Nantes | Hamburg | Helsinki

THIS DELIVERABLE HAS NOT YET BEEN APPROVED BY THE EC

Deliverable due date: M48 – November 2020

D5.3 Monitoring programs and deployment in the three lighthouses

WP5, Task 5.3

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.

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**
Project Duration	1st December 2016 – 30th November 2021 (60 Months)
Deliverable	D5.3 Monitoring programs and deployment in the three lighthouses
Diss. Level	PU
Status	☐ Working ☐ Verified by other WPs ☒ Final version
Due date	30/11/2020
Work Package	WP5
Lead beneficiary	CAR
Contributing beneficiary(ies)	NAN, ENG, CER, HCU, HAM, VTT, TEC, NBK
Task description	This task aims at the development of a robust and complete monitoring program that will include a methodology for the monitoring of the project activities and allow the introduction of future data after the end of the project. All the necessary requirements will be considered and systems for monitoring, metering and data acquisition will be selected according the KPIs and evaluation procedure defined in Task 5.1. Considering the definition of a baseline for the different themes identified by CITYkeys, the monitoring program will define the necessary requirements for monitoring and metering the project activities. The results of this task should be gathered by lighthouse work packages (WP2, WP3, WP4) in order to embed the mechanisms in the different urban Platform to enable the collection of the necessary data and information.

Date	Version	Author	Comment
21/10/2019	0.1	CAR	Generation of Table of Contents and wording common sections 1, 2 and 3
03/11/2020	0.2	All	Feedback from the iterations of the monitoring programmes with the cities
12/11/2020	0.3	CAR, NAN, ENG, CER	Nantes monitoring programmes integration
18/11/2020	0.4	CAR, VTT, FVH, HEL, HEN	Helsinki monitoring programmes integration
23/11/2020	0.5	CAR, HAM, SNH, KNO	Hamburg monitoring programmes integration
24/11/2020	0.6	CAR	Data quality and conclusions
25/11/2020	0.7	All	Feedback and comments
30/11/2020	1.0	CAR	Final proof-reading and final version
16/12/2020	1.1	HAM, CAR	Modifications in the monitoring programmes for Hamburg

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

Table of Content

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

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

Table of Figures

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

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

Table of Tables

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

Abbreviations and Acronyms

Acronym	Description
BEST	Building Energy Specifications Table
CHP	Cogeneration Heat-Power
DHW	Domestic Hot Water
DoA	Description of Action
ECM	Energy Conservation Measure
ESCO	Energy Services Company
FCR-N	Frequency Containment Reserve for Normal operation
ICT	Information and Communication Technologies
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key Performance Indicators
M&V	Measurement & Verification
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
PV	Photovoltaics
TEST	Transport Energy Specifications Table
TSO	Transmission System Operator
SCIS	Smart Cities Information System
WP	Work Package

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

1. Executive Summary

mySMARTLife project is a demonstration project where actions and interventions are carried out in the three lighthouse cities. In this sense, evaluation methodologies are necessary for the assessment of the performance and final impacts. Nonetheless, for such a purpose, monitoring is essential as real data are required to determine how the facilities are running. For instance, in order to obtain the operational parameters of a district heating, data are key element.

The evaluation framework, developed in D5.1, is based on a set of indicators (or KPIs) split into multiple application fields: energy/environment, mobility, ICTs, social, economic and governance. From them, energy and mobility are the ones dependent on the monitoring data, as the rest derives from other sources like statistics, surveys with citizens, urban policies or, as happening with ICTs, snapshots of the urban platforms statuses. That is to say, there is no a continuous monitoring for these pillars, while a single value from such data sources is made available.

However, in order to prepare a reliable and feasible monitoring campaign, a monitoring programme is needed so as to define monitoring requirements to accomplish with the calculation of the aforementioned KPIs. Whereas this document establishes the requirements and the methodology for monitoring, the implementation and deployment of equipment is part of WP2/3/4. In this way, this deliverable tries to answer the following questions:

- What to measure? Referred as the variables and data-points for KPI calculation.
- Where to measure? Location of the equipment according to the KPIs.
- How to measure? Type of equipment, such as heat meter.
- When to measure? Frequency of measurements.

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

2. Introduction

2.1 Purpose and target group

This deliverable is the submission of D5.3 related to T5.3 about the definition of the monitoring program, including systems definition and data acquisition according the evaluation procedure in D5.1. As stated per DoA [1], the main goal of the T5.3, named "Monitoring Program", is to establish a robust and complete monitoring program. For that end, a monitoring methodology is also set up with the aim of allowing further data integration and acquisition procedures along the project. Within the deliverable, the requirements for the evaluation are taken into account for the selection of monitoring systems and data acquisition equipment [1].

In general terms, WP5 is composed of 5 tasks, as depicted in Figure 1, where the first two tasks are related to the definition of the evaluation procedure and definition of data-sets, respectively. Both are used as input for T5.3 in order to define the monitoring programmes. At the same time, the output of the T5.3 will serve for the T5.4 about data collection and T5.5 for KPI and impact calculation, because all the data-points being defined within this deliverable must be collected in the next step.

Figure 1: T5.3 within WP5 tasks

As stated before, T5.1 and T5.2 inputs the T5.3. The schema how this works is illustrated in Figure 2. Here, it is observed as from one big context, like the definition of both project and city level KPIs, it is reduced into data-sets definition. The last slab in the chain is the T5.3, which takes the KPIs and data-sets and determines the variables to be measured, being the lowest level in the process.

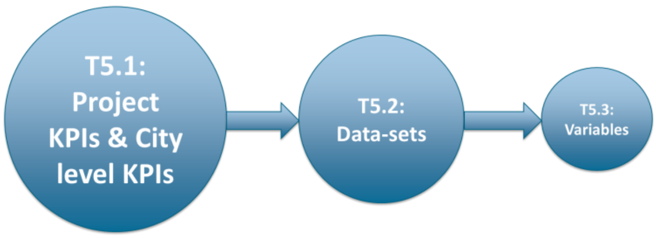

Figure 2: T5.1, T5.2 and T5.3 relationship

In summary, T5.3 tries to provide answers to the following questions:

- What to measure? This means the variables and data-points that are necessary to acquire for the proper calculation of KPIs.

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

- Where to measure? That is to say, the definition of the location of the metering equipment in order to obtain the expected values in the KPI calculation process. Note it is not the same measuring in the inlet or return circuits for an energy distribution system.
- How to measure? This question relates the data-points to the equipment that is used for the data collection (e.g. heat meter for thermal energy or wattmeter for electricity).
- When to measure? Measurements should be taken with a determined periodicity and frequency depending on the data-set. In this sense, D5.3 does not establish the periodicity of the data samples, while the cities itself within the deployment of these monitoring programmes determine the frequency. Such a piece of information is included in D5.4 within data collection approach.

It should be noted the answer to the previous questions are mostly applicable to the energy and mobility pillars, which are covered within this deliverable. Social, economic, ICTs and governance pillars' monitoring definition will be determined within D5.4 (data collection). The reason is because these do not need a monitoring programme due to the way to collect data. While energy and mobility require dynamic information taken, above all, from meters, the rest of pillars are based on questionnaires or simply data retrieval from databases. Then, monitoring programmes are more focused on the deployment of equipment to ensure the calculation of KPIs, impacts and BEST/TEST table calculation.

It is remarkable to say the output of this task is implemented by the lighthouse work packages (WP2, WP3, WP4) [1], where the real deployment of the equipment is performed. As well, the data-points that are selected within the monitoring programme are finally embedded into the data collection mechanisms in the different Urban Platforms to enable the collection of the necessary data and information.

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
CAR	Task leader and deliverable responsible. Also, the creation of the initial monitoring schemas according to the KPIs defined in D5.1.
NAN	Main contributor in Nantes for the iterative process of defining the monitoring programmes related to the actions.
ENG	Urban Platform developer (data integration) and actions responsible, providing feedback about energy monitoring in Nantes.
CER	Mobility monitoring feedback from Nantes.
HAM	Main contributor in Hamburg for the definition of the monitoring programmes.

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

SNH	Contribution for the Hamburg monitoring programmes.
ENH	Contribution for the Hamburg monitoring programmes.
KON	Contribution for the Hamburg monitoring programmes.
TSY	Urban Platform developer (data integration).
VTT	Contribution for Helsinki for the definition of the monitoring programmes.
HEN	Main contributor in the Helsinki monitoring programmes
HEL	Contribution for the Helsinki monitoring programmes in energy retrofit actions
FVH	Contributor on data acquisition and support from Urban Platform

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 Number	Contributions
D5.1	D5.1 defines the evaluation framework based on KPIs, which provide the input for the establishment of parameters to be monitored and, thus, included in the monitoring programmes.
D5.2	D5.2 sets the requirements for the data-sets according to the KPI selection and, then, input for the variables to be metered.
D5.4	Data collection approach within D5.4 that follows the monitoring programmes and the list of variables determined within them, as well as the data quality procedure introduced in this deliverable.
D2.X	In order to summarise, D5.3 is related to multiple deliverables from WP2. All the ones describing the results of the actions should be taken into account as the actions are monitored, therefore, following the monitoring programme. As well, the deliverables for Urban Platform are included as data need to be integrated.
D3.X	Similar to Nantes, Hamburg deliverables include the actions deployment and, thus, being monitoring. Again, Urban Platform related deliverables should be also considered as data are integrated.
D4.X	Helsinki deliverables follow the same concepts than Nantes and Hamburg. Monitoring programmes are deployed in the cities according to the actions.

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

3. Monitoring methodology

First of all, before defining the monitoring programmes for each of the lighthouse cities, it is important to explain some concepts about the monitoring. Starting from the monitoring period, as explicitly stated in the topic, two years of data are foreseen. Then, under this premise, mySMARTLife project has considered the definition provided by SCIS [2]. Figure 3 [2] shows how the monitoring life-cycle is determined in multiple stages, which are mapped into years.

- Stage 0, or year 0, is defined as the period prior finalisation of the works.
  - Within mySMARTLife, this is the stage just before M36 when the actions should be finished.
- Stage 1, or year 1, where the metering equipment starts collecting data, although this stage is named “commissioning” because it is assumed possible data gaps, errors, etc.
  - Within mySMARTLife, this is the span between M37 and M48 (12 months) of continuous data gathering where data-sets might be incomplete due to, for instance, delays in the final implementation of the actions or improvements in the metering devices. During this stage, it is not necessary the integration of data into the Urban Platforms.
- Stage 2, or year 2: SCIS defines as “optimising” because, during this stage, data must offer the quality enough to optimise the performance of the building. That is to say, it must be reliable data, which represent the real operation.
  - Within mySMARTLife, this corresponds from M49 to M60 (12 months) where all data-sets must be complete, they should be reliable and integrated into the Urban Platforms. At the same time, the periodic calculations of KPIs must be performed during this stage. In this sense, it is defined in D5.1, monthly-basis calculation periodicity, which has been also applied in the baseline calculation deliverables.
- Stage 3, or year 3: After having optimised the data collection approach, the continuous monitoring for optimal operation is then established (this is out of scope of mySMARTLife, but cities will continue afterwards).

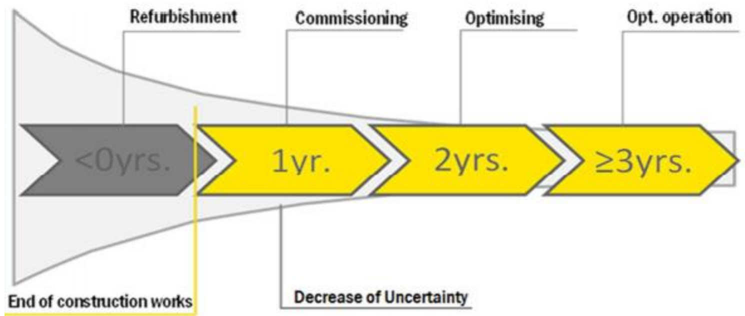

Figure 3: Monitoring life-cycle (source SCIS [2])

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

Secondly, it is important to explain how the monitoring programme has been designed. Due to the complexity of this type of projects, actions have been grouped in terms of interventions. Figure 4 shows the concept, which is basically focused on related actions. That is to say, wherever actions are related among them, they are grouped. The relationships could be in different ways, such as actions that are being carried out within the same area/zone, one action feeds another (e.g. PV panels used for supplying district heating distribution system) or any other. The advantage is to reduce the complexity, as well as avoid repetition or duplication of metering elements.

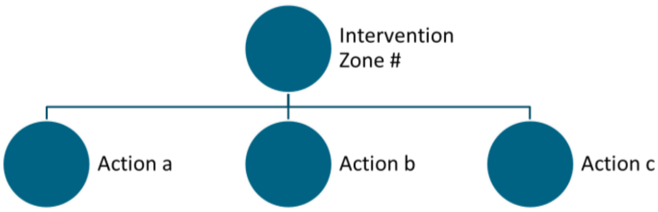

Figure 4: Actions and interventions grouping

3.1 Monitoring definition procedure

Once the concepts are clear, how the monitoring procedure is being defined. In this sense, the concept from SCIS [2] has been also taken into consideration. SCIS defines 4 phases [2]:

1. Definition of the monitoring concept. During this phase KPIs and monitoring elements are defined for each demonstration project and unit (buildings, energy supply units, ICT etc.). As suggested by SCIS, within this stage, firstly, the KPIs should be established so that, secondly, the monitoring parameters might be extracted in order to calculate these KPIs. This is exactly the procedure that mySMARTLife is approaching within D5.1, D5.2 and D5.3. As highlighted in Figure 2, from KPIs, the data-sets are determined and, from these last ones, the monitoring parameters or variables are obtained.
2. Implementation of the monitoring measures. This is basically the deployment of the metering equipment, following the expected location from the KPIs definition. This second part is also covered within this deliverable, where the monitoring approach also contains the ideal location. Nevertheless, the deployment of the devices is part of WP2/WP3/WP4. Finally, SCIS suggests that this installation of the monitoring devices has to be developed in parallel to the actions' implementation. The advantage is to follow a minimal invasive strategy.
3. Monitoring of the energy supply and consumption. The intention is to collect dynamic data in a continuous way to reveal the actual energy performance of the facilities. This phase is out of scope of D5.3, whereas it will be delivered in D5.4.
4. Voluntary long-term monitoring, which aims to keep the monitoring and collection of data afterwards. This is, indeed, out of scope of mySMARTLife project as it will be from M60 on (then, out of the DoA commitments).

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

3.2 Monitoring schemas template

Before providing the way how the monitoring schema is being drawn, it is pivotal to understand the concept of measurement boundary. Similar to D5.1, the boundary definition is taken from the IPMVP protocol for Measurement&Verification [3]. It states that is “a notational boundary drawn around equipment, systems or facilities to segregate those which are relevant to savings determination from those which are not”. In order to better understand, it should be comprehended as a geographical or physical boundary that separates the equipment and the Energy Conservation Measure (ECM). In short, the boundary should include the facilities related to energy demand-consumption where the energy savings are really produced.

