TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ ✣ TARTU ✣ SONDERBORG

Deliverable 7.9: Data Collection Approach

WP7, Task 7.3

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Abbreviation/Acronym	Description
APP	Application Software
BEMS	Building Energy Management System
CAR	Fundacion Cartif
CEA	Centro de Estudios Ambientales
CEE	Agrupación Cluster de Electrodoméstcs de Euskadi
CIOP	Common Information Object Protocol
ERP	Enterprise Resource Planning
ETL	Extraction, Transform and Loading
EC	European Commission
ECM	Energy Conservation measures
EV	Electric Vehicle
HEMS	Home Energy Management System
ICT	Information and Communication Technology
IBS	Institute of Baltic Studies
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LH	Lighthouse
MU	Mondragon University
NA	Not Applicable
PLAN	Planenergi Fond
RES	Renewable Energy Source
SCIOSS	Platform for Internet of Things
SmartEnCity	Towards Smart Zero CO_2 Cities across Europe
ZERO	ProjectZERO
TAR	Tartu Linnavalitsus
TREA	Mittetulundusühing Tartu Regiooni Energiaagentuur
UTAR	Tartu Ülikool
VIS	Vivienda y Suelo de Euskadi
WP	Work Package

Table 1: Abbreviations and acronyms

0 Publishable summary

This deliverable defines the data collection approach as one step in a series of processes for developing a cohesive approach for information collection in the SmartEnCity framework and assessing the possible impacts of the interventions in selected topics.

This deliverable first describes the importance of data collection approach, describes the link to the data model, detangles the data collection process starting from defining the requirements and ending with data storage and visualization, and constructs the data flow in the SmartEnCity CIOP. Secondly, an important focus is set on data quality aspects. Thus, a methodology for supervision of data collection is described that also includes indicators for data quality assessment. More specifically related to the three LH cities, data quality approach for every LH city is described. This includes description of different data sources used and defining the data quality assessment procedures.

The core of this document focuses on the general procedure proposed for the data collection approach and, also, on procedures implemented in the LH cities. Since the KPIs are the key to assessing the impacts of the project interventions, a detailed description of connections between KPIs, data sources and associated quality assessment procedures is brought. These are listed in the Annexes.

1 Introduction

1.1 Purpose and target group

SmartEnCity aims to contribute to create Smart Zero CO_2 Cities across Europe through urban regeneration strategies, integrated urban plans and district integrated interventions. The success of the interventions on different levels can be measured. This deliverable aims to provide a framework for data collection in city impacts (D7.4) and in eight different themes (D7.3) that have been defined by previously developed seven protocols:

- Energy Assessment Protocol,
- ICT Protocol,
- LCA Protocol,
- Mobility Protocol,
- Social Acceptance Protocol,
- Citizen Engagement Protocol,
- Economic Performance Protocol.

This approach should contribute to deliver a full and integrated impact assessment. At least two years of full set of data will be considered for the reporting period after the implementation of the actions in each demo site. For this every LH city has defined the data sources, the data collection frequency and aspects to estimate data quality. In addition to defining the framework of data collection this deliverable will also produce evaluation reports to assess the procedure of collecting data. The reports will be made every 6-months to allow a proper supervision and analysis of the data collection process and data quality.

The deliverable has defined a comprehensible and cohesive framework for data collection before, during and after the interventions for every LH city to estimate the baseline, project intervention and possible impacts. The target groups involve LH cities that use the defined protocols and procedures to conduct the data collection. The introduced approach and methodology can be replicated in other cities focusing on the smart city development and measuring its impact.

1.2 Contributions of partners

The following Table 2: Contribution of partners

depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
UTAR	Task leader. Overall content to sections 1 to 3 and 6 to 11. Sections 7 and 8, 11.2.5 and 11.2.6
CAR	Proposal on deliverable structure and inner review of the document. IInput for sections 5, 11.1.3 and 11.2.3, overview of summary of monitoring in sections 6.1.1, 6.2.1 and 6.3.1

MU	Section 4: Data collection approach
VIS	Energy related aspects in sections 11.1.1, 11.1.7, 11.1.8
CEA	Mobility related aspects in different sections (11.1.4, 11.1.5, 11.1.7, 11.1.8)
CEE	Sections 11.1.5 and 11.1.6
TREA	Energy related aspects in sections 11.2.1, 11.2.7, 11.2.8, 11.4.3
TAR	Input for sections 11.2.2 and 11.2.4, mobility related aspects in 11.2.7, 11.2.8, ICT and mobility related aspects in 11.4.2.
IBS	Input for section 11.2.5 and 11.2.6
PLAN	Sections 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.4.3
ZERO	Sections 11.3.5, 11.3.6, 11.3.7, 11.3.8, 11.4.3
ETIC, MTEL	Deliverable review (core part)

Table 2: Contribution of partners

1.3 Relation to other activities in the project

The following Table 3 depicts the main relationships 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
D3.1, D4.1, D5.1 and D3.2, D4.2, D5.2	City diagnosis and baseline have been described in D3.1, D4.1 and D5.1 by each LH city (input for sections 11.1.8, 11.2.8 and 11.3.8). This deliverable (D7.9) is connected to collecting necessary data for baseline calculations that are presented in integrated planning reports before the interventions start for every LH city (D3.2, D4.2 and D5.2).
WP6	One of the main tools for data gathering will be the City Information Open Platform that is developed in WP6, in which information from some fields (i.e. building retrofitting, district heating, smart grid, smart mobility) will be gathered and stored automatically. D6.3 Data Model Architecture Implementation describes the data model that accommodates data from different data sources and demonstrators. Quality checks and surveillance procedures are implemented in some phase of the development of the data model.
D7.1, D7.2	D7.1 KPIs Definition for Pre-intervention Data Collection and D7.2 KPIs Definition for information.

D7.3	D7.3 SmartEnCity Evaluation Protocols compiles the holistic methodology developed for the evaluation of the performance of the interventions carried out in the three LH cities participating in the SmartEnCity project. This methodology consists of seven protocols where each protocol covers the description of the objectives to be evaluated and the methods to be applied. These are represented by a set of KPIs which will be used as tool to quantify the results reached after the execution of the interventions and actions. Specific procedures are described for each city and further advanced in this deliverable regarding data quality.
D7.4	D7.4 City Impact Evaluation Procedure defines the procedure which integrates all the evaluation protocols to estimate the overall impact and performance of the actions at a city level by means of indicators that allow explaining the impact of the integrated actions. Data collection and quality procedures advanced here related to impact measurement described in D7.4.
D7.6, D7.7, D7.8	Monitoring programmes (D7.6, D7.7 and D7.8) aim at the definition of a comprehensive and complete monitoring program in three subthemes: 1) district intervention, 2) vehicle and urban mobility, and 3) integrated infrastructure, that define the necessary requirements for monitoring and metering the actions selected in these three fields.
D7.12	The present deliverable becomes one of the stepping stones for WP7 deliverable D7.12 Monitoring Summary. Further steps in D7.9 include creating evaluation reports every 6-months to provide a proper supervision and analysis of data collection process.
D7.13	The impact of the integrated actions is assessed in D7.13 Evaluation: Assessment of the Overall Performance.
D8.2, D8.7	Replication Toolkit: WP7 deliverables as methodological tools for collecting information and measuring impacts. The methodology proposed could be transferred to the follower cities and through Smart Cities Network as knowlededge acquired in WP7.

Table 3: Relation to other activities in the project

2 Objectives and expected impact

2.1 Objective

This deliverable aims to provide a framework for data collection. The scheme of D7.3 SmartEnCity Evaluation Protocols and D7.4 City Impact Evaluation Procedure are further developed to reach concrete steps that are necessary for data collection to allow the analysis of KPIs that are important for understanding the impacts of the project interventions. At first, an overall data collection approach is described that provides the data model and procedures for data collection. Secondly, for every LH city a specific data collection plan is presented. Also, checks for data quality and validation are introduced to ensure up-to-date data collection.

2.2 Expected impact

The deliverable contributes to a comprehensible and cohesive framework set up for measurisng the possible impacts of interventions in the SmartEnCity framework. The focus has been on data sources and data quality in relation to specific KPIs selected for assessing the impacts of the interventions. Approach described here can be used as one of the tools in the process of collecting information and measuring impacts in the cities intending to implement smart city solutions.

3 Overall Approach

The content of this deliverable is structured as follows:

- Section 4 describes the overall data collection approach, link to the data model, data collection procedures and data flows related to SmartEnCity CIOP.
- Section 5 describes methodology for supervision of data collection approach that helps to assure the data quality and integrity.
- Section 6 presents the description of the data quality approaches for LH cities: selected data sources and data quality assessment procedures. This section relates to sections 11.1, 11.2 and 11.3 that focus on the data sources and KPIs every LH city has selected to estimate the impact of the interventions under 7 different protocols and, also, the city impact. For this, full description of KPIs, input parameters and variables, units, calculation procedures, frequency of data collection and KPI reporting, data sources and methods are provided. In addition, detailed description of data quality assessment is presented in section 11.4.
- In section 7 there is presented the general template for evaluation reports and surveillance.
- Section 8 presents the overall description of reporting data collection for the coming months.
- Section 9 describes the deviations to the plan and section 10 presents the outputs for other WPs.

4 Data collection approach

Data collection is the process of gathering information on specific variables following a systematic method that enables measuring and evaluating outcomes. Data collection is essential to many disciplines. In every discipline, the emphasis is put on ensuring accurate data collection.

In SmartEnCity, protocols in heterogeneous fields (energy, mobility, citizen engagement, economic performance, etc.) need to be analysed. All of them require information and consequently data collection for evaluation.

The heterogeneous nature of those fields implies that data sources and means of data collection and storage might differ. In some cases, data will be provided by systems that include sensors or data acquisition systems that automatically collect data and upload it to a repository. In other cases, it resides in another system's repository and simply needs to be moved or copied. Data can be collected by other methods such as questionnaires, interviews, direct observations or detailed reports and their results are registered in forms (digitally or on paper).

In many cases, some kind of data transformation is necessary in order to present information in a way that eases analysis and evaluation. For example, instantaneous data about electrical power provided by a sensor might not be easy to interpret but the electrical energy consumed by a building during one month is relevant. This second value can be calculated from the information of several sensors like the first one providing information during a whole month.

In this section, the process necessary to collect relevant information from data available in the CIOP platform and how that data is collected originally from the source is outlined. That is, the data flow describes what happens to data since it enters the CIOP platform to the time it is presented on reports or visualization applications.

The section is divided into two subsections. The first one describes how the data collection process related to KPIs is linked to the city platform. KPIs are selected as an example since they are key to the project and are valid to show the whole process. Mainly the data models outlined in WP6 (D6.3) are presented indicating the flow of data between the different data models provisioned for the CIOP platform.

The second subsection includes the description of the process the data will follow from the source to its final storage and further use in the platform.

4.1 Link to the data model

In WP6, the reference architecture for SmartEnCity CIOP is defined (see D6.2 for details). The CIOP architecture is based on AENOR[2]'s reference architecture proposal, standardised as UNE 178104:2015[3]. AENOR's reference architecture (Figure 1: AENOR's UNE 178104:2015 reference architecture) presents the layers and modules necessary to build a platform valid for

[2] AENOR is the Spanish Association for Standardisation and Certification, the standardisation and certification body that represents Spain before European bodies (CEN, CENELEC and ETSI) and international organisations (ISO and IEC).
[3] AENOR intends to standardize UNE 178104:2015 as an ISOstandard in the near future.

Smart Cities. A reference architecture implementation gathers different types of data through the acquisition layer: Real time data (sensor data), Open Data (weather forecast), district heating, mobility, social networks, etc. These datasets are stored and treated in the knowledge layer. The interoperability layer enables the consumption of those data through APIs. The intelligent service layer offers services and applications for the different vertical domains (energy, environment, mobility, etc.) that have been developed based on the Smart City infrastructure and available data sources.

AENOR's reference architecture also proposes several repositories to store the data. The data models proposed in AENOR's reference architecture is generic so one of the tasks in WP6 was to build the data models to be used in the platform. CIOP's data models are defined and implemented in a demonstrator in deliverable D6.3. The selected data models for the CIOP architecture are shown in Figure 2: CIOP's architecture implementation. Data models are interoperable among them. Refer to deliverable D6.3 for details on each of those data models. Finally, it is important to highlight that the data collection approach and data models are quite related. The reason is based on the storage of data samples, i.e. the read measurements are stored within the data repositories, e.g. real-time repo saves real-time data from the sensors and the quality of this information needs to be ensured.

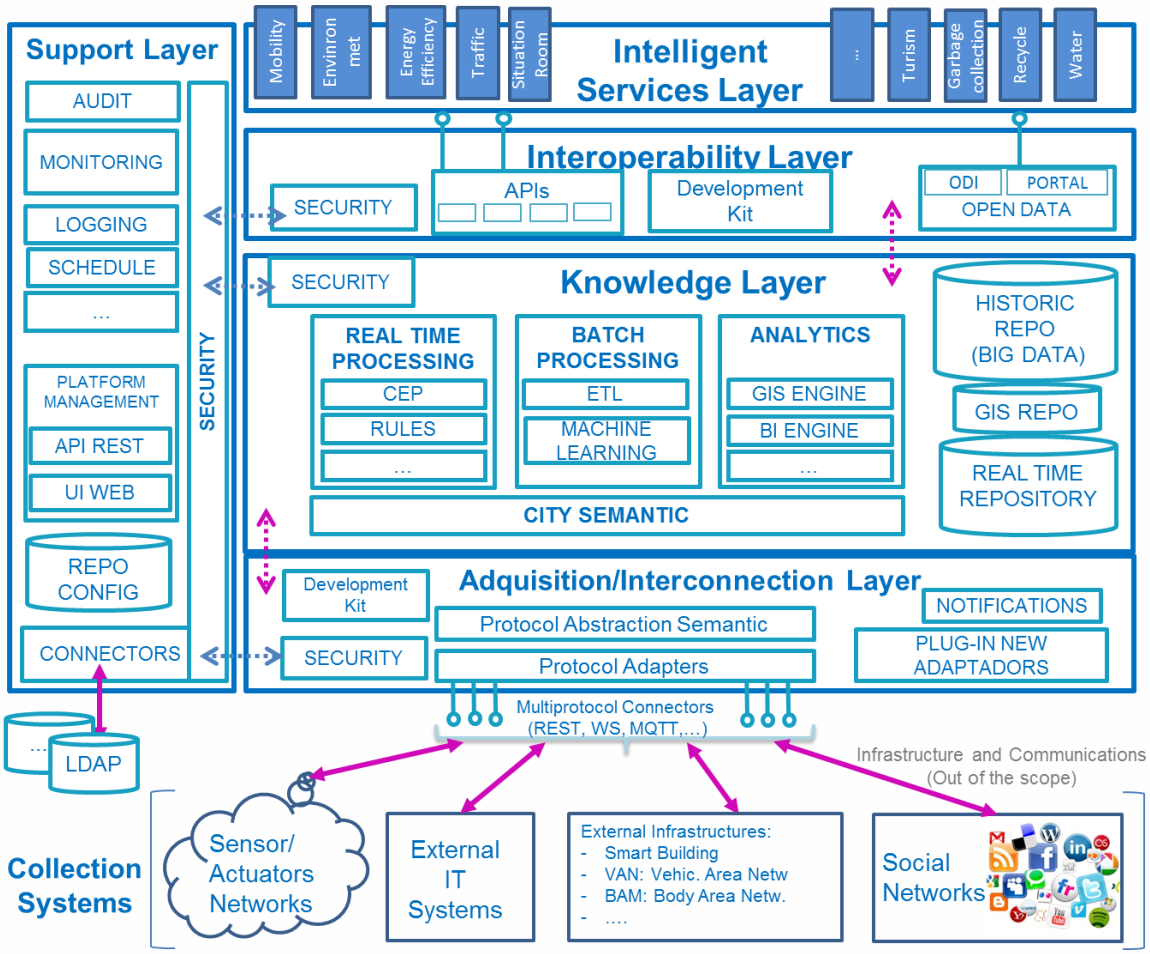

Figure 1: AENOR's UNE 178104:2015 reference architecture

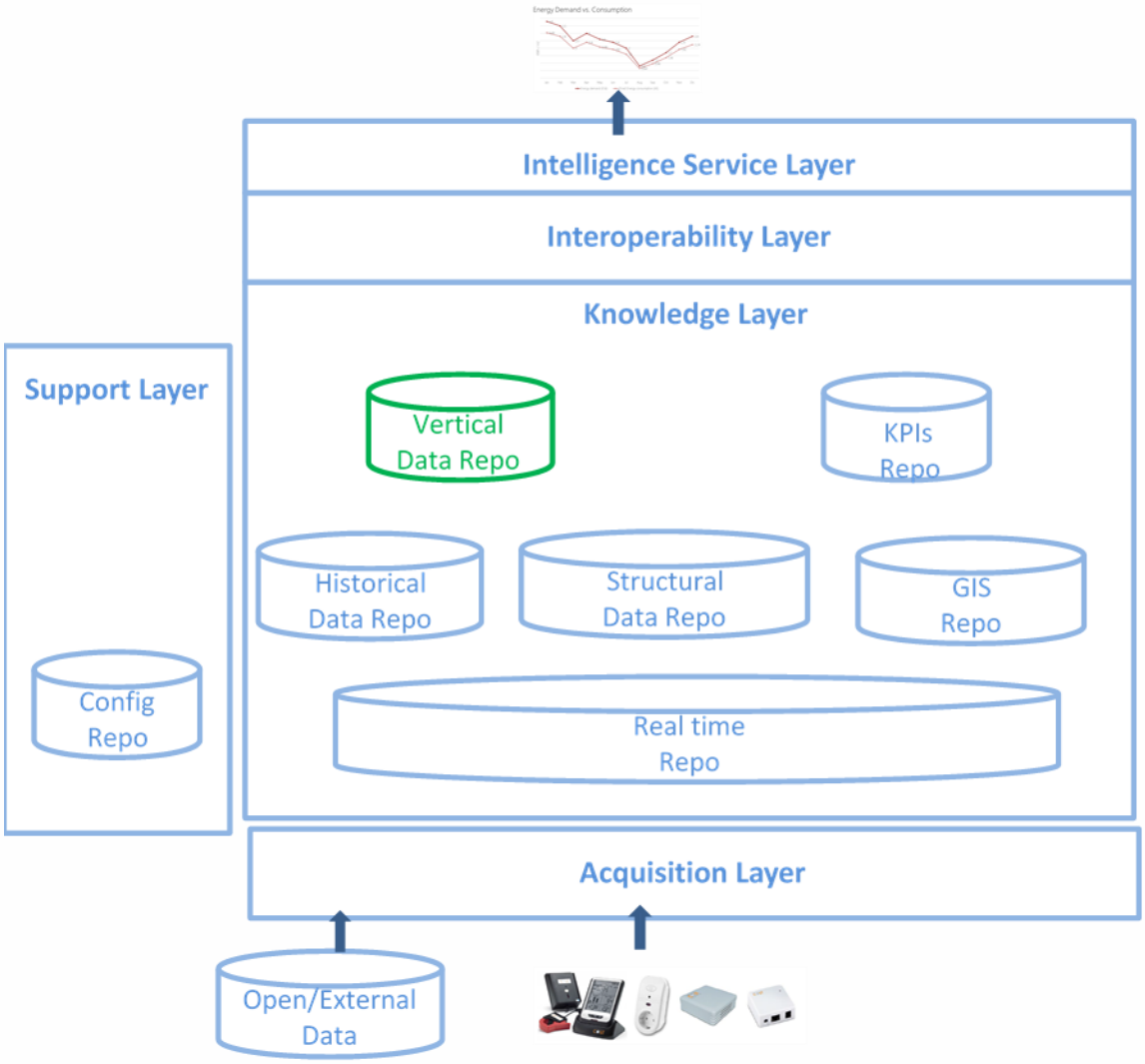

Figure 2: CIOP's architecture implementation

A brief description of each of those models is outlined next.

Vertical Data Repository: Vertical data models are closely related to the different applications and data that is used in the lighthouses (energy, mobility, citizen engagement, etc.). Therefore, the implementation of this repository depends on each lighthouse and the application to be developed in those (for example, an application to present the availability of electrical charge stations in a city or the energy consumed by a given building).

KPI Repository: The data model for the Key Performance Indicators (KPIs) is the that stores the calculated/aggregated key indicators. KPIs have been modelled for the considering the KPIs and the context selected in this work package (WP7). Its data representation (data model) has been deployed in a demonstrator available in WP6 6.3). The data model used for the demonstrator in D6.3 is shown in Figure 3: The KPI data model for the demonstrator

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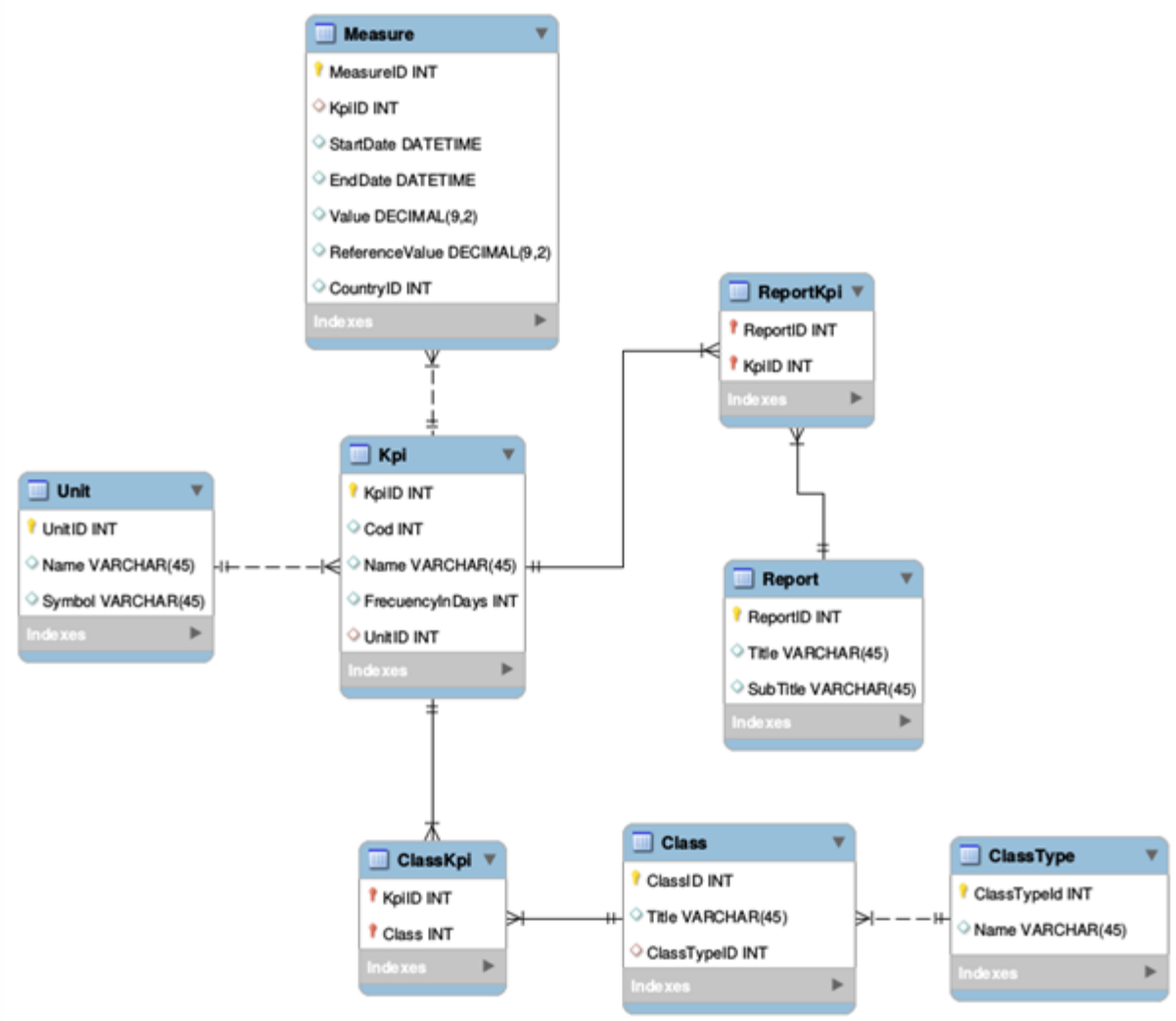

Figure 3: The KPI data model for the demonstrator

Historical Data Repository: The objective of the historical data repository is to store the historical data collected in the platform. Historical data is gathered from other repositories and stored permanently in a common space where historical data can be recovered if necessary (data analysis, disaster recovery, etc.). Historical data is moved from one of the other "live" repositories to this one in order to free up space in the main repositories (verticals, real time, KPIs, etc.).

Structural Data Repository: The data model for the Structural Data Repository stores the urban data model, which sets the basis for the structural information of the city. The structural data repository is based on the standard CityGML, which is an open standardised data model and exchange format to store digital 3D models of cities and landscapes.

GIS Repository: In this repository, the information to describe geographically the city area is kept. It stores the 2D geometry of the common city elements as well as the alphanumerical info associated to them. This repository is closely related to the structural repository mentioned above and will take the data stored in it to complete the information.

Configuration Repository: The Configuration Repository is the database where information to manage the different users, profiles and security permissions is stored. The Configuration Repository acts in a transversal way to the rest of the layers and components of the platform.

Real-time Repository: The Real-time Repository stores data coming from sensors, systems, other applications or repositories, etc. Its purpose is to collect information in real time that will latter be processed in the platform.

Since KPIs are the core of this work package, it is important to understand the or links of the KPI repository with other repositories. This is presented in Figure 4: Related data models and data flow

Having in mind the relationships, it is remarkable that the data quality process within the data collection approach takes into consideration the KPI repository as pivotal because it allows the final performance. Nevertheless, the related repositories are also important because they feed the KPI repository. For instance, thanks to the real-time and historical repositories, KPIs may be calculated, then, the quality of these two repos is crucial.

. Two types of relationships are identified: data flows (blue arrows) and logical or data model relations (red thin arrows). Thin red lines in Figure 4: Related data models and data flow

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show which repositories are related from the KPIs point of view, while thick blue lines show how the data coming from outside the platform, that is needed to calculate the KPIs, flows through the different repositories of the platform. These data flows may include processing and modification of the data as it moves from one repository to another, i.e., it is not just moving the data around. Data flows are explained in the next subsection 4.2.

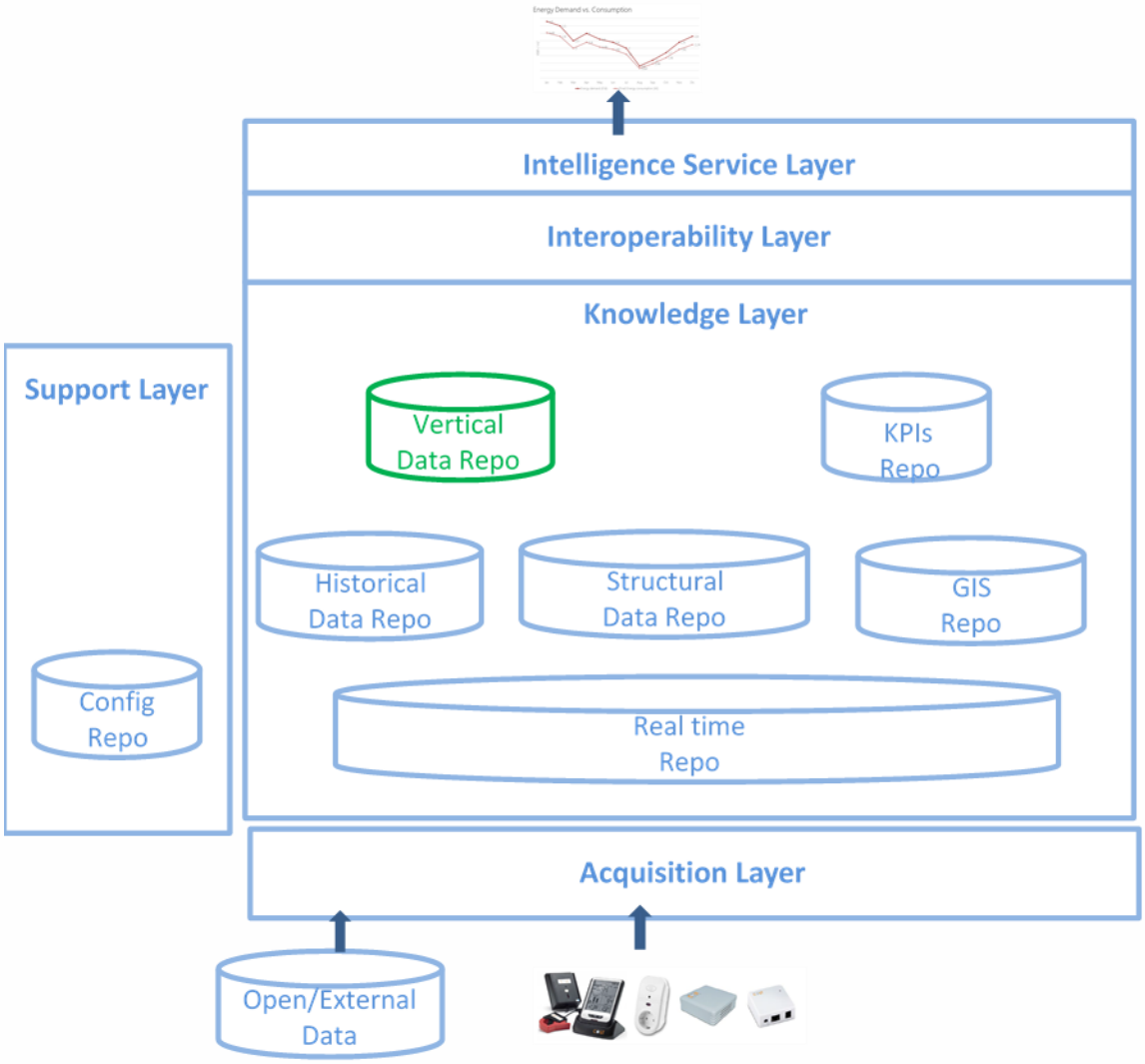

Figure 4: Related data models and data flow

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4.2 Data collection

Data collection in a platform is a process that goes beyond the action of just uploading data. Data can be transformed, aggregated, filtered or used for calculation in complex formulas. In the process, there are several phases. Those phases are not sequential. They are iterative, in that feedback from later phases may result in additional work in earlier phases (Figure 5).

Data requirements: The data necessary for the analysis are specified based upon the requirements of those conducting the analysis.

Data collection: Data are collected from a variety of sources. The data may be collected from sensors in the environment, such as traffic cameras, SCADA systems, environmental sensors, etc. It may also be obtained through interviews, downloads from online sources, or by registering events.

Data cleaning: Data may contain duplicates or errors, or might be simply incomplete. Data cleaning is the process of preventing and correcting these errors. Common tasks include record matching, deduplication, and column segmentation. There are several types of data cleaning methods. Quantitative data methods can be used to get rid of likely incorrectly entered data. Textual data spellcheckers can be used to lessen the amount of mistyped words, etc.

Data aggregation: Having completed data sets of data, it is possible to perform data aggregation of data samples. This step covers KPI calculation where the single data sets that have been analysed during the previous step are aggregated to obtain meaningful data to assess final performance. Here, interpolation techniques are wide, such as linear, polynomial and other interpolation algorithms. Apart from the KPI calculation, a second issue is data visualization, which sometimes needs aggregated data at visualization level to be compliant with privacy regulations.

Data processing: Raw data initially obtained can be processed or organized for analysis. This phase is part of the intelligence cycle used to convert raw information into knowledge. Mathematical formulas or **models** called **algorithms** may be applied to the data to identify relationships among the variables, such as correlation or causation. Some algorithms are regression, classification, random forest, neural networks, Bayesian networks, etc. Another approach to data processing is the generation of data products. A data product is a computer application that takes data inputs and generates outputs, feeding them back into the environment. It may be based on a model or algorithm. An example is an application that analyses data about customer purchasing history and recommends other purchases the customer might enjoy. A specific type of data processing is data aggregation.

