TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ + TARTU + SØNDERBORG

Deliverable 7.8: Integrated Infrastructures action monitoring program

WP7, Task 7.2

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Abbreviations and Acronyms

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Abbreviation/Acronym	Description
BEMS	Building Energy Management System
CIOP	City Information Open Platform
DEMS	District Energy Management System
DH	District Heating
DHW	Domestic Hot Water
EV	Electrical Vehicles
HEMS	Home Energy Management System
ICT	Information and Communication Technologies
IoT	Internet of Things
KPI	Key Performance Indicator
LH	Lighthouse
PV	Photovoltaic
SmartEnCity	Towards Smart Zero CO2 Cities across Europe

Table 1: Abbreviations and Acronyms

0 Publishable Summary

The objective of the monitoring program task under WP7 (monitoring and evaluation) is the definition of monitoring programs for the LH cities. Three parallel documents are being generated covering the monitoring and metering aspects for three main pillars of the project: the district intervention actions, the vehicles and urban mobility actions and the actions related to the integrated infrastructure pillar.

All the necessary requirements defined up to now for the interventions have been taken into account to define systems for monitoring, metering and data acquisition, to be chosen according to the set of KPIs selected to quantify the result reached after the execution of the interventions and actions in each LH city as were established on the evaluation protocols defined in D7.3 and D7.4.

This specific report compiles the monitoring program for the actions related to the integrated infrastructure pillar for the three LH cities participating in SmartEnCity project, following the evaluation strategy drawn through the different documents delivered previously on WP7 and applying the evaluation protocols of each city. This document jointly with the other two monitoring deliverables and the data collection approach deliverable show how the data gathering and collection from the different sources (dwellings, buildings, district, vehicles, etc.) will be done to allow the proper evaluation of the final performance.

It was intended to include on this document more specific details of devices and monitoring equipment to be installed, but no many final monitoring equipment has been yet decided being thus instead included indications, recommendations and guidelines for the definition on the cases needed. A final report including the detailed and more comprehensive information of all monitoring elements and the data collection process will be done at the end of the project (D7.12).

In the meantime, a follow-up process will be done to check periodically the advances of the actuations, and the implementation of the different measures, as well as the data collection process. This will be contemplated on internal periodic reports and also on the supervision of the interventions deliverables (D7.5, D7.10 and D7.11).

1 Introduction

1.1 Purpose and target group

This deliverable aims to provide a specific description of the monitoring items to be installed relative to the integrated infrastructures actions. The KPIs included on D7.3 “Evaluation Protocols” and, in some cases indicators coming from the D7.4 “City impact evaluation procedure”, are further deployed to match the monitoring elements that will provide the information for the project interventions evaluation stage.

The direct target group are the three LH cities.

1.2 Contributions of partners

The following Table 2 depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
CAR	Core of the document and main contributions.
MON	Specific contribution about Vitoria-Gasteiz monitoring equipment.
TAR, FTAR, CTEL	Specific contribution about Tartu monitoring equipment.
SONF	Specific contribution about Sonderborg monitoring equipment. Connection to information about Sonderborg through D5.2.
MON, GIR, CEA, TEC	Connection to information about Vitoria-Gasteiz through D3.2.
TREA, ET, TAR, FTAR	Connection to information about Tartu through D4.2.
TAR, MON	Deliverable review

Table 2: Contribution of partners

1.3 Relation to other activities in the project

The following Table 3 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the SmartEnCity project and that should be considered along with this document for further understanding of its contents.

Deliverable Number	Contributions

D7.3 & D7.4	Reference for the evaluation protocols and project impacts measurement
D7.6 & D7.7	Other two twin monitoring documents, referred to the district refurbishment and the mobility actions respectively. The one for mobility will be launched once the actions on each city are definitely signed after the current amendment process is finished.
D7.5, D7.10, D7.11	Supervision of interventions in LH projects (Versions 1, 2 and 3). The monitoring and commissioning aspects treated here are reflected on those 3 documents.
D7.9	Data collection approach. This document includes a detailed description of connections between KPIs and data sources with high interconnection to the monitoring process.
D3.2, D4.2, D5.2	Integrated planning reports for the three LH cities. Each of these documents gather information applied to all project domains including building retrofitting, integrated infrastructures, ICT deployment (SmartEnCity platform) and sustainable mobility that have been valuable to report the monitoring basis.
D7.12	Monitoring summary. This document foreseen for the end of the project will contain specific information gathered from the project actuations based on the monitoring documents.

Table 3: Relation to other activities in the project

2 Overall Approach

The content of this deliverable is structured as follows:

- Introduction, objectives and expected impacts: These previous sections introduce the purpose of the report, the relations with other project tasks and contributions from different partners.
- Sections 3, 4 and 5: These sections include the monitoring approach for each one of the LH cities on SmartEnCity. Initially they depict the KPIs & city indicators applicable for the integrated infrastructure action evaluation that set the monitoring needs from the KPI calculation point of view. Then some additional data perspectives are included that cover the non-KPI related monitoring requirements. Finally it is done an exercise to define the type of equipment to be used and related location in order to measure all the variables.
- Section 6: This section contains the guidelines for the commissioning plan including the main steps to be followed for a complete procedure.
- Final general sections 7 and 8 include the potential deviations to the plan (none mayor in this case) as well as the relation of this document with other previous and future reports to come in further stages of the project that will be fed with the information contained in this deliverable.

3 Vitoria-Gasteiz integrated infrastructures action monitoring

Starting with the case of Vitoria lighthouse city, the approach is similar to D7.6, where the interventions are briefly described in order to identify the integrated infrastructures that are affected in this deliverable. Summing up:

- Renovation of the façades and roofs of the buildings covering up to 750 dwellings, by improving the U-value of the envelope, including the replacement of the windows.
- Biomass-based district heating to feed both heating and DHW to the buildings in order to substitute the existing gas boilers.
- Integration of new thermostats in the dwellings to manage comfort and, thus, the energy generation sources.
- Management systems for the smart grid and district heating. While the D7.6 was focused on the HEMS, here, Building Energy Management System (BEMS) and District Energy Management Systems (DEMS) are considered. These monitore and control the energy sources at substation level and district heating level.
- Sustainable mobility which promotes the electric vehicle, including charging stations and needed infrastructure.
- Last but not least, development of the City Information Open Platform (CIOP).

In the case of this deliverable, the integrated infrastructures that should be taken into consideration are the biomass-based district heating, the management systems (BEMS and DEMS) and, finally, the CIOP.

3.1 Collection of KPIs applicable for the integrated infrastructures action evaluation

Using as base for information deliverable D7.3 – Evaluation protocols, and D7.4 – City impact, this section includes the specific KPIs for Vitoria-Gasteiz LH city that will be used for the evaluation of the integrated infrastructures action. All protocols were checked, and the selected KPIs finally included come from the Energy and ICT protocols. Of course, only the KPIs related to the integrated infrastructures action have been included. These KPIs require a set of variable in order to calculate the final value which allows the final evaluation and the impact of the renovation actions. That is why the first requirement in terms of monitoring is the measurement of the data-points that allow the calculation of the indicators for the city impacts. Then, Table 4 and Table 5 include the list of KPIs with the data sources required.