Additionally, it should be considered the interactive effects, which are the “energy impacts created by an ECM that cannot be measured within the measurement boundary” [3]. That is to say, the interrelationships between actions and different energy types (e.g. electricity consumption derived from a thermal ECM).

Following the aforementioned definitions, mySMARTLife takes them into account. Therefore, the measurement boundary is the whole facility where energy savings may be produced in terms of demand and/or consumption. Typically, these are the distribution and final elements, while the generation sources are not yielding energy savings, but simply covering certain demand.

Having clarified the measurement boundary concept, then, the schema is detailed. Figure 5 depicts such a schema, where the boundary, as stated before, covers the demand side (distribution facilities and district buildings). On the other hand, the generation sources are represented on the right part of the schema, being possible its division in two: electricity and thermal (heating and domestic hot water). For the energy flows, the black and thin arrows represent the electricity flows, from the generation side to the consumption (including distribution elements). In the case of thermal energy flows, grey and coarser arrows represent them.

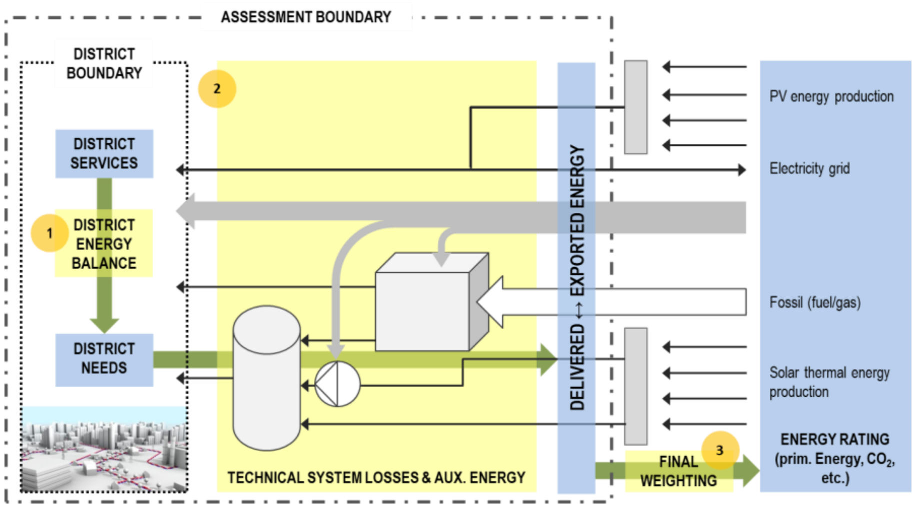

Figure 5: Monitoring schema template

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

It should be also mentioned the final weighting from the boundary to the generation part. At the end, the final evaluation and comparison should be rendered in primary energy savings. Therefore, the consumption should be translated into primary energy, which is basically obtained by weighting it by the primary energy conversion factors.

As well, about the icons for the representation of the measurements, their objective is to determine a type of data-point, either being a physical sensor/meter or another way to obtain data (e.g. invoices). In summary, the legend for the thermal measurements is:

Electricity measurement (wattmeter)

Thermal measurement (heatmeter)

x# Number of measurements or devices (empty means 1 device)

Thermal energy flow

Electrical energy flow

Temperature probe

Water heater

In terms of mobility actions, these differ from the energy and boundaries are not applicable. Mobility actions apply to the city; hence, creating a boundary is not possible. In contrast, action per action is represented with the measurements for the KPIs and/or impact calculation. Although these mobility actions make use of some icons from energy (e.g. electricity measurement), it also adds complementary icons to represent some data-points as below.

eVehicle meter

- Battery level
- Fuel use (in case of hybrid)
- GPS
- Driving parameters

Charging station vehicle detection

Electricity grid

Renewable source

3.3 Data gathering approaches

Finally, for the monitoring procedure, it is important to define the data gathering approaches. Although data collection is T5.4, here, the possibilities about how to gather data are described. Figure 6 summarises it. Basically, starting from the left side, three possible data acquisition systems are detected:

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

- Raw data directly connected to the communication network (whatever protocol is) and ingested by the urban platform with the use of drivers. This means as many signals as parameters should be read and stored.
- Second case is when a data-logger is aggregating signals from the raw data. This reduces the signal processing (one single signal containing all the parameters).
- Finally, the third case is pretty much similar to second one, but with the difference that the data-logger is proprietary from a third-party. For instance, an ESCO in charge of the management of a district heating is already collecting data. Hence, by simply accessing this data-logger, raw data may be obtained.

Last but not least, after the integration of data into the urban platform according to the open specifications framework defined for interoperability of data and to ensure the data life cycle [4], this needs to be stored in a persistent system (i.e. database). Then, KPIs can be processed and calculated to support the assessment procedure that is defined in D5.1.

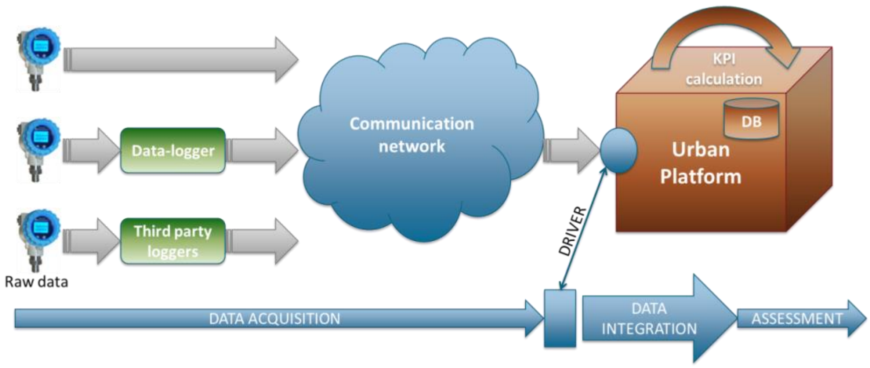

Figure 6: Data gathering approach

Nonetheless, within the data gathering process, SCIS recommends a proper labelling in order to facilitate the interpretation of data [2]. In this sense, within the automated data collection, metadata is desirable, such as corresponding units (e.g. kWh), building, location, etc. The concept is illustrated in Figure 7. mySMARTLife is already implementing this schema through the use of SensorThingsAPI data model in the urban platforms, where the observations are labelled with metadata in order to self-interpret the data-sets.

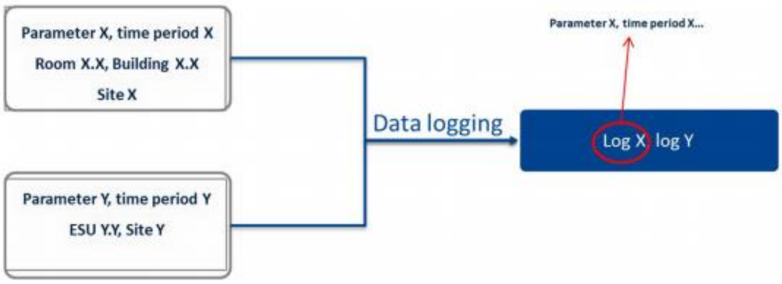

Figure 7: Data labelling approach (source [2])

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

4. Nantes monitoring programme

Once the template and methodology is defined, now, the monitoring programmes are detailed for each group of actions (i.e. interventions) for each one of the cities. Starting with Nantes, two subgroups are established: energy and mobility. As introduced, the rest of pillars do not require the deployment of equipment, therefore, they are neglected within this deliverable.

4.1 Energy and mobility primary KPIs

As it was mentioned previously, the monitoring programmes are prepared in basis of the defined KPIs in D5.1. These, at the same time, have been defined to comply with the impacts and BEST/TEST tables. Then, monitoring programmes should be defined to assure the calculation of KPIs. This section summarises the primary KPIs for Nantes grouped by the interventions (note that secondary KPIs are obtained from primary ones, while primaries require measured data). These KPIs establish the background over which the requirements for monitoring are obtained in accordance to the parameters used as variables in the formula or equation to calculate each of the KPIs. Thus, Table 3 collects the list of KPIs that were defined in D5.1 and require the definition of monitoring programmes for their calculation. Note that the table only aims to list the indicators and the header interventions (grouping core actions that are explain in each specific section), but not to directly relate interventions and indicators (for instance, smart lighting does not apply for E1).

Table 3: KPIs for actions/interventions implemented in Nantes

Pillars	Interventions	Objectives of evaluation	Applicable indicators
Energy & Environment	**Building/District** Inspiration (A1) Pierre Landais (A4, A7, A17) Oiseau des Iles (A5, A7) Individual houses (A3, A6, A12) Multi-owner buildings (A2, A17) **City infrastructure** Smart lighting (A18) Urban RES: District Heating (A16) Urban RES: PV (Cité des congrès-A21a, Public building-A21b)	Reduction in energy consumption Reducion in greenhouse gas emissions	E1. Thermal energy consumption
			E2. Electrical energy consumption
			E3. Public lighting energy consumption
			E6. Energy use for heating
			E7. Energy use for DHW
			E8. Energy use for lighting
		Increase in the RES production	E13. Total renewable thermal energy production
			E14. Total renewable electrical energy production
		Fraction of energetic self-supply by RES Energy provided from existing energy city infrastructure	E17. Degree of energy self - supply by RES
			E18.Total heat supplied to the buildings connected to district heating network
			E24. Recovery
			E25. Total heat supplied to the buildings connected to district heating network
			E26. Degree o heating suply by district heating
Mobility	**EV** Electrical buses (A23a)	Reducion in greenhouse gas emissions	MO1. Annual number of passengers (or users)
			MO4. Annual number of trips

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

	Autonomus electrical bus (A23b)	Use and energy consumption of EV Change in mobility due to solutions implemented	MO5. Annual distance travelled
			MO7. Availability rate of e-buses
			MO9. Annual energy consumption
			M14. Number of incidents and traffic accidents
	Charging stations Charging points for e-buses (A24) Smart charging points (A25) Solar road (A23b)	Degreee of energy supplied to EV by RES Use and usage pattern of charging stations Change in mobility due to solutions implemented Energy demand management	M16. Annual energy delivered by each charging point
			M19. Total number of charges per year
			M20. Total operating time for charging operations
			M24. Number of different users per year
			M29. Station uptime per year
			M30. Charging points powered by renewable energy sources (number and rate)
			M33. Annual energy produced by each charging point or solar road
Energy & Environment & Mobility	**Building & Multimodality & Demand Management** CIC building (A31-A8-A14-A22-A27)	Energy demand management	E2. Electrical energy consumption
			E14. Total renewable electrical energy production
			M30. Charging points powered by renewable energy sources (number and rate)

4.2 Energy actions

Within Nantes, the energy actions are grouped as a set of interventions. These are defined as actions related among them taking always into consideration the BEST tables, being trendy the selection of one intervention per BEST table. However, in Nantes, it should be noticed some of the BEST tables correspond to the same intervention, i.e. multi-owner buildings are split into multiple BEST tables, but under the same monitoring concept. Then, next subsections depict the interventions for Nantes.

4.2.1 Inspiration (new construction) and CIC building

The first monitoring programme corresponds to the Inspiration and CIC building as this building is part of the Inspiration zone, although it has some differences in the actions, but all together are the BEST table 4. Then, Figure 8 illustrates the monitoring programme for the 4 blocks of buildings (including CIC building), representing 28,500 m^2. There are some other actions related as A14, which is the power management system for the A8 (PV plant) and A22 (Battery storage), or A15 that is the deployment of smart meters. Moreover, it is important to highlight that this schema only shows the part of the buildings, while the multimodal hub related to A8-A14-A22-A27-A31 will be detailed in the mobility section. Finally, the objectives of the monitoring should be clarified. Here, the district needs in terms of electricity and thermal energy are the main result to be obtained with the KPIs, therefore, the assessment boundary rounds the distribution and demand sides. The actions within the project aim the reduction of demand (with respect to regulation) and increase of renewables by the integration of PV (only in CIC building) and renewable district heating.

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

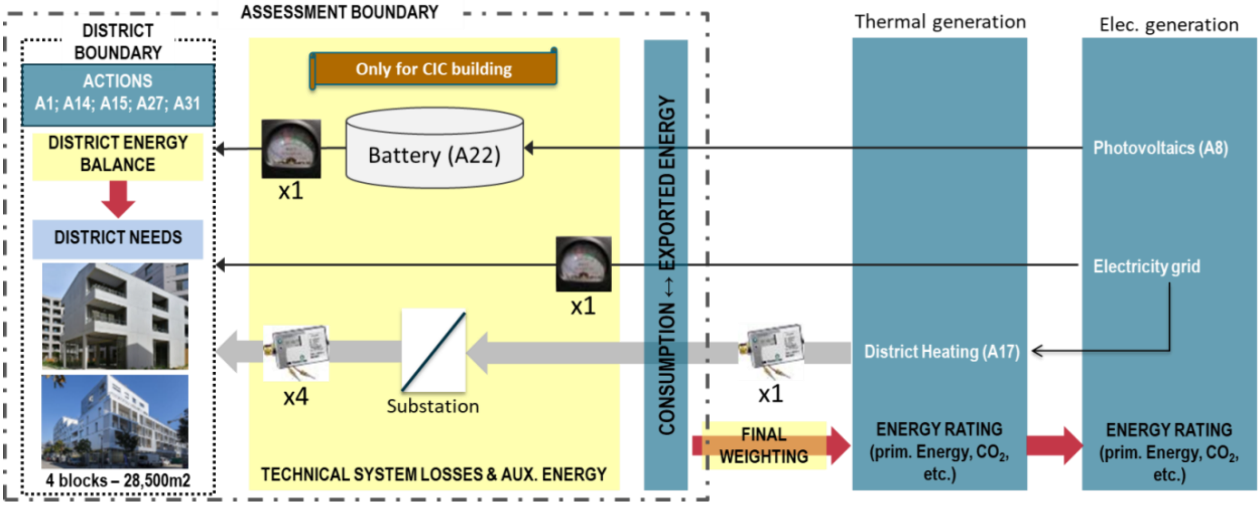

Figure 8: Inspiration and CIC building monitoring schema

Entering into details of the monitoring programme, as explained in the template, on the right side, the generation sources are drawn (both electrical and thermal). Electrical sources are the grid and the PV (A8), but this only feeds the CIC building through the battery. Then, the contribution from this renewable source is measured in order to determine the percentage of renewables injected in the building. For the rest of buildings, the only contribution for electricity comes from the grid, not being measured.

Related thermal energy, district heating supplies the buildings. Before the substation, only one circuit is available, while after the substation both heating and DHW can be measured. That is the reason why one meter is used as output of the district heating. Here, it should be remarked that this single meter is related to the same than included in “Urban RES: District heating” (section 4.2.7). In this specific case, after the station, 4 meters are established for the 4 blocks, being only related to heating, as DHW was not selected as KPI within D5.1.

Last but not least, from the district energy delivery and demand (final use), the national conversion factors are used to obtain the primary energy.

