicles, including the free floating car-sharing cars and all bike sharing stations are shown on the map of the Hamburg public transportation app, the HVV App. Beyond this common geographical application, there are no common functions yet. Therefor a new app is currently being created which will contain extended functions and bring the offers of the various partners closer together (see chapter 5.3.6).

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The current and possible future mobility partners, car-sharing, bike-sharing, ride-sharing etc. are to be deeply integrated into the app. Eventually, users can make use of all integrated mobility services inside the switchh app without having to change to the app of the particular mobility provider. This also means that all payment systems should be integrated into one app. Only one registration will be required for all mobility providers and the billing should be handled via one common user account (see also chapter 5.3.6).

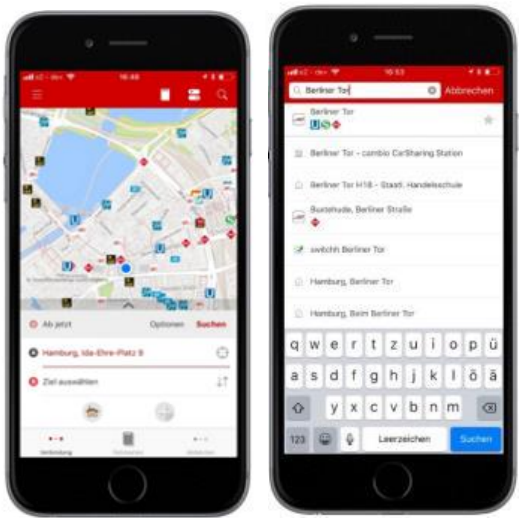

Figure 41: Pictures of the Hamburg transportation App (HVV App). Car-sharing and bike-sharing are already displayed in the map function (left picture), but not bookable yet (source: Hochbahn, 2019a).

5.3.5 Advantages for partner and customers

As a multi-modality platform, switchh offers users many advantages and participating partners several new business models. Advantages for the customers are:

- Improved use of local transport as the complementary forms of mobility car-sharing and bike-sharing densify the local transport network and make more individual arrival and departure points possible.
- A visual concentration of these offers at central locations facilitates a quick change between the systems.
- As a financial incentive: price advantages for the services of the participating mobility partners.
- Less bureaucratic effort thanks to the one-off central registration at the switchh info points, through which all partner systems are subsequently used.
- The partner systems cambio, car2go and DriveNow are also active in other major German cities and these systems can also be used there.

The advantages of the site on the part of the participating partners are:

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- Through the visible presentation of the car-sharing offers at the switchh points, the topic of car-sharing is brought into the awareness of the citizens. Synergy effects in marketing and customer acquisition are generated, through the joint appearance on the homepage, on site etc.
- Registration via switchh establishes a further sales channel for the partners.
- The areas of the switchh points are centrally located and offer inexpensive free parking spaces for car-sharing companies' users.
- The offers of the partners, also the vehicles of the free floating car-sharing providers, are shown in the map of the surroundings of the HVV App, the central mobility app of the public transport in Hamburg.

The city/public benefits benefit from following advantages and possibilities:

- The combined offer of switchh provides users with more individualized mobility services and ensures mobility options for use cases that public transport cannot cover thus enabling users to go without an own car while still being able to meet all their mobility needs.
- The combination of the different modes of transport can lead to traffic reductions within the city area
- The combined offer of switchh provides users with more individualized mobility services and ensures mobility options for use cases that public transport cannot cover.
- The combination of the different modes of transport can lead to traffic reductions within the city area

5.3.6 Extension of the switchh App in mySMARTLife by stationary Car-sharing

So far, the participating partners have only been digitally linked via the joint presentation of the services on the map of the Hamburg public transport app (HVV App). In the future, a real integration of the various partner systems into a new switchh App is to take place. Not only will the services of the different partners that are participating in switchh be presented in the app, but the various booking systems will also be integrated and harmonized. The aim is for customers to be able to book all switchh services via one app, without having to use further apps.

This is a very complex project, as several digital systems of different companies and also several billing systems, as well as different systems for opening the car-sharing cars have to be linked with each other. So far, this project was hindered by the high programming effort required to create a solution for partner apps that is only valid for the City of Hamburg. In mySMARTLife, the problem was identified as an important hurdle on the way to real multi-modality and solutions were coordinated with the partners. Together with the stationary car-sharing provider cambio, which also supports the project as a partner in community car-sharing (see Section 5.1.3); an exemplary solution is now to be demonstrated.

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The work assigned to the car-sharing company in the project is therefore a preparatory part for the extended switchh app, a larger and very complex project. The overall implementation of which is currently being developed between Hochbahn Hamburg and the other mobility partners from the areas ride-sharing, car-sharing and bike-sharing.

The solution developed here aims to enable the server of a partner system, here switchh, to act on behalf of defined customers and their customer apps, here cambio Car-sharing. For this purpose, so-called "virtual" apps are administered in the system of the car-sharing company. The objective of this software extension is for the central partner server (switchh) to be able to execute bookings and booking changes via the booking interface of the car-sharing company using the same functionalities that are comparable to those from the app of the car-sharing company.

For this purpose, the software of the car-sharing company creates its own app profiles for "customer apps" each time the app is personalised, which control the needs, preferences and authorisations of the "customer app".

In the present case of integration into the switchh mobility platform, or the switchh partner server, the corresponding switchh end customer app is not registered on the car-sharing server. The communication of the switchh end customer app therefore only takes place with the switchh partner server.

The switchh partner server in turn communicates with the car-sharing system. To be able to clearly distinguish at the server-server communication in the name of which app, switchh or end customer, a certain interaction is authorized, this can be bookings, cancellations, complaints etc. – the cambio server generates a "virtual AppProfile" for each end customer.

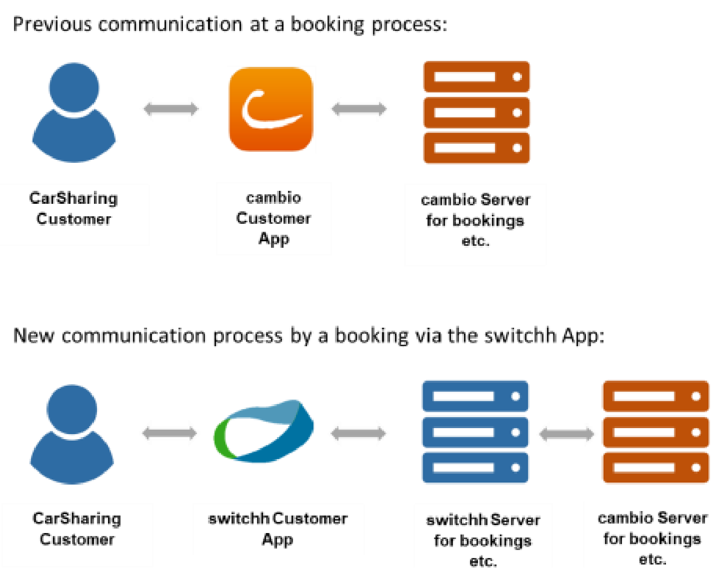

Figure 42: Communication within the framework of the mobility platform switchh, the switchh server acts like a cambio customer app (as a virtual APP), all necessary information about the customer, the booking options and adjustments are handled via this new communication channel (source: cambio Hamburg Car-sharing GmbH, personal note)

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The technical realization takes place in following steps:

Table 7: Work steps of the technical implementation of the virtual apps in mySMARTLife

Work steps of the technical implementation of the virtual apps in mySMARTLife	
Work step	Description
1	**Basis: Creation/deletion of virtual apps for individual access via server servers** Since it is not the individual switchh App that logs on to the booking server, but rather the switchh server places requests in the name of the switchhApp, for each customer who activates the "cambio booking" service via switchh a virtual app must be created and upon termination be blocked again. Additionally, push notifications need to be submitted to switchh after successful creation of the profile.
2	**Enhancement of booking for VCS (Virtual Card Swipe) for customers without chip card** The cambio booking system must be upgraded to enable VCS without the presence of a chip card. Adjustments to the fleet management and the booking system are necessary to distinguish between car-sharing stations, e.g. the car-sharing stations in Hamburg Bergedorf, where VCS is possible, but access to the car may not be possible without a chip card and car-sharing stations which can only be fully used with VCS without a chip card. It needs to be ensured that switchh customers only book cars at stations where they can get along without a chip card.
3	**Static information via virtual apps** Personalized information about car-sharing vehicle categories and car-sharing stations, already restricted to those stations and vehicle categories usable by the user. Calls are existing, yet the transmission via the virtual app and the dispatcher are to be completed.
4	**Bookings and changes in bookings via virtual apps:** The function calls are existing; here it is about the transmission via virtual app and dispatcher. It needs to be secured that switchh-bookings that are placed via the switchh-server are visible in the cambio app and in the cambio booking system (BUZE) and the other way around.
5	**Pick up and return of vehicles incl. VCS via virtual app** The basic functionality has already been created in the course of the cambio-intern VCS project. Here, only the transmission via the virtual app and the dispatcher are to be completed

With the end of the year 2019, the HVV will make a beta version of the new switchh app available to a closed user group for testing. This group can use the app under circumstances for a certain amount of time to gain experiences and give feedback to the project. In 2020 the beta version will be replaced, once the final version of the app is launched. Moreover, in the course of the next year, further mobility providers and services will be successively integrated into the app.