ENERGY			
Name of indicator	Definition	Unit	Data source
Delivered energy (for energy supply units)	The delivered energy of a large-scale or building-integrated energy supply unit corresponds to the energy entering the energy supply unit (e.g. energy content of light oil, electricity, district heat). To enable the comparability between energy supply units, the total delivered energy is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In case of cogeneration the input is matched to the output using an exergy based approach. This indicator represents the reciprocal efficiency of the energy supply unit. * Exergy factor: In case of polygeneration the raw energy used as input has to be allocated to the different outputs. The exergy-based approach only considers that part of energy that can be converted into mechanical work. If e.g. a CHP plant produces heat and power, the exergy of one KWh electricity is higher than the exergy of the same amount of thermal energy. Therefore the major part of the input can be assigned to the generated electricity and the smaller portion to the generated heat. This approach therefore considers how useful the forms of energy are for the final consumers.	kWh_{in}/kWh_{out}	Energy meters
Primary energy (for energy supply units)	The primary energy approach makes possible the simple addition from different types of energies (e.g. thermal and electrical) because primary energy includes the losses of the whole energy chain, including those located outside the building system boundary. These losses (and possible gains) are included in a primary energy factor. The energy performance of a building is the balance of the delivered energy and the exported energy. The annual amount of primary energy (net delivered primary energy) is calculated as the difference between the weighed delivered energy, summed over all energy carriers and weighed exported energy summed over all energy carriers (EN 15603:2008).	kWh_{in}/kWh_{out}	Energy meters and primary energy factors (standards, tables)
CO_2 equivalent (for energy supply units)	The CO_2 emissions of a large-scale or building-integrated energy supply unit correspond to the emissions that are caused by the energy output. In different variants of this indicator the emissions caused by the production of the energy supply unit components can be either included or excluded. To enable the comparability between energy supply units, the total energy demand is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In the case of cogeneration, the input is matched to the output using an exergy-based approach.	$t\ CO_2/\ m^2a$	Energy meters and primary energy factors (standards, tables)

ENERGY			
Name of indicator	**Definition**	**Unit**	**Data source**
Degree of energetic self-supply	The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity. Furthermore, the quantity of locally produced energy can be interpreted as by renewable energy sources (RES) produced energy or by combined heat and power (CHP) plants produced energy.	%	Estimated
Share of renewable energy	Total share of renewable energy sources in a complex energy supply system.	%	Estimated

Table 4: KPIs for energy in Vitoria

ICT – CIOP			
Name of indicator	**Definition**	**Unit**	**Data source**
Response time	Measure the time the requests take to provide the information to the user (citizen or other system). Data may be taken from database engine or framework	time	Data from the platform
Scalability	This indicator will give information on the how well the ICT systems will be replicated. The data will be obtained by counting the times each class is instantiated	Number of instances per service/class	Data from the platform
Extensibility	Increase of sensors managed (note that currently this number is 0). Number of services implemented. This data will be a count of services and classes in the system	Number of newer services or classes implemented	Data from the platform
Storage Capacity	As ICTs are deployed and host the data captured from sensors and operations, the storage needs will be incremented. The increase in storage needs will provide information on how much the system is connected and integrated to the physical world. Calculated from the storage needs.	disk/cloud storage space	Data from the platform
Hours of maintenance	Expressed as the time needed to upgrade the system, this information provides an insight on how much the system needs to provide newer services (demanded by users) or increase the functionality by connecting to other existing or newer systems. The data is related to the number of additional developing hours for new services	time	Data from the platform
Non-expected hours off-line	This is a measure of the down time of the system, which should be kept closest to zero. The data is the number of hours the system is not operative	time	Data from the platform

ICT – elements managed			
Name of indicator	**Definition**	**Unit**	**Data source**
# of HEMS connected	This is related to the number of sensing systems installed in the dwellings and integrated into the urban platform. It can be easily obtained from the instances declaration in the Platform	Units	Extracted from the platform
# of BEMS connected	Number of systems installed per building, related to common operations (not dwellings), integrated in the platform. It can be easily obtained from the instances declaration in the Platform	Units	Extracted from the platform
# of EV connected	Electric vehicles integrated the platform. Could be further enhanced with vehicle class definition (cars, bikes, etc.) Measure the number of classes and number of instances of each in the platform declarations	Units (per class)	Extracted from the platform
# of mobility equipment connected	Other equipment integrated to the platform and also related to mobility. Measure the number of classes and number of instances of each in the platform declarations	Units (per class)	Extracted from the platform
Total amount of data generated	This will measure the amount of data generated. Obtained from the storage used.	Disk/cloud storage space	Extracted from the platform
Types of measurements	This relates to the magnitude definition of the data (temperature, energy, speed, etc.) It will be obtained from the magnitudes of the data definitions in the city data model	Units	Extracted from the platform
Percentage of equipment connected	This relates to the degree of achievement of the intervention to existing system. This data will be obtained from the number of elements managed with the platform comparing to the total number of candidate elements.	Percentage	Extracted from the platform
Recharging points equipment connected	This relates to the number of EV post installed in the City. Count of instances of this class.	Units	Extracted from the platform
Smart lighting equipment connected	This relates to the number of streetlights installed in the City and managed with the platform. Count of instances of this class.	Units	Extracted from the platform

ICT – applications			
Name of indicator	**Definition**	**Unit**	**Data source**
Number of services developed	Relates to the amount of services based on ICTs to offered citizens and third parties. The KPI will be the count of services implemented	Units	Extracted from the platform
Types of services	The services will be classified by area (mobility, engagement, energy efficiency, management, etc.). The count of services deployed for each area will be measured.	Classification/ units	Extracted from the platform

ICT – CIOP			
Name of indicator	Definition	Unit	Data source
Percentage of dwellings connected	This relates to the success of the system deployment throughout the project implementations. The KPI will be calculated considering how many are on-line out of the number considered in the actions	Percentage	Extracted from the platform
Percentage of Buildings connected	This relates to the number of buildings with common systems connected. The KPI will be calculated considering how many are on-line out of the number considered in the actions	Percentage	Extracted from the platform
APIs integrated	This will measure the ease of connectivity for third parties to provide services through the ICT system. The measure will be the number of APIs developed for interoperability	Units	Extracted from the platform
Open-Data sets available	This indicates the availability of data for citizens and third parties for evaluation and service building. The sets considered will be related to the services defined before.	Units	Extracted from the platform

Table 5: KPIs for ICT in Vitoria-Gasteiz

3.2 Non-KPI related monitoring requirements

In this case, the main monitoring requirements are similar to D7.6 and the weather station and forecast services are non-KPI related monitoring requirements. In this way, the same variables that are detailed in that deliverable are included in this case.

Moreover, the integrated infrastructures include indicators for the ICT solutions that are being developed under the project framework. These measurements are not real measuring processes, but registering data is completely necessary. In this case, performance of the ICT solutions is one important aspect to be measured in order to assess the final implementation. This entails the need to log in the CIOP.

It is also remarkable that the interventions require additional data for the control and management systems, but these are the common devices as pumps, valves, etc. which do not send data to the CIOP, therefore, are not considered in the deliverable.

3.3 Monitoring equipment and other sources of information

Once established the requirements for monitoring both in the case of KPI-related measurements and non-KPI variables, the next step is to define the monitoring recommendations. Table 6 and Table 7 collect the variables that are measured, its definition, meter type and reading location.

Variable	Definition	Meter	Location
Generated DHW energy	Total energy generated by the district heating for DHW feeding to the district.	Heatmeter	DHW main boiler output circuit
Generated heating energy	Similar as above, but for heating purposes.	Heatmeter	DHW main boiler output circuit
Generated DHW energy by support boiler	Total energy generated by the support boiler to cover the DHW demand peaks.	Heatmeter	DHW main boiler output circuit
Generated heating energy by support boiler	Similar as above, but for heating purposes.	Heatmeter	DHW main boiler output circuit
Consumed fuel	Total boilers fuel consumption, in terms of biomass (or gas if applicable), which is helpful to determine the performance of the boiler.	Volume Meter/Counter	Boiler input
Electricity	Boiler and distribution elements electricity consumption for heating energy generation	Wattmeter	Boiler room main cabinet

Table 6: Infrastructure equipment for Vitoria

Variable	Definition	Meter	Location
CIOP performance	Under this variable, the measurements to obtain response time, maintenance hours, storage and hours off-line are covered in order to determine the final performance of the CIOP.	CIOP logs	CIOP
# of elements	There are multiple equipment to be integrated in the CIOP, but the number of elements managed by the CIOP may be obtained through keeping records in the logging system, The same is applicable to the number of services, APIs and open data sets available.	CIOP logs	CIOP

Table 7: Other sources of information in Vitoria

Figure 1 schematically represents the measurements in Vitoria-Gasteiz in terms of district heating, and where the meters would be installed. Two circuits are drawn, one for DHW services and the second one for heating purposes. Then, as stated in the table before, the energy measurements for DHW and heating services are obtained from meters, while the total energy may be obtained by means of adding both contributions.