4.2.2 Pierre Landais

Pierre Landais building (BEST 2) is mainly A4 and A7 (digital boiler) where the main objectives are the reduction of the energy demand (with respect to regulation as it is new construction), as well as the connection to the district heating (A17) and the integration of the digital boiler (A7) for the heat recovery so as to generate renewable DHW. This building covers 905 m^2, which is pointed out in the schema illustrated in Figure 9.

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

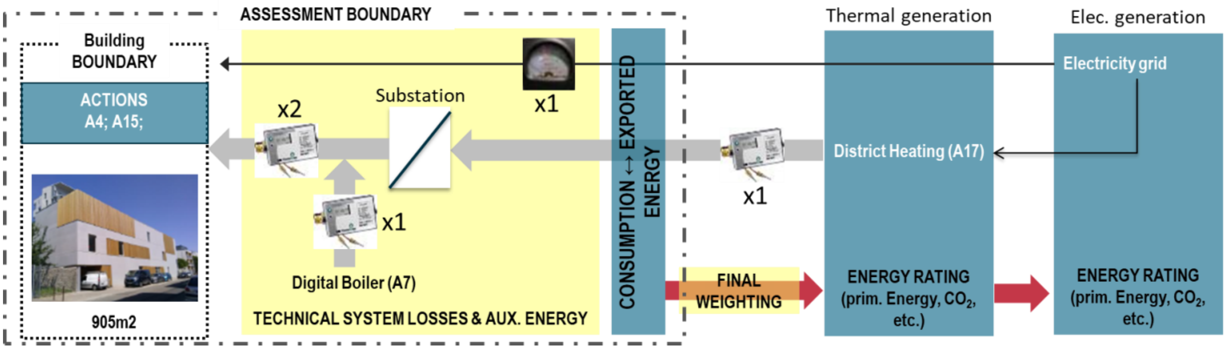

Figure 9: Pierre Landais monitoring schema

Then, following the same approach than before, thermal energy is measured from district heating, while, after the substation, both heating and DHW are measured. In this case, the contribution from the digital boiler must be measured to determine the contribution from renewable DHW (or better said recovery energy) to the total DHW demand or usage. Regarding electricity, the total consumption of the building is also obtained, whose unique supply is the electricity grid.

4.2.3 Social housing (Oiseau des Iles)

Oiseau des Iles building, whose BEST is number 5, follows the same approach than Pierre Landais. There are mainly two differences. Firstly, the electricity is not measured in this building (not being either a KPI). Second, the total square meters for this building are 2,204 m^2. Its monitoring schema is, therefore, depicted in Figure 10.

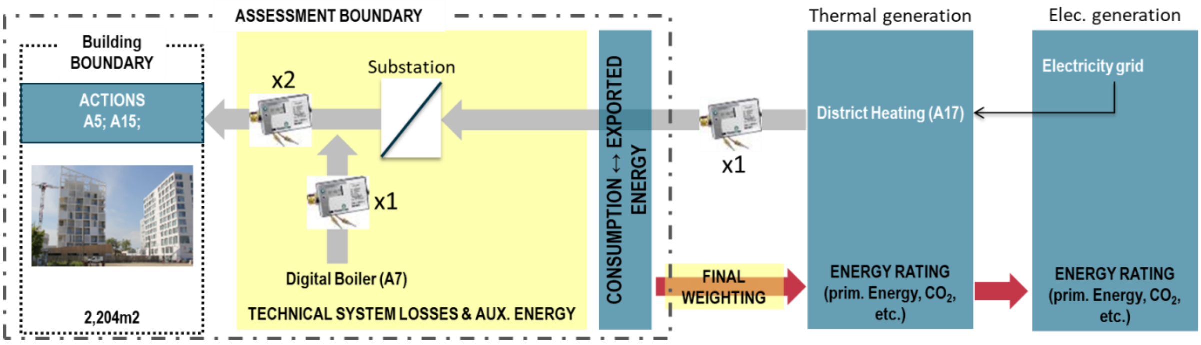

Figure 10: Oiseau des Iles monitoring schema

4.2.4 Multi-owner buildings (retrofitting)

Next is the multi-owner building, whose main objective is the retrofitting of the building and, thus, the decrease of the energy demand. In this case, this intervention is composed by 6 buildings with their respective BEST tables: BAT A (BEST 1A); BAT B (BEST 1B); Benoni Goulin (BEST 1C); Le Strogoff (BEST 1D), Val de Loire (BEST 1E) and Massillon (BEST 1F). In total, the covered area is 17,890 m^2. Within this renovation, two buildings are connected to the district heating (BAT A and BAT B), while the rest of buildings keep the gas boilers and water heaters. Its monitoring schema is drawn in Figure 11.

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

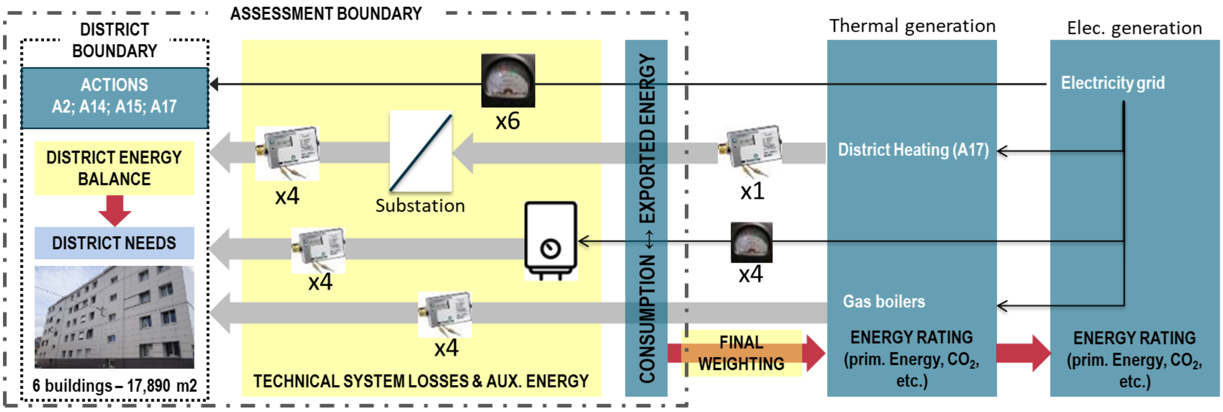

Figure 11: Multi-owner buildings monitoring schema

Within the schema, total electricity measurement for each of the buildings is taken, being the grid the only source. In terms of thermal energy, the two buildings connected to the district heating follow the same procedure than before (i.e. district heating measurement and split into heating and DHW after the substation). The main difference here to be explained is the use of the individual gas boilers and the water heaters. In terms of gas boilers, its delivered heating energy is measured. For the water heaters, both the consumed electricity and the delivered DHW-related energy are gathered. Although it is not a KPI, it has also a benefit, which will be the calculation of the performance of this distribution element.

4.2.5 Individual houses (retrofitting)

Individual houses (A3) is originally composed by 10 houses, increased up to 32, to cover a total area of 3,500 m^2 (in contrast to the initial 1,000 m^2 from BEST #3). Additionally, one hybrid solar system is included in one house, which generates both electricity and solar thermal energy. Then, basically, the aims are the reduction of the energy demand due to the retrofitting works and the increase of renewable energy (although in this case for one out of 32 houses). Taking into consideration these objectives, the monitoring schema is shown in Figure 12.

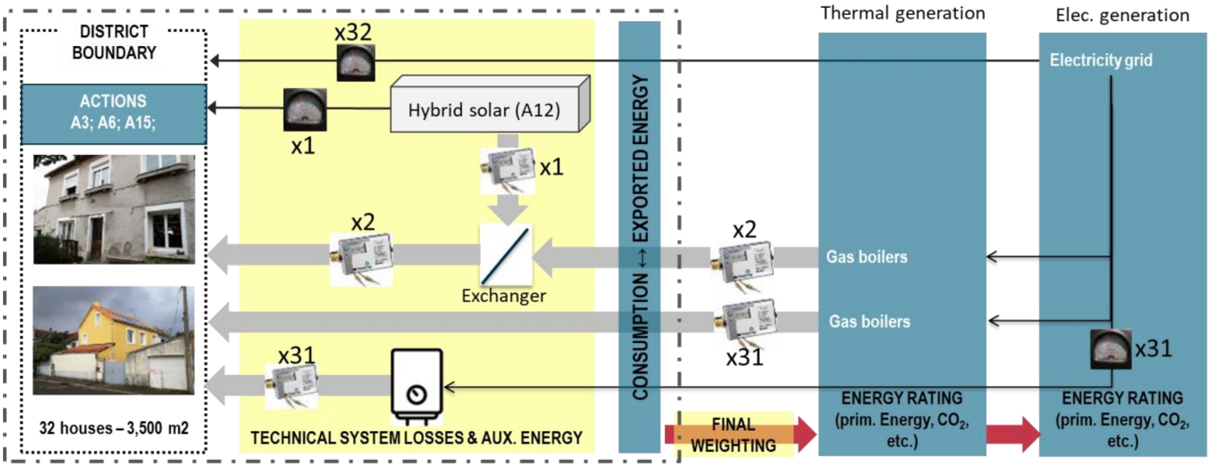

Figure 12: Individual houses monitoring schema

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

Entering into the details of the monitoring schema for individual houses, it is needed to remark the multiple configurations that the individual houses have. However, to keep the monitoring schema simple, not all the configurations are included, but the main concept. Starting with these configurations, 31 out of 32 houses combine individual gas boilers for heating and/or DHW, with individual gas boilers plus water heaters. In any case, the schema aims the representation of the measurement of the 31 heating consumption and the 31 DHW-related energy data-points. Nonetheless, it should be noted that DHW will be estimated by using ratios from the initial thermal audits. Then, this is a clear example about the representation of a measurement that is not physically measured with the meter, but used for KPIs, impacts and/or BEST tables. Then, by using the performance of the systems, the related electricity consumption for the water heaters can be obtained.

For the one that integrates the hybrid solar panel, two contributions are required. Firstly, talking about thermal energy, the DHW contribution should be obtained in order to determine the percentage of renewable thermal energy. Similar approach for the electricity so as to obtain the final renewable electrical injection. In this house, both heating and DHW energies are collected.

Finally, the total electricity consumption of the 32 houses is compiled, supplied by the grid.

4.2.6 Smart lighting

Until previous section, all the building-related interventions are included. Now, it is time to go into the details for city infrastructures and urban RES. The first infrastructure is the public lighting, whose action lies in the replacement of 79 bulbs, aiming the energy demand (in terms of electricity). Therefore, the consumption of the bulbs should be monitored, as depicted in Figure 13. As the infrastructure is connected to the electricity grid, the delivered energy by this generation system is the measurement to be taken under this action.

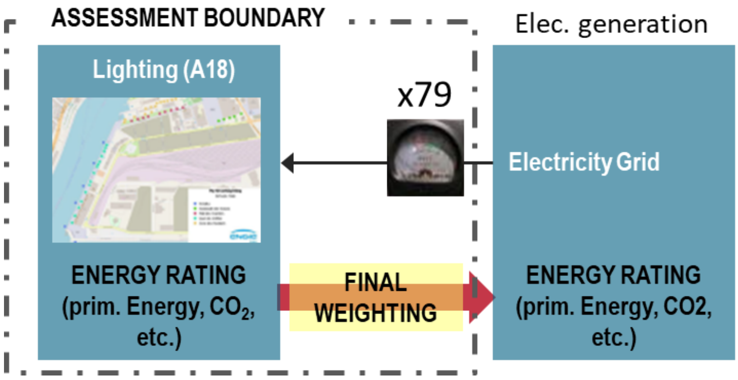

Figure 13: Smart lighting monitoring schema for Nantes

65 out of the 79 lighting points incorporate LED and telegestion including 8 with presence detectors and 1 light point without telegestion. Added to those, there are 14 points CITEOS with telegestion.

THIS DELIVERABLE HAS NOT YET BEEN APPROVED BY THE EC

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

4.2.7 Urban RES: District Heating

Next city infrastructure is the district heating, which is closely related to the buildings as, in some of them, the district heating is the main generation source. Then, the meter that is here included as output of the district heating represents the same measurement than the one included in the previous monitoring schemas. The objective to be achieved with the district heating is to assure around 80% of renewable energy in the production side, where three sources are used: gas, biomass and the waste incineration plan, such as printed in Figure 14. Then, each one of the contributions needs to be compiled to determine that the sum of biomass and waste incineration cover the 80%. Again, as before, this monitoring schema is conceptually drawn, while the real validation of the renewable will be achieved via the district heating operator and certificates for guarantee of origin.

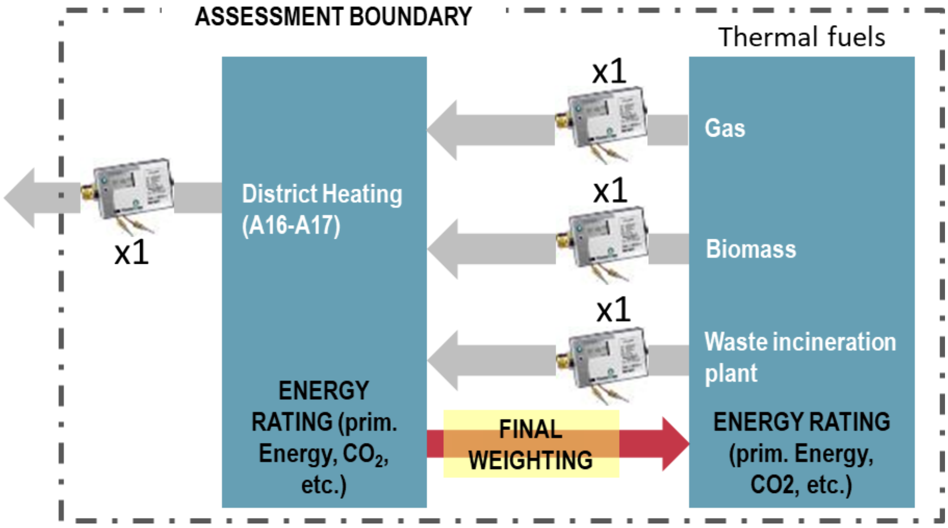

Figure 14: Urban RES: District heating monitoring schema for Nantes

4.2.8 Urban RES: PV

Last city infrastructure in Nantes is the PV generation to produce renewable energy and, hence, increase the ratios of renewable electricity. In this sense, the two actions that deploy PVs are A21a and A21b (see Figure 15). A21a covers an organic PV in the Cité des Congrès, whose production is metered, although the total consumption of the building is not for this specific action A21a. The reason is because the organic PV panel is a new and innovative product and these actions aims at testing this new material for PV production in real conditions but in a small scale (it is is linked to a phone charging station (inside Cité des Congrès)). Hence, this action is not linked to the overall Cité des Congrès consumption in any electrical way.

On the other hand, A21b consists of 9 PV plants contributing to 9 different buildings whose contribution from the grid is also obtained. Therefore, the percentage of the contribution from the PV panels can be calculated in order to determine the increase of renewables.