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5.3.7 Key findings

With switchh, the city of Hamburg already has a concept to link public transport with car- and bike- sharing services. It enable users, to go without owing a car thanks to an attractive and easy-to-use mobility offer, that combines public transport with car-, bike- and ride-sharing services. So far, this has been just a spatial connection of the mobility options, combined with a coordinated marketing and pricing model. The mySMARTLife project extends this with a multi-modal approach by the integration of stationary car-sharing into the new switchh app.

In addition, a concept for the electrification of the switchh locations was developed in the project, which is now to be rolled out in the city of Hamburg and is described in the next chapter.

5.4 Charging infrastructure solution for intermodal concept in Hamburg

5.4.1 Project description

The aim of SNH for this action is to support an intermodal concept for electric vehicles. SNH's job here is to conceptually and technically plan the charging infrastructure that is to be developed, coordinate its development, and then connect it to its internal IT backend. This will ensure vehicle charging and evaluation of the charging data.

This action is a twin action to Volkswagen's Action 41 to develop the initially planned "Multi Mobility Marketplace". As part of the action, various approaches to develop an intermodal concept or hub were tried out. These approaches are shown in Section 3.

The mobility concepts to be tried out in this action are based on the thesis repeatedly highlighted in current scientific publications that the mobility behaviour of broad swathes of the population, especially of younger generations, is in a process of profound change.

Receptiveness to new forms of inner-city mobility, acceptance of those offerings aiming at a new and intermodal understanding of use and utilisation of various means of transport and, finally, the premise of "using instead of owning", which radically questions the traditional understanding of vehicle use, are key elements of a phase of social change relevant to transport and social science.

5.4.2 Baseline situation

The switchh concept aims to integrate electric mobility services sustainably and holistically into intermodal transport chains without users having to own electric vehicles. While electric mobility has already been implemented in local rail public transport and does not need to be implemented in cycling due to a lack of environmental pollution, electromobility is not yet widespread in public transport by bus (see section 3.1) and in collective transport via car-sharing (see section 5.4). While there is still technical progress to be made in the bus sector (see Section 3.2), products are already available in the area of car-sharing.

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In Hamburg, so-called switchh points have been set up, where car-sharing vehicles are provided at the local public transport hubs and inner-city residential areas where they can also be preferentially parked and rented again by the users.

In terms of methodology, it is planned electrify switchh points as the next step in development on the switchh platform, which is operated by the municipal public transport operator HOCHBAHN in the Hamburger Verkehrsverbund (Hamburg Public Transport Association) (HVV). The SNH action is considering developing a charging infrastructure tailored to demand. Particular attention should be paid to the following areas.

Charging power level (22 kW)

As a rule, the existing charging infrastructure has an output per charging point of approx. 22 kW (AC), individual charging stations could provide an output >=50 kW (DC, HPC). The short range of car-sharing vehicles with current lower demand for battery size does not need to be charged with DC fast charging technology. In this way, the possible capacity utilisation of the vehicles can be efficient. However, higher charging capacities are associated with special requirements on the part of the hardware, the grid connection and are expensive compared to ac technology. Such requirements should be taken into account.

Multi-part charging infrastructure concept with local charging management (master-slave concept)

For use in public spaces, a one-piece solution is generally aimed for, in which the charging device and the house connection are combined in one-housing. A combined solution not only saves space in public spaces, but also provides a more visually appealing solution.

For multi-vehicle applications that require simultaneous or sequential charging, other charging infrastructure concepts can increase the efficiency of vehicle charging. With such master-slave concepts, as many identical parts of the charging infrastructure as possible (e.g. communication unit for data transfer or house connection box) are bundled in a master station. “Slim" satellites with plugs (user functional components) can be installed at the individual bays. The costs per charging point can thus be significantly reduced and there is no need to change vehicles after each charging process.

For high charging capacities with limited available capacity at the corresponding house connection, the use of a charging management system is also an option (see action "Load management"). Such local load management ensures intelligent distribution of the available power to the connected vehicles. This can increase the efficiency of the charging processes and thus the availability of the vehicles.

IT connection of car-sharing vehicles

In contrast to public charging infrastructure with private use, the dedicated use of charging infrastructure for car-sharing vehicles also entails some special IT aspects that must be taken into account when

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connecting the charging infrastructure. Charging processes as such, but also the intermodal billing processes, could deviate from the standard (Charge Detail Record).

Parking Space Detection

Current charging infrastructure can indicate to what extent an electric vehicle is connected there, but no information can be given about the general occupancy of the corresponding charging car park by a vehicle. Information about the availability of a charging point is therefore inevitably only possible to a limited extent. Only by monitoring the occupancy of the charging car park independently of the charging process can reliable information be provided. This occupancy information is extremely important for the acceptance of the users, since the intermodal path chain is to be secured. Drives searching for parking or charging points therefore have a negative effect. It can be assumed that, in future, all mobility concepts in connection with public charging infrastructure and car-sharing will be positively influenced by occupancy sensors or that specific business models will only become possible in the first place. See also Action "Parking Space Detection".

5.4.3 Concept/realisation

The work in this subproject is divided into two different approaches or phases. In the first phase of the project work an intermodal approach, "Park+Ride" was developed and implemented. First of all, the previous approach should be explained. Before focusing on Switchh, an intermodal approach was conceived and planned in cooperation with the former partner Volkswagen in connection with the development of the charging infrastructure in the Park + Ride areas at Bergedorf main station. However, this approach proved to be infeasible as there is currently no need for a second model in Hamburg, Volkswagen did not want to enter the existing project as a partner and finally left the project. Instead of this intended introduction of a Mobility marketplace in cooperation with VW, the concept of the "switchh" was included in the project.

Approach 1: "Park+Ride"

The idea behind this approach is to electrify the Park+Ride car park at Bergedorf railway station. In this way, drivers of electric vehicles can park and recharge their vehicles in this car park free of charge. Hamburg has granted free access for electric vehicles to the (usually chargeable) P+R areas in order to promote the substitution of conventional vehicles by electric vehicles. The intermodal route chain can thus be started with a (private) electric vehicle and the change to the next means of transport (bus, train, city bike, car sharer) is made possible.

Approach 2: Electrification of Switchh points

At heart, this action deals with the conception and electrification of the switchh location (Switchh Punkt) at Bergedorf main station in cooperation with the Free and Hanseatic City of Hamburg and Hamburger HOCHBAHN (public).

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Together with a group of car- and bike- sharing companies, the Hamburger HOCHBAHN operates a multimodal transport platform called "switchh". Switchh points were successfully built at 17 strategic rapid transit and underground stations in Hamburg and 55 inner city-city densely populated residential areas. The Switchh service combines mobility services such as car- and bike-sharing. The aim is torender access to and use of the various mobility offers particularly easy and convenient in order to offer (city) residents an attractive alternative to their own car.

The aim is to integrate electric mobility sustainably and holistically into intermodal transport chains based on a new concept, without users having to have their own electric vehicle. Electric mobility is not yet widespread in public transport by bus (see VHH activities), nor in private transport via car-sharing and taxis (FHH/ BMW, 2017).

The following points describe the conceptual design of electrification.

Locations: At this point of time it is planned to equip about 9 Switchh locations with more than 30 charging stations or more than 60 charging points. Since the relevant locations are very different, the placement of the stations must be determined specifically based on the cable routes and micro-location characteristics.

Technical equipment: All set-up areas to be electrified are equipped with a charging point and an AC charging capacity of 22 kW. The following technical requirements were selected. The recommended hardware is based on the AC charging stations used in public roads. A master-slave network is planned for the stations (one master station per location and 16 possible charging points per station).