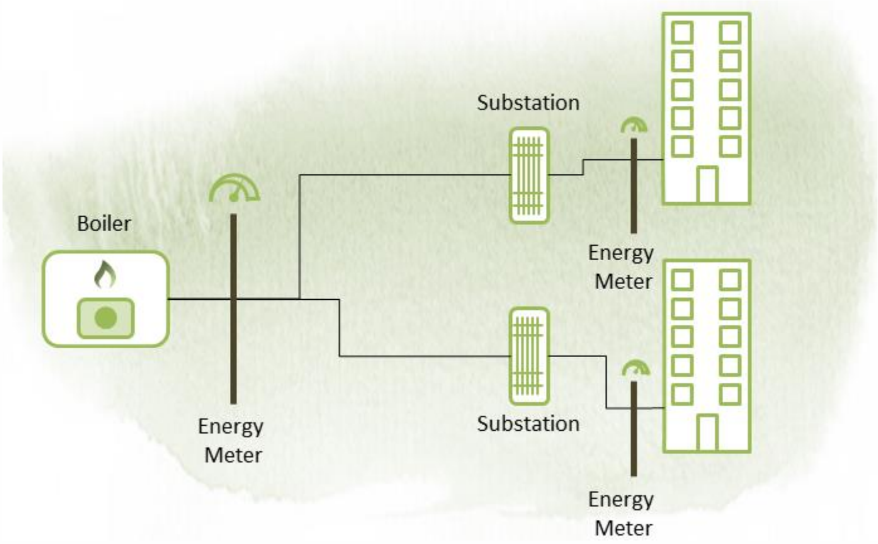

Figure 1: District Heating monitoring schema

Then, thanks to the aforementioned measurement process, the information may be managed by the CIOP so the neighbourhoods have access to the consumptions. In fact, the visualization tools illustrated in Figure 2 are a combination of the information of the district heating and data from the building/dwelling consumption, as described in D7.6. Nevertheless, the information is integrated under integrated infrastructures due to the strong relationship with the CIOP deployed services.

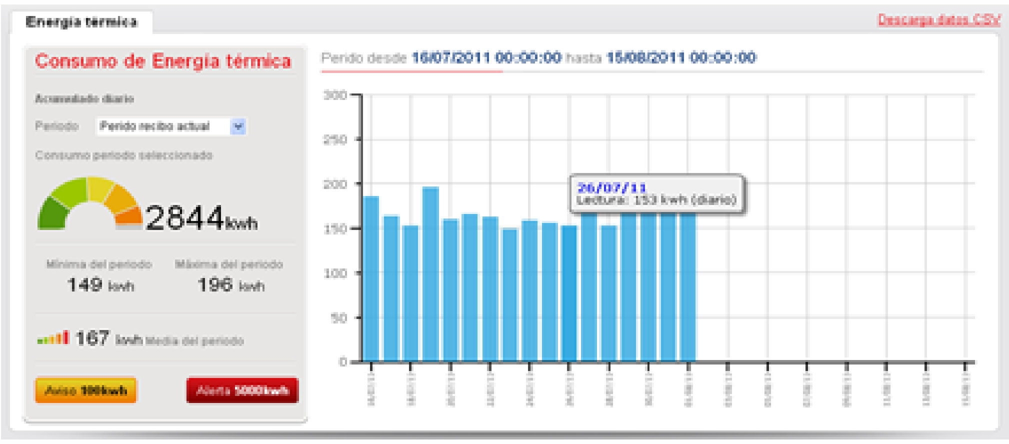

Figure 2: Visualization tool for district heating consumption

The main features of this website, extracted from D3.2, are as follows:

- The user can see the consumption for predefined periods of time: last 30-60-90 days.
- To ease the graph interpretation, a table with the data readings (date and value) shows up when the cursor passes over, allowing the user to review them.
- The user has an overview of the consumption thanks to the information on the maximum, minimum and averages.
- The user has the possibility to configure two alarm levels: "Warning" and "Alert".
- The user has access at all times to the invoices from past and current periods.
- From the community administration panel, readings, invoices and personal data may be individually managed per owner.

The information collected by the meters is transmitted to the regulation and control system located in the electrical panel of the substation via typical communication cable-bus (tentatively RS-485). The readings collected and registered by the building regulation and control system will be sent to a server where they will be treated and stored by a computer application, in charge of making the automatic billing and generate the web pages. This way, the tenants can access in real time the consumptions, billing, data logs, etc. The meter readings are daily recorded. The frequency of the data collected can be changed.

As stated before, data are integrated into the CIOP; however, several levels of data providers are identified, e.g. Building Manager, HEMS… Then, it is necessary to establish a communication infrastructure that allows data collection. Thus, Figure 3 depicts the infrastructure for data collection where coaxial cable routers are installed in the houses and in the TV headend to create an Ethernet network. These routers provide non-invasive distribution system that preserves the quality of the transmission. The router also offers WIFI in the houses working as an access point, enabling the connection of WIFI sensors and devices such as WIFI thermostats. The devices to be installed in the dwellings and the TV distribution systems are shown in Figure 4.