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

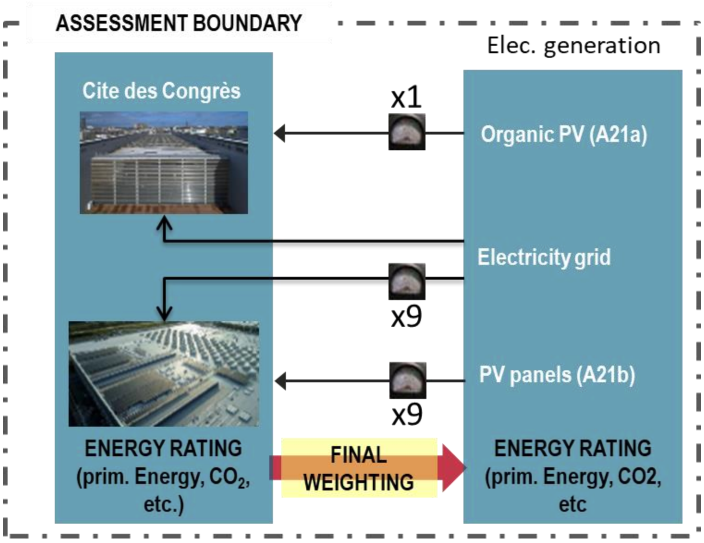

Figure 15: Urban RES: PV monitoring schema for Nantes

4.3 Mobility actions

With respect to the mobility, as stated above, there is no sense for grouping actions in interventions, while the own actions have the specific monitoring. The monitoring for mobility is very simple and, more than schemas, includes the type of sensor used for each one of the actions. In order to define the monitoring programme for the mobility actions, both the KPIs (see Table 3) and TEST tables have been considered so that the evaluation and final impact assessment would be ensured.

Starting with the electrical buses, Figure 16 shows the monitoring for both the buses and the charging points in the path. The related actions are A23 and A24. A22 monitors the 22 buses deployed in Nantes, whose variables represented by the sensor icon are (as already stated in the legend): battery level (that includes Status of Charge and Status of Health), fuel use (in case of hybrid), GPS, driving parameters. A24 is the pantograph to charge the eBuses in the path, having 12 deployed; therefore, 12 electricity measurements are taken. These correspond to the delivered electrical energy from the grid to the charging points, being directly the energy used to charge the eBus.

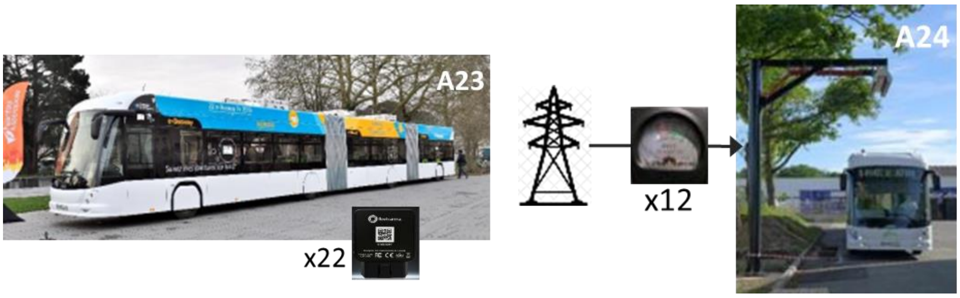

Figure 16: eBuses related monitoring in Nantes

Complementary to the A23 and A24, it is the A23-1, i.e. autonomous shuttle experiment together the solar road, as depicted in Figure 17. This is not directly one of the actions with impact in the current expected

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

goals. However, its contribution is unneglectable as the autonomous bus covers a part of distance that would not be driven by common cars. Additionally, the solar road generates a certain amount of energy that is dumped into the electricity grid, contributing to a "greener" electricity grid.

Figure 17: Autonomous shuttle and solar road monitoring in Nantes

Following with mobility actions, Nantes has currently deployed 75 charging stations (out of 65 committed, having an objective to get to 195). Related action is A25, whose monitoring goal is the same than A24, i.e. used energy by the charging points (or what is the same, delivered energy from the grid to the charging points), as it is observed in Figure 18.

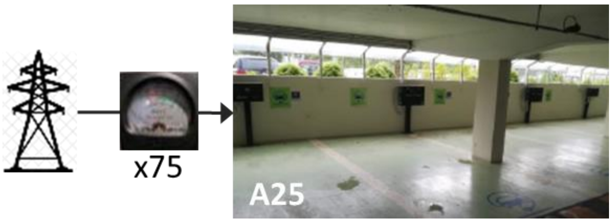

Figure 18: eCar charging stations monitoring in Nantes

Finally, A31, multimodal hub, which is connect to the CIC building schema (see Figure 8), where a charging station is deployed. Recapping from this intervention, a PV plus battery is installed, which is not only used for the building, but also the charging station. Then, Figure 19 complements the CIC building intervention where the contribution from the renewable energy for the charging station is measured, as well as the grid contribution to determine the ratio of renewable energy used for charging processes, while CIC building schema looked for the contribution of renewable energy into the building energy use.

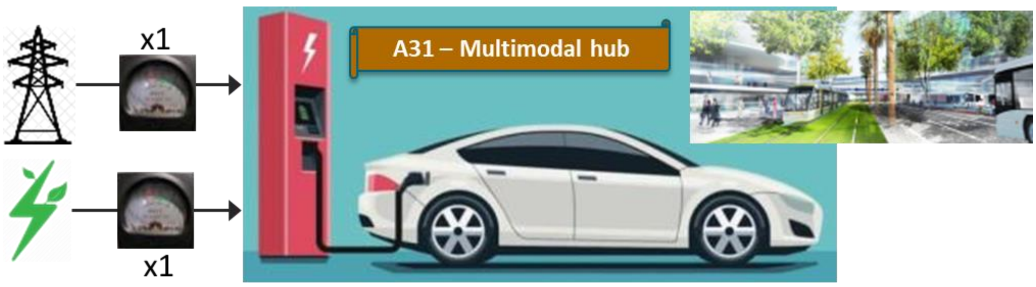

Figure 19: Multimodal hub monitoring in Nantes

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

4.3.1 Other mobility variables

Mobility KPIs depend on additional data that needs to be compiled in a different way, such as database registers, tickets counting, manual writing or other methods. The list of variables to be collected for these additional KPIs can be summarised in the bullets below:

- # of users of eVehicle, whose aim is to obtain the usage of electrical buses, replacing common diesel or “common” vehicles.
- Distance travelled by eV, so that the kilometres travelled by each eV could be obtained to determine the CO2 emissions avoided.
- # of trips of eV, complementary to the distance about the amount of trips per each eV.
- Availability rate of eV, mostly focused when a fleet is available to be shared, this variable helps to determine if the number is enough.
- # of incidents and traffic accidents in eV.
- # of (distinct) users of charging stations, i.e. types of vehicles.
- # of charges, time of charge, time of occupancy, station uptime per year that is included here, but these are indirect values extracted from the charging station used energy for the charging processes carried out.

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

5. Hamburg monitoring programme

5.1 Energy and mobility primary KPIs

Same than Nantes, the starting point is the definition of the (primary) KPIs that affect the energy interventions and mobility actions. In case of Hamburg, these are summarised in Table 4. As well, here it should be noted the idea is to list the header interventions, which group the core actions and list the indicators. This does not mean the indicators apply to all the interventions. To go into details, it is advisable to check D5.1.

Table 4: KPIs for actions/interventions implemented in Hamburg

Pillars	Intervention	Objectives of evaluation	Primary Indicators
Energy & Environment	**Building/District** Schleusengraben-Schilfpark (A1, A3, A13, A18) Bergedorf Süd (A2*, A9, A14) **City infrastructure** Galab (A19a-b) Smart lighting (A15, A16), Urban RES: PV & batteries (A5, A7) Urban RES: DH (A13, A18) Urban RES: eBus depot (A17, A20)	Reduction in energy consumption Reducion in greenhouse gas emissions	E1. Thermal energy consumption
			E2. Electrical energy consumption
			E3. Public lighting energy consumption
			E6. Energy use for heating
			E7. Energy use for DHW
			E8. Energy use for lighting
		Increase in the RES production	E13. Total renewable thermal energy production
			E14. Total renewable electrical energy production
		Fraction of energetic self-supply by RES Energy provided from existing energy city infrastructure	E17. Degree of energy self - supply by RES
			E18.Total heat supplied to the buildings connected to district heating network
			E25. Total heat supplied to the buildings connected to district heating network
			E26. Degree o heating suply by district heating
			E27. Degree of energy supply by Urban RES infrastructure
Mobility	**EV** Electrical buses (A21) e-vehicles for public fleet (A22) e-community fleet (A23)	Reducion in greenhouse gas emissions Use and energy consumption of different EV Change in mobility due to solutions implemented	MO1. Annual number of passengers (or users)
			MO4. Annual number of trips
			MO5. Annual distance travelled
			MO9. Annual energy consumption
	Charging stations Charging points for e-buses (A24) Semi-public fast charging points (A25) Charging infrastructure for share e-community fleet (A26)	Degreee of energy supplied to EV by RES Use and usage pattern of charging stations Change in mobility due to solutions implemented	M16. Annual energy delivered by each charging point
			M19. Total number of charges per year
			M24. Number of different users per year

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

	Clean energy charging stations (A27)		
	Multimodality Community Car Sharing (A33)	Change in mobility due to solutions implemented	M43. Electric vehicles penetration rate
	Demand management Load management (A30a)	Energy demand management	M34: Charging capacity managed
	I.T.S Parking space detection (A35)	Change in mobility due to solutions implemented	Vehiculo detection (TBC)

5.2 Energy actions

5.2.1 Schleusengraben (Am-Schilfpark - new construction)

Schleusengraben area (action A1) corresponds to the new construction programme in Hamburg, where 79 buildings are built. Within mySMARTLife project, the action covers an area of 24,832 m^2, corresponding to the Am-Schilfpark zone with 9 buildings (BEST 6A). The main objective of the A1 is the new construction of buildings going beyond the current standards, therefore, with reduced energy demand. Here, the energy demand of the 9 buildings should be measured, but, due to lack of agreement with the building owner one simple global value for the total energy of the set of 9 building is obtained.

Moreover, A1 is complemented with the district heating connection (A13-A18) in order to increase the renewable energy to cover the aforementioned reduced demand. In this sense, A13-A18 are related to A1, although the district heating has its own monitoring programme in the section 5.2.6.

Finally, although A3 and A10 are not directly related to the A1, they represent smart meters, which are necessary for the data compilation, therefore, the reason for being included. Under these objectives, the monitoring schema is printed in Figure 20.

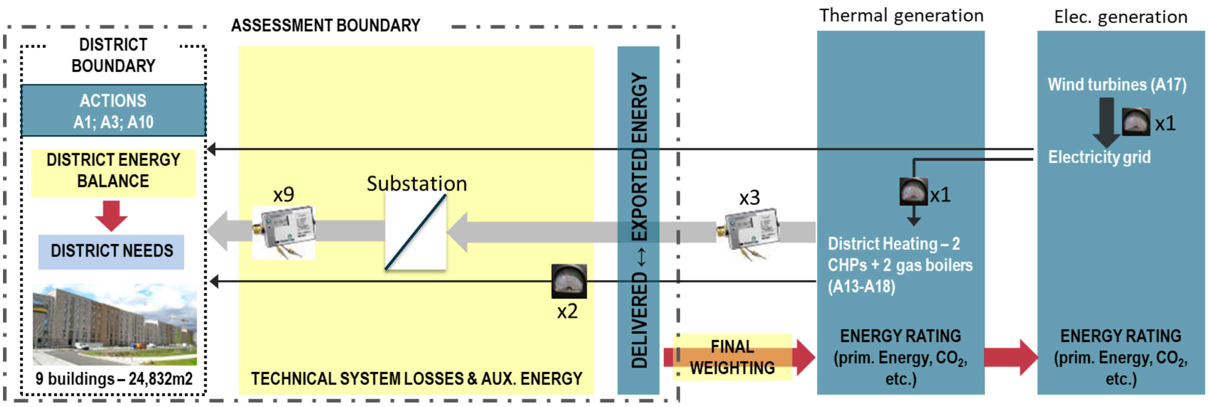

Figure 20: Schleusengraben (Am-Schilfpark) area monitoring schema

Starting with the electrical generation side, it is not objective of this intervention, but wind turbines (A17) generation is fed into the grid, contributing to the renewable energy that is used within the buildings. Then, although not directly related to this intervention, knowing the renewable contribution also helps to determine

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

the renewable increase. Additionally, the electricity contribution from the 2 CHPs that are part of the district heating is obtained to increment this renewable usage.

For the thermal side, two parts are split. On one hand, the thermal energy demand (A1) of the 9 buildings after the substation for the distribution of the energy from district heating. However, as mentioned earlier, one simple data-point will be gathered compiling the 9 buildings, whereas the monitoring programme represents the monitoring requirements. On the other hand, the generation side (A13-A18 about district heating), composed by 2 CHPs and 2 gas boilers, while the schema includes 3 meters (2 for the CHPs and 1 for the gas boilers generation, see section 5.2.6 for more details).

Finally, Hamburg is also interested in the indirect effects, as named by IPMVP [3], of the district heating. That is to say, even though the main goal is the heating, the generation and distribution systems also consume electricity (e.g. pumps), whose measurement is taken as indirect effect for thermal generation.

5.2.2 Bergedorf - Sud (Retrofitting)

Bergedorf – Sud is the second intervention where the total square meters to be retrofitted are 18,805 m^2 (BEST 7). Within this area, 3 buildings are included: hotel with 9,137 m^2 of heated area and 10,437 m^2 of total area; apartment block with 5,654 m^2 of heated area and 7,491 m^2 of total area; school with 876 m^2. The two objectives of this intervention are to reduce the energy demand of the buildings, at the same time than the renewables are increased thanks to the Smart Heating Island (A9-A14) and solar collectors available on the school (not part of mySMARTLife). It should be also highlighted the Smart Heating Island project includes the hotel and apartment block, while school makes use of its own thermal-electrical generation systems, not being connected to the Smart Heating Island. In this way, Figure 21 illustrates the monitoring schema for the Bergedorf – Sud area, distinguishing between both projects. Moreover, it should be remarked here the assessment boundary is extended to cover not only the buildings, but also the Smart Heating Island as part of the interventions in mySMARTLife.