Mains connection and installation: In contrast to the decentralised structure of the charging stations for the public Hamburg network, the existing system configurations are multi-part charging devices. This means that distribution cabinets must be integrated into the public street scene in the immediate vicinity of the charging hub. The switchh locations are supplied exclusively via low-voltage connections with up to 270 kVA connected load. The protection of a theoretically possible overload can be carried out via load management. This is currently not yet considered to be absolutely necessary, but will be examined more closely in the course of implementation planning. The knowledge acquired within the framework of the project is very helpful in this respect. SNH is independent in route planning and therefore chooses the most advantageous route based, on the one hand, on a cost-benefit analysis and on the other hand, the central transfer point (in close consultation with HOCHBAHN). The prioritisation of the locations takes place according to the requirements of HOCHBAHN.

5.4.4 Findings

- Social change is strengthening the motto "use instead of own". The traditional understanding of vehicle use is being radically questioned. It is the task of the metropolises to support this change

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through targeted intermodal (sharing) concepts and non-discriminatory environmentally compatible offers.

- With the switchh Concept, the City of Hamburg supports sustainable social change in the field of intermodal mobility. Electrification has been "thought through" from the very beginning and has now been successively promoted and gradually implemented in the future.
- The demand for intermodal multimodal hub concepts is lower in peripheral areas of Hamburg (see Bergedorf) than in inner-city areas. A company like Volkswagen that is interested in strongly scaling its business is currently developing its offerings from the inner-city areas of a metropolis outwards.

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6. New Logistic solutions

The following chapter introduces the concept for a new logistic solution: the multi-label Micro logistic hub (Action 31 “Logistic Micro hub”). It starts with a brief overview of the delivery process in urban areas, including its negative impact on traffic and pollutant emissions. In particular, the problem of "the last mile", the last stage of a supply chain, is explained. Afterwards the Micro Logistic Hub concept developed in mySMARTLife is explained in detail and the initial findings from its implementation are pointed out.

6.1 Delivery traffic in urban areas

Delivery traffic in urban areas is characterised by a high degree of heterogeneity, both in terms of the vehicles used and the frequency. These range from the supply deliveries to supermarkets made by trucks, to weekday parcel deliveries, to high-frequency supply traffic for pharmacies or car workshops.

In principle, deliveries can also be divided into the B2B, B2C and C2X segments. These are deliveries from commercial consignors to traders (Business to Business, B2B), from traders to consumers (Business to Consumer, B2C) and consignments sent by consumers to any recipient (Consumer to X, C2X).

Overall, the share of freight and delivery traffic in the total traffic volume in Germany amounts to about one third (NKI, 2018). In Hamburg alone, delivery traffic accounts for around 4 percent of the city's total traffic volume - related to regular delivery traffic, since delivery traffic occurring in situ, such as construction site traffic, is subject to strong fluctuations (MRU GmbH, 2018).

The largest share of regular delivery traffic, by sector, is accounted for by catering establishments and bakeries, which account for around 15 per cent of delivery traffic in Hamburg. The supply of the retail trade as well as workshops and newspaper and magazine dealers each account for around 3 percent. Each of these accounts for just fewer than 20,000 transports per day in Hamburg. Two percent is accounted for by deliveries to pharmacies and around 0.2 percent by bookstores, while parcel deliveries account for seven percent of the delivery traffic. The bulk of the delivery traffic in Hamburg, 50 percent, is accounted for by the supply of catering establishments and bakeries. The other sectors, such as catering, office supplies, florists etc. account for almost 70 per cent of all delivery traffic (MRU GmbH, 2018).

6.1.1 Emissions from delivery traffic

In addition to the high traffic load in urban areas caused by delivery traffic, the emissions caused by this traffic have also become the focus of public debate in recent years. This development was intensified by the action brought by the EU Commission against Germany and five other member states for exceeding the limit values for these emissions. Hamburg was one of the regions decisive in the action against Germany (EC, 2019).

The share of NO2 emissions caused by traffic in Germany amounts to almost 20 percent (BMU, 2018). A total of 163 million tonnes of CO2 equivalents were released by traffic in 2018. With regard to carbon

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dioxide emissions, there are no overall surveys for delivery and freight traffic. However, CO2 emissions correlate with vehicle consumption, which in the case of commercial vehicles is higher than that of private vehicles due to their higher weight compared with passenger cars, so that a share of more than 30 percent of the amount of CO2 emitted by traffic in Germany can be assumed. Accordingly, it can be assumed for 2018 that more than 53 million tonnes of CO2 equivalents were emitted through delivery and freight traffic (UBA, 2019).

6.1.2 The parcel market in Germany

The most dynamically growing segment in the area of delivery traffic is the parcel market, particularly as a result of continued strong e-commerce growth. In 2018, the volume of parcels delivered by the 6 major parcel services in Germany approached the 3 billion mark. A total of 2.95 billion items were delivered – which is an increase of 8.1% over the previous year. As in previous years, this development was primarily driven by strong growth in online business: the B2C segment in particular grew strongly by 11.6% (a total of just under 1.8 billion parcels) and now accounts for 61% of the total volume (MRU GmbH, 2019). At the same time, the volume of business customer parcels passed the 1 billion mark for the first time (+4%) with 1.02 billion parcels. The smallest part in terms of volume and growth rate are the private customer parcels (C2C), which recorded a decline of 3% and, at 130 million parcels, represent only about 4 percent of the parcel volume.

The German parcel market is characterised by fierce competition, particularly in terms of price. Deutsche Post DHL is the largest player in the parcel market (measured by the number of parcels transported), followed by DPD and Hermes. UPS and GLS are ranked 4th and 5th respectively. Newcomer Amazon Logistics is the smallest service provider to date, but is showing above-average growth. Amazon, primarily active in larger conurbations, takes over volumes previously delivered by other parcel services and is thus growing at the expense of other providers. They are now regarded as the 6th largest parcel service alongside the 5 established carriers. All the companies mentioned have parcel depots in or around Hamburg from which the delivery tours to the city area start. Figure 43 shows the locations of the parcel services.

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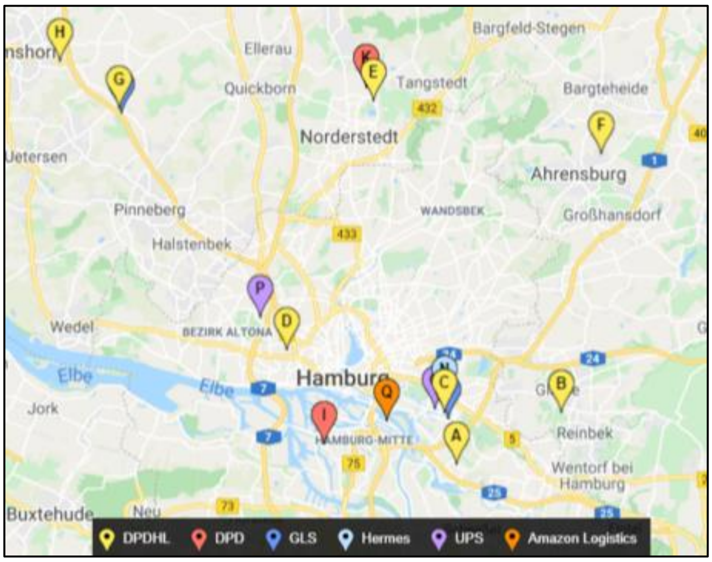

Figure 43: Parcel depots in and around Hamburg (source MRU GmbH 2019, own source)

6.1.3 Last mile logistics

In principle, all parcel services deliver on the last mile from regional depots (see also Figure 43). The depots, on the other hand, are supplied with consignments by hubs as part of line hauling service. The decisive determinants for the design of delivery routes are, in addition to volumes, the stop density, the parcels delivered per stop and the distribution of B2B and B2C items. These factors vary significantly from parcel service to parcel service. In addition, the use of subcontractors and the geographical position of depots have an impact on route planning over the last mile.

The delivery on the last mile in the Hamburg city area represents an increasing hurdle for the service providers, especially in highly densely populated quarters, due to a lack of parking and loading zones. As a result, parcel drivers are often forced to accept longer journeys or park in the "second row", often posing an obstacle for other road users. Against the background of increasing delivery volumes - especially in the so-called B2C sector - this practice leads to increased friction in road traffic. This effect is intensified by a longer stay of delivery vehicles and other commercial traffic, such as craftsmen, in loading zones that may have been set up. Additionally, the distribution of shipments to recipients is the largest cost item within the process chain of road-based transports. This effect is now reinforced by rising wages due to the shortage of personnel. In this respect, an increase in efficiency over the last mile not only relieves the traffic situation and emissions, but can also help to reduce the effects of the increasingly noticeable shortage of personnel in the logistics sector.