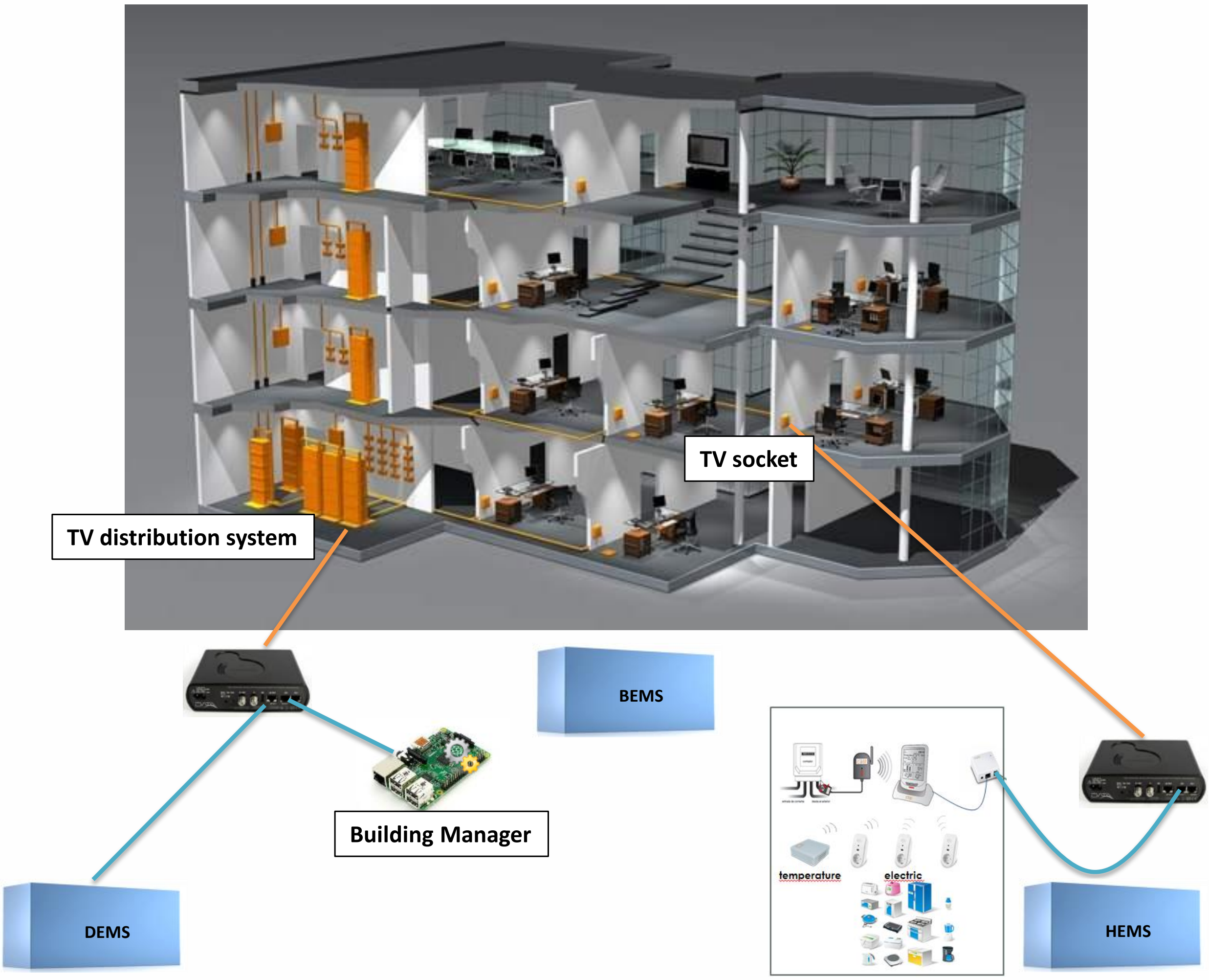

Figure 3: Infrastructure for data integration in Vitoria-Gasteiz

Figure 4: Routers to be installed in Vitoria-Gasteiz

Also, a Building Manager System will be installed in the TV distribution system to collect and store data from the houses and common infrastructure of the building, and to offer services or ICT solutions locally. For example, it could be used to provide informative panels in the homes using HMI and a television channel. It will also communicate with the monitoring platform.

The BEMS needs to connect to the DEMS in order to reach Internet and the CIOP monitoring platform. The best option is to take advantage of the works to be developed in the DH intervention to provide a connection between each of the buildings and the centre point of the district. Thus, the intervention in the DH has to account for the connection between the substations and the BEMS routers installed in the TV distribution system. The requirements at this level are; provision of an Ethernet connection, selection of network topology (ring, star…) as for example in Figure 5, and selection of the Internet connection equipment.

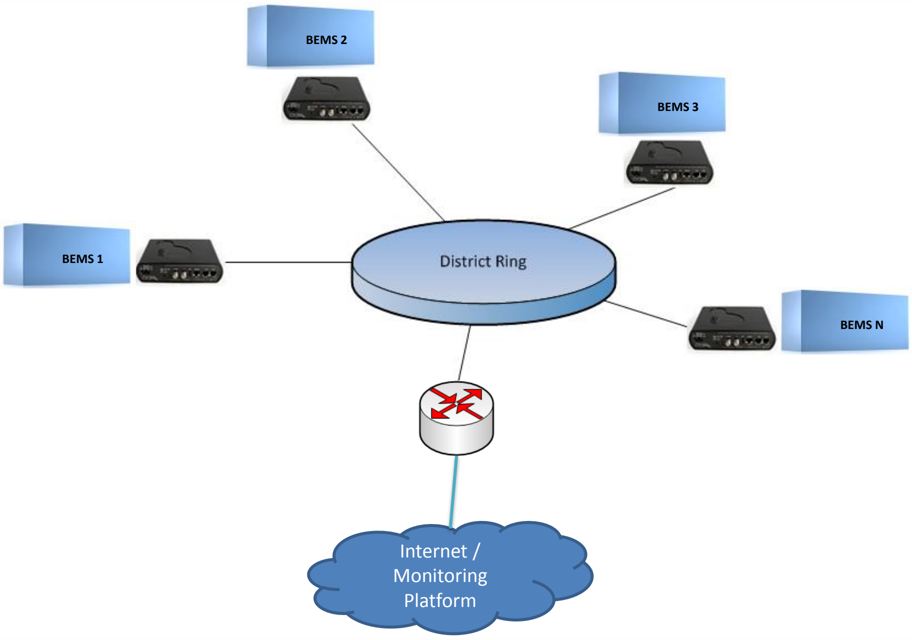

Figure 5: Ring connection for the DEMS in Vitoria-Gasteiz

4 Tartu integrated infrastructures action monitoring

Similar approach than Vitoria is followed in Tartu. Although the information is already collected in D7.6, this section is more focused on identifying the interventions that are related to the integrated infrastructures instead of building/district retrofitting. In short:

- Renovation of the thermal envelope by means of insulation systems in the façade and roof, including replacement of windows.
- PV-based electricity generation.
- New ventilation systems to be more efficiency, complemented by new individual heating systems.
- Dwelling level intervention to include monitoring and new thermostats able to manage more efficiently the energy consumption and comfort levels.
- DH based on biofuels and heat pump. District cooling based on free cooling from river water, heat pump and compressor chillers solution. PV is used to produce power for the heat pump.
- Heat recovery system.
- Reuse of EV batteries as long- term charging elements, getting energy from PV panels.
- Street lighting with intelligent control systems.
- Sustainable mobility based on electrical vehicles and charging stations, as well as car sharing approaches.
- Implementation of the CIOP.

Having in mind the aforementioned interventions, the ones that are applicable in the case of the integrated infrastructures are the district heating/cooling solutions, including the integration of the PV electricity generation, street lighting and urban platform, as well as the heat recovery system.

4.1 Collection of KPIs applicable for the integrated infrastructures action evaluation

Using as base of information deliverable D7.3 – Evaluation protocols, this section includes for Tartu LH city the specific KPIs that will be used for the evaluation of the integrated infrastructures action. All protocols have been checked and the selected KPIs included come finally from the Energy and ICT ones. Of course, only the KPIs related to the integrated infrastructures action have been included. From the list of KPIs included in Table 8 and Table 9, the first requirements in terms of monitoring may be extracted as those variables necessary to be metered with the aim of obtaining the final value of the indicator.

ENERGY			
Name of indicator	Definition	Unit	Data source
Primary energy (for energy supply units)	The primary energy approach makes possible the simple addition from different types of energies (e.g. thermal and electrical) because primary energy includes the losses of the whole energy chain, including those located outside the building system boundary. These losses (and possible gains) are included in a primary energy factor. The energy performance of a building is the balance of the delivered energy and the exported energy. The annual amount of primary energy (net delivered primary energy) is calculated as the difference between the weighed delivered energy, summed over all energy carriers and weighed exported energy summed over all energy carriers (EN 15603:2008).	kWh_{in}/kWh_{out}	Energy meters and primary energy factors (standards, tables)
CO_2 equivalent (for energy supply units)	The CO_2 emissions of a large-scale or building-integrated energy supply unit correspond to the emissions that are caused by the energy output. In different variants of this indicator the emissions caused by the production of the energy supply unit components can be either included or excluded. To enable the comparability between energy supply units, the total energy demand is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In the case of cogeneration, the input is matched to the output using an exergy-based approach.	t CO_2/ m^2a	Energy meters and primary energy factors (standards, tables)
Degree of energetic self-supply	The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity. Furthermore, the quantity of locally produced energy can be interpreted as by renewable energy sources (RES) produced energy or by combined heat and power (CHP) plants produced energy.	%	Estimated
Share of renewable energy	Total share of renewable energy sources in a complex energy supply system.	%	Estimated
Efficiency	Evaluation the efficiency of systems (boiler, solar collector, etc.)	%	monitored