Data storage: It is the action or phase of saving data in a repository. There are many techniques to store data. The alternatives go from structured database systems to non-structured data systems such as distributed file systems (Hadoop Distributed File systems or Google File systems) or no relational databases (noSQL). Depending on the technology used for storage the tools for data analysis and processing change.

Data analysis: Data analysts may apply a variety of techniques referred to as exploratory data analysis to begin understanding the messages contained in the data. The process of exploration may result in additional data cleaning or additional requests for data, so these activities may be iterative in nature. Descriptive statistics such as the average or median may be generated to help understand the data. Data visualization may also be used to examine the data in graphical format, to obtain additional insights regarding the messages within the data. Moreover, whitin this process, data completion is included whose aim is the “reconstruction” of data trends to have continuous data. This process bridges data gaps that may appear during data collection.

Data visualization: Once the data is analysed, it may be reported in many formats to the users of the analysis to support their requirements. The users may have feedback, which results in additional analysis. As such, much of the analytical cycle is iterative.

When determining how to communicate the results, the analyst may consider data visualization techniques to help clearly and efficiently communicate the message to the audience. Data visualization uses information displays such as tables and charts to help communicate key messages contained in the data. Tables are helpful to a user who might look up specific numbers, while charts (e.g., bar charts or line charts) may help explain the quantitative messages contained in the data.

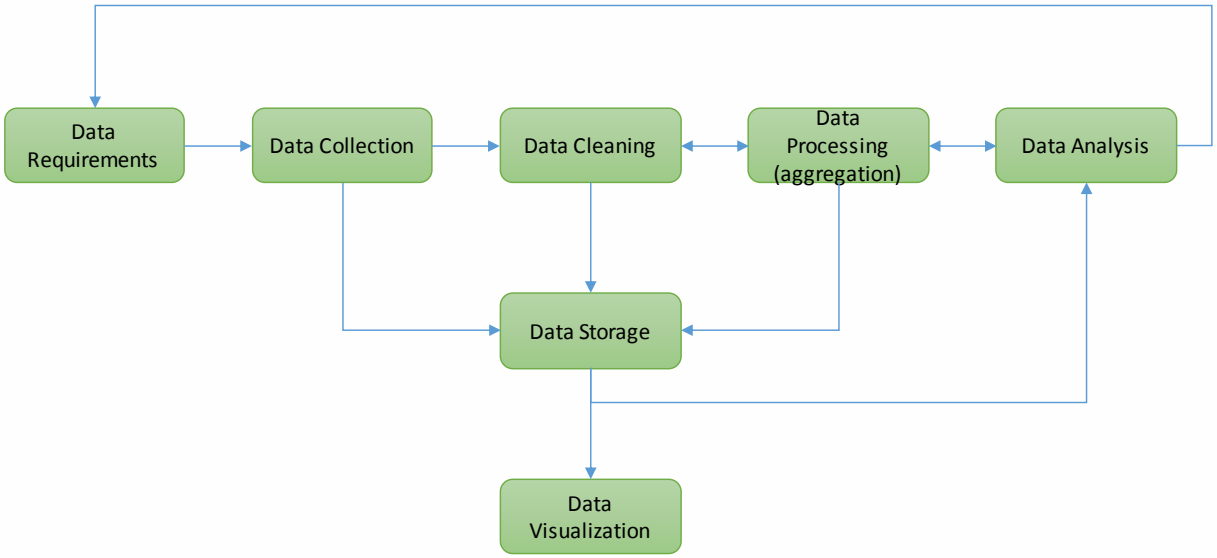

Figure 5: Data Process

4.2.1 Data flow construction in SmartEnCity CIOP

The different applications and solutions to be provided in SmartEnCity are data centred. Thus, different flows of data are considered depending on the process data to be followed for a specific application or solution. A data flow is the process the data follows from the moment it enters the platform until it is consumed by an application. As it was shown in the previous section, the data process includes data uploading/collecting, transformation, storing, analysis, recovering and data downloading or consumption (visualization).

Each application may depend on different data sources, may apply different processing algorithms or models for analysis and may be presented in a different manner. The storage of that data might be different as well. Some data are locally stored in structured databases; other might come from other repositories (structured or not) or even from external sources (open data). Consequently, each application builds the data flows depending on those characteristics.

In order to have a common framework to design, construct, validate and commission the data flows, this section describes a framework based on (Ralph Kimball, 1998) data processing lifecycle. The framework is shown in **¡Error! No se encuentra el origen de la referencia.** and it is used for the definition of the data quality methodology.

Next, the details of each stage are presented.

Project Planning: The objective of this stage is to plan all the possible activities that ensure an effective and efficient time, human and material resource management for the data flow lifecycle.

Project Management: The objective of this stage is to track project planning and adjust the plan if issues happen.

Business Requirements Definition: The aim of this stage is to collect requirements to determine the key factors affecting the project by focusing on what data flow stakeholders need. Major opportunities across the project are identified, prioritized based on value and feasibility, and then detailed requirements are gathered.

Data Modelling: The objective of this stage is to understand the data flow end to end in relation to the platform and to design the repository data models required for the data flow.

Technical Architecture Design: The objective of this stage is to design the architecture required to make possible the data flow.

Product Selection, Installation, Configuration and Security: Based on the technical architecture designed, the product selection must be done, followed by the installation and configuration.

ETL Design and Development: The objective of this stage is to design the necessary data extraction, cleaning, validation and transformation rules to certify data quality in the data flow process.

Data Gathering Application Design and Development: The objective of this stage is to provide an intuitive/efficient interface to collect data involved in the data flow.

Data Delivery Application Design and Development: The objective of this stage is to provide an operative interface to extract data from platform.

Validation: The aim of this stage is to contrast with data flow stakeholders the accomplished developments. If requirements are not properly covered, a new iteration of the process should be performed.

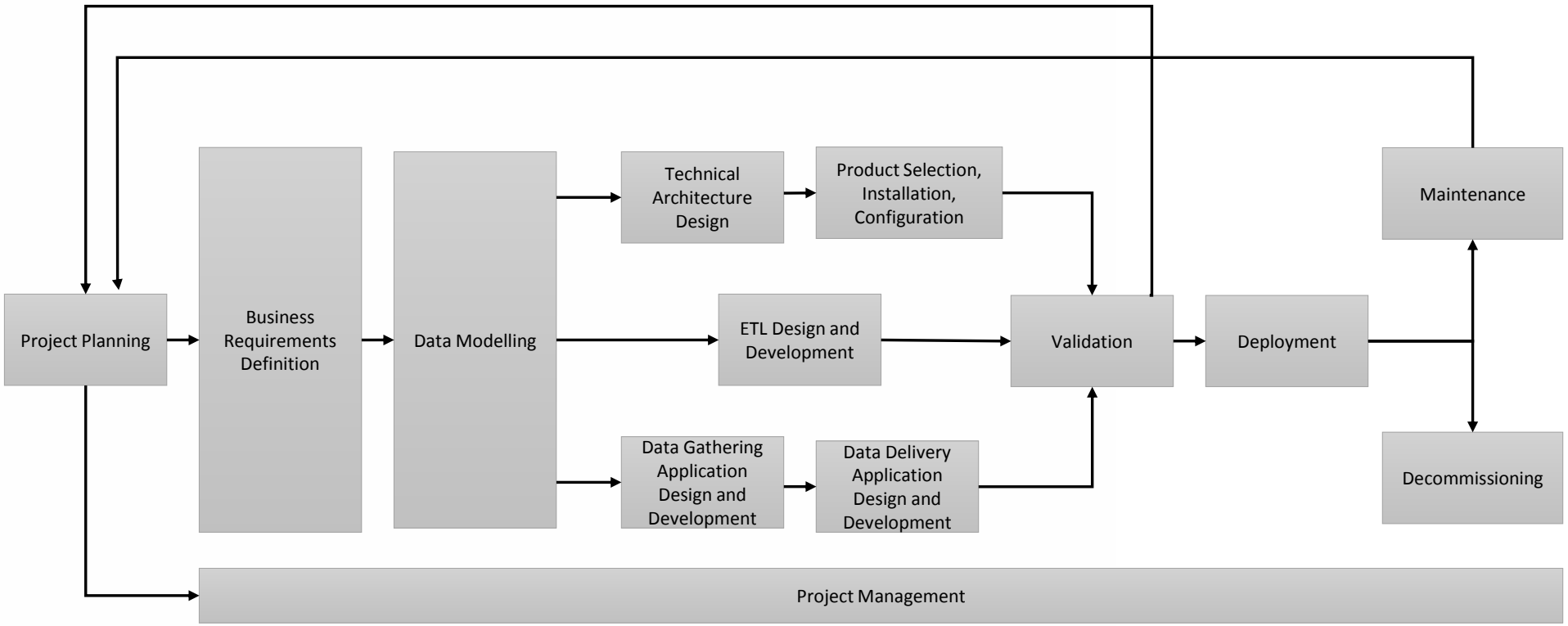

Figure 6: Data Process lifecycle

Deployment: The objective of this stage is to deploy the solution in the environment where the stakeholders will use it.

Maintenance: The objective of this stage is to deal with issues identified during the usage of the data flow solution. If required a new work iteration should be performed.

Decommissioning: The objective of this stage is to define the procedure to be carried out to ensure data flow dismantle.

The focus of this WP is on KPIs and consequently this section focuses on the data flows necessary to calculate and present KPIs, including the aforementioned repositories necessary for this KPI calculation process. KPIs are calculated in a different manner depending on their nature.

Some KPIs are calculated by aggregating data from sensors and computing their values for specific periods. Additional data might be required in these cases such as constants (conversion factors), structural data (surface of building or district) or data from external sources (weather forecast). Other systems such as SCADAs might be the providers of data.

Other KPIs might be the result of surveys. Depending on the survey, the way to score those KPIs might be quantitative or qualitative. Those data might be stored in digital files. Data extraction and transformation tools might be necessary in those cases.

Economic KPIs are the result of economic calculations from data not always available at CIOP level (available at companies' ERP).

Independently to the type of KPI or data flow to be constructed, the data process framework proposed in this section will be used to guarantee a successful completion of all activities required in the data flow lifecycle.

5 Methodology for supervision of data collection approach

Based on the aforementioned Kimball's Lifecycle methodology[4], SmartEnCity has adapted this methodology for the case of the Data Quality aspects, which is the objective of the present deliverable. While Kimball approach includes the complete life cycle of the monitoring process, this document treats exclusively the consistency and coherency of the data, being part of other deliverables in the definition of other steps within the monitoring life cycle, for example, D7.6, D7.7 and D8.8.

Having clarified the scope, data gathering is not an uncontrolled collection of data, but quality and up-to-date information should be considered in the data collection approach. Then, it is necessary to ensure data quality with surveillance tools that check the inconsistencies and/or errors in the data sets. In this sense, the proposed approach is illustrated by the diagram in Figure 7**¡Error! No se encuentra el origen de la referencia.**.

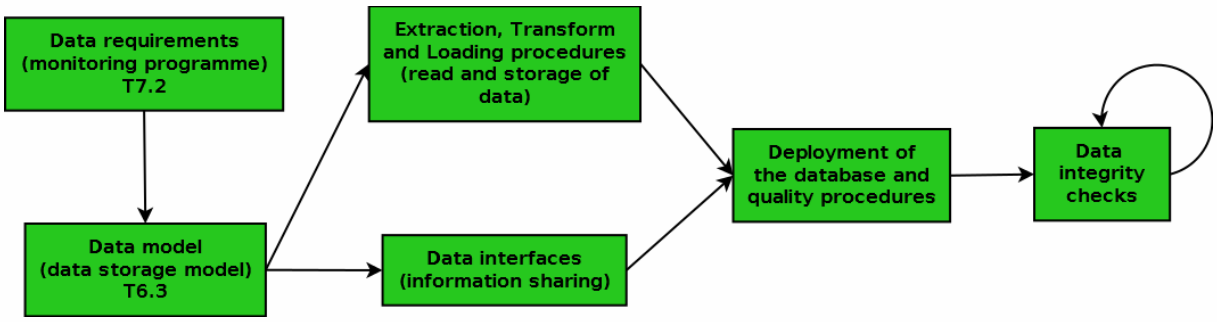

Figure 7: Data quality approach

In the picture above, the left side is focused on the inputs from other tasks of the project. In particular, data quality methodology needs data that come from the monitoring network, which is defined in T7.2. Moreover, simply monitoring is not enough and the information should be stored in a persistent way, i.e. the data model that is defined in T6.3 (see also section 4.1). Having the monitoring programme and the data storage system ready, data collection may begin. There are several steps as follows:

1. Extraction, Transform and Loading (ETL) procedures implementation to get data from the data sources, adapt the information into the data model and persistently store data. This stage is periodical, being data samples read from the field with a pre-defined frequency, as well as for some cases eventual when any data point must be stored according to a change of value (CoV), for instance, occupancy.
2. A second stage, after or in parallel with the implementation of the ETL procedures, is the definition of the data interfaces through which the data will flow both for reading and writing. These are key points in the data collection approach because the interface determines the channel by which data are inserted and/or obtained.
3. Next step is the deployment of both the database according to the aforementioned data model defined in T6.3, including the ETL procedures of step 1, and the interfaces of step 2. Then, the combination of the elements will constitute the data

[4] Ralph Kimball DW/BI methodology http://www.kimballgroup.com/data-warehouse-business-intelligence-resources/kimball-techniques/dw-bi-lifecycle-method/

collection approach itself where data will flow from data resources to the database, as well as from the database to the sharing interfaces (e.g. CIOP services).

4. Finally, data collection is able to run until step 3, but data quality may not be assured. That is why the data integrity checks ought to be deployed too. The intention is the supervision of the data quality. In this sense, the most used methodology is the application of stored procedures which periodically check stored data to calculate a set of indicators (defined in the following subsection 5.1) with the aim of assessing the data quality.

5.1 Indicators for data quality assessment

Once the methodology is explained, it is also necessary to determine an objective procedure to evaluate the quality of data. Then, a set of indicators are very helpful for this goal. It is important to remark that these indicators are not related to the indicators defined in previous deliverables for the project. In contrast to them, the set of indicators for data quality are very specific and applicable just for data quality procedures, being this the reason for not having established them at project level.

As stated before, indicators are the way to measure the quality of any process in an objective manner. Then, it is important to establish criteria about the evaluation of the surveillance tools, and therefore, the set of indicators that are being defined in this section will comply with both the data quality and the data failure. In fact, two subsets are determined. Starting with the data quality indicators, the next bullets describe those that are to be applied in SmartEnCity.

- Data completeness. First of all, data completeness indicator aims at calculating the lack of data samples or even the duplication of information. In this sense, the indicator measures the percentage of data samples that are stored in contrast to the expected ones. For instance, if the temperature variable is measured every 15 minutes, this means there should be 4 samples per hour, 96 per day and 2,880 per month. Thus, in a hypothetic situation of having 2,304 samples of this variable in one month, this would mean that 80% of data is saved. Regarding the frequency of data checks is up to the demo site implementation to define it, meaning, the demo is free to select daily, monthly, etc. basis for the checks, although they are recommended monthly checks. On the other hand, the success of the indicators is set in a threshold of at least 90% of data samples per month. Note that the value could also be higher than 100%, in case that duplicated values are inserted in the database, which is not desirable at all. Nevertheless, this case is related to the surveillance methods explained below. Finally, the formula would be the following:
    - $DataCompleteness_{\mathrm{var}i,j}(\%) = \frac{samples_{i,j}}{totalsamples_{i,j}} \times 100$, where "*i*" is the variable (e.g. temperature) and "*j*" is the frequency (e.g. month 4). The numerator counts the samples in the database, whereas "*totalsamples*" are the expected registers.
- Out of range. Once checked the previous aspect, data could be completed up to 100%, but, there is a second type of mistakes when storing data into databases to be checked, that is having out of range values. Imagine that the indoor temperature is

being gathered without loss of communication (i.e. 100%), but all the polls are 60ºC. This value does not make any sense when measuring an indoor temperature. In this way, each demo (according to its specific monitoring programme and, hence, variable) should define the thresholds for the data-points. In terms of evaluation, the indicator would provide the percentage of data samples that are out of range in a specific time slot (see previous indicator). The method for obtaining the indicator is depicted below.

- $\begin{cases} data-sample \geq \max \ldots \sum_{i,j} values\_out\_of\_range \\ data-sample \leq \min \ldots \sum_{i,j} values\_out\_of\_range \\ other \ldots do\_nothing \end{cases}$, where "*i*" is the variable and "*j*" the periodicity, similar to the case before. Then, if the data-sample is out of either the maximum or minimum, the counter of the values out of range is incremented in one unit. Once got all the values out of range, the final value of the indicator is as follows.
- $Out\_of\_range_{\mathrm{var}i,j}(\%) = \frac{values\_out\_of\_range_{i,j}}{totalsamples_{i,j}} \times 100$, where the success criterion is to have less than 5% of samples out of range, according to the error ranges that the manufacturers of equipment provide.

These two indicators are enough to determine the data quality because they provide both an overview of lack of data and data correctness, having the information within the range.

Additionally, surveillance procedures complement the indicators. The following methods are to be set up within SmartEnCity project:

- Communication losses. One of the major issues when gathering data is related to communication losses which come with data gaps, being thus, associated with the data completeness indicator. Keeping this in mind, this surveillance procedure should warn if a communication channel cannot be established with the data source, whichever it is. Hence, an alarm would be launched to report the responsible about this communication loss with the aim of minimizing the data gaps.
- Interpolation. Similar to before, this procedure is associated to the data completeness in the sense that a method for interpolating data needs to be set when data gaps appear and, thus, complete a continuous and harmonized trend of data. There exist several methodologies, such as linear, bilinear or polynomial interpolation, but each demo should select the method, if any, to be applied according to certain boundary conditions and/or the variable itself. As said, each demo will be able to select to which variables will apply this surveillance procedure, to all of them or only to a group of them depending on the needs and importance (e.g. since energy is pivotal having in mind that the evaluation of the final performance will be carried out based on this value, this variable must logically be one of the selected).
- Data correction. This last procedure is mostly related to the out of range values, although it also requires the interpolation method. The values that are out of range are not valid for the evaluation; therefore, they should be corrected if any valuable result is foreseen. The way this procedure works is deleting those data-points that are

out of range and, then, it is applied any of the aforementioned interpolation methods to reconstruct the data trend associated to the variable. Nevertheless, this is not always an easy task and not always applicable.

6 Data quality approaches for lighthouse cities

There are several different data sources used to collect the data and information about the effect of interventions. All these data sources have different properties. To guarantee the quality of data, some predefined procedures are implemented.

During the process of data collection evaluation reports are created. The aim of the evaluation reports of data quality and surveillance is to assess the quality of data produced, and if necessary give suggestions for improving the data collection procedure. The focus is on describing predefined routine data checks and surveillance procedures, i.e. data integrity checks (see also Figure 7 in section 5), but other aspects are described as well to grant the supervision of data quality.

Routine checks for stored data integrity are built in to the database for different repositories defined in D6.3 Data Model Architecture Implementation. Thus, data integrity checks can be considered automatic. The repositories include Vertical Data Repository, KPI Repository, Historical Data Repository, Structural Data Repository, GIS Repository, Configuration Repository and Real Time Repository (see Figure 4 in section 4.1 for connections between repositories). In a sense of KPI related quantitative data collection, quality checks on Real Time Repository and Vertical Data Repository that store input parameters as raw data for the KPI calculation, and KPI Repository that stores the KPI values, but also the Historical Repository, are the most relevant.

The data produced are mostly quantitative, i.e. can be measured with numbers. Some data have qualitative meaning, but by using decoding it is still possible to handle the data as quantitative. Since most of the data points take a numerical value, it is possible to implement procedures to assess the data quality with indicators like data completeness and out of range values. In addition, some of the data is qualitative, i.e. data produced by interviews. The validity, reliability and other characteristics of these data is left to assess to the producers of the data.

The indicators to estimate **data quality** and the procedures which periodically check stored data to calculate the set of indicators are depicted in Table 4 (also described in section 5.1).

Indicator	Procedure
Data completeness (%) – calculates the lack of data samples and duplication of information. Interpretation: the success of the indicator is set in a threshold of at least 90% of data samples per month; the value higher than 100% indicates that duplicated values are inserted.	Frequency of quality checks: decided by the LH city, dependent on the nature of the data.

Out of range[5] (%) – calculates the percentage of data samples that are out of range in a specific time slot. Interpretation: the success criterion is to have less than 5% of samples out of range, according to the error ranges that the manufacturers of equipment provide.	Frequency of quality checks: same as for the data completeness indicator. Thresholds: set individually for every input parameter and KPI if applicable.

Table 4: Indicators to measure data quality

Surveillance is done continuously, periodically or once the data are inserted in the database (for interpolation and data correction). Surveillance procedures complement the indicators defined to assess the data quality to help to increase the data quality. The surveillance includes detecting communication losses and the need for editing that is defined as the application of checks that identify missing, invalid, or inconsistent entries or that point to data records that are potentially error. Data editing[6], an activity aimed at detecting and correcting errors, logical inconsistencies and suspicious data can be divided into two: 1) macro-editing is a procedure for tracking suspicious data by checking aggregates or applying statistical methods on all records or on a subset of them; the checks are typically based on the models, either graphical or numerical formula based, that determine the impact of specific fields in individual records on the aggregate estimates; 2) micro-editing is a procedure of exhaustive check to find errors by inspecting each individual observation.

The initial focus of surveillance procedures is on micro-editing using interpolation and data correction where possible. The following methods (described in section 5.1) are to be set up within the SmartEnCity project (Table 5).

Method	Procedure
Communication losses – procedure that warns when communication channel cannot be established with the data source whichever it is. Associated with the data completeness indicator.	Methods for warning procedures will be described in the development of the database. In the surveillance report the description of incidents is reported.
Interpolation – method to provide continuous and harmonized trend of data if data gaps appear. The method for interpolation, if any, should be set and applied according to certain boundary conditions and/or the variable itself and to which variables will apply surveillance procedure.	Interpolation methods used by KPI or input parameter. In the surveillance report the description of incidents is reported.
Data correction – method for correcting out of range values.	Data correction methods used by KPI or input parameter. In the surveillance report the

[5] The procedure for defining out of range values described in section 5.1 describes the calculation procedure for continuous values. Checks can also be done for discrete values, where only a set of predefined values are possible and if the value is not in a predefined list, the value can be defined as out of range.

[6] Eurostat's Metadata Server (RAMON), Concepts and Definitions, http://ec.europa.eu/eurostat/ramon/index.cfm

	description of incidents is reported.

Table 5: Methods for surveillance

In the evaluation reports, to report the data quality there are presented the values of quality indicators for collected data and associated incidents. Besides quantitative indicators as described above, qualitative descriptions are also necessary for understanding the measurable aspects of quality[7] and the procedure as a whole. These include textual assessment and interpretation. Due to the nature of data collected, i.e. having different properties, the choice of which indicators or parameters to use to describe the data collected varies. There is a need to test the template described in section 7 before the final set of aspects besides the predefined quality indicators are selected to describe all the different data types. The evaluation report advances over the course of the project as the data are being collected.

6.1 Vitoria-Gasteiz data collection specific plan

This section gives a generic overview of different data sources used during the data collection process. This section strongly relates to the KPIs (described in section 11.111.2) selected by Vitoria-Gasteiz in preceding deliverables. The description of every KPI includes: definition, unit, data source/method, input parameters, calculation procedure (if applicable), and data collection and reporting frequency (separately for the KPI and input parameters). Although the focus here is on KPIs, it is important to keep in mind that not all the data collected may be related to the KPIs. Also, related to the defined KPIs and data sources the quality procedures are also defined.

6.1.1 Summary of monitoring

Monitoring in terms of district renovation and integrated infrastructures are documented in D7.6 and D7.8 (mobility part is delayed). Vitoria-Gasteiz's solutions are mainly based on the renovation of the thermal envelope and integration of a district heating. In this way, the main parameters that need to be gathered are the energy consumption at three levels: generation, distribution and consumption. That is to say, as represented in Figure 8, the total energy provided by the boilers (including the DHW and heating contributions), building substations distribution and the individual dwelling consumptions are envisaged. As crossed effect, according to the measurement and verification plans, the electricity consumption is also a helpful value to determine the amount of electricity necessary for the new generation and distribution system.

[7] European Commission (2007) Handbook on Data Quality Assessment Methods and Tools. Wiesbaden.

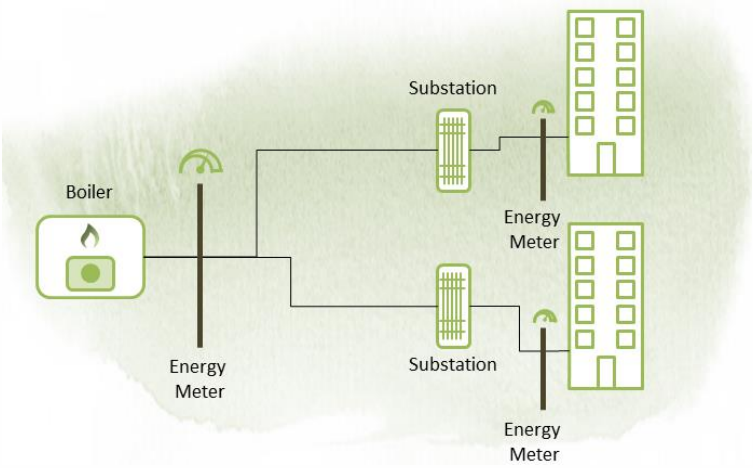

Figure 8: Monitoring schema for Vitoria-Gasteiz

Moreover, at dwelling level, Vitoria-Gasteiz will carry out actions to obtain individual consumption of electricity both at house level and appliances level. Of course, at dwelling level, comfort parameters are important too. In this way, Figure 9 represents the metering equipment to be integrated.

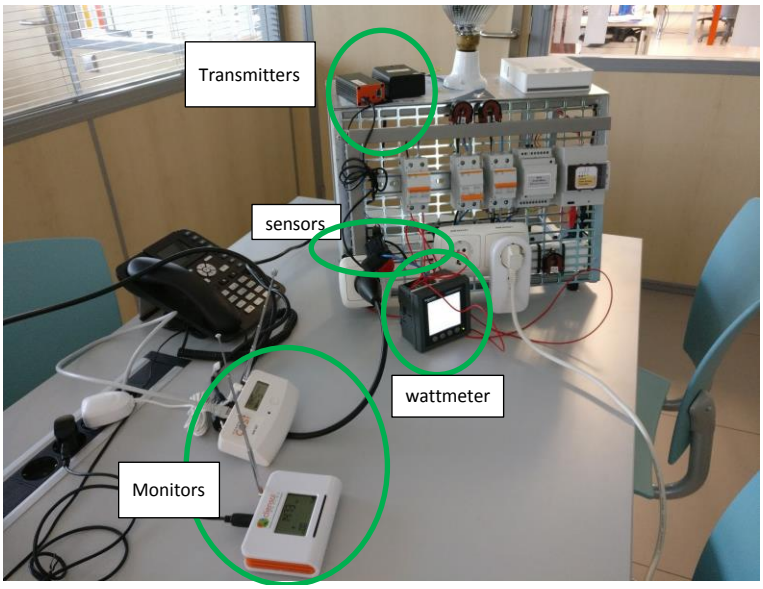

Figure 9: Dwelling monitoring equipment for Vitoria-Gasteiz

6.1.2 Data sources for each assessment protocol

The data sources used can broacly be divided in three: 1) data from monitoring, 2) data requested by surveys, 3) additional data from external sources (i.e. institutions, municipality, etc.), and 4) other data sources (

Data source	Description
Data from monitoring	Quantitative (numerical) data that is derived using automated systems that allow to collect and store continuous flow of data. Included are:

	• Data registered by sensors and monitoring equipment (energy, electricity, temperature, etc.), • Data from the ICT system/platform that automatically stores variables that have been defined previously, i.e. for ICT and mobility. **Data acquiring** The procedures for acquiring requested data are described in section 11.2 under every KPI. See also section 6.2.1. and D7.6, D7.7 and D7.8 for additional information. **Data quality** Frequency to estimate data quality: monthly, annually, once as the data are inserted into the database. For numerical data, there are defined thresholds for the values certain data points can take to calculate quality indicators (completeness, out of range). **Surveillance** Manual checks are implemented for detected faulty inputs. No automatic data correction is implemented. No specific interpolation methods are applied.
Data from surveys	Used to collect both quantitative and qualitative data. Included are: • Questionnaire, • Interview. **Data acquiring** The procedure for carrying out the surveys is defined in section 11.2 for possible cases. **Data quality** Frequency to estimate data quality: once as the data are inserted into the database. For numerical values, it is possible to define thresholds to indicate the possible value the data point can take. For categorical data, the data point can take a value from predefined categories. Besides predefined quality indicators (completeness, out of range), a list of other quality measures (i.e. response rate, etc.) have been defined that can be used to estimate the quality of data produced. These are described in section 7. The quality of data derived from interviews is left to be decided by the producers of the data. No specific procedure is defined here (i.e. reliability, etc). **Surveillance** If the data is out of range, the data point is substituted with “-1” indicating missing value. Also, manual checks are implemented for that data point, minimizing the possible error coming from faulty data insertion. No specific interpolation methods are applied.
External data sources	Data sources that provide additional information regarding the calculation of the KPIs (mostly quantitative data). Included are: • Registries, • Producer’s/suppliers information, • Institutions, • Municipality.

	Data acquiring The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.
Other data sources	Other data sources cover national regulations, manufacturers data sheets, attendees' lists, working group discussions, etc. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.

Table 7).

Data source	Description
Data from monitoring	Quantitative (numerical) data that is derived using automated systems that allow to collect and store continuous flow of data. Included are: • Data registered by sensors and monitoring equipment (energy meters, temperature sensors), • Data from the ICT system/platform that automatically stores variables that have been defined previously, i.e. for ICT. **Data acquiring** The procedures for acquiring requested data are described in section 11.1 under every KPI. See also sections 6.1.1. and D7.6, D7.7 and D7.8 for additional information. **Data quality** Frequency to estimate data quality to be decided (monthly, annually, once as the data are inserted into the database, etc.). For numerical data, there can be defined the thresholds for the values certain data points can take to calculate quality indicators (completeness, out of range). **Surveillance** Surveillance methods and procedures to be decided.

Data from surveys	Used to collect both quantitative and qualitative data. Included are: • Questionnaire, • Interview. **Data acquiring** The procedure for carrying out the surveys is defined in section 11.1 for possible cases. **Data quality** Frequency to estimate data quality: once as the data are inserted in the database. For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calclulate the quality indicators. For categorical data, the data point can take a value from predefined categories. Besides predefined quality indicators (completeness, out of range), a list of other quality measures (i.e. response rate, etc.) have been defined that can be used to estimate the quality of data produced. These are described in section 7. The quality of (qualitative) data derived from interviews is left to be decided by the producers of the data. No specific procedure is defined here (i.e. reliability, etc). **Surveillance** If the data is out of range, the data point is substituted with "-1" indicating missing value. Also, manual checks are implemented for that data point, minimizing the possible error coming from faulty data insertion. No specific interpolation methods are applied.
External data sources	Data sources that provide additional information regarding the calculation of the KPIs (mostly quantitative data). Included are: • Housing associations, • Institutions, • Municipality. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take and calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Surveillance methods and procedures to be decided.
Other data sources	Other data sources cover existing building plans, invoices, national regulations, standards and tables, attendees' lists, log books, etc. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take and calculate the quality indicators. For categorical

	data, the data point can take a value from predefined categories. **Surveillance** Surveillance methods and procedures to be decided.