6.2 The concept of the Logistic Micro Hub

In the following section, the approach in mySMARTLife and the developed concept of the new logistic micro hub, which its individual project tiers, are explained.

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6.2.1 Approach in mySMARTLife

In the course of 2017, it became evident that the action 31 “Introduction of a universal trunk delivery concept with mobile access” will not be realised by VWG. This approach based on the idea, to reduce the delivery traffic on the last-mile, by using the trunk of cars for the deployment of parcels. Due to unexpectedly high costs in another test area in Germany, VW decided that they could not test this action in Hamburg as well.

Since traffic caused by delivery services is an important topic in the City of Hamburg, the City stepped in and took over this logistics-oriented action. The Borough of Bergedorf analysed the local situation and developed a new approach for an inner city logistic solution. Instead of focusing on final destination of a delivery, the concept of the Borough focuses on the entire last-mile delivery process.

The new concept will be developed around an existing multi-label parcel shop in a local shopping center and will be expanded to a multi-label logistic micro hub that is to be used by different parcel delivery services for deliveries in the inner city of Hamburg-Bergedorf. “Multi-label” means here that different delivery companies use the same infrasturctures, but other than in a so-called “white-label” solution, still operate under their own brand. “White Label” means that no brand of the parcel service is shown. This hub should help to reduce traffic and emissions in the inner city when delivery routs are rearranged and electric vehicles are used on the last mile.

For the final development and eventual implementation of the concept, the Borough commissioned the consulting firm, MRU GmbH, who are specialized in the logistics sector. In a one-year planning phase, the Borough of Hamburg-Bergedorf and MRU conducted workshops and investigations to analyse the demand for this new concept within the urban area of Bergedorf and adjusted the focus. The borough provides deep knowledge about the structures and relevant stakeholders in the area, whereas MRU has expertise in logistic procedures and market players, as well as comprehensive data records on deliveries in the project area. The creation of the concept has started and a supply concept for the inner-city area of the Borough of Bergedorf is developed as new logistic solution for the smart city. The consulting firm MRU has developed the name "GLoBe - Green Logistics Bergedorf" for this purpose, which will be the new brand of the micro hub. The aim is to describe an integrated service system and to set up a pilot micro hub that combines the previously self-sufficient supply networks in a provider-neutral system, taking into account Bergedorf's specific traffic and infrastructure requirements, and gradually adds new end-customer-oriented services.

6.2.2 The key elements of the Logistic Micro Hub concept

The concept essentially comprises three elements:

1) A parcel shop that serves as a "front-end" for end consumers and serves as a contact point for the parcel services DHL, DPD, GLS, Hermes and UPS.

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2) Establishment of a central delivery and transshipment point for parcel and other delivery services, the Logistic Micro Hub. The aim is to consolidate as many business to business (B2B) delivery services as possible. At the same time, the hub is to act as an "overflow" for the quantities consolidated in the parcel shop at peak times.

3) Development of new end customer services: Based on the conditions of the first two project steps, new forms of service will be designed and introduced on a trial basis. These include, for example, individualised collection and delivery of parcels to private households as well as delivery and collection services for laundries and repair services.

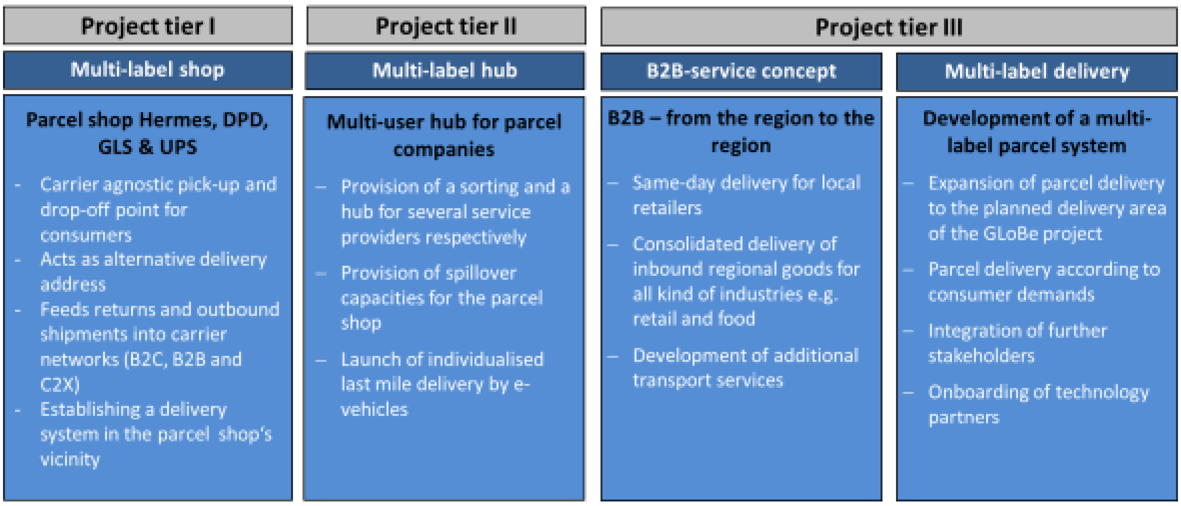

Figure 44: The modular approach at the Logistic Micro Hub, the project tiers I and II are the focus of mySMARTLife, the project tier III is a future task (source MRU GmbH, 2019, own source)

The central element, and first milestone of the service and supply concept, is the establishment of a physical logistic micro hub within the central shopping centre "City-Center Bergedorf". In the development phase, the Logistic Micro Hub will be used to consolidate parcel shipments to private recipients (B2C) in the immediate neighbourhood as well as to supply the shops in the shopping centre with parcels. A key element here is the focus on the end customers, who are enabled to receive parcels from as many service providers as possible and to hand in their (returns) shipments at a location that is as central as possible.

A modular approach also ensures that the solution can be flexibly expanded and individually transferred to other districts, taking into account the specific urban conditions. The Bergedorf location, as a comparatively self-sufficient secondary centre in Hamburg's urban area, offers a suitable framework for this. The planned gradual expansion of the pilot location by a central hub will take into account the foreseeable volume growth and create the basis for the integration of further services. The planned central delivery and transhipment point also opens up the possibility for the cooperating parcel services to set up their own structures, in which conventional delivery traffic is replaced by deliveries with cargo bicycles. At

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the same time, this makes it possible, to reduce the number of transports carried out with conventionally driven vehicles, which in turn will lead to a significant reduction in emissions in Bergedorf.

The concept includes the planning and construction of the pilot location and the development of relevant principles for the planning and construction of the centrally located hub in Bergedorf, which as an extension of the pilot hub has increased capacities and enables the successive integration of further services focused on the local supply of end customers and stationary shops. The design and implementation of this expansion is not part of the project mySMARTLife and will be a future task. One of the focus points of the expansion is the reduction of emissions through the use of electric vehicles. In addition, the central hub can help to sustainably strengthen the local retail trade in Bergedorf by integrating it into the overall logistic concept.

The first step towards consolidated delivery traffic was taken by the "City Center Bergedorf" shopping centre in autumn 2017 with the establishment of a multi-label parcel shop in which the two parcel services DPD and GLS were initially involved. In the following months, the parcel services Hermes and UPS also participated in this project. Due to the central location and the participation of 4 of the 5 parcel services, the volume increased to 2,000 parcels per month within one year and finally reached around 3,000 parcels per month in 2019. After the departure of Hermes, because of an internal decision, in October 2019, the volume dropped to approximately 1,700 parcels per month.

6.2.3 Multi-user Logistic Micro Hub operating model

A multi-user hub is a transshipment point (e.g. a hall) where each participating parcel service provider uses an area to be defined in sqm for the handling of its processes. The multi-user hub is to be managed economically by an independent operator in cooperation with the parcel service providers. The delivery on the last mile is to be carried out by e-vehicles, e.g. by e-cargo bicycles (Figure 45). Depending on the parcel delivery company's own process, the parcels are then transhipped there and distributed to the e-cargo bicycles, which deliver the parcels emission-free within a radius of approx. one kilometre.

