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mySMART Life

D3.12 Report – Submission Date 31.05.2020

D3.12 Baseline report of Hamburg demonstrator area

WP3, Task 3.1 “Baseline assessment”

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.

Project Acronym	mySMARTLife		
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**		
Grant Agreement Number	731297		
Project Duration	1st December 2016 – 30st November 2021 (60 Months)		
Deliverable	D3.12 Baseline report of Hamburg demonstrator area (final)		
Diss. Level	Public		
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	■	Final version	
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Work Package	WP3		
Lead beneficiary	HAM		
Contributing beneficiary(ies)	HAW, ENH, KON, LSBG, VHH, CAR		
Task description	Task 3.1: Baseline Assessment This task will set and assess a baseline for Hamburg demonstration. Analysis of the district in which the interventions will be implemented with information about the main architectural issues, energy facilities and energy consumption, mobility data and urban infrastructures are necessary for the definition of the baseline and for identifying the improvements potential. More details are needed in the case of the existing urban plans, public procurement and the current citizen engagement strategies in Hamburg.		

Date	Version	Author	Comments
04.02.2020	0.1	CAR	Overview, proposal for baseline report
12.02.2020	0.2	HAM, CAR	Discussions regarding the inputs for the deliverable
25.02.2020	0.3	HAM, CAR	Identification of interventions to be included
25.02.2020	0.4	All	Start of compilation of data for the baselines
25.03.2020	0.5	HAM, HAW, ENH, KON, CAR	Energy baseline/monitoring workshop
03.04.2020	0.6	HAM, HAW, VHH, CAR	Mobility baseline/monitoring workshop
08.04.2020	1.0	HAM, CAR	Preparation of table of contents for deliverable
24.04.2020	1.1	HAW, HAM, CAR	Calculations energy baselines and text contributions
29.04.2020	1.2	VHH, HAM, CAR	Calculations mobility baselines and text contributions
15.05.2020	1.3	All	Sent to Review 1

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20.05.2020	2.1	All	Corrections, additions after review 1
27.05.2020	2.2	All	Sent to Review 2
28.05.2020	3.1	All	Corrections after review 2
29.05.2020	3.2	HAW, LSBG, KON, ENH	Finalization of contributions
30.05.2020	4.0	HAM, CAR	Final Corrections and submission

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Abbreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CHP	Combined heat and power plant
CO_2	Carbon Dioxide
CO_2eq	Equivalent Carbon Dioxide
DIN V 18599	German norm for energy balancing
EPBD	Energy Performance of Buildings Directive
GHG	Greenhouse gas emissions
g-value	Total solar energy transmittance of glazing
ICE	Internal Combustion Engine
IPMVP	International performance measurement and verification protocol
KPI	Key Performance Indicators
M&V	Measurement and Verification
TRY	Test reference year
U-value	Total heat transfer coefficient

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1. Executive summary

The purpose of this document is to describe the performance of Hamburg demonstration actions in building, city infrastructure and mobility sectors before the implementation of Hamburg project actions.

The present deliverable provides information and data that will be used for the final evaluation of the impact of the project's interventions. The baselines and baseline values that are presented in this deliverable serve as reference for the assessment of the performance of the interventions. In detail, the baseline describes the situation previously to the implementation of the project's interventions. The focus of the baselines for the here presented interventions from the energy and infrastructure and the mobility pillars is primarily on greenhouse gas emissions and different energy consumption values. In this context KPI that will be covered during the project's monitoring are used to illustrate the baseline situation (these KPIs are included in WP5 - Deliverable 5.1: Integrated evaluation procedure). Whereas the interventions also aim at a reduction of the climate-damaging effects caused by the use of non-renewable energies in urban areas in the areas covered by the named pillars, it is important to have knowledge about the previous emissions in order to be able to assess the impact of the mySMARTLife interventions. The interventions presented should reduce greenhouse gas emissions by reducing energy demands through retrofitting measures of buildings or energy supply systems, introducing innovative efficient energy carriers or systems to urban infrastructures or increasing the generation of renewable energy in this area. With regards to mobility, greenhouse gas emissions should be reduced by replacing fossil-fuelled vehicles by vehicles with electrical drives.

This report is a complement to the already approved Hamburg baseline deliverable D3.1, submitted at M12. That document described the city audit in Hamburg as Part I. Now, this document complements this city audit with the baseline values, once the common project indicators became available with the finalisation of D5.1 at M36. Therefore, this report can be considered as Part II of D3.1.

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2. Introduction

2.1 Purpose and target group

The present deliverable is part of the Task 3.1 – *Baseline Assessment* and located within Work Package 3 – *Demonstration in Hamburg*. It delivers an essential part that is required for the overall evaluation of relevant interventions in the project areas energy, infrastructure and mobility, a description of the initial situation before the implementation of the project interventions has been performed. In this sense, this document constitutes the second part of the Baseline report of Hamburg demonstration area, whereas the City Audit (D3.1), submitted in November 2017, was the first part. The descriptions of these initial situations are data-based and form the baseline for the selected interventions and hence serve as reference for the evaluation of the achievement of the set goals of these interventions at the end of the project.

This deliverable describes the interventions in terms of objectives and technical content. In order to allow their evaluation at the end of the project, the evaluation indicators selected for each action (indicators defined in the framework of WP5 and more particularly deliverable D5.1) are presented here, together with their reference values, before deployment of the actions. The process of collecting and analysing this baseline data was based on a tool developed by CARTIF (and supported by Tecnalia). This tool, common to the 3 cities of the project (Nantes, Hamburg, Helsinki) enabled the consideration of the key issues in following a M&V (measurement and verification) plan.

The target group of the document are the partners responsible of the data collection and evaluation of the project actions. Moreover, also stakeholders or decision makers who are active in similar areas as mySMARTLife should be addressed. They can on the one hand gain information about the initial situation of the project's interventions to discover the whole picture of the completed intervention. On the other hand, they can gain further knowledge of the evaluation procedure of this project as an example of a unified procedure in a multi-facetted project, such as mySMARTLife.

2.2 Contribution of partners

The following Table 1 shows the main contributions from participant partners in the development of this deliverable. Additional support and exchanges between the different partners are not stated specifically.

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Table 1: Contribution of partners

Participant's short name	Main contributions
HAM-BGD	Chapters 1, 1.1, 1.2, 1.3, 2, 3, 4, 4.1, 4.1.2, 4.1.3, 4.2, 4.2.5, 5, 5.1, 5.1.2, 5.1.3, 6, overall coordination and alignment of deliverable contents
CAR	Chapter 3
HAW	Chapters 4.1.1, 4.2.1, 4.2.2, 4.2.3
ENH	Chapters 4.1.2, 4.2.5
KON	Chapters 4.1.3
HAM-LSBG	Chapter 4.2.4
VHH	Chapter 5.1.1

Chapter 2 provides descriptions of the background of the present deliverable that help to place it within the context of the whole project.

Chapter 3 explains the scope of this baseline deliverable and what part the assessment of the baseline plays in the evaluation procedure of the project.

Chapter 4 shows the specific methodology followed for the generation and presentation of the baseline situations of the selected building and infrastructure interventions from the energy pillar in Hamburg. The building interventions range from new energy supply solutions for new and existing buildings to energetic refurbishments. The infrastructure interventions include the use of wind and solar power to generate electricity, the use of hydrogen within a district heating network and an ice storage as energy storage solution, as well as the replacement and introduction of new energy-efficient street lighting.

Chapter 5 provides information about the baseline of mobility interventions. Those interventions presented in this deliverable deal with the introduction of electric vehicles in order to replace fossil-fuelled vehicles. The vehicles replaced and newly introduced are passenger cars and public buses. Additionally, an e-car sharing solution is presented.

Chapter 6 summarizes the results from chapters 4, 5 and 6 and attempts to deliver an overall conclusion that should help to use the presented results in the following evaluation process.

2.3 Relation to other activities in the project

This present deliverable relates to different deliverables previously prepared by HAM that already cover aspects of the baseline. Here are to be mentioned D3.1 with a wider general focus on the baseline of the

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demonstrator area in Hamburg and D3.2, as well as D3.13 that already deal with data-based assessments of the baseline of individual interventions, but still have a broader perspective as D3.12.

Further relations between the present deliverable and previously prepared deliverables refer to comprehensive descriptions of the planned and implemented interventions provided in these. Interventions from the area of energy and buildings, for example, are covered in D3.3 and D3.4, whereas explanations of the mobility interventions can be found in D3.8. The infrastructure actions that deal with the improvement and upgrading of the public lighting in the project area are covered in D3.10 and D3.11.

D5.1 defines the evaluation procedure to assess the success of the project's interventions and therefore provides the larger framework D3.12 fits in. The present deliverable refers at different points to D5.1 when for specific calculations or individual factors or values, further explanations are necessary. Eventually, the results from D3.12 will be used for the final evaluation in D5.5.

As for the demonstrator area in Hamburg, also for the other two lighthouse cities Nantes and Helsinki, reports of the baseline of similar interventions as those that are covered here are prepared. These are D2.18 in the case of Nantes and D4.21 for Helsinki.

Table 2: Relation of D3.12 to other activities in the project

Deliverable Number	Contributions
D3.1	*Baseline report of Hamburg demonstrator area (M12)* – This deliverable provides information of Hamburg demonstrator area based on the City Audit.
D3.2	*Simulation models of the building stock, energy system, transportation, urban infrastructure (M12)* – An assessment of potentials for the generation of renewable energies and an outsight of further required simulations are provided.
D3.13	*Simulation models of the building stock, energy system, transportation, urban infrastructure (M42)* – This deliverable provides the description of the baseline report of interventions at the project start that are elaborated in D3.12.
D3.3	*Report on retrofitted actions and implemented actions new buildings including RES and storages in Hamburg* – A comprehensive description of building related measures is given in this deliverable.
D3.4	*Smart energy Supply and demands. Integration of RES and storages management and control* – This deliverable provides smart energy supply and demand solutions, as well as control systems and smart appliances in the project area and beyond.
D3.8	*Development of new mobility services and intermodality strategies* –provides the description of mobility interventions like e-busses, e-fleets and charging stations which are also located in the project area and beyond.

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D3.10	*Adaptive lighting concept* – describes the development of smart lighting at a planned bicycle way at the channel “Schleusengraben”,
D3.11	*Design and implementation of the humble lampposts concept* –provides primarily a technical description of the implementation of LED lighting in Hamburg-Bergedorf.
D5.1	*Integrated Evaluation Procedure* – This deliverable develops an evaluation procedure to assess the performance and success of the actions implemented in the mySMARTLife project.
D5.5	*Evaluation. Impact assessment at Smart City Project level and Smart City level* – Here, the results from the monitoring and the final evaluation of mySMARTLife are presented.
D2.18 and D4.21	These deliverables provide the baseline of the interventions from the other two lighthouse cities involved in the project: Nantes and Helsinki.

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3. Background and context

To be able to value the present deliverable and better understand how it fits into the set of previously prepared deliverables already dealing with the baseline topic but with different perspectives, it is necessary to further expand on the differences between and particularities of the different deliverables. On the one hand, D3.1 - *Baseline report of Hamburg demonstrator area,* which was due in project month 12, has to be mentioned. This deliverable is the first part of the baseline assessment of the Hamburg demonstrator area and provides information from the city audit that deals with general information on policies, developments and strategies that are relevant for the mySMARTLife project in Hamburg. On the other hand, the present deliverable directly connects to D3.13 - *Simulation models of the building stock, energy system, transportation, urban infrastructure* from month 36 and the corresponding interim version D3.2 from month 12. Whereas D3.1 looks at the City of Hamburg and the demonstrator area as a whole, D3.12 now focuses specifically on individual interventions and provides specific values that are essential for the evaluation of the achievements of these interventions. The intention of D3.13, the final version of D3.2, is similar to the one underlying D3.12. Both describe the situation of the interventions previously to the introduction of the project's measures. In D3.13, however, with the exception of a few interventions, the largest part of the descriptions provided are less based on values that are required for the final evaluation, but provide general calculations and simulations regarding the expected energy savings or reductions in carbon dioxide emissions. The most significant difference between D3.12 and the previously prepared deliverables is that for the baseline the focus is set on the KPI of the individual intervention and that actual simulations are performed in order to retrieve data that can be used as reference for the final evaluation. Simulations are used for the building related interventions, whereas for the other interventions existing data is used to depict the baseline situation. Figure 1 illustrates and summarises how the baseline assessment presented in the present deliverable fits into the project's evaluation framework developed in WP5.

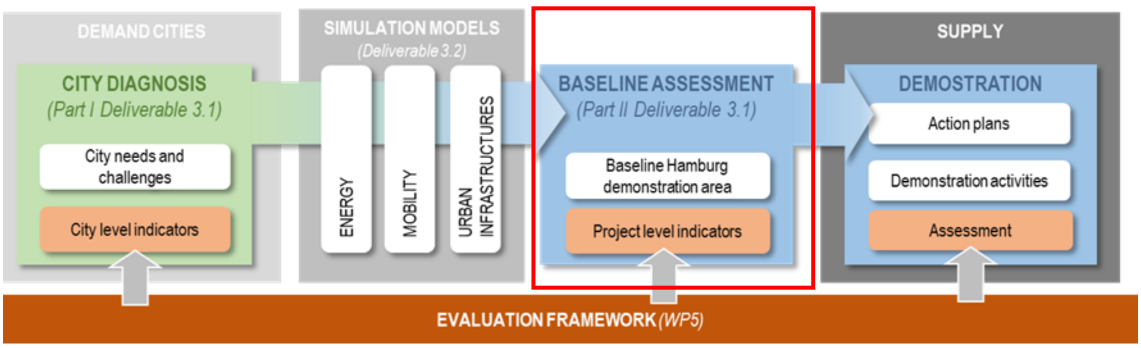

Figure 1: Baseline assessment as part of the mySMARTLife evaluation framework

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4. Scope of baseline assessment

The baseline assessment is part of the larger evaluation framework applied in mySMARTLife, as shown in Figure 1. Within this framework defined in the context of WP5, the effects of the project actions should be quantified by the use of project level indicators. As mentioned previously, the baseline refers to the initial situation of the project, or more precisely, to the situation before the project's actions have been implemented. In this sense, taking into account the definition provided by IPMVP (International Performance Measurement and Verification Protocol), the baseline period is the prior to the energy conservation measures and mobility actions.

The reasoning for the baseline need is the calculation of the energy savings. As illustrated in Figure 2, these are obtained during the period after the implementation of the actions. By means of comparing the real data obtained during this period with the "hypothetical" energy use of the baseline during post-retrofitting period. That is to say, translation of the baseline evaluation to the reporting period, which is named as adjusted baseline (baseline adjusted by the new parameters, e.g. climate conditions). Thus, energy savings (or namely avoided energy use) are obtained as,

$$Energy\ savings = Adjusted\ baseline - measured\ energy\ use$$

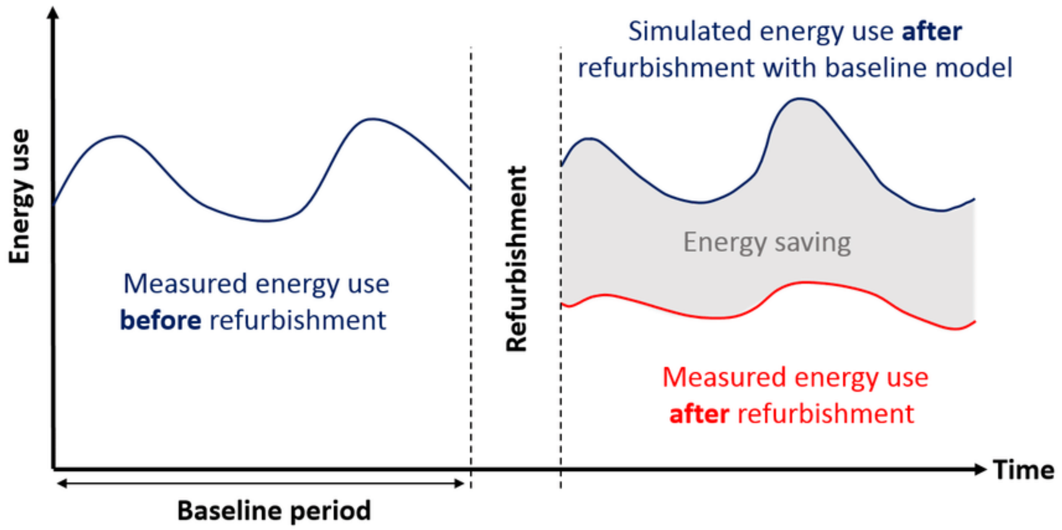

Figure 2: Energy savings definition by IPMVP

Nevertheless, to carry out a proper baseline calculation, the definition of the boundary is crucial. In this sense, a two-level boundary has been defined in WP5, as illustrated in Figure 3. These boundaries are:

- Building actions, where the objective is to evaluate the reduction in the energy demand by the retrofitting activities, as well as the increase of renewables in the generation / distribution. Therefore, the boundary considers the energy flow that is entering into the building.

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- City infrastructures, where the objective is to analyse the impact in terms of generation elements and how these are incrementing the renewable energy production. Therefore, the boundary, in this case, considers these generation systems, while the buildings would be considered as an energy load.

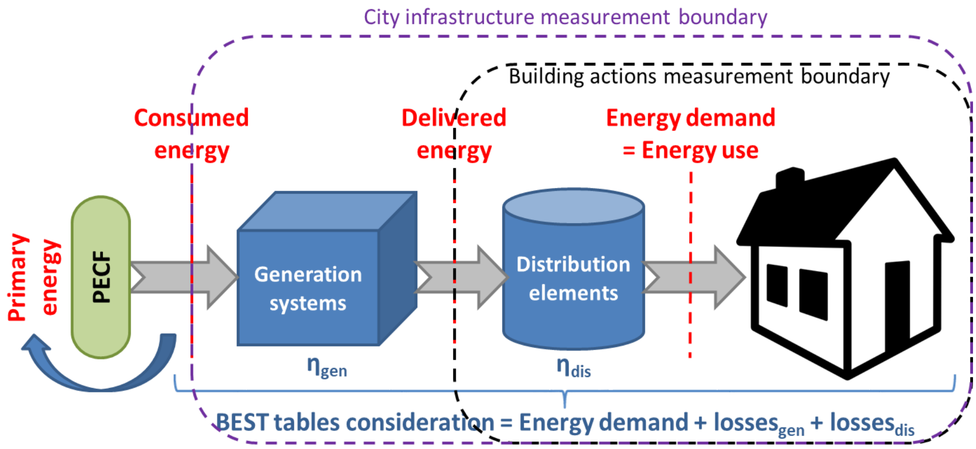

Figure 3: Measurement boundary definition

It should be noted this procedure is followed in energy context. Mobility is easier, where boundaries are not applicable and the baseline, at high-level, represents the CO_2 emissions emitted by conventional vehicles (diesel, gasoline…) that are substituted by electrical vehicles.

Having said that, the baseline reference period is selected according to the available data (e.g. climate conditions) to determine the “current” conditions (i.e. before mySMARTLife). Then, the baseline is considered as a reference year before the implementation of the actions. Along this year, the KPIs defined in D5.1 have been used for each intervention, which comprises a set of related actions, following a similar approach to BEST tables.

In this way, an Excel sheet has been used as support tool for the baseline methodology, as well as calculation of the indicators for the reference year. This Excel guides the cities at the time of selecting the proper procedure (real data or simulation), protocol (e.g. IPMVP), selection of boundary (a sample of building, all the district) and useful parameters for the adjustments (e.g. Heating Degree Days).

Moreover, as stated before, the Excel sheet allows the automatic calculation of KPIs based on some basic data, such as thermal / electrical energy consumption. The example for Schleusengraben-Schilfpark is illustrated in Figure 4, which includes actions A1, A13 and A18.

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Intervention	Indicator	Frequency	Baseline (reference year) kWh/year	Baseline (reference year) kWh/year (m2)	Baseline M1 kWh/month	Baseline M1 kWh/month (m2)
Schleusengraben-Schilfpark (A1, A13, A18)	E1) Thermal energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E2) Electrical energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E4) Annual energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E6) Energy use for heating	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E13) Total renewable thermal energy production	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E14) Total renewable electrical energy production	Monthly	0	0	0	
Intervention	**Indicator**	**Frequency**	**Baseline (reference year)**	**Baseline (reference year)**	**Baseline M1 kWh/month**	**Baseline M1 kWh/month (m2)**
Schleusengraben-Schilfpark (A1, A13, A18)	E19) Primary thermal energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E20) Primary electrical energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E21) Total primary energy consumption	Monthly	0	0	0	
Schleusengraben-Schilfpark (A1, A13, A18)	E23) Total primary energy consumption related to heating delivered	Monthly	0	0	0	
Intervention	**Indicator**	**Frequency**	**Baseline (reference year)**	**Baseline (reference year)**	**Baseline M1 kgCO2/month**	**Baseline M1 kgCO2/month (m2)**
Schleusengraben-Schilfpark (A1, A13, A18)	E28) Total greenhouse gas emissions (thermal)	Monthly	0	0	0	0
Schleusengraben-Schilfpark (A1, A13, A18)	E29) Total greenhouse gas emissions (electrical)	Monthly	0	0	0	0
Schleusengraben-Schilfpark (A1, A13, A18)	E31) Total greenhouse gas emissions	Monthly	0	0	0	0

Figure 4: Excel sheet sample for KPI calculation

The details about the methodology applied for each intervention are described in the following two chapters, as well as further explanations regarding derivation of the baseline and eventually the baseline values. These can be considered as the key result of the present deliverable. The actions and interventions considered in these presentations come from the project pillars energy and environment on the one hand and mobility on the other hand. The other project pillars, urban platform and ICT and social, economy and governance are not part of the baseline assessment.