Table 8: KPIs for energy in Tartu

ICT – CIOP			
Name of indicator	**Definition**	**Unit**	**Data source**
Response time	Measurement of time during which the system conforms to the request from outside the system. Data will be taken from database engine.	Time	Data from the platform
Scalability	This indicator will give information on the how well the ICT systems will be replicated. The data will be obtained by counting the times each class is instantiated	Number of instances per service/class	Data from the platform
Extensibility	Number of sensors and services integrated. Data will be taken from the platform itself.	Number of services or classes integrated	Data from the platform
Storage Capacity	Total storage space in use needed to service the system. Data will be taken from the platform itself.	Disk/cloud storage space	Data from the platform
Hours of maintenance	Time needed to upgrade and development of the system due to integration of new services and classes. Data will be calculated on basis of information from system.	Time	Data from the platform
Non-expected hours off-line	The number of hours the system is not in operation. Data will be taken from the platform itself.	Time	Data from the platform
ICT – elements managed			
Name of indicator	**Definition**	**Unit**	**Data source**
# of HEMS connected	Number of sensing systems installed in the dwellings and integrated in the CIOP. Data will be taken from the platform itself.	Units	Extracted from the platform
# of BEMS connected	Number of sensing systems installed per building and integrated in the CIOP. Data will be taken from the platform itself.	Units	Extracted from the platform
# of EV connected	Number of electric vehicles integrated to the system. Data will be taken from the platform itself.	Units (per class)	Extracted from the platform
# of mobility equipment connected	Number of other mobility related equipment integrated to the system. Data will be taken from the platform itself.	Units (per class)	Extracted from the platform
Total amount of data generated	The amount of data generated by the system. Data will be taken from the platform itself.	Disk/cloud storage space	Extracted from the platform
Recharging points equipment connected	The number of EV recharging units installed in the pilot area and integrated into the CIOP. Data will be taken from the platform itself.	Units	Extracted from the platform
Smart lighting equipment connected	The number of streetlights installed in the pilot area and managed by the system. Data will be taken from the platform itself.	Units	Extracted from the platform

ICT – applications			
Name of indicator	Definition	Unit	Data source
Number of services developed	The amount of services based on ICTs offered to citizens and third parties. Data will be gathered manually using information from the system and questionnaires.	Units	Extracted from the platform
Types of services	The services will be classified by area (mobility, engagement, energy efficiency, management, etc.). Data will be gathered manually using information from the system and questionnaires.	Classification/units	Extracted from the platform
Percentage of dwellings connected	The percentage of dwellings of pilot area connected to the system. Data will be gathered from the platform itself.	Percentage	Extracted from the platform
Percentage of Buildings connected	The percentage of dwellings of pilot area connected to the system. Data will be gathered from the platform itself.	Percentage	Extracted from the platform
Open-Data sets available	Available number of data sets for citizens and third parties for evaluation and service building. Data will be gathered from the platform itself.	Units	Extracted from the platform

Table 9: KPIs for ICT in Tartu

4.2 Non-KPI related monitoring requirements

This case is similar to Vitoria case because, despite having control and management systems for ventilation, these additional variables are related to the dwellings, being already explained in D7.6.

Nevertheless, at integrated infrastructures level, there exists another system that needs to be fully monitoring. That is the case of the smart lighting because the control systems require some variable for the decision-making algorithm. For instance, the statues of the lights are necessary at time of deciding whether switch on/off the lights.

Apart from the aforementioned requirements, it is noticeable to say that there exist additional devices, but they are not going to capture data to be stored in the CIOP. This equipment is related to the essential equipment of the management networks. For example, district heating requires pumps, valves, etc. that provide data to the controller.

4.3 Monitoring equipment and other sources of information

Thanks to the requirements obtained from the indicators and the solutions to be implemented in Tartu, Table 10 establishes the recommendation in terms of monitoring for this lighthouse city. Apart from these devices, additional data sources are required, but those are similar to those already described in Table 7.

Variable	Definition	Meter	Location
District heating DHW consumption	Measurement of the consumption of energy from the district heating to provide DHW.	Heatmeter	Output circuit for DHW of main heat substation
Heating/cooling consumption	Similar to DHW, but for the case of heating and or cooling.	Heatmeter	Output circuit for heating of main heat substation
Consumed energy	Total fuel that is consumed by the houses, in terms of energy consumed from DH, power grid, PV	Counter	Measured inputs
Electricity	Electricity consumption of houses and district cooling plant (separately)	Wattmeter	Main electrical cabinets
PV contribution	Electricity produced by PV. (houses and cooling plant)	Wattmeter	Output of the inverter
EV - PV-contribution	PV panels will fed a system of old EV batteries that will be used to charge electric taxis. The system will be also connected to grid and surplus of the electricity from PV-panels will be inserted in to grid. Electricity produced by PV-panels and electricity re-charged will be monitored.	Wattmeter	Batteries input and output to the grid.
PV power	Active power of the PV plant.	Wattmeter	Output of the inverter
Lux level	According to the intervention of smart lighting the luminance needs to be measured in order to ensure comfort levels.	Lux meter	Distributed in the streets at medium-size height.
Lighting consumption	The new smart lighting system consumption is necessary to extract conclusions about the performance.	Wattmeter	Lamps supply circuits
Light status	In order to render control systems for smart lighting, the status of the light is necessary.	Relay	Lamps
Light dimmer	One of the control parameters is the dimmer in order to regulate the lux.	Dimmer	Lamps
CO_2, NO_x, particles (2,5/10) level	Although it is not directly related with the lamp posts, they include air quality sensors to obtain the level of pollution of the city.	CO_2, NO_x and particles probe	Lamp posts
Temperature, humidity, atmospheric pressure	Although it is not directly related with the lamp posts, they include weather sensors to obtain the weather information and combine it with air quality sensor information for Big Data analysis.	Temperature, humidity and pressure probe	Lamp posts
Noise	Although it is not directly related with the lamp posts, they include noise sensors to obtain the weather information and combine it with air quality sensor information for Big Data analysis.	Noise probe	Lamp posts

Variable	Definition	Meter	Location
Road surface temperature	Although it is not directly related with the lamp posts, they include road surface temperature sensors to obtain this information and to improve road maintenance quality and speed at near zero degree conditions	Infrared temperature probe	Lamp posts
Water flow	The heat recovery system needs to measure the performance, therefore, the water flow via heat substation is necessary to be measured.	Flowmeter	Water ducts
District cooling plant performance	Utilization of surplus heat from DC system. How much residue heat from cooling is used in DH system	Metering system of DC plant	DC plant
Performance of heat pump	Coefficient of performance (COP) of heat pump	Metering system of DC plant	DC plant
Performance data of heat pump	Operation hours, and other relevant measurement data	Metering system	Heat pump
Inlet/Outlet DH temperatures at houses	Inlet and outlet temperatures	Metering data from heat meters	Heat substation

Table 10: Infrastructures equipment for Tartu

It is important to clarify that the district heating and cooling system to be tested in Tartu is based on a heat pump installed to return the flow of the district cooling system, to produce heat for the district heating system partly by using residual heat from cooling. Then, that is the reason why the consumed energy by the district heating/cooling is required, as well as, the performance of the heat pump needs to be extracted.

Regarding the smart street low energy consumption, 314 LED luminaires are installed, including wireless controllers and 58 smart sensors. The system that will be implemented in Tartu is simple and fast to deploy also on a large scale. The unique combination of field-proven wireless technology, which has been previously applied in security, smart city applications, and smart energy management, enables massive and low-cost smart street lighting installations for reducing energy consumption. The aim is to bring intelligence and data processing to the device level and build networks of locally collaborating self-aware devices – sensors (that gives the opportunity to gather and communicate different moving, weather and other needed data) and luminaire controllers – which enable to take into account local weather and traffic conditions and adjust street light operation based on this without any central server data processing.

There are a number of different actuators capable of performing some actions such as turning off a street light when no road users are detected or adjusting building heating and ventilation based on the current and predicted weather conditions. A street light can be controlled taking into account the current time of the day, the light intensity and/or the number of nearby road users.

