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D4.21 Baseline report for Helsinki demonstration area

WP4, Task 4.1 “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.

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Contributing beneficiary(ies)	VTT, HEN, HMU, TEC, CAR	
Task description	Task 4.1: Baseline Assessment [VTT] (HEL, FVH, HEN, CAR, TEC) This task will set and assess baseline for Helsinki demonstration, including calculated and measured values from one year period. An integrated protocol for monitoring the progress of the demonstration will be followed according to WP5. The task is split in 7 subtasks, corresponding this deliverable to the subtask described below: - Subtask 4.1.1: Buildings and district baseline: VTT will coordinate partners in the definition and assessment of the baseline and protocol for building and district energy consumption, share of renewables, CO_2 emissions and use of waste energy sources. In addition the base line sets the baseline for control and management systems.	

Date	Version	Author	Comment
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30/05/2020	1.0	Ana Quijano (CAR)	Final document

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Abbreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
DHW	Domestic hot water
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key performance indicator
M&V plan	Measurement and verification plan
PTOs	Public transport operators
DSO	Distribution System Operator
TSO	Transport System Operator
BEST	Building Energy Specifications Table
GHG	Greenhouse Gas
RES	Renewable Energy Source
HDD	Heating Degree Days
DoA	Description of Action (part of the contract with the European Commission)
PV	Photovoltaics
LED	Light-emitting Diode

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1. Executive Summary

The main objective of this deliverable is to describe the baseline values of Helsinki buildings, city infrastructure and mobility interventions before the implementation of mySMARTLife project actions.

The baseline of Helsinki interventions has been defined from the common indicators developed in the project and included in Deliverable 5.1. A tailored excel template to collect and process the baseline data was used in the baseline evaluation. The template, provided by CARTIF, enabled the consideration of the key issues in following a M&V plan. Additionally, baseline evaluation is based on the IPMVP protocol.

The established baseline values will provide a reference for comparison in tasks 5.4 and 5.5 that will monitor and evaluate the impacts of Helsinki demonstration once all mySMARTLife actions have been deployed.

Finally, it has to mention that this deliverable is a new deliverable that updates to the already approved Helsinki baseline deliverable D4.1 submitted at M12 in order to use the common list of indicators defined in the project at M36.

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2. Introduction

2.1 Purpose and target group

The purpose of this document is to describe the performance of Helsinki demonstration actions before mySMARTLife actions. This is done by using the common project indicators that have been assigned for assessment of specific Helsinki demo actions in deliverable 5.1: Integrated evaluation procedure. This document describes the baseline values of project indicators for building, city infrastructure and mobility actions. These values provide a reference for comparison in WP5 that will monitor and evaluate the impacts of Helsinki demonstration.

This report is an update to the already approved Helsinki baseline deliverable D4.1 submitted at M12. That previous report described baseline situation in Helsinki demonstration in two parts: 1) Part I of the deliverable on Helsinki city audit described the state and improvement potential in all fields relevant for mySMARTLife, and 2) Part II defined Helsinki demo action specific KPIs and related baseline values. At later stages of the project, as the common project indicators became available in D5.1 at M36, it was considered necessary to align Helsinki baselines with the other LH cities using the common project indicators, in order to allow consistency and comparability for monitoring and evaluation in WP5. Therefore, this report replaces the Part II of D4.1 and describes the baseline values for Helsinki demo actions with the common project indicators defined in D5.1.

2.2 Contributions of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
VTT	Main responsibility of the deliverable
HEN	Major contributions to building and city infrastructure interventions
HMU	Major contributions to Autonomous Bus (Action 23)
CAR	Support in the development of deliverable. Excel template for baseline data collection and baseline evaluation of buildings, city infrastructure and mobility
TEC	Support in the development of deliverable. Support in the baseline data collection and baseline evaluation of buildings and city infrastructures

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2.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the mySMARTLife project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable/Task Number	Contributions
D4.1	This deliverable is an update to the previous baseline deliverable D4.1 submitted at M12. The purpose for the update is to align the baseline evaluation according to the common project indicators described in D5.1
D5.1	The deliverable uses the indicators and procedures defined in D5.1 where is described the framework to evaluate project actions implemented in LH cities of mySMARTLIfe
D5.4	The baseline values of Helsinki demonstration will be considered in T5.4 for the calculation of KPIs
D5.5	The performance and impacts of Helsinki demonstration will be assessed in T5.5 on evaluation against the baseline values presented in this deliverable

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3. Scope of baseline evaluation

The baseline assessment is part of the larger evaluation framework applied in mySMARTLife, as shown in **¡Error! No se encuentra el origen de la referencia.**. 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 energy savings. As illustrated in Figure 1, 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,

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

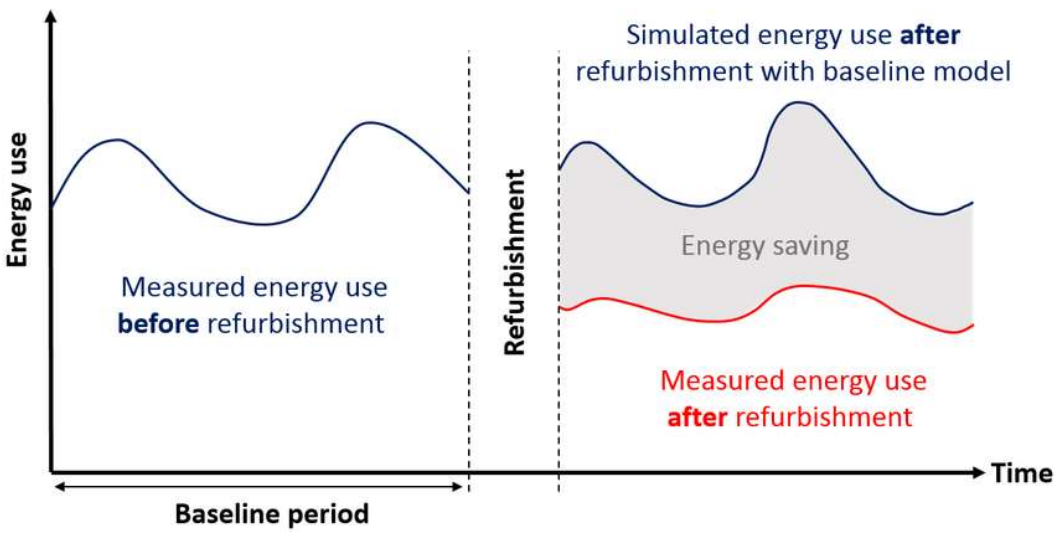

Figure 1: Energy savings definition by IPMVP

Nevertheless, to carry out a proper baseline calculation, the definition of the boundary is crucial. In this sense, two level boundary has been defined in WP5, as illustrated in Figure 2.

These boundaries are:

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- 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.
- 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.

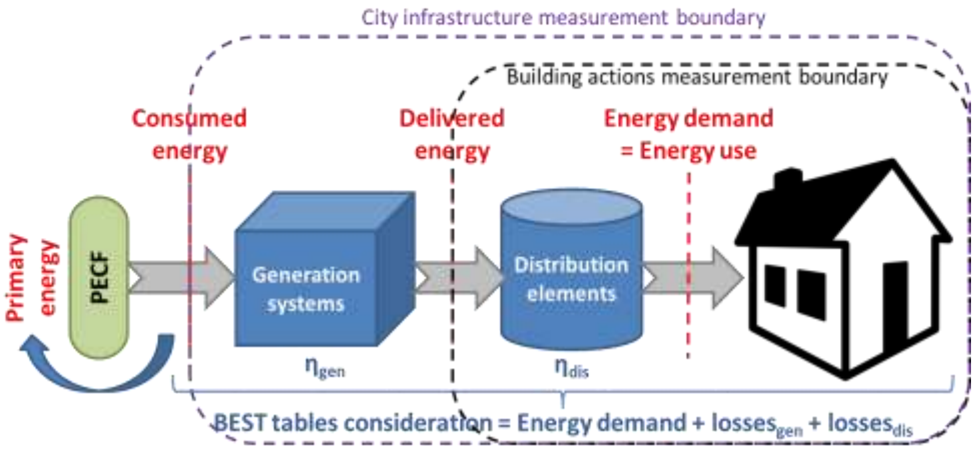

Figure 2: Measurement boundary definition

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 for each intervention, which comprises a set of related actions, following similar approach than BEST tables (e.g. Kalasatama interventions include the new solutions in the building plus the renewables).

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 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 parameters useful 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 New Construction Kalasatama is illustrated in Figure 3, which includes actions A2, A15, A7, A10 and A13.

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Intervention	Indicator	Baseline M1 kWh/month	Baseline M1 kWh/month (m2)
New construction Kalasatama (A2, A5, A7, A10, A13)	E1) Thermal energy consumption		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E2) Electrical energy consumption		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E4) Annual energy consumption	0	#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E6) Energy use for heating		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E7) Energy use for DHW		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E13) Total renewable thermal energy production		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E14) Total renewable electrical energy production		#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E15) Total renewable energy production	0	#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E17) Degree of energy self-supply by RES	#¡DIV/0!	#¡DIV/0!
New construction Kalasatama (A2, A5, A7, A10, A13)	E26)Degree of heating supply by district heating		#¡DIV/0!

Figure 3: 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 mainly on CO_2 eq.

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4. Baseline of buildings and city infrastructures

As part of the mySMARTLife project, several actions have been undertaken in buildings and city infrastructures in order to test different technical and financial solutions and to reduce the energy demand and CO_2 emissions to the atmosphere and increase the energy production with RES. Building interventions consists of retrofitting interventions (Merihaka and the Viikki environment building intervention) and new buildings (Kalasatama) and these interventions correspond exactly with:

- Merihaka intervention (A1) covers the installation of smart controls for management of apartment level heat and electricity demand (A4) and smart meters (A10).
- New construction Kalasatama (A2) includes smart controls (A5, A7) smart meters (A10) and connection to a DH (A13).
- Viikki Environment House office building intervention (A3) consists of smart demand response system (A6), and developing smart management of solar panels (A8) and RES storage (A9).

On other hand, diverse city infrastructures have been implemented and improved as is described below:

- Integration of renewable and waste heat sources in the heating and cooling network (A16)
- Optimization of renewables in a district heating and cooling system (A14, A16, A19)
- Solar power plants (A11, A12, A18, A20)
- New solar power plant (A17) with possibility to rent a PV panel
- Public lighting (A15)

These interventions take part of the zones named as Zone 1 (Merihaka and Vilhonvuori residential retrofitting areas), Zone 2 (Kalasatama area) and Zone 3 (Viikki Environment office Building area).