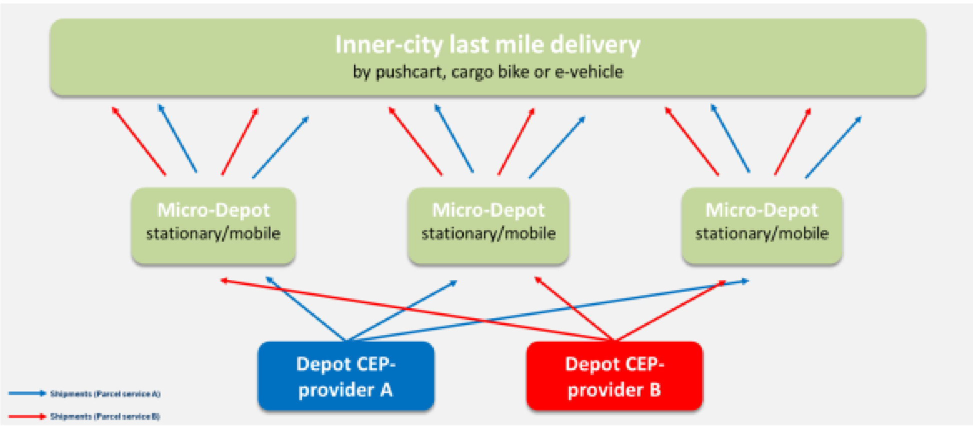

Figure 45: Scheme of a Logistic Micro Hub (source MRU GmbH, 2019, own source)

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Moreover, the Logistic Micro Hub concept is planned to successively integrate the supply of the retail sector in Bergedorf as well as other forwarding deliveries in addition to the parcel services (Figure 46), thus increasing the degree of consolidation of commercial delivery traffic within Bergedorf.

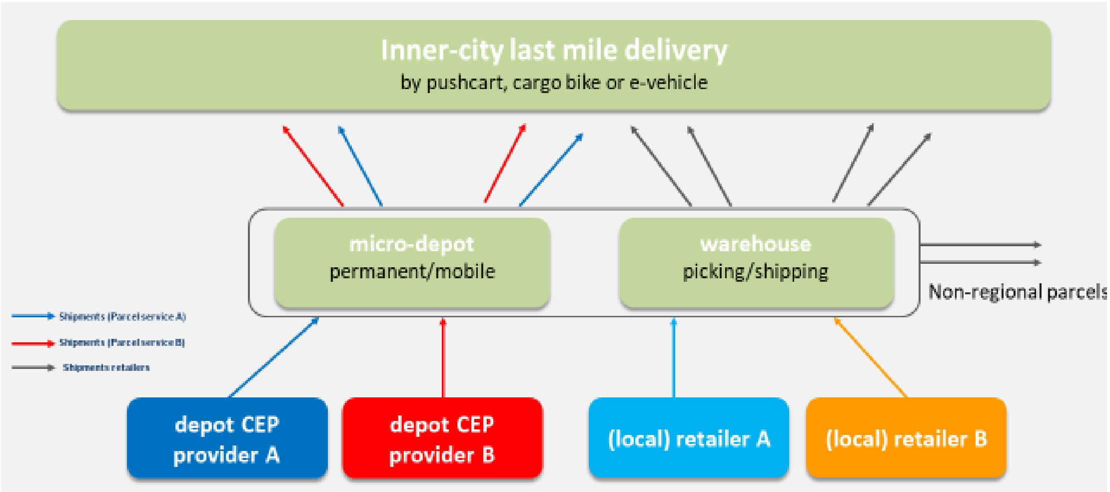

Figure 46: Scheme of a Logistic Micro Hub inclusive warehouse and retailers (source MRU GmbH, 2019, own source)

6.2.4 Process description

As described above, when using the Logistic Micro Hub cooperatively, the consignments to be delivered in Bergedorf are delivered by the parcel service providers to their respective area of the hub and should be transferred there to emission-free vehicles. From there, the delivery and collection tours start. If delivery is successful, the tour is continued. If a delivery obstacle, such as the absence of the recipient, occurs and it cannot be delivered to an alternative delivery location, the shipment is taken back. In addition, at the delivery points it is possible to give shipments, such as returns, to the delivery driver. After completion of the delivery tour, the undeliverable and collected items are transported back to the respective part of the multi-user hub. In the final step, the parcel services collect their shipments with conventional vehicles, usually 7.5 tons, and feed them into their network for delivery.

In order to ensure that the processes can be traced throughout and to document the transfer of liability, the shipments are also scanned by the individual parcel service providers while they are being loaded onto the delivery vehicles. A confirmation scan is also performed when a shipment is taken along and when delivery is successful. Parcels originating from the Micro Hub are rescanned when picked up by the respective parcel service provider, which updates the shipment status in the network of the service provider.

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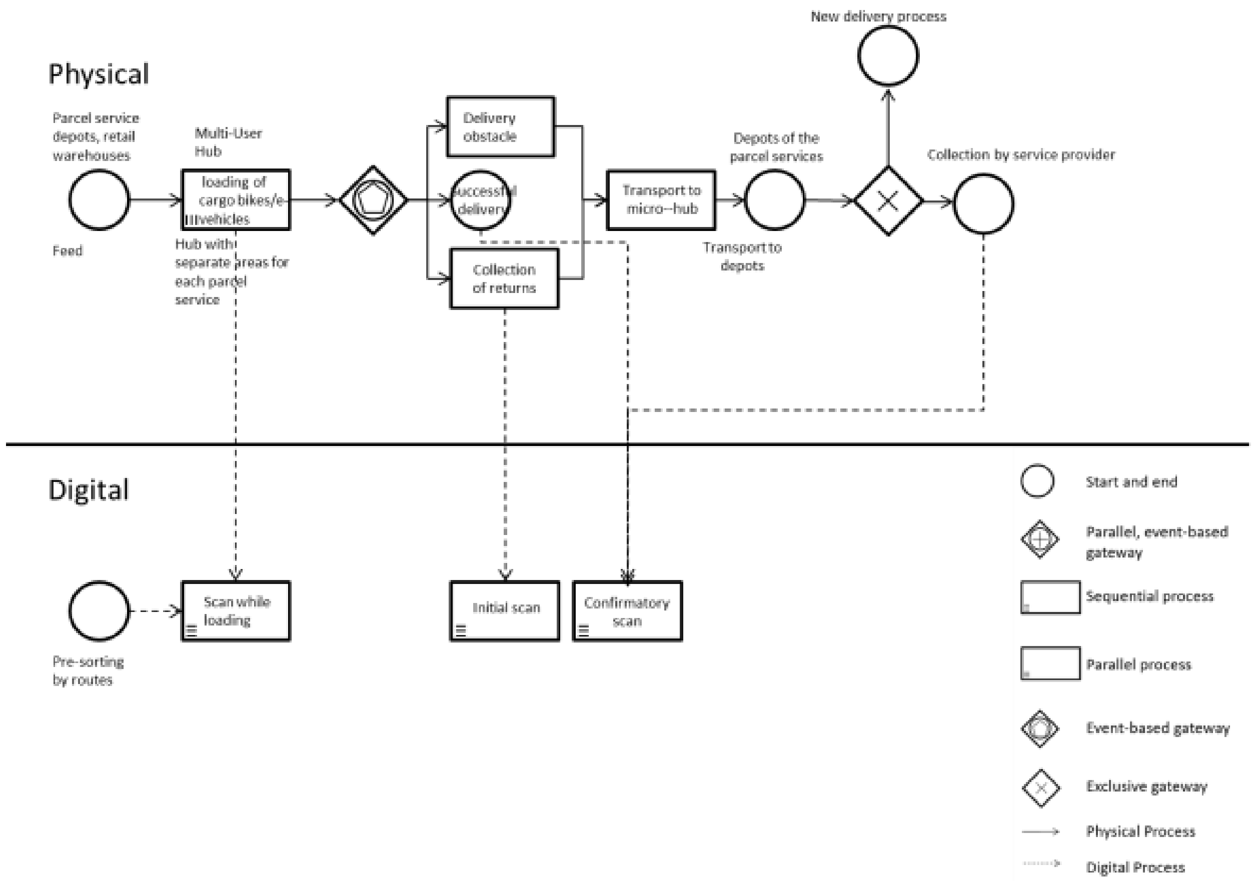

Figure 47: Description of the process in a Logistic Micro Hub in BPMN 2.0 (source MRU GmbH, 2019, own source)

Depending on the volume of shipments and vehicle size, the vehicles oscillate between the multi-user hub and the delivery area so that the process described in Figure 47 is repeated, with the exception of the delivery and collection of shipments by the parcel service. It should be noted that the process description is a prototypical representation, so there may be minor deviations from these processes depending on the parcel service provider.