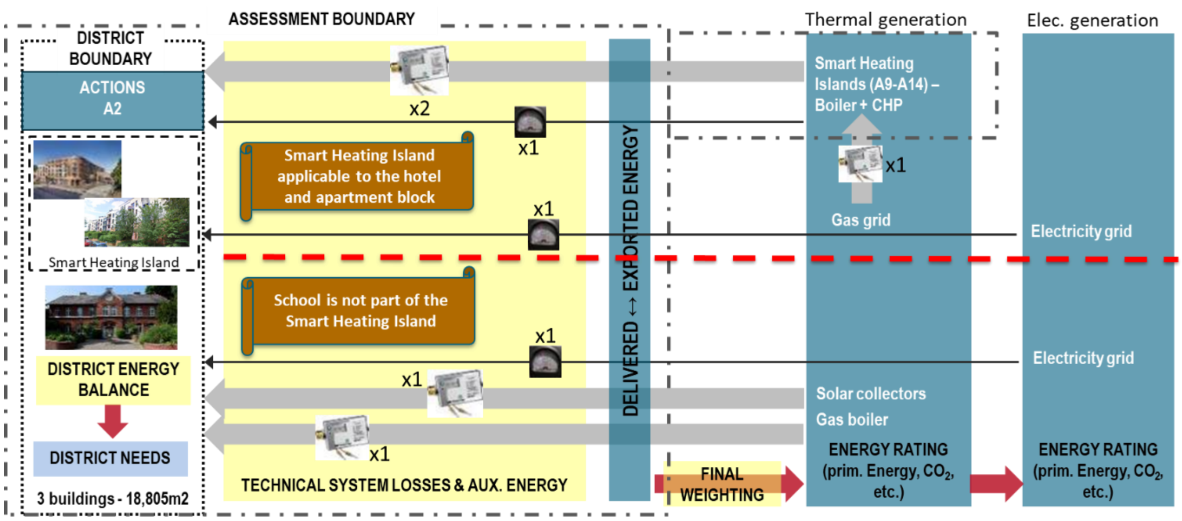

Figure 21: Bergedorf – Sud area monitoring schema

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

In term of the monitoring schema, starting with the electrical side, the apartment block and school buildings are connected to the grid, while the hotel take advantage of the Smart Heating Island (that is composed by a boiler plus a CHP). The generated electricity by the CHP supplies the hotel, therefore a single meter to determine its contribution.

Regarding thermal side, it should be noted again the Smart Heating Island is applicable to the hotel and apartment block. Then, the thermal energy (generated by the boiler and CHP (part of the Smart Heating Island)) used by the hotel and apartment block is gathered. As well, the contribution from the gas grid is compiled to determine the fossil fuel that is consumed within the Smart Heating Island.

On the other hand, as stated, the school is not part of the Smart Heating Island and has its own gas boiler for heating and the solar collectors for DHW, whose contributions are measured.

5.2.3 Galab

Next building intervention is Galab, which does not have any BEST table associated, but it contributes with technology for renewables thermal and electrical energy generation. Figure 22 represents the monitoring schema. In terms of electricity, a PV system supplies the electrical grid of GALAB (formed by the heat pump (A19) and the ice cooling storage (A19b)), therefore, also part of the assessment boundary. In this intervention, only electrical energy is regeneratively generated, namely by the newly installed PV system (A19a) and it never feeds into the general electricity grid, because the load of GALAB is never below the maximum power that can be generated by the PV system.

Regarding thermal energy, the generated energy by the heat pump is obtained, produces heat when needed (i.e. on demand), which is used in the building. The ice storage is used to absorb and release thermal energy as needed; both the stored and released energy flows are monitored. Having this in mind, the x2 meters in the output of the heat pump mean the contribution to the building and the absorbed energy in the ice cooling storage (although the schema is slightly simplified in this sense).

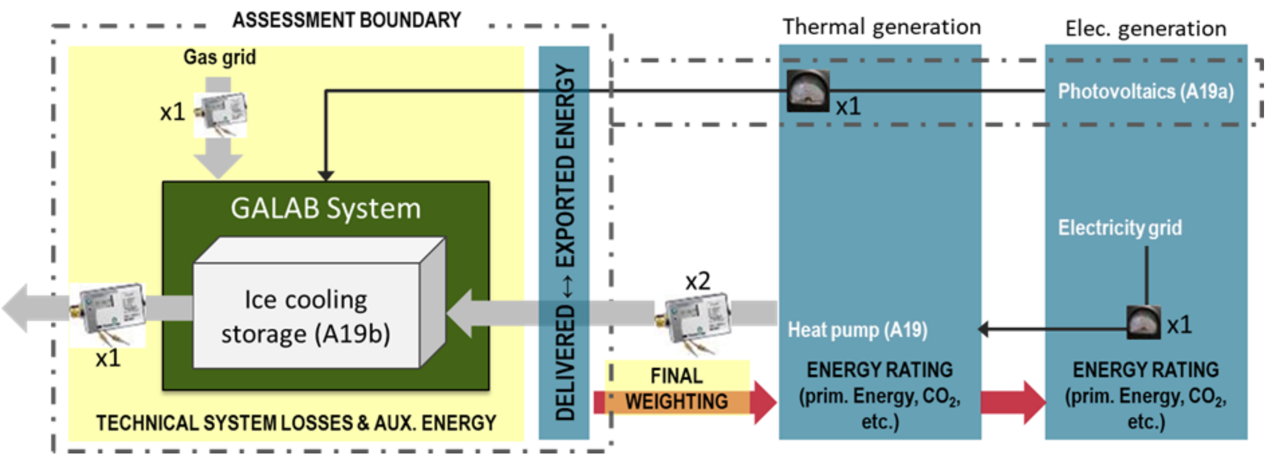

Figure 22: Galab monitoring schema

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

5.2.4 Smart lighting

Similar to Nantes, Hamburg implements smart lighting solutions. In this case, two zones are included within this intervention: Schleusengraben (A15) and Bergedorf – Sud (A16). However, in both cases, the monitoring schema is similar, therefore, included under the same conceptual schema. Both schemas are depicted in Figure 23, where A15 is composed by 30 lamps and A16 45 lamps, being the monitoring focused on the electricity consumption.

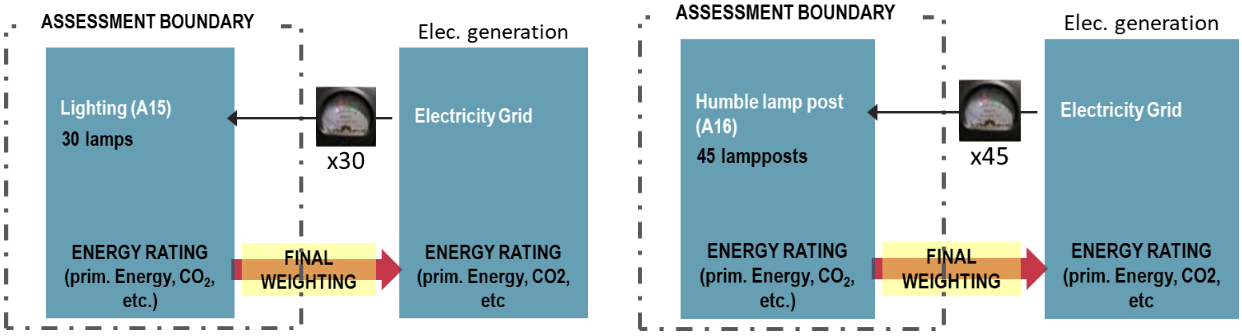

Figure 23: Smart lighting monitoring schema for Hamburg

5.2.5 Urban RES: PV + batteries

The first urban RES intervention is the integration of PV plants (to cover a total of 300 kWp in the A5). Here, the schema shown in Figure 24 has to be split into two parts: Kampweg building and the other PV plants.

With regard to the Kampweg building (which is connected to the BEST 6B, as the only objective of such a BEST is to increase renewable energy), the RES from the PV-plant can be fed directly or by the combined PV + battery into the Kampweg-building. Therefore, a meter measures the electricity produced by the PV. This electricity is partly consumed directly in the Kampweg-building, temporarily stored in the battery for later direct consumption, or fed into the regional grid, where the amount fed in is measured. The PV direct consumption of Kampweg is calculated this way: “total PV production measured at the PV production meter” minus “PV grid feed-in measured at the two-way meter”. Of the final electricity consumption, i.e. the electricity flow associated with the Kampweg building, there are also 2 virtual measurements representing the total electricity consumption of the Kampweg building and the lighting-related electricity consumption. Finally, the renewable line is not able to cover the full electricity demand for Kampweg building, therefore, the contribution from the grid is also obtained.

The other PV plants (now there are 4 plants, although additional ones will be included in 2021) measure both the generated renewable PV electricity and the contribution from the grid to calculate the ratio of self-supply. Within these plants, one also includes the battery, following the same schema than Kampweg. That is why the contribution from PV is split in 3 measurements for 3 building, while the fourth one measures the renewable energy coming from PV or PV + battery. The meters that are illustrated for the measurement of the electricity consumption from the grid are actually able to measure electricity flows into two directions, as the PV plants also feed electricity into the grid when it is not needed in the buildings.

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

The meters that are illustrated for the measurement of the electricity consumption from the grid are actually able to measure electricity flows into two directions, as the PV plants also feed electricity into the grid when it is not needed in the buildings. This information is necessary as e.g. the PV direct consumption in Kampweg is calculated this way: "total PV production measured at the PV production meter" minus "PV grid feed-in measured at the two-way meter".

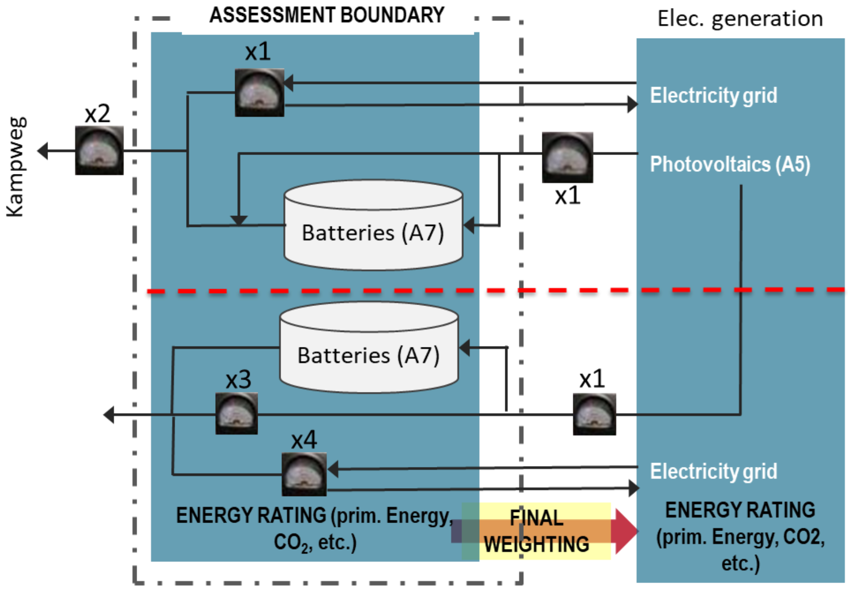

Figure 24: Urban RES: PV + batteries monitoring schema for Hamburg

5.2.6 Urban RES: District heating

Next urban RES is the district heating, composed by the actions A18 and A13. The main aim of this city infrastructure in the injection of hydrogen in the system to convert hydrogen into electricity with CHP when hydrogen is part of a gas mixture (i.e. heating is not provided with hydrogen). Therefore, as illustrated in Figure 25, the contribution both for gas and hydrogen is measured, while the output of the district heating is also obtained. Three thermal contributions are measured (1 for the 2 gas boilers generation plus the 2 CHPs) and two electrical contributions due to CHPs.

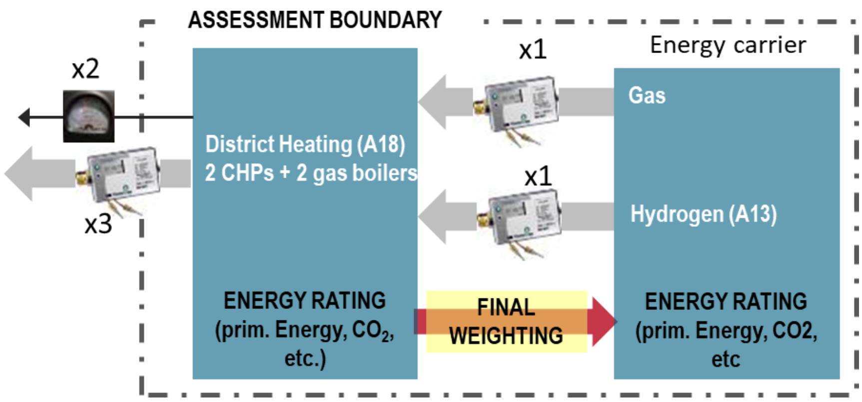

Figure 25: Urban RES: District heating monitoring schema in Hamburg

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

5.2.7 Urban RES: eBus depot

Last urban RES is the eBus depot, which is partly energy intervention and mobility. The reason for being included as RES or energy intervention is due to the use of wind power and batteries for increase the renewable energy. It is true that the final use is charging stations for electric vehicles, but the impact is related to increase of renewables, therefore, green energy generation and distribution.

In this sense, Figure 26 draws the monitoring schema, where the wind turbines (A17) feeds the wind part battery (A20), but also the electricity grid. At the same time, the electricity grid supplies the eBus charging infrastructure. On the other hand, there is a battery storage within the concept of bus depot, although, during the mySMARTLife project span, the physical connection to the wind part battery will not be possible (as explained in different reports), that is why dotted line. In the future, it is planned to analyse the possibility to physically connect both systems (if the evaluation of the connectivity is positive) and, then, be able to measure the efficiency of the system.

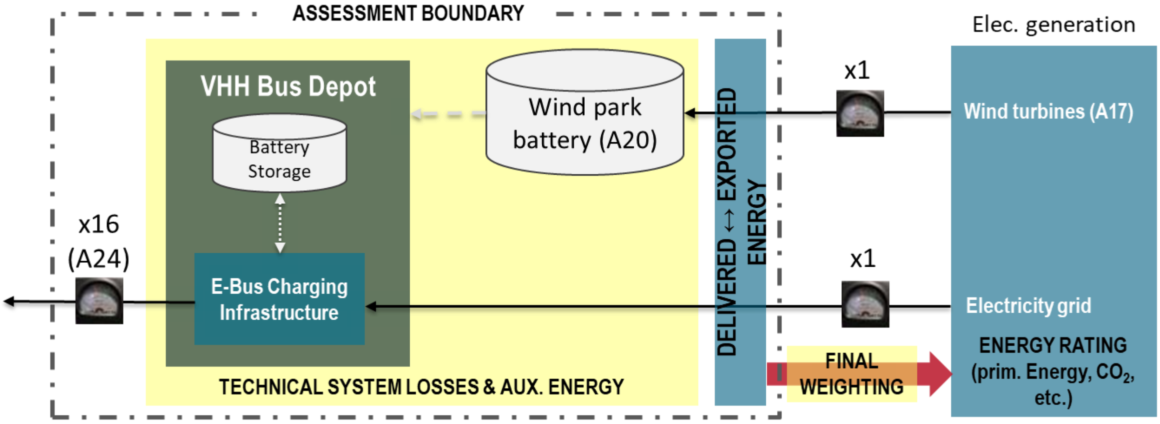

Figure 26: Urban RES: eBus depot monitoring schema in Hamburg

5.3 Mobility actions

As per Nantes, mobility is not grouped as per actions, then, monitoring of the individual assets is defined for each of the mobility actions. Starting with the electrical buses, two actions are the main ones, A21 where 16 eBuses (6 more than the 10 original committed per DoA) are monitored with the same metering concept than in Nantes: battery level (or mentioned in a different way, the consumed energy to enable the calculation of TEST tables), fuel use (in case of hybrid vehicles, if any), GPS, driving parameters. Second is the A24 with 16 charging points whose electricity use is measured.