4.1 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).

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   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).
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 4 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 4: 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 6.

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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 5: 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 6: Baseline period selection

Finally, the description of the parameters that affect the adjustments, such as Figure 7.

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 7: 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.

4.2 Baseline of building interventions

For all the building interventions in Helsinki, 2015 was selected as baseline year. For the retrofitting intervention in Merihaka and the Viikki environment building intervention, whole baseline is based on actual monitored data from 2015. In case of new building intervention Kalasatama, the baseline was

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calculated by extrapolating the data of 2015 from a sample city block from the Kalasatama district to an equal size of an area as is currently being monitored in the project.

Since the baseline period is 1.1.2015-31.12.2015 for all building interventions, the thermal energy consumption of the buildings are all normalized with the heating degree days (HDD) from 2015 against the reference HDD in Helsinki. Heating degree days for 2015, reference HDD and the coefficients calculated are presented in Table 3**¡Error! La autoreferencia al marcador no es válida.**. The temperature base used for defining the heating degree days in 17 ºC (FMI).

Table 3: Heating degree days in Helsinki and corresponding coefficients

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Reference	**647**	**612**	**566**	**383**	**153**	**11**	**1**	**12**	**125**	**316**	**464**	**588**	**3,878**
Year 2015	555	451	454	350	190	0	0	0	30	321	343	424	**3,118**
Coefficient	1.166	1.357	1.247	1.094	0.805	1.000	1.000	1.000	4.167	0.984	1.353	1.387	**1.244**

Other parameters required in the calculation of KPIs for the Helsinki interventions are primary energy factors and emissions factors for 2015. The values used in the KPI calculations are presented in Table 4.

Table 4: Factors used in KPI calculation

	Factor used in KPI calculation
Primary energy factor for district heat (kWhe/kWh)	0.5*
Primary energy factor for district cooling (kWhe/kWh)	0.28 *
Primary energy factors for electricity (kWh/kWh)	1.0*
Emission factor for district heat (kgCO_2/kWh)	0.092**
Emission factor for district cooling (kgCO_2/kWh)	0.062**
Emission factor for electricity (kgCO_2/kWh)	0.158***

Sources: * Ministry of Environment, ** Helen, ***Motiva

** The calculation of specific emissions of district heating and cooling was based on the primary energy method in 2015. Specific emissions have been calculated for the amount of energy sold to the customer, taking into account the production and distribution losses.

4.2.1 Merihaka retrofitting

Building blocks in Merihaka and Vilhonvuori area are part of a wide energy advisory action promoted by the city of Helsinki. In mySMARTLife, according to the timeline of its execution, 10,000 square meters from this area were committed to be retrofitted and evaluated during mySMARTLife execution. These building blocks were constructed in the 1970s and 1980s, and as such they represent a vast amount of building stock waiting for energy refurbishment in Helsinki (10,262 residential high-rise buildings with 22.28 m^2, of which 4,427 buildings with 9 m^2 have been built in 1960s-1980s). The area borders the

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district towards the old city centre and Kallio, which are built in 1800s and early 1900s. A 3D model of Merihaka district is shown in Figure 8.

Figure 8: Merihaka district [figure from Helsinki city 3D model]

In general, the effectiveness of the building insulation materials (U-values) of this residential building stock are already relatively good compared to average European buildings. For example, more than two-layer windows have been a standard since 1970s in Finland. A substantial amount of the residential buildings from the suburban growth era has recently been through either façade and/or pipeline renovations in Helsinki. Hence, to produce replicability and impact, the interventions (Action 1) are focused more on improving the overall energy performance of the buildings than renovating the building structures (e.g. insulation of the envelope or glazing). Installation of smart controls for managing the heating and electricity demand at the apartment level is one of the key retrofitting interventions. For the retrofitting and domotics up-take, the project executed pilot approach with planning the action and demonstrating the smart home management solution (i.e. smart thermostats solution of Salusfin) at a pilot building located in Haapaniemenkatu 12 (in total 167 flats) in Action 4. This uptaking has included retrofitting potential analyses, thermographic camera shootings and guidance, which have all aimed for encouraging private housing associations in Merihaka to increase the overall energy efficiency of their apartments and buildings. In addition, energy advisor has supported this action and the uptake of such renovation actions.

In order to align the calculation of baseline with the impact analysis in WP5, a set of indicators was selected for the Merihaka intervention in accordance with the project indicators defined in T5.1. The indicators that have been applied in calculation of the baseline of Merihaka intervention are presented in Table 5. The units refer both on monthly level and on annual level.

Table 5: Merihaka baseline indicators

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KPIs	Unit
E1) Thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E2) Electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E4) Annual energy consumption	kWh/m^2,a, kWh/m^2,month
E6) Energy use for heating	kWh/m^2,a, kWh/m^2,month
E7) Energy use for DHW	kWh/m^2,a, kWh/m^2,month
E26) Degree of heating supply by district heating	%
E19) Primary thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E20) Primary electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E21) Total primary energy consumption	kWh/m^2,a, kWh/m^2,month
E28) Total greenhouse gas emissions (thermal)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E29) Total greenhouse gas emissions (electrical)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E31) Total greenhouse gas emissions	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month

The indicators are calculated using monitored data for both thermal and electrical consumption. District heat data is from Helen and electricity consumption data is from Helen Sähköverkko. The measurement boundary of the analysis is the one pilot building in which the project retrofitting actions have been implemented in Haapaniemenkatu 12, with a total floor area of 10,113 m^2.

Data gathered from Merihaka intervention is presented in Table 6. The normalisation with degree days was done for heating only, excluding the energy need for domestic hot water (DHW) which was estimated to be 40 kWh/m^2 on average (RakMkD3). Energy use for heating has been normalized according to the coefficients presented in Table 3.

Table 6: Merihaka montly data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Thermal energy consumption	244,800	225,300	205,800	142,200	83,000	56,700	33,500	33,500	102,700	118,200	175,800	228,600
Electrical energy consumption	39,565	34,962	37,969	35,980	37,126	34,569	34,901	35,489	36,401	39,747	40,460	40,654
Energy use for heating	211,300	191,800	172,300	108,700	49,500	23,200	0	0	69,200	84,700	142,300	195,100
Energy use for DHW	33,500	33,500	33,500	33,500	33,500	33,500	33,500	33,500	33,500	33,500	33,500	33,500
District heat supplied to building	244,800	225,300	205,800	142,200	83,000	56,700	33,500	33,500	102,700	118,200	175,800	228,600

The KPIs for Merihaka intervention are presented in Table 7. The values are calculated both on monthly level and on annual level. The primary energy and emissions factors used in the calculation are presented above in Table 4.

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

Table 7: Merihaka baseline KPIs

KPI *kWh/month (m2) ; kWh/a (m2); kgCO₂eq/month (m2); kgCO₂eq/a (m2)*	Month I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Baseline year total	Baseline year total /m2
E1) Thermal energy consumption	24.2	22.3	20.4	14.1	8.2	5.6	3.3	3.3	10.2	11.7	17.4	22.6	1,650,100	163.2
E2) Electrical energy consumption	3.9	3.5	3.8	3.6	3.7	3.4	3.5	3.5	3.6	3.9	4.0	4.0	447,822	44.3
E4) Annual energy consumption	28.1	25.7	24.1	17.6	11.9	9.0	6.8	6.8	13.8	15.6	21.4	26.6	2,097,922	207.4
E6) Energy use for heating	20.9	19.0	17.0	10.7	4.9	2.3	0.0	0.0	6.8	8.4	14.1	19.3	1,248,100	123.4
E7) Energy use for DHW	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	402,000	39.8
E26) Degree of heating supply by district heating [%]	100	100	100	100	100	100	100	100	100	100	100	100	100	100
E19) Primary thermal energy consumption	12.1	11.1	10.2	7.0	4.1	2.8	1.7	1.7	5.1	5.8	8.7	11.3	825,050	81.6
E20) Primary electrical energy consumption	4.7	4.1	4.5	4.3	4.4	4.1	4.1	4.2	4.3	4.7	4.8	4.8	537,386	53.1
E21) Total primary energy consumption	16.8	15.3	14.7	11.3	8.5	6.9	5.8	5.9	9.4	10.6	13.5	16.1	1,362,436	134.7
E28) Total greenhouse gas emissions (thermal)	2.2	2.0	1.9	1.3	0.8	0.5	0.3	0.3	0.9	1.1	1.6	2.1	151,810	15
E29) Total greenhouse gas emissions (electrical)	0.6	0.5	0.6	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.6	70,756	7
E31) Total greenhouse gas emissions	2.8	2.6	2.5	1.9	1.3	1.1	0.9	0.9	1.5	1.7	2.2	2.7	222,565	22

Energy consumption KPIs for Merihaka are presented in Figure 9. Domestic hot water energy consumption remains steady throughout the year due to the constant consumption assumption. Also the consumption of electricity appears to remain steady on a monthly basis.

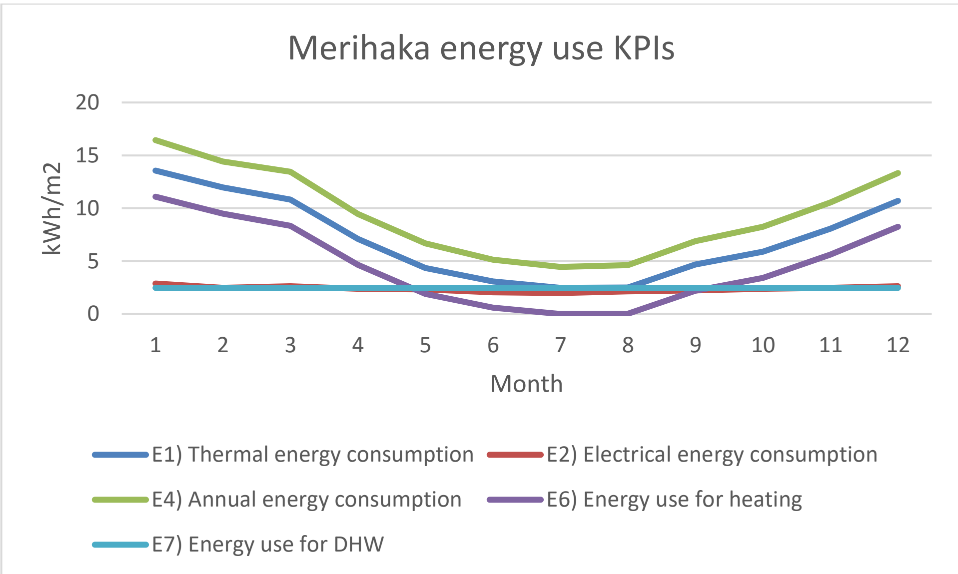

Figure 9: Merihaka energy consumption KPIs

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

The total normalized annual thermal energy consumption of the pilot building in Merihaka during 2015 was 1 650 000 kWh and electrical energy consumption was 447 822 kWh.The E-value for building energy certificate with the monitored baseline consumptions for the building is 135 kWh/m^2, giving the building energy class D on the energy certificate. The building is built during 1970s so there is energy efficiency improvement potential with mySMARTLife actions. With the implementation of Smart thermostats during mySMARTLife project the thermal energy consumption of the building is expected to decrease.