The covered actions and interventions deal with building and city interventions for the energy part and e-vehicles for the mobility part. The key focus at the assessment of the baseline at energy actions and interventions is on energy consumption, generation or use of renewable energies and greenhouse gas (GHG) emissions. At mobility, the focus is solely on GHG emissions. It is important to note that not only carbon dioxide (CO_2) emissions are considered, but greenhouse gas emissions in total or more precisely, additionally to CO_2, the climate-damaging potentials of other gases such as methane (CH_4) or nitrous dioxide (N_2O) are included in the expression equivalent CO_2 (CO_{2eq})

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5. Baseline of buildings and city infrastructures

The following chapter provides descriptions of the baseline of interventions from the energy and environment pillar. According to the measurement boundary, these are divided into building-related actions on the one hand, and actions dealing with city infrastructure on the other hand. The first include the utilization of new energy systems in newly constructed or existing buildings, as well as the retrofitting of buildings. The latter comprise actions referring to specific systems for the generation of renewable energies or energy efficient infrastructures. In section 5.2 the Schleusengraben-Schilfpark intervention with the utilization of hydrogen in the local heating supply system, the photovoltaic and battery storage use at an office building at Kampweg and different examples from the retrofitting area are described. The last section 0 includes the infrastructure interventions which deal with the use of a battery storage at a local wind park, the utilization of hydrogen in a residential quarter at system-level, a building service system that is based on an ice cooling storage unit, further photovoltaic plants, as well as modern street lighting. A general description of the methodology followed is already provided in section 4. As the procedure followed differs between the interventions, for some interventions previously recorded data could be used, for others simulations had to be performed, and individual specifics need to be considered. Therefore, detailed information on the derivation of the baseline values is presented in the following sub-chapters.

5.1 Procedure followed to calculate baseline

As it was explained in the previous section, the scope of the baseline is the creation of a reference model that allows the adjustments during post-intervention in order to determine the energy savings. In this sense, IPMVP is selected as the reference protocol to apply the baseline calculation, which consists of 10 steps:

1. Objective of the action (included in the DoA and summarised in each section for the interventions).
2. Selection of the IPMVP action. In this sense, IPMVP offers 4 possibilities as follows:
    a. IMPVP Option A: Isolated system with a key parameter (e.g. performance of a new boiler)
    b. IMPVP Option B: Isolated system measuring all the parameters (e.g. all data-points from a new boiler)
    c. IPMVP Option C: Whole facility with monitored data (e.g. boiler + building + final energy use…)
    d. IPMVP Option D: Whole facility with simulated data (baseline through simulation tools, but assessment with real data)

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3. Selection of the baseline period (done in each one of the actions depending on its own life cycle).
4. Reporting period selection that starts just after the implementation of the intervention and ends at the end of mySMARTLife.
5. Adjustment parameters, which are included in the next chapters (e.g. HDD).
6. Analysis procedure, also explained, i.e. simulation, data… Nevertheless, the reporting period will be always based on real-data as a mySMARTLife project requirement.
7. Energy prices for the cost analysis. This is out of the scope of this deliverable and it will be evaluated from the economic pillar perspective within WP5.
8. Measurement specifications, which could be checked in the project description (DoA, web site…).
9. Monitoring responsible, but, this is being dealt in WP5.
10. Expected accuracy, which will be treated in the D5.5 when the impact assessment will be analysed.

To that end, the tool developed by CARTIF (and supported by Tecnalia) guides the cities in this selection. Figure 5 guides the selection of the procedure, based on data, simulation or others, while, in the case of data, determine the type of data (sensors, bills…). Moreover, the tool also offers the explanation of the option to be selected following the previous explanations.

Calculation procedure to be used	
Data-driven (KPIs)	Yes or No
Simulation tools (e.g. TRNSYS, Energy+…)	Yes or No
Others	To be detailed

Data source for the baseline calculation	
Bills	Yes or No
Sensor data	Yes or No
Others	To be detailed

Figure 5: Calculation procedure selection

Also, the tool supports the definition of the boundary, where the level to be covered, its area and sample size are set. When a subset of building is selected, the extrapolation method is also explained. Also, the baseline period selection, as Figure 7.

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Measurement boundary	
Level (Energy System, Dwelling, Building, District)	
Total area covered by the boundary (m2)	
Sample size for the baseline (m2)	
Aggregation/extrapolation methods when sample size is not the same than total area (e.g. simulation of 1 building out of 10)	
Selected dwellings (number, which ones)	
Selected buildings (number, which ones)	

Figure 6: Selection of the boundary

Baseline period	
Baseline period (required)	1 Full year
Baseline period (defined)	Start date (from which month/year)
	Final date (until which month/year)

Figure 7: Baseline period selection

Finally, the description of the parameters that affect the adjustments, such as Figure 8.

Parameters	
Heating Degree Days (HDD)	M1:
	M2:
	M3:
	M4:
	M5:
	M6:
	M7:
	M8:
	M9:
	M10:
	M11:
	M12:
Other parameters (affecting baseline)	e.g. radiation
	e.g. occupancy

Figure 8: Parameters for adjustments

In this way, as a summary, the procedure is based on the 10 steps of IPMVP, which are supported by the tool to calculate the KPIs. This provides guidance for the cities at time of implementing the measurement and verification plans. The details of how this procedure is applied in the different interventions is shown in the next chapters.

5.2 Baseline of building interventions

In order to derive the baseline values for the three interventions included here, simulations are performed. Not for all of these interventions historic data are available or they cannot be used directly for the assessment because they are influenced by external aspects, e.g. weather. In such cases, it is necessary to perform simulations of the initial situation for the baseline period. The latter case especially holds true

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for the building related interventions. For these, the weather conditions need to be corrected and be adjusted in order to make the comparison between the baseline and the monitored results comparable (as stated before in the followed methodology). Changes in the temperature, to stay with this example, from one year to another, can have significant impacts on the energy consumption, which would make the evaluation of the energy savings coming from the implemented measure, more difficult. For this reason, it is convenient to conduct simulations for all building related energy actions or interventions, even when there are historical data available. Yet, simulations are always subject to a certain degree of assumptions and uncertainties. These need to be minimized as far as possible. One method that is used for generating the baseline in order to receive plausible and also replicable results is the application of a standardized procedure. As described in section 4, IPMVP is applied here, to provide a methodology on how to deal with the before mentioned issue about different weather conditions in the periods that should be compared, but also to clearly define the boundaries of the intervention considered for the baseline.

The tool that is used to simulate the baseline of the building-related energy interventions is EnerCalC. EnerCalC is an Excel-based simulation tool based on the German norm for energy balancing, DIN V 18599. This norm is the transposition of the European Directive 2002/91EC on the energy performance of buildings. The method that is used in DIN V 18599 is incorporated in the European standardization EPBD CEN standards (Erhorn et al., 2007).

Main Topics of DIN V 18599 are

- Part 1: General balancing procedures, terms, zoning and evaluation of energy sources
- Part 2: Net energy demand for heating and cooling of building zones
- Part 3: Net energy demand for energetic air treatment
- Part 4: Net and final energy demand for lighting
- Part 5: Final energy demand of heating systems
- Part 6: Final energy demand of ventilation systems, air heating systems and cooling systems for residential buildings
- Part 7: Final energy demand of air conditioning and refrigeration systems for non-residential buildings
- Part 8: Useful and final energy demand of water heating installations
- Part 9: Final and primary energy demand of electricity producing plants
- Part 10: Boundary conditions of use, climate data
- Part 11: Building automation
- Part 12: Tabular procedure for residential construction

as well as:

- Supplement 1: Demand-consumption comparison

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- Supplement 2: Description of the application of characteristic values from DIN V 18599 for verifications of the law on subsidies EEWG
- Supplement 3: Conversion of the calculation results of an energy balance according to DIN V 18599 into a standardized output format

In EnerCalC, the building energy demands are simulated. This includes the energy demands for heating, cooling, ventilation, domestic hot water and lighting. Additionally, it is also possible to simulate on-site energy production by RES. Electricity use by the users of the building, for other applications as the named standardized applications, cannot be simulated. The Excel-based input mask of the used tool is depicted in Figure 9.

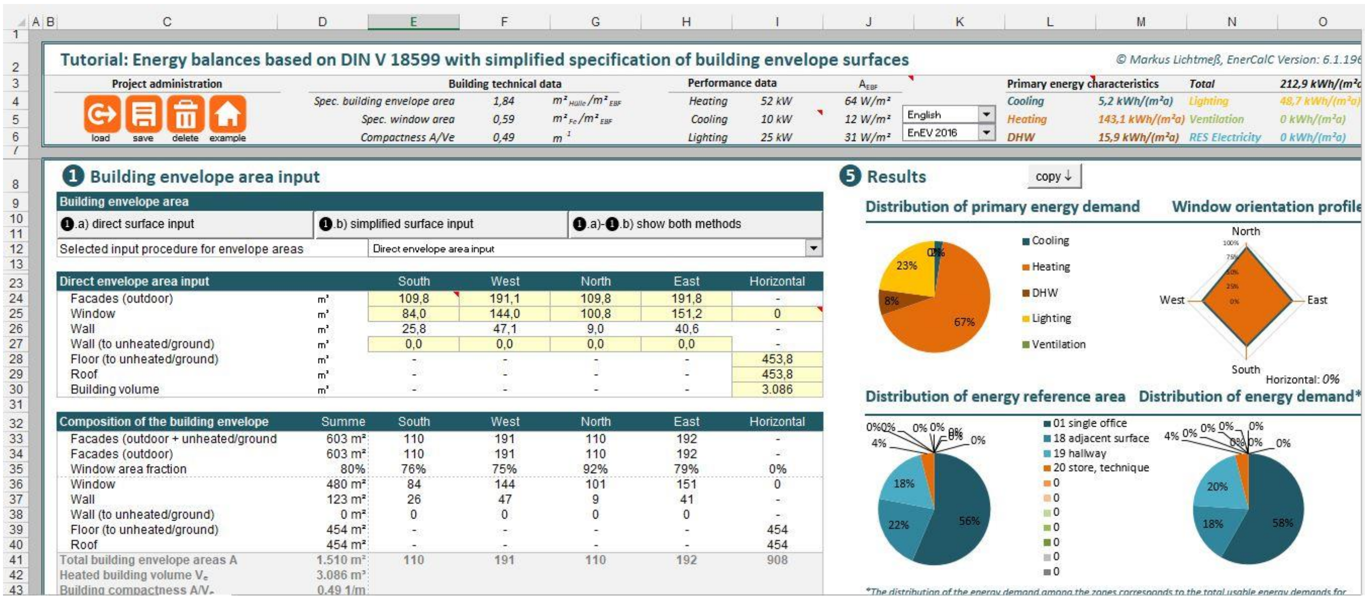

Figure 9: Extract from the EnerCalC input mask with values from the Kampweg simulation

The simulation can be divided into two parts that, both, have a major influence on the building energy demand. The first one is the building envelope, defined by the area of the floors and the facade, and parameters for individual building components, such as the U-values, the total heat transfer coefficient, of the main building components, including the outside walls and windows. In the other part, the use of the building is defined, which can strongly influence the building energy demands. The use of the building is defined in the simulation by the selected zoning for the building. It is possible to indicate different zones and uses for the area of the building. The zones correspond to usage profiles that are defined in the norm DIN V 18599. These primarily comprise profiles for non-residential uses, such as offices, hotels, industrial facilities, theatres, but also for residential buildings. The profiles provide, among others, standardized

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annual average values for the occupation, indoor climate conditions, lighting use and internal heat gains. For this reason, it is not necessary to incorporate further occupancy profiles or similar in the simulations that are performed with EnerClaC on the basis of DIN V 18599. By default standardized weather profiles from the norm for different regions in Germany can be selected. Yet, it is also possible to include an own weather profile.

EnerCalC provides a large set of results including monthly values for the demands of useful energy, end energy and primary energy as well as for CO_2 emissions (Figure 10). For the baseline simulations in this present report, however, only the useful energy demands are considered. The primary energy demands and the GHG emissions are calculated by the use of the before presented Excel table. This table includes calculations unified for the KPI calculations in mySMARTLife and should be considered as the standard procedure.

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1															
2	**1 - Meteorological data** English	EnEV 2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
3	Average outdoor air temperature	°C	1,6	2,3	4,7	8,9	13,2	15,7	18,2	18,0	14,2	9,9	5,5	1,7	9,5
4	Global radiation	W/m^2	19	39	86	164	208	202	185	174	97	71	27	15	108
5	Days per month	d/M	31	28	31	30	31	30	31	31	30	31	30	31	365
6															
7	**2 - Usable energy balance**	Detail balance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
8	Heating	kWh/(m^{2}M,a)	26,4	21,3	15,0	7,3	2,0	0,7	0,1	0,2	3,4	7,6	18,3	26,4	128,7
12	DHW heating	kWh/(m^{2}M,a)	1,1	1,0	1,1	1,0	1,1	1,0	1,1	1,1	1,0	1,1	1,0	1,1	12,4
16	Cooling	kWh/(m^{2}M,a)	0,0	0,0	0,2	0,5	1,4	1,6	2,1	2,0	0,4	0,4	0,0	0,0	8,7
19	Lighting	kWh/(m^{2}M,a)	2,5	2,1	2,2	2,1	2,1	2,0	2,1	2,1	2,2	2,4	2,5	2,8	27,1
20	Ventilation	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
21															
119	**2.1 - Distribution of thermal demand**	Detail balance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
120	Heating source 1 (Solar), coverage fraction:0%	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
121	Heating source 2 (CHP), coverage fraction:0%	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
122	Heating source 3 (Kessel) CF:100%	kWh/(m^{2}M,a)	27,5	22,2	16,0	8,3	3,1	1,7	1,2	1,2	4,4	8,6	19,3	27,5	141,1
123	Decentral DHW	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
124	Refrigeration machine	kWh/(m^{2}M,a)	0,0	0,0	0,2	0,5	1,4	1,6	2,1	2,0	0,4	0,4	0,0	0,0	8,7
139	**Usable energy via fuel / district heating**	**kWh/(m^{2}M,a)**	**27,5**	**22,2**	**16,0**	**8,3**	**3,1**	**1,7**	**1,2**	**1,2**	**4,4**	**8,6**	**19,3**	**27,5**	**141,1**
140	Heating	kWh/(m^{2}M,a)	26,4	21,3	15,0	7,3	2,0	0,7	0,1	0,2	3,4	7,6	18,3	26,4	128,7
141	DHW heating	kWh/(m^{2}M,a)	1,1	1,0	1,1	1,0	1,1	1,0	1,1	1,1	1,0	1,1	1,0	1,1	12,4
142	Cooling	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
143	**Usable energy via electricity**	**kWh/(m^{2}M,a)**	**2,5**	**2,1**	**2,4**	**2,6**	**3,5**	**3,6**	**4,2**	**4,2**	**2,6**	**2,8**	**2,5**	**2,8**	**35,7**
144	Heating	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
145	DHW heating	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
146	Cooling	kWh/(m^{2}M,a)	0,0	0,0	0,2	0,5	1,4	1,6	2,1	2,0	0,4	0,4	0,0	0,0	8,7
147	Lighting	kWh/(m^{2}M,a)	2,5	2,1	2,2	2,1	2,1	2,0	2,1	2,1	2,2	2,4	2,5	2,8	27,1
148	Ventilation	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
149	**Electricity production (on-site)**	**kWh/(m^{2}M,a)**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
150	Electricity from PV	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
151	Electricity from WT	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
152	Electricity from CHP	kWh/(m^{2}M,a)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
153															
154	**3 - Final energy balance**	Detail balance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Show Reference building: 943 kWh/(m^{2}a)

Figure 10: Summary of results in EnerCalC with the results from the Kampweg simulation

As the reference year can differ between the interventions, certain parameters applied in the simulations are the same for all the building-related interventions. This is because some values are standards or apply for the whole of Germany or Hamburg. Additionally, this should also make it possible to compare the results of the individual actions. These values are, among others, the primary energy factors for the energy carriers, as well as the emission factors of these.

For reasons of legibility, in the following resulting baseline, values are presented as annual values. The corresponding monthly baseline values for the interventions can be found in the annex. This also accounts

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for the interventions described in section 0. Additionally to the baseline values for the KPIs, a diagram with the most relevant KPIs for the interventions is shown as result to evaluate these and to illustrate changes over the period of the reference year. In most cases the total energy demand, the total primary energy demand and the total CO_2eq emissions are covered.

5.2.1 Schleusengraben Schilfpark

Figure 11: Picture of the new houses at the Schilfpark area, view from east (Borough of Bergedorf, 2019, own source)

In the area Schleusengraben Schilfpark, a new housing complex with ten residential buildings and more than 27.000 m2 of space was built. The aim of the action in mySMARTLife, described here, is to reach a heating energy demand that is 10 % below national regulation. This will be reached by better average U-values for the building envelope. How this goal will be quantified is described in the following section. Furthermore, the heating concept for the whole complex uses Combined Heat and Power (CHP). The CHP and boilers will be set up for hydrogen use up to 30 vol.% instead of full natural gas usage. The assessment of this action is described in section 5.3.2. More detailed descriptions of the action can be found in the deliverables D3.4 and D3.3.

Figure 12 shows schematically how these two topics are connected. The orange system boundary shows which energy flows are calculated in the baseline calculation. The heat is supplied from the generation system for heating and DHW and electrical energy.

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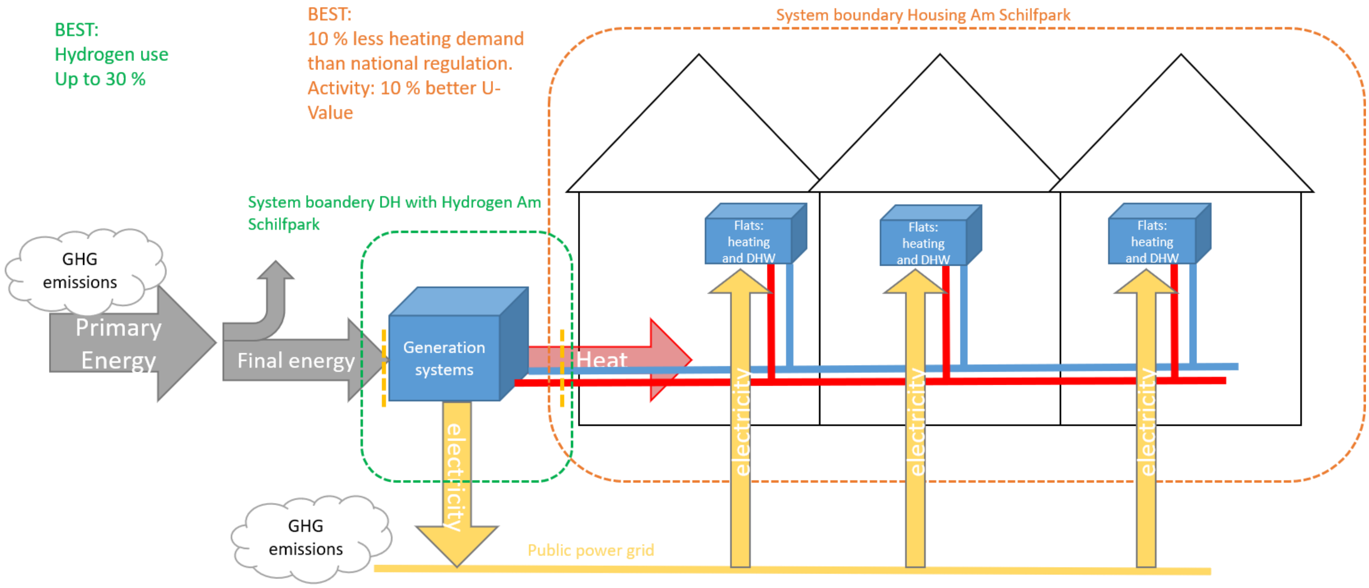

Figure 12: Relation between housing complex and district heating

5.2.1.1 Framework of evaluation

In order to determine and assess the achieved improvements in each action, a reference – called baseline - has to be defined. Main focus is to identify what parameters besides the impact of an action have influence on the measurement and qualify that influence. For example, lower energy demand for heating as in the year before can be caused by a milder winter. To quantify the impact of insulation, this effect has to be normalized and therefore deducted.

The new build housing complex at the Schleusengraben Schilfpark area (Figure 13) has two goals within mySMARTLife. The buildings themselves were built in a way to have a 10 % lower heating demand than national regulation for new constructions requirements. And secondly, the CHP system will be run with up to 30 % hydrogen instead of completely natural gas, which is described in section 5.3.2. Both will be compared to a baseline. Because of the new construction, no historical bills or measurements about heating demand exist. Therefore, a baseline is calculated based on a simulation. The calculation is based on German technical standards given by DIN V 18599.