Figure 27 includes both simple monitoring schemas. It should be noted that A24 is related to the Urban RES: eBus depot intervention explained in section 5.2.7. The eBus depot energy generation and distribution is finally contributing to the A24 charging points.

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

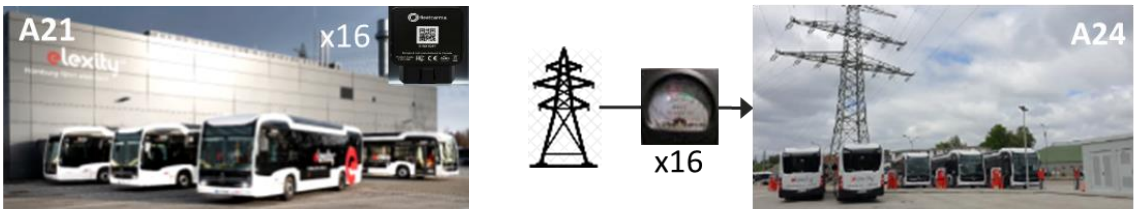

Figure 27: eBuses related monitoring in Hamburg

Regarding eCars, A22 aims the electrification of public fleet with 25 eCars (complemented by A30a for load management for 10 charging stations located in Bergedorf-Sud for these eCars), which also includes 5 eBikes, as highlighted in Figure 28. Here, the measurement data concept consists of the same type of variables than other electric vehicles actions, e.g. travelled distance, battery status (or said in a different way, consumed energy) … in order to calculate the KPIs, impacts and, in this case, the TEST tables.

Figure 28: eCars and eBikes monitoring in Hamburg

Next action for the electromobility in Hamburg is the charging stations. The monitoring schemas for these actions are included into Figure 29. The first one is A25, whose aim is the deployment of 1 fast charging station in Bergedorf and the monitoring of 7 fast charging stations (the one in Bergedorf and 6 further in the rest of Hamburg. In this sense, the electricity use for the charging stations is the one taken data-point for the calculation of the KPIs.

Following with charging station actions, A27 aims the deployment of a single flexible charging point for residential quarters. Then, within this action, both the grid contribution and the charging station energy delivered to the eCar are the two data-points.

Last but not least, the clean energy charging stations connected to the energy campus (A28). This charging station is directly connected to the grid, which is also fed by renewable sources, as shown in Figure 29. This renewable contribution is provided by the wind park (illustrated in Figure 20). However, for the evaluation of this action A28, the electricity use for the charging station is enough, while the share of renewables is maintained from the renewable contribution from the grid. As the charging station is not directly connected to the renewable source, the direct contribution is not possible, but indirectly from the grid.

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

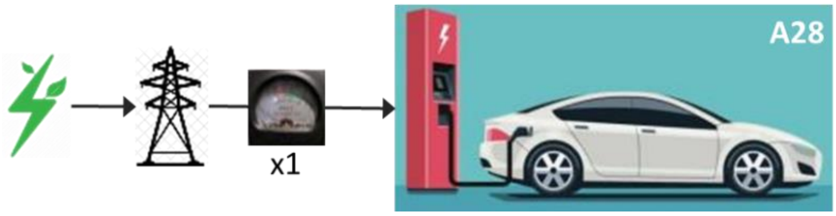

Figure 29: Charging stations monitoring in Hamburg

The last action related to mobility pillar is A35, which is the parking space detection in order to determine the conventional powered vehicles using the space for eVehicles. Hence, the single monitoring equipment is the named “vehicle detection” sensor, which represents this data-point (i.e. the detection of misuse). At the moment, up to 500 parking space detection points are deployed at charging stations across the Hamburg city. This is the number of sensors included in the monitoring schema in Figure 30.

Figure 30: Parking space detection monitoring in Hamburg

5.3.1 Other mobility variables

To finalise with the mobility monitoring, there is needed the additional variables that can be monitored with or without physical equipment (such as database registers, tickets counting, manual writing or other methods). The list of variables to be collected for these additional KPIs can be summarised in the bullets below:

- # of users per eV (applicable to e-bus and pedestrian and bicycle connections), where the case of the eBuses will be obtained either aggregated to all the fleet of buses (e.g. ticket counting) o for those buses that collect these registers.
- Distance travelled by eV
- # of trips of eV (e-buses, public fleet, community fleet)
- # of (distinct) users of e-buses and pedestrian / bicycle connection and charging stations (i.e. for charging stations, it means types of vehicles).
- # of charges, average occupancy time of charging points, but these are indirect values extracted from the charging station used energy for the charging processes carried out (meter value start, meter value stop).

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

Finally, the action A30a, which is not an action that requires physical installation, but it is a software in order to manage the load of charging stations. Then, it is evaluated in a different way, where the variables to be measured correspond to the next ones:

- Number of charging stations with renewable energy load.
- Number and power of charging points subjected to an energy demand management.

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

6. Helsinki monitoring programme

6.1 Energy and mobility primary KPIs

Following the same approach than Nantes and Hamburg, the first step is to recall the primary KPIs (be reminded the secondary KPIs are calculated from the primary ones), which guide the definition of the monitoring programmes. As mentioned, these monitoring programmes describe the collection of the variables and parameters through field measurements and, as highlighted in the other cities, there is no aimed to depict the direct relationship between interventions and indicators within such a table.

Table 5: KPIs for actions/interventions implemented in Helsinki

Pillars	Interventions	Objectives of evaluation	Primary Indicators
Energy & Environment	**Building/District** Merihaka & Vilhonvouri (A1, A4, A10) Kalasatama (A2, A5, A7, A10, A13) Viikki building (A3, A6, A8, A9) **City infrastructure** Smart lighting (A15) Urban RES: Heat pump plants (A16) City infrastructure: District heating and Cooling (A14, A16, A19) City infrastructure: New solar power Plant (A17) City infrastructure: Smart grids (A11-A20, A12-A18)	Reduction in energy consumption Reducion in greenhouse gas emissions	E1. Thermal energy consumption
			E2. Electrical energy consumption
			E3. Public lighting energy consumption
			E6. Energy use for heating
			E7. Energy use for DHW
			E8. Energy use for lighting
		Increase in the RES production	E13. Total renewable thermal energy production
			E14. Total renewable electrical energy production
		Fraction of energetic self-supply by RES Energy provided from existing energy city infrastructure	E17. Degree of energy self - supply by RES
			E18.Total heat supplied to the buildings connected to district heating network
			E25. Total heat supplied to the buildings connected to district heating network
			E26. Degree o heating suply by district heating
Mobility	**EV** Electrical buses (A21) Truck for city logistics (A22) Autonomus electrical bus (A23)	Reducion in greenhouse gas emissions Use and energy consumption of EV Change in mobility due to solutions implemented	MO1. Annual number of passengers (or users)
			MO5. Annual distance travelled
			MO7. Availability rate of e-buses
			MO9. Annual energy consumption
			MO15: Number of heavy-duty vehicles compatible
	Charging stations Charging points for e-buses (A24)	Degreee of energy supplied to EV by RES Use and usage pattern of charging stations	M16. Annual energy delivered by each charging point
			M20. Total operating time for charging operations

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

	Clean charging points for e-bikes (A25) Electromobility charging node (A26)	Change in mobility due to solutions implemented Energy demand management	M24. Number of different users per year
			M25. Number of external charging events
			M26. Utilization ratio of external charging
			M27. Total charged energy from the external connection
			M29. Station uptime per year
			M30. Charging points powered by renewable energy sources (number and rate)
			M33. Annual energy produced by each charging point
	Demand management Smart personal EV charging (A27-A28)	Energy demand management	M34. Charging capacity managed
			M35. Number of charging sessions

6.2 Energy actions

Similar to Nantes and Hamburg, the first block of actions to be explained is the energy pillar. Here, as well, the actions grouping into interventions has been carried out, resulting in the next subsections

6.2.1 Merihaka & Vilhonvouri

Merihaka action (A1) consists of the retrofitting of residential buildings. In complementing action, A40 Implementing energy advisor, the goal was to facilitate energy retrofits of the 12 buildings of the district, but the implementation of these renovations was up to the homeowners. A1 contained the implementation of smart retrofit of one single building. Therefore, this one is the only measured building that is also committed for monitoring (10,000 m^2) such as indicated in the monitoring schema of Figure 31. Moreover, related to A4 and A10, the building contains smart meters (smart thermostats system of Salusfin) and heat demand response pilot as part of the retrofitting, respectively. Thus, the main aim of these actions in Merihaka is the reduction of the heating demand and the renewable contribution from district heating (recycled excess heat and biomass) such as pointed in BEST 8.

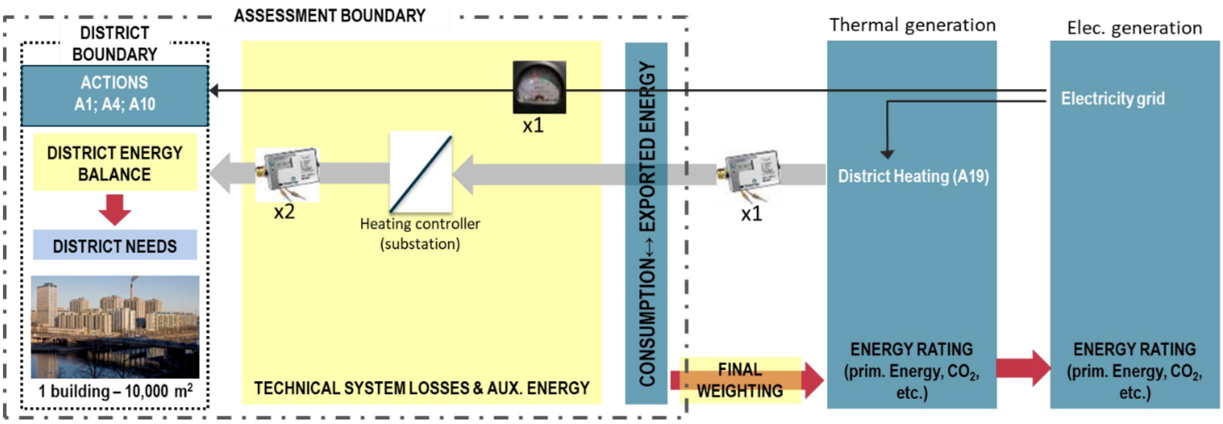

Figure 31: Merihaka area monitoring schema

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

In terms of thermal measurements, the output of the district heating is obtained (note that this measurement is the same than the one for the City infrastructure: District heating, section 6.2.6). Also, the thermal energy use by the building is monitored, after the substation. Here, it should be highlighted there is one single meter obtaining the thermal contribution. Nevertheless, two measurements are obtained, heating and DHW. In this sense, DHW consumption (and the KPI of this) is a calculated value from the physical measurement of the thermal use based on the regulation for DHW use.

In the case of the electricity, total electricity use of the one building is monitored. This data-point consists of the consumption for 167 apartments plus the "common" real estate electricity of the building, therefore a total of 168 smart electricity meters.

6.2.2 Kalasatama

Kalasatama is a new construction area in Helsinki (A2). During the project span (2017-2021), 67 residential buildings are being built, although, within mySMARTLife, just 10,000 m² are committed (according to BEST 9). Moreover, smart home solutions (A5) and smart management (A10) are related to the Kalasatama intervention. Thus, similar to Merihaka, the main objective is the rduction of the energy demand plus the renewable energy contribution from the share of renewables in the district heating and, in a case of few residential buildings, renewable electrical energy contribution from privately owned PV panels. Having this in mind, the resulting monitoring schema is illustrated in Figure 32.

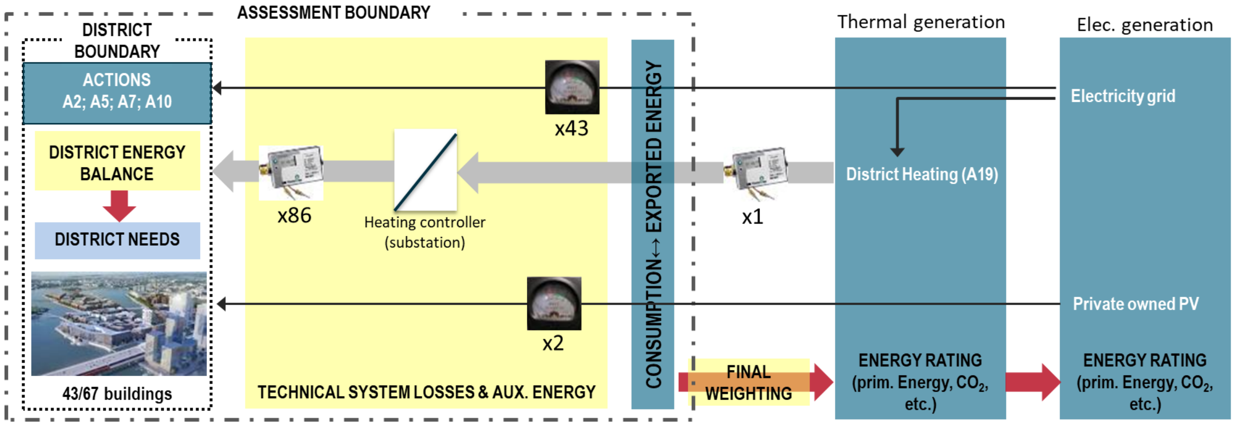

Figure 32: Kalasatama area monitoring schema

For the measurements, thermal data follow the same approach than before, i.e. the output of the district heating plus the building level thermal use after the substation. It should be noted that, although 10,000 m² are simply committed, 43 out of 67 buildings will be finally monitored, corresponding to a total area around 180,000 m² (180% of additional area than committed). Besides, although 86 thermal measurements are indicated in the schema, 43 physical meters are actually deployed, but DHW measurements are estimated from regulation. In the evaluation phase, district heating consumption data is presented as a total sum of the consumption of 43 buildings.

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

About electricity, measurement consists of 2271 smart electricity meters (i.e. electricity consumption measurement for every apartment and "common" real estate electricity use). However, due to data privacy issues, the electricity consumption data is presented as a sum of 2271 measurements, representing a total sum of the consumption of 43 apartment buildings. Additionally, the current two private owned PVs data are obtained (although in this case it is physical meter due to the privately ownership).

For the BEST table comparison and evaluation of the action, an area of 10,000 m² is used in addition to the monitored total area of 180,000 m². The 10,000 m² consists of few new buildings including one SunZEB concept building. The monitoring approach of the 10,000 m² area is the same as described for the 43 buildings.