6.2.5 Unique features of the Logistic Micro Hub concept

In contrast to the multi-user hub concepts tried and tested in Germany to date, the Logistic Micro Hub concept that is being developed within mySMARTLife in Hamburg does not rely exclusively on cargo-bicycles, but also on other e-vehicles. Thus, the concept is potentially in a position to integrate a larger proportion of parcel deliveries, especially in the B2B segment. In addition, the integration in the future of the retail trade's supply, which up to now has primarily been provided by freight forwarding, in the course of a local, consolidated delivery from the same hub is an innovative concept. Additionaly to these operational features, an operator concept is also being developed for the Logistic Micro Hub and the additional services, which is intended to ensure economic profitability regardless of any subsidy measures. The concept combines different approaches for traffic reduction in delivery with a concept for

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sustainably strengthening local dealers and service providers. Therefore, it is possible to make an economic and ecological contribution to improving the quality of life in the city as an integral part of modern neighbourhood planning.

6.2.6 Transferability and contributions to traffic reductions in Bergedorf

An essential feature of the concept for the Logistic Micro Hub is its modular structure, which ensures a relatively simple transferability to other quarters in Hamburg, as well as to other cities. Thus, individual components of this concept can be transferred as required. While the integration of parcel delivery is the core component of the concept, the service offerings, type and extent of integration of the retail trade and other businesses can be adapted to local requirements and, if necessary, supplemented by additional services.

The extensive use of the potential that is inherent in the described concept ensures a significant reduction in emissions generated by delivery traffic, as the concept focuses not only on parcel delivery traffic, but also on delivery traffic provided by freight forwarders.

6.3 The implementation of the Logistic Micro Hub

Due to the high demand for living space in Hamburg and numerous large-scale housing projects in the urban area of Hamburg-Bergedorf, the Borough moved more and more into the focus of Hamburg's urban development.

The mixture of industry, trade and housing in the Bergedorf urban area corresponds to that of a central centre. This makes the district within Hamburg its own microcosm and an ideal test area for an urban logistic micro hub. This is particularly true as Bergedorf is also a unit of its own, connected to the centre of Hamburg via the main road (Bundesstraße) B 5, and also has its own catchment area in Schleswig-Holstein. At the same time, however, Bergedorf's increasing settlement development is accompanied by an increase in the complexity of the supply structures and the necessary commercial traffic. For example, the number of transports induced by deliveries on the Bergedorfer Strasse (B 5) alone can be estimated at up to 1,600 daily trips (Geoportal Hamburg, 2019; MRU GmbH, 2018).

Thus the location Bergedorf, as a comparatively self-sufficient secondary centre in the urban area of Hamburg, offers a suitable framework for evaluation and implementation of this concept. The mySMARTLife project with its visibility and dynamism generates additional public awareness, which promotes the involvement of local stakeholders in the Logistic Micro Hub concept.

6.3.1 Identification of relevant locations

For the development of the concept for the Logistic Micro Hub, it is not only necessary to convice different stakholders about the benefits of such a concept, but also different locations need to be identified and investigated, whereas the location of the components of the concept can be crucial for a success of

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animplementation in Bergedorf in the future. So far, first findings regarding the front end, where people can pick up parcels and also for the Logistic Micro Hub itself can be presented.

6.3.1.1 Location of the Front-End

The first implementation step of the Logistic Micro Hub Concept is the establishment of a so-called front-end. This contains a multi-user parcel shop, which is to be supplemented by an overflow area. In the course of location identification, a shopping centre in the city centre of Bergedorf was identified as an ideal location. Due to the immediate proximity to Bergedorf railway station and the bus transfer facilities there, which cover Bergedorf's catchment area in Schleswig-Holstein, as well as the high passenger frequency on site, the shopping centre is an ideal location for the front end. In the course of the discussions held in advance to support the installation, conceptual requirements for the front-end were developed. Subsequently, the management of the shopping centre was able to set up a multi-user parcel shop that can handle up to 3,000 parcels per month.

Figure 48: The multi-user parcel shop in the shopping centre CCB as first keystone of the logistic micro hub (source: Borough of Bergedorf, 2019, own source)

In order to clarify the next steps for integration into the overall concept, further discussions were held with the management. Further possibilities for cooperation were discussed, such as the use of the e-charging infrastructure of the shopping centre for delivery vehicles or the provision of premises for a consolidated delivery to the shopping centre. In addition, in cooperation with the Borough of Bergedorf, a letter of support was drawn up for the centre management in which the importance of the parcel shop for the Logistic Micro Hub development within the mySMARTLife project was emphasised to investors and perspectives for further development were pointed out. Additionally, alternative areas and locations for a front-end were identified and evaluated for their suitability.

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6.3.1.2 Location of the Logistic Micro Hub

The central step for the implementation of the Logistic Micro Hub is the conception and location finding for the hub itself. For the identification of the location, the relevant parameters for the identification of suitable locations were worked out in cooperation with a globally active real estate developer. The site identification was started in October 2019 and had not yet been completed at the time of writing. However, it was already possible to identify a shortage of logistics space in the vicinity of the city centre. So far, two locations at a direct or acceptable distance from the front-end shop have proven to be ideal. But it is currently to prove whether and to what extent these locations are available. Other locations at a sufficient distance from the front-end are being examined as further options.

6.3.2 Parcel delivery volumes in Hamburg-Bergedorf

The establishment of a multi-user hub for parcel services planned in the second implementation step requires an analysis of the potential for the planned delivery area. In a first step, the parcel volumes for the district of Bergedorf and around three quarters of the district of Lohbrügge were modelled. The calculation of B2C volumes is based on an annual survey of 40,000 consumers conducted by the German E-Commerce and Mail Order Association (Bundesverband E-Commerce und Versandhandel - bevh). The B2B volumes were modelled based on the number and structure of businesses in the Bergedorf district. The private customer package segment was updated for the Federal Network Agency based on MRU surveys. As a result, a working day volume of 10,000 parcels in the planned area was forecasted for 2019, as it can be seen in Table 8. Of this total, just under 3,700 parcels were in the B2B segment, almost 6,000 in the B2C segment and just over 300 in the private customer parcel segment.

Table 8: Parcel volume in the planned delivery area by segment 2016 to 2020 (MRU GmbH, 2019)

Paketvolumina Liefergebiet pro Werktag	**2016**	**2017**	**2018**	**2019**	**2020**
B2B pro Werktag	3.149	3.292	3.469	3.691	3.763
B2C pro Werktag	4.727	4.682	5.535	5.992	6.490
C2X pro Werktag	333	333	331	327	324
Paketvolumen gesamt Liefergebiet	**8.209**	**8.308**	**9.335**	**10.011**	**10.576**

In 2020, growth of 5.6 percent to 10,576 parcels is expected, primarily driven by the B2C segment. This indicates a slight slowdown in growth, which averaged 6.8 percent between 2016 and 2019 (CAGR - Compound Annual Growth Rate). This means that parcel delivery in Bergedorf in 2018 induced around 82 transports per working day, which will rise to around 87 journeys as a result of the volume growth. The emissions caused by the delivery of these volumes in the delivery area in 2018 summed up to approximately 767 tonnes of CO2 and around 2.8 tonnes of NOX. Due to the 7 percent increase in parcel volumes from 2018 to 2019, emissions this year will rise to 822 tonnes of CO2 and 3 tonnes of NOX. The emission values are based on the consumption values of the vehicle types normally used by parcel services and subcontractors in the Euro 3 to 5 emission classes. Based on the projections of the package volumes, the Logistic Micro Hub concept could reduce emissions by around 714 tonnes of CO2 2 and around 2.6 tonnes of NOX within one year as early as 2020. By integrating freight forwarding into the

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concept, this value can be significantly increased. In addition, statistical data on the number of colli and pallets delivered in the Bergedorf district were collected as part of a research project. Accordingly, around 3.1 million colli were delivered in 2018, primarily from B2B e-commerce. This corresponds to approx. 420,000 pallets. However, a serious estimate of the total emissions caused by these delivery transports in the Bergedorf district in view of the different intervals and the heterogeneity of the vehicle types used for this purpose requires the collection of empirical data.