4.2.2 Kalasatama

Kalasatama area consists of a former fish harbour, and now it is developed as a reference district for smart urban construction. When the high-performance area of Kalasatama will be ready in 2032, it will consist of 67 buildings with nearly 4,500 flats and 1 million square meters of residential buildings for 20,000 residents (urban plan with the planned construction schedule in Figure 10). mySMARTLife has been involved in the process of updating the plot assignment stipulations for Kalasatama. The updated plot stipulations enable better compatibility with the technical requirements and interoperability of the smart buildings integration with smart energy systems. The part of Kalasatama which is included in baseline calculations and monitoring is highlighted in green. These buildings include Smart Home solutions, smart meters in all flats, integration of RES and waste heat in the buildings, and the co-creation area called Kalasatama living lab. Many energy production units are included in the Kalasatama district or nearby the area, such as a solar power plant with a possibility to rent a PV panel (340 kWp in Suvilahti), world's largest heat and cooling pump of its kind (Katri Vala heat pump plant in Sörnäinen, 105 MW heat, 70 MW cooling), and the first grid-scale battery energy storage system at Nordics (600 kWh/1.2 MW) located in Suvilahti.

Figure 10: The construction schedule of Kalasatama district [City of Helsinki, 2016]

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

The indicators, which have been applied in calculation of the baseline of Kalasatama intervention, are presented in Table 8.

Table 8: Kalasatama baseline indicators

KPIs	Unit
E1) Thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E2) Electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E4) Annual energy consumption	kWh/m^2,a, kWh/m^2,month
E6) Energy use for heating	kWh/m^2,a, kWh/m^2,month
E7) Energy use for DHW	kWh/m^2,a, kWh/m^2,month
E13) Total renewable thermal energy production	kWh/m^2,a, kWh/m^2,month
E14) Total renewable electricity production	kWh/m^2,a, kWh/m^2,month
E15) Total renewable energy production	kWh/m^2,a, kWh/m^2,month
E17) Degree of energy self-supply by RES	%
E26) Degree of heating supply by district heating	%
E19) Primary thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E20) Primary electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E21) Total primary energy consumption	kWh/m^2,a, kWh/m^2,month
E28) Total greenhouse gas emissions (thermal)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E29) Total greenhouse gas emissions (electrical)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E31) Total greenhouse gas emissions	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month

To calculate the baseline of Kalasatama new building district, 6 buildings were selected as a sample of the district to represent the building typology of the total area covered by the boundary and will be used to extrapolate the baseline consumption. The sample buildings are part of a district in Kalasatama, which began building during 2011. The sample size in floor area is 43,215 m^2 and the total area covered by the boundary of the district is 218,169 m^2. All of the sample buildings as well as the buildings included in the total area used to calculate the baseline are residential buildings.

Data gathered from Kalasatama intervention is presented in Table 9. The normalisation with degree days was done for heating only, excluding the energy need for domestic hot water (DHW) which was estimated to be 40 kWh/m^2 on average. (RakMkD3) Energy use for heating has been normalized according to the coefficients presented in Table 3.

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

Table 9: Kalasatama montly data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Thermal energy consumption	2,958,174	2,609,738	2,360,448	1,550,060	949,982	669,375	538,367	543,365	1,017,971	1,285,530	1,761,581	2,337,175
Electrical energy consumption	628,774	539,493	570,891	516,375	507,598	448,970	432,514	465,090	484,461	516,142	539,050	568,804
Energy use for heating	2,419,807	2,071,370	1,822,081	1,011,693	4,11,615	131,007	0	4,998	479,603	747,163	1,223,213	1,798,808
Energy use for DHW	538,367	538,367	538,367	538,367	538,367	538,367	538,367	538,367	538,367	538,367	538,367	538,367
Renewable thermal energy production	0	0	0	0	0	0	0	0	0	0	0	0
Renewable electrical energy production	0	0	0	0	0	0	0	0	0	0	0	0
District heat supplied to building	2,958,174	2,609,738	2,360,448	1,550,060	949,982	669,375	538,367	543,365	1,017,971	1,285,530	1,761,581	2,337,175

The KPIs for Kalasatama intervention are presented in Table 10. The values are calculated both on monthly level and on annual level. The primary energy and emissions factors used in the calculation are presented above in Table 4.

Table 10: Kalasatama baseline KPIs

KPI	Month													
kWh/month (m2) ; kWh/a (m2) ; kg CO2eq/month (m2); kg CO2eq/a (m2)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Baseline year total	Baseline year total /m²
E1) Thermal energy consumption	13.56	11.96	10.82	7.10	4.35	3.07	2.47	2.49	4.67	5.89	8.07	10.71	18,581,766	85.17
E2) Electrical energy consumption	2.88	2.47	2.62	2.37	2.33	2.06	1.98	2.13	2.22	2.37	2.47	2.61	6,218,162	28.50
E4) Annual energy consumption	16.44	14.43	13.44	9.47	6.68	5.13	4.45	4.62	6.89	8.26	10.55	1.,32	24,799,928	113.67
E6) Energy use for heating	11.09	9.49	8.35	4.64	1.89	0.60	0.00	0.02	2.20	3.42	5.61	8.25	12,121,358	55.56
E7) Energy use for DHW	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47	6,460,404	29.61
E13) Total renewable thermal energy production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
E14) Total renewable electrical energy production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
E15) Total renewable energy production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
E17) Degree of energy self-supply by RES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
E26) Degree of heating supply by district heating **[%]**	100	100	100	100	100	100	100	100	100	100	100	100	100	100
E19) Primary thermal energy consumption	6.78	5.98	5.41	3.55	2.18	1.53	1.23	1.25	2.33	2.95	4.04	5.36	9,290,883	42.59
E20) Primary electrical energy consumption	3.46	2.97	3.14	2.84	2.79	2.47	2.38	2.56	2.66	2.84	2.96	3.13	7,461,794	34.20
E21) Total primary energy consumption	10.24	8.95	8.55	6.39	4.97	4.00	3.61	3.80	5.00	5.79	7.00	8.48	16,752,677	76.79
E28) Total greenhouse gas emissions (thermal)	1.25	1.10	1.00	0.65	0.40	0.28	0.23	0.23	0.43	0.54	0.74	0.99	1,709,522	7.84
E29) Total greenhouse gas emissions (electrical)	0.46	0.39	0.41	0.37	0.37	0.33	0.31	0.34	0.35	0.37	0.39	0.41	982,470	4.50
E31) Total greenhouse gas emissions	1.70	1.49	1.41	1.03	0.77	0.61	0.54	0.57	0.78	0.92	1.13	1.40	2,691,992	12.34

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Energy consumption KPIs for Kalasatama are presented in figure below. In addition to the fixed thermal energy consumption of domestic hot water, the electricity consumption remains steady throughout the year. Additionally, RES production is considered such as 0 since there were any RES facility implemented.

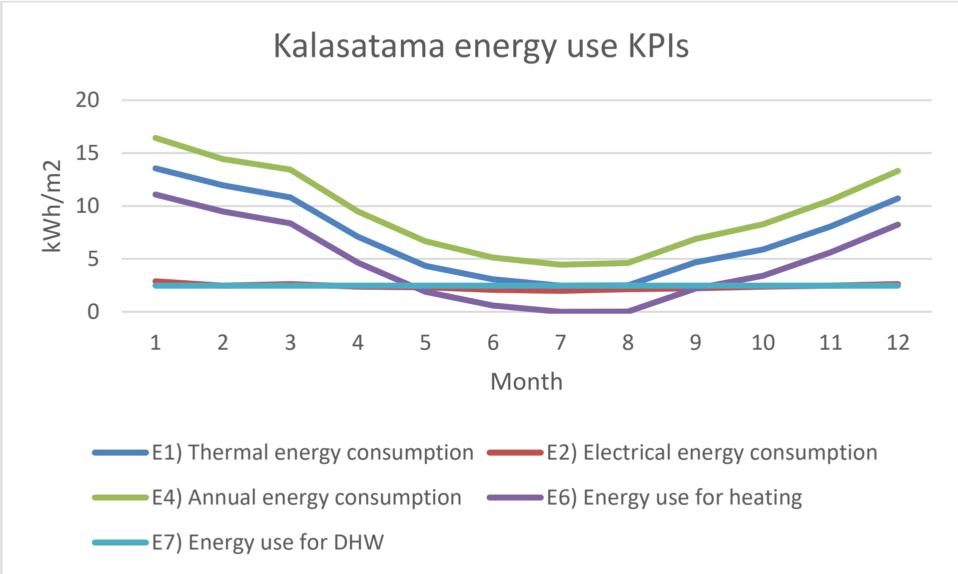

Figure 11: Kalasatama energy use KPIs

4.2.3 Viikki

Viikki Environmental house, an energy efficient office building, was constructed in 2011 and is owned and used by the Environment Centre of the City of Helsinki, and the University of Helsinki. The building gross floor area is 6,791 m^2, of which 6,390 m^2 is heated (net floor area), and gross volume is 23,480 m^3. It has five floors. Mean occupant density is 25 m^2/person on average, and its occupied hours are 2,600 h.

Figure 12: Viikki Environmental House [Figure from City of Helsinki]

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The building design process of the Viikki Environmental House targeted to low energy building with holistic approach. The efficiency of the Environment House is achieved by combining several different energy saving solutions. Low energy consumption is implemented mainly by means of commonly-used technical solutions, including:

- energy-efficient building structures (insulation and air tightness)
- bedrock-based cooling of the premises (25 boreholes),
- the south façade designed for the efficient utilisation of solar panels, which also shade the façade to prevent an excessive heat load in the summer, and
- natural daylight is utilised e.g. by means of light shafts.