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Figure 13: Site plan "Wohnen am Schilfpark" https://awb-ing.de/staging/wp-content/uploads/2019/09/AWB-Ingenieure-Ingenieurbau-Luebeck-Projekte-Tragwerk-Schilfpark-4.png)

Several calculation tools calculate energy demands of buildings based on DIN V 18599. One of these is EnerCalC which is used for the following calculations. Object of the simulation is the whole set of ten buildings shown in Figure 13. The simulation calculates the heating, cooling and electrical demands based on the occupation profile and climate characteristics for the location for each month of the year. For climate characteristics and occupation profile standard values from DIN V 18599 are used. With these standard values, the measured data within the monitoring phase are comparable with the simulated data. A principle challenge is given through the point that simulations never completely match the actual circumstances as these are based on some assumptions, while real operation sometimes differs. Hence, during T5.5, adjustments (as stated before) will be needed to make baseline and post-intervention periods comparable. To hold this approximation as close as possible with the real buildings, the parameters shown in Table 3 are used, obtained from the DIN V 18599 norm.

Indoor lighting and heat gains are yearly average based on data from over 270 flats. Because of individual behaviour and usage of electronical equipment and lighting of the residents, this can only be an approximation. As an assumption, LED bulbs are used for lighting in the simulation. Indoor heat gains are $3.75 \frac{\mathrm{W}}{\mathrm{m}^2}$ based on the net living space. Because the buildings have non-living areas (i.e. staircases, technic rooms), the value for the whole complex shown in Table 3 is slightly lower. The regional heating season is approx. from September to April, but the heating system is always on. This is because of the DHW demand which is assumed to be $12.5 \frac{\mathrm{kWh}}{\mathrm{m}^2\mathrm{a}}$ due to national standard. The necessary energy for DHW is supplied by the heating system as well. The external wall U-value shown in the table is the one required by national regulation and therefore not reduced by 10 %. Accordingly, the results in Table 6 describe the situation before the mySMARTLife actions.

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Table 3: Parameters of baseline simulation for the Schleusengraben Schilfpark intervention

Parameter	Unit	Value
Area	m^2	27,708
Indoor lighting	W/m^2	7.0
Indoor equipment heat gains (e.g. computers)	W/m^2	3.75[1]
Heating season	-	Sep-Apr
Heating system ON	-	always
Heating system OFF	-	never
Indoor temperature (set-point)	°C	20[1]
Weather conditions	-	Region 3, Hamburg[1]
Infiltration	h^{-1}	1.4[1]
Natural ventilation in winter	h^{-1}	0.1[1]
Natural ventilation in summer	h^{-1}	0.1[1]
External wall U-value	W/m^2K	0.28
Roof U-value	W/m^2K	0.2

[1] According to DIN V 18599

The assessment can then be done by normalizing the simulation results and converting them to the measurement conditions. This procedure matches with the option D approach in the International performance measurement and verification protocol (IPMVP).

For the normalizing the parameters shown in Table 4 are used. The chosen weather conditions correspond to the test reference year (TRY) 2017. A TRY is a fictional weather time series with the duration of one year. It is based on statistical values over several years, in this case from 1995 to 2012. In total the test reference year has 2,470.7 Kd heating degree days (HDD) with a heating limit temperature of 15 °C. This temperature describes the outdoor temperature at which the heaters are switched off.

Table 4: Heating Degree Days for normalizing

Month	HDD in Kd
January	505.3
February	446.4
March	337.9
April	170.5
May	65.1
June	0
July	0

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August	0
September	18.6
October	182.9
November	319.3
December	424.7

With this information the energy demand for heating, cooling, ventilation and the electrical energy demand can be calculated. The calculation of primary energy and greenhouse gas (GHG) emissions depends on the chosen factors. For the assessment it is necessary to use equal factors for baseline and measured data. The factors shown in Table 5 are used.

Table 5: Primary energy and emission factors

Factor	Unit	Value
Primary energy factor for natural gas	kWh/kWh	1.1
Primary energy factor for electrical energy	kWh/kWh	1.8
Emission factor for natural gas	$kgCO_2eq/kWh$	0.247
Emission factor for electrical energy	$kgCO_2eq/kWh$	0.502

5.2.1.2 Data collection and analysis

With the results of the baseline calculation, the KPIs are calculated, based on the unified calculations sheet described in Figure 4. The KPI values for the baseline are shown in Table 6. Monthly values can be found in the annex. The Table shows the annual values per square meter and year for each KPI and its formula.

Indicators E1 and E6 are energy use like heat and domestic hot water. Electrical energy as E2 is final energy because it has to be converted in usable energy like light, heat or kinetic energy. For the baseline period, the annual thermal energy consumption is calculated as 87.2 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$. The annual electrical energy consumption was calculated as 11.5 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$. For the baseline, no renewable energy sources where used, so the renewable energy production is zero (following the assumptions in the national regulation from BEST). Primary energy production and GHG emissions are calculated as shown in the table and based on the method described in Figure 12 with the factors shown in Table 5. These factors depend on the national use of renewable energy sources and the calculation method and therefore are subject to annual fluctuations. For a better comparison the factors are assumed as constant. Nevertheless, the values for useful energy consumption should be used for comparison.

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In relation to the intended impact of mySMARTLife, the goal for the BEST is to reach an energy use for thermal energy demand of 79.27 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$ which is 10 % less than 88.08 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$ - the national regulation requirement. The baseline simulation gives 74.7 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$ as a result for annual heating demand (E6) and 87.2 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$ for annual thermal energy demand (E1) with the given values for occupancy and weather. In the monitoring period the sum of heating and DHW energy use (E1) is measured.

The necessary reduction $1 - x$ of E1 for 10 % less heating demand (E6) can be calculated with

$$x = \frac{E1(x)}{E1} = \frac{E6 + DHW}{\frac{E6}{0.9} + DHW} = \frac{74.7\frac{\mathrm{kWh}}{\mathrm{m^2a}} + 12.5\frac{\mathrm{kWh}}{\mathrm{m^2a}}}{\frac{74.7\frac{\mathrm{kWh}}{\mathrm{m^2a}}}{0.9} + 12.5\frac{\mathrm{kWh}}{\mathrm{m^2a}}} = 0.913$$

With 12.5 $\frac{\mathrm{kWh}}{\mathrm{m^2a}}$ as national standard for energy demand for DHW. That means, E1 is about 8.7 % less when the heating demand reduces by 10 %.

Table 6: Baseline results of the building intervention at Schleusengraben Schilfpark, annual values

Indicator	Formula	Unit	Baseline, per m²	Baseline, total building
E1) Thermal energy consumption	$E1 = \frac{\text{Thermal energy consumption of all forms of energy}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	87.2	2,416,138
E2) Electrical energy consumption	$E2 = \frac{\text{Electrical energy consumption}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	11.5	318,641
E4) Annual energy consumption	$E4 = E1 + E2$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	98.7	2,734,780
E6) Energy use for heating	$E6 = \frac{\text{Heating energy demand}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	74.7	2,069,789
E13) Total renewable thermal energy production	$E13 = \frac{\text{Thermal renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	0	0
E14) Total renewable electrical energy production	$E14 = \frac{\text{Electrical renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	0	0
E19) Primary thermal energy consumption	$E19 = E1 \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	95.92	2,657,753
E20) Primary electrical energy consumption	$E20 = E2 \cdot \text{Primary energy factor for electrical energy from energy carrier}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	20.7	573,555
E21) Total primary energy consumption	$E21 = E19 + E20$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	116.62	3,231,308
E23) Total primary energy consumption related to heating delivered	$E23 = \text{Heating energy flow} \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	82.17	2,276,766
E28) Total greenhouse gas emissions (thermal)	$E28 = \text{thermal energy consumption (E1)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{\mathrm{kg\ CO_2}eq}{\mathrm{m^2a}}$	21.54	596,788
E29) Total greenhouse gas emissions (electrical)	$E29 = \text{electrical energy consumption (E2)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{\mathrm{kg\ CO_2}eq}{\mathrm{m^2a}}$	5.77	159,953
E31) Total greenhouse gas emissions	$E31 = E29 + E30$	$\frac{\mathrm{kg\ CO_2}eq}{\mathrm{m^2a}}$	27.31	756,743

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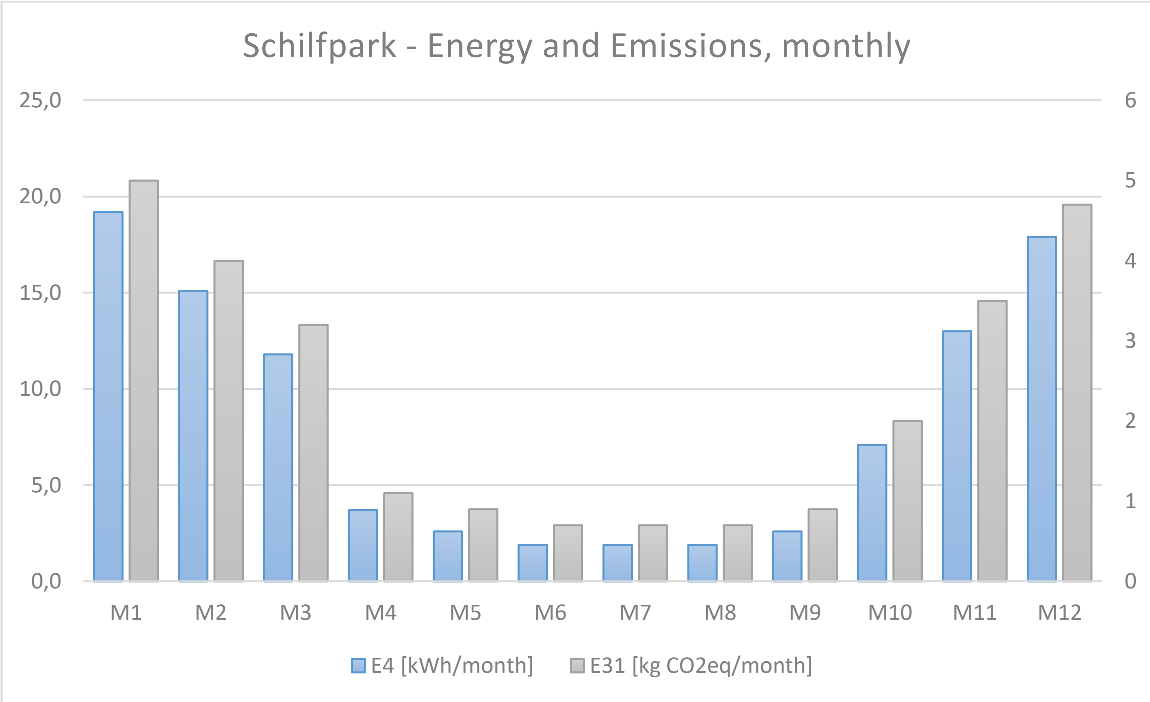

Figure 14: Monthly energy consumption (E4) and GHG emissions (E31) of Schleusengraben Schilfpark

Figure 14 shows the monthly changing of energy consumption and greenhouse gas emissions. Both are dominated by the energy demand for heating. This results in far less energy demand and therefore GHG emissions in summertime. While over the year electrical energy and DHW demand stay more or less the same, during the heating period the thermal energy demand increases with falling outdoor temperatures. This parabolic course is typical for monthly energy demand over one year. However, the actual demand depends most, but among other things, on weather conditions like outdoor temperature and sun radiation. Considering this, the measured data during the monitoring period will be adjusted to the conditions used for baseline calculation.

5.2.2 Photovoltaic and battery storage at Kampweg

The objective of the Action 5 is to install 300 kWp of PV-plants on roofs whenever possible with the concept of direct power delivery to the users and tenants of the buildings. The PV-systems for which it makes sense and where it is technically and economically feasible, will be supplemented by a battery storage system to increase the self-sufficiency rate and grid relief (Action 7).

These facilities are parts of decentralized power supply with renewable energies and an improved degree of autarky. Homeowners and tenants will be supplied with real green electricity from their "own" roof. The

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power could be used for standard consumption (light, home appliance, office equipment) or driving other energy facilities, like heat-pumps and air handling units.

Apart from the installation of the PV-plants on the roof (and possibly a battery storage unit), no changes will be made to the buildings. Therefore, no changes in consumption will result from the actions. Only a consumer-related production of electricity will come about.

One selected example where both actions are to be implemented, form the intervention at Kampweg at the site of the department for public spaces of the Borough of Bergedorf. There, on a roof of a storage facility, a PV-plant with nearly 100 kWp is in operation since October 2019. The installation of 10kWh battery storage is planned for summer 2020. Together with an office building of the department on that site, the PV-plant and the battery storage are seen as one system.

Figure 15: Construction of the plant: Module on a roofer's elevator (source ENH)

Figure 16: View over the finished PV plant Kampweg (source ENH)

Table 7: Technical specification of the plant Kampweg.

Designation/Component	Value	Measuring unit/specification
PV generator power	99.83	kWp
PV array surface	590.60	m²
Number of PV modules	363	LX-275P/156-60+ of Luxor Solar GmbH

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Number of inverters	2	1 x Sunny Tripower CORE1 and 1 x Sunny Tripower 25000TL-30 of SMA Solar Technology AG

More details about the technical components of the PV-plant at Kampweg, as well as of other PV-plants that are installed in the context of the mySMARTLife action, can be found in deliverable D3.4, section 4. These further PV-plants are also part of the present baseline report (section 5.3.5).

5.2.2.1 Framework of evaluation

As the baseline describes the initial situation of the intervention, before the mySMARTLife measures have been implemented, the focus of the baseline for this intervention is solely on the energy consumption of the office building. The PV-plant and the battery storage are the key components of this intervention, which should bring the anticipated advantages but these are not installed during baseline (as obvious), therefore the renewable generation is zero. These systems that should increase the use of RES will be evaluated in the evaluation of the monitoring at the end of the project, as well as in the evaluation of the Building Energy Specification Table (BEST) number 6B.

In order to monitor and later outline the impacts of the PV-plant, following KPIs are considered and will be monitored as followed:

- E14 – *Total renewable electrical energy production* will be measured at the smart production meter of the PV-plant. The monthly electricity production is determined and made available in a table.
- E15 – *Total renewable energy production* is the sum of thermal and electrical RES. Since only electrical energy is produced in a renewable way, the RES in this case is equal to E14.
- E17 – *Degree of energy self-supply by RES* will be calculated from the amounts of electricity produced and consumed. The amount of the power self-supply will be measured if possible, by an internal consumption meter or calculated by simulation from the total consumption curve of the connected building and the production curve of the PV system.
- E27 *Degree of energy supply by Urban RES infrastructure* the feed-in quantity describes the residual amount of electricity that will be supplied via the urban electricity grid. The share will be calculated from the difference between the total electricity production (E14) and the electricity power produced and consumed (E17) directly on site.

Whereas it is the office building with its energy consumption that defines the baseline of this intervention, a simulation similar to the one for the residential buildings at Schilfpark, as described in section 5.2.1 is conducted here.

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5.2.2.2 Data collection and analysis

The already mentioned BEST 6B provides a first assessment of the building energy demands and further energy-related data of the building envelope (Table 8). Additionally, the BEST also provides energy demand values (Table 9). These, as well as the values from Table 8, should be used as reference for the simulation of the office building at Kampweg. As this building is no new construction that has been built after mySMARTLife has started, but was planned and constructed in 2004/2005, the values in the BEST should correspond to actual energy demands.

Table 8: Extract from BEST 6A, U-values and building data for Kampweg

Building component	Indicator	Unit	Value
Façade/wall	U-value[1]	W/m²K	0.9
Roof	U-value[1]	W/m²K	0.9
Ground floor	U-value[1]	W/m²K	0.8
Glazing	U-value[1]	W/m²K	1.3
Average	U-value[1]	W/m²K	0.94
Glazing	g-value[2]	%	0.6

[1] Total heat transfer coefficient

[2] Total solar energy transmittance of glazing

Table 9: Key energy applications and demands from BEST 6B for Kampweg

Energy application	Energy form	Unit	Value
Heating	Heat (gas)	kWh/m²a	115
Cooling	Electricity	kWh/m²a	9
Ventilation	Electricity	kWh/m²a	0
Lighting	Electricity	kWh/m²a	28
Domestic hot water (DHW)	Heat (gas)	kWh/m²a	12.5
	total	kWh/m²a	164.5

As explained in the section 5.2, the variables that are needed for the simulation of the building energy demands in EnerCalC primarily include the building envelope area, building parameters, such as the U-values of the main building components, zoning data and specifications of the building's energy system. Data for the building envelope area and the zoning is retrieved from construction plans of the building.

Other information about the building's energy system and for lighting and shading are gathered at on-site inspections.

The results from the simulation that can be transferred to the previously shown Excel file for the calculation of the KPI that are used as baseline values are presented in Table 10:

Table 10: Values from EnerCalc simulation for calculation of baseline values

Energy application	Energy form	Unit	Value
Heating	Heat (gas)	kWh/m²a	114.9
Cooling	Electricity	kWh/m²a	9.0
Ventilation	Electricity	kWh/m²a	0
Lighting	Electricity	kWh/m²a	27.1
Domestic hot water (DHW)	Heat (gas)	kWh/m²a	12.7
	total	kWh/m²a	163.7

In the first run of the simulation of the office building at Kampweg with the building parameters from BEST 6B the annual total energy demand was at 176.9 kWh/m²a, compared to the 164.5 kWh/m²a from the BEST. The difference can be considered as to be with in an acceptable range for the simulation. Yet, whereas the U-values for the building components from the BEST already are considerably high, compared to other modern constructions, the decision to improve these values in order to reach the stated energy demands appeared to be more suitable. For this reason the values presented in Table 11, or more precisely the monthly values that form the sums listed in the table, are used for the calculation of the baseline KPI for the Kampweg intervention.

Table 11: Parameters of baseline simulation for the Kampweg intervention

Parameter	Unit	Value
Area	m^2	820
Indoor lighting	W/m^2	31
Indoor equipment heat gains (e.g. computers)	W/m^2	6.81
Heating season	-	Sep-Apr
Heating system ON	-	always
Heating system OFF	-	never
Indoor temperature (set-point)	°C	20
Weather conditions	-	Region 3, Hamburg
Infiltration	h^{-1}	1.15

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Natural ventilation in winter	h^{-1}	0.1
Natural ventilation in summer	h^{-1}	0.1
External wall U-value	W/m^2K	0.75
Roof U-value	W/m^2K	0.75

As it can be seen in the comparison between Table 11 and Table 3 for the parameters of the baseline, simulations for the Kampweg intervention and the intervention at Schilfpark are the same. This has to do with the fact that both simulations are performed with the same tool, EnerCalC, which is based on the norm DIN V 18599. Additionally, also the heating degree days (Table 4) and primary energy and emission factors (Table 5) are the same because. Both interventions are in the same area, hence, the same weather data can be used and in both intervention the same energy carriers are used. Yet, with regards to the emission factor that is applied here, it needs to be taken into account that the GHG emissions are to be considered as potential emissions, whereas for this building, owned by the Borough of Bergedorf, renewable electricity is used. The boundary of the simulation according to IPMVP is the same as in the Schleusenpark intervention whereas here as well, the whole facility is simulated for the baseline.

The results from the simulation are presented as summed up annual values in Table 12, the complete monthly values for the KPI can be found in the annex.