Finally, the ICT platform will have information related to integrated infrastructures on:

- District heating / cooling: Energy consumption monitoring on building level.
- The energy that is produced by PV panels for recharging reused batteries of the EV.

- Energy used in the renovated houses.
- Smart street lightning: Lightning, traffic and weather data will be gathered and presented via ICT platform to inhabitants of pilot area:
    - The weather monitoring devices will be installed on the lightning poles.
    - Weather data (CO_2, temp., illumination, etc.) will be shown in smart home devices placed into flats during renovations.

In short, Figure 6 illustrates the monitoring schema in Tartu and how the monitoring system is connected to the CIOP. In this case, the urban infrastructures that are integrated as project actions are represented as long as they need to be evaluated to obtain the final impact. In terms of district renovation, the same information than the energy suppliers are measured with the difference of the level of granularity (i.e. dwelling monitoring), as it may be looked into the D7.6.

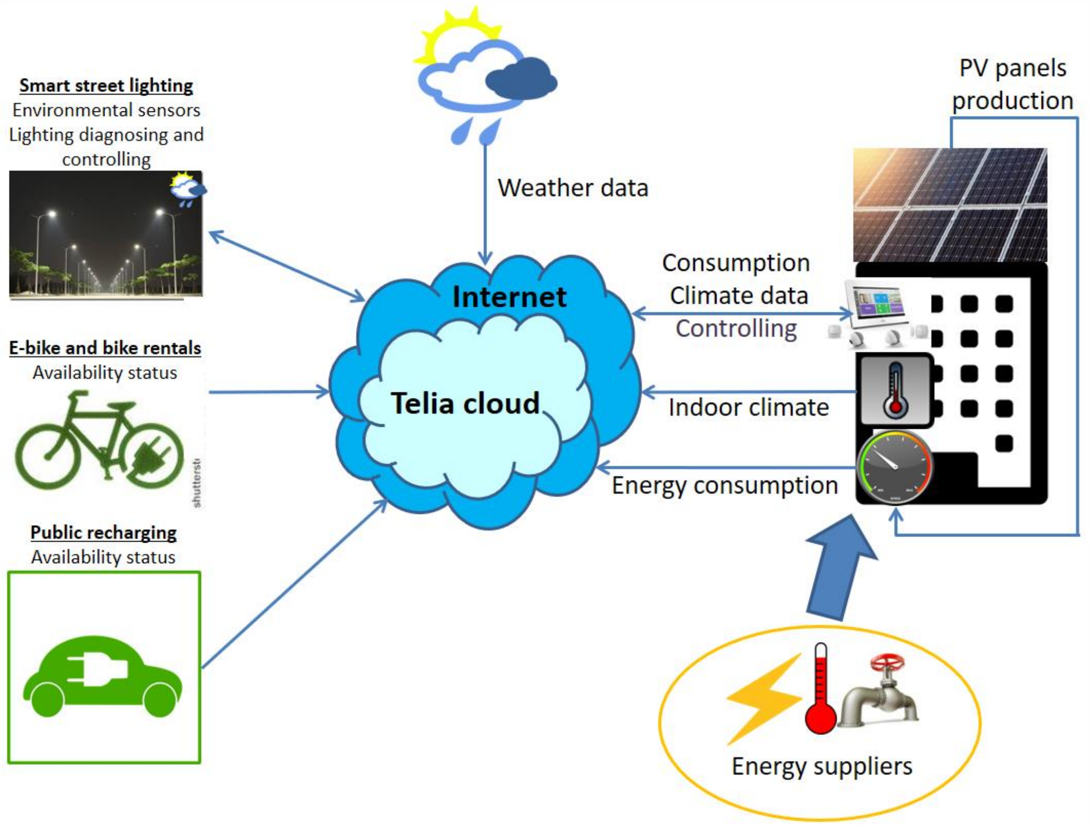

Figure 6: Monitoring schema for Tartu

5 Sonderborg integrated infrastructures action monitoring

Finally, the case of Sonderborg, whose interventions are summarised in the bullets below:

- Improvement of the thermal envelope in order to increase the level of insulation in façades and roof, including renovation of windows and walls.
- Improvement of the ventilation systems with heat recovery systems that replace the traditional exhaust air ventilation systems.
- LED integration in common zones and some rooms of dwellings. Also, LED-based street lighting solution.
- RES-supply for the district heating based on heat pumps with sea water as source.
- Automatic heating control systems in district heating supply of the buildings
- Installation of in total 6.000 m² of solar photovoltaic plants for electricity supply with focus on good architectural integration of the solar panels in roofs and façades.
- Wind farms.
- Sustainable mobility with biogas buses and electric vehicles with charging stations.
- Implementation of monitoring and CIOP deployment, including energy manager in order to manage the energy facilities.

From the integrated infrastructures point of view, the solutions that include the street lighting, district heating (sea water source), wind farms and solar panels, as well as the CIOP development, are being treated under this deliverable.

5.1 Collection of KPIs applicable for the integrated infrastructures action evaluation

As happening in the previous sections, the first way to get the requirements comes from the selected KPIs, whose values need to be calculated. In this way, using as base of information deliverable D7.3 – Evaluation protocols – this section includes for Sonderborg LH city the specific KPIs that will be used for the evaluation of the integrated infrastructures action.

ENERGY			
Name of indicator	Definition	Unit	Data source
Primary energy (for energy supply units)	The primary energy approach makes possible the simple addition from different types of energies (e.g. thermal and electrical) because primary energy includes the losses of the whole energy chain, including those located outside the building system boundary. These losses (and possible gains) are included in a primary energy factor. The energy performance of a building is the balance of the delivered energy and the exported energy. The annual amount of primary energy (net delivered primary energy) is calculated as the difference between the weighed delivered energy, summed over all energy carriers and weighed exported energy summed over all energy carriers (EN 15603:2008).	kWh_{in}/kWh_{out}	Energy meters and primary energy factors (standards, tables)

ENERGY			
Name of indicator	Definition	Unit	Data source
CO_2 equivalent (for energy supply units)	The CO_2 emissions of a large-scale or building-integrated energy supply unit correspond to the emissions that are caused by the energy output. In different variants of this indicator the emissions caused by the production of the energy supply unit components can be either included or excluded. To enable the comparability between energy supply units, the total energy demand is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In the case of cogeneration, the input is matched to the output using an exergy-based approach.	t CO_2/ m²a	Energy meters and primary energy factors (standards, tables)
Degree of energetic self-supply	The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity. Furthermore, the quantity of locally produced energy can be interpreted as by renewable energy sources (RES) produced energy or by combined heat and power (CHP) plants produced energy.	%	Estimated
Share of renewable energy	Total share of renewable energy sources in a complex energy supply system.	%	Estimated
Efficiency	Evaluation the efficiency of systems (boiler, solar collector, etc.)	%	monitored

Table 11: KPIs for energy in Sonderborg

ICT – CIOP			
Name of indicator	Definition	Unit	Data source
Response time	Depending on request type	Time	Data from the platform
Scalability	SCIOSS Scalability is defining SCIOSS horizontal and vertical scaling. SCIOSS support horizontal scaling (scale out/in): - Add new nodes such as adding new blade (computer). - Scaling out from x Web Server systems to more Web systems on more nodes. SCIOSS support vertical scaling (scale up/down): - Virtualization technology is used. - Single node scale up such as increase CPU power, memory or storage.	Number of instances per service/class	Data from the platform