Table 6: Data sources used in Vitoria-Gasteiz

6.1.3 Data quality assessment approach

Vitoria-Gasteiz applies the quality assessment procedure described in section 5, but more specific aspects related to the quality assessment of KPIs and input parameters is still open. For that Vitoria-Gasteiz has defined the required variables for the calculation of two indicators measuring data quality: 1) data completeness, and, 2) out of range. The variables necessary to be defined include frequency of quality checks both for the KPI and its input parameters, and thresholds to define the out of range values that indicate possible mistakes in the data or data flow (thresholds also set both for the possible KPI value and its input parameters). Since the nature of the data used is different, the thresholds and descriptions are defined in section 11.4.1 for the KPIs Vitoria-Gasteiz has decided to measure. In addition, there are indicated for every KPI and their input parameters if and when the surveillance procedures apply (these include interpolation and data correction). The table in section 11.4.1 will be finished before the system for quality assessment is set up.

The approach to the data quality assessment is quantitative, i.e. there are defined numerical thresholds for quality checks. Thus, the quality of datasets that have been produced using qualitative approaches (i.e. interviews) is not estimated here.

6.2 Tartu data collection specific plan

This section gives a generic overview of different data sources used during the data collection process. This section strongly relates to the KPIs (described in section 11.2) selected by Tartu in preceding deliverables. The description of every KPI includes: definition, unit, data source/method, input parameters, calculation procedure (if applicable), and data collection and reporting frequency (separately for the KPI and input parameters). Although the focus here is on KPIs, it is important to keep in mind that not all the data collected may be related to the KPIs. For example, Tartu has decided to carry out interviews to understand the attitudes of pilot area residents. This allows to get additional information that quantitative methods do not deliver. Also, related to the defined KPIs and data sources the quality procedures are also defined.

6.2.1 Summary of monitoring

In the case of monitoring for Tartu, the same deliverables as for Vitoria-Gasteiz are applicable in this case (D7.6 and D7.8). The difference comes from the solutions because apart from the renovation of the envelopes and district heating interventions, integration of PV and street lighting are foreseen (Figure 10). Therefore, it is necessary to increase the monitoring equipment presented before (Figure 9) to cover the KPIs that are in the annexes. Thus, the amount of energy produced by the PV, as well as the contribution, are variables for Tartu. Besides, the smart lighting system consumes energy in contrast to the original lamp

posts, therefore, its measurement to obtain the final performance is necessary. Complementary, the status of the lamps and the lux levels are required to carry out the control operations. Finally, there is a heat pump to be integrated within the solutions. Although the energy consumption is related to the previous measurements, its performance is important, hence, those parameters that characterize the heat pump are recommended.

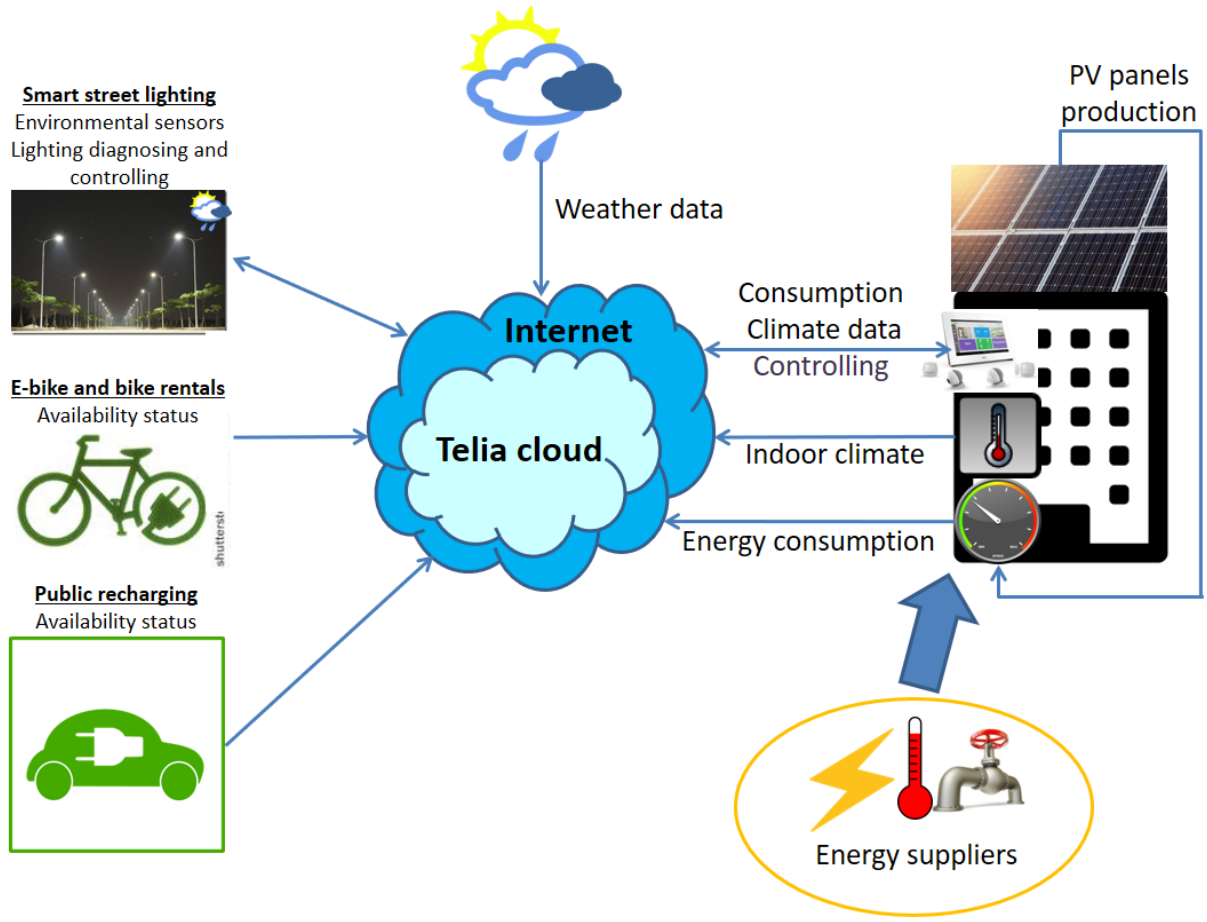

Figure 10: Monitoring schema for Tartu

6.2.2 Data sources for each assessment protocol

The data sources used can broadly be divided in three: 1) data from monitoring, 2) data from surveys, 3) additional data from external sources (i.e. registries, suppliers, etc.), and 4) data from other sources (

Data source	Description
Data from monitoring	Quantitative (numerical) data that is derived using automated systems that allow to collect and store continuous flow of data. Included are: • Data registered by sensors and monitoring equipment (energy, electricity, temperature, etc.), • Data from the ICT system/platform that automatically stores variables that have been defined previously, i.e. for ICT and mobility.

	Data acquiring The procedures for acquiring requested data are described in section 11.2 under every KPI. See also section 6.2.1. and D7.6, D7.7 and D7.8 for additional information. **Data quality** Frequency to estimate data quality: monthly, annually, once as the data are inserted into the database. For numerical data, there are defined thresholds for the values certain data points can take to calculate quality indicators (completeness, out of range). **Surveillance** Manual checks are implemented for detected faulty inputs. No automatic data correction is implemented. No specific interpolation methods are applied.
Data from surveys	Used to collect both quantitative and qualitative data. Included are: • Questionnaire, • Interview. **Data acquiring** The procedure for carrying out the surveys is defined in section 11.2 for possible cases. **Data quality** Frequency to estimate data quality: once as the data are inserted into the database. For numerical values, it is possible to define thresholds to indicate the possible value the data point can take. For categorical data, the data point can take a value from predefined categories. Besides predefined quality indicators (completeness, out of range), a list of other quality measures (i.e. response rate, etc.) have been defined that can be used to estimate the quality of data produced. These are described in section 7. The quality of data derived from interviews is left to be decided by the producers of the data. No specific procedure is defined here (i.e. reliability, etc). **Surveillance** If the data is out of range, the data point is substituted with "-1" indicating missing value. Also, manual checks are implemented for that data point, minimizing the possible error coming from faulty data insertion. No specific interpolation methods are applied.
External data sources	Data sources that provide additional information regarding the calculation of the KPIs (mostly quantitative data). Included are: • Registries, • Producer's/suppliers information, • Institutions, • Municipality. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality**

	For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.
Other data sources	Other data sources cover national regulations, manufacturers data sheets, attendees' lists, working group discussions, etc. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.

Table 7).

Data source	Description
Data from monitoring	Quantitative (numerical) data that is derived using automated systems that allow to collect and store continuous flow of data. Included are: • Data registered by sensors and monitoring equipment (energy, electricity, temperature, etc.), • Data from the ICT system/platform that automatically stores variables that have been defined previously, i.e. for ICT and mobility. **Data acquiring** The procedures for acquiring requested data are described in section 11.2 under every KPI. See also section 6.2.1. and D7.6, D7.7 and D7.8 for additional information. **Data quality** Frequency to estimate data quality: monthly, annually, once as the data are inserted into the database. For numerical data, there are defined thresholds for the values certain data points can take to calculate quality indicators (completeness, out of range). **Surveillance** Manual checks are implemented for detected faulty inputs. No automatic data correction is implemented. No specific interpolation methods are applied.
Data from surveys	Used to collect both quantitative and qualitative data. Included are: • Questionnaire,

	• Interview. **Data acquiring** The procedure for carrying out the surveys is defined in section 11.2 for possible cases. **Data quality** Frequency to estimate data quality: once as the data are inserted into the database. For numerical values, it is possible to define thresholds to indicate the possible value the data point can take. For categorical data, the data point can take a value from predefined categories. Besides predefined quality indicators (completeness, out of range), a list of other quality measures (i.e. response rate, etc.) have been defined that can be used to estimate the quality of data produced. These are described in section 7. The quality of data derived from interviews is left to be decided by the producers of the data. No specific procedure is defined here (i.e. reliability, etc). **Surveillance** If the data is out of range, the data point is substituted with "-1" indicating missing value. Also, manual checks are implemented for that data point, minimizing the possible error coming from faulty data insertion. No specific interpolation methods are applied.
External data sources	Data sources that provide additional information regarding the calculation of the KPIs (mostly quantitative data). Included are: • Registries, • Producer's/suppliers information, • Institutions, • Municipality. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.
Other data sources	Other data sources cover national regulations, manufacturers data sheets, attendees' lists, working group discussions, etc. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take to calculate the quality indicators. For categorical data, the data point can take a value from predefined categories.

	Surveillance Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.

Table 7: Data sources used in Tartu

6.2.3 Data quality assessment approach

Tartu applies the quality assessment procedure described in section 5. For that, Tartu has defined the required variables for the calculation of two indicators measuring data quality: 1) data completeness, and, 2) out of range. The variables necessary to be defined include frequency of quality checks both for the KPI and its input parameters, and thresholds to define the out of range values that indicate possible mistakes in the data or data flow (thresholds also set both for the possible KPI value and its input parameters). Since the nature of the data used is different, the variables and descriptions are defined in section 11.4.2 separately for every KPI Tartu has decided to measure. In addition, there are indicated for every KPI and their input parameters if and when the surveillance procedures apply (these include interpolation and data correction).

The approach to the data quality assessment is quantitative, i.e. there are defined numerical thresholds for quality checks. Thus, the quality of datasets that have been produced using qualitative approaches (i.e. interviews) is not estimated here.

6.3 Sonderborg data collection specific plan

This section gives a generic overview of different data sources used during the data collection process. This section strongly relates to the KPIs (described in section 11.3) selected by Sonderborg in the preceding deliverables. The description of every KPI includes: definition, unit, data source/method, input parameters, calculation procedure (if applicable) and data collection and reporting frequency (separately for the KPI and input parameters). Although the focus here is on KPIs, it is important to keep in mind that not all the data collected may be related to the KPIs. Also, related to the defined KPIs and data sources the quality procedures are also defined.

6.3.1 Summary of monitoring

Sonderborg is the most completed in terms of interventions for district renovation and heating, as documented in D7.6 and D7.8. Apart from the previous measurements explained already in Vitoria-Gasteiz and Tartu, Sonderborg includes a wind farm to provide electricity. That is the reason why its contribution and performance need to be metered. Figure 11 depicts the monitoring schema for this case.

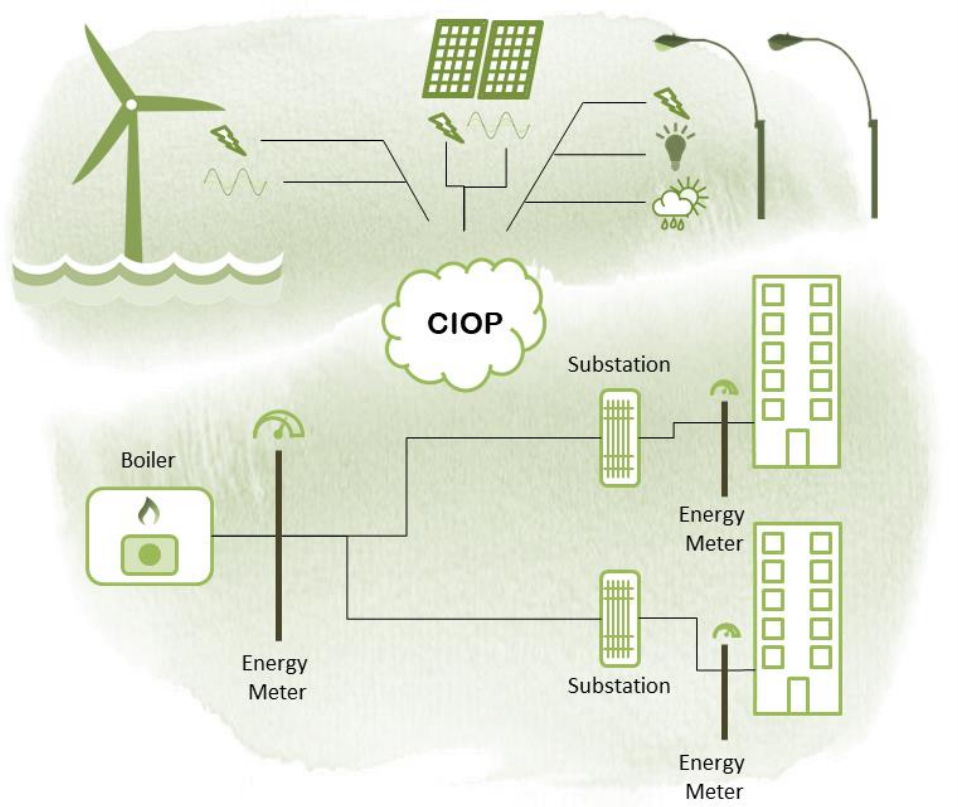

Figure 11: Monitoring schema for Sonderborg

6.3.2 Data sources for each assessment protocol

The data sources used can broadly be divided in three: 1) data from monitoring, 2) data from surveys, 3) additional data from external sources (i.e. housing associations, suppliers, etc.), and 4) data from other sources (Table 8).

Data source	Description
Data from monitoring	Quantitative (numerical) data that is derived using automated systems that allow to collect and store continuous flow of data. Included are: • Data registered by sensors and monitoring equipment (energy, mobility, etc.), • Data from the ICT system/platform that automatically stores variables that have been defined previously, i.e. for ICT, mobility. **Data acquiring** The procedures for acquiring requested data are described in section 11.3 under every KPI. See also section 6.3.1 and D7.6, D7.7 and D7.8 for additional information. **Data quality** Frequency to estimate data quality: annually, once as the data are inserted to the database. For numerical data, there are defined thresholds for the values certain data points can take to calculate the quality indicators (completeness, out of range). **Surveillance**

	Manual checks are implemented for detected faulty inputs. Thus, no automatic data correction is implemented. No specific interpolation methods are applied
Data from surveys	Used to collect both quantitative and qualitative data. Included are: • Questionnaire, • Interview. **Data acquiring** The procedure for carrying out the surveys is defined in section 11.3 for possible cases. **Data quality** Frequency to estimate data quality: once as the data are inserted in the database. For numerical values, it is possible to define thresholds to indicate the possible value the data point can take. For categorical data, the data point can take a value from predefined categories. Besides predefined quality indicators (completeness, out of range), a list of other quality measures (i.e. response rate, etc.) have been defined that can be used to estimate the quality of data produced. These are described in section 7. The quality of data derived from interviews is left to be decided by the producers of the data. No specific procedure defined here (i.e. reliability, etc). **Surveillance** If the data is out of range, the data point is substituted with “-1” indicating missing value. Also, manual checks are implemented for that data point, minimizing the possible error coming from faulty data insertion. No specific interpolation methods are applied.
External data sources	Data sources that provide additional information regarding the calculation of the KPIs (mostly quantitative). Included are: • Housing associations, • Electricity companies, • Private recharging station companies, • Housing association companies, • Municipality, • Institutions, • Energy balance. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take and calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.

Other data sources	Other data sources cover national statistics, standard factors, energy balance data, reports from meetings, etc. **Data acquiring** The procedure of acquiring data and the format of the data is defined by the LH city. **Data quality** For numerical values, it is possible to define thresholds to indicate the possible value the data point can take and calculate the quality indicators. For categorical data, the data point can take a value from predefined categories. **Surveillance** Manual checks are implemented to guarantee the correctness of the data. Manual checks are implemented for detected faulty inputs. No interpolation methods applied. No automatic data correction applied.

Table 8: Data sources used in Sonderborg

6.3.3 Data quality assessment approach

Sonderborg applies the quality assessment procedure described in section 5. For that, Sonderborg has defined the required variables for the calculation of two indicators measuring data quality: 1) data completeness, and, 2) out of range. The variables necessary to be defined include frequency of quality checks both for the KPI and its input parameters, and thresholds to define the out of range values that indicate possible mistakes in the data or data flow (thresholds also set both for the possible KPI value and its input parameters). Since the nature of the data used is different, the variables and descriptions are defined in section 11.4.3 separately for every KPI Sonderborg has decided to measure. In addition, there are indicated for every KPI and their input parameters if and when the surveillance procedures apply (these include interpolation and data correction).

The approach to the data quality assessment is quantitative, i.e. there are defined numerical thresholds for quality checks. Thus, the quality of datasets that have been produced using qualitative approaches (i.e. interviews) is not estimated here.

7 Evaluation reports of data quality and surveillance

The following template of the evaluation report is described for both the data quality and surveillance procedures. Associated terminology and definitions are based on preceding information provided in this deliverable, European Commission's Handbook on Data Quality Assessment Methods and Tools[8], European Commission's Working Group "Assessment of Quality in Statistics" Item 4.2C: Methodological Documents Glossary[9] and Eurostat's Concepts and Definitions Database[10].

Similar procedure is implemented for every assessment protocol and for city indicators relevant for the period. It must be acknowledged that dependent on the topic and methods used to collect the data, the problems and relevant topics to cover in the assessment of data quality can vary.

7.1 Template of Evaluation Report for data quality and surveillance

- **ADMINISTRATIVE INFORMATION**

Report No.	
Date of report	
Authors of report	
Period estimated	For example, M19 – M24
Summary	Overall summary of the report – main results

- **GENERAL DESCRIPTION**

General description includes the aim of the report, overall description of topics covered, data collection processes, database and repositories, etc. relevant for this period's (for example, M19–M24) quality checks. Since the evaluation reports are made in every six months, if there were issues raised in previous report(s) that needed to be solved, then the description of solutions can be brought here as well.

- **ASSESSMENT OF DATA QUALITY**

Assessment of data quality is presented protocol wise (from energy assessment to economic assessment and city indicators) since issues related to the data collection according to one protocol are assumed to be somewhat similar. Here only protocols that are relevant for certain period – data that are supposed to be and/or data that have been collected and/or stored in the repositories are listed. For example, data collected according to the Social

[8] European Commission (2007) Handbook on Data Quality Assessment Methods and Tools. Wiesbaden.

[9] Eurostat, Working Group "Assessment of Quality in Statistics", item 4.2C "Methodological documents, Glossary", Luxembourg, 2–3 October 2003 http://ec.europa.eu/eurostat/ramon/coded_files/QGLOSSARY%202003.pdf

[10] Eurostat's Metadata Server (RAMON), Concepts and Definitions, http://ec.europa.eu/eurostat/ramon/index.cfm

Acceptance Protocol will be described at the end of the project, but data from ICT Protocol must be stored and described right after the implementation of the interventions. Indicators of data quality will then be estimated KPI wise and input data wise (if applicable).

Assessment Protocol #1

Summary of topic

Describes what is being assessed, data sources and methods, description of data flows and repositories, coding[11] procedures, description of (target) population[12], description of sample(s), description of reference periods[13], assessment of relevance[14], definition of study domains[15], assessment of unit response rate[16], etc.

Data quality indicators

Data quality indicators are calculated based on the frequency every LH city has ascribed. The colour in Table 9 indicates if the value meets the threshold(s), indicated in green, and if not, indicated in red. The table is complemented with textual explanation of the results (revision, interpretation, validation, etc.). Also, here can be described how the surveillance procedures, like data correction to decrease data gaps, can affect the indicators and data quality.

Estimated parameter (KPI or input parameter of the KPI)	Data completeness (%)	Out of range (%)
KPI #1	…	…
Input parameter #1 of KPI #1	*95*	*2.3*
Input parameter #2 of KPI #1	…	…
KPI #2	…	…
Input parameters of KPI #2	*53*	*10.2*

Table 9: Results of calculation of data quality indicators

[11] Process of converting verbal or textual information into codes representing classes within a classification scheme, to facilitate data processing, storage or dissemination.

[12] Population is the total membership or population or "universe" of a defined class of people, objects or events. There are two types of population, viz, target population and survey population. A target population is the population outlined in the survey objects about which information is to be sought and a survey population is the population from which information can be obtained in the survey. The target population is also known as the scope of the survey and the survey population is also known as the coverage of the survey.

[13] Timespan or point in time to which the measured observation is intended to refer, the period of time for which data are collected.

[14] Relevance is the degree to which statistics meet current and potential users' needs. It refers to whether all statistics that are needed are produced and the extent to which concepts used (definitions, classifications etc.) reflect user needs.

[15] Segment of the population for which separate statistics are needed. Statistics are presented for different sub-groups of the population, so called study domains. These study domains are usually defined according to some classification (e.g. territorial units, economic activity, etc.)

[16] The ratio, expressed in percentage of the number of interviews to the number of eligible units in the sample.

Surveillance procedures

Surveillance procedures include communication losses, interpolation and data correction. Occuring incidents can be described in the report according to predefined variables (Table 10).

COMMUNICATION LOSSES	List of variables to be described: • Number of incidents; • Reasons for communication losses (description); • Number of incidents solved; • Average count of restoring communication attempts; • Average time for restoring the communication; • Description of corrective actions.
INTER-POLATION	Interpolation is described KPI-wise and data point wise for those KPIs and data points that have been previously selected eligible for interpolation. List of variables to be described in the report: • Number of incidents, imputation rate; • Interpolation techniques described; • Expected improvements in data quality.
DATA CORRECTION	Data correction is described KPI-wise and data point wise. List of variables to be described in the report: • Number of incidents (data correction activities), imputation rate, division by type; • Data correction techniques described (deletion, substitution, etc.); • Expected improvements in data quality. Data correction procedures should also be described even if they are not automatic.

Table 10: Summary of surveillance procedures

Description of problems

Problems related to data quality are described here: Why are there outliers[17] or inliers[18] (if any), why are there missing values (if any), why are there problems with data storing (if any), why the data collection did not start at the right time and reasons for late delivery, errors[19] (programming errors, coding errors, processing errors[20], item non-response[21], non-response[22], refusal rate[23]), etc.

[17] Abnormal value in a time series.

[18] A data value that lies in the interior of a statistical distribution and is in error. Because inliers are difficult to distinguish from good data values they are sometimes difficult to find and correct.

[19] In general, a mistake or error in the colloquial sense. There may, for example, be a gross error or avoidable mistake; an error of reference, when data concerning one phenomenon are attributed to another; copying errors; an error of interpretation.

[20] Error in final survey results arising from the faulty implementation of correctly planned implementation methods.

[21] Item non-response occurs when a respondent provides some, but not all, of the requested information, or if the reported information is not usable.

[22] Form of observation present in most surveys, which means failure to obtain a measurement on one or more study variables for one or more elements k selected for the survey.

[23] Proportion of observation units for which the reporting unit has been successfully contacted, but has refused to give the information sought.

Timeliness and punctuality

Here are described the data frequency and average data freshness. Timeliness of information reflects the length of time between its availability and the event or phenomenon it describes. Punctuality refers to the time lag between the release date of data and the target date when it should have been delivered.

Comparison with previous Evaluation Report(s) and coherence

Comparison with previous evaluation reports is important for understanding continuous monitoring and data flow (description of data completeness from the time perspective). Coherence[24] as quality parameter is important to understand, for example, in describing city indicators as the data sources and methods used to estimate may be different for the city diagnosis, baseline and final performance.

Suggestions for improvement

Includes possible suggestions and recommendations for improving data quality, data collection procedures, etc. and describes the plan for implementation.

Accessibility and clarity

A description of the conditions of access to data and a summary description of the information accompanying the statistics (documentation, explanation, metadata, etc.). These are relevant aspects for those who use the data for analysis or for other purposes (for example, D7.12 Monitoring Summary, D7.13 Evaluation: Assessment of Overall Performance).

[24] An attribute of statistics measuring the adequacy of the data to be reliably combined in different ways and for various uses.

8 Reporting data collection

At least two years of full set of data will be considered for the reporting period after the implementation of the actions in each demo site (these include retrofitting, urban platform development and mobility). The task leader with the help of partners from LH cities will report the data collection process to allow a proper supervision and analysis of data collection process. Thus, the reports on data quality and surveillance will be produced for every six months of the project (until M60) after the data collection has been designed in M18. The reports will be created during the following three months after the data collection period, i.e. the evaluation report for data collected during M19–M24 will be presented in M27. Thus, there will be created 7 evaluation reports.

Table 11 describes the initial time-frame the data under every protocol are collected and thus the results presented in the evaluation reports. For different LH cities, the period when the data are collected varies, since in some cases the data collection is dependent on when the interventions have been finished.

Topic	M9 City diagnosis[25]	M18 Baseline[26]	M24	M30	M36	M42	M48	M54	M60	M66
Energy assessment	–	Baseline estimation	Data collected between M19–M60							Final performance
ICT	–	Baseline estimation	Data collected between M19–M60							Final performance
LCA	–	Baseline estimation	–							Final performance
Mobility	–	Baseline estimation	Data collected between M19–M60							Final performance
Social acceptance	–	–	Data collected between M19–M60							Final performance
Citizen engagement	–	–	Data collected between M19–M60							Final performance
Economic performance	–	Baseline estimation	Data collected between M19–M60							Final performance
City indicators	City diagnosis	–	Indicators related to energy assessment and mobility protocols need to be coordinated with data collection under these protocols. Other data collected between M19–M60							Final performance

Table 11: Overall time-frame for data collection and reporting

[25] Described in D3.1, D4.1 and D5.1.

[26] Described in D3.2, D4.2 and D5.2.

The evaluation reports concerning data quality and surveillance are designed to be used both for the inside usage (for data collectors) and outside usage (for data users). The Evaluation Report for every period is added as annex to this deliverable.

9 Deviations to the plan

No major deviations are reported.

Some of the indicators, mainly those related to mobility, could not be described in the case of Vitoria-Gasteiz (related to Mobility Protocol, Enonomic Assessment protocol and City Impacts) since there has not been done a final decision on the actions that will be considered part of SmartEnCity once the current Amendment process is closed. Also, the detailed description for indicators and data sources related to ICT and citizen engagement protocol in Vitoria-Gasteiz is pending. For Vitoria-Gasteiz the parameters for data quality checks are pending also and need to be defined during the following months.

Compared to D7.3 and D7.4 that form the basis for the procedures to assess the KPIs and impacts, some of the KPIs defined in these two deliverables have been left out due to the lack of data, or definition changed due to the data sources that can provide the closest estimation.

10 Outputs for other WPs

The data quality procedures described here need to be implemented in the databases/platforms developed (WP6, WP3, WP4, WP5) to guarantee proper data collection and supervision of the data quality.

The present deliverable becomes one of the stepping stones for WP7 deliverable D7.12 Monitoring Summary. Further steps in D7.9 include creating evaluation reports every 6-months to provide a proper supervision and analysis of data collection process. For this, the partners' roles in the data quality reporting need to identified to guarantee a smooth communication flow and the process of data collection reporting.

The impact of the integrated actions is assessed in D7.13 Evaluation: Assessment of the Overall Performance. For this, the evaluation reports created in the process can be important to understand the data quality and the limitations of the collected data.

Approach described in this deliverable can be listed as one of the tools in the replication toolkits described in WP8 for collecting information and measuring impacts of smart city initiatives.

11 Annexes

11.1 Description of KPIs and used data sources for Vitoria-Gasteiz

11.1.1 Energy assessment

ECM for Vitoria-Gasteiz is envelope insulation and new district heating network. Objectives, methods and respective data sources involved in the evaluation of energy assessment in the city of Vitoria-Gasteiz are brought in Table 12. Energy savings will be measured using Protocol IPMVP (Option D) and comfort will be evaluated using data measurements (internal temperature) and questionnaires. The reference period for energy assessment evaluation is April 2019–April 2021.

Vitoria-Gasteiz	
Objective	Methods and data sources
Energy performance of the renovated dwellings and new district equipment, including energy savings, comfort and CO_2 emissions reduction.	Protocol IPMVP - Option D - Whole district (main heater) - Individual apartments (heat meters)
	Internal temperature (data) measurement Questionnaire

Table 12: Energy assessment objectives for Vitoria-Gasteiz

ENERGY SAVINGS

Energy demand – Energy that the building requires to meet its needs/uses (i.e. heating, DHW, cooling, electricity, etc.)

Unit: kWh/m²a

Data source/method: Simulation/theoretical calculation. Based on building properties and occupancy schedules, through building energy simulation tools.

Input parameter	Data source
Detailed building characteristics, functions and occupancy profiles	Existing building plans + survey, building refurbishment project

Calculation: Building simulation tool.

Reporting frequency and input data collection frequency: One-off calculation, one-off data collection.

Delivered energy (for buildings) – Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into

account (heating, cooling, ventilation, domestic hot water, lighting, etc.) or to produce electricity (EN 15603:2008).

Unit: kWh/m²y

Data source/method: Energy meters.

Input parameter	Symbol	Unit	Data source
Delivered energy per energy carrier	$E_{del,EC}$	kWh/y	Apartment energy meters
Floor area of the building	A	m^2	Building plans

Calculation: Divide data from meters by floor area.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

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.

Unit: kWh_{in}/kWh_{out}

Data source/method: Energy meters.

Input parameter	Unit	Data source
Delivered energy per energy carrier	kg biomass kWh biomass kWh gas	Biomass boiler room weighting devices / invoices, etc.
Output per energy carrier	kWh	Biomass boiler room energy meter

Calculation: Based on the input of biomass (and gas) to the boiler room, and the heat extracted to the network.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

Primary energy (for buildings) – 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).

Unit: kWh/m²y

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Data source
Delivered energy per energy carrier	From delivered energy indicators
Primary energy factor for delivered energy carrier	Primary energy factor for energy source from national regulations, and delivered energy for energy supply units indicator
Floor area of the building	Building plans
Reference time period	-

Calculation: Primary energy factor for delivered energy carrier for the building will be calculated based on the primary energy factors for energy sources from national regulations, multiplied by the delivered energy factor for supply units, that is previously calculated.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

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).

Unit: kWh_{in}/kWh_{out}

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Data source
Delivered energy per energy carrier	From delivered energy factor for supply units
Primary energy factor for the delivered energy carrier	From national regulations

Calculation: Calculate the primary energy associated with delivered energy for the supply unit, by multiplying the delivered energy factor for supply units (which is previously calculated) by the primary energy factor for the energy source.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

CO_2 equivalent (for buildings) – The CO_2 emissions of a building correspond to the emissions that are caused by different areas of application (i.e. space heating, space cooling, domestic water heating, electrical appliances). In different variants of this indicator, the emissions caused by the production of the building components can be either included or excluded. To enable the comparability between buildings, the emissions relate to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. year). The greenhouse gases are considered as t of carbon dioxide (CO_2) or a CO_2 equivalent (CO_2e).