6.2.3 Viiki building

Viikki Environment House (A3) is already a high-performance building, whose aim within mySMARTLife is the improvement in terms of renewable contribution (A8-A9), better management and domotics (A6, A10) to reduce, in this case, the final fossil energy use and partially the demand (glazing U and g values improvement). The building represents 6,791 m² (BEST 10), being heated/cooled by the district heating and water (drilled) wells to increase the renewable contribution for thermal energy (in this case, cooling). Also, it contributes to renewable increase in electricity generation by means of a PV and wind turbines, whose generated energy is stored in batteries in order to maximise this renewable contribution. Under these concepts, monitoring schema is illustrated in Figure 33.

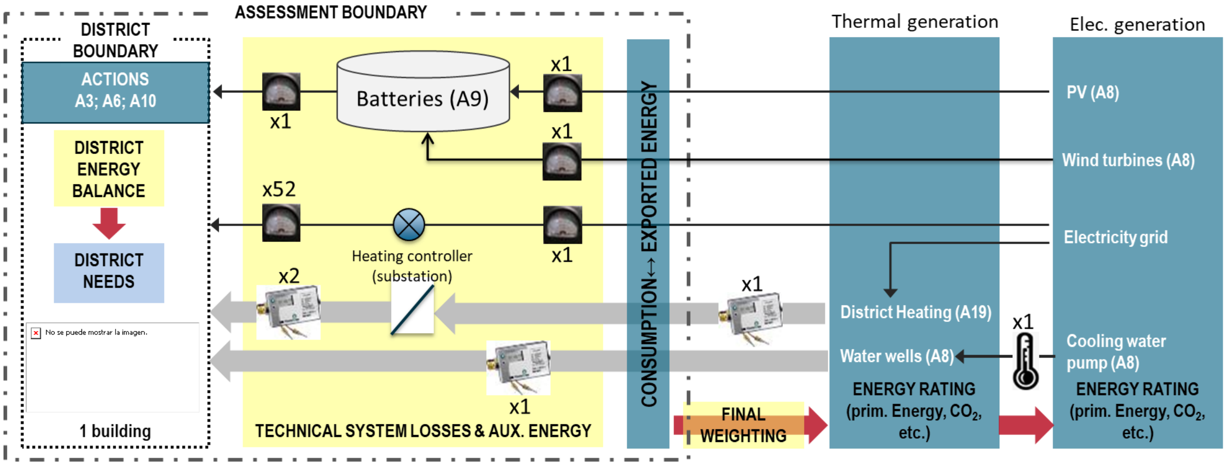

Figure 33: Viiki environmental house monitoring schema

Entering into the details of the monitoring schema, as mentioned before, thermal energy supply is based on district heating (one meter representing the total district heating production in Helsinki and 1 physical meter for the district heating consumption of the Viikki Environment House, although two measurements are obtained: heating and DHW by estimation based on regulation). Thermal generation is complemented with the water wells for cooling, whose thermal contribution is not directly measured with a meter, but the temperature probes for inlet and outlet temperatures are measured. The flow rate is a table value determined

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

by the temperature difference between inlet and outlet temperature, allowing the calculation of cooling energy extracted from the boreholes. However, the combination of these data-points deals with the cooling energy contribution (then, represented by the meter icon).

About electricity, there are two general meters. The first one is for the electricity grid, which is split into 52 sub-meters for different uses of the building. The second measures the renewable line contribution from the output of the batteries, while the supply to the battery from both PV and wind turbines is also monitored.

6.2.4 Smart lighting

Once building-related interventions are explained, it is time to start with the city infrastructures. The first one is the smart lighting (A15), whose monitoring schema is drawn in Figure 34. Basically, it consists of 40 lamps with smart drivers fed by the electricity grid. The energy consumption from these 40 lamps is measured on the drivers. The heat pump plants use carbon-neutral sources as fuels (waste heat sources and electricity generated by renewables).

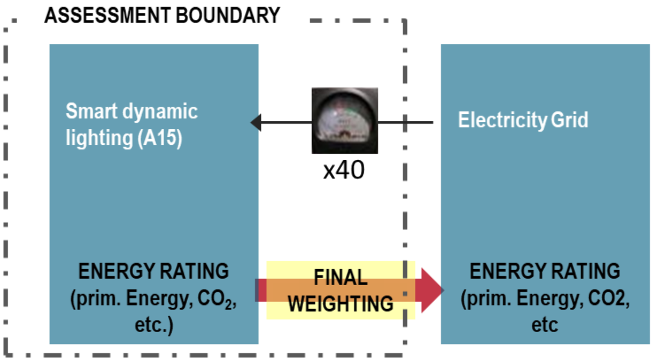

Figure 34: Smart lighting monitoring schema in Helsinki

6.2.5 Urban RES: Heat pump plants

Continuing with the city infrastructures, and as first urban RES intervention, the heat pumps for Katri Vala and Esplanade (A16) that generate thermal energy, being supplied directly to the district heating and cooling networks. Then, the monitoring basically consists of metering the thermal contribution from such heat pumps as illustrated in Figure 35.

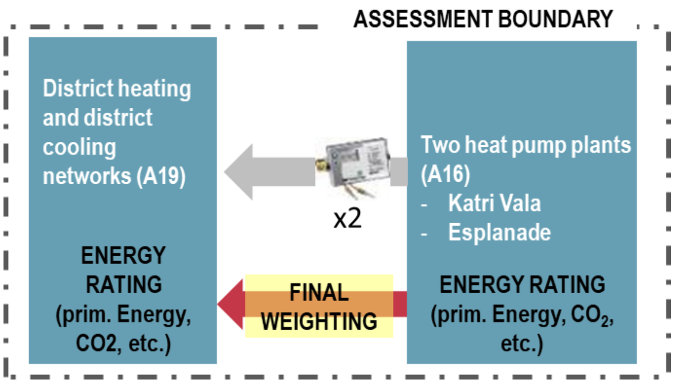

Figure 35: Urban RES: Heat pumps monitoring schema in Helsinki

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

6.2.6 City Infrastructure: District heating and cooling

Next city infrastructure is the district heating and cooling network (A19), whose monitoring schema is shown in Figure 36. The district heating generation side is, within this intervention, supplied by two renewable/carbon-neutral sources (including generation of heat pump plants utilizing renewable electricity and waste heat sources as fuels (A16, A14)) and by fossil fuels. Moreover, the thermal storage tanks (A19) allow the optimisation of the generation system for the district heating and cooling. According to this concept, the measurements are taken from the different contributions (the renewable and the non-renewable), while, the storages are used to better optimize the operation of the district heating and cooling networks (temperature measurements, but not used for the KPI calculation). Finally, the production of the district heating and cooling network is gathered to determine total production/consumption.

In the monitoring programme, the total consumption of the buildings connected to district heating and/or cooling networks is monitored as a sum of the building level measurements.

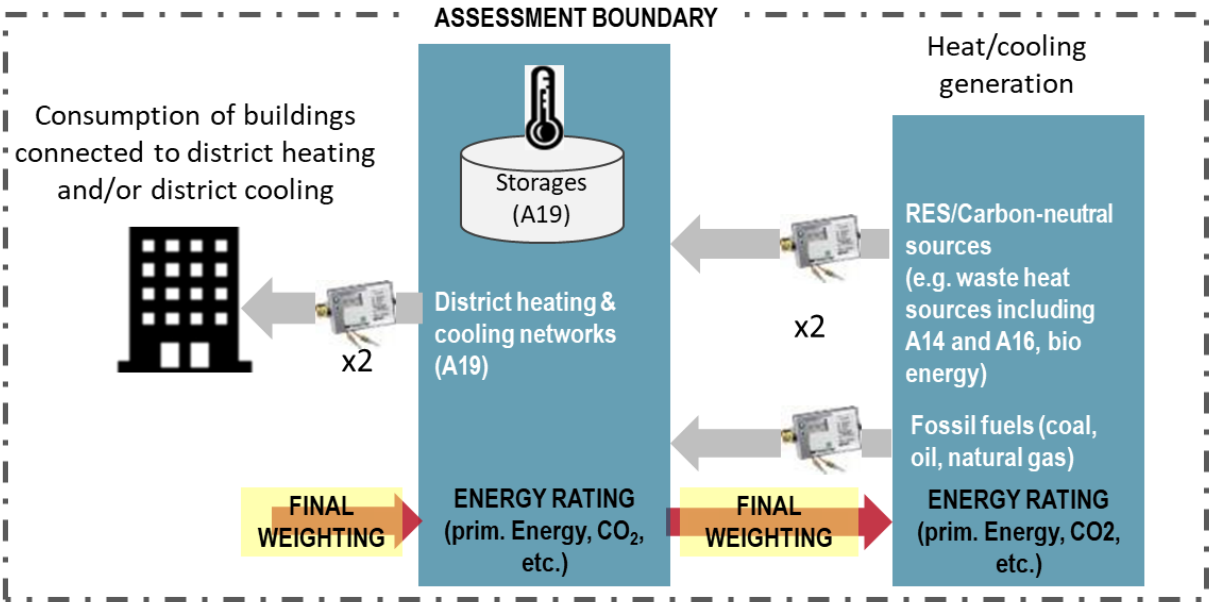

Figure 36: City Infrastructure: District heating and cooling monitoring schema in Helsinki

6.2.7 City Infrastructure: New solar power plant

In Helsinki, a new concept for solar power plant is deployed under the A17, consisting of a solar power plant implementation with an innovative business model of designated solar panels (i.e. electricity customers of Helen can rent a PV panel from the solar power plant). In A17, total PV production is monitored. The demand side is not specified for the action, as it is neither part of the mySMARTLife KPIs and/or impacts, just the renewable production, as depicted in Figure 37.

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

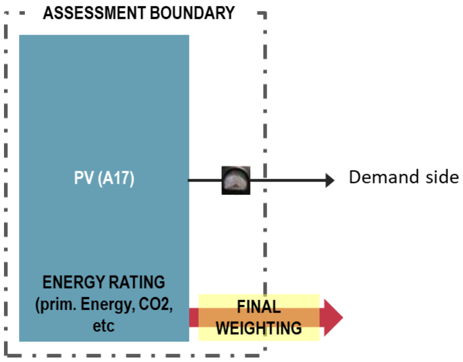

Figure 37: City Infrastructure: New solar power plant monitoring schema in Helsinki

6.2.8 City Infrastructure: Smart grids

The last city infrastructure for energy interventions is related to smart grid, being a combination of four actions to deploy this city infrastructure:

- Action A11. Technical integration of the EV charging point, energy storage and Solar plant
- Action A12. Compensation of reactive power – with solar power
- Action A18. Solar power plants (Suvilahti and Kivikko) to compensate reactive power
- Action A20. Integration of existing district-level electrical storage

In order to show the schemas in a better way, two figures have been created. The first one indicates the A12 and A18 actions of power plant in Kivikko, Helsinki, as printed in Figure 38. Here, it should be noted the boundary not only covers the final energy demand side, but also the generation of the PV, such as it was explained in D5.1 about the boundaries for the diverse type of interventions. Then, the generated energy from the PV and the contribution from the grid to the final consumers is obtained. Also, to be highlighted, when there is no demand, the PV production is fed directly into the grid.

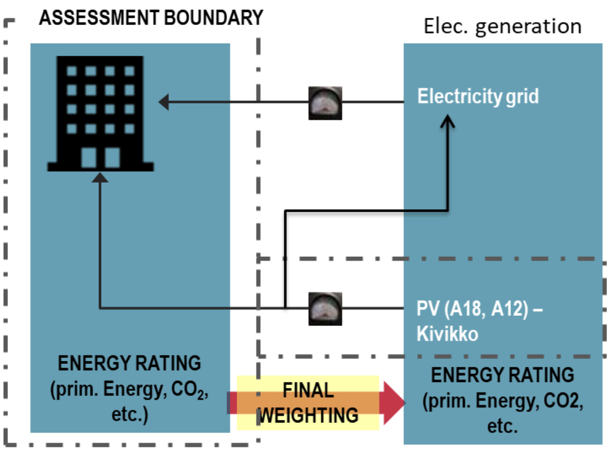

Figure 38: City Infrastructure: Smart Grid A12-A18 monitoring schema for PV plant in Kivikko, Helsinki

The second schema covers the A11 and A20 actions, as depicted in Figure 39, which also includes the connection schema of the smart grid case of Suvilahti to better understand the monitoring lines. Then, the

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

measurements correspond to the PV plant production, the battery energy storage system and the final energy use by the two EV charging stations. Since the PV plant, the battery and the EV charging stations are connected to the same grid connection point, it is difficult to distinguish when the contribution comes from one source or another as the PV generated energy is fed into the grid that, at the same time, feeds the battery. Lastly, the EV charging station demands energy that could come from the battery, PV or grid depending on the availability from each one of the sources.

As an additional information, nowadays, in the case of the Suvilahti smart grid, the battery energy storage system operates in the reserve markets of the TSO (transmission system operator) and therefore, the battery contributes to the stability of the power system. This functionality (frequency control) was also tested as a part of the research phase of the battery energy storage system and as a part of the A20. In the research phase and as a part of A20, the operation of a bundle of battery storage + PV plant was also tested so that the battery-operated peak power shaving to flatten the peak production times of the PV as well as to reduce the variations of the PV production that is fed to the electricity grid.

Nowadays, after the various tests done in the research phase, the battery is operated fully in the reserve markets of the TSO since, business wise, the operation in the reserve markets (FCR-N, frequency containment reserve for normal operation) is the best option for this battery in its specific location.

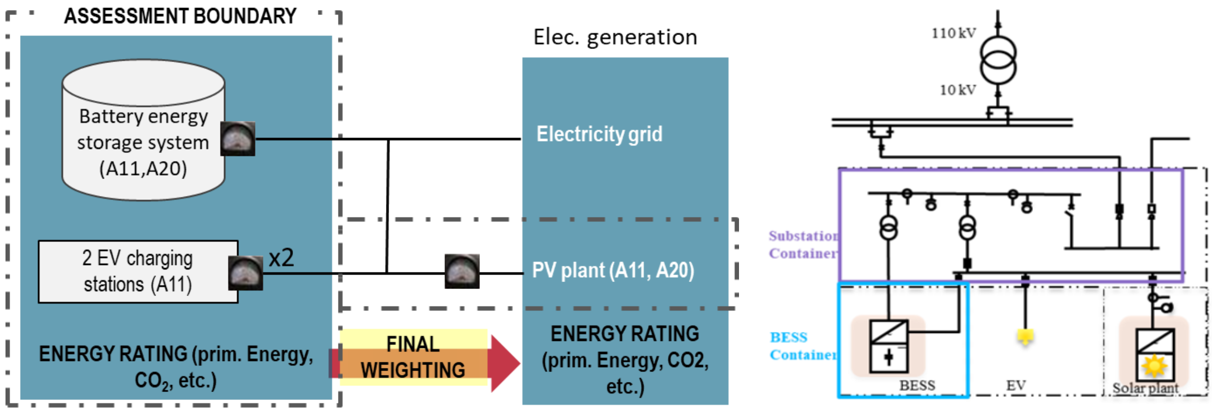

Figure 39: City infrastructure: Smart Grid A11-A20 monitoring schema for Suvilahti, Helsinki

6.3 Mobility actions

Similar to the previous cities, mobility actions are explained individually instead of creating groups of them due to their nature. Then, KPIs and TEST tables have been accounted for the preparation of the monitoring. Starting from the eBuses, Figure 40 provides the monitoring elements that are denoted for each action. These are summarised in the following bullets:

- A21: Currently, 35 buses are included and ensured for the minimum 12-months monitoring, although additional ones are being included to reach the 260 eBuses by 2022 (as specified in the DoA).