ICT – CIOP			
Name of indicator	**Definition**	**Unit**	**Data source**
Extensibility	SCIOSS interoperability is the ability to share data with other systems and support for sensors by different manufactures. The physical IoT gateway device support drivers for a range of sensors and meters by different manufactures. The physical Web Services support open standards for data exchange with other systems.	Number of services or classes integrated	Extracted from the platform
Storage Capacity	Extendable – cloud based	Disk/cloud storage space	Extracted from the platform
Hours of maintenance	Time to keep system running and patch-up	Time	Extracted from the platform
Non-expected hours off-line	The number of hours the system is not in operation.	Time	Extracted from the platform
ICT – elements managed			
Name of indicator	**Definition**	**Unit**	**Data source**
# of HEMS connected	Number of sensing systems installed in the dwellings and integrated in the CIOP.	Number	Extracted from the platform
# of BEMS connected	Number of sensing systems installed per building and integrated in the CIOP.	Number	Extracted from the platform
# of EV connected	Number of electric vehicles integrated to the system.	Number (per class)	Extracted from the platform
# of mobility equipment connected	Number of other mobility related equipment integrated to the system.	Number (per class)	Extracted from the platform
Total amount of data generated	The amount of data generated by the system.	Disk/cloud storage space	Extracted from the platform
Recharging points equipment connected	The number of EV recharging units installed in the pilot area and integrated into the CIOP.	Number	Extracted from the platform
Smart lighting equipment connected	The number of streetlights installed in the pilot area and managed by the system.	Number	Extracted from the platform
ICT – applications			
Name of indicator	**Definition**	**Unit**	**Data source**
Number of services developed	The amount of services based on ICTs offered to citizens and third parties.	Number	Extracted from the platform

ICT – CIOP			
Name of indicator	Definition	Unit	Data source
Types of services	The services will be classified by area (mobility, engagement, energy efficiency, management, etc.).	Classification/units	Extracted from the platform
Percentage of dwellings connected	The percentage of dwellings of pilot area connected to the system.	Percentage	Extracted from the platform
Percentage of Buildings connected	The percentage of dwellings of pilot area connected to the system.	Percentage	Extracted from the platform
Open-Data sets available	Number of web service functions.	Number	Extracted from the platform

Table 12: KPIs for ICT in Sonderborg

5.2 Non-KPI related monitoring requirements

As happening in the other lighthouse cities, the non-KPI requirements are related to the weather station and forecast services that are already explained in D7.6.

In contrast to Vitoria-Gasteiz and equal to Tartu, Sonderborg is being deployed a smart lighting systems through new lamp post which are required to be metered and controlled in an optimal way. Therefore, the data-points related to this intervention need to be obtained and integrated in the CIOP.

Additionally, as happening in the other demos, those elements related to the distribution, such as pumps or valves, are not included because these values are normally measured for the decision-making of the controller and they are not integrated in the CIOP.

5.3 Monitoring equipment and other sources of information

With the aforementioned requirements, the monitoring equipment may be defined. Table 13 collects the variables, their definition, type of meter and recommended location for the Sonderborg lighthouse. In the case of other sources of information, see Table 7.

Variable	Definition	Meter	Location
District heating DHW consumption	Measurement of the consumption of energy from the district heating to provide DHW. As well, here, it is included the support boiler.	Heatmeter	Output circuit for DHW of main boiler
Heating consumption	Similar to DHW, but for the case of heating.	Heatmeter	Output circuit for heating of main boiler
Consumed fuel	Total fuel that is consumed by the boilers, in terms of biomass (or gas if applicable), which is helpful to determine the performance of the boiler.	Counter	Input of the boilers
Electricity	Electricity consumption of the district heating and its distribution circuit, which is a crossed effect for the Measurement and Verification.	Wattmeter	Main cabinet of boilers room

Variable	Definition	Meter	Location
PV contribution	There is a PV plant that partially feeds the building electricity, but also the distribution system (pumps, etc.), therefore, its contribution needs to be metered.	Wattmeter	Output of the inverter (boilers room circuit)
PV power	Active/reactive power of the PV plant.	Wattmeter	Output of the inverter
Wind contribution	The energy generated by the wind power serves to feed the infrastructures, hence, its contribution is necessary for the evaluation of the renewable sources.	Wattmeter	Output of the wind farm (contribution to network)
Wind power	Active/reactive power of the wind farm.	Wattmeter	Output of the wind farm (contribution to network)
Lux level	According to the intervention of smart lighting the luminance needs to be measured in order to ensure comfort levels.	Lux meter	Distributed in the streets at medium-size height.
Lighting consumption	The new smart lighting system consumption is necessary to extract conclusions about the performance.	Wattmeter	Lamps supply circuits
Light status	In order to render control systems for smart lighting, the status of the light is necessary.	Relay	Lamps
Light dimmer	One of the control parameters is the dimmer in order to regulate the lux.	Dimmer	Lamps
Water flow	The heat recovery system needs to measure the performance, therefore, the water flow is necessary.	Flowmeter	Water ducts
Pump power	By means of the power, it may be extracted performance in terms of operation hours, consumption, etc. of the heat pump.	Wattmeter	Heat pump
Inlet/Outlet temperatures	To complement the water flow, the temperatures of the heat recovery systems are very useful.	Temperature probe	Water ducts

Table 13: Monitoring equipment in Sonderborg

Looking at the monitoring equipment, Sonderborg covers most of the solutions from the previous lighthouse cities. Then, from a holistic point of view, Figure 7 depicts the measurements taken depending on the infrastructure. Then, the below part represents the district heating with the measurements of the DHW and heating circuits both as output of the boilers and entrance of the buildings. Taking into account the wind energy, the energy contribution and the active/reactive power are necessary. Similar happens to the solar plant. Finally, with respect to the smart lighting systems, mainly energy, lux level and status are the three variables. Of course, all this information is integrated into the CIOP.

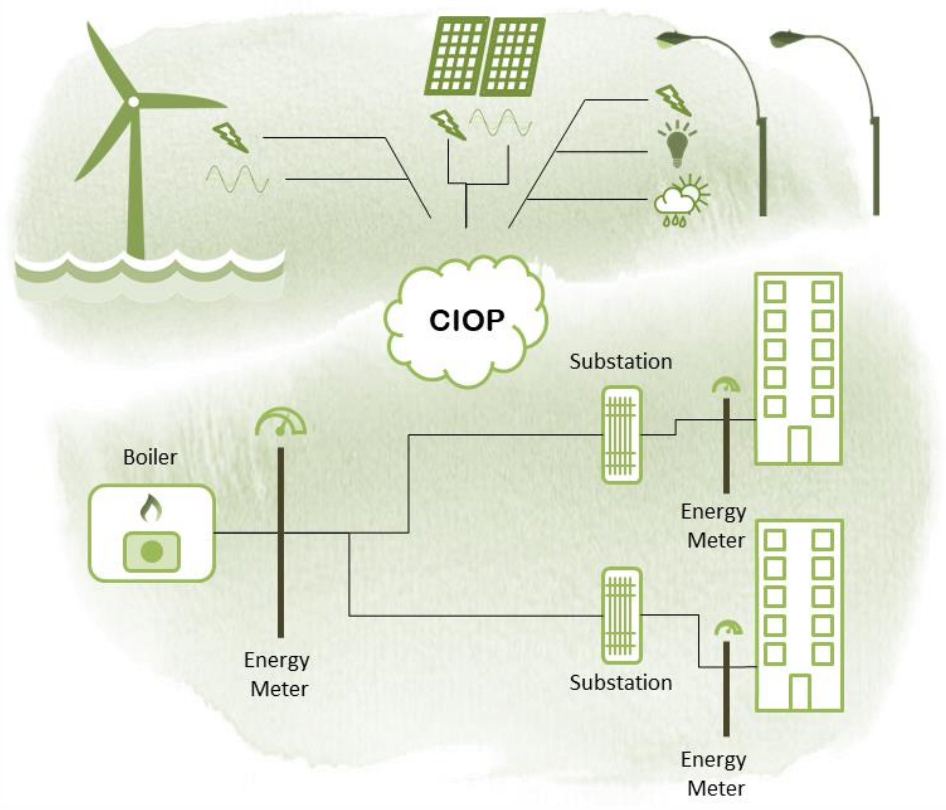

Figure 7: General overview of the monitoring equipment

In regards to the CIOP, in the case of Sonderborg, it is a cloud-based system that collects IoT data. From technical point of view, the VikMote VX40i M2 Pro product line is being used. The VikMote VX40i M2 Pro includes the VikMote VX40i M2 Pro and the VikMote VX40i M2 Pro+. The VikMote VX40i M2 Pro has been designed from the ground up for professional wireless industrial applications with its strong on-board I/O capabilities and multiple communication interfaces such as: dual RS232, dual RS485, 1-Wire, CAN and USB. Housed in a standard DIN-rail encapsulation, it is a perfect component for automation and control applications. The on-board I/O system can be expanded almost indefinitely and completely transparently by adding external MODBUS compatible I/O modules. This unique I/O expansion capability, combined with the ability to operate as a MODBUS master and slave simultaneously, positions the VikMote unit DX4i pro as the perfect product for SCADA-like applications.