Unit: t CO_2/m^2y

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Data source
Delivered energy per energy carrier	Delivered energy for buildings indicator
CO_2 conversion factors	CO_2 conversion factor for energy carrier for buildings

Calculation: The delivered energy for buildings indicator should be multiplied by the CO_2 conversion factor for energy carrier for buildings. This CO_2 conversion factor will be calculated from the delivered energy for supply system and the CO_2 conversion factor from national regulations for different energy sources.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

Density of energy demand – The indicator is defined as ratio of final energy demand (for heating or cooling) of a cohesive set of buildings and a simple figure representing the effort that a district heating or cooling network operator would have to supply these buildings. For the latter the territory area or the number of buildings is chosen in order to represent the length of the network and the number of connections that are required.

Unit: kWh/m²a

Data source/method: Estimated.

Input parameter	Data source
Delivered energy (per building)	Delivered energy indicators
Building area	Plans

Calculation: Divide total delivered energy by the total area.

Reporting frequency and input data collection frequency: Annual reporting, annual data collection.

Peak load and load profile of electricity demand – The load profile describes the demand characteristics over time, while peak load is what the electricity supply has to be able to

cover. The load profile gives information about the possibilities or potentials of storage, demand-side management and self-supply via photovoltaic, etc.

Unit: kW

Data source/method: Measured electricity meters.

Input parameter	Unit	Data source
Hourly electricity power required by the apartments	kW	Electricity meters housing
Peak electricity power required by the apartments	kW	Electricity meters housing

Calculation: Discharge of the hourly energy data (kWh) recorded in the electricity meters. Graphing with the data obtained (daily, monthly and annual demand curves) will give the load profiles. Peak load will be on that moment with maximum electricity demand.

Reporting frequency and input data collection frequency: Annual reporting, annual data collection.

Peak load and load profile of thermal (heating/cooling) energy demand – The load profile describes the demand characteristics over time. The thermal energy supply has to be able to cover the peak load. The load profile gives information about the possibilities or potentials of storage as well as supply-side and demand-side management.

Unit: kW

Data source/method: Energy meters.

Input parameter	Unit	Data source
Load profile		
Hourly thermal energy (power) provided by the boilers	kW	Data recorded on the boiler energy meters
Peak load		
Peak thermal energy (power) provided by the boilers	kW	Data recorded on the boiler energy meters

Calculation: Discharge of the hourly energy data (kWh) recorded in the thermal energy meters of the boilers. Sum of the data recorded hourly in each of the boiler meters. Graphing with the data obtained (daily, monthly and annual demand curves). Peak load will be on that moment with maximum thermal energy demand.

Reporting frequency and input data collection frequency: Annual reporting, annual data collection.

Degree of congruence of calculated annual final energy demand and monitored consumption ($DC_{i,t}$) – Ratio of the theoretical energy demand of a building or set of buildings (calculated) and the final energy consumption of a building or set of buildings (measured) over a period of time (e.g. year).

Unit: %

Data source/method: Estimated.

Input parameter	Symbol	Unit	Data source
Final energy demand of building I based on annual simulated data of year t	$EN_{i,\ t,(demand)}$	kWh/(m^2 y)	Space heating and hot water demand from building simulation
Final energy consumption of building I based on annual data of year t	$EN_{i,\ t,\ (consumption)}$	kWh/(m^2 y)	Data from apartments' energy meters (delivered energy for buildings indicator)

Calculation: $DC_{i,t} = \frac{EN_{i,t,(demand)}}{EN_{i,t,(consumption)}}$

Reporting frequency and input data collection frequency: Annual reporting, annual data collection.

Degree of energetic self-supply – The 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.

Unit: %

Data source/method: Estimated.

Input parameter	Unit	Data source
Local Biomass energy use	Kg / kWh	Biomass boiler room meters, biomass invoices
Gas energy use	kWh	Biomass boiler room meters, biomass invoices

Calculation: Share of local biomass in relation to total energy use.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

Share of renewable energy – Total share of renewable energy sources in a complex energy supply system.

Unit: %

Data source/method: Estimated.

Input parameter	Unit	Data source
Biomass energy use	Kg / kWh	Biomass boiler room meters, biomass invoices
Gas energy use	kWh	Biomass boiler room meters, biomass invoices

Calculation: Share of biomass in relation to total energy use.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

The following KPI is omitted from the analysis:

- CO_2 equivalent (for supply units).

COMFORT

Internal air temperature – This parameter is directly involved in the determination of internal comfort condition but it also allows to investigate (with another parameter as the heat quantity for set point achievement) how much energy is necessary to reach a particular desired condition known as set point. Use both this parameter (before and after an Energy Conservation Measure (ECM) considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.

Unit: ºC

Data source/method: Temperature sensors.

Input parameter	Symbol	Unit	Data source
Internal air temperature	*Tint*	ºC	Temperature sensors

Calculation: Measurement.

Reporting frequency and input data collection frequency: Annual reporting, hourly data collection.

Heat quantity for set point achievement – This parameter allows to collect information about the quantity of energy that is needed to reach a particular temperature condition known as set point. Using this data before and after an ECM (considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.

Unit: kWh

Data source/method: Simulation/meters.

Input parameter	Unit	Data source
Energy demand for heating before building refurbishment for the measured temperature	kWh	Building simulation
Energy demand for heating after building refurbishment for the measured temperature	kWh	Energy meters

Calculation: Simulate/calculate the energy demand that would be required by the building before refurbishment, to achieve the temperatures they have after the refurbishment. Compare with real energy demand after refurbishment.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

Thermal comfort – This indicator represents the level of thermal comfort measured as the number of hours that the indoor temperature and relative humidity conditions are within

range of values defined. The range of comfort values varies with the seasons (as it depends on the metabolic rate and clothing of the building users) and the climatology of each city (average monthly temperatures (max & min) and average monthly relative humidity).

Unit: Predicted Mean Vote (-3…3)

Data source/method: Questionnaires.

Input parameter	Unit	Data source
Responses from questionnaires	Seven-point scale from cold (-3) to hot (+3)	Questionnaires

Calculation: Question as part of a post-refurbishment survey.

Reporting frequency and input data collection frequency: Reporting once after the survey, surveys to be organized after refurbishment.

Other issues: The questionnaire for measuring thermal comfort is distributed to owners and tenants under the Social Acceptance Protocol (section 11.1.5) and will be measured once after the intervention. The KPIs addressed to measure thermal comfort include the following aspects:

- Gains in summer comfort conditions with the district renovation;
- Gains in winter comfort conditions with the district renovation;
- Comfort conditions to be checked include: natural light, temperature (thermal comfort), air quality, acoustic comfort, etc.

11.1.2 ICT

The final selection of ICT related KPIs and their description need to be decided. The predefined KPIs to measure according to D7.3 are:

- Response time,
- Scalability,
- Extensibility,
- Storage capacity,
- Hours of maintenance,
- Non-expected hours off-line,
- # of HEMS connected,
- # of BEMS connected,
- # of EV connected,
- # of mobility equipment connected,
- Total amount of data generated,
- Types of measurements,
- Percentage of equipment connected,
- Recharging points equipment connected,
- Smart lighting equipment connected,
- Number of services developed,
- Types of services,
- Percentage of dwellings connected,

- Percentage of buildings connected,
- APIs integrated,
- Open-Data sets available.

11.1.3 LCA

Objectives, methods and respective data sources involved in the evaluation of LCA in the city of Vitoria-Gasteiz are brought in Table 13. Table 14 presents the measures for retrofitting.

Vitoria-Gasteiz	
Objectives	Methods and data sources
Evaluation in terms of LCA for - building retrofitting actions - integrated infrastructures - energy	CML-IA Ecological footprint method Cumulative energy demand methodology Life cycle inventory account Reference study period: 50 years

Table 13: LCA assessment objectives for Vitoria-Gasteiz

The LCA assessment consists of:

- Definition of baseline scenario and the evaluation of KPIs,
- Life cycle inventory,
- Definition of post-intervention scenario and evaluation of KPIs,
- Final reporting.

	Before retrofitting	After retrofitting
Passive measures	Envelop insulation. Little or no insulation	Envelop insulation (type): External insulation or ventilated façade (U=0,21 W/m^{2}k)
	Roof insulation. Little or no insulation	Roof insulation (type): Depending on the building but reaching a U value of 0,21 W/m^{2}k)
	Windows: replaced some time ago, old: Mostly old, few replaced recently	Windows: Double low-e glazing
Active measures (Integrated infrastructures)	The heating system consists of natural gas boilers (80% correspond with individual boilers and 20% with centralized boilers)	The renovated dwellings will be connected to the new district heating network which will be fuelled by a biomass boiler (chips)

Table 14: Measures for retrofitting in Vitoria-Gasteiz

The LCA is done using a commercial software called SimaPro version 8.3, that includes the strongest database in the market (Ecoinvent version 3.3) and several environmental calculation methods. The data that was collected in the previous stage is modelled according to the different flows existing in the Ecoinvent database.

The input parameters for the indicators are described only for the first indicator (KPI), since the inputs are the same for all the Environmental indicators selected (Global warming, ecological footprint, etc.). There has been prepared an Excel spreadsheet where more detailed information is brought but not presented here. The same set of indicators will also be used for final assessment (after the intervention), but the values may differ (i.e. windows, boilers, etc.).

Global warming potential (EI_1) – Index that attempts to integrate the overall climate impacts of a specific action. It relates the impact of emissions of a gas to that of emission of an equivalent mass of CO_2. The duration of the perturbation is included by integrating radiative forcing over a time horizon (e.g., standard horizons for IPCC have been 20, 100, and 500 years). The time horizon thus includes the cumulative climate change and the decay of the perturbation. 100 years has been chosen for the LCA study.

Unit: kg CO_2 eq

Data source/method: CML methodology, IPCC 2013 GWP 100 years. CML-IA is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands. More information on: http://cml.leiden.edu/software/data-cmlia.html.

This method is an update of the CML 2 baseline 2000 and released by CML in April 2013 (version 4.2). The CML 2 baseline 2000 version can be found in the 'superseded' list. For most impact categories, substances have been added and removed and/or characterisation factors were updated, according to new scientific insight. Only the impact category Photochemical oxidation did not undergo any changes. The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into:

- A: Obligatory impact categories (category indicators used in most LCAs).
- B: Additional impact categories (operational indicators exist, but are not often included in LCA studies).
- C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA).

Input parameter	Value	Unit	Data source
Conditioned area of the district (sum of the surface of all the dwellings)	98 447	m^2	Vitoria municipality / VISESA and Ecoinvent database
Envelop insulation total surface (façade)	84 974	m^2	
Roof surface	26 323	m^2	
Windows: Window surface in the district	16 995	m^2	
Windows: Current windows frame description (wood, PVC, aluminium)	67.75	% wood	
	25	% PVC	
	7.25	% aluminium	
Description of the windows replacement for the next 50 years considering no SmartEnCity actions			

Input parameter	Value	Unit	Data source
Wood-frame windows life time service	30	years	Vitoria municipality / VISESA and Ecoinvent database
Destination after replacement (recycling/landfill/others)	landfill	-	
Distance to final disposal/treatment	50	km	
% of wood-frame windows that will be replaced according to the life-time service in the district	150	%	
PVC-frame windows life time service	30	years	
Destination after replacement (recycling/landfill/others)	recycling	-	
Distance to final disposal/treatment	250	km	
% of PVC-frame windows that will be replaced according to the life-time service in the district	150	%	
Aluminium-frame windows life time service	20	years	
Destination after replacement (recycling/landfill/others)	recycling	-	
Distance to final disposal/treatment	250	km	
% of aluminium-frame windows that will be replaced according to the life-time service in the district	200	%	
Windows replacement origin (Distance form the new windows supplier)	50	km	
Description of boilers			
Number of individual boilers	1134 (965 natural gas and 169 electric)	number	Vitoria municipality / VISESA and Ecoinvent database
m^2 heated by individual boilers	85 539 (72 790 natural gas and 12 749 electric)	m^2	
Fuel (Natural gas/Other)	natural gas/electricity	-	
Number of centralized boilers	6	number	
Number of dwellings dependent of centralized boilers	171	number	
m^2 heated by centralized boilers	12 900	m^2	
Fuel (Natural gas/Other)	gasoil	-	
Boilers replacement/use plan			
Individual boilers life time service	15	years	Vitoria municipality / VISESA and Ecoinvent
Individual boilers end of life final destination	recycling	-	

Input parameter	Value	Unit	Data source
Individual boilers final destination distance	250	km	database
Individual boilers (new boilers origin)	50	km	
Centralized boilers life time service	20	years	
Centralized boilers end of life final destination	recycling	-	
Centralized boilers final destination distance	250	km	
Centralized boilers (new boilers origin)	50	km	
Energy			
Global thermal energy consumption from individual boilers (kWh/year, m^3 fuel/year, etc.) please be clear with the units (per m^2, per total district, etc.)	Gas: 86.9 kWh/m^2y (117 kWh/m^2y in average for 74% dwellings)	kWh/m^2y	Vitoria municipality / VISESA and Ecoinvent database
Global thermal energy consumption from centralized boilers (kWh/year, m^3 fuel/year, etc.) please be clear with the units (per m^2, per total district, etc.)	Gasoil: 11.4 kWh/m^2y (87 kWh/m^2y for gasoil heating in 13% dwellings)	kWh/m^2y	
Global electricity energy consumption (kWh/year) please be clear with the units (per m^2, per total district, etc.)	Electricity: 57 kWh/m^2y (full electricity bills including appliances equals 47kWh/m^2y in average, plus electricity for heating in 13% of dwellings, and electricity for hot water in 26% of dwellings)	kWh/m^2y	

In addition to numerical values there are some input parameters that are descriptive. These include:

- Is there any envelop insulation? (if yes, please elaborate on type of insulation, thickness, surface, renovation plan, etc.) for the envelop and roof.
- Description of individual and centralized boilers.
- Sources on thermal energy data.

Calculation: In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Other issues: The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalent/kg emission.

All adaptions of the method (2001–2012) are present in CML-IA_update_info.xls which can be downloaded from the CML website: http://cml.leiden.edu/software/data-cmlia.html

Munoz, I. and Schmidt, J.H. (2016). Methane oxidation, biogenic carbon, and the IPCC's emission metrics. Proposal for a consistent greenhouse-gas accounting. The International Journal of Life Cycle Assessment, 21:1069–1075.

Ecological Footprint (EI_2) – The Ecological Footprint is defined as the area of productive land and water ecosystems required to produce the resources that the system needs and assimilate the wastes generated.

A measure of how much area of biologically productive land and water that an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption. Ecological Footprint is often referred to in short form as Footprint. "Ecological Footprint" and "Footprint" are proper nouns and thus should always be capitalized.

Unit: ha

Data source/method: Ecological footprint method. Method directly taken from Ecoinvent 2.0; Contact info: http://www.ecoinvent.org/contact/. Method published by Niels Jungbluth, ESU-services Ltd., Uster.

Calculation: Ecological Footprint (EF) = sum of time integrated direct land occupation and indirect land occupation. Normalisation is not a part of this method. Weighting: as each impact category is expressed in the same unit, a weighting factor of 1 is used for every impact category. For more information see the Database manual Version 1.01 (April 2009)- Added substance "Carbon dioxide" with a factor of 2.6722 to impact category "carbon dioxide".

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Use of renewable primary energy excluding energy resources used as raw material (RU_1) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non-renewable, as well as energy used for raw material and other uses.

Unit: MJ

Data source/method: Cumulative energy demand methodology. Method to calculate Cumulative Energy Demand (CED), based on the method published by Ecoinvent version 2.0 and expanded by PRé Consultants for raw materials available in the SimaPro 7

database.
Contact info: http://www.ecoinvent.org/contact/

Frischknecht R., Jungbluth N., et al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, www.ecoinvent.ch

- Wood is not included in this methodology due to the frequent use of wood as feedstock in Simapro.
- Normalization: it is not a part of this method.
- Weighting: Each impact category is given the weighting factor 1.
- For more information see the Database manual.
- Adaptations (August 2004, v1.01):
  - Added: Additional oil resources;
  - Water, barrage
  - Corrected values: Uranium ore, 1.11 GJ per kg, in ground; Uranium, 2291 GJ per kg, in ground; Uranium, 451 GJ per kg, in ground; Uranium, 560 GJ per kg, in ground.
  - Not included: Energy from hydrogen; Energy, recovered; Energy, unspecified; Oil; Steam from waste incineration.
- Other adaptations (March 2005, v1.02):
  - Sulphur removed.
- Other adaptations (August 2005, v1.03):
  - In impact category Non-renewable, fossil the characterisation value for "Gas, natural in ground" has been changed from 40,3 to 38.3 MJ LHV/m^3 following the ecoinvent 1.2 update.
- Other adaptations (February 2008, v1.04):
  - Minor adaptations in Unit names and Impact category names (capitals, points) for more consistency with other categories.
- Other adaptations (April 2008, v1.05):
  - Seven extra substance flows are added:
    - Energy, gross calorific value, in biomass, primary forest,
    - Geothermal converted,
    - Energy, solar, converted,
    - Energy, from hydrogen,
    - Energy, unspecified
  - The characterisation factor of Peat, in ground' raw biotic in IC non-renewable, fossil has a new characterisation factor = 9
- Other adaptations (November 2009, v1.06):
  - Created a new impact category: 'Non-renewable, biomass' and moved the substance 'energy, gross calorific value, in biomass, primary forest' to this new impact category.
- Other adaptations (March 2010, v1.07):
  - Weighting: The weighting factor of impact category non-renewable biomass was changed to 1.
- Other adaptations (August 2010, v1.08):
  - The quantity and unit of the single score is changed:
    - 1.07: Indicator (Pt)
    - v1.08: Energy (MJ)
- Other adaptations (August 2014, v1.09):
  - The following flows were added:
    - Coal, bituminous, 24.8 MJ per kg

- Coal, hard, 30.7 MJ per kg
- Gas, natural/kg

- The factor for Methane was changed from 35.9 to 55.53 MJ/kg (the previous value was in MJ/m^3, which is the incorrect unit).

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the cumulative energy demand methodology, the following KPIs will also be calculated:

Use of renewable primary energy resources used as raw material (RU_2) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy excluding energy resources used as raw material (RU_3) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy resources used as raw material (RU_4) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Exported energy (OF_1) – Energy that is produced in the context of the district studied that can be exported from the system to other use out of the systems boundaries. Unit: MJ

Hazardous wastes disposed (WC_1) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC.

Unit: kg

Data source/method: Life cycle inventory account

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the same methodology (life cycle inventory account), the following KPI will also be calculated:

Non-hazardous wastes disposed (WC_2) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC. Unit: kg

11.1.4 Mobility

The final selection of mobility related KPIs will be done after the mobility actions have been confirmed. The predefined KPIs to measure according to D7.3 are:

- Average vehicle speed (peak/off-peak),
- Accuracy of timekeeping for freight,
- Energy consumption,
- CO_2 emission by travelled distance,
- Total number of recharges per year (biogas and EV),
- Total kWh recharged in the EV charging stations (biogas and EV).

11.1.5 Social acceptance

Objectives, methods and respective data sources involved in the evaluation of social acceptance in the city of Vitoria-Gasteiz are brought in Table 15.

Vitoria-Gasteiz	
Objective	Methods and data sources
Evaluation of the acceptance of owners and tenants living in the district on SmartEnCity solutions implemented in the district renovated. Evaluation of the gains in life quality of owners and tenants living in the district retrofitted.	Questionnaire Data measurements Log book
Evaluation of the acceptance of the agents involved in the last mile vehicles (manager of the company that buys the vehicles, manager of the companies that operate the vehicles and vehicle users) on EVs acquired. Evaluation of the gains in life quality of the agents involved in last mile vehicles (manager of the company that buys the vehicles, manager of the companies that operates the vehicles and the vehicle users) after the acquisition of EV vehicles.	Individual interview which also includes questions defined in the log books Data measurements

Table 15: Social acceptance assessment objectives for Vitoria-Gasteiz

DISTRICT RENOVATED

- *Questionnaire*

Method	**Questionnaire for the residents living in buildings renovated**
Materials (what?)	KPIs and related questions in the questionnaires directed to the residents of the district renovated are divided into five groups: 1) social background of a respondent, 2) environmental background of a respondent, 3) individual perceptions of residents (aka respondents), 4) economic value of the solution estimated by the respondent, 5) technical value of the solutions estimated by the respondent. The questions will be close ended (multiple choice). Some of the answers use the Likert-scale (scale from 1 to 5).

Agents to involve (who?)	The questionnaire will be addressed to residents living in retrofitted buildings. Total population forms of 10 property of owners constituting of in total about 1305 apartments (households). The questionnaire will be sent to the 50% of apartments. The estimated response rate is 15%. There will be sent out a second wave of invitations if the first wave does not meet the response rate.
Means (how?)	The invitations and the questionnaire itself will be distributed on paper (by mail) and the questionnaire can be filled on paper or in the Web. Every invitation has a unique ID to identify houses and apartments that have answered. Afterwards the data will be anonymized, i.e. the apartment number will be removed. The survey will be carried out at least one year after the end of retrofitting activities.

Social background

KPI/element	Description of KPI	Question	Response
Individual characteristics			
Age of residents (% of categories)	The age of residents.	How old are you?	1) under 18 years old 2) 18–30 years old 3) 31–50 years of old 4) 51–65 years old 5) more than 65 years old
Highest level of completed education of inhabitants (% of categories)	The highest level of completed education of residents.	What is your highest level of completed education?	1) without studies 2) primary studies 3) secondary studies 4) vocational education 5) university studies
Nationality (% of main nationality, % of foreigners)	The nationality data corresponds to (i) the percentage of main nationality and (ii) percentage of foreigners.	What is your nationality?	1) Morocco 2) Asia and Oceania 3) South America 4) Rest of Africa
Net monthly income of the households (% of categories)	The net monthly income of the households (may vary for each state).	What is the net monthly income of your household per month?	1) less than 1,000 € 2) between 1,001 and 2,000 € 3) between 2,001 and 3,000 € 4) between 3,001 and 4,000 € 5) more than 4,000 €
Characteristics of the dwelling			
Type of building (% of types)	The building types.	What is the type of your building where your	1) single house 2) semi-detached house

		household lives?	3) terraced house 4) line block building 5) tower block building 6) central patio building 7) non-residential building
Size of dwelling – heated area (% of categories)	The size of the dwelling corresponds to the surface in m^2.	What is the size of your dwelling?	1) less than 50 m^2 2) 51–70 m^2 3) 71–90 m^2 4) 91–110 m^2 5) more than 110 m^2
Ownership structure (% of categories)	The ownership structure.	What is the ownership of your dwelling?	1) owner(ship) 2) rental
Accommodation time (% of categories)	The years of occupancy in the current home.	How long have you lived in your dwelling?	1) until 3 years 2) 4–6 years 3) 7–10 years 4) 11–20 years 5) more than 21 years

Environmental background

KPI/element	Description of KPI	Question	Response
Knowledge and environmental awareness on environmental problems			
Environmental awareness (average score, %)	The knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on global environmental problems. The following values are derived from the Special Eurobarometer 416 report: Attitudes of European Citizens Towards the Environment[27]	How do you assess your awareness and knowledge on the following global environmental problems? #1: Climate change #2: Air pollution #3: Water pollution (seas, rivers, lakes and underground sources) #4: The impact on our health of chemicals used in everyday products #5: The growing amount of waste #6: Depletion of natural resources #7: Agricultural pollution (use of pesticides,	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.

[27] http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_416_en.pdf

		fertilisers, etc.) #8: Shortage of drinking water #9: Loss of extinction of species and their habitants and of natural ecosystems (forests, fertile soils) #10: Our consumption habits #11: Urban problems (traffic jams, pollution, lack of green spaces, etc.) #12: Land take (i.e. that more land is used to build roads or cities, and that cities expand into the surrounding countryside) #13: Noise pollution #14: Soil degradation #15: The spread of harmful non-native plants and animals (invasive species)	
Awareness of environmental problems in the city (average score, %)	The level of knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing environmental problems in the city.	How do you assess your awareness and knowledge on the following environmental problems in the city? #1: Air pollution #2: Noise pollution #3: The growing amount of waste #4: Urban problems (traffic jams, pollution, lack of green spaces, etc.)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Knowledge and benefits of the solutions implemented in energy efficient retrofit projects			
Knowledge about efficient energy measures (average score, %)	The level of knowledge of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing efficient energy measures at building level.	How aware are you about the following measures and benefits to achieve energy efficiency? #1: Insulation to decrease the thermal loss in cold climate and thermal gain in warm climate #2: Lightning (more economic systems: energy saving light bulb, movement sensors, etc.) #3: Energy-efficient	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

		windows #4: Smart meters & energy dashboards #5: Technology for producing renewable energy (i.e. solar panels) #6: Ventilation (to regulate air temperature, humidity and CO_2 concentration) #7: Home appliance energy efficiency (i.e. Energy Star)	

Individual perception of residents

KPI/element	Description of KPI	Question	Response
Fairness and inclusiveness in the decision-making process: satisfaction with the project, with the level of information received, with the involvement degree			
Residents project satisfaction (average score, %)	The level of satisfaction of the dwelling's resident with regard to the project in general terms. The project is surrounded by technical solutions, information, costs, intervention phases and external conditions, among others.	How satisfied are you with the project?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the information accessibility (average score, %)	This KPI determines whether the residents with energy monitoring systems are satisfied with the access to such data.	How satisfied are you with the accessibility of information of energy monitoring?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Residents information satisfaction (average score, %)	Satisfaction with the information level provided to the neighbours about the intervention, costs and so on.	How satisfied are you with the information received?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Project involvement degree (% of categories)	The type of beneficiary is classified as: beneficiary related to building retrofitting, related to mobility action or through dissemination activities addressed for whole citizens	*This KPI/question is omitted, since residents living in buildings retrofitted will be asked, thus the respondent is automatically accounted as "building retrofitted".*	
Residents involvement degree (average score, %)	% of people who feel involved during the intervention project life cycle.	How involved did you feel?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at

			all (1)
Trust in decision makers in terms of suitable time plan for the execution of actions and the communication and dialogue with decision makers			
Satisfaction with time plan for the execution of actions (average score, %)	-	How satisfied are you with the time plan for the execution of retrofitting?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the communication and dialogue with decision makers (average score, %)	-	How satisfied are you with the communication and dialogue with the decision makers? *(Decision makers to be defined)*	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Economic value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the investment costs			
Satisfaction with the investment costs (average score, %)	Determines the level of satisfaction of the dwelling's residents with the investment costs.	How satisfied are you with the investment costs?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the access to financing			
Satisfaction with the access to financing (average score, %)	Determines the level of satisfaction of the dwelling's residents with the access to financing.	How satisfied are you with the access to financing?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the payback period			
Satisfaction with the payback period (average score, %)	Determines the level of satisfaction of the dwelling's residents with the payback period. Payback period is defined as the length of time required for an investment to recover its initial outlay in terms of profits or savings.	How satisfied are you with the payback period?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction level with the reduction in the energy bills			
Energy bill reduction: subjective (average score, %)	Reduction in the energy bills that is directly translated into money. Subjective measure.	How satisfied are you with the reduction in energy bill?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Willingness to invest in further energy projects			
Further investments in energy related projects (average score, %)	The percentage of inhabitants who would like to invest in further energy projects taking into consideration the results of the SmartEnCity one.	Given your present economic situation how willing are you to invest in further energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Technical value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the solution implemented as a whole			
Whole solution satisfaction (average score, %)	The whole solution covers the technical side.	How satisfied are you with the solution implemented as a whole?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Technical solution satisfaction (average score, %)	Any renovation project has the main objective of improving the performance of the building. However, other problems can arise such as new moisture issues. All the inconveniences during the retrofitting stage may be classified in different levels of impact from an objective point of view, but the residents' perspective is also important. With this aim, this KPI evaluates the satisfaction of the owners with regard to technical concerns.	How satisfied are you with the technical solution?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction from the energy perspective (comfort)			
Comfort conditions (average score, %)	Another goal of this sort of projects is the comfort, even the most important from the end user together the reduction of the energy bills. In contrast to the subjective evaluation, the objective result gives the real performance compared to the National regulations which limit the maximum and minimum conditions associated to the building typology. Thus, the opinion of the owners can be compared with the regulations to obtain the real context.	The aspects to address are: #1: Gains in summer comfort conditions with the district renovation; #2: Gains in winter comfort conditions with the district renovation. #3: Comfort conditions to be checked include: natural light, temperature (thermal comfort), air quality, acoustic comfort, etc.	
Satisfaction from the energy perspective (energy savings satisfaction)			
Energy savings satisfaction (average score, %)	One of the main objectives of this kind of projects is the reduction of the energy consumption both at district and building and dwelling levels. However, from the social perspective, not only the numeric value is enough, but also the owners' opinion is required. Nevertheless, this result is compared with the objective KPI about energy savings, because both must be aligned so that the results would be consistent.	How satisfied are you with the energy savings?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Satisfaction from aesthetic perception			
Aesthetical satisfaction (average score, %)	Aesthetical satisfaction of the solutions.	How satisfied are you with the aesthetics of the implemented solutions?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

The design of **data measurements** and **refurbishment log books** are open. Data from the monitoring system can be used for assessing real parameters, providing the comparison of both survey and measurement methods for a better knowledge of the real situation rather than each of them individually considered. The log book consists of records of important events in the management and operation of the actions for the identification of technical problems before, throughout and after the renovation process. The log book will collect the problems detected by technicians and users to keep record of any occurrence. The associated predefined KPIs are as follows:

- Complaints of residents with the time plan before the starting of works,
- Complaints of residents with the aesthetic of buildings before retrofitting,
- Complaints of residents with the time plan due to delays,
- Complaints with the persons working in the district,
- Complaints due to failure of heating system,
- Complaints due to the aesthetics of the buildings,
- Complaints of residents with the investment cost before works,
- Complaints of residents with the payback before works,
- Complaints of residents with the financial scheme before works,
- Complaints of residents with the energy savings after retrofitting since they do not respond to expected results (low impact in energy bills),
- Complaints due to investment costs significantly higher,
- Complaints with the operating expenses after the retrofitting (higher than expected).

Based on the collected information it is possible to understand the associated complaints about different aspects of retrofitting and store the information as the number of complaints. It is necessary to define the responsibles of log books before, during and after the works (e.g. company involven in the retrofitting, Energy Company, etc.).

LAST MILE VEHICLES

The final design of individual interviews for mobility actions will be done after the mobility actions have been confirmed. The predefined dimensions to measure according to D7.3 are:

- Social background,
- Environmental background,
- Individual perception of residents,
- Economic value of the solutions,
- Technical value of the solutions,

- Technical (problems),
- Economic (problems).

11.1.6 Citizen engagement

Objectives, methods and respective data sources involved in the evaluation of citizen engagement in the city of Vitoria-Gasteiz are brought in Table 16. Citizen engagement will be assessed in four topics: 1) engagement strategy, 2) engagement activities, 3) urban platform, 4) project objectives of the district.

Vitoria-Gasteiz	
Objective	Methods and data sources
Evaluate the citizen engagement strategy through the perception of responsible of their design and residents.	Data collection (attendees' lists, etc.)
Evaluate the level of attendance of residents to information campaigns and events held in the city as part of citizen engagement actions.	Questionnaire (see also Social Acceptance)
Evaluate the use of urban platform/web application.	Urban platform
Evaluate the success of the project objectives in the district.	Citizen Engagement Plan

Table 16: Citizen engagement assessment objectives for Vitoria-Gasteiz

The final decision which KPIs are measured is still open. The predefined KPIs that can possibly be measured are listed in D7.3 Table 76.