Table 12: Baseline results of the building intervention at Kampweg, annual values

Indicator	Formula	Unit	Baseline, per m²	Baseline, total building
E1) Thermal energy consumption	$E1 = \frac{\text{Thermal energy consumption of all forms of energy}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	127.6	108.650
E2) Electrical energy consumption	$E2 = \frac{\text{Electrical energy consumption}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	36.1	29.930
E4) Annual energy consumption	$E4 = E1 + E2$	$\frac{kWh}{m^2a}$	163.7	138.580
E6) Energy use for heating	$E6 = \frac{\text{Heating energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	114.9	98.154
E8) Energy use for lighting	$E8 = \frac{\text{Lighting energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	27.1	22.550
E9) Energy use for cooling	$E9 = \frac{\text{Cooling energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	9	7.380
E13) Total renewable thermal energy production	$E13 = \frac{\text{Thermal renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	0	0
E14) Total renewable electrical energy production	$E14 = \frac{\text{Electrical renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	0	0
E15) Total renewable energy production	$E15 = E13 + E14$	$\frac{kWh}{m^2a}$	0	0
E17) Degree of energy self-supply by RES	$E17 = \frac{E15}{E4} \cdot 100$	%	0	0
E27) Degree of energy supply by Urban RES infrastructure	$E27 = \frac{\text{RES energy supply}}{\text{total energy consumption}}$	%	0	0

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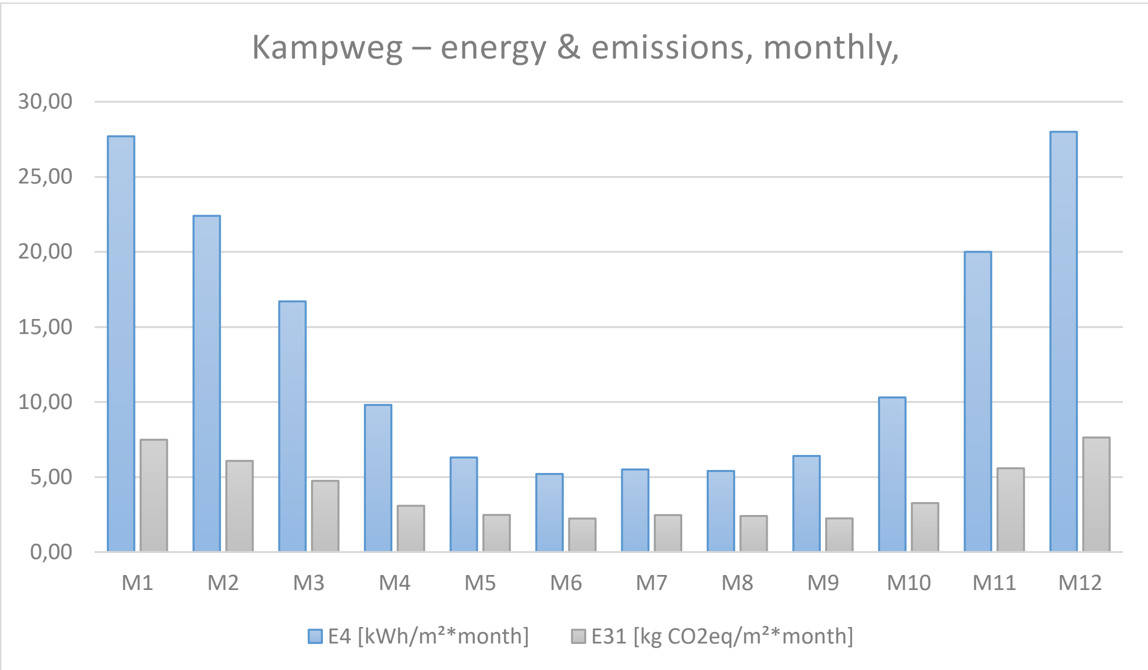
E19) Primary thermal energy consumption	$E19 = E1 \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	140.36	115.095
E20) Primary electrical energy consumption	$E20 = E2 \cdot \text{Primary energy factor for electrical energy from energy carrier}$	$\frac{kWh}{m^2a}$	64.98	53.284
E21) Total primary energy consumption	$E21 = E19 + E20$	$\frac{kWh}{m^2a}$	205.34	168.379
E23) Total primary energy consumption related to heating delivered	$E23 = \text{Heating energy flow} \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	126.39	103.640
E28) Total greenhouse gas emissions (thermal)	$E28 = \text{thermal energy consumption (E1)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\, CO_2eq}{m^2a}$	31.52	25.844
E29) Total greenhouse gas emissions (electrical)	$E29 = \text{electrical energy consumption (E2)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\, CO_2eq}{m^2a}$	18.12	14.860
E31) Total greenhouse gas emissions	$E31 = E29 + E30$	$\frac{kg\, CO_2eq}{m^2a}$	49.64	40.704

Table 13: Monthly energy consumption (E4) and GHG emissions (E31) at Kampweg



5.2.3 Bergedorf Süd retrofitting project

The area Bergedorf-Süd, Zone 2, is the retrofitting area at the mySMARTLife lighthouse city Hamburg and the location of the intervention that is reported on here. In this area, a broad mixture of old residential buildings with a diversified owner structure can be found. In total, the area encompasses around 330,000 m² with approximately 500 buildings. The objective of the corresponding task is to realize an energetic retrofitting of existing buildings of all together 14,000 m². The approach konsalt, the action leader of this retrofitting action follows, aims at the activation of the building owners to implement the retrofitting measures by providing information and contacts to further experts. The background and

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objective, as well as the mentioned approach, are further described in deliverable D3.3 in chapter 4. In addition to the retrofitting action, the intervention in Bergedorf-Süd also includes the smart heating island action. In the context of this action by konsalt, the heating system of a local heat supply system between the mentioned hotel and residential building block has been renewed. Both approaches lead to reduced energy consumption, here primarily heat, which leads to reduced GHG emissions. A more detailed description of the measures can be found as well in D3.3, chapter 4. The monitoring of this action will include following buildings: A hotel, a residential building block and a school building. Table 14 provides a brief overview with the key facts of these buildings which are all located in the retrofitting area, Zone 2 (Figure 17).

Table 14: Overview of the buildings included in baseline of Bergedorf-Süd.

No.	Building	Location	Measure	Area
1	H4 Hotel	Zone 2; Holzhude 2, Bergedorf	Replacement and renewal of heating system	10,437 m²
2	Residential building at H4 Hotel	Zone 2; Holzhude 4-12, Bergedorf	Replacement and renewal of heating system	7,492 m²
3	Rudolf-Steinar-School	Zone 2; Am Bring 7, Bergedorf	Energetic refurbishment of building envelope	876 m²
			Total area	18,805 m²

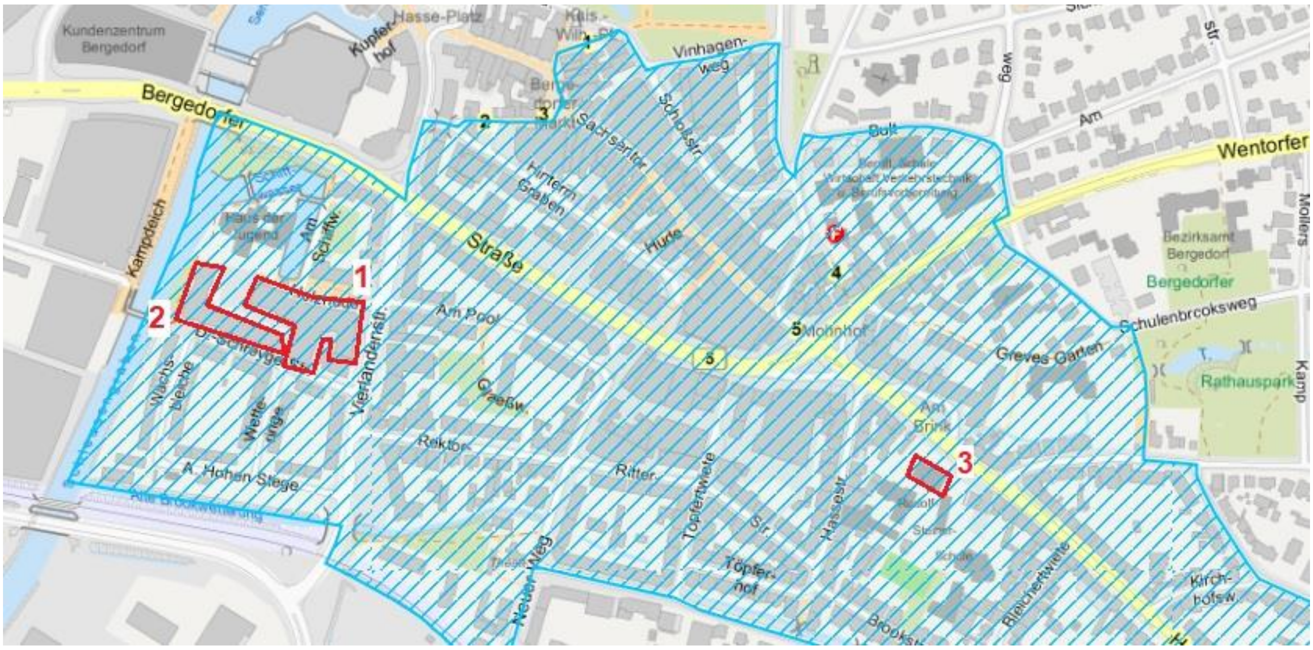

Figure 17: Location of the buildings (red outlines) included in baseline of Bergedorf-Süd in the retrofitting area, Zone 2 (light blue area)

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A baseline for this intervention in Bergedorf-Süd should eventually consider the retrofitting and the optimization of the heating island. Initially, simulations as for the interventions at Schilfpark and Kampweg should have been performed for the three buildings in order to receive the baseline results that indicate the energy demands before the measures have been implemented. However, it turned out that for the buildings considered only rough estimations regarding the initial situation were possible. With the data that is currently available for these buildings, no reliable simulations could be performed.

As it is described before, for a good simulation it is necessary to minimize errors and the degree of uncertainty by calibrating and validating the assumptions made for the simulation. The less actual data and information of the buildings that should be simulated are available, the more assumptions need to be made. If actual energy demand values would have been known, then the assumptions made could be validated. For the hotel and the residential buildings, some energy demand data were available, also profound assumptions concerning the building areas were possible, based on construction plans. However, valid information regarding the building components and the zoning were not available. Especially for a hotel of the stated size, assumptions regarding the zoning need to be validated by actual consumption data. Otherwise great over- or under estimations of the energy demands could be possible that would be of no use for the assessment of the baseline. Because the heating supply system of the residential building is connected to the hotel, both have to be seen as one system. Due to the still lack of data for calibration, no reliable simulation is yet possible for the residential building, even though the possible assumptions were more funded. During T5.5, when data will be available, the simulations for this intervention will be run and validated.

For the school, only limited information regarding the building components were available and no consumption data. Since the school building is a heritage-protected building that is more than 150 years old, it is not possible to apply standard building catalogues or other references for energy consumption data of schools or building components. Nevertheless, ad hoc solutions are required due to the peculiarities of this building, which will be analysed from the baseline perspective in D5.5, when retrofitted actions will be established (note that this action A2 is under negotiation with European Commission).

The comprehensive baseline assessment supported with data from the upcoming investigations will then be presented latest in the deliverable D5.5. The simulations for this intervention will cover the buildings and the corresponding heat supply systems and provide baseline results including the KPI listed in Table 15.

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Table 15: KPI that will be part of the baseline for the buildings included in the Bergedorf-Süd intervention

Indicator	Formula	Unit
E1) Thermal energy consumption	$E1 = \frac{\text{Thermal energy consumption of all forms of energy}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$
E2) Electrical energy consumption	$E2 = \frac{\text{Electrical energy consumption}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$
E4) Annual energy consumption	$E4 = E1 + E2$	$\frac{kWh}{m^2a}$
E6) Energy use for heating	$E6 = \frac{\text{Heating energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$
E25) Total heat supplied to the buildings connected to district heating network	$E25 = \frac{\text{Total thermal energy supplied to the demosite buildings}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$
E26) Degree of heating supply by district heating	$E26 = \frac{\text{Total heat supplied to the buildings (E25)}}{\text{Total energy supply by district heating}}$	%
E19) Primary thermal energy consumption	$E19 = E1 \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$
E20) Primary electrical energy consumption	$E20 = E2 \cdot \text{Primary energy factor for electrical energy from energy carrier}$	$\frac{kWh}{m^2a}$
E21) Total primary energy consumption	$E21 = E19 + E20$	$\frac{kWh}{m^2a}$
E23) Total primary energy consumption related to heating delivered	$E23 = \text{Heating energy flow} \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$
E28) Total greenhouse gas emissions (thermal)	$E28 = \text{thermal energy consumption (E1)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2eq}{m^2a}$
E29) Total greenhouse gas emissions (electrical)	$E29 = \text{electrical energy consumption (E2)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2eq}{m^2a}$
E31) Total greenhouse gas emissions	$E31 = E29 + E30$	$\frac{kg\ CO_2eq}{m^2a}$

5.3 Baseline of city infrastructure interventions

In this chapter the baselines for a different set of interventions are presented. Whereas in the previous chapter the descriptions and procedures followed for the generation of the baseline for the building-related actions were similar to one another, the interventions, as well as the methodology applied differ for the interventions presented in this chapter much more. In the following interventions that deal with the generation of renewable electricity, the operation of innovative energy systems as well as with the implementation of modern infrastructures are described. Because the scope and the approaches are different among those interventions described in this chapter, the description of the methodology is included in each sub-chapter. For the presentation of the results the procedure here is the same as in section 5.2. Annual baseline results are presented here together with a diagram depicting the most relevant KPI, whereas the complete monthly baseline values can be found in the annex of the present deliverable.

5.3.1 Building intervention Wind Farm

A wind farm (A17) was built near the Technology Centre Energy Campus (TCEC) of the University of Applied Sciences (HAW). The wind farm consists of five wind turbines (Nordex model type N117) with a total capacity of 12.6 MW and is designed to generate around 35 GWh per year. A large energy storage was also installed (A20) next to the wind farm. The integration of the battery is part of the research SINTEG-project NEW 4.0, in which key technologies of the energy turnaround are demonstrated by the city of Hamburg and the federal state of Schleswig-Holstein. The wind farm and the battery system are intended to provide ancillary services for the electricity grid. Further information can be found in the deliverable D3.4.

5.3.1.1 Framework of evaluation

Actions A17 and A20 consist of the implementation of the wind farm and the integration of the energy storage. The system consisting of battery and wind farm feeds electricity into the public grid; this power supply is to be optimised. The testing of innovative possibilities for additional services, such as the instantaneous reserve as a very fast frequency response reserve, is part of the "NEW 4.0" research project. The system also provides control energy so that short-term fluctuations in the grid frequency can be compensated. This is intended to ensure that wind turbines are not switched off when the grid is overloaded. The main three cases instantaneous reserve, primary control power and reactive power will be investigated during the SINTEG-project NEW 4.0 and are explained in more detail in D3.4. The aim is to increase the understanding of specific issues relating to wind energy production, plant operation and grid integration as well as electricity storage. Therefore, the electricity production of the wind farm and its share in covering the load in the study area are presented and analysed with the help of the indicators.

The indicators are determined using a data-driven calculation method (historical data). For this purpose, data measured at the wind turbines on the one hand and data provided on the website "Energieportal" (http://www.energieportal-hamburg.de/distribution/energieportal/) by the project partner Stromnetz Hamburg (SNH) on the other hand were used. The actions A17/20 are represented by option A of the IPMVP. The generated power of the wind farm, which is the key parameter of this action, is measured continuously and depends on the prevailing wind speed. The amount of energy produced is calculated from the power generated. The savings can be determined by comparing the monthly energy amounts normalised by the average wind speed, which is measured at hub height (Table 16). The wind farm was commissioned in November 2017 and was not changed during the term of mySMARTLife. After commissioning, a one-year test run was carried out until October 2018 and one of the five wind turbines was serviced in August 2018. The energy storage system added in November 2018 does not affect the energy generated by the wind turbines. There were no major maintenance outages or disruptions in 2019, so this period was chosen for the baseline.

Table 16: Average wind speed for normalisation

Month	Average wind speed at hub height in m/s
January	6.61
February	6.06
March	7.25

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April	5.69
May	5.58
June	5.09
July	4.95
August	4.63
September	5.45
October	5.78
November	5.72
December	6.30

5.3.1.2 Data collection and analysis

The formulae for calculating the KPI can be found in "Annex II: Project level indicators" of deliverable D5.1. The calculations are explained in more detail at those points where there are deviations from those specified in Annex II. Table 17 shows the annual result values of the calculation.

The wind farm was commissioned in September 2017 and after a test phase its official opening was celebrated on the 12th of October 2018. Since then data has been recorded from which the KPI can be calculated. For the calculation of the total renewable electrical energy production (E14), the generated power at the individual wind turbines is required, from which the total amount of energy of the wind farm is calculated. Here, the amount of energy is not related to a defined area, because the electricity from the wind farm is fed into the electricity grid and is not directly consumed by a building or similar.

In order to be able to compare the baseline data with the monitoring data later, it is necessary to record the wind speed in both phases. This allows the respective energy productions to be normalized to a defined wind speed and then compared. The comparison would thus take into account the differences in wind supply in the different years.

No thermal energy is produced by the wind farm, so that the total renewable electrical energy production (E14) corresponds to the total renewable energy production (E15).

E27 is calculated as described in D5.1. Data from the Energy Portal is used to determine E27. The “Energieportal” presents, among many other information, the current course and the values of power generation and load in the districts of Hamburg. For our purposes, the load and generation in the Bergedorf district is relevant, because together with the total renewable energy production of the wind farm, it allows us to determine the degree of energy supply by urban RES infrastructure.

The table shows the annual value of the KPI calculated for this intervention. These are total, not area-specific values.

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Table 17: Baseline results of the infrastructure intervention at the wind park Curslak, annual values

Indicator	Formula	Unit	Baseline, total system
E14) Total renewable electrical energy production	$E14 = \frac{\text{Electrical renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{kWh}{a}$	30,631,344.87
E15) Total renewable energy production	$E15 = E13 + E14$	$\frac{kWh}{m^2a}$	30,631,344.87
E27) Degree of energy supply by Urban RES infrastructure	$E27 = \frac{\text{RES energy supply}}{\text{Total energy consumption}}$	%	5.48

The diagram shows the total renewable energy production of the wind farm for 2019 in monthly resolution. The most energy (4,254,997.43 kWh/month) was produced in March, as wind speeds were highest on average in this month.

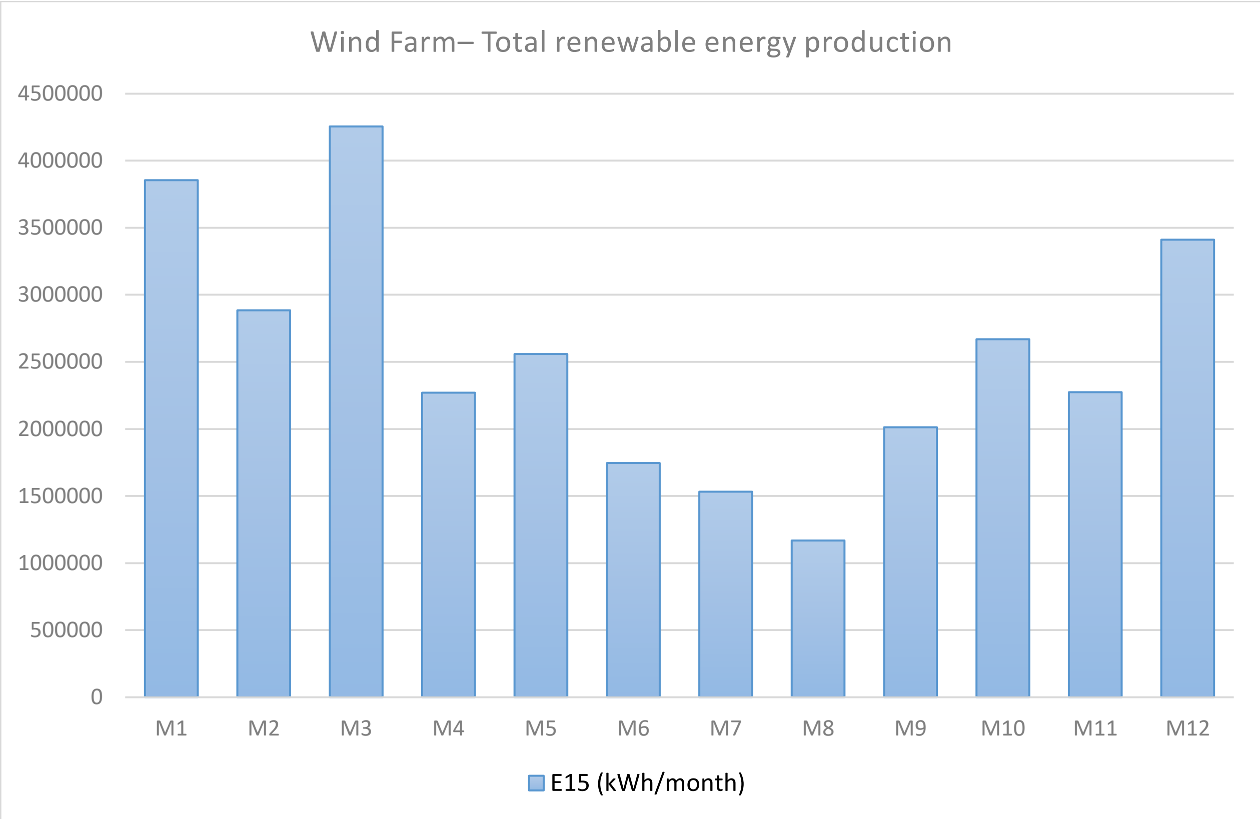

Figure 18: Monthly total renewable energy production of the Windpark Curslak in the baseline reference year

5.3.2 District heating with a high share of hydrogen

In the area of Schleusengraben Schilfpark, a new housing complex was built. The heating concept for the whole complex uses CHP. The CHP and boilers will be set up for hydrogen use up to 30 vol.% instead of full natural gas usage. How this goal will be quantified is described in the following section. Furthermore,

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the heating energy demand of the complex will be 10 % less than required by national regulation. This will be reached by better average U-values for the building envelope. The assessment of this action is described in section 5.2.1. More detailed descriptions of the action can be found in D3.4 and D3.3.

5.3.2.1 Framework of evaluation

In order to determine and assess the achieved improvements in each action, a reference – called baseline - has to be defined. Focus is to identify which parameters beside the impact of an action have influence of the measurement and qualify that influence. For example, lower energy demand for heating as in the year before can be caused by a milder winter. To quantify the impact of an insulation, this effect has to be normalized and therefore deducted.

In the case of hydrogen use instead of natural gas, the achieved performance can directly be measured. To supply the demanded thermal energy, the heating system needs a specific amount of energy delivered by the energy carrier. This amount of energy does not change with different energy carriers. Because of this, no adjustment and correction is needed. This procedure matches with the option A approach in the International performance measurement and verification protocol (IPMVP). When measuring the flow of hydrogen per time delivered to the CHP and boilers, it can be calculated, how much natural gas was saved.