6.3.3 Initial talks with parcel service providers to be involved

A very important part of the project is the early involvement of the parcel service providers in the project. Decisive for the planned implementation are the identification and - as far as possible - inclusion of the specific requirements of the parcel service providers in the conception. Initial talks have already taken place with 3 providers; these companies have agreed in principle to participate in the project. Talks with 2 further providers are in preperation. After the agreed signing of non-disclosure agreements with the service providers, the exchange of the data necessary for the detailed planning of the multi-user hub and other requirements is planned.

In general, the relevance of the issue of emission reduction in the city is perceived by the parcel services and each service provider has its own concepts and plans to reduce emissions for the last mile. In addition, a discussion partner expressed concerns regarding the planning period, as experience with urban logistics concepts had shown that the necessary approval procedures were lengthy.

The Borough of Bergedorf as representatives of the City of Hamburg assured the attending discussion partners that the Logistic Micro Hub concept would receive full support and, if successfully implemented, would serve as a best practice example for other parts of the city. The discussions already held have shown that there are strong differences in the assessment of the Logistic Micro Hub concept and its potential on the part of the parcel services. While one of the three parcel service providers takes a critical view of the use of cargo bicycles, another interlocutor expressly supports the use of cargo bicycles in order to achieve a reduction in the truck fleet. However, another aspect is relevant for the implementation of the concept: some parcel service providers expressed concerns whether that they would be able to acquire suitable electrically powered delivery vehicles in due time. All providers have so far been critical or even hostile to cooperation within the framework of general “white label” or “multi label” delivery.

6.3.4 Initial talks with software manufacturers

In the course of the third stage of the Logistic Micro Hub concept, the inclusion of B2B deliveries is planned, and in addition, a white label delivery is to be established in Bergedorf in the final expansion stage. Flexible, up-to-date route planning is indispensable for efficient delivery of consignments while at the same time meeting customer requirements. For the conception of a delivery by the Logistic Micro Hub operator, discussions were held with two software manufacturers of route planning software. A letter of intent was signed with one of the companies, who also supplies the route optimisation software for one of

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the large parcel services. This should ensure to have the route planning and optimisation software of this manufacturer available for the Logistic Micro Hub. Discussions with the alternative provider have not yet been completed at the time the report was prepared. Both companies are able to provide software and interfaces that would enable the operator of the Logistic Micro Hub to optimize routes in real time, based on current traffic, and to flexibly include ad hoc collection of returns in route planning. In addition, possibilities for integrating further services into the route planning for the third expansion stage of the concept were discussed.

Furthermore, talks were started with a software manufacturer to integrate the retail trade in the Bergedorf district. This company offers local portals that can be used as an online platform for local retailers and service providers or as a platform for marketing activities, e.g. via social media. Besides that, the platform offers interfaces to enable same-day delivery of goods ordered online. A Click & Collect function is also implemented. In order to concretize such possibilitie, further discussions with representatives of the retail trade in Bergedorf are necessary.

6.3.5 Initial talks with stakeholders from the retail segment in Bergedorf

Another important stakeholder for the development of the concept is the local retail trade. For this reason, an initial meeting was held with the Bergedorf trade association. In the course of the discussion, possibilities for integrating the Bergedorf retail trade and local service providers into the Logistic Micro Hub concept as well as a local portal were discussed. This includes both the use of a “GLoBe portal” as a virtual shop window and the integration of Click & Collect Services as well as the possibility of ordering directly online from the participating retailers and having these goods delivered via complementary services of the Logistic Micro Hub. In addition to the conceptual aspects, there were also opportunities to use multipliers such as the local press to make the project known to the residents of Bergedorf as well as to business people and to increase the acceptance of such a project in Bergedorf in advance.

6.3.6 Initial talks with the police

With regard to the approvability of the traffic caused by newly introduced vehicles with the implementation of the Logistic Micro Hub concept, here especially cargo bicycles, as well as any existing transit and supply restrictions, a discussion was held with the police in Bergedorf. The concept and its potential effects on traffic were presented. In addition, some of the potential locations were presented in order to clarify the extent to which the delivery and delivery traffic there would require approval. The Bergedorf police consider the number of expected transports caused to be uncritical and expressly welcomes the transfer of deliveries to cargo bicycles. This is particularly true against the background of the expansion of the cycle paths in Bergedorf within the next two years.

6.3.7 Initial talks with manufacturers of intralogistic systems

Talks were held with one of the world's leading manufacturers of intralogistics systems regarding the Logistic Micro Hub concept and its requirements for intralogistics, and possibilities were evaluated for the

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technical equipment of the Logistic Micro Hub with sorting and conveyor technology. The manufacturer's portfolio includes electric and diesel forklifts, warehouse equipment, lift trucks, fleet management software, automation solutions and driver assistance systems.

In the course of further discussions, the use of electric vehicles for the delivery of consignments was specified. The manufacturer agreed to equip the Logictic Micro Hub with the necessary conveying and sorting technology and also to make e-vehicles available for the delivery of consignments in the direct vicinity of the shopping centre. Moreover, talks were held with a company specialiced in the automation of intralogistics processes. In the course of several discussions, the manufacturer agreed to make available the prototype of the world's first fully automatic loading system. This is a solution for sorting parcels on delivery vehicles that completely replaces the previous manual loading process.

6.4 Key findings

Since the start of the development of the concept for the Logistic Micro Hub within the mySMARTLife project, a large number of partners from the fields of real estate development, retail, software production and intralogistics have been won over to the project through discussions and negotiations. In addition, the potential package volumes for the Logistic Micro Hub were calculated and the conception was initiated. At the same time the identification of the location is in progress and the basic approvability of the delivery traffic was confirmed by the police. This laid the foundations for the implementation of the the expanded Logistic Micro Hub concept.

At the same time, obstacles could be identified at an early stage in the discussions, which will be taken into account for further planning in order to overcome them in the conception phase. An example of this is the integration of the retail trade. This significantly requires the use of merchandise management systems, since the respective inventory must be made available online. These challenges and possible alternatives are currently being analysed together with the retail trade in Bergedorf and will be incorporated into the further conception of of the Logistic Micro Hub concept. If approval is required for the establishment of loading zones, the operational start of the Logistic Micro Hub could be delayed in the case of lengthy approval processes.

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7. Conclusions

This deliverable contains 14 subprojects of mySMARTLife with the focus on mobility in Hamburg. It considers a wide variety of sub-areas of the mobility sector. VHH expands its fleet with purely electrically operated buses. It could be reached a technology readiness level of 8 within the project. The first experiences with charging systems could already be made before the mySMARTLife project has started. The electrification of the bus fleet has also been in preparation for several years. Experiences of other bus companies in Germany could be included. As a result, large bus companies in Germany had already joined forces to act as customers for manufacturers. Within the framework of mySMARTLife, the initial initiative has now been carried out. This involved ordering 20 buses, building a workshop, revising the bus maintenance plan and setting up a charging infrastructure.

After an analysis of the route plan, it was possible to identify the necessary range, which covers a good 50% of all journeys. With this and other requirements, negotiations with manufacturers were started. However, the VHH later had to separate itself from the manufacturer and now procures the buses elsewhere.

- Local differences in requirements are proving a challenge for manufacturers.
- Smaller manufacturers are more adaptable and respond quicker to innovative market demands as their aversity to risks is lower. However, this requires a better assessment of the scale of challenges and requirements set in relation to the potential efforts needed to fulfil requirements.

The experience gained in relation to requirements was supplemented by analyses of other processes affecting buses. As a result, the cleaning process was changed and a new training programme especially designed for electric busses was established. As a result for the entire VHH, the company is increasingly developing into a digital company.

- The change for the company towards e-mobility requires significantly more than training drivers and work shop members. Almost all processes are affected and the efforts to involve all company members and all departments are easily underestimated.
- Digitalisation can significantly support innovative changes but is itself a very demanding implementation in and of itself which is difficult to achieve simultaneously. The process of transition is ongoing at VHH.

With the mySMARTLife project important steps could be taken to electrify the bus fleet as part of a more sustainable form of public transport.

As a consequence of electrification, the direct question is how and when the battery of the new buses will be recharged and how this process will fit into the provision of the buses. In order to avoid the construction

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of cost-intensive charging points at the end points of individual lines, the buses have a corresponding range and are to be charged overnight. This requires appropriate charging capacity, as the time for charging is limited, but also with limited connection capacity and charging management, as the buses have to be charged simultaneously. The solution is a new design of shared modules between charging points, which allows the power to be concentrated or distributed to charging points.