11.1.7 Economic performance

Economic performance will be measured for district renovation and mobility (Table 17). The data source for collecting data for economic KPIs is a questionnaire, some of the KPIs will be estimated based on the data collected by questionnaires. The questionnaires are addressed to SmartEnCity partnership members and individual apartments or communities of owners, dependent on the information needed.

In total, there will be estimated eight KPIs for district renovation (Table 18). KPI number 3 (Total annual costs) will be calculated for the baseline as well as for the final performance, other KPIs will be estimated as the final performance. Old costs must be calculated for the baseline of the project, since demo's partners must know what is the value of these costs before the beginning of the renovation. The predefined KPIs for mobility will be described after the mobility actions have been confirmed.

To facilitate the calculation of the different KPIs, an Excel sheet has been prepared under D7.3 SmartEnCity Evaluation Protocols where the information with the indicators disaggregated is depicted in the annex of D7.3. The required data is indicated and when completing it, the Excel sheet gives the KPI resulting value.

Vitoria-Gasteiz	
Objective	Methods and data sources

Economic performance of district interventions	
Energy costs reductions in district for residents with the implementation of energy solutions in district (in comparison with the initial situation). Economic viability of district retrofitting (for owners).	Questionnaire Estimation of energy use after refurbishment Invoices of energy use and other economic data (investment and maintenance for installations) for situation before refurbishment
Economic performance of mobility	
Energy costs reductions in last mile EV (in comparison with the initial situation). Economic viability of investment made in last mile EV.	Questionnaire Estimation

Table 17: Economic performance assessment objectives for Vitoria-Gasteiz

Eq. #	KPI (unit)	Method	Components of KPI (unit)	Data source for the input data	Target respondent(s)
District renovation					
1	Resident costs (€/m^2)	Questionnaire	Total project investment (€)	Preliminary refurbishment project	Individual apartments or communities of owners
			Total grant (€)	Depends on various factors, such as family income, apartment area and cost of the intervention	SmartEnCity partnership
			Total area (m^2)	-	
2	Grant rate (%)	Questionnaire	Total project investment (€)	See Eq. 1	SmartEnCity partnership
			Total grant (€)	See Eq. 1	
3	Total annual costs (€/m^2)	Questionnaire	Total maintenance costs (€)	Invoices	Individual apartments or communities of owners
			kWs uptakes (kW)	Invoices	
			kWs country price (€)	Statistics	SmartEnCity partnership
			Total area (m^2)	-	

4	Total annual benefits for residents (€/m^2)	Questionnaire	Old costs (€)	Invoices	Individual apartments or communities of owners
			Total annual costs (€/m^2)	See Eq. 3	SmartEnCity partnership
5	Cost saving rate (%)	Questionnaire	Total annual benefits for residents (€/m^2)	Estimated from expected energy use and costs before refurbishment, and total costs after refurbishment, see Eq. 4	SmartEnCity partnership
			Old costs (€/m^2)	See Eq. 4	
6	Net present value for resident (€/m^2)	Estimated	Resident costs (€/m^2)	Calculated from previous indicators 1 to 5	SmartEnCity partnership
			Number of years to study (years)		
			BF1+n (number of flows)		
			Inflation rate	National data	-
7	ROI for resident (%)	Estimated	Resident costs (€/m^2)	Calculated from previous indicators 1 to 5	SmartEnCity partnership
			Total annual benefits for residents (€/m^2)		
8	Payback for resident (year, €/m2)	Estimated	Resident costs (€/m^2)	Calculated from previous indicators 1 to 5	
			Total annual benefits for residents (€/m^2)		
			Number of years to study (years)		

Table 18: KPIs, input parameters and data sources for economic assessment for Vitoria-Gasteiz

Mobility related economic assessment KPIs according to D7.3 include:

- Total annual costs,
- Annual costs difference,
- Benefits by uptake savings,
- Benefits,

- Cost of saving a kg CO_2,
- Net present value overall.

These KPIs will be described after the mobility actions for intervention have been selected.

11.1.8 City indicators

The city indicators will provide an overall picture of the interventions and evaluate the impact by the project. The frequency to evaluate the city impacts and the baseline for different topics will be done before the intervention (estimated in M9 and M18) and at the end of the project (M66).

Green background corresponds to impacts to be potentially evaluated as a result of the difference between the value of the indicators used in the city diagnosis made in D3.1 and the value of the intervention performance to be evaluated by the relevant KPIs.

Blue background corresponds to those impacts which require collecting new data by the consortium (maybe not available through the current or foreseen infrastructure).

Red background is associated to those impacts which require involving companies or other type of entities, from the consortium or hired from consortium, in charge of the district renovation, mobility actions and citizen engagement actions to gather the information needed. In this case, the distribution of questionnaires or doing interviews will be required.

The city diagnosis indicators are described in D3.1 and the data have already been collected. Data for KPIs for intervention and the final diagnosis need to be collected.

ENVIRONMENTAL INDICATORS FOR EVALUATING CITY IMPACTS

- **Impact: Energy savings in the city due to district renovation**

Indicator from city diagnosis

Residential buildings energy consumption per year – Residential consumption in the city for heating and electricity uses

Unit: GWh/inhab.year

Data source/method: AVG

Calculation: Energy consumption in residential buildings over a calendar year / Total city population

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Total building energy consumption in the city per capita *(including residential and non-residential uses)* – Residential + non-residential consumption in the city for heating and electricity uses.

Unit: GWh/year per inhabitant

Data source/method: AVG

Calculation: Total energy use / Total city population

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

Energy savings due to district renovation *(Energy Assessment Protocol)*

Unit: GWh

Data source/method: AVG/VISESA

Input parameter	Unit	Data source
Coronation area residential buildings energy consumption per year – before building refurbishment	GWh	Energy bills, simulation, estimated energy use
Coronation area residential buildings energy consumption per year – after building refurbishment	GWh	Energy bills, simulation, estimated energy use, delivered energy indicators

Calculation: Energy savings are calculated for the Coronation district by deducting the measured energy use after renovation from the estimated energy use before the renovation. Estimations of pre-refurbishment energy use have been performed within the LCA protocol. Energy use after the renovation will be measured and reported within the intervention energy protocol.

Reporting frequency and input data collection frequency: Annual reporting, monthly data collection.

- **Lower emissions of CO_2 in the city due to district renovation**

Indicator from city diagnosis

Emissions of residential and non-residential sectors (CO_2 equiv.) – Described as Global Warming Potential (GWP) per capita. Does not include (data not available) the industrial sector as stated in D3.1.

Unit: Tn. equiv. CO_2 / year capita

Data source/method: AVG

Calculation: Emissions of residential and non-residential sectors / city population.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

CO_2 emissions savings due to district renovation *(Energy Assessment Protocol)*

Unit: Tn. equiv. CO_2

Data source/method: AVG/VISESA

Input parameter	Unit	Data source
Coronation area residential buildings energy consumption per year – and energy carriers – before building refurbishment	GWh	Energy bills, simulation, estimated energy use

Coronation area residential buildings energy consumption per year – and energy carriers – after building refurbishment	GWh	CO_2 equivalent indicator
CO_2 conversion factor for energy carriers	Tn. equiv. CO_2 / GWh	National regulations

Calculation CO_2 savings are calculated for the Coronation district by deducting the CO_2 emissions calculated for after renovation from the estimated CO_2 emissions calculated for the situation before the renovation. Calculation of the pre-refurbishment energy use have been performed within the LCA protocol, and CO_2 emissions can be calculated applying the corresponding conversion factors. CO_2 emissions for after the renovation are calculated within the energy protocol for the intervention.

Reporting frequency and input data collection frequency: Annual reporting, annual data collection.

- **Increase in the use of RES in the city due to district renovation**

KPI for intervention

Share of renewable energy – Total share of renewable energy sources in a complex energy supply system.

Unit: %

Data source/method: Estimated.

Input parameter	Unit	Data source
Biomass energy use	kg / kWh	Biomass boiler room meters, biomass invoices
Gas energy use	kWh	Biomass boiler room meters, biomass invoices

Calculation: Share of biomass in relation to total energy use.

Reporting frequency and input data collection frequency: Annually.

- **Number of dwellings/buildings retrofitted due to SmartEnCity project**

Final diagnosis

Number of dwellings and buildings retrofitted – The number of dwellings and buildings retrofitted in the project.

Unit: Number of retrofitted

Data source/method: VISESA's databases.

Input parameter	Unit	Data source
Number of buildings	number	VISESA's databases
Number of dwellings	number	VISESA's databases

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **Number of new buildings/dwellings in the city that demand a retrofitting or to include energy efficient measures**

Final diagnosis

Number of new buildings/dwellings that demand a retrofitting or to include energy efficient measures – The number of buildings/dwellings that claim an energy retrofitting.

Unit: number of buildings, number of dwellings

Data source/method: VISESA's databases.

Input parameter	Unit	Data source
Number of buildings	number	VISESA's databases
Number of dwellings	number	VISESA's databases

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

The final selection of mobility related impacts and associated KPIs will be done after the mobility actions have been confirmed. The predefined impacts and KPIs to measure according to D7.4 are:

- **Energy savings in the city due to sustainable mobility actions**

Indicator from city diagnosis

Transport energy use (per capita)

KPI for intervention

Energy savings due to sustainable mobility actions *(Mobility protocol)*

- **Lower emissions of CO_2 in the city due to sustainable mobility actions**

Indicator from city diagnosis

Transport greenhouse gas emissions

KPI for intervention

CO_2 emissions savings due to sustainable mobility actions *(Mobility protocol)*

- **New sustainable vehicles (EV) in the city due to SmartEnCity project**

Indicator from city diagnosis

Electric vehicles by category (cars, taxis, motorbikes, e-bikes, last mile logistic, bus)

Final diagnosis

Number of new EV

- **Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project**

Indicator from city diagnosis

Number of public EV charging stations *(initially it was required to count only public EV charging stations)*

Final diagnosis

Number of new (public) EV charging stations

- **Increase in the use of EV charging infrastructures due to the project**

Indicator from city diagnosis

Total number of recharges per year

Total kWh recharged in the EV charging stations

KPI for intervention

Total number of recharges per year (biogas and EV) *(Mobility Protocol)*

Total kWh recharged in the EV charging stations (biogas and EV) *(Mobility Protocol)*

Final diagnosis

In the case it is not evaluated through the protocols, other option would be to find this indicator in statistics but It is not clear whether for the LH cities make sense to evaluate this indicator at the end of the project. Changes in the indicator could not be only associated to SmartEnCity.

The following indicators under the following different topics need to be described further:

- Economic indicators for evaluating city impacts,
- Employment indicators for evaluating city impacts,
- City plans and governance indicators for evaluating city impacts.

11.2 Description of KPIs and used data sources for Tartu

11.2.1 Energy assessment

ECM for Tartu is envelope insulation and new windows, ventilation with heat recovery, heating system renovation, heat exchanger for domestic hot water and PV panels. Objectives, methods and respective data sources involved in the evaluation of energy assessment in the city of Tartu are presented in Table 19. Energy savings will be measured using Protocol IPMVP (Option C) and comfort will be evaluated using questionnaires. Reference period for energy assessment evaluation is January 2019–December 2020.

Energy assessment is comparison between baseline situation (energy consumption) and situation after project implementation. Energy assessment for buildings will be done by

collecting data of automatic energy meters and indoor climate sensors readings. Renovated buildings energy meters data will be normalized by degree days and compared with normalized energy consumption data collected before renovation.

Tartu	
Objective	Methods and data sources
Energy performance of the renovated dwellings and new district equipment, including energy savings and CO_2 emissions reduction.	Protocol IPMVP - Option C Building level (main heat meter, dwellings electricity meters and general electricity meter, main gas meter)
	Estimated CO_2 emissions (considering with energy meters monitoring) Questionnaire

Table 19: Energy assessment objectives for Tartu

Monitoring system/home automation (including energy meters, indoor climate sensors) in refurbished buildings is essential for energy assessment. The monitoring system and monitoring devices are not confirmed yet. There are requirements for home automation and monitoring systems, but there is no final confirmation for home automation system and no contracts with home automation installation companies. We do not know the final capabilities of the home automation devices and the monitoring system.

ENERGY SAVINGS

Energy demand – Energy that the building requires to meet its needs/uses (i.e. heating, DHW, cooling, electricity, etc.)

Unit: kWh/m²a

Data source/method: Energy/Flow (gas) meters.

Input parameter	Symbol	Unit	Data source
Buildings main heat meter (before, after)	E_{hb}, E_{ha}	kW·h/m^2·a, kW·h/a	Energy meters
Dwellings electricity meter and buildings general electricity meter (before, after)	E_{eb}, E_{ea}	kW·h/m^2·a, kW·h/a	Energy meters
Buildings main gas meter (before, after)	E_{gb}, E_{ga}	kW·h/m^2·a, kW·h/a	Flow meters
Buildings PV panels electricity on-site consumption	$E_{pv\text{-}o}$	kW·h/m^2·a, kW·h/a	Energy meters (solar inverters data)

Calculation: Buildings energy demand before and after renovation will be calculated by summing energy meters data (heat energy consumption will be normalized by using degree

days. Energy savings: baseline (before) energy consumption deduced from renovated building's energy consumption.

Reporting frequency and input data collection frequency: Data will be collected in two stages (except PV panels data) – 1) energy consumption before renovating (baseline), 2) energy consumption after all renovated buildings have had at least one whole heating season (winter) – renovated buildings data will be collected monthly. For calculating energy savings, both, energy demand before and after renovation could be reported at the end of the project. Energy demand before renovation has been reported in baseline – energy demand for 22 buildings was calculated by using energy consumption data of 16 buildings.

Delivered energy (for buildings) – Delivered energy is energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, etc.) or to produce electricity (EN 15603:2008). Often, comparability with respect to electricity can be achieved if only lighting and auxiliary energy are considered. Thus, user-dependent electricity consumer (computer, refrigerator etc.) are not considered. To enable the comparability between buildings, the delivered energy is related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered time interval (e.g. year).

Unit: kWh/m²a

Data source/method: Energy meters.

Input parameter	Symbol	Unit	Data source
Buildings main heat meter (before, after)	E_{hb}, E_{ha}	kWh/m^2·a, kWh/a	Energy meters
Dwellings electricity meter and buildings general electricity meter (before, after)	E_{eb}, E_{ea}	kWh/m^2·a, kWh/a	Energy meters
Buildings main gas meter (before, after)	E_{gb}, E_{ga}	kWh/m^2·a, kWh/a	Flow meters

Calculation: Buildings energy demand before and after renovation will be calculated by summing energy meters data (heat energy consumption will be normalized by using degree days. Energy savings: baseline (before) energy consumption deduced from renovated building's energy consumption

Reporting frequency and input data collection frequency: Data will be collected in two stages – 1) energy consumption before renovating (baseline), 2) energy consumption after all renovated buildings have had at least one whole heating season (winter) – renovated buildings data will be collected monthly. Both, energy demand before and after renovation could be reported at the end of project. Delivered energy for buildings before renovation has been reported in baseline – energy demand for 22 buildings was calculated by using energy consumption data of 16 buildings.

Primary energy (for buildings) – 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).

Unit: kWh/m²·a

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Symbol	Unit	Data source
Delivered energy per energy carrier	E_d	kWh/a	Energy meters monitoring
Exported energy per energy carrier	E_e	kWh/a	Energy meters monitoring
Primary energy factor for delivered energy carrier	Ef_{pd}	-	Producer, energy supplier
Primary energy factor for exported energy carrier	Ef_{pe}	-	Producer, energy supplier
Floor area of the building	A	m^2	Register of Buildings
Reference time period	T_{ref}	year	-

Calculation: Primary energy for buildings will be calculated by using energy meters data and primary energy factors by using producer and energy supplier data.

Reporting frequency and input data collection frequency: Reported at the end of the project. Data collected monthly.

CO_2 equivalent (for buildings) – The CO_2 emissions of a building correspond to the emissions that are caused by different areas of application (i.e. space heating, space cooling, domestic water heating, electrical appliances). In different variants of this indicator, the emissions caused by the production of the building components can be either included or excluded. To enable the comparability between buildings, the emissions relate to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. year). The greenhouse gases are considered as t of carbon dioxide (CO_2) or a CO_2 equivalent (CO_2e).

Unit: tCO_2/m^2a

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Symbol	Unit	Data source
Electricity CO_2 equivalent	E_{CO2e}	tCO_2e	National institution
Heat CO_2 equivalent	H_{CO2e}	tCO_2e	Producer
Gas CO_2 equivalent	G_{CO2e}	tCO_2e	National institution

Calculation: Will be calculated by using monitored energy consumption data and factors issued by national institution or producer.

Reporting frequency and input data collection frequency: Data collected monthly. Reported at the end of the project.

Density of energy demand – The indicator is defined as ratio of final energy demand (for heating or cooling) of a cohesive set of buildings and a simple figure representing the effort that a district heating or cooling network operator would have in order to supply these buildings. For the latter, the territory area or the number of buildings is chosen in order to represent the length of the network and the number of connections that are required.

Unit: kWh/m²a

Data source/method: Producer, registry.

Input parameter	Unit	Data source
Tartu district heating area	m^2	Registry
Heat energy consumption of Tartu district heating area	kWh/a	Producer/Supplier

Calculation: Tartu district heating area is derived from heat energy consumption of buildings connected with district heating

Reporting frequency and input data collection frequency: Input data collected once. KPI reported at the end of the project.

Peak load and load profile of electricity demand – The load profile describes the demand characteristics over time, while peak load is what the electricity supply has to be able to cover. The load profile gives information about the possibilities or potentials of storage, demand-side management and self-supply via photovoltaic, etc.

Unit: kW

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Load profile (average usage/normal usage)	P_n	kW	Energy meters monitoring
Peak load	P_{peak}	kW	Energy meters monitoring

Calculation: All buildings based/one building based energy consumption graphs by using monitoring data (hourly).

Reporting frequency and input data collection frequency: Data collected monthly, but energy meters measuring frequency is higher (at least hourly based data should be provided). KPI reported at the end of the project.

Other issues: In buildings, there are two types of electric energy meters – general meter(s) for stairway(s) and meters for every dwelling. For determining building's peak load and load

profile it is essential to access both types of energy meters. Accessing dwellings energy meters data could have some privacy issues.

Peak load and load profile of thermal (heating/cooling) energy demand – The load profile describes the demand characteristics over time. The thermal energy supply has to be able to cover the peak load. The load profile gives information about the possibilities or potentials of storage as well as supply-side and demand-side management.

Unit: kW

Data source/method: Monitoring (building's main heat meter)/calculation.

Input parameter	Symbol	Unit	Data source
Outside temperature	t_{out}	°C	Estonian Weather Service
Heating Degree Days	*HDD*	-	Estonian Weather Service
Load profile (base power in heating season)	P_{Hn}	kW	Energy meters monitoring
Peak load	P_{Hpeak}	kW	Energy meters monitoring, National regulations

Calculation: Considering that cooling devices are not installed and heating energy demand depends on outside temperature, peak load should be calculated by using design requirements issued by ministry. Load profile composed by using Estonian climate data could be compared with energy meters monitoring data – all buildings based/one building based energy consumption graphs.

Reporting frequency and input data collection frequency: Data collected monthly. Reported at the end of the project.

Degree of congruence of calculated annual final energy demand and monitored consumption ($DC_{i,t}$) – Ratio of the theoretical energy demand of a building or set of buildings (calculated) and the final energy consumption of a building or set of buildings (measured) over a period of time (e.g. year). Only self-supply supply energy source will solar electricity produced by PV panels.

Unit: %

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Final energy demand of building I based on annual data of year	$EN_{i,\ t,(demand)}$	kWh/(m^2·a)	Energy meters, energy audits
Final energy consumption of building I based on annual data of year	$EN_{i,\ t,\ (consumption)}$	kWh/(m^2·a)	Energy meters

Calculation: $DC_{i,t} = \frac{EN_{i,t,(demand)}}{EN_{i,t,(consumption)}}$

Reporting frequency and input data collection frequency: Data collected monthly. KPI reported at the end of the project.

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. Only self-supply supply energy source will solar electricity produced by PV panels.

Unit: %

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Renovated buildings PV panels annual production	$E_{pv\text{-}p}$	kWh	Energy meters monitoring (solar inverters data)
Renovated buildings annual electricity consumption	E_{ea}	kWh	Energy meters monitoring
Renovated buildings annual energy consumption	E	kWh	Energy meters monitoring

Calculation: Electric self-supply – $E_{pv\text{-}p}$ /E_{ea}, Energetic self-supply – $E_{pv\text{-}p}$ /E

Reporting frequency and input data collection frequency: Data collected monthly. KPI reported at the end of the project.

Share of renewable energy – Total share of renewable energy sources in a complex energy supply system. Only self-supply supply energy source in SmartEnCity buildings will be solar electricity produced by PV panels.

Unit: %

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Renovated buildings PV panels annual production	$E_{pv\text{-}p}$	kWh	Energy meters (solar inverters data) monitoring
Renovated buildings annual electricity consumption	E_{ea}	kWh	Energy meters monitoring
Renovated buildings annual energy consumption	E	kWh	Energy meters monitoring

Calculation: Electric RES – $E_{pv\text{-}p}$ /E_{ea}, Energetic RES – $E_{pv\text{-}p}$ /E

Reporting frequency and input data collection frequency: Data collected monthly. KPI reported at the end of the project.

Efficiency – Evaluation the efficiency of systems (boiler, solar collector, etc.).

Unit: %

Data source/method: Data sheets, monitoring, producers' data.

Input parameter	Symbol	Unit	Data source
PV panels production	$E_{pv\text{-}p}$	kWh	Energy meters monitoring (solar inverter data)
Direct solar radiation	S	kWh/m^2·a	Estonian Weather Service
PV panels efficiency	e_{pv}	%	Manufacturer data sheets
Heat unit heat exchangers efficiency (hot water, heating)	e_h	%	Manufacturers data sheets
Ventilation heat recovery efficiency	e_{vent}	%	Manufacturers data sheets

Calculation: Total system efficiency is calculated by using different systems' efficiencies. PV panels manufacturer issued efficiency will be compared with actual efficency - $E_{pv\text{-}p}$ /S.

Reporting frequency and input data collection frequency: Collecting data starts with when construction project(s) data is available. PV panels production data are collected monthly, Direct solar radiation data is issued annually and rest of the data is constantly collected (collected when data is available). Results are presented once, at the end of the project.

The following KPIs will not be estimated in Tartu context:

- Primary energy (for energy supply units),
- CO_2 equivalent (for supply units).

COMFORT

Internal air temperature – This parameter is directly involved in the determination of internal comfort condition but it also allows to investigate (with another parameter as the heat quantity for set point achievement) how much energy is necessary to reach a particular desired condition known as set point. Use both this parameter (before and after an Energy Conservation Measure (ECM) considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.

Unit: ºC

Data source/method: Monitoring, questionnaire.

Input parameter	Symbol	Unit	Data source
Internal temperature	t	°C	Temp. sensors monitoring, questionnaire

Calculation: Average temperature for dwelling or building will be calculated.

Reporting frequency and input data collection frequency: Data collected monthly. KPI reported once, at the end of the project.

Heat quantity for set point achievement – This parameter allows to collect information about the quantity of energy that is needed to reach a particular temperature condition known as set point. Using this data before and after an ECM (considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.

Unit: kWh

Data source/method: Simulation/meters.

Input parameter	Symbol	Unit	Data source
Dwelling/one building's dwellings average temperature	t_{avg}	°C	Temp. sensors monitoring
Heating energy used by dwelling/building	E_a	kWh	Energy meters monitoring

Calculation: If average temperature is lower than set point, heat quantity for set point achievement could be calculated.

Reporting frequency and input data collection frequency: Data collected monthly. Results could be reported at the end of the project or if all renovated buildings have passed at least one whole heating season.

Other issues: Not sure that private data like room temperature of dwelling could be used.

Thermal comfort – This indicator represents the level of thermal comfort measured as the number of hours that the indoor temperature and relative humidity conditions are within range of values defined. The range of comfort values varies with the seasons (as it depends on the metabolic rate and clothing of the building users) and the climatology of each city (average monthly temperatures (max & min) and average monthly relative humidity).

Thermal comfort will not be measured using data measurements, but questionnaires to capture subjective opinions. The questionnaire for measuring thermal comfort is distributed to owners and tenants under the Social Acceptance Protocol (section 11.2.5). The aspects will be measured once after the intervention. The KPI "Comfort conditions" will address the following aspects that will be measured on a scale 1 to 5 (Not at all … Extremely), on a scale from -2 to 2 (Too cool … Too warm) and on a scale from -3 to 3 (Cold … Hot) dependent on the aspect:

- How satisfied are you with the internal temperature of your apartment in summer(time)?
- How satisfied are you with the internal temperature of your apartment in winter(time)?
- How satisfied are you with ventilation air distribution in your apartment (Is blowing air disturbing you)?
- How satisfied are you with the air quality in your apartment?
- How satisfied are you with the heating, ventilation and air conditioning (HVAC) systems noise level in your apartment?
- What is your perception of the environmental temperature during your presence in the apartment?

- What kind of temperature change would you prefer during your presence in the apartment?

11.2.2 ICT

Objectives, methods and respective data sources involved in the evaluation of ICT in the city of Tartu are presented in Table 20.

Tartu	
Objective	Methods and data sources
O3. To assess the ICT services' features, in terms of performance, such as response time, scalability and extensibility. O4. To assess the impact that the urban platform has over the urban transformation	Meter/analysis – ICT platform
O1. To evaluate the improvements of the existing urban platforms themselves.	Meter/analysis – ICT platform
O2. To evaluate the new ICT developments and services carried out under the SmartEnCity umbrella and integrated into the existing smart urban platforms. O4. To assess the impact that the urban platform has over the urban transformation	Meter/analysis – ICT platform

Table 20: ICT assessment objectives for Tartu

CIOP INDICATORS

Response time – Measurement of time during which the system conforms to the request from outside the system.

Unit: Time (seconds)

Data source/method: Data will be taken from database engine.

Input parameter	Symbol	Unit	Data source
Response time of system	*Tresp*	sec	ICT system

Calculation: Σ = Tresp (cumulative)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously/stored cumulatively.

Scalability – This indicator will give information on how well the ICT systems will be replicated.

Unit: Number of instances per service/class

Data source/method: The data will be obtained by counting the times each class is instantiated.

Calculation: Sum of instances per sevice/class.

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Extensibility – Number of sensors and services integrated.

Unit: Number of services or classes implemented

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Services/classes	*Nserv*	number	ICT system

Calculation: Σ = Σ Nserv (cross sectional).

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Storage capacity – Total storage space in use needed to service the system.

Unit: Disk/cloud storage space (Tb)

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Storage capacity	*Cstor*	Tb	ICT system

Calculation: Σ = Cstor (cross sectional).

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Hours of maintenance – Time needed to upgrade and develop the system due to integration of new services and classes.

Unit: Time (h)

Data source/method: Data will be calculated on basis of information from system.

Input parameter	Symbol	Unit	Data source
Maintenance of ICT system	*Msys*	hour	ICT system

Calculation: Σ = Σ Msys (cumulative).

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously/stored cumulatively.

Non-expected hours offline – The number of hours the system is not in operation.

Unit: Time (h)

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Total hours (cumulative)	*Tsyst*	hour	ICT system
System on (cumulative)	*Tsyson*	hour	ICT system
System in maintenance (cumulative)	*Tsysm*	hour	ICT system

Calculation: Σ = Σ Tsyst – Tsyson – Tsysm

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously/stored cumulatively.

ELEMENTS MANAGED WITH THE ICT SYSTEMS

# of HEMS connected – Number of sensing systems installed in the dwellings and integrated in the CIOP.

Unit: Number of HEMS connected

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
HEMS connected	*Nhems*	number	ICT System

Calculation: Σ = Σ Nhems (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

# of BEMS connected – Number of sensing systems installed per building and integrated in the CIOP.

Unit: Number of BEMS

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
BEMS connected	*Nbems*	number	ICT System

Calculation: Σ = ΣNbems (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

# of EV connected – Number of electric vehicles integrated to the system.

Unit: Number of electric bikes

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Electric bikes	*EV*	number	ICT System

Calculation: Σ = ΣEV (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

# of mobility equipment connected – Number of other mobility related equipment integrated to the system.

Unit: Number of equipment (per class)

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Connected mobility equipment	*EVother*	number	ICT System

Calculation: Σ = Σ EVother (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Total amount of data generated – The amount of data generated by the system.

Unit: Disk/cloud storage space (Tb)

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Disc storage space	*Ds*	Tb	ICT System
Cloud storage space	*Cs*	Tb	ICT System

Calculation: Σ = Ds + Cs (cumulative)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously, stored cumulatively.

Recharging points equipment connected – The number of EV recharging units installed in the pilot area and integrated into the CIOP.

Unit: Number of recharging units

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source

Recharging equipment	*Re*	number	ICT System

Calculation: Σ = Σ Re (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Smart lighting equipment connected – The number of streetlights installed in the pilot area and managed by the system.

Unit: Number of equipment units connected

Data source/method: Data will be taken from the platform itself.

Input parameter	Symbol	Unit	Data source
Connected luminaires	*Lum*	number	ICT System
Connected smart sensors	*Sen*	number	ICT System

Calculation: Σ = Σ Lum + Σ Sen (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

APPLICATION OF ICTs FOR THE CITIZEN

Number of services developed – The amount of services based on ICTs offered to citizens and third parties.

Unit: Number of services

Data sources/method: Data will be gathered manually using information from the system, and questionnaires (will be compiled if necessary in accordance with the situation).

Input parameter	Symbol	Unit	Data source
Mobility services	*SrvM*	number	ICT System
Energy efficiency services	*SrvEE*	number	ICT System
Management services	*SrvMng*	number	ICT System
To be added if relevant	*Srv[…]*	…	…

Calculation: Σ= Σ SrvM + Σ SrvEE + … (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Types of services – The services will be classified by area (mobility, engagement, energy efficiency, management, etc.).

Unit: Number of services by type

Data sources/method: Data will be gathered manually using information from the system and questionnaires (will be compiled if needed to clarify the type of certain services).

Input parameter	Symbol	Unit	Data source
Mobility services	*SrvM*	number	ICT System
Energy efficiency services	*SrvEE*	number	ICT System
Management services	*SrvMng*	number	ICT System
To be added if relevant	*Srv[…]*	…	…

Calculation: Σ = SrvM + SrvEE + … (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Percentage of dwellings connected – The percentage of dwellings (apartments) of pilot area connected to the system.

Unit: %

Data source/method: Data will be gathered from the platform itself.

Input parameter	Symbol	Unit	Data source
Dwellings in pilot area	*Dw total*	number	ICT System
Dwellings in pilot area connected to platform	*Dw connected*	number	ICT System

Calculation: Σ = (Dw connected x 100)/Dw total (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Percentage of buildings connected – The percentage of buildings of pilot area connected to the system.

Unit: %

Data source/method: Data will be gathered from the platform itself.

Input parameter	Symbol	Unit	Data source
Buildings in pilot area	*B total*	number	ICT System
Buildings in pilot area connected to platform	*B connected*	number	ICT System

Calculation: Σ = (B connected x 100)/B total (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Open-Data sets available – Available number of data sets for citizens and third parties for evaluation and service building.

Unit: Number of Open-Data sets

Data sources/method: Data will be gathered from the platform itself.

Input parameter	Symbol	Unit	Data source
Open datasets	*Op data*	number	ICT System

Calculation: Σ = Σ Op data (cross sectional)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

11.2.3 LCA

Objectives, methods and respective data sources involved in the evaluation of LCA in the city of Tartu are presented in Table 21. Table 22 presents the measures for retrofitting.

Tartu	
Objectives	Methods and data sources
Evaluation in terms of LCA for - building retrofitting actions - integrated infrastructures - energy	CML-IA Ecological footprint method Cumulative energy demand methodology Life cycle inventory account Reference study period: 30 years

Table 21: LCA assessment objectives for Tartu

The LCA assessment consists of:

- Definition of baseline scenario and the evaluation of KPIs,
- Life cycle inventory,
- Definition of post-intervention scenario and evaluation of KPIs,
- Final reporting.