Because of independency of energy demand from energy carrier, applies:

$$\hat{E}_{NG} = E_{H_2} = V_{H_2} \cdot e_{H_2}$$

$$\hat{K} = E_{H_2} \cdot (k_{NG} - k_{H_2})$$

$$\hat{E}_p = E_{H_2} \cdot (PEF_{NG} - PEF_{H_2})$$

$\hat{E}_{NG}$ – saved Natural Gas in kWh

$\hat{K}$ – saved CO_2 emissions in kg

$\hat{E}_p$ – saved primary energy in kWh

k_i – specific CO_2 emissions of carrier i in $\frac{\text{kg}}{\text{kWh}}$

PEF_i – primary energy factor of carrier i in $\frac{\text{kWh}}{\text{kWh}}$

E_{H_2} – Energy supplied by Hydrogen in kWh

V_{H_2} – Volume of Hydrogen in m^3

e_{H_2} – specific Energy of Hydrogen in $\frac{\text{kWh}}{\text{m}^3}$

Because of the innovative character of this action, a testing period takes place within the monitoring period. In this period the CHP and boilers have to be adjusted for hydrogen use. Therefore, the volume ratio of hydrogen used varies over the monitoring period. This will be shown in the measurements within the monitoring period.

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5.3.2.2 Data collection and analysis

The decisive measured value is the volume measurement of the hydrogen. With this value, the previous described formula can be used to calculate the savings. Together with the measurements described in section 5.2.1 relative saving regarding to the energy demand can be calculated. HoweverTable 18 shows the annual values based on the housing complex described in section 5.2.1. With the results of the baseline calculation, the KPIs are calculated, based on the unified calculations sheet described in 5.2. Monthly values can be found in the annex.

Figure 12 on page 25 shows schematically how these two topics are connected. The final energy arrow will be a mixture of natural gas (NG) and hydrogen. For the baseline it is only NG. When comparing the district heating system and the housing complex (section 5.2.1) the values cannot be summed up. For example, the GHG emissions for heating the housing area in section 5.2.1 are located at the district heating system described here. But the GHG emissions from district heating contain emissions related for the electrical energy production as well.

Some of the values shown in Table 18 are connected to those described in Table 6 in section 5.2.1. The thermal energy demand of the housing complex is supplied by the heating system described here. The supplied heat is 7 % higher than the heat demand because of distribution losses. Electrical energy demand of the heating system is the necessary electrical energy to operate the machinery. Resulting GHG for heating the housing complex in section 5.2.1 are emitted from the heating system described in this section. Because of the use of CHP, final energy demand for heating increases with the number of electricity produced. The final energy demand has to be divided between heat and electricity production. The use of hydrogen as intended within the BEST will be assessed with the formulas described in this section. Table 18 shows the annual KPIs for the baseline of this intervention. The total and area-specific KPI-values for each month can be found in the appendix.

Table 18: Baseline results for the district heating infrastructure intervention, annual values

Indicator	Formula	Unit	Baseline, per m²	Baseline, total system
E1) Thermal energy consumption	$\mathrm{E1} = \frac{\text{Thermal energy consumption of all forms of energy}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	93.3	2,585,269
E2) Electrical energy consumption	$\mathrm{E2} = \frac{\text{Electrical energy consumption}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	1.4	38,780
E4) Annual energy consumption	$\mathrm{E4} = \mathrm{E1} + \mathrm{E2}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	94.7	2,624,045
E6) Energy use for heating	$\mathrm{E6} = \frac{\text{Heating energy demand}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	93.3	2,585,269
E13) Total renewable thermal energy production	$\mathrm{E13} = \frac{\text{Thermal renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	0	0
E14) Total renewable electrical energy production	$\mathrm{E14} = \frac{\text{Electrical renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{\mathrm{kWh}}{\mathrm{m^2a}}$	0	0

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E15) Total renewable energy production	$E15 = E13 + E14$	$\frac{kWh}{m^2a}$	0	0
E17) Degree of energy self-supply by RES	$E17 = \frac{E15}{E4} \cdot 100$	%	0	0
E25) Total heat supplied to the buildings connected to district heating network	$E25 = \frac{\text{Total thermal energy supplied to the demosite buildings}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	93.3	2,585,269
E26) Degree of heating supply by district heating	$E26 = \frac{\text{Total heat supplied to the buildings (E25)}}{\text{Total energy supply by district heating}}$	%	100	100
E19) Primary thermal energy consumption	$E19 = E1 \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	102.6	2,843,793
E20) Primary electrical energy consumption	$E20 = E2 \cdot \text{Primary energy factor for electrical energy from energy carrier}$	$\frac{kWh}{m^2a}$	2.5	69,801
E21) Total primary energy consumption	$E21 = E19 + E20$	$\frac{kWh}{m^2a}$	105.2	2,913,598
E23) Total primary energy consumption related to heating delivered	$E23 = \text{Heating energy flow} \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	102.6	2,843,793
E28) Total greenhouse gas emissions (thermal)	$E28 = \text{thermal energy consumption (E1)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\,CO_2eq}{m^2a}$	23.0	638,561
E29) Total greenhouse gas emissions (electrical)	$E29 = \text{electrical energy consumption (E2)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\,CO_2eq}{m^2a}$	0.7	19,468
E31) Total greenhouse gas emissions	$E31 = E29 + E30$	$\frac{kg\,CO_2eq}{m^2a}$	23.7	658,028

5.3.3 Ice Cooling Storage with PV plant

The building of the food analysis laboratory GALAB uses a cooling and heating system supported by an ice storage system. A PV system (29 kWp) is installed on the outdoor storage area of the laboratory and integrated into the electrical infrastructure of the company. The system control is to be optimized in terms of power consumption and power peaks are to be reduced. The electrical energy generated by the PV system will be consumed in the laboratory building and not fed into the power grid. More information about the PV system and its possible power generation depending on the selected solar cell type are presented in D3.4.

5.3.3.1 Framework of evaluation

Action A19 deals with the integration of a newly installed PV plant into the system of the food laboratory GALAB. The electricity generated by the integrated PV system can be used to drive the heat pump and thus smooth power peaks. For this purpose, the energy data of the ice storage, the heat pumps and the entire building are analysed. By calculating the indicators, the renewable energy production, the reduction of CO_2 emissions and the primary energy demand are mapped.

The indicators are determined using a data-driven calculation method (historical data). In the building of GALAB the data are recorded by sensors, from which the indicators can be calculated. Data from the SNH "Energieportal" (see A17/20) are used to determine E27. A19a+b is represented by option C of the IPMVP, data of the whole facility is monitored. The period from 31.07.2017 to 30.06.2018 was selected for the calculation of the baseline, as the required data was completely available. The outdoor temperatures during the baseline period are necessary to determine the monthly heating degree days (HDD). For

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calculating the HDD a heating limit temperature of 15 °C was used. In addition to the HDD, the global radiation amount is also important for normalisation (

Table 19). The global radiation is an important factor for the design of PV systems and is important for the comparability of radiation between baseline and monitoring period. The outside temperatures and the global radiation quantities were measured by “Deutscher Wetterdienst (DWD)” at the measuring station "Hamburg-Fuhlsbüttel" and provided on the website (https://opendata.dwd.de/climate_environment/CDC/observations_germany/climate/hourly/solar/).

Table 19: Heating Degree Days (HDD) and solar radiation amount for normalisation

Month	HDD in Kd	Global radiation amount in kWh/m^2
July 2017	0.6	141.6
August 2017	1.7	127.5
September 2017	41.3	81.8
October 2017	97.3	44.3
November 2017	264.8	18.6
December 2017	339.6	10.4
January 2018	355.3	14.7
February 2018	444.4	46.4
March 2018	401.6	68.3
April 2018	120.0	116.0
May 2018	32.8	198.5
June 2018	9.2	131.7

The calculation of primary energy demand and greenhouse gas (GHG) emissions depends on the chosen factors, which depend on the energy source. The energy sources electricity (electricity mix in Germany) and natural gas are relevant for this action. The factors which should be the same for baseline and monitoring are shown in Table 20.

The thermal energy (heat and cold) is generated by the cooling machine ($W_{th,CM}$), the heat pump ($W_{th,HP}$) and the gas boiler ($W_{th,B}$). The cooling machine and the heat pump are operated with electricity and the boiler with natural gas. In order to calculate the thermal primary energy consumption (E19) and greenhouse gas emissions, the CO_2 and primary energy factors (PEF) must be adjusted to this combined energy supply. The contribution of the boiler to the thermal supply is determined (share of natural gas in the thermal energy supply: $s_{NG,th.ES}$).

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$$s_{NG,th.ES} = \frac{W_{th,B}}{W_{th,B} + W_{th,HP} + W_{th,CM}} = 0.031$$

The share of electricity in the thermal energy supply can be calculated with the following formula:

$$s_{E,th.ES} = 1 - 0.031 = 0.969$$

The share of natural gas can be used to weight the emission and primary energy factors (electricity mix and natural gas) and to calculate an overall thermal primary energy factor (PEF_{th}) and emission factor (EF_{th}), these are used to evaluate E19 and E28.

$$PEF_{th} = s_{NG,th.ES} \cdot PEF_{NG} + s_{E,th.ES} \cdot PEF_{GEM} = 0.031 \cdot 1.1 + 0.969 \cdot 1.8 = 1.778$$

$$EF_{th} = s_{NG,th.ES} \cdot EF_{NG} + s_{E,th.ES} \cdot EF_{GEM} = 0.031 \cdot 0.247 \frac{kg_{CO_2eq}}{kWh} + 0.969 \cdot 0.502 \frac{kg_{CO_2eq}}{kWh} = 0.494 \frac{kg_{CO_2eq}}{kWh}$$

To determine the total primary energy consumption based on heat consumption (E23), a weighted PEF must be used. For this purpose the share of heat production by the boiler ($s_{NG,th,H}$) is calculated in relation to the total heat production. The share allows to weight the PEFs for the electricity mix and natural gas and to determine a new PEF for this indicator.

$$s_{NG,th,H} = \frac{W_{th,B}}{W_{th,B} + W_{th,HP}} = 0.039$$

$$s_{E,th,H} = 1 - 0.039 = 0.961$$

$$PEF_{th,H} = s_{NG,th,H} \cdot PEF_{NG} + s_{E,th,H} \cdot PEF_{GEM} = 0.039 \cdot 1.1 + 0.961 \cdot 1.8 = 1.772$$

Table 20: Primary energy and emission factors

Factor	Symbol	Unit	Value
Primary energy factor for natural gas	PEF_{NG}	kWh/kWh	1.1
Primary energy factor for electrical energy (German electricity mix)	PEF_{GEM}	kWh/kWh	1.8
Primary energy factor for thermal energy	PEF_{th}	kWh/kWh	1.778
Primary energy factor for thermal energy used for heating	$PEF_{th,H}$	kWh/kWh	1.772
Emission factor for natural gas	EF_{NG}	kgCO_2eq/kWh	0.247
Emission factor for electrical energy (German electricity mix)	EF_{GEM}	kgCO_2eq/kWh	0.502
Emission factor for thermal energy	EF_{th}	kgCO_2eq/kWh	0.494

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5.3.3.2 Data collection and analysis

The KPIs are calculated according to the formulae explained in "Annex II: Indicators at Project Level" of the Deliverable D5.1. If there have been deviations in the calculations, these are explained below. Table 21 shows the annual result values of the calculation related to the area in square meters, monthly values can be found in the annex.

The system of GALAB is complex, so that the assignment of the thermal and electrical indicators is described here in more detail. The thermal values of energy consumption and production are determined by means of the measured flows and temperatures (flow and return).

The thermal energy consumption (E1) is composed of the consumption of the heating and cooling circuit of the building and the cooling circuit of the laboratory. The electrical energy consumption (E2) is represented by the electricity drawn from the grid (house connection) minus the electricity consumption of the heat pump and the refrigeration machine, since these components are electrically operated, but the energy is consumed thermally. The energy consumption of the cooling circuits building and laboratory together represent the energy used for cooling (E9) and the energy consumption of the heating circuit of the building represents the energy used for heating (E6). Before the construction of the PV system, the GALAB system does not have a renewable energy production, because the heating and cooling plants are powered by electricity or natural gas. The electricity produced by the PV plant in the future corresponds to the electrical renewable energy production (E14) and the total renewable energy production (E15). For the baseline both are zero, since no electricity is produced by renewable generation plants. The degree of self-sufficiency through renewable energy (E17) and the degree of energy supply through RES infrastructure (E27) are therefore zero for the entire baseline period.

When calculating the thermal primary energy demand (E19), it should be noted that the primary energy factor (PEF_{th}) is used here, which is composed as explained in the upper section. The electrical primary energy consumption (E20) is calculated using the PEF for the electricity mix in Germany. To calculate the total primary energy consumption due to heat supply (E23), the energy consumption of the building heating circuit is multiplied by the $PEF_{th,H}$ weighted for heat production.

To calculate the CO_2 emissions caused by thermal energy consumption (E28), the combined emission factor (EF_{th}) must be used. E29 and E31 are calculated as described in D5.1.

The annual, area-specific values for this intervention are presented in the following table. It should be noted that M1 is July 2017 and M12 is June 2018 (Figure 19).

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Table 21: Baseline results of the ice cooling storage infrastructure intervention, annual vaues

Indicator	Formula	Unit	Baseline per m²
E1) Thermal energy consumption	$E1 = \frac{\text{Thermal energy consumption of all forms of energy}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	255.68
E2) Electrical energy consumption	$E2 = \frac{\text{Electrical energy consumption}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	197.78
E4) Annual energy consumption	$E4 = E1 + E2$	$\frac{kWh}{m^2a}$	453.46
E6) Energy use for heating	$E6 = \frac{\text{Heating energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	157.99
E9) Energy use for cooling	$E9 = \frac{\text{Cooling energy demand}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	97.69
E13) Total renewable thermal energy production	$E13 = \frac{\text{Thermal renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	0
E14) Total renewable electrical energy production	$E14 = \frac{\text{Electrical renewable energy production}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	0
E15) Total renewable energy production	$E15 = E13 + E14$	$\frac{kWh}{m^2a}$	0
E17) Degree of energy self-supply by RES	$E17 = \frac{E15}{E4} \cdot 100$	%	0
E25) Total heat supplied to the buildings connected to district heating network	$E25 = \frac{\text{Total thermal energy supplied to the demosite buildings}}{\text{Floor area of the buildings}}$	$\frac{kWh}{m^2a}$	0
E26) Degree of heating supply by district heating	$E26 = \frac{\text{Total heat supplied to the buildings (E25)}}{\text{Total energy supply by district heating}}$	%	0
E19) Primary thermal energy consumption	$E19 = E1 \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	454.67
E20) Primary electrical energy consumption	$E20 = E2 \cdot \text{Primary energy factor for electrical energy from energy carrier}$	$\frac{kWh}{m^2a}$	356.00
E21) Total primary energy consumption	$E21 = E19 + E20$	$\frac{kWh}{m^2a}$	810.67
E23) Total primary energy consumption related to heating delivered	$E23 = \text{Heating energy flow} \cdot \text{Primary energy factor for thermal energy from energy carrier}$	$\frac{kWh}{m^2a}$	280.06
E27) Degree of energy supply by Urban RES infrastructure	$E27 = \frac{\text{RES energy supply}}{\text{Total energy consumption}}$	%	0
E28) Total greenhouse gas emissions (thermal)	$E28 = \text{thermal energy consumption (E1)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2eq}{m^2a}$	126.33
E29) Total greenhouse gas emissions (electrical)	$E29 = \text{electrical energy consumption (E2)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2eq}{m^2a}$	99.28
E31) Total greenhouse gas emissions	$E31 = E29 + E30$	$\frac{kg\ CO_2eq}{m^2a}$	225.61

The new installed PV system should reduce primary energy demand and CO_2-emissions. The reporting period will show to what extent the use of a PV system influences the electrical energy consumption at GALAB and whether this would lead to a practical load reduction. For this purpose, the diagram shows the monthly data of the total energy consumption (E4), the total primary energy demand (E21) and the total CO_2-emissions (E31). The energy consumption is largely independent of the seasons, as laboratory operations require constant cooling throughout the year.

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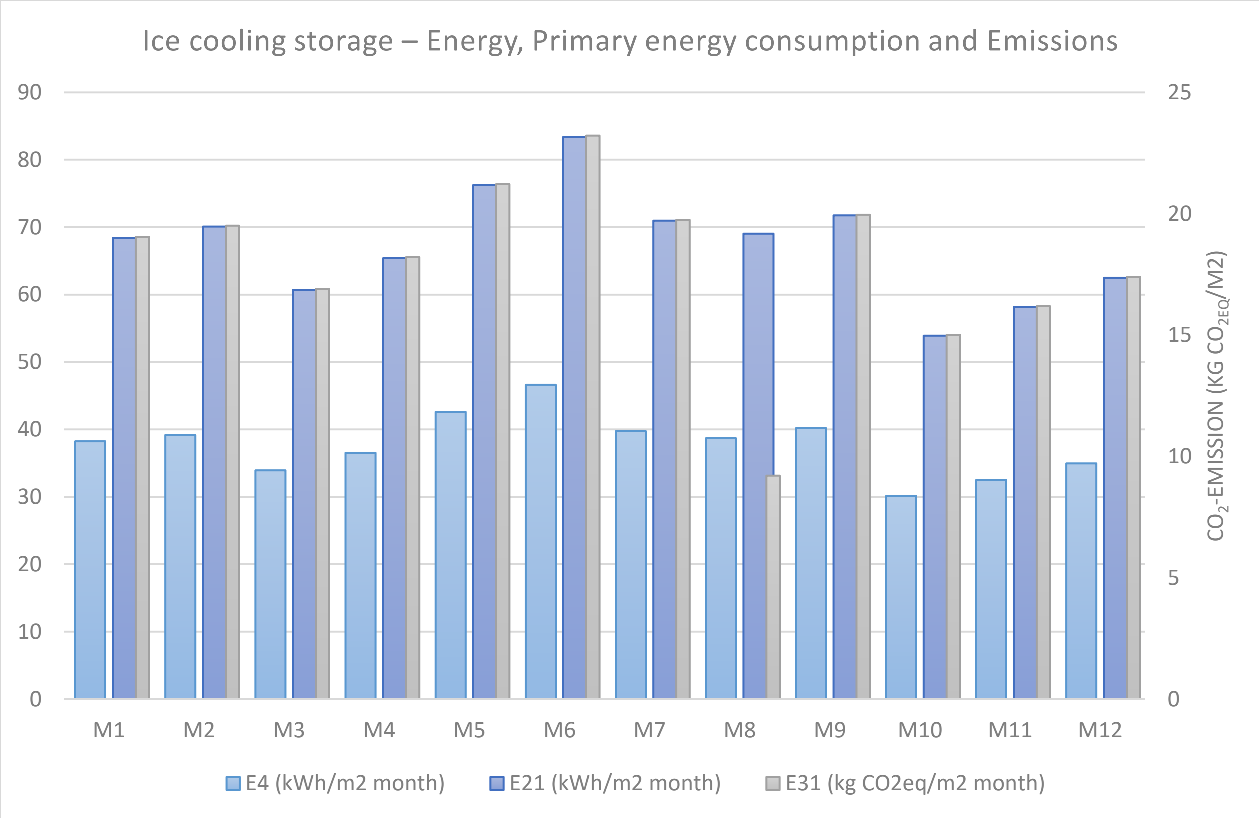

Figure 19: Monthly energy consumption (E4), primary energy demand (E21) and GHG emissions (E31) in the ice cooling storage intervention

5.3.4 Public lighting improvements

The main goal of the actions 15 and 16 is the reduction of the annual lighting energy consumption. This is achieved by the use of modern LED technology for public lighting. In addition an adaptive lighting will be installed along the new bicycle track at the Schleusengraben. The two actions, the different efforts to reduce the energy consumption for public lighting and the technical implementation are described in the deliverables D3.10 and D3.11.

5.3.4.1 Framework of evaluation

The defined KPIs for both actions are the lighting energy consumption, the reduction in annual energy consumption, the total greenhouse gas emissions for lighting and the reduction of total greenhouse gas emissions. While the lighting energy consumption is a primary KPI, the other ones are secondary, which means they are calculated on behalf of the primary KPI.

The framework and the calculation of the annual energy consumption is described in chapter 4.2 of the deliverable D3.13. As the electricity cost of the public lighting are calculated by a flat rate to the city of

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Hamburg, there is no specific calculation of the energy consumption for every street light. For the calculation, the specified energy consumption of a lamp is multiplied by the average burning time for a specific switching command. Most street lamps have a burning time of about 4,100 hours / year. The switching times are logged, so that it is reproducible at which time the lighting was switched on or off.

$$Specified\ energy\ consumption * Burning\ time = \text{Energy consumption}$$

To calculate the reduction in annual energy consumption the energy consumption of LED lighting is subtracted from the energy consumption of conventional public lighting.

$$\text{E}nergy\ saving = \text{Energy consumption, total}\ conventional - \text{Energy consumption, total}\ LED$$

Although green electricity is used for public lighting, to calculate the greenhouse gas emissions the emission factor for the German electricity mix (0.502 kg/kWh) is used to calculate the CO_2-equivalent.

$$Annual\ energy\ consumption * \text{Emission factor} = \text{Total greenhouse gas emissions for lighting}$$

$$\text{E}nergy\ saving * \text{Emission factor} = \text{Reduction of total greenhouse gas emissions for lighting}$$

As stated before, the energy consumption for the public lighting is calculated by a flat rate as there are no electric meters for every lamp post. Depending on the burning time of the lamps the energy consumption can be calculated per month.