The VikMote VX40i M2 Pro is based on the X32 Execution Architecture offering high performance along with a large memory capacity for both program and data - meeting the requirements of today's most demanding and sophisticated M2M/IoT applications.

The VikMote VX40i M2 Pro rests on the M2M Platform which brings all the necessary tools together to develop, implement and maintain today's sophisticated M2M/IoT applications. The VikMote unit Gateway 2 is the corner stone of the communication infrastructure and ensures reliable two-way device communication in any network environment. Deploying and maintaining new application and firmware versions for devices in the field is handled by the powerful RTCU Deployment Server.

The digital outputs control eight “high-side” switches. They function like a contact, where one side is connected to the positive supply of the VikMote unit and the other is the output. The switches are protected against short circuit, ESD and electronic kickback from inductive loads such as relays etc. The maximum switchable inductance is 20mH and must not be exceeded. The digital outputs are supplied directly from the SUPP power pins which also supply the rest of the VikMote unit. As the power is also the main power of the unit, a power-fail would also affect the digital outputs. The VikMote VX40i M2 Pro series offers very advanced power management which makes it possible to have one or more outputs enabled while the VikMote unit is in low-power mode.

The VikMote VX40i M2 Pro series has four analog inputs which can be configured individually to work either as voltage or current measurement inputs by using the configuration jumper. The range in voltage mode is 0- 10VDC and in current mode it is 0-20mA. The conversion resolution is 12 bit. By default the analog inputs are configured as voltage inputs, and are converted to a digital value with a resolution of 10-bit before being presented to the application (0..1023). The application can change the resolution to the full 12 bit (0..4095). The input signal is connected between AINx and AGND. AGND must be connected to the reference of the connected equipment.

The analog outputs can individually be configured to work either as voltage or current outputs. The range in voltage mode is 0-10VDC and in current mode it is 0-20mA. The resolution of the digital-to-analog converter is 10bit or 1024 in decimal scale. The decimal value for 10V/20mA output are 1023 and 512 for 5V/10mA. As default the outputs are configured as voltage outputs. For placement and configuration of the hardware jumpers inside the unit, please refer to the unit configuration guide in Appendix A. The output signal is connected to external equipment between AOUTx and AGND. AGND must be connected to the reference of the connected equipment. In current mode the specifications for the analog output only valid if the load is maximal 250Ω. Each output is ESD and transient protected.

6 Commissioning plan guidelines

After the definition of the equipment, one important aspect to be taken into consideration is the commissioning of the equipment. In this way, D7.6 already provides an explanation about the commissioning process for the monitoring system. As the monitoring equipment is similar in both deliverables, it does not make sense to repeat the same description of the procedure. Hence, this section summarizes the six stages, while more details are available in D7.6.

- Design
  - This phase is established for the collection of the monitoring requirements, what has been done in D7.6 and D7.8 (as well as the upcoming D7.7). Moreover, the planning is also detailed.
- Initial setup
  - Once the equipment is delivered, initial calibrations are necessary in order to ensure proper measurements.
- Installation
  - Physical deployment of the devices in the monitoring location.
- Commissioning & set up
  - After installing, the test of the data gathering and fine-tuning process is carried out. Besides, continuous monitoring is left along some days to assure communication continuity.
- Maintenance & data collection
  - Devices may break or miss calibration, therefore, maintenance is the phase where the staff is in charge of keeping the quality. Moreover, the data collection is running in order to store the information in the persistent databases and applying data quality methodologies.
- Decommissioning
  - Last but not least, although out of scope of SmartEnCity, the final stage is dismantling, if necessary, of the equipment.

7 Deviations to the plan

There are no deviations with respect to the plans, neither related to the content envisaged.

8 Outputs for other WPs

This document provides output mainly for activities and deliverables under WP7 although also has a reflection on the activities carried out on the LH cities, as there is where the final implementations take place.

The evaluation scheme that has been drawn through the different documents delivered previously on WP7, have its continuation on D7.6, D7.7 and D7.8 monitoring programs.

The evaluation scheme started to be deployed in D7.1 and D7.2 with the definition of a strategy of evaluation consisting of a set of objectives to be reached and KPIs for their evaluation. This strategy was be validated by the local partners participating on the interventions and depicted on the evaluation plan delivered in D7.3 jointly with D7.4, where the procedures for the evaluation of the baseline and final performance of the interventions were described.

The baseline evaluation of each LH city has been included as part of D3.2, D4.2 and D5.2 respectively by applying the protocols described in D7.3 and D7.4. In parallel, the monitoring programs deliverables for the district retrofitting and integrated infrastructures actions and the data collection approach deliverable have been defined. Those documents jointly show how the data gathering and collection from the different sources (dwellings, buildings, district, vehicles, etc.) will be done to allow a final evaluation of the final performance. The final evaluation will be done under task T7.5 and the results of this assessment included on Deliverable D7.13.

Also, a final report including the detailed information of all monitoring elements and the data collection process will be done at the end of the project (D7.12).

Figure 8 below shows the process described before of the evaluation scheme in parallel to the corresponding tasks/deliverables associated:

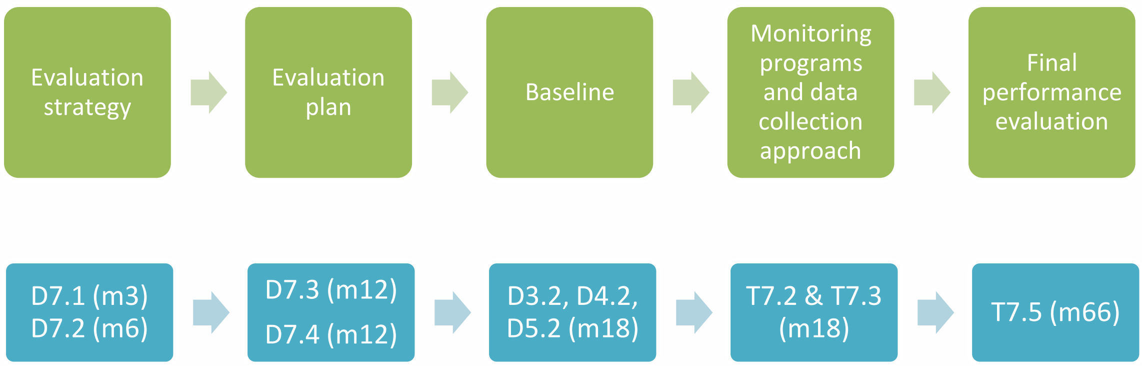

Figure 8: Deliverable D7.8 in the framework of the evaluation scheme

In parallel a follow-up process is done to check periodically the advances of the actuations, and the implementation of the different measures, as well as the data collection process. This will be contemplated on internal periodic reports and also on the supervision of the interventions deliverables (D7.5, D7.10 and D7.11).