	Before retrofitting	**After retrofitting**
Passive measures	Envelop insulation poor and insufficient.	Envelope insulation according to energy calculations approx. 0,15 W/m²deg
	Roof insulation insufficient.	Roof insulation approx. 0,1 W/m²deg
	Windows: replaced some time ago, old.	Windows u-value < 0,9 W/m²deg
		Heat recovery ventilation system,

		efficiency factor > 0,8
Active measures (Integrated infrastructures)	Currently houses are connected to district heating grid. The system inside buildings is usually a "one pipe" system. There are no thermostats and the system is hydraulically unbalanced which leads to uneven temperatures in different dwellings. Ventilation is originally calculated to be free flowing with fresh air coming in through insufficiently tightened windows and doors. As windows are replaced with ones of higher quality the air flow has become insufficient which has led to poor indoor air quality.	Reconstructing the central heating system based on adjustability and mounting thermostatic valves with limiters to radiators.
		Radiators and pipes are replaced with modern ones. Heating system is designed house by house and is adjusted to cooperate with specific ventilation system.
		Ventilation system includes heat recovery with efficiency factor no less than 80%. Ventilation will also be demand-based dwelling wise on the basis of carbon dioxide concentration in indoor air.
		Building integrated (mostly on rooftop) PV panels will be installed to cover electricity demand and over buildings needs produced electricity will be sent to the grid.

Table 22: Measures for retrofitting for Tartu

The LCA is done using a commercial software called SimaPro version 8.3, that includes the strongest database in the market (Ecoinvent version 3.3) and several environmental calculation methods. The data that was collected in the previous stage is modelled according to the different flows existing in the Ecoinvent database.

The input parameters are described only for the first indicator, since the inputs are the same for all the Environmental indicators selected (Global warming, ecological footprint, etc.). There has been prepared an Excel spreadsheet where more detailed information is brought but not presented here. The same set of indicators will also be used for final assessment (after the intervention), but the values may differ (i.e. windows, boilers, etc.).

Global warming potential (EI_1) – Index that attempts to integrate the overall climate impacts of a specific action. It relates the impact of emissions of a gas to that of emission of an equivalent mass of CO2. The duration of the perturbation is included by integrating radiative forcing over a time horizon (e.g., standard horizons for IPCC have been 20, 100, and 500 years). The time horizon thus includes the cumulative climate change and the decay of the perturbation. 100 years has been chosen for the LCA study.

Unit: kg CO_2 eq

Data source/method: CML methodology, IPCC 2013 GWP 100 years. CML-IA is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands. More information on: http://cml.leiden.edu/software/data-cmlia.html.

This method is an update of the CML 2 baseline 2000 and released by CML in April 2013 (version 4.2). The CML 2 baseline 2000 version can be found in the 'superseded' list. For most impact categories, substances have been added and removed and/or characterisation factors were updated, according to new scientific insight. Only the impact category Photochemical oxidation did not undergo any changes. The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into:

- A: Obligatory impact categories (Category indicators used in most LCAs).
- B: Additional impact categories (operational indicators exist, but are not often included in LCA studies).
- C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA).

Input parameter		Value	Unit	Data source
Conditioned area of the district (sum of the surface of all the dwellings)		41 000	m^2	TREA, Ecoinvent database
Envelop insulation total surface (façade)		32 000	m^2	
Roof surface	gable roof	12 700	m^2	
	flat roof	10 700		
Windows: Window surface in the district		6 500–7 500	m^2	
Windows				
Windows: Current windows frame description (wood, PVC, aluminium)		10–20	% wood	TREA, Ecoinvent database
		80–90	% PVC	
		0	% aluminium	
Wood-frame windows life time service		40	years	
Destination after replacement (recycling/landfill/others)		demolished or recycled	-	
Distance to final disposal/treatment		4	km	
% of wood-frame windows that will be replaced according to the life-time service in the district		99	%	
PVC-frame windows life time service		25	years	
Destination after replacement (recycling/landfill/others)		demolished or recycled	-	
Distance to final disposal/treatment		4	km	
% of PVC-frame windows that will be replaced according to the life-time service in the district		99	%	
Aluminium-frame windows life time service		40	years	
Destination after replacement (recycling/landfill/others)		-	-	

Input parameter	Value	Unit	Data source
Distance to final disposal/treatment	-	km	
% of aluminium-frame windows that will be replaced according to the life-time service in the district	-	%	
Windows replacement origin (Distance form the new windows supplier)	4–10	km	
District heating			
Detailed description of boilers can be found in the Excel sheet.			TREA, Ecoinvent database
Energy			
Global thermal energy consumption from individual boilers (kWh/year, m^3 fuel/year, etc.) please be clear with the units (per m^2, per total district, etc.)	650	MWh/year per 22 buildings	TREA, Ecoinvent database
Global thermal energy consumption from centralized boilers (kWh/year, m^3 fuel/year, etc.) please be clear with the units (per m^2, per total district, etc.)	7 100	MWh/year per 22 buildings	
Global electricity energy consumption (kWh/year) please be clear with the units (per m^2, per total district, etc.)	1500	MWh/year per 22 buildings	

Calculation: In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Other issues: The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalent/kg emission.

All adaptions of the method (2001–2012) are present in CML-IA_update_info.xls which can be downloaded from the CML website http://cml.leiden.edu/software/data-cmlia.html

Munoz, I. and Schmidt, J.H. (2016). Methane oxidation, biogenic carbon, and the IPCC's emission metrics. Proposal for a consistent greenhouse-gas accounting. The International Journal of Life Cycle Assessment, 21:1069–1075.

Ecological Footprint (EI_2) – The Ecological Footprint is defined as the area of productive land and water ecosystems required to produce the resources that the system needs and assimilate the wastes generated.

A measure of how much area of biologically productive land and water that an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption. Ecological Footprint is often referred to in short form as Footprint. "Ecological Footprint" and "Footprint" are proper nouns and thus should always be capitalized.

Unit: ha

Data source/method: Ecological footprint method. Method directly taken from Ecoinvent 2.0; Contact info: http://www.ecoinvent.org/contact/. Method published by Niels Jungbluth, ESU-services Ltd., Uster.

Calculation: Ecological Footprint (EF) = sum of time integrated direct land occupation and indirect land occupation. Normalisation is not a part of this method. Weighting: as each impact category is expressed in the same unit, a weighting factor of 1 is used for every impact category. For more information see the Database manual Version 1.01. (April 2009) – Added substance "Carbon dioxide" with a factor of 2.6722 to impact category "carbon dioxide".

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Use of renewable primary energy excluding energy resources used as raw material (RU_1) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non-renewable, as well as energy used for raw material and other uses.

Unit: MJ

Data source/method: Cumulative energy demand methodology. Method to calculate Cumulative Energy Demand (CED), based on the method published by Ecoinvent version 2.0 and expanded by PRé Consultants for raw materials available in the SimaPro 7 database.
Contact info: http://www.ecoinvent.org/contact/

Frischknecht R., Jungbluth N., et al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, www.ecoinvent.ch

- Wood is not included in this methodology due to the frequent use of wood as feedstock in Simapro.

- Normalization: it is not a part of this method.
- Weighting: Each impact category is given the weighting factor 1.
- For more information see the Database manual.
- Adaptations (August 2004, v1.01):
  - Added: Additional oil resources;
  - Water, barrage
  - Corrected values: Uranium ore, 1.11 GJ per kg, in ground; Uranium, 2291 GJ per kg, in ground; Uranium, 451 GJ per kg, in ground; Uranium, 560 GJ per kg, in ground.
  - Not included: Energy from hydrogen; Energy, recovered; Energy, unspecified; Oil; Steam from waste incineration.
- Other adaptations (March 2005, v1.02):
  - Sulphur removed.
- Other adaptations (August 2005, v1.03):
  - In impact category Non-renewable, fossil the characterisation value for "Gas, natural in ground" has been changed from 40,3 to 38.3 MJ LHV/m^3 following the Ecoinvent 1.2 update.
- Other adaptations (February 2008, v1.04):
  - Minor adaptations in Unit names and Impact category names (capitals, points) for more consistency with other categories.
- Other adaptations (April 2008, v1.05):
  - Seven extra substance flows are added:
    - Energy, gross calorific value, in biomass, primary forest,
    - Geothermal converted,
    - Energy, solar, converted,
    - Energy, from hydrogen,
    - Energy, unspecified
  - The characterisation factor of Peat, in ground' raw biotic in IC non-renewable, fossil has a new characterisation factor = 9
- Other adaptations (November 2009, v1.06):
  - Created a new impact category: 'Non-renewable, biomass' and moved the substance 'energy, gross calorific value, in biomass, primary forest' to this new impact category.
- Other adaptations (March 2010, v1.07):
  - Weighting: The weighting factor of impact category non-renewable biomass was changed to 1.
- Other adaptations (August 2010, v1.08):
  - The quantity and unit of the single score is changed:
    - 1.07: Indicator (Pt)
    - v1.08: Energy (MJ)
- Other adaptations (August 2014, v1.09):
  - The following flows were added:
    - Coal, bituminous, 24.8 MJ per kg
    - Coal, hard, 30.7 MJ per kg
    - Gas, natural/kg
  - The factor for Methane was changed from 35.9 to 55.53 MJ/kg (the previous value was in MJ/m3, which is the incorrect unit).

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the same methodology, the following KPIs will also be calculated:

Use of renewable primary energy resources used as raw material (RU_2) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy excluding energy resources used as raw material (RU_3) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy resources used as raw material (RU_4) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Exported energy (OF_1) – Energy that is produced in the context of the district studied that can be exported from the system to other use out of the systems boundaries. Unit: MJ

Hazardous wastes disposed (WC_1) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC.

Unit: kg

Data source/method: Life cycle inventory account

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the same methodology, the following KPI will also be calculated:

Non-hazardous wastes disposed (WC_2) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC. Unit: kg

11.2.4 Mobility

Objectives, methods and respective data sources involved in the evaluation of mobility in the city of Tartu are presented in Table 23.

Tartu	
Objectives	Methods and data sources
To measure activity of usage of EVs	Data will mainly be gathered by ICT system.

(electric bikes) and environmental impact from traffic.	Environmental impact will be calculated separately based on cancelled car trips.

Table 23: Mobility assessment objectives for Tartu

Average occupancy (EVs, in Tartu case electric bikes) – Mean number of persons per vehicle/day. Description replaced with mean number of electric bike rentals (per electric bike) per day.

Unit: Number of rentals by bike/day

Data source/method: Data will be gathered from the platform.

Input parameter	Symbol	Unit	Data source
EV (electric bike)	*Num veh*	number	ICT system
Number of rentals (cumulative)	*Num rentals*	number	ICT system
Period to cover (days)	*Num days*	number	-

Calculation: Σ = (Num rentals/Num veh)/Num days

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously, stored cumulatively.

Accuracy of timekeeping for public bus – Number and percentage of services arriving/departing on time.

Unit: Number of services, % of services

Data source/method: Meter, data from real time bus system.

Input parameter	Symbol	Unit	Data source
Total departures (in a year)	*Dep total*	number	Real time bus info system
Total departures within allowed time of delay or ahead of schedule (in a year)	*Dep in time*	number	Real time bus info system

Calculation: Σ = (Dep in time/Dep total)*100

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously, stored cumulatively.

CO_2 emissions by travelled distance – CO_2 emissions produced by travelled distance (cars).

Unit: kg CO_2

Data source/method: Estimated.

Input parameter	Symbol	Unit	Data source

Distances travelled	*Dst*	km	Estimated calculations
Emissions CO_2 by km	*Em CO_2*	kg	Calculations

Calculation: $\Sigma = Dst \times EmCO_2$

Reporting frequency and input data collection frequency: KPI reported annually. Data collected once a year.

Other issues: More detailed methodology will be developed.

Total number of recharges per year (EV) – Total number of recharges during a year in the public and private charging stations. It will be required to infrastructure operator and vehicle owners in order to compare this indicator with energy consumption and distance travelled. Charges by electric cars are accounted.

Unit: Number of recharges

Data source/method: Data from ICT system. Questionnaire will be used to map the service providers and the number of chargers and recharges.

Input parameter	Symbol	Unit	Data source
Recharges in year	*Num rec*	number	ICT system

Calculation: Σ = Num rec (cumulative)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously, stored cumulatively. Questionnaire addressed once a year.

Other issues: To be decided if private charging stations are included in the analysis. Distance travelled will not be measured.

Method	Questionnaire for the assessment of total number of recharges per year
Materials (what?)	Questions to be addressed: 1) How many EV-chargers do you own and maintain? 2) How many recharges were made through your EV-chargers in a year? 3) What is the total kWh recharged through your system?
Agents to involve (who?)	EV-charger owners
Means (how?)	On-line survey, addressed once a year

Total kWh recharged in the EV charging stations (EV) – Number of kWh recharged during a year in the public and private charging stations. It will be required to infrastructure operator and vehicle owners to compare this indicator with energy consumption and distance travelled. Charges by electric cars are accounted.

Unit: kWh

Data source/method: Data from ICT system.

Input parameter	Symbol	Unit	Data source
Total kWh recharged	kWrec	kWh	ICT system

Calculation: Σ = kWrec (cumulative)

Reporting frequency and input data collection frequency: KPI reported annually. Data collected continuously, stored cumulatively.

Other issues: To be decided if private charging stations are included in the analysis. Distance travelled will not be measured.

11.2.5 Social acceptance

Objectives, methods and respective data sources involved in the evaluation of social accpetance in the city of Tartu are presented in Table 24. There will be conducted three questionnaire based surveys to understand the social acceptance of agents: 1) among people living in the district renovated (people living in the retrofitted buildings), 2) among people benefitting from the mobility actions of the project, and 3) among citizens. In addition, there will be conducted an interview based survey to understand the attitudes of the residents living in the pilot area, and focus group interviews that aim to specify results gained from the questionnaires.

Tartu	
Objective	Methods and data sources
Evaluation of the acceptance of owners and tenants living in the district on SmartEnCity solutions implemented in the district renovated. Evaluation of the gains in life quality due to the project in owners and tenants from district.	Questionnaire Individual interview Focus group interview
Evaluation of the acceptance on EV by users of rented EV and e-bikes. Evaluation of the gains in life quality due to the project in users of rented EV and e-bikes.	Questionnaire
Evaluation of the acceptance on actions implemented in SmartEnCity project by citizens. Evaluation of the gains in life quality due to the project in citizens of Tartu.	Questionnaire

Table 24: Social acceptance assessment objectives for Tartu

DISTRICT RENOVATED

- *Questionnaire*

Method	Questionnaire for the residents living in the buildings renovated
Materials (what?)	KPIs and related questions in the questionnaires directed to the residents of the district renovated are divided into five groups: 1) social background of a respondent, 2) environmental background of a respondent, 3) individual perceptions of residents (aka respondent), 4) economic value of the solution estimated by the respondent, 5) technical value of the solutions estimated by the respondent. The questions, answer choices considering Estonian context and units are defined below. The questionnaire will be sent out in Estonian and Russian. Depending on the question, most of the questions will be close-ended (multiple choice) or requiring a short answer. Some of the pre-defined answer choices use the Likert-scale (from 1 to 5).
Agents to involve (who?)	The questionnaire will be addressed to residents (16-years old and older) living in retrofitted buildings. Total population forms of 22 buildings constituting of in total about 800 apartments (households). The questionnaire will be sent to all apartments. The estimated response rate is 15%. There will be sent out a second wave of invitations if the first wave does not meet the response rate.
Means (how?)	The invitations and the questionnaire itself will be distributed on paper (by mail) and the questionnaire can be filled on paper or in the Web. Every invitation has a unique ID to identify houses and apartments that have answered. Afterwards the data will be anonymized, i.e. the apartment number will be removed. The survey will be carried out at least one year after the end of retrofitting activities.

Social background

KPI/element	Description of KPI	Question	Response
Individual characteristics			
Age of residents (average, % of categories)	The age of residents.	How old are you?	Numerical value (Categories can be defined later, if necessary)
Gender (% of categories) *Complementary question*	The gender of respondents.	What is your gender?	1) Male 2) Female 3) Other
Highest level of completed education of inhabitants (% of categories)	The highest level of completed education of residents.	What is your highest level of completed education?	1) Secondary educations 2) High school education 3) Vocational education 4) Secondary-vocational education 4) Higher education
Primary language of communication (% of categories)	The nationality data corresponds to (i) the percentage of main nationality and (ii)	What is your primary language of communication?	1) Estonian 2) Russian 3) English

	percentage of foreigners. The KPI of nationality is substituted with primary language of communication.		4) Other […]
Net monthly income of the households (% of categories)	The net monthly income of the households. All incomes without taxes.	What is the net monthly income of your household for the previous month (all incomes without taxes)?	1) <= 320 € 2) 321–640 € 3) 641–959 € 4) 960–1280 € 5) 1281–1600 € 6) >= 1601 €
Employment (% of categories) *Complementary question*	Employment structure	What describes your current employment?	1) Employed 2) Entrepreneurial employer 3) Self-employed, freelance 4) Unpaid family worker 5) Member of a commercial association 6) Student (incl. university) 7) Unemployed 8) Long-term unemployed (over 12 months) 9) Retired 10) Stay-at-home 11) In other circumstances, a non-working
Size of the household (average, % of categories) *Complementary question*	The number of household members. Household is defined as those who dwell under the same roof and compose a family.	How many people are there in your household?	Numerical value (Categories can be defined later, if necessary)
Characteristics of the dwelling			
Type of building (% of number of types)	The building types.	*This KPI/question is omitted, since all buildings are hruchovkas.*	
Size of dwelling – heated area (average m^2, % of categories)	The size of the dwelling corresponds to the surface in m^2.	What is the size of your apartment?	Numerical value (Categories can be defined later, if necessary)
Size of dwelling – number of rooms (average number, % of categories)	The size of the dwelling according to number of rooms in apartment.	How many rooms (bedrooms and living room) do you have in your apartment?	Numerical value (Categories can be defined later, if necessary)

Complementary question			
Ownership structure (% of categories)	The ownership structure.	What is the ownership of your apartment?	1) Owner 2) Rental 3) Apartment belongs to a family member/relative/friend (i.e. I do not pay rent)
Accommodation time (% of categories)	The years of occupancy in the current home.	How long have you lived in your apartment?	1) <= 3 years 2) 4–6 years 3) 7–10 years 4) 11–20 years 5) >= 21 years

Environmental background

KPI/element	Description of KPI	Question	Response
Knowledge and environmental awareness on environmental problems			
Environmental awareness (average score, %)	The knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on global environmental problems. The following values are derived from the Special Eurobarometer 416 report: Attitudes of European Citizens Towards the Environment[28]	How do you assess your awareness and knowledge on the following global environmental problems? #1: Climate change #2: Air pollution #3: Water pollution (seas, rivers, lakes and underground sources) #4: The impact on our health of chemicals used in everyday products #5: The growing amount of waste #6: Depletion of natural resources #7: Agricultural pollution (use of pesticides, fertilisers, etc.) #8: Shortage of drinking water #9: Loss of extinction of species and their habitants and of natural ecosystems (forests, fertile soils) #10: Our consumption habits #11: Urban problems (traffic jams, pollution, lack of green	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.

[28] http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_416_en.pdf

		spaces, etc.) #12: Land take (i.e. that more land is used to build roads or cities, and that cities expand into the surrounding countryside) #13: Noise pollution #14: Soil degradation #15: The spread of harmful non-native plants and animals (invasive species)	
Awareness of environmental problems in the city (average score, %)	The level of knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing environmental problems in the city.	How do you assess your awareness and knowledge on the following environmental problems in the city? #1: Air pollution #2: Noise pollution #3: The growing amount of waste #4: Urban problems (traffic jams, pollution, lack of green spaces, etc.)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.
Knowledge and benefits of the solutions implemented in energy efficient retrofit projects			
Knowledge about efficient energy measures (average score, %)	The level of knowledge of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing efficient energy measures at building level.	How aware are you about the following measures and benefits to achieve energy efficiency? #1: Insulation to decrease the thermal loss in cold climate and thermal gain in warm climate #2: Lightning (more economic systems: energy saving light bulb, movement sensors, etc.) #3: Energy-efficient windows #4: Smart meters & energy dashboards #5: Technology for producing renewable energy (i.e. solar panels) #6: Ventilation (to regulate air temperature, humidity and CO_2 concentration) #7: Home appliance energy efficiency (i.e. Energy Star)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every measure and benefit separately.

Individual perception of residents

KPI/element	Description of KPI	Question	Response
Fairness and inclusiveness in the decision-making process: satisfaction with the project, with the level of information received, with the involvement degree.			
Residents project satisfaction (average score, %)	The level of satisfaction of the dwelling's resident with regard to the project in general terms. The project is surrounded by technical solutions, information, costs, intervention phases and external conditions, among others.	How satisfied are you with the project as a whole?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the information accessibility (average score, %)	This KPI determines whether the residents with energy monitoring systems are satisfied with the access to such data.	How satisfied are you with the accessibility of information related to energy monitoring?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Residents information satisfaction (average score, %)	Satisfaction with the information level provided to the residents about the intervention, costs and so on. A subjective KPI which assesses the residents' opinion.	*This KPI/question is omitted since the following KPI described in the Citizen Engagement protocol is used.*	
Resident information satisfaction (average score, %) *Related to Citizen Engagement KPI*	Residents who considered to be well-informed during the information campaigns that were carried out as part of citizen engagement actions.	How informed did you feel during the information campaigns about the project?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Project involvement degree (% of number of suitable categories)	The type of beneficiary is classified as: beneficiary related to building retrofitting, related to mobility action or through dissemination activities addressed for whole citizens.	*This KPI/question is omitted, since residents living in buildings retrofitted will be asked, thus the respondent is automatically accounted as "building retrofitted".*	
Residents involvement degree (average score, %)	% of people who feel involved during the intervention project life cycle.	*This KPI/question is omitted since the following KPI described in the Citizen Engagement protocol is used.*	
Involvement degree (average score, %) *Related to Citizen Engagement KPI*	Residents who felt involved in the decisions taken in the district.	How involved did you feel in the decision-making process?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Resident consultation satisfaction (average score, %) *Related to Citizen Engagement KPI*	Residents who felt well-consulted during the information campaigns that were carried out as part of citizen engagement actions.	How well-consulted did you feel during the information campaigns?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Trust in decision makers in terms of suitable time plan for the execution of actions and the			

communication and dialogue with decision makers			
Satisfaction with time plan for the execution of actions (average score, %)	-	How satisfied are you with the time plan for the execution of retrofitting?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the communication and dialogue with decision makers (average score, %)	-	How satisfied are you with the communication and dialogue with the decision makers? *(Decision makers to be defined)*	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Economic value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the investment costs			
Satisfaction with the investment costs (average score, %)	Determines the level of satisfaction of the dwelling's residents with the investment costs. Investment costs are defined as the percentage the residents need to pay.	How satisfied are you with the project investment costs at the moment?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) – Don't know/No opinion (6)
Satisfaction with the access to financing			
Satisfaction with the access to financing (average score, %)	Determines the level of satisfaction of the dwelling's residents with the access to financing.	*This KPI/question is omitted since the decision to participate in the project and the application to a loan is a collective decision of the building cooperative. The previous KPI/question already covers the opinion of residents about the size of their investment cost.*	
Satisfaction with the payback period			
Satisfaction with the payback period (average score, %)	Determines the level of satisfaction of the dwelling's residents with the payback period. Payback period is defined as the length of time required for an investment to recover its initial outlay in terms of profits or savings.	How satisfied are you with the payback period?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) – Don't know/No opinion (6)
Satisfaction level with the reduction in the energy bills			
Energy bill reduction (average score, %)	Reduction in the energy bills that is directly translated into money. Subjective measure.	How has the size of your energy bill (heat and electricity) changed compared to the period before retrofitting?	Scale from 1 to 5. Decreased a lot (1) – Decreased a little (2) – No change (3) – Increased a little (4) – Increased a lot (5)

Willingness to invest in further energy projects			
Further investments in energy related projects (average score, %)	The percentage of inhabitants who would like to invest in further energy projects taking into consideration the results of the SmartEnCity one.	Given your present economic situation how willing are you to invest in further energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Technical value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the solution implemented as a whole			
Whole solution satisfaction (average score, %)	The whole solution covers the technical side: retrofitting, smart home solution, etc., and their benefits.	How satisfied are you with the solution implemented as a whole?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Technical solution satisfaction (average score, %)	Any renovation project has the main objective of improving the performance of the building. However, other problems can arise such as new moisture issues. All the inconveniences during the retrofitting stage may be classified in different levels of impact from an objective point of view, but the residents' perspective is also important.	*This KPI/question is omitted, since whole solution satisfaction covers the topic for technical satisfaction.*	
Satisfaction from the energy perspective (comfort)			
Comfort conditions (average score, %)	Another goal of this sort of projects is the comfort, even the most important from the end user together the reduction of the energy bills. In contrast to the subjective evaluation, the objective result gives the real performance compared to the National regulations which limit the maximum and minimum conditions associated to the building typology. Thus, the opinion of the owners can be compared with the regulations to obtain the real context.	#1: How satisfied are you with the internal temperature of your apartment in summer(time)? #2: How satisfied are you with the internal temperature of your apartment in winter(time)?	Scale from -2 to 2. Too cool (-2) – Cool (-1) – Satisfied (0) – Slightly warm (1) – Too warm (2) Response required for every comfort condition separately.
		#3: How satisfied are you with ventilation air distribution in your apartment (Is blowing air disturbing you)? #4: How satisfied are you with the air quality in your apartment? #5: How satisfied are you with the heating, ventilation and air conditioning (HVAC)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every comfort condition separately.

		systems noise level in your apartment?	
		#6: What is your perception of the environmental temperature during your presence in the apartment? #7: What kind of temperature change would you prefer during your presence in the apartment?	PMV[29] Scale from -3 to 3 Cold (-3) – Cool (-2) – Slightly cool (-1) – Neutral (0) – Slightly warm (1) – Warm (2) – Hot (3) Response required for every comfort condition separately.
Satisfaction from the energy perspective (energy savings satisfaction)			
Energy savings satisfaction (average score, %)	One of the main objectives of this kind of projects is the reduction of the energy consumption both at district and building and dwelling levels. However, from the social perspective, not only the numeric value is enough, but also the owners' opinion is required. Nevertheless, this result is compared with the objective KPI about energy savings, because both must be aligned so that the results would be consistent.	*This KPI/question is omitted, since KPI "Energy bill reduction" covers the topic.*	
Satisfaction from aesthetic perception			
Aesthetical satisfaction (average score, %)	Aesthetical satisfaction of the solutions. This covers the retrofitted buildings and artwork.	How satisfied are you with the aesthetics of the implemented solutions?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

- *Focus group interview*

Method	**Focus group interview with residents**
Materials (what?)	The aim of the focus groups is to specify the results gained from the questionnaire, which is mostly closed end questions and have no room for explaining the answers. Focus group interviews allow for initiating further discussions around the reasons which may help to explain certain results from the survey and bring along further issues regarding the social acceptance of the project, remaining problems that the residents may have with the project, understand more the energy behaviour of the citizens in the changed context, etc. Main materials will be the questionnaire results and also the interview results carried out in 2017.
Agents to involve	Focus groups will be conducted among the pilot area residents. The invitation to the focus group interviews will be public and participation voluntary, however, dependent

[29] The Predicted Mean Vote (PMV) refers to a thermal scale that runs from Cold (-3) to Hot (+3). Predicted Mean Vote sensation scale: (-3) Cold, (-2) Cool, (-1) Slightly cool, (0) Neutral, (1) Slightly warm, (2) Warm, (3) Hot (https://sustainabilityworkshop.autodesk.com/buildings/human-thermal-comfort). PMV is based on AMV (Actual Mean Vote).

(who?)	on the interest to take part in the focus groups, as various sample as possible will be formed (e.g. by owner type, age, social status, etc.). It is envisaged to conduct 2–5 focus groups in the pilot area.
Means (how?)	Invitation to the focus groups will be distributed through the project's local web-page, social media and through the e-mail list that has been created for the residents of the pilot area buildings.

- *Individual interview*

Method	**Individual interview** The interviews provide additional information and more deep understanding about the attitudes toward environment, technology and the project. Research questions are set as follows: 1. What are the attitudes toward environment and technology? 2. How people evaluate the role of technology in environmental sustainability? 3. What are the motives and barriers of using more environmentally friendly technologies? 4. How aware are people about the SmartEnCity project?
Materials (what?)	Qualitative research methods – 20 interviews that will be carried out among the pilot area residents. Interview questions will be both closed and open-ended. The interview is expected to last approximately 60–75 minutes. The interview consists of the aforementioned thematic blocks: 1. dwelling and mobility – satisfaction with dwelling and neighbourhood, mobility habits (24 main questions); 2. environmental awareness and environmental behaviour – attitudes and beliefs towards environment, actual behaviour (14 main questions); 3. technology – attitudes towards technology, actual behaviour (11 main questions); 4. the concept of smart city and the SmartEnCity project – knowledge about smart city concept and the SmartEnCity project, attitudes toward the project and the foreseen project outcomes (12 main questions); 5. socio-demographic background (10 main questions).
Agents to involve (who?)	Invitations were sent to 8 different panel houses. The panel houses were chosen dependent on their activity level (active or inactive) to participate in the SmartEncity project and the level of previous retrofitting activities (more retrofitted, less retrofitted). Apartments in every building were chosen by random sampling. There were two waves of invitations (the second wave invitations were sent to those who had not replied in the first wave). The invitations were sent to the letter boxes both in Estonian and Russian. If there are problems with the response rate it is up to the researchers to alter the sampling methods.
Means (how?)	100 invitations were sent out to participate in the interview. The participants were offered a 10€ gift token as a reward for participating. The invitation allowed to be interviewed in Estonian, Russian or English. Two interviewers carry out the interviews. The interviews will be recorded. Afterwards,

	the interviews will be transcribed and analysed.

MOBILITY

Method	Questionnaire for citizens associated with mobility actions
Materials (what?)	KPIs and related questions in the questionnaires directed to the residents of the district renovated are divided into five groups: 1) social background of a respondent, 2) environmental background of a respondent, 3) individual perceptions of a respondent, 4) economic value of the solution estimated by the respondent, 5) technical value of the solutions estimated by the respondent. The questions (in English), answer choices taking into account Estonian context and units are defined below. Depending on the question, most of the questions will be close-ended (multiple choice) or short answer. Some of the answers use the Likert-scale (1 to 5). There can be developed complementary questions related to specific services (i.e. bike rental, users of EV chargers) and the use of these services (why they use this service, etc.) The questionnaire presented here has been designed in English, but for further distribution and implementation it needs to be translated to Estonian.
Agents to involve (who?)	There are two approaches to the sample: the first one derives from the need to understand what are the attitudes toward more sustainable mobility modes, the second derives from the need to understand the attitudes of those who already are using or have used the service. The mobility questionnaire targets: **Residents of the pilot area** – questions addressed as part of the residents' survey to understand their opinion about mobility actions. **Users of the services** (electric bike rental, electric car chargers, gas buses) – questions related to economic and technical aspects of the service. **Other citizens** – survey to understand citizens' opinions about mobility actions.
Means (how?)	**Residents of the pilot area** – see the description of questionnaire for "District renovated". **Users of the services** – Dependent on the services it is possible to create mobile surveys that request to assess the quality and other characteristics of the service. If possible, then questionnaire addressed using mobile phones (mobile survey), otherwise other methods need to be discussed. What methods to use is dependent on the services developed and partners associated with service development. Additional agreements needed with service providers. **Other citizens** – see the description of the questionnaire for "Full SmartEnCity Actions".