The indicators which have been applied in calculation of the baseline of Viikki intervention are presented in Table 11.

Table 11: Viikki baseline indicators

KPIs	Unit
E1) Thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E2) Electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E4) Annual energy consumption	kWh/m^2,a, kWh/m^2,month
E6) Energy use for heating	kWh/m^2,a, kWh/m^2,month
E7) Energy use for DHW	kWh/m^2,a, kWh/m^2,month
E9) Energy use for cooling	kWh/m^2,a, kWh/m^2,month
E13) Total renewable thermal energy production	kWh/m^2,a, kWh/m^2,month
E14) Total renewable electricity production	kWh/m^2,a, kWh/m^2,month
E15) Total renewable energy production	kWh/m^2,a, kWh/m^2,month
E17) Degree of energy self-supply by RES	%
E26) Degree of heating supply by district heating	%
E19) Primary thermal energy consumption	kWh/m^2,a, kWh/m^2,month
E20) Primary electrical energy consumption	kWh/m^2,a, kWh/m^2,month
E21) Total primary energy consumption	kWh/m^2,a, kWh/m^2,month
E28) Total greenhouse gas emissions (thermal)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E29) Total greenhouse gas emissions (electrical)	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month
E31) Total greenhouse gas emissions	kg_{CO2eq}/m^2,a, kg_{CO2e}/m^2,month

The indicators are calculated using monitored data for both thermal and electrical consumption. District heat data is from Helen and electricity consumption data is from Helen Sähköverkko. Renewable electricity production data is gathered by the building automation system. Cooling energy consumption has been calculated with the inlet and outlet temperatures of the cooling boreholes and the set point

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flowrate of the cooling circuit. The measurement boundary of the analysis is the Viikki Environment building with a total floor area of 6,791 m^2.

Data gathered from Viikki intervention is presented in Table 12. The normalisation with degree days was done for heating only, excluding the energy need for domestic hot water (DHW) which was estimated to be 5.8 kWh/m^2 on average. (RakMkD3) Energy use for heating has been normalized according to the coefficients presented in Table 3.

Table 12: Viikki montly data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Thermal energy consumption	76,889	71,088	62,238	40,432	17,078	8,720	36,344	73,913	26,316	34,522	49,714	68,954
Electrical energy consumption	27,956	24,513	26,158	24,101	22,169	22,534	21,780	20,678	23,804	24,733	27,837	28,479
Energy use for heating	73,607	67,806	58,955	37,150	13,796	5,438	1,668	2,048	23,034	31,240	46,432	65,671
Energy use for DHW	3,282	3,282	3,282	3,282	3,282	3,282	3,282	3,282	3,282	3,282	3,282	3,282
Energy use for cooling	0	0	0	0	0	0	31,394	68,583	0	0	0	0
Renewable thermal energy production	0	0	0	0	0	0	31,394	68,583	0	0	0	0
Renewable electrical energy production	528	1,434	3,067	3,928	4,755	4,230	4,449	4,933	2,617	2,480	338	523
District heat supplied to building	76,889	71,088	62,238	40,432	17,078	8,720	4,950	5,330	26,316	34,522	49,714	68,953

The KPIs for Viikki intervention are presented in Table 13. The values are calculated both on monthly level and on annual level. The primary energy and emissions factors used in the calculation are presented above in Table 4.

Table 13: Viikki baseline KPIs

KPI	Month													
kWh/month (m2); kWh/a (m2); kgCO2eq/month (m2); kgCO2eq/a (m2)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Baseline year	Baseline year /m^2
E1) Thermal energy consumption	11.32	10.47	9.16	5.95	2.51	1.28	5.35	10.88	3.88	5.08	7.32	10.15	566,208	83.38
E2) Electrical energy consumption	4.12	3.61	3.85	3.55	3.26	3.32	3.21	3.04	3.51	3.64	4.10	4.19	294,742	43.40
E4) Annual energy consumption	15.44	14.08	13.02	9.50	5.78	4.60	8.56	13.93	7.38	8.73	11.42	14.35	71,746	126.78
E6) Energy use for heating	10.84	9.98	8.68	5.47	2.03	0.80	0.25	0.30	3.39	4.60	6.84	9.67	426,845	62.85
E7) Energy use for DHW	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	39,388	5.80
E9) Energy use for cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99,977	14.72
E13) Total renewable thermal energy production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99,977	14.72
E14) Total renewable electrical energy production	0.08	0.21	0.45	0.58	0.70	0.62	0.66	0.73	0.39	0.37	0.05	0.08	33,282	4.90
E15) Total renewable energy production	0.08	0.21	0.45	0.58	0.70	0.62	5.28	10.83	0.39	0.37	0.05	0.08	133,259	19.62

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KPI *kWh/month (m2); kWh/a (m2); kgCO2eq/month (m2); kgCO2eq/a (m2)*	Month I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Baseline year	Baseline year /m²
E17) Degree of energy self-supply by RES [%]	0 %	0 %	0 %	0 %	0 %	0 %	62 %	78 %	0 %	0 %	0 %	0 %	24 %	24 %
E26)Degree of heating supply by district heating [%]	100	100	100	100	100	100	14	7	100	100	100	100	85	85
E19) Primary thermal energy consumption	5.66	5.23	4.58	2.98	1.26	0.64	2.68	5.44	1.94	2.54	3.66	5.08	283,104	3.47
E20) Primary electrical energy consumption	4.94	4.33	4.62	4.26	3.92	3.98	3.85	3.65	4.21	4.37	4.92	5.03	353,690	4.34
E21) Total primary energy consumption	10.60	9.57	9.20	7.24	5.17	4.62	6.52	9.10	6.14	6.91	8.58	10,11	636,794	7.81
E28) Total greenhouse gas emissions (thermal)	1.04	0.96	0.84	0.55	0.23	0.12	0.49	1.00	0.36	0.47	0.67	0,93	52,091	0.64
E29) Total greenhouse gas emissions (electrical)	0.65	0.57	0.61	0.56	0.52	0.52	0.51	0.48	0.55	0.58	0.65	0,66	46,569	0.57
E31) Total greenhouse gas emissions	1.69	1.53	1.45	1.11	0.75	0.64	1.00	1.48	0.91	1.04	1.32	1,60	98,660	1.21

Energy consumption KPIs for Viikki are presented in **¡Error! No se encuentra el origen de la referencia.**. The peak in total energy consumption (E4 Annual energy consumption) during summer time is due to the increased cooling energy consumption of the building during July and August. However, since the cooling of the building is provided by boreholes the curve is different when emissions are considered as can be seen in figures below.

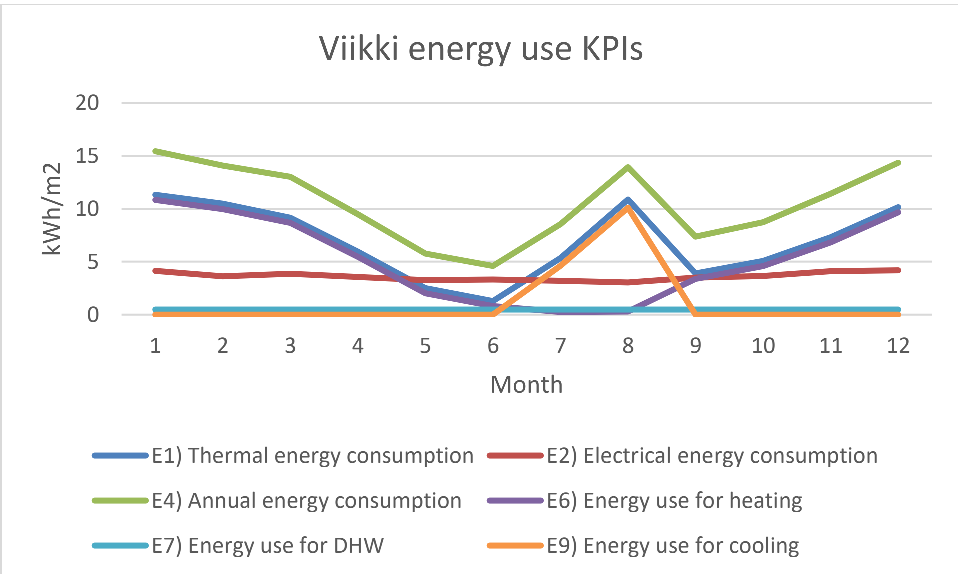

Figure 13: Wiikki energy consumption KPIs

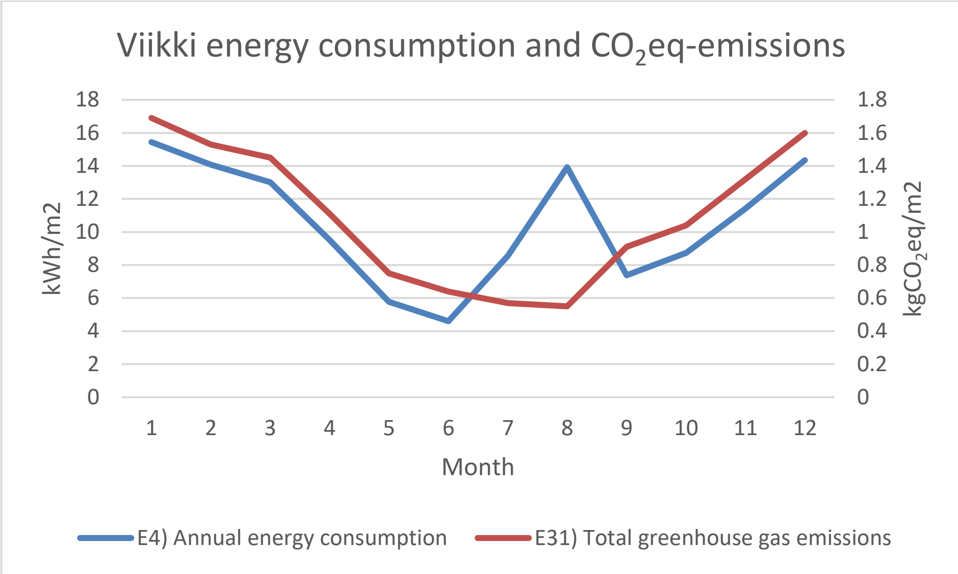

Figure 14: Wiikki comparison

4.3 Baseline of city infrastructure interventions

4.3.1 Urban RES (A16)

According to the mySMARTLife action description, RES and waste heat are to be integrated to the heating and cooling network to achieve system performance optimisation. The action is a district city level intervention and the demonstration was being implemented close to Zone 2, since Kalasatama area is close to the Katri Vala heat pump. Katri Vala heat pump plant utilizes purified waste water, return water from district cooling and electricity. The heat pump plant (in 2019: 105 MW heat, 70 MW cooling; in 2015: 90 MW heat, 60 MW cooling) was constructed in 2006. The heat pump plant is currently (2020) under expansion with a new heat pump (18 MW heat, 12 MW cooling). The new heat pump is scheduled to start operation during 2021.