5.3.4.2 Data collection and analysis

The public lighting energy consumption is calculated with the monthly burning times and the specific energy consumption of the lamps. The monthly rates are added up to get the annual energy consumption. By multiplying the annual energy consumption with the energy consumption emission factor for the German electricity mix the total greenhouse gas emissions are calculated. By comparing the results with the Baseline, the energy savings can be evaluated and analysed.

The following tables show the baseline of the annual reference of the five different areas. The baseline with the monthly rated can be found in the annex. As the public lighting at “Am Schilfpark” and at the “Schleusengraben” are newly built, the baselines are estimated. For this purpose the average burning times for the district of Bergedorf from December 2018 to November 2019 were taken into account. In addition to that a rough planning of the public lighting with conventional lamps has been made, to get the number of lamps needed for the public lighting.

The baselines of the other areas “Reinbeker Redder”, “Kirchwerder Landweg” and “Weidemoor” are based on the energy consumption and burning times before the modernisation with LED-lamps.

The energy savings and the reduction of greenhouse gas emission will be calculated for every area and for the two actions 15 and 16.

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Table 22: Annual baseline values for the public lighting at Am Schilfpark

Indicator	Formula	Unit	Baseline energy, total
E3) Public lighting energy consumption	$E3 = \text{Energy consumption due to public lighting facility}$	$\frac{kWh}{a}$	3,616.65
E30) Total greenhouse gas emissions (lighting)	$E30 = \text{electrical energy consumption (E3)} \cdot \text{emissionsfactor for energy carrier}$	$\frac{kg\ CO_2 eq}{a}$	1,815.56

Table 23: Annual baseline values for the public lighting at Schleusengraben

Indicator	Formula	Unit	Baseline energy, total
E3) Public lighting energy consumption	$E3 = \text{Energy consumption due to public lighting facility}$	$\frac{kWh}{a}$	1,734.85
E30) Total greenhouse gas emissions (lighting)	$E30 = \text{electrical energy consumption (E3)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2 eq}{a}$	870.89

Table 24: Annual baseline values for the public lighting at Reinbeker Redder

Indicator	Formula	Unit	Baseline energy, total
E3) Public lighting energy consumption	$E3 = \text{Energy consumption due to public lighting facility}$	$\frac{kWh}{a}$	4,967.79
E30) Total greenhouse gas emissions (lighting)	$E30 = \text{electrical energy consumption (E3)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2 eq}{a}$	2,493.83

Table 25: Annual baseline values for the public lighting at Kirchwerder Landweg

Indicator	Formula	Unit	Baseline energy, total
E3) Public lighting energy consumption	$E3 = \text{Energy consumption due to public lighting facility}$	$\frac{kWh}{a}$	17,238.29
E30) Total greenhouse gas emissions (lighting)	$E30 = \text{electrical energy consumption (E3)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2 eq}{a}$	8,653.62

Table 26: Annual baseline values for the public lighting at Weidemoor.

Indicator	Formula	Unit	Baseline energy, total
E3) Public lighting energy consumption	$E3 = \text{Energy consumption due to public lighting facility}$	$\frac{kWh}{a}$	2,898.22
E30) Total greenhouse gas emissions (lighting)	$E30 = \text{electrical energy consumption (E3)} \cdot \text{Emissionsfactor for energy carrier}$	$\frac{kg\ CO_2 eq}{a}$	1,454.91

The total baseline values result to an annual energy demand of 30,455.80 kWh/a that potentially cause GHG emissions of 15,288.81 kg CO_2eq/a if the mentioned emission factor for the German energy mix is applied.

As it can be seen in the two diagrams below, the GHG emissions are directly linked to the energy consumption. Well illustrated are the different operation times of the lamps over the year with the highest use in winter and least in summer. The peak use in January (M1) is more than twice as high as the low in

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July (M7). With the use of LED it is expected that the energy consumption as well as the potential GHG emissions will be reduced in general

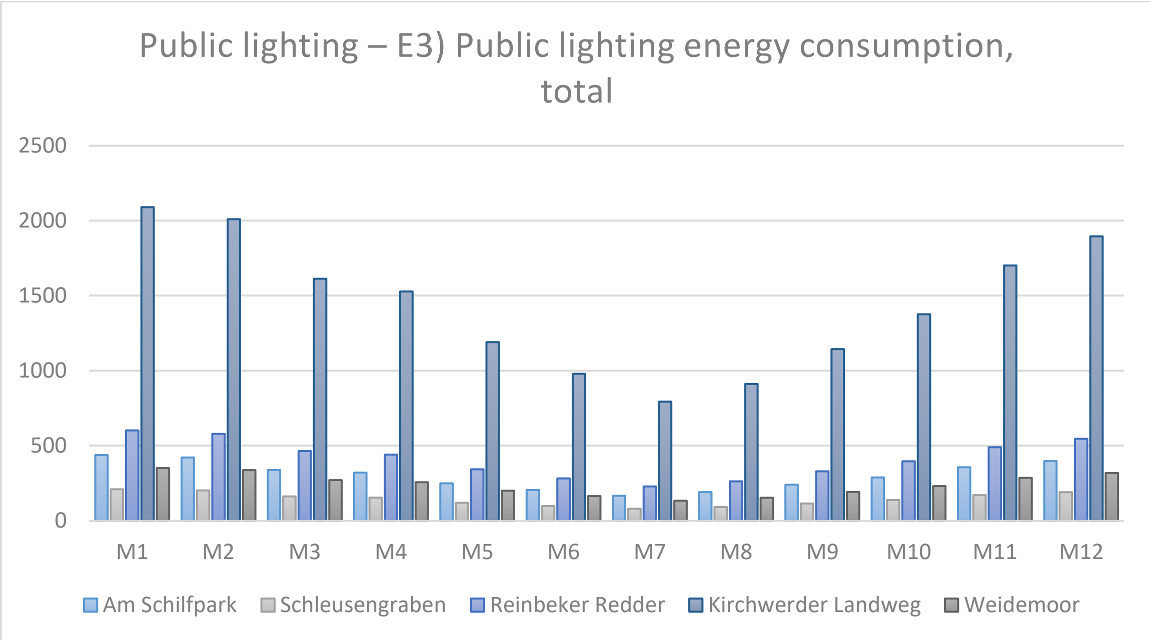

Figure 20: Development of the energy consumption of the public lighting during the baseline year

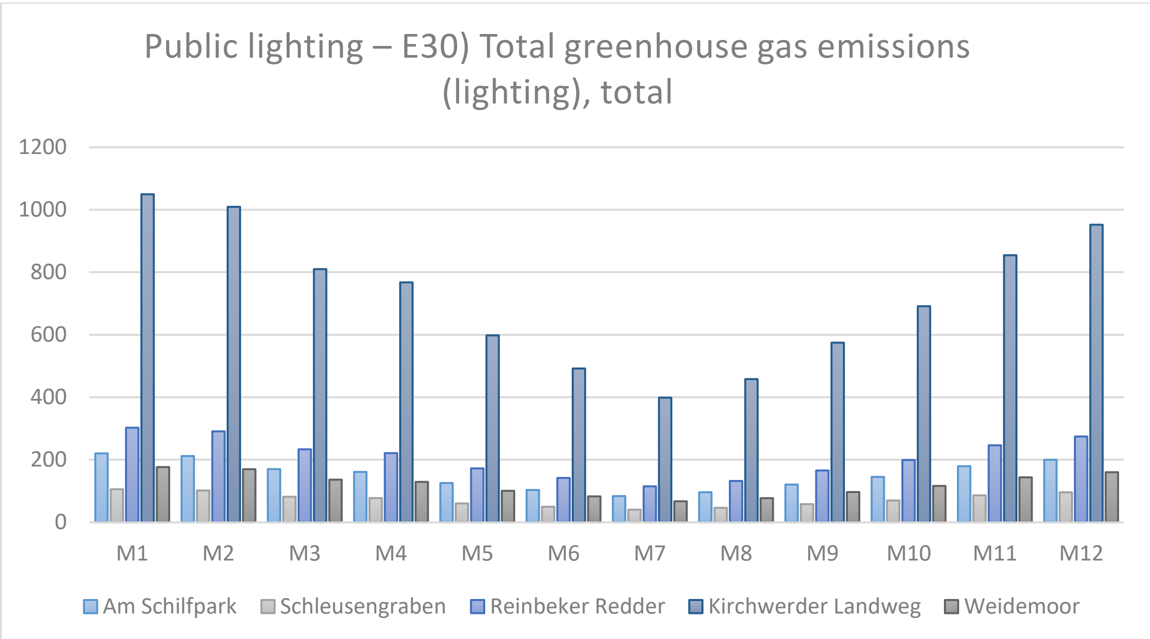

Figure 21: Development of the GHG emissions caused by the public lighting during the baseline year

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5.3.5 Maximization of RES production

Additionally to the already installed PV-plant and the battery storage that should as well become part of the intervention at Kampweg, as described in section 5.2.2, the objective of the two actions, Action 5 – PVs on roofs and Action 7 – Home batteries for self-consumption, is to install further systems. In total PV-plants within mySMARTLife a total of 300 kWp and battery storages with 100 kWh should be installed. So far, four PV plants with an installed peak capacity of more than 250 kWp have been put into operation, battery storages are still in the planning.

The renewably generated electricity from the PV-plants should increase the degree of local energy supply based on renewable energy sources. The battery storage can further increase that share, when electricity is stored in the battery when no further electricity can be used at the building that is connected to the PV and battery system. Because of the replacement of non-renewable electricity, a positive impact, lowered GHG emissions, can be registered.

Yet, since the PV-plants only come through the project mySMARTLife into operation and because the replaced non-renewable energy will correspond to the amount of energy generated by the PV-plants or temporarily stored in the battery. As already stated for the intervention at Kampweg, no values, other than zero, can be provided for the four KPIs that are used for these actions during the baseline period.

In the following some additional information of the already installed PV plants as well as of one additional plant that should be put into operation in summer 2020.

- **PV-plant at GALAB**

The laboratory building and the energy consumption is analysed in Action 19 which is described here in section 5.3.3. The PV-plant has been built on an open storage building on the site of the service laboratory GALAB and is part of the energy supply system that is supported by the ice cooling storage. The whole electricity power produced will be exhausted by the laboratory.

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Figure 22: The open storage building of GALAB, on which the PV system will be installed (source ENH).

Figure 23: The PV-plant of GALAB (source ENH).

Table 27: Technical specification of the plant at GALAB

Designation/Component	Value	Measuring unit/specification
PV generator power	26.04	kWp
PV array surface	136.7	m²
Number of PV modules	84	AXIpremium AC-310M/60S of AXITEC Energy GmbH & Co. KG
Number of inverters	1	SE25K-EU-APAC/AU of SolarEdge
Expected Annual Power Production (PV-Energy AC)	23,185	kWh/a

- **PV-plant Organic-Bakery**

The electricity consumption of the organic bakery is 165,000 kWh per year. 38% of the electricity produced by the PV system can be consumed there directly. Thus, a self-sufficiency rate of 21 % is achieved. The stepwise replacement of diesel-powered delivery vehicles to electrical driven vehicles, which is planned over the next few years, will increase both the total electricity consumption of the bakery and its self-consumption. Fuel consumption and thus CO_2 pollution will be reduced.

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Figure 24: The PV system on the roof of the organic bakery (Source ENH).

Figure 25: The inverters of the PV system on the outside wall (source ENH).

Table 28 Technical specification of the PV-plant on an organic bakery building

Designation/Component	Value	Measuring unit/specification
PV generator power	99.82	kWp
PV array surface	537.7	m²
Number of PV modules	322	Q.PEAK-G4.1 310 Rev5 of Hanwha Q.Cells
Number of inverters	3	3 x SUN2000-33KTL-A of Huawei Technologies
Expected Annual Power Production (PV-Energy AC)	93,843	kWh/a

- **PV-plant at the apiculture building at Ochsenwerder**

The beekeeping was expanded from a sideline to a full-time business with the new construction of the farm building. For this reason, and because the business has a very irregular energy demand, limited by a few weeks spread over the year, it is not possible to make a serious forecast for either the total electricity consumption and the own consumption.

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Figure 26: The Ochsenwerder beekeeping with the PV plant under construction (Source ENH).

Figure 27: View over the PV plant Ochsenwerder (source ENH).

Table 29: Technical specification of the PV-plant at Ochsenwerder

Designation/Component	Value	Measuring unit/specification
PV generator power	29.93	kWp
PV array surface	175.,4	m²
Number of PV modules	105	Hanwha Q.PLUS BFR-G4.2 285Watt
Number of inverters	1	STP 25000TL-30 of SMA Solar Technology AG
Expected Annual Power Production (PV-Energy AC)	25,751	kWh/a

- **PV-plant at the Paul-Gerhard church**

There is one more PV-plant in progress. The facility will be installed on a residential complex that now (May 20) is under construction. The concept is tenant power supply to the residents of the building. Due to a change in the roof plan, the system design is currently being revised. Therefore, no precise technical data are available yet. The installation of the PV-plant is planned for August 2020.

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6. Baseline of mobility actions

In the following subchapters the baselines for three mobility actions from Hamburg are described. These include the electrification of the public bus fleet (6.1.2), as well as of a public vehicle fleet (6.1.1). The objective of these actions is to primarily replace previously used vehicles with internal combustion engines (ICE) fueled by fossil fuels with electrically powered vehicles to reduce GHG emissions. A different approach is followed in the third action, where an electrical car is introduced at a community car sharing station (6.1.3) to lower the demand for private owned cars in that specific residential quarter.

Within mySMARTLife in the Hamburg only battery electric vehicles (BEV, BE-vehicles) are considered. The Borough of Bergedorf also has one hydrogen fuel cell electric car (FCEV) in its fleet. This car, however, is not part of the project and moreover has a different use than the cars that can be considered in the project. Yet, additionally to the ICE cars and ICE buses that are replaced by BEV within mySMARTLife, also the introduction of electrical bicycles is part of the electrification of the public fleet. The deliverable D3.13 already provided first calculations for the previously used vehicles.

Similar as for the energy and infrastructure interventions presented in the previous chapters, an excel file is used for the calculations of the baseline. This excel file takes the evaluation procedure and methodology for the presentation of the baseline for mobility actions, as described in D5.1, into account. Other than for the building and infrastructure interventions, for mobility the focus in the baseline assessment is solely on greenhouse gas emissions, CO_2eq. In the final evaluation, the KPI M13 – *Annual* CO_2eq *emissions saved* will be considered. For this, it is necessary to indicate in the baseline assessment the previous CO_2eq emissions caused by ICE vehicles that are replaced by BEV during the implementation of the mySMARTLife measures. In the final evaluation the following calculation will be performed in order to receive a result for the KPI M13:

$$CO_2eq\ emissions\ saved\ =\ CO_2eq\ emissions\ before\ action - CO_2eq\ emissions\ after\ action$$

Because the methodology for the baseline of the mobility interventions differs slightly from the energy and infrastructure interventions, also the presentation of the mobility baselines differs. Whereas for the other interventions primarily results of the actual KPIs are presented, for the mobility interventions the result of an auxiliary calculation is presented, the *CO_2eq-emissions before action*, as shown in the formula above. For this calculation, different methods can be applied, depending on the data that are available from the previously used vehicles or the previous situation as such:

- Evaluation according to the travelled distance (based on CO_2eq emissions per km)
- Evaluation according to the energy consumption (based on CO_2eq emissions per km)
- Evaluation according to the energy consumption (based on CO_2eq emissions per MWh)
- Evaluation according to the fuel consumption (based on CO_2eq emissions per l)

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For the two electrification interventions that are considered here, the last method in the list is used. The CO_2eq emissions are calculated based on the consumption. The actual calculations are presented in more detail in the following chapters. Because at the location where the intervention is implemented, no previous situation can be used as reference, the procedure for the baseline of the community cars sharing intervention differs slightly from the other two interventions. The current status and the planned procedure regarding the baseline, as well as the finalization of the intervention are further described below.

6.1 Baseline of mobility interventions

Whereas the key-focus of the mobility interventions that are taken into account for the present baseline report is on the electrification of fleets, the replacement of ICE vehicles by BE-vehicles, the above stated formula can be further specified:

$$CO_2eq\ emissions\ saved = CO_2\text{eq}\ emissions\ due\ to\ combustion\ of\ fuel\ -\ CO_2\text{eq}\ emissions\ from\ new\ E-cars$$

The baselines for the two electrification actions describe the situation before the electrification as part of mySMARTLife has been performed. This means the CO_2eq emissions caused by the combustion of fossil fuels, here petrol or diesel, are presented as the baseline value. The public BEV are powered with renewable electricity. Therefore, the emissions saved at the end of the project monitoring will correspond to the emissions from the baseline period. As mentioned before, the emissions are calculated based on the fuel consumption of the previously used vehicles. Yet, it needs to be taken into account that the fuel consumption is calculated based on the mileage and average fuel consumption per kilometre as specified by the manufacturer. The specific calculations and further considerations are presented in the following.

For the electrification interventions it is only possible to provide annual data. The records of the replaced vehicles only stated annual data and a simulation or conversion to monthly data is not possible, since the use of the vehicles does not follow a specific scheme. For this reason, other than for the energy interventions no diagrams are used here to illustrate the baseline results and no more specific values can be presented in the annex. Yet, in the monitoring period, monthly data will be recorded in order to provide monthly KPI for the final evaluation.

6.1.1 Electrification of public vehicle fleet

The action 2 that deals with the electrification of the public vehicle fleet can be divided into two parts. For one thing, the action includes the electrification of the passenger car fleets of the Borough of Bergedorf, as well as of the VHH, the public transport company located in Bergedorf. For the other thing, the introduction of e-bicycles into the bicycle fleet of the borough is also foreseen in this action. The deliverable 3.8 - *Development of new Mobility Services and Intermodality Strategies* provides a comprehensive description of previous efforts and already achieved results in the electrification of the fleets. All together 25 e-cars

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and 5 e-bikes should be introduced through this mySMARTLife action. These cars replace ten ICE cars at the borough, six petrol-fuelled and four diesel-fuelled, and ten diesel-fuelled cars at VHH. The fuel consumption and eventually the CO_2eq emissions caused by these cars form the baseline for this action.

For the most part this chapter deals with the electrification of the car fleets of the Borough of Bergedorf and the VHH because it is possible to describe and present in detail the situation prior to the implementation of the mySMARTLife intervention and to calculate baseline values. The description of the baseline for the introduction of the e-bikes at the Borough of Bergedorf cannot be presented equally extensive. The reason for this is described at the end of this chapter.

6.1.1.1 Framework of evaluation

In D3.8 and D3.13 it has been reported that the borough had introduced 12 Renault Zoe to the fleet. Because these have been purchased very early in the project, they have been replaced by electrical smart EQ in early 2020. Additionally to the replacement of the first BEV, the borough also increased the number of vehicles. Now, 15 BEV are in use. The number of vehicles was increased because at the same time as the electrification of the vehicle fleet at the Borough of Bergedorf started, the department that uses the e-cars started expanding. With the expansion more personnel was required and accordingly more vehicles. Other than it is the case with the e-busses, the larger number of BEV at the borough is not connected to potentially reduced range of BEV compared to ICE vehicles, but only with the increased personnel and tasks. For the monitoring it is planned to use data from the 15 new electric smart EQ against the afore-mentioned ICE vehicles. Further, it has to be noted that from the ten ICE cars at the borough, only for nine data were available that could be used for the following calculations. The procedure how to deal with the missing set of data is explained later in this chapter.

The BEV, at the borough, as well as at VHH, are used in the same departments by the same personnel, as the conventional cars they replaced, which is why it is possible to use the usage data of these cars as baseline for this intervention. However, for the final evaluation it is not possible to directly compare the presented baseline values car by car with the results from the monitoring. The e-cars are generally used for the same purposes, but the vehicles are not strictly assigned to one staff member or one specific route.

As mentioned, the CO_2eq emissions that serve as baseline values for the electrification measures are calculated on the basis of the fuel consumption which is calculated in consideration of the mileage and average fuel consumption as specified by the manufacturer. These calculations have already been performed in the deliverable D3.13. Yet, in the present deliverable a standardized procedure is followed that should also allow a comparison of the results with the other lighthouse cities. This primarily includes the use of aligned conversion factors for the GHG emissions. In the following first the calculations for the fleet of the Borough of Bergedorf are presented, followed by the calculations for the VHH BEV fleet.

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6.1.1.1 Data collection and analysis

Because the period where the previous cars have been used in the Borough of Bergedorf slightly differs from one to another, it is necessary to calculate the average mileage for each car during its usage period. Despite the mentioned adjustments for the present baseline report, the results from D3.13 shown in Table 30 for the average mileage of the ICE vehicles are still valid.