Social background

KPI/element	Description of KPI	Question	Response
Characteristics of the vehicle user			

Age of the respondent (average age, % of categories)	The age of vehicle user/driver.	How old are you?	Numerical value (Later it can be dividend into suitable categories)
Gender (% of categories)	Gender of the respondent. The number of women and men as a percentage of the total respondents.	What is your gender?	1) Male 2) Female 3) Other
Highest level of completed education of respondents (% of categories)	The highest level of completed education of the respondents.	What is your highest level of completed education?	1) Secondary education 2) High school education 3) Vocational education 4) Secondary-vocational education 4) Higher education
Primary language of communication (% of categories)	The nationality data corresponds to (i) the percentage of main nationality and (ii) percentage of foreigners. The KPI of nationality is substituted with primary language of communication.	What is your primary language of communication?	1) Estonian 2) Russian 3) English 4) Other […]
Employment (% of categories) *Complementary question*	Employment structure	What describes your current employment?	1) Employed 2) Entrepreneurial employer 3) Self-employed, freelance 4) Unpaid family worker 5) Member of a commercial association 6) Student (incl. university) 7) Unemployed 8) Long-term unemployed (over 12 months) 9) Retired 10) Stay-at-home 11) In other circumstances, a non-working
Net monthly income of the households	The net monthly income of the households. All incomes	What is the net monthly income of your household for	1) <= 320 €

(% of categories) *Complementary question*	without taxes.	the previous month (all incomes without taxes)?	2) 321–640 € 3) 641–959 € 4) 960–1280 € 5) 1281–1600 € 6) >= 1601 €
Size of the household (average, % of categories) *Complementary question*	The number of household members.	How many people are there in your household?	Numerical value (Categories can be defined later, if necessary)
Transport modes (% of categories) *Complementary question*	Main transport mode.	What is the main transport mode you use daily? #1: In summer #2: In winter	1) On foot 2) Bicycle 3) Car 4) Public transport (bus) 5) Other
Years as vehicle user (average years, % of categories)	Years as vehicle user.	*This KPI/question is omitted since vague in Tartu context.*	
Characteristics of vehicle replaced			
Years of vehicle to be replaced (Average years, % of categories)	The years of vehicle.	*This KPI/question is omitted since no vehicle replacement takes place.*	

Environmental background (this block can be addressed to all three target groups)

KPI/element	Description of KPI	Question	Response
Knowledge and environmental awareness on environmental problems			
Environmental awareness (average score, %)	The knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on global environmental problems. The following values are derived from the Special Eurobarometer 416 report: Attitudes of European Citizens Towards the Environment[30]	How do you assess your awareness and knowledge on the following global environmental problems? #1: Climate change #2: Air pollution #3: Water pollution (seas, rivers, lakes and underground sources) #4: The impact on our health of chemicals used in everyday products	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every environmental problem separately.

[30] http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_416_en.pdf

		#5: The growing amount of waste #6: Depletion of natural resources #7: Agricultural pollution (use of pesticides, fertilisers, etc.) #8: Shortage of drinking water #9: Loss of extinction of species and their habitants and of natural ecosystems (forests, fertile soils) #10: Our consumption habits #11: Urban problems (traffic jams, pollution, lack of green spaces, etc.) #12: Land take (i.e. that more land is used to build roads or cities, and that cities expand into the surrounding countryside) #13: Noise pollution #14: Soil degradation #15: The spread of harmful non-native plants and animals (invasive species)	
Awareness of environmental problems in the city (average score, %)	The level of knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing environmental problems in the city.	How do you assess your awareness and knowledge on the following environmental problems in the city? #1: Air pollution #2: Noise pollution #3: The growing amount of waste #4: Urban problems (traffic jams, pollution, lack of green spaces, etc.)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every environmental problem separately.
Knowledge and benefits of the solutions implemented in energy efficient projects related to mobility			
Knowledge about efficient energy measures (average score, %)	The level of knowledge of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing efficient energy measures at building level.	Have you heard about the following measures and benefits? #1: Public transport #2: Green transport #3: Car-sharing #4: Car-pooling #5: Park-and-ride	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every measure separately.

		#6: Infrastructure for alternative modes of transport (i.e. bicycle): light traffic, public bicycle storage #7: Limiting free parking spaces for cars #8: Alternative fuel based transport (gas, electricity, etc.) #9: Bicycle rent	

Individual perception of service users (these questions will be asked if the respondent has heard about the SmartEnCity project and project's results, and/or has used the service(s))

KPI/element	Description of KPI	Question	Response
Acquaintance with the project (% of categories)	Indicates whether the person has heard about the SmartEnCity project.	Have you heard about the SmartEnCity project?	1) Yes 2) No
Use of mobility services (% of categories)	Indicates whether the person has used the service.	Have you used the service? #1: Public transport #2: Electric bikes #3: EV chargers	1) Yes 2) No
Fairness and inclusiveness in the decision-making process: satisfaction with the project, with the level of information received, with the involvement degree.			
Service user's project satisfaction (average score, %)	The driver's (here service users') project satisfaction KPI determines the level of satisfaction of the driver's owners with regard to the project in general terms. The project is surrounded by technical solutions, information, costs, intervention phases and external conditions, among others.	How satisfied are you with the project outcomes related to mobility actions? *(actions include bike rental, new gas buses, new EV chargers)*	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the information accessibility (average score, %)	This KPI determines whether the drivers with energy monitoring systems are satisfied with the access to such data.	*This KPI/question is omitted, since the drives do not have energy monitoring systems.*	
Service user's information satisfaction (average score, %)	As stated before, one important part of this kind of projects is the information level provided to the vehicle drivers (here service users) about the intervention, costs and so on. Similar to the previous one, it is a subjective.	*This KPI/question is omitted since the following KPI described in the Citizen Engagement protocol is used.*	
Service users' information satisfaction	Number of EV rental users (here service users) who considered to be well-informed during the information campaigns that were carried out as part of citizen engagement	*This KPI/question is omitted since in Tartu no EV rental is set up, and there will not separate mobility related information*	

(average score, %) *Citizen Engagement KPI*	actions	*campaigns carried out.*
Project involvement degree (% of categories)	The type of beneficiary is classified as: beneficiary related to building retrofitting, related to mobility action or through dissemination activities addressed for whole citizens	*This KPI/question is omitted since the respondent answering the mobility questionnaire is automatically accounted as "mobility".*
Service user involvement degree (average score, %)	% of people who feel involved during the intervention project life cycle (for mobility).	*This KPI/question is omitted, since defining the project life cycle for mobility actions is difficult to measure for mobility actions.*
Service users' consultation satisfaction (average score, %) *Citizen Engagement KPI*	Number of EV rental users (here service users) who considered to be well-consulted during the information campaigns that were carried out as part of citizen engagement actions	*This KPI/question is omitted, since users of mobility services are not consulted.*

Economic value of the solutions (these questions will be asked if the respondent has heard about the SmartEnCity project and project's results)

KPI/element	Description of KPI	Question	Response
Satisfaction level with the reduction in the operation costs			
Satisfaction level with the reduction in the operation costs (average score, %)	Reduction in the operation costs that is directly translated into money.	*This KPI/question is omitted since it is not possible to correctly estimate the change in operation costs if there is a shift in transport modes.*	
Willingness to purchase/invest in new EV (or other energy related projects in mobility)			
Willingness to purchase/invest in new EV (average score, %) *Individual level*	The percentage of inhabitants who would like to invest in or purchase new EV taking into consideration the results of the SmartEnCity one. Although the wish to invest in or purchase new EV (incl. electrical bike) may not derive from the project results.	Given your present economic situation how willing are you to invest in or purchase a new EV – car or bike?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Further investments in energy related projects (average score, %) *City/society perspective* *Complementary question*	The percentage of inhabitants who would like the city to invest in further energy projects related to mobility taking into consideration the results of the SmartEnCity one.	How willing the city should be to invest in further mobility related energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Technical value of the solutions (these questions will be asked if the respondent has used the service). Addressed using mobile surveys (if possible).

KPI/element	Description of KPI	Question	Response
Use of mobility services (% of categories)	Indicates whether the person has used the service. This question forms the basis which kind of service(s) the respondent is evaluating.	Have you used the service? #1: Public transport #2: Electric bikes #3: EV chargers	1) Yes 2) No
Satisfaction with the solution implemented as a whole			
Whole solution satisfaction (average score, %)	Technical perspective in a sense of the service.	How satisfied are you with the solution implemented as a whole? Separate for: bike rental, public transport (biogas buses, EV charging)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Technical solution satisfaction (average score, %)	With this KPI, it wants to evaluate the satisfaction of the vehicles owners with regard to technical issues of new vehicles and charging infrastructures.	*This KPI/question is omitted, since technical value is estimated with the "Whole solution satisfaction".*	
Satisfaction with the solution in terms of comfort due to change in the type of energy source vehicle)			
Comfort conditions (average score, %)	Another goal of this sort of projects is the comfort, even the most important from the end user together the reduction of the fuel costs. Nevertheless, the comfort is, perhaps, the most subjective parameter because every person's comfort level differs from each other.	How satisfied are you with the comfort of the system (ease of use of the solution and other parameters together)?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the solution in terms of cost savings due to change in the type of energy source vehicle			
Cost saving satisfaction (average score, %)	-	*This KPI/question is omitted since it is not possible to correctly estimate the change in costs if there is a shift in transport modes.*	

FULL SMARTENCITY INTERVENTIONS

Method	Questionnaire for the citizens to estimate SmartEnCity interventions
Materials (what?)	KPIs and related questions in the questionnaires directed to the residents of the district renovated are divided into five groups: 1) social background of a respondent, 2) environmental background of a respondent, 3) individual perceptions of a respondent, 4) economic value of the solution estimated by the respondent, 5) technical value of the solutions estimated by the respondent. The questions (in English), answer choices taking into account Estonian

	context and units are defined below. Depending on the question, most of the questions will be close-ended (multiple choice) or requiring short answer. Some of the answers use the Likert-scale (1 to 5). The questionnaire presented here has been designed in English, but for further distribution and implementation it needs to be translated to Estonian.
Agents to involve (who?)	The questionnaire will be addressed to all the citizens. The total population forms of all the people older than 16 years old living in Tartu (approx. 75 000 inhabitants). The initial approach to deliver the questionnaire is to integrate the questions in to the survey called "Tartu ja tartlased" that is a citywide study scheduled regularly. This study focuses on topics like work and social wellbeing, housing, transport use, living environment, security, satisfaction with services and the development of the city. Integrating the following questions to this study will guarantee the representativeness of the sample. In the last wave of the study there were 1500 respondents.
Means (how?)	The methodology will follow the study "Tartu ja tartlased" ("Tartu and citizens of Tartu").

Social background

KPI/element	Description of KPI	Question	Response
Individual characteristics			
Age of respondent (average age, % of categories)	The age of respondent	How old are you?	Numerical value (Later it can be dividend into suitable categories)
Gender (% of categories)	The gender of respondents.	What is your gender?	1) Male 2) Female 3) Other
Highest level of completed education of respondents (% of categories)	The highest level of completed education of respondents.	What is your highest level of completed education?	1) Secondary educations 2) High school education 3) Vocational education 4) Secondary-vocational education 4) Higher education
Primary language of communication (% of language	The nationality data corresponds to (i) the percentage of main nationality and (ii) percentage of foreigners.	What is your primary language of communication?	1) Estonian 2) Russian

groups)	The KPI of nationality is substituted with primary language of communication.		3) English 4) Other […]
Project involvement degree (% of categories)	The type of beneficiary is classified as: beneficiary related to building retrofitting, related to mobility action or through dissemination activities addressed for whole citizens	*This KPI/question is omitted, since residents living in buildings retrofitted will be asked, thus the respondent is automatically accounted as "building retrofitted".*	
Net monthly income of the households (% of categories)	The net monthly income of the households. All incomes without taxes.	What is the net monthly income of your household for the previous month (all incomes without taxes)?	1) <= 320 € 2) 321–640 € 3) 641–959 € 4) 960–1280 € 5) 1281–1600 € 6) >= 1601 €
Size of the household (average, % of categories) *Complementary question*	The number of household members.	How many people are there in your household?	Numerical value (Categories can be defined later, if necessary)
Employment (% of categories) *Complementary question*	Employment structure	What describes your current employment?	1) Employed 2) Entrepreneurial employer 3) Self-employed, freelance 4) Unpaid family worker 5) Member of a commercial association 6) Student (incl. university) 7) Unemployed 8) Long-term unemployed (over 12 months) 9) Retired 10) Stay-at-home 11) In other circumstances, a non-working
Type of dwelling/building (% of categories)	The building types corresponds to seven categories, which are (i) single house, (ii) semi-detached house, (iii) terraced house, (iv) line block building, (v) tower block building, (vi) central patio building and (vii) non-residential building.	What is the type of the building where your household lives?	1) Single-family house 2) Two-family house 3) Terraced house 4) Less than a five-

	Categories are modified to meet the Estonian context.		story multi-apartment building 5) Five or more storey apartment building 6) Non-residential building (i.e. dormitory, etc.)
City district (% of categories)	City district the respondent's dwelling is located	In what city district do you live?	1) Annelinn 2) Ihaste 3) Jaamamõisa 4) Kesklinn 5) Karlova 6) Maarjamõisa 7) Raadi-Kruusamäe 8) Ropka 9) Ropka tööstusrajoon 10) Ränilinn 11) Supilinn 12) Tammelinn 13) Tähtvere 14) Vaksali 15) Variku 16) Veeriku 17) Ülejõe

Environmental background

KPI/element	Description of KPI	Question	Response
Knowledge and environmental awareness on environmental problems			
Environmental awareness (average score, %)	The knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on global environmental problems. The following values are derived from the Special Eurobarometer 416 report: Attitudes of European Citizens Towards the Environment[31]	How do you assess your awareness and knowledge on the following global environmental problems? #1: Climate change #2: Air pollution #3: Water pollution (seas, rivers, lakes and underground sources) #4: The impact on our health of chemicals used in	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.

[31] http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_416_en.pdf

		everyday products #5: The growing amount of waste #6: Depletion of natural resources #7: Agricultural pollution (use of pesticides, fertilisers, etc.) #8: Shortage of drinking water #9: Loss of extinction of species and their habitants and of natural ecosystems (forests, fertile soils) #10: Our consumption habits #11: Urban problems (traffic jams, pollution, lack of green spaces, etc.) #12: Land take (i.e. that more land is used to build roads or cities, and that cities expand into the surrounding countryside) #13: Noise pollution #14: Soil degradation #15: The spread of harmful non-native plants and animals (invasive species)	
Awareness of environmental problems in the city (average score, %)	The level of knowledge and awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing environmental problems in the city.	How do you assess your awareness and knowledge on the following environmental problems in the city? #1: Air pollution #2: Noise pollution #3: The growing amount of waste #4: Urban problems (traffic jams, pollution, lack of green spaces, etc.)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.
Knowledge and benefits of the solutions implemented in energy efficient projects			
Knowledge about efficient energy measures (average score, %)	The level of knowledge of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing efficient energy measures at building level.	How aware are you about the following measures and benefits to achieve energy efficiency? #1: Insulation to decrease the thermal loss in cold climate and thermal gain in warm climate #2: Lightning (more economic systems: energy	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every measure and benefit

		saving light bulb, movement sensors, etc.) #3: Energy-efficient windows #4: Smart meters & energy dashboards #5: Technology for producing renewable energy (i.e. solar panels) #6: Ventilation (to regulate air temperature, humidity and CO_2 concentration) #7: Home appliance energy efficiency (i.e. Energy Star) *(+ related to mobility if necessary)*	separately.

Individual perception of residents (asked only if the respondent has heard of the SmartEnCIty project or related activities; related activities to be listed)

KPI/element	Description of KPI	Question	Response
Fairness and inclusiveness in the decision-making process in terms of satisfaction with the project and with the level of information received			
Citizens' project satisfaction (average score, %)	The level of satisfaction of the citizens with regard to the project in general terms. The project is surrounded by technical solutions, information, costs, intervention phases and external conditions, among others	How satisfied are you with the project?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the information accessibility (average score, %)	This KPI determines whether the residents with energy monitoring systems are satisfied with the access to such data. The achievement limit of the KPI is established at 75% of people who score 6 point marks or upper.	*This KPI/question is omitted, since citizens are not provided with the indicated information.*	
Citizen information satisfaction (average score, %)	Satisfaction with the information level provided to the neighbours about the intervention, costs and so on.	*This KPI/question is omitted, since citizens are not directly provided with all the relevant information. Also, the following KPI from the Citizen Engagement Protocol will be used.*	
Citizen information satisfaction (average score, %) *Related to Citizen Engagement KPI*	Number of citizens who considered to be well-informed during the information campaigns that were carried out as part of citizen engagement actions	How informed did you feel during the information campaigns?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Trust in decision makers and other relevant stakeholders in terms of suitable time plan for implementing the actions in the city and the confident in decision makers and stakeholders involved in this project as well as in others similar projects			
This section is omitted, since not relevant for the citizens to estimate.			

Economic value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the investment costs			
Satisfaction with the investment costs (average score, %)	Determines the level of satisfaction of the dwelling's residents with the investment costs.	*This KPI/question is omitted, since not relevant for the citizens to estimate.*	
Satisfaction with the access to financing			
Satisfaction with the access to financing (average score, %)	Determines the level of satisfaction of the dwelling's residents with the access to financing.	*This KPI/question is omitted, since not relevant for the citizens to estimate.*	
Satisfaction with the payback period			
Satisfaction with the payback period (average score, %)	Determines the level of satisfaction of the dwelling's residents with the payback period. Payback period is defined as the length of time required for an investment to recover its initial outlay in terms of profits or savings.	*This KPI/question is omitted, since not relevant for the citizens to estimate.*	
Satisfaction level with the reduction in the energy bills			
Energy bill reduction (average score, %)	Reduction in the energy bills that is directly translated into money. Subjective measure.	*This KPI/question is omitted, since not relevant for the citizens to estimate.*	
Willingness to invest in further energy projects			
Further investments in energy related projects (average score, %) *Individual perspective*	The percentage of inhabitants who would like/are willing (themselves) to invest in further energy projects taking into consideration the results of the SmartEnCity one.	Taking into account your household's economic situation how willing are you to invest in further energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Further investments in energy related projects (average score, %) *City/society perspective* *Complementary question*	The percentage of inhabitants who would like the city to invest in further energy projects taking into consideration the results of the SmartEnCity one.	How willing the city should be to invest in further energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Technical value of the solutions (these questions will be asked if the respondent has heard about the project and project's results)

KPI/element	Description of KPI	Question	Response

Satisfaction with the solution implemented as a whole			
Whole solution satisfaction (average score, %)	This covers mobility actions, retrofitting actions. This covers the retrofitting, mobility actions (bike rental, gas buses, EV chargers), etc.	How satisfied are you with the solution implemented as a whole?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction from aesthetic perception			
Aesthetical satisfaction (average score, %)	Aesthetical satisfaction of the solutions. This covers the appearance of the buildings, artworks, mobility actions (bike rental, gas buses, EV chargers), etc.	How satisfied are you with the aesthetics of the implemented solutions?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

11.2.6 Citizen engagement

Objectives, methods and respective data sources involved in the evaluation of citizen engagement in the city of Tartu are presented in Table 25. Citizen engagement will be assessed in three topics: 1) citizen engagement strategy, 2) engagement activities and urban platform, and 3) project objectives of the district.

Tartu	
Objective	Methods and data sources
Evaluate the citizen engagement strategy through the perception of responsible of their design and residents.	Data collection (attendees' lists, etc.)
Evaluate the level of attendance of residents to information campaigns and events held in the city as part of citizen engagement actions.	Questionnaires (see also Social Acceptance)
Evaluate the use of urban platform/web application.	Urban platform
Evaluate the successful of the project objectives in the district.	Citizen Engagement Plan

Table 25: Citizen engagement assessment objectives for Tartu

CITIZEN ENGAGEMENT STRATEGY

Questions related to the perception of residents, users of services related to mobility actions and citizens are integrated and will be asked as part of the social acceptance questionnaires for residents, mobility actions or citizens. The methodology has been described in section. 11.2.5.

- **Objective: Evaluate the citizen engagement strategy through the perception of residents, EV rental users and citizens**

Resident information satisfaction – Number of residents who considered to be well-informed during the information campaigns that were carried out as part of citizen engagement actions / Number of residents who answered this question

Unit: %

Data source/method: Survey for residents living in retrofitted apartments.

Input parameter	Symbol	Unit	Data source
Respondents who considered to be well-informed	*R*	number	Survey for residents
Respondents who answered this question	*N*	number	Survey for residents

Calculation: (R/N)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: The question uses Likert-scale from 1 to 5 (Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)). Respondents answering “Extremely” or “Very” are interpreted as residents who are considered to be well-informed.

Citizen information satisfaction – Number of citizens who considered to be well-informed during the information campaigns that were carried out as part of citizen engagement actions / Number of citizens who answered this question.

Unit: %

Data source/method: Survey for citizens.

Input parameter	Symbol	Unit	Data source
Respondents who considered to be well-informed	*R*	number	Survey for citizens
Respondents who answered this question	*N*	number	Survey for citizens

Calculation: (R/N)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: The question uses Likert-scale from 1 to 5 (Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)). Respondents answering “Extremely” or “Very” are interpreted as citizens who are well-informed.

Resident consultation satisfaction – Number of residents who felt well-consulted during the information campaigns that were carried out as part of citizen engagement actions / Number of residents who answered this question.

Unit: %

Data source/method: Survey for residents living in retrofitted apartments.

Input parameter	Symbol	Unit	Data source
Respondents who felt well-consulted	*R*	number	Survey for residents

Respondents who answered this question	*N*	number	Survey for residents

Calculation: (R/N)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: The question uses Likert-scale from 1 to 5 (Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)). Respondents answering “Extremely” or “Very” are interpreted as residents who are well-consulted.

Involvement degree – Number of residents who felt involved in the decisions taken in the district / Number of residents who answered this question.

Unit: %

Data source/method: Survey for residents living in retrofitted apartments.

Input parameter	Symbol	Unit	Data source
Respondents who felt involved	*R*	number	Survey for residents
Respondents who answered this question	*N*	number	Survey for residents

Calculation: (R/N)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: The question uses Likert-scale from 1 to 5 (Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)). Respondents answering “Extremely” or “Very” are interpreted as residents who are involved.

Response rate for surveys – Separate values for resident, mobility and citizen survey. Added as an additional KPI to substitute the KPIs aforementioned and omitted.

Unit: %

Data source/method: Surveys (questionnaire distributed to the residents living in retrofitted buildings, and if applicable, then questionnaires for citizens and mobility actions as well).

Input parameter	Symbol	Unit	Data source
Surveys filled	*SF*	number	Survey
Surveys distributed	*SD*	number	Survey

Calculation: (SF/SD)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the surveys have been carried out.

The following KPIs are omitted from the analysis, since not logical to estimate in Tartu' context:

- Number of surveys filled by residents/Number of residents involved in the citizen engagement actions.
- Number of surveys fulfilled by EV rental users/Number of EV rental users involved in the citizen engagement actions.
- Number of surveys fulfilled by citizens/Number of citizens involved in the citizen engagement actions.
- EV rental consultation satisfaction.
- EV rental user information satisfaction.

- **Objective: Evaluate the citizen engagement strategy through the perception of responsible of their design**

Perception of success or failure by actors involved about citizen engagement activities performed

Data source/method: The perception of the citizen engagement strategy by the own designers will be evaluated through a qualitative assessment in the working group discussion/interview with the members of citizen engagement working group and, when needed, with additional relevant stakeholders. This will include joint discussion around the process and evaluation results. Regarding when to evaluate this objective, taking into account that Citizen Engagement working group is meeting bimonthly and regularly reviewing the activities according to the strategy as well as updating the action plan, this could be measured at the end of the citizen engagement activity but also it could be evaluated each year from 2017 to monitor the process.

Reporting frequency and input data collection frequency: KPI will be formally assessed once at the end of the project, discussions around the progress of the local citizen engagement strategy will be held annually and documented in the relevant working group meeting minutes.

CITIZEN ENGAGEMENT PLAN (ENGAGEMENT ACTIVITIES AND URBAN PLATFORM)

Engagement activities

- **Objective: Evaluate the level of attendance of residents, EV rental users and citizens to information campaigns and events held in the city as part of the citizen engagement strategy**

The following KPIs are omitted from the analysis, since not logical to estimate in Tartu context:

- Number of activities carried out for informing EV rental users about the project.
- Number of activities carried out for informing citizens about the project.
- Number of EV rental users involved in the citizen engagement actions carried out.
- Number of citizens involved in the citizen engagement actions carried out.

Number of activities carried out for informing citizens (incl. residents) about the project

Unit: Number of activities

Data source/method: Monitored constantly (citizen engagement plan/report).

Input parameter	Unit	Data source
Activity type: public campaigns	number	Citizen Engagement plan
Activity type: thematic event	number	Citizen Engagement plan
Activity type: newspaper articles	number	Citizen Engagement plan
Activity type: television	number	Citizen Engagement plan

Calculation: Sum of activities in different activity types.

Reporting frequency and input data collection frequency: KPI reported once after all the activities have been finished. The data on the number of activities recorded constantly.

Number of residents involved in the citizen engagement actions (residents, mobility actions) carried out – All target groups (residents, citizens, etc.) attending the event (targeted at the public). The events may be directed to specific topics, but here will not be made a differentiation between different stakeholder groups who participate.

Unit: Number of participants

Data source/method: Registration lists.

Calculation: The number of people listed in the registration lists will be summed.

Reporting frequency and input data collection frequency: The data collected for every engagement activity (recorded constantly throughout the project). KPI estimated after all the engagement actions have been carried out.

Urban platform

The final decision which KPIs are possible to estimate will depend on the developed system, services and partners developing them.

- **Objective: Evaluate the use of urban platform (apps, added value services, social media and website) as part of the citizen engagement strategy by residents, EV rental users and citizens**

Number of citizens (registered users) using web application – Number of citizens (registered users) using the web in a time basis (daily, monthly). If it is possible, it could be evaluated by user typology (e.g. company, administration, citizen).

Unit: Average number of registered users using web application per month.

Data source/method: Urban platform and mechanisms available in them.

Calculation: Sum of number of unique registered users using the web application per month / time-period in months.

Reporting frequency and input data collection frequency: KPI reported annually, data collected monthly.

Number of visits (daily/monthly) (in the web application) – Number of daily and monthly visits: registered or anonymous.

Unit: Number of visits (number of sessions) both registered and anonymous.

Data source/method: Urban platform and mechanisms available in them.

Calculation: Total number of visits per month.

Reporting frequency and input data collection frequency: KPI reported monthly, data collected daily (cumulatively).

Increase of new visitors in the web application – Percentage of increase (or decrease) in registered citizens, monthly.

Unit: % of increase in the number of new registered users (decrease can be measured if there is the possibility to delete accounts, etc.).

Data source/method: Urban platform and mechanisms available in them.

Input parameter	Unit	Data source
New registered users	number	Urban platform
Old registered users	number	Urban platform
(Deleted users)	(number)	(Urban platform)

Calculation: (new registered users/old registered users)*100. Calculated this way it needs to be acknowledged that the “old registered users” increases every month and thus can affect the interpretation of the outcome value. It may be important to consider the number of deleted users.

Reporting frequency and input data collection frequency: KPI reported monthly, data collected monthly.

Time spent on the web – Average time that people spent on the website. It could be measured monthly.

Unit: Time (seconds)

Data source/method: Urban platform and mechanisms available in them.

Input parameter		Unit	Data source
Total time spent on the website by all visitors (registered +	*T*	seconds	Urban platform

anonymous)			
Total number of visitors	*V*	number	Urban platform

Calculation: T/V

Reporting frequency and input data collection frequency: KPI reported annually, data collected monthly (cumulative number of users and cumulative time spent on the website for one year).

Number of Apps developed in the framework of SmartEnCity – Number of mobile app developed during the project, detailing the number addressed to residents, drivers and citizens. Urban platform will be free for public use. Thus, the scope can be broader than only the SmartEnCity project.

Unit: Number of Apps

Data source/method: Urban platform and mechanisms available in them.

Reporting frequency and input data collection frequency: KPI reported annually. Data collected cumulatively.

Number of mobile app downloads – Number of mobile app downloads for each specific core service.

Unit: Number of downloads for each specific core service. The services need to be further defined.

Data source/method: Urban platform and mechanisms available in them.

Reporting frequency and input data collection frequency: KPI reported annually. Data collected cumulatively.

Number of active users of Apps – This indicator intends to evaluate how many active users are in the whole users of Apps. They are defined as those that log into the applications at least with a certain frequency. To set some threshold, we'll define active users as those that have logged in at least the same number of times than months in the reporting period with a gap no greater than two months between logins.

Unit: Number of active users

Data source/method: Urban platform and mechanisms available in them.

Reporting frequency and input data collection frequency: KPI reported annually. Data collected annually, although the "logins" must be stored continuously to assess the "active users".

Other issues: Included are those who have logged in at least 12 times during a one-year period and the gap between two consecutive logins is always no greater than two months.

Number of active users of Apps in the category of citizens – This indicator intends to evaluate how many active users are in the whole users of Apps in the category of citizens. They are defined as those that log into the applications at least with a certain frequency. To set some threshold, we'll define active users as those that have logged in at least the same number of times than months in the reporting period with a gap no greater than two months between logins.

Unit: Number of active users

Data source/method: Urban platform and mechanisms available in them.

Reporting frequency and input data collection frequency: KPI reported annually. Data collected annually, although the "logins" must be stored continuously to assess the "active users".

Other issues: Included are those who have logged in at least 12 times during a one-year period and the gap between two consecutive logins is always no greater than two months. This KPI is measured if the category of "citizens" can be defined.

Quality of services/added value services – This indicator will be measured through the surveys distributed.

Unit: Average based on Likert-scale (from 1 to 5), % of categories

Data source/method: Urban platform and mechanisms available in them, for example, mobile survey.

Input parameter	Unit	Data source
Respondents by category	number	Urban platform
Total number of surveys distributed	number	Urban platform

Calculation: Share of Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) from the total number of surveys distributed.

Reporting frequency and input data collection frequency: KPI reported annually, data collected annually.

Other issues: The survey will be done once a year.

CITIZEN ENGAGEMENT STRATEGY + PLAN (PROJECT OBJECTIVES IN THE DISTRICT)

- **Objective: To evaluate the success of project objectives: building refurbishment action and district heating with RES**

Number of dwellings retrofitted

Unit: Number of dwellings

Data source/method: Tartu City

Reporting frequency and input data collection frequency: KPI will be calculated after the dwellings have been retrofitted/at the end of the project.

Number of residents benefitted by the intervention

Unit: Number of residents

Data source/method: Tartu City (population register).

Reporting frequency and input data collection frequency: KPI will be calculated after the dwellings have been retrofitted/at the end of the project.

The following KPI is omitted from the analysis:

- Number of doubts solved through citizen inbox.

11.2.7 Economic performance

Economic performance will be measured for district interventions, mobility and citizen engagement actions (Table 26). The data source for collecting data for economic KPIs is questionnaire/enquiry, some of the KPIs will be estimated based on the data collected by the questionnaires or enquiries. The enquiries are addressed to Tartu City Government, and if necessary other possible target groups, such as consultants, businesses, citizens. Some of the information can be derived from the ICT system.

In total, there will be estimated five KPIs for district interventions, four KPIs for mobility and three KPIs for citizen engagement (Table 27). According to D7.3 KPIs number 3 and 9 (Total annual costs) and KPI number 12 (Cost of saving a kg CO_2) will be calculated for the baseline as well as for the final performance, other KPIs will be estimated as the final performance. Old costs must be calculated for the baseline of the project, since demo's partners must know what is the value of these costs before the beginning of the renovation.

To facilitate the calculation of different KPIs, an Excel sheet has been prepared under D7.3 SmartEnCity Evaluation Protocols where the information with the indicators disaggregated is depicted in the annex of D7.3. The required data is indicated and when completing it, the Excel sheet gives the KPI resulting value.