An important finding is that a good forecast of energy consumption is essential to ensure that all electrical components are sufficiently dimensioned. Later changes, e.g. a greater expansion of the e-bus fleet, will entail enormous additional costs. At the same time, a loading concept represents a new challenge for bus companies. As a rule, there is no previous knowledge about high voltage current, battery technology or charging management. Building up expertise and experience is a non-negligible issue in the electrification of public transport. This applies not only to procurement, but also to maintenance and operation of such infrastructure. These requirements offer the opportunity to advance and use the digitalisation of one's own operations.

Along the road mapping out the VHH path towards more sustainable public transport the first successful implementation of 16 charging points and electrical infrastructure to support the new fleet of e-busses is an important milestone achieved through mySMARTLife. While first tests in real operational conditions are yet to come, the scale-up at the Bergedorf depot has already continued. Within mySMARTLife project a TRL of 9 could be reached.

To ensure that the new eBusses of the VHH can be charged with renewable energy not only on the balance sheet but also pyhsically, the possibility of using wind power is being tested. The Curslack wind farm is located only about one kilometre from the bus depot. Within the framework of mySMARTLife, feasibility studies are being carried out to clarify the legal and technical framework conditions. These have already been commissioned and are currently being prepared. The findings of the investigations will determine the further course of action. The aim is to create a business case in accordance with the legal assessments which opens up monetary possibilities for both the wind farm operator and the VHH. The technical investigation will also show what the route of the pipeline should look like. Implementation could then take place during the course of the project until the end of 2021.

In addition to public transport, numerous service trips for the city of Hamburg are undertaken every day. These are usually undertaken with a company car or private car. In order to make this part of transport increasingly sustainable, the City of Hamburg has initiated the procurement of e-cars as part of mySMARTLife. As the existing vehicles are exclusively leased, it was first necessary to wait until the leasing contracts expired. Subsequently, ten e-cars together with charging infrastructure and charging management could be procured and implemented.

In addition, eBikes were purchased, which was different than expected, more complicated than the procurement of eCars. There are already fixed processes and needs analyses for cars, which are

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necessary for public procurement. These do not exist for bicycles, so that they would have to be created first. Together with high costs for eBikes, this is the reason why no eBike was purchased at the time of this deliverable. However, within the framework of information events, employees could be offered test rides for employees. A survey showed that many of the employees could imagine an eBike as an alternative for private use and for the way to work.

Some of them might get an e-car instead. The number of e-cars on Hamburg's roads is increasing, which places increasing demands on the charging infrastructure. The requirements range from fast charging and handling of numerous charging points in public spaces to charging management of private charging stations at home.

The distribution network operator in Hamburg, Stromnetz Hamburg (SNH), operates the charging stations in the City of Hamburg. In mySMARTLife SNH tested locations in Bergedorf for the installation of quick charging stations for electric cars. Section 0 describes that SNH has already installed and operates a number of charging and quick-charging stations in the Hamburg city area. In Bergedorf there was no fast charging station planned at the beginning of the project. The investigations carried out during the project did not reveal a suitable location for a DC fast charging station. The main reasons for this are the low demand for such stations in Bergedorf.

However, findings could be made about the process of location search. In order to better bring together the numerous stakeholders and their interests in the future, methods and tools are proposed that allow greater transparency in this process. Together with the expected increasing market share of the e-car fleet in Germany and in urban areas, this will lead to the installation of further fast charging stations in the Hamburg urban area (currently 64) and in Bergedrof.

In connection with the rapidly rising number of electric vehicles and the simultaneous growth in the number of charging stations, site-specific grid connection capacities are becoming increasingly important. The electrification of (public) fleets often shows that the existing grid capacities are not sufficient. The necessary expansion is usually cost-intensive. An intelligent charging technology, a so-called intelligent load management, provides a solution here.

In the mySMARTlife project, SNH was able to further develop the company's own IT backend with regard to intelligent load management and successfully demonstrate the functionality and suitability for everyday use of such a load control system.

This strategy is complemented by HAW's developed charging management system for a private charging station of the Energy Campus e-vehicle. The aim was to increase the share of renewable energies in charging the e-car. To achieve this, the charging process must be made more flexible. Additional hardware that communicates with the charging station makes it possible to make the charging process dependent on other factors. The control system developed now makes it possible to set a target value and

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plan the charging process accordingly. The basis for determining the target value is the forecast feed-in quantity of renewable energy in the Bergedorf district. Based on the forecast for the next 48 hours and the desired departure time, the controller determines the time window that uses a high feed-in capacity of renewable energies. The system is currently being tested in daily use and further improved. Target value adjustments are also conceivable, such as the PV feed-in of the building or the residual load in Germany and Bergedorf.

In addition to the above-mentioned enterprises, there are other strategies for inter- and multimodality. In most cases, car-sharing services are connected to public transport. Opportunities are created for car-sharing to promote electrification there as well.

The use of car-sharing services has increasingly become a popular form of transport in recent years. Especially in larger cities, there is a wide range of car-sharing companies, which favor the goal of reducing the number of cars per person in the city. In Hamburg there are about 1,700 vehicles of the classic car-sharing options, which are distributed among 11 different providers. This puts the city in 10th place among German cities in terms of the ratio of car-sharing vehicles to people.

In the City of Hamburg, a large number of car, bike and ride sharing companies have already established. The City of Hamburg regards car-sharing as an important approach to reduce individual car traffic. However, most car-sharing companies are concentrated in the Hamburg city centre, as this is the area, with the greatest customer potential and a spatially concentrated range of station services is easier to maintain for the companies. In order to reduce commuter traffic, however, car-sharing must also be offered in residential areas in the outskirts of the city.

The biggest challenge in the development of car-sharing stations in residential areas is the start-up phase. A permanent user community needs to be developed as quickly as possible around the station, so that the station is economically viable. For this purpose, the station must be positioned as visibly and easily accessible as possible. Moreover, the residents must be addressed directly and simply several times by reliable project partners. It should also be as easy as possible to register and to book the car-sharing services. The concept developed in mySMARTLife distributes clear roles and tasks. The partners contribute their strengths and were able to develop new business models.

To ensure that the divided vehicles can also be loaded in the vicinity of the place of residence, approaches for loading concepts in housing estates are evaluated. In order to use the given connection capacities efficiently, load management is often necessary here. Thus, the "intelligence" on the part of the hardware and backend functionalities used plays an important role.

In the course of advising and supporting the project, Stromnetz Hamburg elaborated on the central technical hardware and software requirements for the required charging infrastructure in detail and made them available to the implementing project partners.

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Key findings are that Car-sharing can make a substantial contribution to reducing the number of vehicles in a city such as Hamburg and to the targeted use of electric vehicles. However, apartment buildings and apartment owners in particular face legal obstacles: often tenants do not yet have the option to install their own private charging station at their parking space.

With the “switchh” mobility platform, the city of Hamburg already has a concept to link public transport with car- and bike- sharing services. It enable users, to go without owing a car thanks to an attractive and easy-to-use mobility offer, that combines public transport with car-, bike- and ride-sharing services. So far, this has been just a spatial connection of the mobility options, combined with a coordinated marketing and pricing model. The mySMARTLife project has extend this with a multi-modal approach by the integration of stationary car-sharing into the new switchh app.

In order to create additional incentives for the use of e-cars at the Multimodal Hubs in Hamburg, these are to be electrified. Various concepts play together, which include fast charging stations with at least 50 kW, multi-part solutions (so-called master-slave), parking space detection and the IT connection of the aforementioned. They all play together to overcome different challenges in the electrification of the hubs. These result from the requirements of the Park+Ride function of the hubs, as well as from the platform for Car-Sharing providers "SwitchHH". In order to electrify these two areas, both fast charging stations and concepts for parked private vehicles, which can only clear a charging point after a few hours, will be developed. One approach is the master-slave procedure. The power electronics are centrally positioned and can be extended by additional charging points at low cost. This makes it possible to operate significantly more charging points than can be charged simultaneously. A charge management system ensures that all vehicles are charged one after the other during the day. Parking space detection enables parallel determination of whether a charging point is blocked by a vehicle but not connected to the charging station.

In the individual subprojects, the measures were first evaluated and examined. In some places, this resulted in new challenges which necessitated adjustments to the project objective. Ultimately, however, valuable findings were gathered in all areas that will enable a good basis to be created for the electrification of the mobility sector in Hamburg beyond the term of mySMARTLife. This basis will make a significant contribution to Hamburg's traffic turnaround.

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