The baseline year 2015 presents the production value of Katri Vala heat pumps. In 2018, Helen invested in a new heat pump plant, which was constructed under the Esplanade park in Helsinki city centre (22 MW heat, 15 MW cooling). The Esplanade heat pump plant utilizes return water of district cooling and heating, and electricity. Both heat pumps, Katri Vala and Esplanade, use renewable electricity. The production of the heat pumps is counted as renewable production within mySMARTLife baseline and monitoring and in the Carbon Neutral Helsinki 2035 plan. During the mySMARTLife monitoring phase, values of Urban RES represent the sum of the production of both heat pump plants (Esplanade and Katri Vala).

The indicators, which have been applied in calculation of the baseline of Urban RES intervention, are presented in Table 14. The annual values are presented in the public deliverable due to the confidentiality of monthly production values. Renewable thermal energy is split into two indicators, production of district

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heating and production of district cooling. Degree of energy supply by Urban RES (i.e. by heat pump plant) for the baseline year is calculated by comparing the production values of Katri Vala to the total district heating and district cooling production values in Helsinki.

Table 14: Urban RES A16 baseline indicators

KPIs	Unit
E13) Renewable thermal energy production (of heat pumps, district heating)	GWh/a
E13) Renewable thermal energy production (of heat pumps, district cooling)	GWh/a
E15) Total renewable energy production (of heat pumps, district heating + district cooling)	GWh/a
E17) Degree of energy supply by Urban RES (district heating)	%
E17) Degree of energy supply by Urban RES (district cooling)	%

NOTE; in the case of Urban RES

E17) Degree of energy supply by Urban RES = district heating production by heat pumps / total production of district heating (in %)

E17) Degree of energy supply by Urban RES = district cooling production by heat pumps / total production of district cooling (in %)

Data for the calculation of Urban RES KPIs is presented in Table 15. Both the renewable thermal energy production of heat pumps (district heat and cool production) and the total district heating and cooling production data are provided by Helen.

Table 15: Urban RES A16 data

Data *GWh*	Baseline year
Total district heating production of heat pumps	422
Total district heating production (in Helsinki)	6,404
Total district cooling production of heat pumps	97
Total district cooling production (in Helsinki)	131

The KPIs for Urban RES intervention are presented in Table 16. In mySMARTLife, Urban RES refers to the production of heat pump plants.

Table 16. Urban RES A16 baseline KPIs

KPI *GWh/year*	Baseline year
E13) Total renewable thermal energy production (of heat pumps, district heating)	422
E13) Total renewable thermal energy production (of heat pumps, district cooling)	97
E15) Total renewable energy production (of heat pumps, district heating + district cooling)	519
E17) Degree of energy supply by Urban RES (district heating)	7 %
E17) Degree of energy supply by Urban RES (district cooling)	74 %

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

4.3.2 City Infrastructure (A14, 16, 19)

The focus of this action group has been the identification of future improvements in the district heating and cooling system in Helsinki. Different kind of optimization and simulation models were created by VTT (i.e. Tali area case simulation, heat storages optimization model). These models are presented in the deliverable D4.5 Report on District Heating and Cooling Improvements and New Concepts. Furthermore, a preliminary evaluation project on production optimization and potential of heat demand response was conducted at Helen during 2019 and 2020 (related actions A13, A19) and the outcome of this project will help Helen in the future decisions about system level optimization and implementations regarding production units and storages as well as heat demand response. One objective of the preliminary evaluation project was also to define the most profitable and realistic way of possible deployment of demand response of district heating in the future. More information about the scope of Helen's preliminary evaluation project can be found in deliverable D4.5 Report on District Heating and Cooling Improvements and New Concepts.

A new heating and cooling plant (Esplanade, two heat pumps, heat 22 MW and cooling 15 MW) mentioned under Action 19 was implemented in 2018. The new heat pumps are located under the park of Esplanade in Helsinki City Centre. The heat pumps utilize return water from district heating and cooling, and electricity.

As mentioned above, the focus of this action group has been about analytical calculations and identifications of future improvements, which are essential in the future to reach carbon neutrality in 2035. Therefore, the focus of this action group has not been about implementations during the mySMARTLife project. Since the actions under city infrastructure tackle the whole energy system of Helsinki, the monitored values are total renewable district heating and cooling production as well as the total production and consumption values of district heating and cooling in Helsinki.

Electricity production and consumption have not been the focus in these actions of City Infrastructure (A14, A16, A19) and therefore electricity production and consumption are not monitored. In mySMARTLife, the data of renewable district heating contains the production of heat pumps and the production using pellets as a fuel (bio energy production). In mySMARTLife baseline, the data of renewable district cooling contains the production of heat pumps. The data is provided by Helen.

As an additional information, the Figure 15 shows the origin of district heating in Helsinki for the baseline year 2015. The production of district heating was ca 6,400 GWh in 2015. Outdoor temperatures affect the yearly production and consumption values.

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

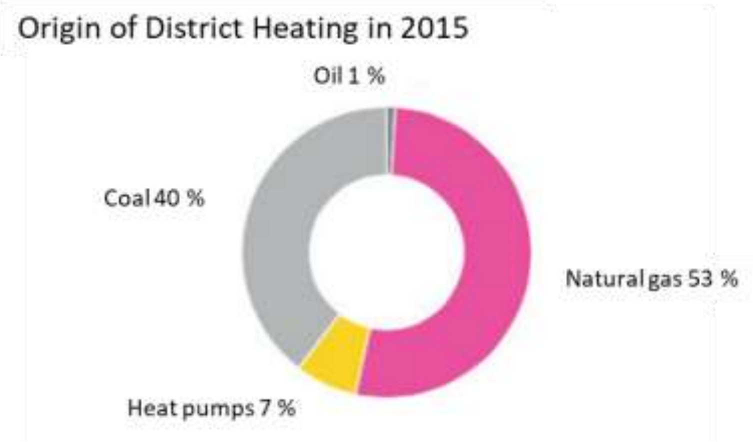

Figure 15: Origin of district heating, 2015. Source: Helen, 2015.

In 2015, Helen produced district heating and electricity in CHP plants located in Vuosaari, Salmisaari and Hanasaari (CHP = combined heating and power). The CHP plants use natural gas, coal and wood pellets as fuels. The heat production was supplemented with eleven heat plants located in various parts of Helsinki. The heat plants use natural gas and oil as a fuel and the plants guarantee a sufficient heat supply during cold weather, in power plant fault situations and during maintenance outages. In 2015, district cooling was produced by heat pumps, via absorption process and by free cooling utilizing sea water.

Helen has a goal to reach carbon neutral energy production by 2035. The Hanasaari CHP plant (coal as a fuel) will be decommissioned in 2024 and the heat production of the plant will be replaced by new investments in bioenergy, heat pumps and heat storages. Helen's steps towards carbon neutrality can be divided to three phases:

- Carbon dioxide emissions -40 % from the level of 1990, renewables to 25 % and halve the use of coal by 2025
- Phase out coal in 2029
- Carbon neutral energy production by 2035

More information about Helen's planned investments and plans to reach carbon neutrality in 2035 are presented in D4.5 Report on District Heating and Cooling Improvements and New Concept. More information can be also found on Helen's webpage under section Responsibility (Helen, 2020).

The KPIs for the interventions are presented in Table 17. The values are presented on annual level, due to the confidentiality of monthly values. The primary energy and emissions factors used in the calculation are presented in Table 4. The production and consumption values are presented in GWh.

Table 17: City infrastructure (A14, A16, A19) baseline indicators

KPIs	Unit
E13) Total renewable thermal energy production (district heating)	GWh/a
E13) Total renewable thermal energy production (district cooling)	GWh/a
E15) Total renewable energy production (district heating + district cooling)	GWh/a
E17) Degree of energy supply by RES (district heating)	%
E17) Degree of energy supply by RES (district cooling)	%
E25) Total heat supplied to the buildings connected to district heating network (in Helsinki)	GWh/a
E25) Total cool supplied to the buildings connected to district cooling network (in Helsinki)	GWh/a
E26) Degree of heating supply by district heating in Helsinki	%
E23) Total primary energy consumption related to heating delivered (district heating)	GWh/a
E23) Total primary energy consumption related to cooling delivered (district cooling)	GWh/a
E28) Total greenhouse gas emissions (district heating)	ton_{CO2eq}/a
E28) Total greenhouse gas emissions (district cooling)	ton_{CO2eq}/a

NOTE; in the case of City infrastructure

E17) Degree of energy supply by RES = district heating production by renewables / total district heating production (in %)

E17) Degree of energy supply by RES = district cooling production by renewables / total district cooling production (in %)

Data for the calculation of the interventions´ KPIs is presented in Table 18. The data is provided by Helen. In mySMARTLife, the total renewable district heating production contains production of heat pump plants and production using pellets (bio energy) and the total renewable district cooling production contains production values of the heat pumps.

Table 18: City infrastructure (A14, A16, A19) data

Data *GWh; %*	Baseline Year
Total renewable district heating production	450
Total renewable district cooling production	97
Total district heating production (in Helsinki)	6,404
Total district cooling production (in Helsinki)	131
Degree of heating supply by district heating in Helsinki (*)	90 %
Total heat supplied to the buildings connected to district heating network (in Helsinki)	5,985
Total cool supplied to the buildings connected to district cooling network (in Helsinki)	125

(*) ca 90 % of the volume of the buildings in Helsinki is connected to district heating

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The KPIs for the city level actions are presented in

District **heating** is used for space heating as well as to heat domestic hot water. Since Finland has a cold winter, the need for district heating production is highest during the winter months. The need for district heating is significantly higher than for district cooling in Helsinki due to the weather conditions. A lot of buildings in Finland do not use cooling at all.

The total district heating consumption in Helsinki (5,985 GWh) is about 20 % of the whole district heating consumption in Finland. The renewable district heating production (450 GWh) corresponds to the annual heating need of a medium-sized town in Finland. In Helsinki, the need for district heating is significantly higher than for district cooling. A significant amount of district cooling is produced by renewables in Helsinki and Helen is also the largest producer of district cooling in Finland.