Table 30: Annual driving performance of the replaced cars in the Borough's fleet

No	Model	Fuel	Registration date	Deregistration date	Mileage, total [km/a]	Mileage, average [km/a]
P1	VW Polo 6R	Petrol[1]	15.12.2014	22.03.2017	11,213	4,943
P2	VW Polo 6R	Petrol[1]	15.12.2014	22.03.2017	26,372	11,625
P3	VW Polo 6R	Petrol[1]	15.12.2014	22.03.2017	18,121	7,988
P4	VW Polo 6R	Petrol[1]	01.12.2014	22.03.2017	17,138	7,429
P5	VW Polo 6R	Petrol[1]	01.12.2014	22.03.2017	19,008	8,240
P6	VW Polo 6R	Petrol[1]	15.12.2014	22.03.2017	12,860	5,669
D1	VW Polo 6R	Diesel[2]	26.01.2015	22.03.2017	37,441	17,387
D2	VW Polo 6R	Diesel[2]	15.12.2014	22.03.2017	40,196	17,719
D3	VW Polo 6R	Diesel[2]	15.12.2014	22.03.2017	33,588	14,806

The underlying claculations for the average mileage include the following steps:

Firstly, as only the mileage for the entire usage period is known, it is necessary to calculated the number of usage days:

$$Usage\ days = Registration\ date - Deregistration\ date$$

Ongoing from this value it is then possible to calculate an annual average:

$$Average\ mileage\ [km/a] = (Total\ mileage\ [km]/\ Usage\ days) * 365\ days$$

The values stated in Table 30 shall then serve as basis for the calculation of the CO_2eq emissions. Before the emissions can be calculated using the factor for the emissions per litre as stated in D5.1, it is necessary to calculate the fuel consumption per vehicle. For this information form the car manufacturer has to be used. For the fuel consumption different values are provided, urban, extra-urban and a combination of both. Whereas the Borough of Bergedorf has both urban and rural areas, and the responsible area of the department for management of public space includes the entire borough, the values for the combined use are applied as presented in Table 31.

For the calculation of the fuel consumption the applied formula is the following:

$$Fuel\ consumption\ [l/a] = (fuel\ consumption\ value\ [l/100km] *\ Mileage\ [km/a] *)/100$$

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Table 31: Annual fuel consumption of the replaced ICE vehicles of the Borough of Bergedorf

No	Model	Fuel	Mileage [km/a]	Fuel consumption, combined [l/a]
BGD-P1	VW Polo 6R	Petrol[1]	4,943	242
BGD-P2	VW Polo 6R	Petrol[1]	11,625	546
BGD-P3	VW Polo 6R	Petrol[1]	7,988	375
BGD-P4	VW Polo 6R	Petrol[1]	7,429	349
BGD-P5	VW Polo 6R	Petrol[1]	8,240	387
BGD-P6	VW Polo 6R	Petrol[1]	5,669	266
		Total, petrol-fuelled vehicles	45,894	2,157
BGD-D1	VW Polo 6R	Diesel[2]	17,387	591
BGD-D2	VW Polo 6R	Diesel[2]	17,719	602
BGD-D3	VW Polo 6R	Diesel[2]	14,806	503
		Total, petrol-fuelled vehicles	49,912	1,697
		Total, all vehicles	95,807	3,854

[1] Fuel consumption* [l/100 km]: urban: 5.7, extra-urban: 4.1, combined: 4.7

[2] Fuel consumption* [l/100 km]: urban: 4.0, extra-urban: 3.1, combined: 3.4

* according to manufacturer's specifications

The conversion factors for the calculation of the greenhouse gas emissions for the different types of fuel are taken from D5.1 (Table 32).

Table 32: Default emission factors by type of fuel in Europe

Type of fuel	Emissions factor [CO_2eq/l]
Petrol (95, 95 E10, 98)	3.00
Diesel	3.18

The formula that is used to eventually calculate the baseline factors is the following:

$$\text{Greenhouse gas emissions}\left[\frac{kgCO_2eq}{a}\right] = (CO_2eq\ emissions\ value\ \left[\frac{CO_2eq}{l}\right] * fuel\ consumption\ [km/a])/1{,}000$$

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Table 33: Baseline values for the vehicles of the fleet for the Borough of Bergedorf

No	Model	Fuel	Greenhouse gas emissions [$kgCO_2eq/a$]
BGD-P1	VW Polo 6R	Petrol	726
BGD-P2	VW Polo 6R	Petrol	1,638
BGD-P3	VW Polo 6R	Petrol	1,125
BGD-P4	VW Polo 6R	Petrol	1,047
BGD-P5	VW Polo 6R	Petrol	1,161
BGD-P6	VW Polo 6R	Petrol	798
		Total, petrol-fuelled vehicles	6,495
BGD-D1	VW Polo 6R	Diesel	1,879
BGD-D2	VW Polo 6R	Diesel	1,914
BGD-D3	VW Polo 6R	Diesel	1,600
		Total, petrol-fuelled vehicles	5,393
		Total, all vehicles	11,888

Because the number of vehicles that come into use through the presented mySMARTLife intervention is larger than the number of vehicles that have been in use previously to the project, as explained before, it is necessary to extrapolate the results presented in Table 33. This should be done in order to be able to fully consider the whole impact the implementation of BEV in the fleet of the Borough of Bergedorf has. In this step, also the mentioned missing data for one of the previously used ICE vehicles should be compensated. For this, the total value of 11,888kg CO_2eq/a should be divided by the number of cars considered in that calculation, which is nine to get the average emissions per vehicle. This average should then be multiplied by the number of BEV that are in use in the Borough's fleet, which is 15.

This additional calculation leads to the final baseline value for the final baseline that should be taken into account for the electrification of the fleet of the Borough of Bergedorf. As the number of BEV in use is 15, the baseline value should be 19,814 $kgCO_2eq$ per year (Table 34).

Table 34: Final baseline values for the electrification of the vehicle fleet of the Borough of Bergedorf

	Number of vehicles considered	Greenhouse gas emissions [$kgCO_2eq/a$]
Baseline, total extrapolated to number of BEV in use	15	19,814
Baseline, average per number of BEV	1	1,321

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The procedure for the calculation of the baseline values for the VHH fleet is the same as for the fleet of the Borough of Bergedorf. For this reason in the following, only the tables with the interim results and final results are presented, whereas the formulas used are mostly the same. The only difference is that for the now replaced ISE vehicles at VHH it was possible to receive fuel consumption data for one specific year. For this reason, for the VHH fleet the baseline period comprises only the year 2017 and not the period from end of 2014 until early 2017 as for the Borough of Bergedorf. This means that the first calculation to receive an average for the annual mileage is not needed here.

The total annual mileage of the ten diesel-fuelled vehicles that should serve as baseline for the electrification of the VHH car fleet, as well as the fuel consumption that is calculated by the use of the factor taken from the manufacturer's specifications are presented in Table 35.

Table 35: Mileage and fuel consumption of the ICE vehicles at VHH for the baseline year 2017

No	Model	Fuel	Mileage [km/year]	Fuel consumption combined [l/year]
VHH-D1	Smart Fortwo[1]	Diesel	11,278	383
VHH-D2	Smart Fortwo[1]	Diesel	11,519	392
VHH-D3	Smart Fortwo[2]	Diesel	12,556	414
VHH-D4	Smart Fortwo[2]	Diesel	13,623	450
VHH-D5	Smart Fortwo[2]	Diesel	14,426	476
VHH-D6	Smart Fortwo[2]	Diesel	15,824	522
VHH-D7	VW Golf IV[3]	Diesel	5,822	297
VHH-D8	VW Golf IV[3]	Diesel	7,819	399
VHH-D9	VW Golf VI[4]	Diesel	15,222	685
VHH-D10	VW Golf Plus[5]	Diesel	10,663	565
		Total, all vehicles	118,752	4,583
		Average	11,875	458

[1] Fuel consumption* [l/100 km]: combined: 3.4; CO_2-emissions* [g/km]: combined: 88
[2] Fuel consumption* [l/100 km]: combined: 3.3; CO_2-emissions* [g/km]: combined: 86
[3] Fuel consumption* [l/100 km]: combined: 5.1; CO_2-emissions* [g/km]: combined: 138
[4] Fuel consumption* [l/100 km]: combined: 4.5; CO_2-emissions* [g/km]: combined: 119
[5] Fuel consumption* [l/100 km]: combined: 5.3; CO_2-emissions* [g/km]: combined: 138

* according to manufacturer's specifications

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Applying the conversion factor for the CO_2eq emissions per litre fuel emitted, as listed in table 18, following results for the baseline for the electrification of the car fleet at VHH are received (Table 36).

Table 36: Baseline values for the vehicles of the VHH fleet

No	Model	Fuel	Greenhouse gas emissions [kgCO_2eq/a]
VHH-D1	Smart Fortwo[1]	Diesel	1,218
VHH-D2	Smart Fortwo[1]	Diesel	1,247
VHH-D3	Smart Fortwo[2]	Diesel	1,317
VHH-D4	Smart Fortwo[2]	Diesel	1,431
VHH-D5	Smart Fortwo[2]	Diesel	1,514
VHH-D6	Smart Fortwo[2]	Diesel	1,660
VHH-D7	VW Golf IV[3]	Diesel	944
VHH-D8	VW Golf IV[3]	Diesel	1,269
VHH-D9	VW Golf VI[4]	Diesel	2,178
VHH-D10	VW Golf Plus[5]	Diesel	1,797
		Total, all vehicles	14,574
		Average	1,457

Taking the two fleets from the Borough of Bergedorf and VHH together following Table 37 lists the baseline values for the presented intervention that aims at the reduction of greenhouse gas emissions by the electrification of public car fleets.

Table 37: Combined baseline results of the two considered public fleets

	Number of vehicles considered	Greenhouse gas emissions [kgCO_2eq/a]
Baseline, fleet of Borough of Bergedorf	15	19,814
Baseline, fleet of VHH	10	14,574
Baseline, total complete intervention	25	34,388

After the derivation and calculation of the baseline values for the electrification of the car fleets at the Borough of Bergedorf and the VHH are presented, the current status of the implementation of e-bikes, the planned monitoring and an approach for a baseline should be outlined.

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As it is described in the main mobility deliverable D3.8, the introduction of e-bikes in the vehicle fleet of the Borough of Bergedorf could not be performed as successful as the introduction of e-cars to the fleet. Only after a long process of discussions and negotiations in the Borough of Bergedorf that even included an informational event where e-bikes could be tested by the personnel of the department that first showed good prospects for the use of e-bikes, it turned out that no additional resources could be made available to introduce a vehicle that needs to find its place between existing bicycles and both e-cars and conventional cars. Yet, in early 2020, a different department showed interest in the use of e-bikes and the procurement was quickly possible so that the first three e-bikes are planned to be in use in early summer 2020. Even though the interest was still a result of the informational event, with the quick procurement of the e-bikes, it was not possible to make sure that the e-bikes can comply with the projects monitoring. For this reason a questionnaire will be used to evaluate the benefits of the use of e-bikes and to estimate the amount of trips, as well as the distance of these, that are taken by e-bike instead of by car. For later e-bikes the installation of bicycle computers should be considered in order to implement a quantitative monitoring in addition to the qualitative monitoring that will be delivered through the questionnaires. Values regarding the number and distance of trips should be used to evaluate the benefits and expected emission savings that are presented in the TEST (Transport Energy Specification Table) for Hamburg. The assumptions of the TEST are the following:

- 1 e-bike replaces 0.15 cars; 5 e-bikes replace 0.75 private cars
- CO_2 emissions of 0.75 (diesel) cars: 1.4 tCO_2/a
- Energy consumption of 5 e-bikes: 3.75 kWh/a
- CO_2 emissions of 5 e-bikes: 0.0016 tCO_2/a

6.1.2 Electrification of public bus fleet

Public transportation is to be playing an important role in Bergedorf's modal split; thus it needs to be further developed sustainably. The bus lines serve the central part of the high-performance Bergedorf district. Ten new electric buses will be deployed in Bergedorf. Moreover, as a part of the future development, it is already planned to buy 34 additional e-buses by 2020 and more in the following years. At the final stage of expansion 134 e-buses will be based in the bus depot Bergedorf of VHH. Recharging will be at the depot at night within 5 hours (see Action 24). Charging will use renewable energy only (wind & solar, hydro and others). The implementation of both the e-bus and charging infrastructure actions is described in detail in the deliverable D3.8.

6.1.2.1 Framework of evaluation

For the purpose of the baseline modelling, it is important to understand that due to limited range on e-busses with overnight charging (max. range approx. 150-170 km), the possible annual mileage cannot reach the exact same as the monitored baseline ICE diesel busses. Therefore it seems prudent to use the

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km actually performed by the each type of bus as the basis for calculating reduction in CO_2 emissions. Currently, the deployment of the e-buses differs from the normal service deployment of diesel buses to account for range limitations. But ultimately it will be necessary to achieve larger ranges with the e-buses to maintain the efficiency of the overall system or a larger amount of buses will be needed to perform the same service. There is hope that future developments in battery technology will further help increase the range of the e-buses and thus close the current performance gap. This can already be seen happening with the new orders of e-buses, anticipated for delivery at the end of 2020, as they were already tendered successfully with a guaranteed range of 200 km. VHH has purchased 16 e-buses in 2019 within the project framework to both compensate for current range limitations as well as possible difficulties of the new technology and to speed up the fleet transformation process to meet the City of Hamburg’s ambitious climate goals. The additional e-buses in 2020 will likewise help to scale up the uptake of more sustainable transport options within the city.

6.1.2.2 Data collection and analysis

To establish the baseline model, 10 solo diesel busses of EURO Norm III standard were chosen to be replaced by the electric busses in 2018/2019. For the Year 2017 the distances travelled by these busses were recorded by manual readings from the odometers of the buses. Since fuel usage is not recorded in detail per bus, the average use of diesel fuel per 100 km was used as evaluated in the 2017 energy audit of the VHH. Following assumptions are applied for the calculation of the baseline values:

- 10 Diesel EURO III solo buses
- Evaluation period: 01.01.2017 to 31.12.2017 (one year)
- Manual record of odometer reading at beginning and end of year
- Average fuel consumption of 44.29 l diesel fuel per 100 km according to the VHH energy audit 2017

The procedure for the calculation of the baseline values that are shown in Table 38 follows mostly the same steps of calculation as presented in chapter 6.1.1 where the baseline for the electrification of the public car fleet is presented and lead to following baseline values for the presented intervention (Table 38).

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Table 38: Baseline values for the electrification of the VHH bus fleet

Vehicle no.	Indicator	Unit	Baseline
Vehicle 1 - VHH 0501	GHG emissions according to the fuel consumption	$\frac{\mathrm{kg}\ CO_2 eq}{\mathrm{a}}$	65,336.85
Vehicle 2 - VHH 0504			88,144.99
Vehicle 3 - VHH 0507			49,562.74
Vehicle 4 - VHH 0520			49,968.16
Vehicle 5 - VHH 0603			84,380.16
Vehicle 6 - VHH 0610			61,863.78
Vehicle 7 - VHH 0611			89,360.10
Vehicle 8 - VHH 0612			69,532.89
Vehicle 9 - VHH 0614			84,157.52
Vehicle 10 - VHH 0615			73,200.48
		total	715,507.67

The total annual emissions of 715,507.67 kgCO_2eq of these 10 diesel buses can be compared to the total emission savings as calculated by km performance of the 16 procured e-buses to calculate the overall savings in emissions of the project.

6.1.3 Community Car Sharing

The community car sharing intervention summarizes the actions or elements from the actions 22, 23, 27 and 33. The key element that should be considered for the monitoring and hence also for the assessment of the baseline is the planned utilization of a BEV at the car sharing station. The objective of this action is to reduce the number of private cars on the street and to reduce GHG emissions caused by traffic. The latter will be achieved by the use of a BEV. The monitoring will provide data that allows to assess the emissions that are saved by the use of a BEV instead of an ICE vehicle. For this, data from the car sharing e-car, as well as from the sharing station will be recorded and eventually evaluated.

As described in D3.8, the car sharing station has opened in late October 2019. For the start, a diesel-fuelled Ford Fiesta is available at the station. Because car sharing can be considered as a seasonal business, with its high in summer, a starting phase with a lowered request was expected that would slowly build up towards spring. If the demand for car sharing at that station would be high enough, a second car should have been introduced. Considering this, it was planned to introduce the electric car in late spring at the station. With the effects of the Covid 19 pandemic, however, the demand for car sharing broke down and the delivery of the ordered Renault Zoe as the e-car could not be kept by the manufacturer. Yet,

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despite these impeding circumstances the charging station will be installed in early summer 2020 and the e-car should be in place soon after.

Together with the car sharing provider, data for baseline have been identified. For the baseline, data from other similar car sharing stations should have been used. These are suitable for a comparison because the locations of these stations are also not close to the city centre and the social structure is similar to the area where the community car sharing station is located in Bergedorf. The mileage, fuel consumption and eventually CO_2eq emissions from the last 12 months before the station in Bergedorf has opened, should have served as reference for the station that is part of mySMARTLife.

The other stations, however, do not offer e-cars. Even though BEV become increasingly present in the daily traffic and available for car sharing, reservations about BEV still exist. These may be a result of lack of knowledge regarding the handling of BEV or regarding the reduced range compared to ICE vehicles. For these reasons it is necessary to take into consideration that despite the similarities of the stations, rental figures and driving performance of the e-car at Bergedorf can be lower than those of the ICE vehicles at the other stations, only because it is a BEV.

The other objective of the intervention, the reduction of private vehicles in the urban area cannot be directly measured. Within mySMARTLife it is not planned to carry out a survey that investigates the motivation of the car sharing users to use car sharing over a private vehicle or if they have consciously or unconsciously, over the time, decided to abolish or not purchase a private vehicle. Yet, survey-based investigations from other cities in Germany should be used and discussed with the experiences of the car sharing provider in order to evaluate if the assumption from the TEST for Hamburg can be confirmed or not. The assumption stated in the TEST is that one car sharing e-car replaces ten private cars.

Due to the mentioned circumstances, the development of a procedure for the baseline of this intervention could not proceed as it could have been the case under regular circumstances. Eventually, it was not possible for the car sharing provider to gather all the data needed for the description of the baseline in time. Nevertheless, the data will be made available and a comprehensive assessment of the baseline as described above and an evaluation of the number of private cars that could potentially be replaced through the community car sharing station will be provided in the deliverable D5.5.

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7. Conclusions

The present baseline report once more shows the diversity of interventions that are implemented in the mySMARTLife lighthouse city Hamburg. New and existing buildings are considered, innovative energy supplies are introduced and the introduction of sustainable systems is fostered. What all these different measures have in common is that GHG emissions should be reduced through the successful realization of these. The assessment of the baselines of the interventions illustrates very well what factors within the specific interventions are relevant for the reduction of GHG emissions. The illustration of these levers in this report should not only help to better understand the underlying concept of the interventions, the baseline also has an important purpose for the evaluation of the project. Without a valid baseline the achievements of the implemented interventions cannot be verified in full. With the reference to this importance that has been kept in mind during the work on the deliverable, it became obvious that at the current status for a limited number of interventions, the challenge is the availability of data, which adds complexity to the baseline analysis. It then complicates the procedure to calibrate and validate the simulations to provide the more realistic result that corresponds to the important position this element.

For those interventions, however, where simulations of the baseline situation of fitting data were available that represent the situation prior to the project, the presented baseline values will serve as reference. They will serve of course as reference in the final evaluation of the project, but the values can also be used as intermediate indicators to measure the success of the implementation of the intervention during the monitoring phase.