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

- A22: Maintenance and logistics fleet is being also electrified, where two vehicles are included in the monitoring programme with the same variables than A21.
- A24/26: Although A24 is related to the uptake of the 20 eBuses charging points and A26 is the charging node for the fast charging, both are printed together in the schema to simplify the figure as they share the charging points. In this sense, the measurements for the 19 non-renewable energy supply charging stations are taken, as well as the renewable charging point energy.

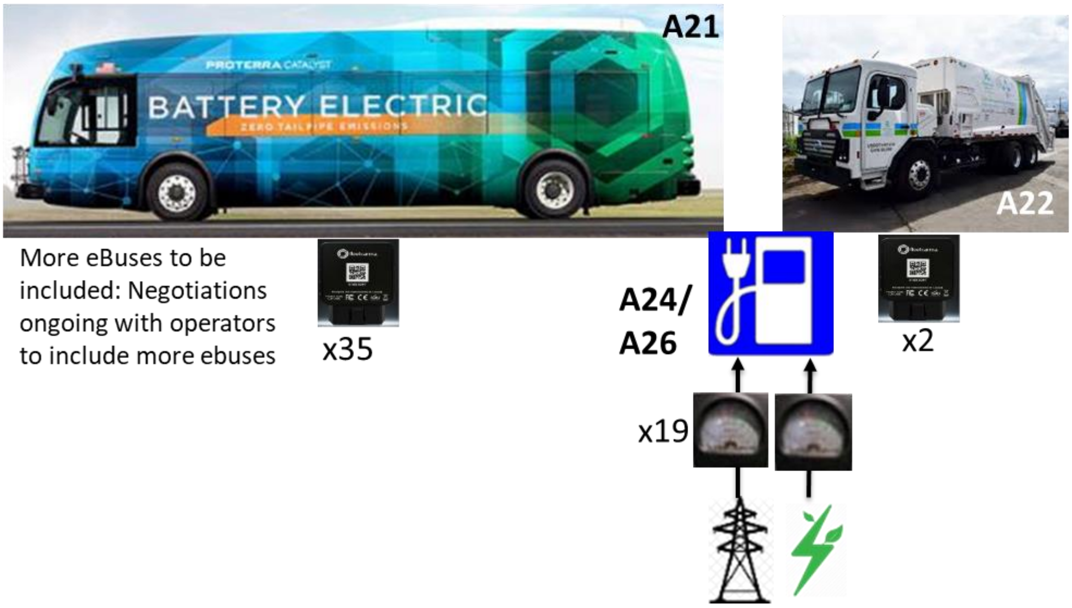

Figure 40: eBus and trucks monitoring in Helsinki

Helsinki has tested an autonomous electric bus for last mile (A23), whose data are compiled, similar to the case of Nantes. Therefore, no additional explanations than Figure 41 are required.

Figure 41: Autonomous bus monitoring in Helsinki

Next mobility action is A25 for the 1 solar powered electric bike station and for 2 solar benches, as depicted in Figure 42. Then, the energy that is used for charging the bikes can be obtained, being 100% renewable and contributing to the total renewable energy for the mySMARTLife impacts. Complementary, within this action, the two solar benches, generating 100 % renewable energy, are included.

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

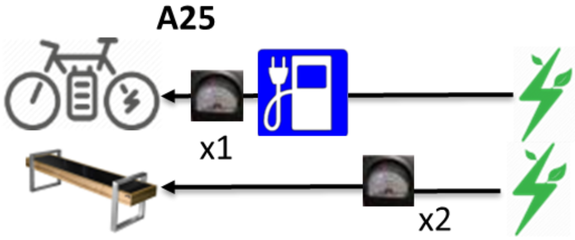

Figure 42: eBikes and solar benches monitoring in Helsinki

To finish with the mobility actions, A28, whose monitoring schema is the one drawn in Figure 43, consists of a smart personal EV charging point to demonstrate dynamic load balancing (A27) of the eV charging stations optimized to low-cost electricity hours of the private eVs. The aim is to reduce the costs by increasing the renewable contribution, combined with electricity prices. Then, to evaluate the action, the contributions from renewables and electricity grid are needed, as well as the charging station energy used to charge the private and personal eVs.

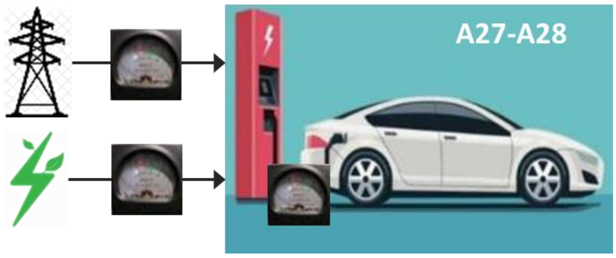

Figure 43: Smart personal eV charging station monitoring in Helsinki

6.3.1 Other mobility variables

There are additional mobility variables to be gathered for the assessment of the mobility actions. In Helsinki, these complementary variables are the next ones:

- # of users of eVehicle.
- Distance travelled by eV, so that the kilometres travelled by each eV (eBuses) could be obtained to determine the CO2 emissions avoided.
- # of trips of eV, complementary to the distance about the number of trips per each eV.
- # of (distinct) users of charging stations, i.e. types of vehicles, for the action A26.
- # of charges, time of charge, time of occupancy, station uptime per year that is included here, but these are indirect values extracted from the charging station used energy for the charging processes carried out.
- # of external charging events (i.e. # of different eV types being charged in A26).

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

7. Data quality assurance procedure

After having detailed the monitoring programmes, the next step is the compilation of the data that are indicated with the sensors and meters. This is not part of this deliverable, but D5.4, corresponding to the T5.4 – Data collection approach. Nevertheless, it is important to establish the data quality requirements, which is part of this section. These requirements are followed within the D5.4 in order to determine the quality. Special care needs to be considered in the quality as the data-points are the basis for the calculation of KPIs and impacts. Therefore, errors in the monitoring data deal with wrong final calculated KPIs and impacts.

Under these premises, within data quality, there exist multiple methodologies, such as Ralph Kimball methodology [5], consisting in multiple steps. Figure 44 shows such a methodology where it is focused on Business Intelligence and data management/treatment, which is related as well to the urban platform implementation.

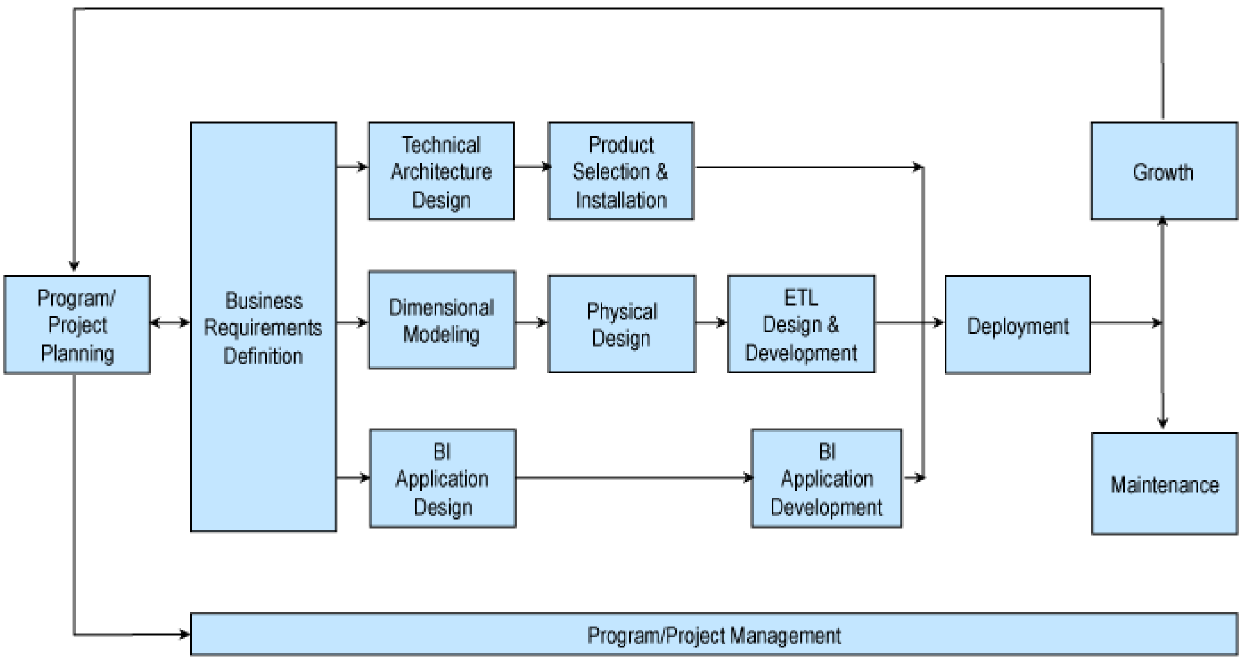

Figure 44: Ralph Kimball methodology (source [5])

In short, summarising them:

1. Project planning, which is already established by the mySMARTLife project planning.
2. Business requirements, which is described in this deliverable, where the KPIs (or Business Intelligence) requirements are extracted for the data collection.

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

3. Technical architecture design, dimensional modelling and physical design, also included in the monitoring schemas as both the location of the sensors/meters and the quantity of them are included.
4. Product selection & installation and physical installation are part of the lighthouse cities and the development of the actions.
5. BI application design and ETLs are indeed integrated as part of the urban platform where data are ingested, treated and KPIs automatically calculated in many cases (see [4]).
6. Deployment is also part of the lighthouse cities (WP2, WP3 and WP4), where, within the actions, the required equipment for monitoring is deployed.

Therefore, mySMARTLife follows an available methodology where the multiple steps are completely covered. However, the methodology ensures that the design, installation, deployment and maintenance is done under a similar strategy, it is not enough to assure data quality. For that end, a set of indicators is required to measure the data quality. Some of them are obtained from previous projects like R2CITIES [6], but these are included in the next chapter.

7.1.1 Indicators for data quality

As previously mentioned, the methodology does not ensure the data quality, but additional aspects should be considered. In this sense, the next indicators are included to verify data quality, which will be compiled and calculated within the D5.4 during the data collection approach.

- Data completeness: This indicator establishes the percentage of data that is being stored in the database. That is to say, if 1 sample per hour correspond to 24 samples per day and 720 samples per month, 648 samples would represent 90% of stored data. Thus, more than 80% of data is considered acceptable and values lower than this threshold would consider data offer gaps.
- Data cleansing: This parameter is complementary to the previous one and it indicates the repetition of data. For instance, let's think that data completeness results in 102%. This means that are more than the expected data or, what is the same, duplicated information. Then, this parameter results in the number of duplicates in the database, whose ideal number is 0. At the same time, a cleansing procedure is encouraged in order to clean these repetitive data with the aim of making use of one sample. This indicator does not need to be measured, just to be considered when the data completeness is upper than 100% as duplicates of data exist and should be cleaned before the calculation of KPIs.
- Data ranges: Sometimes, data measurements are out of expected range. Expected range is defined as the values that the variable would take in a normal operation. It is better to describe with an example. For instance, an indoor temperature is expected not less than 10ºC and not more 35ºC.

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

Then, any temperature measurement out of this range would be considered as a “fault”. As it is obvious, the ideal number is 0 samples out of range.

- Average, maximum and minimum values: This set of indicators are simply a statistical sample of the data, which is very common in business intelligence. Before any data analysis, the first step is to explore data, understand the information and have an initial idea. Then, averages and maximum/minimum values (or what is the same standard deviation) provides statistical information about the data-set and being able to get a quick overview.

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

8. Conclusions

Monitoring is pivotal in Smart City projects (but also other type of projects), where data management and advanced calculation methods are necessary for obtaining KPIs, determining impacts and, in projects like mySMARTLife, the BEST and TEST tables for assessment. Therefore, having a robust and comprehensive monitoring programme is very helpful and useful when designing the monitoring of the actions and interventions. In this sense, this deliverable has defined a monitoring programme according to the KPIs specifications in order to ensure a proper method for calculation based on real data. KPIs are aligned with impacts and BEST/TEST tables, therefore, assuring the evaluation stage.

Within mySMARTLife, a common and "standard" methodology has been applied so that monitoring programmes look similar in the three lighthouse cities (Nantes, Hamburg and Helsinki). The template for the definition of the data samples has been established based on previous experiences and it divides the thermal and electrical generation sides, as well as the distribution and demand sides. This helps to round the area where the assessment boundary is applicable, following the same principles than D5.1 and baseline calculations already performed.

Furthermore, the monitoring programmes simplify the way to define the determination of the monitoring aspects like location of the sensor, type of measurement or conceptual aspects when gathering data. This is not only useful when deploying the equipment within WP2, WP3 and WP4, but also for the assessment procedure as the data samples are correctly identified. It should be noted that, sometimes, the language between different parties complicates the evaluation. That is to say, there is no consensus when naming the measurement points, for instance, delivered energy. Hence, the depicted monitoring programmes clearly identify where the measurement is taken, allowing a common "naming" or understanding.

Having said that, D5.3 has defined, identified and established the requirements for monitoring in the three lighthouse cities according to the set of KPIs defined in D5.1. Moreover, the actions have been grouped into interventions in order to show holistic pictures where related actions are drawn, where common monitoring is applicable.

About next steps further this deliverable, it consists of the deploy of the equipment that is not already installed in the cities, which is carried out within WP2, WP3 and WP4. Besides, the data collection approach is specified in T5.4, which already started for the first batch (first year) of data, while it will continue for the second batch (second year). The data quality approach is also applied within data collection where data-points are evaluated based on the previous indicators. Last but not least, the data samples will be used within T5.5 for the assessment and final calculation of KPIs so as to determine the performance of the actions and, thus, being able to obtain the final impacts of the project.

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

9. References

[1] mySMARTLife, "Description of Action (DoA)", GA 731297.

[2] EU Smart Cities Information System (SCIS), "Technical Monitoring Guide", Deliverable D23.2D, technical report, Contract ENER/C2/2017-97/SI2.765018.

[3] EVO world, "IPMVP: Generally accepted M&V principles", International Performance Measurement and Verification Protocol, technical report, October 2018.

[4] mySMARTLife partners, "D2.16 Open Specifications Framework", mySMARTLife project, technical report, November 2017.

[5] Kimball, R., "Kimball DW/BI Lifecycle Methodology", available on https://www.kimballgroup.com/data-warehouse-business-intelligence-resources/kimball-techniques/dw-bi-lifecycle-method/, last visited November 2020.

[6] R2CITIES partners, "D5.1 Report of commissioning tasks", R2CITIES project, technical report, April 2018.

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