Table 19The values are calculated on annual level. Factors used in the mySMARTLife baseline (used in E23, E28) are presented in Table 4. The E23 is calculated by using annual consumption values of district heating and district cooling (presented in Table 18) and the primary energy factors presented in Table 4. The E28 is calculated using annual consumption values of district heating and district cooling and the annual carbon dioxide emission factors for district heating and district cooling in 2015, which are presented in Table 4.

District heating is used for space heating as well as to heat domestic hot water. Since Finland has a cold winter, the need for district heating production is highest during the winter months. The need for district heating is significantly higher than for district cooling in Helsinki due to the weather conditions. A lot of buildings in Finland do not use cooling at all.

The total district heating consumption in Helsinki (5,985 GWh) is about 20 % of the whole district heating consumption in Finland. The renewable district heating production (450 GWh) corresponds to the annual heating need of a medium-sized town in Finland. In Helsinki, the need for district heating is significantly higher than for district cooling. A significant amount of district cooling is produced by renewables in Helsinki and Helen is also the largest producer of district cooling in Finland.

Table 19: City infrastructure (A14, A16, A19) baseline KPIs

KPI *GWh/a; %* *tonCO2eq/a*	**Baseline year**
E13) Total renewable thermal energy production (district heating)	450
E13) Total renewable thermal energy production (district cooling)	97
E15) Total renewable energy production (district heating + district cooling)	547

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E17) Degree of energy supply by RES (district heating)	7 %
E17) Degree of energy supply by RES (district cooling)	74 %
E25) Total heat supplied to the buildings connected to district heating network (in Helsinki)	5,985
E25) Total cool supplied to the buildings connected to district cooling network (in Helsinki)	125
E26) Degree of heating supply by district heating (*)	90 %
E23) Total primary energy consumption related to heating delivered (district heating)	2,992
E23) Total primary energy consumption related to cooling delivered (district cooling)	35
E28) Total greenhouse gas emissions (thermal, district heating) (tonCo_2eq)	550,580
E28) Total greenhouse gas emissions (thermal, district cooling) (tonCo_2eq)	7,773

(*) ca 90 % of the volume of the buildings in Helsinki is connected to district heating

4.3.3 City Infrastructure (A11, 12, 18, 20)

In August 2016, Helen Ltd. installed a large-scale battery energy storage system into Suvilahti, mySMARTLife Zone 2. It was the largest energy storage in the Nordic countries by the time of its installation. The output power of the energy storage is 1.2 MW and its capacity is 600 kWh. Helen Ltd. together with Fingrid, the Transmission System Operator (TSO) in Finland, and Helen Electricity Network, the Distribution System Operator (DSO) in Helsinki used it as a research platform for different studies. The main objectives of the research phase, which ended in summer 2019, were to:

- test the electric storage as a resource for power system frequency control (Fingrid)
- usage of the energy storage for the control of reactive power and voltage, the peak shaving, and the demand response (Helen Electricity Network)
- support the generation of Suvilahti solar power plant, located in the same medium voltage grid connection point, by storing PV production (Helen Ltd, Helen Electricity Network)

After the research phase of the Suvilahti battery and successful tests, the battery started business operations in the TSO ancillary service markets and therefore it operates nowadays as a resource for power system frequency control. This business operation of this system in the TSO ancillary markets is the next step made from mySMARTLife pilot results.

In spring 2015, Helen Ltd. built a solar power plant in Suvilahti, in the roof of a building owned by Helen Sähköverkko. Both the Suvilahti energy storage and the solar power plant share the same connection point to the local DSO's 10 kV medium voltage network. The maximum output power of the power plant is 340 kWp. Solar power plant in Suvilahti has almost 1200 solar panels and customers of Helen can rent a PV panel. In 2018, Helen extended the PV plant to the wall of the same building. The output of the solar panel in the wall is 280 Wp/panel and the total maximum output of the solar wall is 23.52 kWp (84 panels).

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

Furthermore, a V2G (vehicle to grid) charger, first in Finland, was implemented to the same grid connection point with Suvilahti battery and the PV plant. Charging and discharging capacity of the V2G charger is 10 kW. A demand response test was performed with the V2G during mySMARTLife project. The V2G charger was a first generation device and the V2G technology has already advanced in a couple of years. In addition to the V2G charger, a fast charger has been installed next to the battery in Suvilahti in 2018. More information about these implementations and tests with the Suvilahti battery and with the V2G charger can be found in D4.8 Report on grid vehicles strategies and performance. The deliverable presents also simulation scenarios done under mySMARTLife project.

In addition to the tests in Suvilahti, Helen Ltd. built a solar power plant in the Helsinki district of Kivikko in 2016. Almost 3,000 panels cover an area of about one hectare on the roof of the Kivikko Arctic Sport Center. Nominal power of the solar power plant is 850 kWp and the size of the inverter is 1 MW (2 x 500 kW). As a part of Actions 12 and 18, reactive power compensation was tested with the inverters of Kivikko PV plant in 2017. The results of the tests are presented in D4.5 Report on Smart Grid Improvements.

The KPIs for the intervention are presented in Table 20. The values are calculated both on monthly level and on annual level. The monitoring of these actions is focused on renewable energy production, i.e. to the solar power plants.

Table 20: City infrastructure (A11, A12, A18, A20) baseline indicators

KPIs	Unit
E14) Total renewable electrical energy production	kWh/a, kWh/month
E15) Total renewable energy production	kWh/a, kWh/month
E17) Degree of energy self-supply by RES	%
E29) Total greenhouse gas emissions (electrical)	kg_{CO2eq}/a, kg_{CO2eq}/month
E31) Total greenhouse gas emissions	kg_{CO2eq}/a, kg_{CO2eq}/month

Data for the calculation of the KPIs is presented in Table 21. The renewable electrical energy data for the baseline year 2015 contains the production of Suvilahti PV power plant (340 kWp) since Kivikko PV plant was not yet installed. The data of Suvilahti PV plant is provided by Helen Sähköverkko.

The PV production data of Suvilahti is also available as open data at (https://www.helen.fi/aurinkopaneelit/aurinkosahko/suvilahti), but the accuracy of the data provided by Helen Sähköverkko is higher and therefore it is used in mySMARTLife baseline.

Table 21: City infrastructure (A11, A12, A18, A20) data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Renewable electrical energy production	0	0	13,300	27,309	44,278	41,797	42,988	44,289	19,989	12,568	1,896	691

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

The calculated monthly and annual KPIs are presented in Table 22**.** For the indicator E17) Degree of energy self-supply by RES, the electrical energy consumption of Kalasatama was used as a reference area for the calculation (Table 9). Greenhouse gas emissions are zero since the monitored actions are related to renewable electric energy (PV production).

Table 22: City infrastructure (A11, A12, A18, A20) baseline KPIs

KPI *kWh/month; kWh/a; kg CO_2eq/a; kg CO_2eq/month*	**Month** I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	**Baseline year**
E14) Total renewable electrical energy production	0	0	13,300	27,309	44,278	41,797	42,988	44,289	19,989	12,568	1,896	691	249,105
E15) Total renewable energy production	0	0	13,300	27,309	44,278	41,797	42,988	44,289	19,989	12,568	1,896	691	249,105
E17) Degree of energy self-supply by RES [%]	0.0	0.0	2.3	5.3	8.7	9.3	9.9	9.5	4.1	2.4	0.4	0.1	4.3
E29) Total greenhouse gas emissions (electrical)	0	0	0	0	0	0	0	0	0	0	0	0	0
E31) Total greenhouse gas emissions	0	0	0	0	0	0	0	0	0	0	0	0	0

Electrical energy production for Suvilahti PV plant is presented in **¡Error! No se encuentra el origen de la referencia.**below. The plant was commissioned during spring 2015 and therefore there is no production during January and February although some production is achieved during winter time in December.

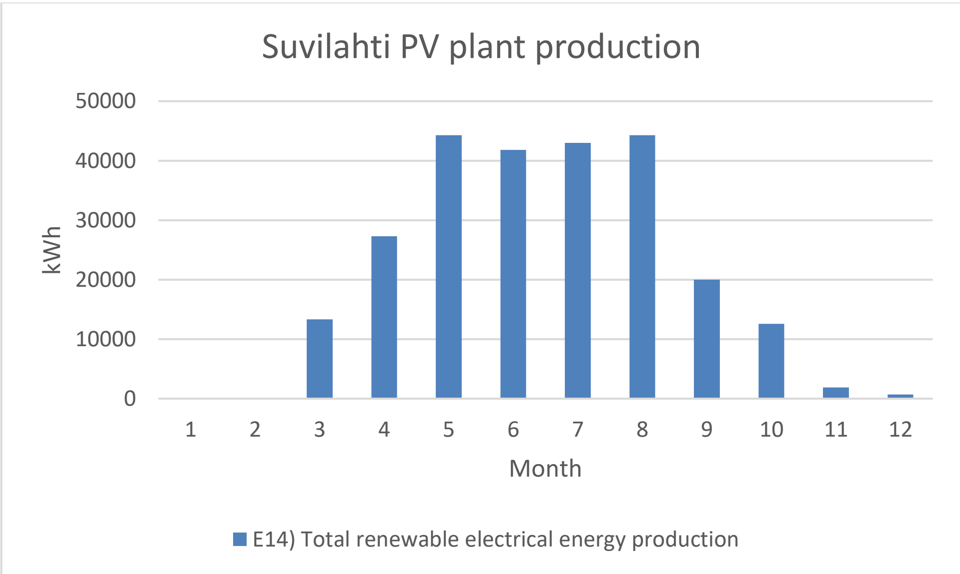

Figure 16: Suvilahti PV plant electricity production KPIs

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

4.3.4 City Infrastructure A17

In Action 17, the original plan was to install a PV power plant to the Korkeasaari Zoo (50-200 kWp), but the original plans were eventually replaced. The original action was replaced with a new plan to install PV power plant in Helsinki. In 2018, Helen decided to invest in a third designated solar power plant after the success it had experienced with the first and the second designated solar power plants (PV plants in Suvilahti and Kivikko, in Helsinki). The demand from customer's side was high for a third designated solar power plant, since both of the existing designated panels, in Suvilahti and in Kivikko, were sold out. A designated panel is an effortless way of becoming a solar energy producer: by renting a solar panel anyone can use renewable solar energy without having to install panels on own roof.