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8. References

Erhorn, H; de Boer, J.; Wössner, S.; Höttges, K.; Erhorn-Kluttig, H. (2007): DIN V 18599: The German holistic energy performance calculation method for the implementation of the EPBD. Retrieved from: http://www.inive.org/members_area/medias/pdf/Inive/PalencAIVC2007/Volume1/PalencAIVC2007_067.pdf

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9. Annex

9.1 Annex: Monthly baseline values for the Schilfpark building intervention

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy consumption	$\frac{kWh}{m^2a}$	18,1	14,2	10,8	2,8	1,7	1,0	1,0	1,0	1,7	6,1	12,0	16,8
E2) Electrical energy consumption	$\frac{kWh}{m^2a}$	1,1	0,9	1,0	0,9	0,9	0,9	0,9	0,9	0,9	1,0	1,0	1,1
E4) Annual energy consumption	$\frac{kWh}{m^2a}$	19,2	15,1	11,8	3,7	2,6	1,9	1,9	1,9	2,6	7,1	13,0	17,9
E6) Energy use for heating	$\frac{kWh}{m^2a}$	17,0	13,1	9,7	1,8	0,7	0,0	0,0	0,0	0,7	5,1	10,9	15,7
E13) Total renewable thermal energy production	$\frac{kWh}{m^2a}$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E14) Total renewable electrical energy production	$\frac{kWh}{m^2a}$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E15) Total renewable energy production	$\frac{kWh}{m^2a}$	19,9	15,6	11,9	3,1	1,9	1,1	1,1	1,1	1,9	6,7	13,2	18,5
E17) Degree of energy self-supply by RES	%	2,0	1,6	1,8	1,6	1,6	1,6	1,6	1,6	1,6	1,8	1,8	2,0
E25) Total heat supplied to the buildings connected to district heating network	$\frac{kWh}{m^2a}$	21,9	17,2	13,7	4,7	3,5	2,7	2,7	2,7	3,5	8,5	15,0	20,5
E26) Degree of heating supply by district heating	%	18,7	14,4	10,7	2,0	0,8	0,0	0,0	0,0	0,8	5,6	12,0	17,3
E19) Primary thermal energy consumption	$\frac{kWh}{m^2a}$	4,5	3,5	2,7	0,7	0,4	0,2	0,2	0,2	0,4	1,5	3,0	4,1
E20) Primary electrical energy consumption	$\frac{kWh}{m^2a}$	0,6	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,6
E21) Total primary energy consumption	$\frac{kWh}{m^2a}$	5,0	4,0	3,2	1,1	0,9	0,7	0,7	0,7	0,9	2,0	3,5	4,7
E23) Total primary energy consumption related to heating delivered	$\frac{kWh}{m^2a}$	18,1	14,2	10,8	2,8	1,7	1,0	1,0	1,0	1,7	6,1	12,0	16,8
E28) Total greenhouse gas emissions (thermal)	$\frac{kg\,CO_2eq}{m^2a}$	1,1	0,9	1,0	0,9	0,9	0,9	0,9	0,9	0,9	1,0	1,0	1,1
E29) Total greenhouse gas emissions (electrical)	$\frac{kg\,CO_2eq}{m^2a}$	19,2	15,1	11,8	3,7	2,6	1,9	1,9	1,9	2,6	7,1	13,0	17,9
E31) Total greenhouse gas emissions	$\frac{kg\,CO_2eq}{m^2a}$	17,0	13,1	9,7	1,8	0,7	0,0	0,0	0,0	0,7	5,1	10,9	15,7

Table A - 1: Monthly baseline values for the Schilfpark building intervention, per square meter

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

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy consumption	kWh/month	501.515	393.454	299.246	77.582	47.104	27.708	27.708	27.708	47.104	169.019	332.496	465.494
E2) Electrical energy consumption	kWh/month	30.479	24.937	27.708	24.937	24.937	24.937	24.937	24.937	24.937	27.708	27.708	30.479
E4) Annual energy consumption	kWh/month	531.994	418.391	326.954	102.520	72.041	52.645	52.645	52.645	72.041	196.727	360.204	495.973
E6) Energy use for heating	kWh/month	471.036	362.975	268.768	49.874	19.396	0	0	0	19.396	141.311	302.017	435.016
E13) Total renewable thermal energy production	kWh/month	0	0	0	0	0	0	0	0	0	0	0	0
E14) Total renewable electrical energy production	kWh/month	0	0	0	0	0	0	0	0	0	0	0	0
E19) Primary thermal energy consumption	kWh/month	551.666	432.799	329.171	85.341	51.814	30.479	30.479	30.479	51.814	185.921	365.746	512.044
E20) Primary electrical energy consumption	kWh/month	54.862	44.887	49.874	44.887	44.887	44.887	44.887	44.887	44.887	49.874	49.874	54.862
E21) Total primary energy consumption	kWh/month	606.528	477.686	379.045	130.228	96.701	75.366	75.366	75.366	96.701	235.795	415.620	566.906
E23) Total primary energy consumption related to heating delivered	kWh/month	518.140	399.272	295.644	54.862	21.335	0	0	0	21.335	155.442	332.219	478.517
E28) Total greenhouse gas emissions (thermal)	kg CO_2eq/month	123.874	97.183	73.914	19.163	11.635	6.844	6.844	6.844	11.635	41.748	82.127	114.977
E29) Total greenhouse gas emissions (electrical)	kg CO_2eq/month	15.300	12.518	13.909	12.518	12.518	12.518	12.518	12.518	12.518	13.909	13.909	15.300
E31) Total greenhouse gas emissions	kg CO_2eq/month	139.175	109.702	87.823	31.681	24.153	19.362	19.362	19.362	24.153	55.657	96.036	130.277

Table A - 2: Monthly baseline values for the Schilfpark building intervention, total

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

9.2 Annex: Monthly baseline values for the Kampweg building intervention

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy consumption	$\frac{kWh}{m^2a}$	25.2	20.3	14.3	7.2	2.7	1.5	1.2	1.2	3.8	7.5	17.5	25.2
E2) Electrical energy consumption	$\frac{kWh}{m^2a}$	2.5	2.1	2.4	2.6	3.6	3.7	4.3	4.2	2.6	2.8	2.5	2.8
E4) Annual energy consumption	$\frac{kWh}{m^2a}$	27.7	22.4	16.7	9.8	6.3	5.2	5.5	5.4	6.4	10.3	20	28
E6) Energy use for heating	$\frac{kWh}{m^2a}$	24.1	19.3	13.2	6.2	1.6	0.5	0.1	0.1	2.8	6.4	16.5	24.1
E8) Energy use for lighting	$\frac{kWh}{m^2a}$	2.5	2.1	2.2	2.1	2.1	2.0	2.1	2.1	2.2	2.4	2.5	2.8
E9) Energy use for cooling	$\frac{kWh}{m^2a}$	0	0	0.2	0.5	1.5	1.7	2.2	2.1	0.4	0.4	0	0
E13) Total renewable thermal energy production	$\frac{kWh}{m^2a}$	0	0	0	0	0	0	0	0	0	0	0	0
E14) Total renewable electrical energy production	$\frac{kWh}{m^2a}$	0	0	0	0	0	0	0	0	0	0	0	0
E15) Total renewable energy production	$\frac{kWh}{m^2a}$	0	0	0	0	0	0	0	0	0	0	0	0
E17) Degree of energy self-supply by RES	%	0	0	0	0	0	0	0	0	0	0	0	0
E27) Degree of energy supply by Urban RES infrastructure	%	0	0	0	0	0	0	0	0	0	0	0	0
E19) Primary thermal energy consumption	$\frac{kWh}{m^2a}$	27.72	22.33	15.73	7.92	2.97	1.65	1.32	1.32	4.18	8.25	19.25	27.72
E20) Primary electrical energy consumption	$\frac{kWh}{m^2a}$	4.5	3.78	4.32	4.68	6.48	6.66	7.74	7.56	4.68	5.04	4.5	5.04
E21) Total primary energy consumption	$\frac{kWh}{m^2a}$	32.22	26.11	20.05	12.6	9.45	8.31	9.06	8.88	8.86	13.29	23.75	32.76
E23) Total primary energy consumption related to heating delivered	$\frac{kWh}{m^2a}$	26.51	21.23	14.52	6.82	1.76	0.55	0.11	0.11	3.08	7.04	18.15	26.51
E28) Total greenhouse gas emissions (thermal)	$\frac{kg\ CO_2eq}{m^2a}$	6.2244	5.0141	3.5321	1.7784	0.6669	0,3705	0,2964	0,2964	0,9386	1,8525	4,3225	6,2244
E29) Total greenhouse gas emissions (electrical)	$\frac{kg\ CO_2eq}{m^2a}$	1.255	1.0542	1.2048	1.3052	1.8072	1,8574	2,1586	2,1084	1,3052	1,4056	1,255	1,4056
E31) Total greenhouse gas emissions	$\frac{kg\ CO_2eq}{m^2a}$	7.4794	6.0683	4.7369	3.0836	2.4741	2,2279	2,455	2,4048	2,2438	3,2581	5,5775	7,63

Table A - 3: Monthly baseline values for the Kampweg building intervention, per square meter

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

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy consumption	$\frac{kWh}{a}$	20664	20664	11726	5904	2214	1230	984	984	3116	6150	14350	20664
E2) Electrical energy consumption	$\frac{kWh}{a}$	2050	2050	1968	2132	2952	3034	3526	3444	2132	2296	2050	2296
E4) Annual energy consumption	$\frac{kWh}{a}$	22714	22714	13694	8036	5166	4264	4510	4428	5248	8446	16400	22960
E6) Energy use for heating	$\frac{kWh}{a}$	19762	19762	10824	5084	1312	410	82	82	2296	5248	13530	19762
E8) Energy use for lighting	$\frac{kWh}{a}$	2050	2050	1804	1722	1722	1640	1722	1722	1804	1968	2050	2296
E9) Energy use for cooling	$\frac{kWh}{a}$	0	0	164	410	1230	1394	1804	1722	328	328	0	0
E13) Total renewable thermal energy production	$\frac{kWh}{a}$	0	0	0	0	0	0	0	0	0	0	0	0
E14) Total renewable electrical energy production	$\frac{kWh}{a}$	0	0	0	0	0	0	0	0	0	0	0	0
E15) Total renewable energy production	$\frac{kWh}{a}$	0	0	0	0	0	0	0	0	0	0	0	0
E17) Degree of energy self-supply by RES	%	0	0	0	0	0	0	0	0	0	0	0	0
E27) Degree of energy supply by Urban RES infrastructure	%	0	0	0	0	0	0	0	0	0	0	0	0
E19) Primary thermal energy consumption	$\frac{kWh}{a}$	22730,4	18310,6	12898,6	6494,4	2435,4	1353	1082,4	1082,4	3427,6	6765	15785	22730,4
E20) Primary electrical energy consumption	$\frac{kWh}{a}$	3690	3099,6	3542,4	3837,6	5313,6	5461,2	6346,8	6199,2	3837,6	4132,8	3690	4132,8
E21) Total primary energy consumption	$\frac{kWh}{a}$	26420,4	21410,2	16441	10332	7749	6814,2	7429,2	7281,6	7265,2	10897,8	19475	26863,2
E23) Total primary energy consumption related to heating delivered	$\frac{kWh}{a}$	21738,2	17408,6	11906,4	5592,4	1443,2	451	90,2	90,2	2525,6	5772,8	14883	21738,2
E28) Total greenhouse gas emissions (thermal)	$\frac{kg\ CO_2eq}{a}$	5104,01	4111,56	2896,32	1458,29	546,86	303,81	243,05	243,05	769,65	1519,05	3544,45	5104,01
E29) Total greenhouse gas emissions (electrical)	$\frac{kg\ CO_2eq}{a}$	1029,10	864,44	987,94	1070,26	1481,90	1523,07	1770,05	1728,89	1070,26	1152,59	1029,10	1152,59
E31) Total greenhouse gas emissions	$\frac{kg\ CO_2eq}{a}$	6133,11	4976,01	3884,26	2528,55	2028,76	1826,88	2013,10	1971,94	1839,92	2671,64	4573,55	6256,60

Table A - 4: Monthly baseline values for the Kampweg building intervention, total

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

9.3 Annex: Monthly baseline values for the wind park intervention

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E14) Total renewable electrical energy production	kWh/month	3854471,79	2884323,89	4254997,43	2269850,71	2558034,22	1745365,47	1531710,85	1167726,76	2012215,60	2668503,31	2273606,54	3410538,30
E15) Total renewable energy production	kWh/month	3854471,79	2884323,89	4254997,43	2269850,71	2558034,22	1745365,47	1531710,85	1167726,76	2012215,60	2668503,31	2273606,54	3410538,30
E27) Degree of energy self-supply by RES	%	6,92	6,61	7,93	5,24	5,48	3,72	3,55	2,52	4,50	5,88	5,43	7,10

Table A - 5: Monthly baseline values for the wind park intervention

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

9.4 Annex: Monthly baseline values for the district heating with hydrogen intervention

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy supply	kWh/month	536.621	420.995	320.194	83.013	50.401	29.648	29.648	29.648	50.401	180.850	355.771	498.079
E2) Electrical energy consumption	kWh/month	8.049	6.315	4.803	1.245	756	445	445	445	756	2.713	5.337	7.471
E4) Annual energy consumption	kWh/month	544.670	427.310	324.997	84.258	51.157	30.092	30.092	30.092	51.157	183.563	361.107	505.550
E6) Energy use for heating	kWh/month	536.621	420.995	320.194	83.013	50.401	29.648	29.648	29.648	50.401	180.850	355.771	498.079
E13) Total renewable thermal energy production	kWh/month	0	0	0	0	0	0	0	0	0	0	0	0
E14) Total renewable electrical energy production	kWh/month	0	0	0	0	0	0	0	0	0	0	0	0
E15) Total renewable energy production	kWh/month	0	0	0	0	0	0	0	0	0	0	0	0
E17) Degree of energy self-supply by RES	%	0	0	0	0	0	0	0	0	0	0	0	0
E25) Total heat supplied to the buildings connected to district heating network	kWh/month	536.621	420.995	320.194	83.013	50.401	29.648	29.648	29.648	50.401	180.850	355.771	498.079
E26) Degree of heating supply by district heating	%	1	1	1	1	1	1	1	1	1	1	1	1
E19) Primary thermal energy consumption	kWh/month	590.283	463.095	352.213	91.314	55.441	32.612	32.612	32.612	55.441	198.935	391.348	547.887
E20) Primary electrical energy consumption	kWh/month	14.489	11.367	8.645	2.241	1.361	800	800	800	1.361	4.883	9.606	13.448
E21) Total primary energy consumption	kWh/month	604.772	474.462	360.858	93.556	56.802	33.413	33.413	33.413	56.802	203.818	400.954	561.335
E23) Total primary energy consumption related to heating delivered	kWh/month	590.283	463.095	352.213	91.314	55.441	32.612	32.612	32.612	55.441	198.935	391.348	547.887
E28) Total greenhouse gas emissions (thermal)	kg CO_2eq/month	132.545	103.986	79.088	20.504	12.449	7.323	7.323	7.323	12.449	44.670	87.875	123.026
E29) Total greenhouse gas emissions (electrical)	kg CO_2eq/month	4.041	3.170	2.411	625	380	223	223	223	380	1.362	2.679	3.751
E31) Total greenhouse gas emissions	kg CO_2eq/month	136.586	107.156	81.499	21.129	12.829	7.546	7.546	7.546	12.829	46.032	90.554	126.776

Table A - 6: Monthly baseline values for the district heating with hydrogen intervention, total

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

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy supply	kWh/m²*month	19,4	15,2	11,6	3,0	1,8	1,1	1,1	1,1	1,8	6,5	12,8	18,0
E2) Electrical energy consumption	kWh/m²*month	0,3	0,2	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,3
E4) Annual energy consumption	kWh/m²*month	19,7	15,4	11,7	3,0	1,8	1,1	1,1	1,1	1,8	6,6	13,0	18,2
E6) Energy use for heating	kWh/m²*month	19,4	15,2	11,6	3,0	1,8	1,1	1,1	1,1	1,8	6,5	12,8	18,0
E13) Total renewable thermal energy production	kWh/m²*month	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E14) Total renewable electrical energy production	kWh/m²*month	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E15) Total renewable energy production	kWh/month	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E17) Degree of energy self-supply by RES	%	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
E25) Total heat supplied to the buildings connected to district heating network	kWh/month	19,4	15,2	11,6	3,0	1,8	1,1	1,1	1,1	1,8	6,5	12,8	18,0
E26) Degree of heating supply by district heating	%	100	100	100	100	100	100	100	100	100	100	100	100
E19) Primary thermal energy consumption	kWh/m²*month	21,3	16,7	12,7	3,3	2,0	1,2	1,2	1,2	2,0	7,2	14,1	19,8
E20) Primary electrical energy consumption	kWh/m²*month	0,5	0,4	0,3	0,1	0,0	0,0	0,0	0,0	0,0	0,2	0,3	0,5
E21) Total primary energy consumption	kWh/m²*month	21,8	17,1	13,0	3,4	2,1	1,2	1,2	1,2	2,1	7,4	14,5	20,3
E23) Total primary energy consumption related to heating delivered	kWh/m²*month	21,3	16,7	12,7	3,3	2,0	1,2	1,2	1,2	2,0	7,2	14,1	19,8
E28) Total greenhouse gas emissions (thermal)	kg CO_2eq/ m²*month	4,8	3,8	2,9	0,7	0,4	0,3	0,3	0,3	0,4	1,6	3,2	4,4
E29) Total greenhouse gas emissions (electrical)	kg CO_2eq/ m²*month	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
E31) Total greenhouse gas emissions	kg CO_2eq/ m²*month	4,9	3,9	2,9	0,8	0,5	0,3	0,3	0,3	0,5	1,7	3,3	4,6

Table A - 7: 1.1 Monthly baseline values for the district heating with hydrogen intervention., per square meter

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

9.5 Annex: Monthly baseline values for the Ice Cooling Storage intervention with PV plant

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
E1) Thermal energy consumption	kWh/m²*month	19,57	20,59	17,16	17,84	21,10	25,01	26,05	28,12	27,52	15,25	17,00	20,18
E2) Electrical energy consumption	kWh/m²*month	18,68	18,60	16,78	18,71	21,22	21,63	13,70	10,58	12,68	14,89	15,52	14,80
E4) Annual energy consumption	kWh/m²*month	38,25	39,19	33,94	36,55	42,62	46,64	39,75	38,70	40,20	30,14	32,52	34,97
E6) Energy use for heating	kWh/m²*month	11,78	12,62	9,61	10,12	13,63	16,92	17,69	20,20	19,09	7,10	7,76	11,48
E9) Energy use for cooling	kWh/m²*month	7,79	7,98	7,55	7,73	7,77	8,09	8,36	7,92	8,42	8,14	9,24	8,70
E13) Total renewable thermal energy production	kWh/m²*month	0	0	0	0	0	0	0	0	0	0	0	0
E14) Total renewable electrical energy production	kWh/m²*month	0	0	0	0	0	0	0	0	0	0	0	0
E15) Total renewable energy production	kWh/m²*month	0	0	0	0	0	0	0	0	0	0	0	0
E17) Degree of energy self-supply by RES	%	0	0	0	0	0	0	0	0	0	0	0	0
E27) Degree of energy supply by RES infrastructure	%	0	0	0	0	0	0	0	0	0	0	0	0
E19) Primary thermal energy consumption	kWh/m²*month	34,80	36,62	30,51	31,73	38,06	44,80	46,32	50,01	48,93	27,11	30,23	35,88
E20) Primary electrical energy consumption	kWh/m²*month	33,63	33,48	30,20	33,67	38,19	38,94	24,66	19,04	22,82	26,81	27,93	26,63
E21) Total primary energy consumption	kWh/m²*month	68,43	70,10	60,72	65,40	76,25	83,42	70,98	69,05	71,76	53,92	58,16	62,51
E23) Total primary energy consumption related to heating delivered	kWh/m²*month	20,87	22,36	17,03	17,93	24,17	29,99	31,36	35,81	33,85	12,59	13,75	20,34
E28) Total greenhouse gas emissions (thermal)	kg CO_2eq/ m²*month	9,67	10,17	8,48	8,81	10,57	12,36	12,87	13,89	13,60	7,53	8,40	9,97
E29) Total greenhouse gas emissions (electrical)	kg CO_2eq/ m²*month	9,38	9,34	8,42	9,39	10,65	10,86	6,88	5,31	6,37	7,48	7,79	7,43
E31) Total greenhouse gas emissions	kg CO_2eq/ m²*month	19,05	19,51	16,90	18,21	21,22	23,22	19,75	19,21	19,96	15,01	16,19	17,40

Table A - 8: 8.5 Monthly baseline values for the Ice Cooling Storage intervention with PV plant

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

9.6 Annex: Monthly baseline values for the public lighting improvement

Indicator	Unit	Baseline M1	Baseline M2	Baseline M3	Baseline M4	Baseline M5	Baseline M6	Baseline M7	Baseline M8	Baseline M9	Baseline M10	Baseline M11	Baseline M12
Am Schilfpark													
E3) Public lighting energy consumption	$\frac{\text{kWh}}{\text{month}}$	438,57	421,74	338,45	320,73	249,85	205,55	166,57	191,38	240,11	288,84	357,06	397,81
E30) Total greenhouse gas emissions (lighting)	$\frac{\text{kg CO}_2eq}{\text{month}}$	220,16	211,71	169,90	161,01	125,43	103,19	83,62	96,07	120,53	145,00	179,24	199,70
Schleusengraben													
E3) Public lighting energy consumption	$\frac{\text{kWh}}{\text{month}}$	210,38	202,30	162,35	153,85	119,85	98,60	79,90	91,80	115,18	138,55	171,28	190,83
E30) Total greenhouse gas emissions (lighting)	$\frac{\text{kg CO}_2eq}{\text{month}}$	105,61	101,55	81,50	77,23	60,16	49,50	40,11	46,08	57,82	69,55	85,98	95,79
Reinbeker Redder													
E3) Public lighting energy consumption	$\frac{\text{kWh}}{\text{month}}$	602,42	579,29	464,89	440,55	343,19	282,34	228,80	262,87	329,81	396,74	490,45	546,43
E30) Total greenhouse gas emissions (lighting)	$\frac{\text{kg CO}_2eq}{\text{month}}$	302,41	290,80	233,38	221,16	172,28	141,74	114,86	131,96	165,56	199,16	246,21	274,31
Kirchwerder Landweg													
E3) Public lighting energy consumption	$\frac{\text{kWh}}{\text{month}}$	2090,39	2010,15	1613,19	1528,73	1190,89	979,74	793,92	912,17	1144,43	1376,70	1701,87	1896,13
E30) Total greenhouse gas emissions (lighting)	$\frac{\text{kg CO}_2eq}{\text{month}}$	1049,37	1009,09	809,82	767,42	597,82	491,83	398,55	457,91	574,51	691,10	854,34	951,86
Weidemoor													
E3) Public lighting energy consumption	$\frac{\text{kWh}}{\text{month}}$	351,45	337,96	271,22	257,02	200,22	164,72	133,48	153,36	192,41	231,46	286,13	318,79

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

E30) Total greenhouse gas emissions (lighting)	$\frac{\text{kg } CO_2 eq}{\text{month}}$	176,43	169,66	136,15	129,02	100,51	82,69	67,01	76,99	96,59	116,19	143,64	160,03

Table A - 9: Monthly baseline values for the public lighting improvement

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