One of the largest solar power plants of Helsinki was built on the roof of Messukeskus, Expo and Convention Centre located in Pasila, Helsinki. 1912 panels have been installed to the rooftop of Messukeskus in 2019. The power output of the PV plant is a bit over 600 kWp and it was commissioned in December 2019. As of 14th May 2020, already 1485 panels have been rented by Helen's customers. The KPIs for the baseline are presented in Table 23.

Table 23: City Infrastructure A17 baseline indicators

KPIs	Unit
E14) Total renewable electrical energy production	kWh/a, kWh/month
E15) Total renewable energy production	kWh/a, kWh/month

Since the Messukeskus PV plant was commissioned after the baseline year of 2015, there is no data to be presented for the baseline (Table 24).

Table 24: City Infrastructure A17 data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Renewable electrical energy production	0	0	0	0	0	0	0	0	0	0	0	0

Also the indicators presented in Table 25 are all zero, since the PV plant was built during the project.

Table 25: City Infrastructure A17 baseline KPIs

KPI	Month												Baseline
kWh/month; kWh/a	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
E14) Total renewable electrical energy production	0	0	0	0	0	0	0	0	0	0	0	0	0
E15) Total renewable energy production	0	0	0	0	0	0	0	0	0	0	0	0	0

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4.3.5 Public lighting (A15)

A dynamic, adaptive LED-based outdoor lighting system to replace the current gas-discharged lamps was up-taken in Zone 2, Kalasatama in 2016-2017, followed by mySMARTLife intervention in Korkeasaari (Zoo) 2017-2018. Korkeasaari ZOO is an island connected by bridge to Kalasatama district. Currently the gas-discharge lamp network adapts to lighting conditions on city-level. The dynamic lighting up-take adapts the lighting to micro-level, e.g. to follow the pedestrian/bicycle presence, and other local conditions (events, logistics, emergencies). In Kalasatama the smart lighting solution is already co-designed with the residents and consists of for example navigation and communication features in addition to energy savings. Also, the lamp post infrastructure will be connected to the urban platform

The KPIs for the public lighting intervention are presented in Table 26. The values are calculated both on monthly level and on annual level.

Table 26: Public lighting intervention baseline KPIs

KPIs	Unit
E3) Public lighting energy consumption	kWh/a, kWh/month
E30) Total greenshouse gas emissions (lighting)	kg_{CO2eq}/a, kg_{CO2e}/month

The energy consumption of the Korkeasaari Zoo public lighting has not been separately monitored prior to mySMARTLife project. Therefore, the baseline energy consumption is estimated by the total number of lamp posts in the Zoo, average utilization hours per month of the lamp posts and average power of light bulb. The number of lamp posts in Korkeasaari Zoo is 147. Average power of 150W per light bulb was used in the calculations. Monthly utilization hours of the public lighting used in the calculations is presented in Table 27.

Table 27: Public lighting utilization hours, monthly

	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
[h]	467	361	305	205	128	84	106	182	258	363	431	488

Monthly energy consumption of the Korkeasaari Zoo public lighting is presented in Table 28.

Table 28: Public lighting intervention monthly data

Data	Month											
kWh	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Public lighting energy consumption	10,297	7,953	6,718	4,528	2,822	1,852	2,345	4,020	5,682	8,012	9,511	10,768

The calculated monthly and annual KPIs for the public lighting intervention are presented in Table 29.

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Table 29: Public lighting intervention baseline KPIs

KPI *kWh/month ; kWh/a ;* *kg CO2eq/a; kg CO2eq/month*	Month I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Baseline year
E3) Public lighting energy consumption	10,297	7,953	6,718	4,528	2,822	1,852	2,345	4,020	5,682	8,012	9,511	10,768	74,508
E30) Total greenhouse gas emissions (lighting)	65,171	50,335	42,519	28,658	17,861	11,722	14,842	25,443	35,962	50,709	60,196	68,152	471,570

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5. Baseline of mobility actions

As part of the mySMARTLife project, new electric transport solutions have been introduced in the city of Helsinki.

- Action 21: 140 electric buses
- Action 22: Electrification of the City Maintenance fleet and logistics
- Action 23: Autonomous Electric bus

This section deals with the methodology applied to evaluate CO_2 emissions of previous vehicles to these electric vehicles.

The data collected for baseline of Helsinki mobility actions aims to calculate the CO_2-emissions of the baseline situation to enable the comparison and impact analysis of the mobility interventions implemented in the project, using the following formula.

eqCO_2 emissions saved = eqCO_2 emissions before action – eqCO_2 emissions after action

5.1 Procedure followed to calculate baseline

The collection of baseline data and calculation of the baseline indicators has been done using an excel template provided by CARTIF. The template has been aligned with the project indicators and methods to evaluate CO_2 savings defined in D5.1 submitted in November 2019. The main objective of this excel was to know the method and assumptions followed for the evaluation of the emissions of the baseline situation given the diversity of options to evaluate CO_2 emissions. Additionally, the file aimed to calculate the CO_2 emissions of the mobility interventions.

The following information was collected for each mobility intervention in the excel template:

- Baseline period: start and finish date
- Baseline assumptions:
  - Type and number of vehicles replaced and fuel used by these
  - Distances travelled
  - Fuel consumed
- Hypothesis:
  - Distances travelled by new EV = distances travelled by previous vehicles
  - Other

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- Data source and data frequency
- Method selected and corresponding formulas:
    - Evaluation according to the travelled distance (1)
    - Evaluation according to the energy charged by equivalent new EVs (2)
    - Evaluation according to the energy consumed (3)
    - Evaluation according to the fuel consumed (4)
- Value of factors (proposed/to be used)
    - Emissions of vehicles per km (geqCO_2 / km)
    - Emissions of the mobile source (g eqCO_2 / MWh)
    - Emissions of the considered fuel (g eqCO_2 / l)
- Space to include explanations about the decision making process

Figures below shows some parts of the excel file template.

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

Figure 17: Excel sheet sample for baseline period selection

Action	Type of vehicles			
		Implemented	Monitored in WP5	Monitored in Baseline
	Number of e-vehicles			
	Type of vehicle (bus, car, bike, etc.) and fuel used			

Figure 18: Excel sheet sample for type of vehicles selection

Hypothesis	
Distances travelled by new EV = distances travelled by previous vehicles	Yes/No
If previous hypothesis is not followed, describe your case	

Figure 19: Excel sheet sample for hypothesis selection

Data collection procedure	
Data source (e.g. bills, surveys)	
Data frequency (e.g. montly, annual)	

Figure 20: Excel sheet sample for data collection procedure selection

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Method to apply					
Method to evaluate baseline	Evaluation according to the travelled distance (1)	Evaluation according to the energy consumption (2)	Evaluation according to the energy consumption (3)	Evaluation according to the fuel consumption (4)	Other
Formula	CO2eq emissions [g,kg] = annual distance travelled [km] x emissions of vehicles per km (CO2eq [g,kg] / km)	CO2eq emissions[g,kg] = (Annual energy charged (kWh) /energy efficiency (kWh/km)) x Emissions of vehicles per km (CO2eq[g,kg] / km)	CO2eq emissions[kg] =Annual energy consumption (MWh) x Emission factor of the considered fuel (CO2eq[kg] / MWh)	CO2eq emissions[kg] =Annual fuel consumed [l] x Emission factor of the considered fuel (CO2eq [kg] / l)	Include formulas, factors and sources for these factors
Method selected					

Figure 21: Excel sheet sample for method selection

5.1.1 Action 21 - 140 Electric Buses Up-take

Large-scale up-take of electric buses in Helsinki region will take place during mySMARTLife, from three (3) e-buses (3/2016) to 12 e-buses (1/2017), to 140 e-buses (2020), to 260 e-buses (2022). The target plan for the Helsinki region transport authority is to have 30% of the bus fleet electric by 2025 (390 e-buses), and 10% of fleet electric by 2020.

mySMARTLife project intervention will monitor the up-take from:

- Grid perspective by analysing the effect to the distribution grids of the electric bus fleet charging
- Detailed measurements of the 10 of the pre-commercial pilot buses and extending this operational analysis to the growing fleet from roll-out, including energy and charging management monitoring of all buses
- Impact to the residential areas from sensoring perspective

Due to complexity of bus operating schedules and lacking operational information, a simplified approach is implemented in the initial baseline calculation. First, direct fuel consumption data is not available as it is held behind the local public transport operators (PTOs) and considered sensitive business information. Thus, the emission baseline is based on driven kilometres multiplied by diesel consumption. The public transport authority of Helsinki (HSL) has determined an average diesel consumption of 41.35 l/100km for the bus fleet operating in the region, which is also utilised in the baseline calculations.

Noteworthy is that only monthly total kilometres of complete bus lines were available for the baseline creation. The planned kilometres vary between each bus in the operation schedule. For example, some buses are appointed only to support rush hour operation, while others operate complete days. As a result, some buses will drive more than others. Moreover, the bus lines are mixed with buses with different propulsion alternatives (e.g. diesel, electric and hybrids). Hence, the data utilised in the baseline creation is not vehicle-specific and it is not possible to separate diesel-driven kilometres reliably from the data. As the electric buses will operate in over 20 different bus lines in the HSL region, encompassing the total

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electric bus operation with the required aforementioned assumptions will arguably result in unrealistic baseline.

Consequently, a simplified approach is applied in the creation of the initial baseline, where focus is on fewer routes. From the selected routes, vehicle-specific averages are calculated and the results extrapolated to match the monitored number of electric buses.

Another issue regarding the operation of electric buses has been identified. As mentioned before, one fourth of the electric buses were introduced in pre-commercial pilot projects. Due to the nature of pilot testing, the monthly distance operated with these vehicles is less than average buses normally operate. Thus, it is proposed that in order to get fully-comprehensive and realistic emission impact of the Action 21, the initial baseline will be updated in the later stages of the project, based on the monitoring data from the electric buses and calculate CO_2 emission impact by comparing emissions produced by diesel-buses if they had driven the same distance.

The baseline period selected for Action 21 is 4/2019 - 3/2020. The types and number of vehicles implemented in the city, monitored for WP5 and monitored for baseline are presented in Table 30.

Table 30: Vehicle types selected for baseline calculation of Action 21

	Implemented in the city	Monitored for Evaluation in WP5	Monitored for Baseline
Number of e-vehicles	45	45	7 (results extrapolated to match 45)
Type of vehicle and fuel used	bus, battery electric	bus, battery electric	bus, diesel

The baseline calculation is done by using real data monitored from 7 buses. It is assumed that an electric bus will replace a diesel bus previously operating on the route. Therefore, the distance travelled by the electric bus equals the distance travelled by the diesel bus. For Action 21, the baseline is calculated according to the distance travelled using an emission factor per kilometre to calculate the annual CO_2-emissions. The monthly travelled distances are presented in Table 31.

Table 31: Data collected for Action 21

Month	Distance travelled [km]
4/2019	250 536
5/2019	257 417
6/2019	242 947
7/2019	245 494
8/2019	257 792
9/2019	248 426
10/2019	259 210

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Month	Distance travelled [km]
11/2019	254 042
12/2019	240 499
1/2020	257 469
2/2020	240 718
3/2020	255 878
Annual total	3 010 428

The CO_2-emissions are calculated by using an average fuel consumption for diesel buses provided by HSL, 41.35 l/100 km and CO_2-emission factor of 3.18 kg-CO2-eq/l. Total annual kg CO_2-eq-emissions (mobility indicator M13) for the baseline of Action 21 are 3 958 502 kg CO_2-eq.

5.1.2 Action 22 - Electrification of the City Maintenance fleet and logistics

The first part of this action is referred to the City Maintenance fleet. There is a large depot of the city maintenance unit at the project district, and first electrification pilots are on-going. mySMARTLife interventions are the following: 1) integration of the charging infrastructure for maintenance fleet in concert and optimal synergy with the electric bus fleets to support the charging and operation of the hybrid-electric machinery fleet, 2) measurement and monitoring of the fleet to collect the big data for operational and impact analysis, as well as 3) analysis of the performance and operation of the maintenance fleet as a whole, including shares of fully electric, hybrid and conventional machine operation. This subtask also includes operational concept analysis of the electric maintenance fleet operation and further innovation of the operational models for expansion of the operations. Secondly, this action is referred to the Electrification of the City logistics and delivery, where fully electric medium-sized truck for city logistics will be brought into operation by a commercial logistics operator Niinivirta in the greater Helsinki area. This truck will serve freight and deliveries.

The baseline period selected for Action 22 maintenance fleet is 10/2018 - 9/2019 and for Action 22 delivery fleet 4/2019 - 3/2020. The types and number of vehicles implemented in the city, monitored for WP5 and monitored for baseline are presented in Table 32.

Table 32: Vehicle types selected for baseline calculation of Action 22

		Implemented in the city	Monitored for Evaluation in WP5	Monitored for Baseline
A22 maintenance fleet	Number of e-vehicles	1	1	1 (average of 13)
	Type of vehicle and fuel used	truck, battery electric	truck, battery electric	truck, diesel
A22 delivery fleet	Number of e-vehicles	2	2	2
	Type of vehicle and fuel used	truck, battery electric	truck, battery electric	truck, diesel

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Data collected for the baseline of Action 22 are presented in diesel delivery trucks, which can be utilised as a reference in the emission impact calculations.

For Action 22, data on the average monthly fuel consumption of 13 diesel-powered maintenance trucks was collected for the duration of one year. However, no data has been available regarding the delivery fleet. The logistics operator does not have any diesel vehicles that correspond to the electric delivery truck size or operation. As a result, it was not possible to calculate a baseline in the delivery fleet part. However, a similar approach as in the Action 21 is proposed to be applied on the delivery fleet in the later stage of the project. In this approach, the electric vehicle operation is monitored and the emission impact is calculated according to the distance travelled by the electric trucks if the same distance would have been covered with similar sized diesel-powered delivery trucks. LIPASTO, a Finnish vehicle unit emission database, provides independent data on distance-specific average fuel consumptions and emissions of corresponding diesel delivery trucks, which can be utilised as a reference in the emission impact calculations.

Table 33: Data collected for Action 22

A22 maintenance fleet		A22 delivery fleet	
Month	**Fuel consumption [litres]**	**Month**	**Distance travelled [km]**
10/2018	777.5	4/2019	N.a.
11/2018	691.8	5/2019	N.a.
12/2018	238.8	6/2019	N.a.
1/2019	283.8	7/2019	N.a.
2/2019	181.6	8/2019	N.a.
3/2019	177.8	9/2019	N.a.
4/2019	157.2	10/2019	N.a.
5/2019	130.0	11/2019	N.a.
6/2019	152.2	12/2019	N.a.
7/2019	210.6	1/2020	N.a.
8/2019	217.3	2/2020	N.a.
9/2019	294.7	3/2020	N.a.
Annual total	3 513	Annual total	N.a.

As monthly fuel consumption was available for the maintenance fleet, the baseline is calculated by applying the CO_2-emission factor for diesel fuel (3.18 kg CO_2-eq/l) to the annual fuel consumption of 3 513 litres, resulting in baseline of 11 172 kg CO_2-eq. As mentioned before, it was not possible to calculate the baseline for the delivery fleet due to data unavailability. As a result, the baseline of Action 22 will comprise only the impact of maintenance fleet, totalling to 11 172 kg CO_2-eq. (mobility indicator M13).

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5.1.3 Action 23 - Autonomous Electric bus

Action 23 focuses on monitoring two separate automated bus pilots that was carried out in Helsinki area during 2018 and 2019. The pilots addressed on the potential last mile issue by implementing one electric automated bus (Navya Autonom Shuttle) on an approximately 1 km long routes in Kivikko (2018) and Kalasatama (2019). Both pilots lasted around 6 months each studying among other things the overall usability of automated buses as part of sustainable public transport, energy efficiency / passenger transferred, operational costs and user experience.

At the current state of the automated bus technology, the buses are not capable of replacing any traditional public transport bus lines and do not work year around in adverse weather conditions. Within Action 23 in mySMARTLife the automated bus was deployed on completely new last mile routes and integrated to the public transport journey planner with line number 94R (Kivikko) and 26R (Kalasatama).

The baseline period selected for Action 23 is 5/2018 - 11/2018 and 5/2019 - 11/2019. The types and number of vehicles implemented in the city, monitored for WP5 and monitored for baseline are presented in Table 34.

Table 34: Vehicle types selected for baseline calculation of Action 23

	Implemented in the city	Monitored for Evaluation in WP5	Monitored for Baseline
Number of e-vehicles	1	1	1
Type of vehicle (bus, car, bike, etc.) and fuel used	1 e-bus	1 e-bus	1 diesel mini bus

The baseline calculation is done by using real data monitored during the operation periods of the automated bus in 2018 and 2019. It is assumed, that on the automated bus's route a diesel mini van would have operated instead of the fully electric vehicle. Therefore, the distance travelled by the electric bus equals the distance travelled by the diesel van. The automated bus is an 8 seated vehicle so it will be compared to a normal diesel mini bus/car with around 8 seats like this vehicle would have been driven on the same route.

For Action 23, the baseline is calculated according to the distance travelled using an emission factor per kilometre to calculate the annual CO2-emissions. The monthly travelled distances are presented in Table 35.

Table 35: Data collected for Action 23

Month	Distance travelled [km]
6/2018	660,2
7/2018	667,6
8/2018	727,6

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Month	Distance travelled [km]
9/2018	388,7
10/2018	236,2
11/2018	0
6/2019	146
7/2019	189
8/2019	241
9/2019	142
10/2019	324
11/2019	283
Annual total	4,005,3

The CO_2-emissions are calculated by using an average CO_2eq emission factor for diesel van, 0.232 kgCOeq/km (LIPASTO). Total annual CO_2eq-emissions for the baseline of Action 23 are 929 kgCO_2eq. (mobility indicator M13).

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6. Conclusions

This deliverable describes the methodological approach for the evaluation of the baseline of Helsinki interventions and provides the baseline values to be used as reference in the evaluation of these impacts in WP5:

- Reduction in final energy consumption, increase in RES production, degree of energy supplied by RES, reduction in primary energy consumption, reduction in greenhouse gas emissions and energy provided from existing energy city infrastructures in the case of buildings and city infrastructures interventions.
- Reduction in greenhouse gas emissions in the case of mobility actions.

To overcome the baseline assessment in Helsinki, IPMVP has been selected as protocol and buildings and city infrastructures have used the data monitored through meters to evaluate the montly baseline values, taking 2015 as baseline year. For the case of mobility actions, monthly distances and fuel consumptions of the initial vehicles were used to evaluate the baseline. In this case, each mobility action considered a baseline year according to the availability of data and moment in which the electric vehicle started to circulate. On other hand, due to complexity of operating schedules of the vehicles and lacking information,some assumptions were considered and a simplify evaluation approach was followed.

Additionally, it has to be remarked that the baseline evaluation has required a strong collaboration among Helsinki partners and technical partners working in the definition and evaluation of indicators in WP5. This cooperation in the process of gathering data and analysis of the monitoring data in baseline phase has paved the way for the future work to be performed during the monitoring period.

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7. References

[01] City of Helsinki, 2016. Construction schedule of Kalasatama district: http://www.uuttahelsinkia.fi/fi/kalasatama/perustietoa/karttoja-ja-aikatauluja

[02] FMI. Heating degree days, Finnish Meteorological Institute website: https://en.ilmatieteenlaitos.fi/heating-degree-days

[03] Ministry of Environment, 2017. Energy factors for different energy carriers. Website (in Finnish): https://www.ym.fi/fi-FI/Ajankohtaista/Rakennusten_energiamuotokertoimet_uudist(45276)

[04] Helen. Emission factors for district heat and cooling. Webpage of Helen (in Finnish). Accessed 26.5.2020
https://www.helen.fi/helen-oy/energia/energiantuotanto/sahkon-ja-lammon-ominaispaastot

[05] Helen, 2015. Vastuullisuusraportti, 2015. Webpage of Helen (in Finnish). Accessed 26.5.2020. https://www.helen.fi/helen-oy/vastuullisuus/vastuullisuusraportti/vastuullisuuden-johtaminen/vastuullisuusraportti

[06] Helen, 2020. Environmental Responsibility, Origin of district heating. Webpage of Helen. Accessed: 26.5.2020

https://www.helen.fi/en/company/responsibility/responsibility-report/environmental-responsibility/carbon-neutral-energy

[07] LIPASTO. LIPASTO unit emissions database. Website: http://lipasto.vtt.fi/yksikkopaastot/indexe.htm

[08] Motiva. Emission factors for electricirty in Finland. Www-site (in Finnish): https://www.motiva.fi/ratkaisut/energiankaytto_suomessa/co2-laskentaohje_energiankulutuksen_hiilidioksidipaastojen_laskentaan/co2-paastokertoimet

[09] RakMkD3, 2012. Finnish building code, part D3. Ministry of Environment

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