Tartu	
Objective	Methods and data sources
Economic performance of district interventions	
Energy costs savings achieved by owners living in district and housing unions with the implementation of energy solutions in district (in comparison with the initial situation).	Enquiry
Economic performance of mobility	

Energy costs savings achieved with the rental of EV (cars) and e-bike (in comparison with the initial situation).	Enquiry/Questionnaire Estimation
Economic performance of citizen engagement	
Cost of citizen engagement activities carried out in the project to achieve the project objectives.	Enquiry

Table 26: Economic performance assessment objectives for Tartu

Eq. #	KPI /unit)	Method	Components of the KPI (unit)	Data source for the component	Target respondent(s)
District interventions					
1	Resident costs (€/m^2)	Enquiry	Investment (€)	Enquiry	Tartu City Government
			Grant (€)	Enquiry	Tartu City Government
			Total area (m^2)	Enquiry	Tartu City Government
2	Grant rate (%)	Enquiry	Investment (€)	Enquiry	Tartu City Government
			Grant (€)	Enquiry	Tartu City Government
3	Total annual costs (€/m^2)	Enquiry	Total maintenance costs (€)	Enquiry	Tartu City Government/TREA
			kWs uptake (kW)	Enquiry	TREA/Tartu City Government
			kWs country price (€)	Enquiry	TREA/Tartu City Government
			Total area (m^2)	Enquiry	Tartu City Government
4	Total annual benefits for residents (€/m^2)	Enquiry	Old costs (€/m^2)	Enquiry	Tartu City Government/TREA
			Total annual costs (€/m^2)	Enquiry, see Eq. 3	Tartu City Government
5	Cost saving rate (%)	Enquiry	Total annual benefits for residents (€/m^2)	Enquiry, see Eq. 4	Tartu City Government

Eq. #	KPI /unit)	Method	Components of the KPI (unit)	Data source for the component	Target respondent(s)
			Old costs (€/m^2)	Enquiry	Tartu City Government/TREA
Mobility					
9	Total annual costs (€)	Questionnaire/ enquiry	Initiative annual costs on public transport (€)	Questionnaire/ enquiry	Tartu City Government
			Initiative annual costs on biking (€)	Questionnaire/ enquiry, estimation	Tartu City Government, citizens
			Initiative annual costs on EVs (€)	Questionnaire/ enquiry, estimation	Tartu City Government, businesses, citizens
10	Benefits by uptake savings (€)	Enquiry	Annual mileage of EVs (electric bikes) (km)	ICT System	Tartu City Government
			Country fuel price per km (€)	Statistics	Tartu City Government
			Electricity uptakes for mobility (kWh)	ICT System	Tartu City Government
			Country average electricity price (kW)	Statistics	Tartu City Government
11	Benefits (€)	Enquiry	Benefits by uptake savings (€)	Enquiry, see Eq. 10	Tartu City Government, citizens, businesses,
			Total annual costs (€)	Estimation, calculation, see Eq. 9	Tartu City Government
12	Cost of saving a kg CO_2 (€/kg)	Enquiry	Total annual costs of CO_2 saving (€)	Calculation, statistics, See Eq. 9	Tartu City Government
			Annual CO_2 saving (kg)	Estimation	Tartu City Government
Citizen engagement					
17	Investment (€)	Enquiry	Initiative investments (€)	Enquiry	Tartu City Government

Eq. #	KPI /unit)	Method	Components of the KPI (unit)	Data source for the component	Target respondent(s)
18	Grant rate (%)	Enquiry	Grant (€)	Enquiry	Tartu City Government
19	Total annual cost (€)	Enquiry	All costs (€)	Enquiry	Tartu City Government

Table 27: KPIs, input parameters and data sources for economic assessment for Tartu

11.2.8 City indicators

The city indicators will provide an overall picture of the interventions and evaluate the impact by the project (see also D7.4). The frequency to evaluate the city impacts and the baseline for different topics will be done before the intervention (estimated in M9 and M18) and at the end of the project (M66).

Green background corresponds to impacts to be potentially evaluated as a result of the difference between the value of the indicators used in the city diagnosis made in D4.1 and the value of the intervention performance to be evaluated by the relevant KPIs.

Blue background corresponds to those impacts which require collecting new data by the consortium (maybe not available through the current or foreseen infrastructure).

Red background is associated to those impacts which require involving companies or other type of entities, from the consortium or hired from consortium, in charge of the district renovation, mobility actions and citizen engagement actions to gather the information needed. In this case, the distribution of questionnaires or doing interviews will be required.

The city diagnosis indicators are described in D4.1 and the data have already been collected. Data for KPIs for intervention and the final diagnosis need to be collected.

ENVIRONMENTAL INDICATORS FOR EVALUATING THE CITY IMPACTS

- **Energy savings in the city due to district renovation**

Indicator from city diagnosis

Residential buildings energy consumption per year – Residential consumption in the city for heating and electricity uses.

Unit: GWh/inhab.year

Data source/method: TREA, district heating usage.

Input parameter	Symbol	Unit	Data source
Heat	*H*	GWh	Value is estimated from usage of district heating
Electricity	*E*	GWh	TREA
Total city population	*P*	number	Statistics Estonia

Calculation: Energy consumption in residential buildings over a calendar year/Total city population

Reporting frequency and input data collection frequency: Reported in the city diagnosis and baseline.

KPI for intervention

Energy savings due to district renovation *(Energy Assessment Protocol)* – Comparison between energy consumption before and after renovation.

Unit: kWh/a

Data source/method: Energy meters.

Input parameter	Symbol	Unit	Data source
Overall energy usage of renovated buildings before renovation	E_b	kWh/a	Energy meters
Overall energy usage of renovated buildings after renovation	E_a	kWh/a	Energy meters

Calculation: $E_{sav} = E_b - E_a$, in calculation need to be used normalized data by degree days

Reporting frequency and input data collection frequency: Data will be collected in two stages (except $E_{pv\text{-}o}$) – 1) energy use before renovating (baseline), 2) energy use after all renovated buildings have had at least one whole heating season (winter) – renovated building data will be collected monthly. KPI reported once at the end of project.

- **Lower emissions of CO_2 in the city due to district renovation**

Indicator from city diagnosis

Emissions of residential and non-residential sectors (CO_2 equiv.) – Described as Global Warming Potential (GWP) per capita. Does not include (data not available) the industrial sector as stated in D3.1

Unit: Tn. equiv. CO_2 / year capita

Data source/method: Data not available.

KPI for intervention

CO_2 emissions savings due to district renovation *(Energy Assessment Protocol)*

Unit: tCO_2e

Data source/method: Estimated

Input parameter	Symbol	Unit	Data source
Overall emissions of renovated buildings before renovation	Em_{bCO2e}	tCO_2e	Estimated
Overall emissions of renovated buildings after renovation	Em_{aCO2e}	tCO_2e	Estimated

Calculation: E_m = Em_{bCO2}- Em_{aCO2e}, in calculation need to be used normalized data by degree days. Emissions savings will be calculated by using energy savings (E_{sav}) monitoring data with producers, energy suppliers and national regulations data.

Reporting frequency and input data collection frequency: Data will be collected in two stages (except E_{pv-o}) – 1) energy use before renovating (baseline), 2) energy use after all renovated buildings have had at least one whole heating season (winter) – renovated building data will be collected monthly. KPI reported once at the end of project.

- **Lower emissions of CO_2 in the city due to sustainable mobility actions**

Indicator from city diagnosis

Transport greenhouse gas emissions – Measure of the total greenhouse gas emissions (per capita) due to public and private transport.

Unit: t/(pers.·a)

Data source/method: Tartu City, estimation, statistics.

Input parameter	Symbol	Unit	Data source
GHG emissions from public transport	*GHGpubtr*	tons	Tartu City
GHG emissions from private transport	*GHGprtr*	tons	Estimation, statistics

Calculation: Transport GHG emissions, in equivalent CO_2 units, generated over a calendar year; CHGpubtr + CHGprtr

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

CO_2 emissions savings due to sustainable mobility actions

Unit: t CO_2

Data source/method: Estimation, statistics, Tartu City.

Input parameter	Symbol	Unit	Data source
Total CO_2 emissions from public and private transport in reference year (2016)	*CHGtotal 2016*	tons	Estimation, statistics
Total CO_2 emissions from public and private transport in current year	*CHGtotal…*	tons	Estimation, statistics

Calculation: GHGtotal 2016 – GHGtotal…

Reporting frequency and input data collection frequency: KPI reported annually, data collected annually.

- **Increase in the use of RES in the city due to district renovation**

Indicator from city diagnosis

Percentage of total energy consumed in the city derived from renewable sources – Percentage of total energy derived from renewable sources.

Unit: %

Data source/method: TREA (estimated considering with available energy compsumtion data)

Calculation: Total renewable energy consumption in the city/gross inland consumption in the city.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

Increase of renewable energy usage *(Energy Assessment Protocol)* – Total share of renewable energy sources in a complex energy supply system.

Unit: MWh/a

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Renewable energy on site usage	$E_{pv\text{-}o}$	MWh/a	Energy meters monitoring (solar inverters data)

Calculation: Total on site renewable energy usage of SmartEnCity buildings PV panels by summing buildings renewable energy on site usage measured with energy meters (Solar inverter data).

Reporting frequency and input data collection frequency: PV panels on site usage data will be collected monthly. Increase of renewable energy usage (in energy units per year) with SmartEnCity project will be reported at the end of project.

- **Increase the production of RES in the city due to district renovation**

Indicator from city diagnosis

Final Energy produced in the city per year – This indicator refers to the renewable & non-renewable energy generated in the city. The energy generation shall be expressed independently by type of energy produced.

Unit: MWh/year

Data source/method: Tartu City, TREA.

Input parameter	Unit	Data source
Heat for private heating	MWh/year	TAR (NA)
Heat for district heating	MWh/year	TREA
Electricity	MWh/year	TREA

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

Increase of renewable energy production *(Energy Assessment Protocol)* – Total share of renewable energy sources in a complex energy supply system.

Unit: MWh/a

Data source/method: Monitoring.

Input parameter	Symbol	Unit	Data source
Renewable energy production by SmartEnCity buildings (PV panels)	$E_{pv\text{-}p}$	MWh/a	Energy meters monitoring (solar inverters data)

Calculation: Total renewable energy production of SmartEnCity buildings PV panels by summing buildings renewable energy production measured with energy meters (Solar inverter data).

Reporting frequency and input data collection frequency: PV panels production data will be collected monthly. Increase of renewable energy production (in energy units per year) with SmartEnCity project will be reported at the end of project.

- **Number of dwellings/buildings retrofitted due to SmartEnCity project**

Final diagnosis

Number of dwellings/buildings retrofitted – The number of dwellings and buildings retrofitted in the project.

Unit: Number of retrofitted dwellings/buildings

Data source/method: Tartu City.

Input parameter	Unit	Data source
Dwellings	number	Tartu City
Buildings	number	Tartu City

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **Number of buildings/dwellings in the city that demand a retrofitting or to include energy efficient measures**

Final diagnosis

Number of buildings/dwellings in the city that demand a retrofitting or to include energy efficient measures – The number of buildings/dwellings that claim an energy retrofitting.

Unit: Number of buildings

Data source/method: Estimated.

Input parameter	Unit	Data source
Buildings	number	Estimated

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **New sustainable vehicles (EV) in the city due to SmartEnCity project**

Indicator from city diagnosis

Electric vehicles by category (cars, taxis, motorbikes, e-bikes, last mile logistic, bus)

Unit: Number of electric vehicles (by category)

Data source/method: Tartu City, Road administration, statistics.

Input parameter	Unit	Data source
Electric private car	number	Road administration, statistics, TAR
Electric commercial cars	number	Tartu City Government, Road Administration (NA)
Electric taxis	number	Road administration, statistics, TAR
Electirc motorcycles	number	Road administration, statistics, TAR
Electric public buses	number	Road administration, statistics, TAR
Electric bikes	number	Tartu City Government (NA)

Calculation: Sum of different types of EVs.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

The number of EV – The number of new EV in the city acquired by the project and the total EV in the city also from other initiatives since the project could influence in promoting these actions.

Unit: Number of electric vehicles

Data source/method: Tartu City, Road Administration, statistics.

Input parameter	Unit	Data source
EVs acquired by the project	number	Tartu City
Total EV in the city from other initiatives	number	Road Administration, statistics

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **New sustainable vehicles (Biogas buses) in the city due to SmartEnCity project**

Indicator from city diagnosis

Biogas buses – Percentage of biogas public buses.

Unit: %

Data source/method: Tartu City.

Input parameter	Symbol	Unit	Data source
Total number of biogas buses	*NUMgasbustotal*	number	Tartu City
Total number of buses	*NUMbustotal*	number	Tartu City

Calculation: (NUMgasbustotal * 100)/ NUMbustotal

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

Biogas buses – Should be reported the number of new Biogas buses in the city acquired by the project and the total biogas buses in the city also from other initiatives since the project could influence in promoting these actions.

Unit: %

Data source/method: Tartu City.

Input parameter	Symbol	Unit	Data source
New Biogas buses acquired by the project	*NUMgasbusproj*	number	Tartu City
Total biogas buses in the city from other initiatuves	*NUMgasbustotal*	number	Tartu City

Calculation: (NUMgasbusproj * 100)/NUMgasbustotal

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project**

Indicator from city diagnosis

Number of public EV charging stations *(initially it was required to count only public EV charging stations)* – Total number of public EV charging stations in the city

Unit: Number of EV charging stations

Data source/method: Tartu City.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

Number of (public) EV charging stations – Should be reported the number of new EV charging infrastructures acquired by the project and total EV infrastructures in the city also from other initiatives since the project could influence in promoting these actions.

Unit: Number of EV charging stations

Data source/method: Tartu City (questionnaire – described in section 11.2.4).

Input parameter	Symbol	Unit	Data source
New EV charging infrastructures acquired by the project	*NUMEVinfrproj*	number	Tartu City
Total EV infrastructures in the city from other initiatives	*NUMEVtotal*	number	Tartu City

Calculation: NUMEVinfrproj + NUMEVtotal

Reporting frequency and input data collection frequency: Reported in the final diagnosis.

- **Increase in the use of EV charging infrastructures due to the project**

Indicator from city diagnosis

Total kWh recharged in the EV charging stations – Number of estimated kWh recharged during a year in the public EV charging stations

Unit: kWh

Data source/method: Tartu City.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

Total kWh recharged in the EV charging stations *(Mobility Protocol)* – Number of estimated kWh recharged during a year in the (public) EV charging stations.

Unit: kWh

Data source/method: ICT system.

Reporting frequency and input data collection frequency: Data collected continuously after the EV charging stations are set to work, KPI reported annually.

Final diagnosis

In the case it is not evaluated through the protocols, other option would be to find this indicator in statistics but It is not clear whether for the LH cities make sense to evaluate this indicator at the end of the project. Changes in the indicator could not be only associated to SmartEnCity.

EVALUATION OF ECONOMIC IMPACTS

- **Investment mobilized for the renovation of the district**

Total investment of the district from local and regional public funding, EC funding and private funding (e.g. dwellings' owners, energy companies, social housing companies, etc.). It should be specified for each type of fund.

Unit: €

Data source/method: Questionnaire/Enquiry.

Input parameter	Unit	Data source
Local public funding	€	Tartu City Government
National funding	€	Tartu City Government
EC funding	€	Tartu City Government
Private funding	€	Inhabitants, businesses

Calculation: Sum of different funding types.

Reporting frequency and input data collection frequency: KPI reported in the final diagnosis.

EVALUATION OF EMPLOYMENT IMPACTS

- **Number of jobs created due to district renovation, mobility actions and citizen engagement actions**

Total number of jobs created – Measured for the three activities, district renovation, mobility and citizen engagement).

Unit: Number of jobs created

Data source/method: Questionnaire to be distributed to actors involved with district renovation, mobility actions and citizen engagement. Question about the total number of jobs (temporary or permanent) created due to the activities related to district renovation, mobility actions and citizen engagement actions. Companies/actors to be defined. Online survey for actors involved to be filled.

Reporting frequency and input data collection frequency: KPI reported in the final diagnosis.

- **Employment profile created due to district renovation, mobility actions and citizen engagement actions**

Number of jobs created in terms of professional specialization (higher education and non-higher education) and a posterior link with city indicator "working age population with higher education"

Unit: Number of jobs created, comparison with "working age population with higher education"

Data source/method: Questionnaire to be distributed to actors involved with district renovation, mobility actions and citizen engagement. Question about the total number

(temporary or permanent) of jobs created due to the activities related to district renovation, mobility actions and citizen engagement actions. There will be made differentiation between jobs or positions requiring hingher education and non-higher education. Companies/actors to be defined. Online survey for actors involved to be filled.

Input parameter	Unit	Data source
Jobs/positions requiring higher education	number	Questionnaire
Jobs/positions not requiring higher education	number	Questionnaire
Working age population with higher education in city	%	Tartu City Government / statistics

Reporting frequency and input data collection frequency: KPI reported in the final diagnosis.

- **New companies created or new services offered by companies due to district renovation, mobility actions and citizen engagement actions during the whole project**

Total number of new services offered by companies due to district renovation, mobility actions and citizen engagement actions during the whole project – Evaluated for the three activities, district renovation, mobility and citizen engagement.

Unit: Number of new services

Data source/method: Questionnaire to be distributed to actors involved with district renovation, mobility actions and citizen engagement. Question about new services offered by companies due to district renovation, mobility actions and citizen engagement actions during the whole project. Companies to be defined. Online survey for actors involved to be filled.

Reporting frequency and input data collection frequency: KPI reported in the final diagnosis.

KPIs that are omitted from the analysis:

- Acquisition of training skills due to district renovation, mobility actions and citizen engagement actions during the whole project;
- Acquisition of training skills of workers by training activities in the project (e.g. workers in the district need to receive some training courses).

CITY PLANS AND GOVERNANCE INDICATORS FOR EVALUATING THE CITY IMPACTS

- **New plans/programs (intended actions) in the city linked with the project (they will be identified)**

Existence of plans/programs to promote energy efficient buildings – Is there any specific document promoted by the municipality which details a set of intended actions for promoting energy efficient buildings in the city?

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

Existence of plans/programs to promote sustainable mobility

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

- **New regulations in the city linked with the project (they will be identified)**

Existence of regulations for development of energy efficient districts – Is there any specific official rule or law performed by the municipality that says how to develop energy efficient districts in the city?

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

Existence of regulations for development of sustainable mobility – Is there any specific official rule or law performed by the municipality that says how to develop energy efficient districts in the city?

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

- **New economic incentives in the city linked with the project (they will be identified)**

Existence of public incentives to promote energy efficient districts – Are there any specific public incentives for promoting the energy efficient districts in the city coming from the municipality (e.g. grant, tax exemptions and special loans)?

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

Existence of public incentives to promote sustainable mobility – Are there any specific public incentives for promoting sustainable mobility in the city coming from the municipality (e.g. grant, tax exemptions and special loans)?

Unit: Yes/No

Data source/method: Tartu City, questionnaire.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

- **More involvement of the administration on smart city projects**

Involvement of the administration on smart city projects – The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated. The valuation will be made by working team working in the city diagnosis.

Unit: Estimation based on Likert-scale (1 to 5).

Data source/method: The evaluation will be made by working team working in the city diagnosis using questionnaire.

Calculation: Likert scale: 1 – Strongly disagree, 2 – Disagree, 3 – Neither agree nor disagree, 4 – Agree, 5 – Strongly agree.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

- **More collaboration among different authorities from different levels**

Multilevel government – The extent to which the city cooperates with other authorities from different levels.

Unit: Estimation based on Likert-scale (1 to 5)

Data source/method: The evaluation will be made by working team working in the city diagnosis using questionnaire.

Calculation: Likert scale: 1 – Strongly disagree, 2 – Disagree, 3 – Neither agree nor disagree, 4 – Agree, 5 – Strongly agree.

Reporting frequency and input data collection frequency: KPI is reported in the city diagnosis and in the final diagnosis.

11.3 Description of KPIs and used data sources for Sonderborg

11.3.1 Energy assessment

ECM for Sonderborg include building renovation actions (roof insulation, retrofitting of existing windows and doors, LED outdoor lamps, Building Integrated PC panels, new heating control systems, new ventilation systems, new windows, attic insulation, façade insulation)

and district heating actions. Objectives, methods and respective data sources involved in the evaluation of energy assessment in the city of Sonderborg are presented in Table 28. Energy savings will be measured using Protocol IPMVP (Option D) and comfort will be evaluated using questionnaires. Reference period for energy assessment evaluation is January 2019–January 2021.

Sonderborg	
Objective	Method and data sources
Primary energy consumption, end use energy demand, renewable energy consumption, CO_2-emissions from energy production/consumption (all in the perspective of the whole Sonderborg area).	Protocol IPMVP - Option D - Whole municipal area (main meters) - Renovated buildings district
	Questionnaires

Table 28: Energy assessment objectives for Sonderborg

ENERGY SAVINGS

Energy demand – Energy that the building requires to meet its needs/uses (i.e. heating, DHW, cooling, electricity, etc.).

Unit: kWh/m²a

Data source/method: Simulation/theoretical calculation.

Input parameter	Unit	Data source
Electricity demand	kWh	Standard factors for theoretical electricity demand
Heat demand	kWh	Standard factors for theoretical heat demand
Heated floor area (renovated buildings)	m^2	Housing associations

Calculation: Average energy demand based on theoretical standard factors.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Delivered energy (for buildings) – Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, etc.) or to produce electricity (EN 15603:2008).

Unit: kWh/m²a

Data source/method: Energy meters.

Input parameter	Symbol	Unit	Data source

Delivered energy per energy carrier	$E_{del,EC}$	kWh/a	Building block energy meters and/or Electricity company Heating bills per building block
Floor area of the building	A	m^2	Housing association companies
Reference time period	t_{ref}	years	-

Calculation: Energy use/floor area.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Primary energy (for buildings) – 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).

Unit: kWh/m²a

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Unit	Data source
Delivered energy per energy carrier	kWh	Building block energy meters and/or Electricity company Heating bills per building block
Exported energy per energy carrier	kWh	Building block energy meters
Primary energy factor for delivered energy carrier	kWh	Primary energy factor for energy source from national regulations, and delivered energy for energy supply units indicator
Primary energy factor for exported energy carrier	-	Primary energy factor for energy source from national regulations
Floor area of the building	m^2	Housing association companies
Reference time period	years	-

Calculation: Net energy use*PEF/floor area

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

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).

Unit: kWh_{in}/kWh_{out}

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Unit	Data source
Delivered energy per energy carrier	MWh	Energy balance: Data about fuel mix from local district energy producers
Primary energy factor for the delivered energy carrier	kWh	Primary energy factor for energy source from national regulations, and delivered energy for energy supply units indicator
Primary energy allocation for co-generation	%	Allocation factors from Covenant of Mayors
Output per energy carrier	MWh	Energy balance: Data about energy production from local district energy producers

Calculation: In*PEF/out*PEF

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

CO_2 equivalent (for buildings) – The CO_2 emissions of a building correspond to the emissions that are caused by different areas of application (i.e. space heating, space cooling, domestic water heating, electrical appliances). In different variants of this indicator, the emissions caused by the production of the building components can be either included or excluded. To enable the comparability between buildings, the emissions relate to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. year). The greenhouse gases are considered as t of carbon dioxide (CO_2) or a CO_2 equivalent (CO_2e).

Unit: t CO_2/m^2a

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Unit	Data source
Electricity use	kWh	Building block energy meters and/or Electricity company Heating bills per building block
Heat use	kWh	Building block energy meters and/or Electricity company Heating bills per building block
CO_2 per delivered electricity	Tonne / kWh	Energy balance: fuel mix for local production and national grid
CO_2 per delivered heat	Tonne / kWh	Energy balance: fuel mix for local district heating production

Calculation: Energy use * CO_2 per delivered energy

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

CO_2 equivalent (for 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.

Unit: t CO_2/MWh

Data source/method: Energy meters and primary energy factors (standards, tables).

Input parameter	Unit	Data source
CO_2 from district heating production	tonne / kWh	Energy balance: fuel mix for local production
CO_2 from electricity production	tonne / kWh	Energy balance: fuel mix for local production
Electricity production	kWh	Energy balance: data about energy production from local district energy producers
District heating production	kWh	Energy balance: data about energy production from local district energy producers

Calculation: Energy production * CO_2 per energy production

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Density of energy demand – The indicator is defined as ratio of final energy demand (for heating or cooling) of a cohesive set of buildings and a simple figure representing the effort that a district heating or cooling network operator would have to supply these buildings. For the latter, the territory area or the number of buildings is chosen in order to represent the length of the network and the number of connections that are required.

Unit: kWh/m²a

Data source/method: Estimated.

Input parameter	Unit	Data source
Floor area (district, city, municipality)	m^2	Housing association companies and municipality
Heat demand (district, city, municipality)	kWh	Housing association companies and energy balance

Calculation: Heat demand / floor area

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Peak load and load profile of electricity demand – The load profile describes the demand characteristics over time, while peak load is what the electricity supply has to be able to cover. The load profile gives information about the possibilities or potentials of storage, demand-side management and self-supply via photovoltaic, etc.

Unit: kW

Data source/method: Energy meters.

Input parameter	Unit	Data source
Load profile: Electricity use	kWh	Housing association companies
Peak load: Electricity use	kWh	Housing association companies

Calculation: Energy meters

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Degree of congruence of calculated annual final energy demand and monitored consumption ($DC_{i,t}$) – Ratio of the theoretical energy demand of a building or set of buildings (calculated) and the final energy consumption of a building or set of buildings (measured) over a period of time (e.g. year).

Unit: %

Data source/method: Estimated.

Input parameter	Symbol	Unit	Data source
Final energy demand of building I based on annual data of year t	$EN_{i,\,t,(demand)}$	kWh/(m^2 a)	Standard factors for theoretical energy demand
Final energy consumption of building I based on annual data of year t	$EN_{i,\,t,\,(consumption)}$	kWh/(m^2 a)	Building block energy meters and heating bills

Calculation: $DC_{i,t} = \frac{EN_{i,t,(demand)}}{EN_{i,t,(consumption)}}$

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Degree of energetic self-supply – The 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.

Unit: %

Data source/method: Estimated.

Input parameter	Unit	Data source
Local electricity and heat production (Sonderborg municipal area)	MWh	Energy balance
Local electricity and heat use (Sonderborg municipal area)	MWh	Energy balance
Electricity and heat production (renovated buildings)	kWh	Building block energy meters and/or Electricity company
Electricity and heat consumption (renovated buildings)	kWh	Building block energy meters and/or Electricity company

Calculation: Energy use/energy production

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Share of renewable energy – Total share of renewable energy sources in a complex energy supply system.

Unit: %

Data source/method: Estimated.

Input parameter	Unit	Data source
Energy consumption (Sonderborg municipal area)	MWh	Energy balance
Energy consumption based on renewables (Sonderborg municipal area)	MWh	Energy balance

Calculation: Renewable energy consumption/energy consumption

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Efficiency – Evaluation the efficiency of systems (boiler, solar collector, etc.).

Unit: %

Data source/method: Monitored.

Input parameter	Unit	Data source
Calculated efficiencies from energy consumption and production data	%	Energy balance: data about energy production from local district energy producers

Calculation: Avg. efficiency from district heating suppliers

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

The following KPI is omitted from the analysis:

- Peak load and load profile of thermal (heating/cooling) energy demand.

COMFORT

Thermal comfort – This indicator represents the level of thermal comfort measured as the number of hours that the indoor temperature and relative humidity conditions are within range of values defined. The range of comfort values varies with the seasons (as it depends on the metabolic rate and clothing of the building users) and the climatology of each city (average monthly temperatures (max & min) and average monthly relative humidity).

Thermal comfort will not be measured using data measurements, but questionnaires to capture subjective opinions. The questionnaire for measuring thermal comfort is distributed to owners and tenants under the Social Acceptance Protocol (section 11.3.5). The aspects will be measured once after the intervention. The KPI "Comfort conditions" will address the following aspects that will be measured on a scale 1 to 5 (Not at all … Extremely).

- What kind of comfort improvements have you experienced after the retrofitting?
  - Less drag from the windows,
  - Better air quality in the apartment,
  - Easier to regulate the warmth in the apartment,
  - Noise reduction,
  - General better comfort in the apartment.

11.3.2 ICT

Objectives, methods and respective data sources involved in the evaluation of ICT in the city of Sonderborg are presented in Table 29.

Sonderborg	
Objective	Methods and data sources
O3. To assess the ICT services' features, in terms of performance, such as response time, scalability and extensibility. O4. To assess the impact that the urban platform has over the urban transformation	Meter/analysis – ICT platform
O1. To evaluate the improvements of the existing urban platforms themselves.	Meter/analysis – ICT platform
O2. To evaluate the new ICT developments and services carried out under the SmartEnCity umbrella and integrated into the existing smart urban platforms. O4. To assess the impact that the urban platform has over the urban transformation	Meter/analysis – ICT platform

Table 29: ICT assessment objectives for Sonderborg

CIOP INDICATORS

Response time – Depending on request type.

Unit: Time (minutes)

Data source/method: From the ICT system.

Input parameter	Symbol	Unit	Data source
Monitoring live data over GSM	*800*	MS	Device
Monitoring from DB	*400*	MS	Database

Calculation: Google tools can be used to test web page response time.

Reporting frequency and input data collection frequency: KPI is reported annually, data is collected continuously by the system.

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.

Unit: Number of instances per service/class

Data source/method: From the ICT system.

Input parameter	Unit	Data source
Datalogger interval	minutes	Database
Sensor scalings	number	Database

Calculation: Logged internal in device.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

Other issues: Data-log interval is variable from 1 to 60 minutes.

Extensibility – SCIOSS interoperability is the ability to share data with other systems and support for sensors by different manufactures. The physical IoT gateway device supports drivers for a range of sensors and meters by different manufactures. The physical Web Services support open standards for data exchange with other systems.

Unit: Number of services or classes integrated

Data source/method: From the ICT system.

Input parameter	Symbol	Unit	Data source
Drivers for energy meters	*Modbus*	RS485	Meter
Driver for heat meters	*Modbus*	RS485	Meter

Calculation: Manufacturer's protocol implemented. Others can be implemented

Reporting frequency and input data collection frequency: Constantly serial communication.

Storage Capacity – Extendable – cloud based.

Unit: Disk/cloud storage space (GB)

Data source/method: Microsoft Datacenter

Input parameter	Unit	Data source
Disc system with on demand disc allocation.	GB	Microsoft Datacenter

Calculation: Calculated from the storage needs.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

Hours of maintenance – Time to keep system running and patch-up.

Unit: Time (h)

Data source/method: Pressler

Input parameter	Unit	Data source
Pressler software used to analyse and monitor backend performance	hours	Pressler

Calculation: Real time statistic and historical statistic.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

Non-expected hours offline – The number of hours the system is not in operation.

Unit: Time (h)

Data source/method: Pressler

Input parameter	Unit	Data source
Time the system is not in operation	hours	Pressler

Calculation: Sum of time the system is not in operation.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

Other issues: Uptime is normal >99.5% so expected is 0.5% of total time

ELEMENTS MANAGED WITH THE ICT SYSTEMS

# of BEMS connected – Number of sensing systems installed per building and integrated in the CIOP.

Unit: Number of sensing systems installed and integrated in the CIOP

Data source/method: Data measurement (energy and heat meters).

Input parameter	Unit	Data source
Measure consumed electricity	kW	Energy meter
Measure produced electricity from solar system	kW	Energy meter
Measure consumed heating	kW	Heat meter

Calculation: Total number of sensing systems installed and integrated in the CIOP.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

# of mobility equipment connected – Number of other mobility related equipment integrated to the system.

Unit: Number of mobility equipment (per class)

Data source/method: ICT system.

Input parameter	Unit	Data source
E-Charger – consumption	kW	Charger

Calculation: From the ICT system. Sum of the number of all the mobility equipment connected.

Reporting frequency and input data collection frequency: KPI reported annually, data collected continuously by the system.

The following KPIs are omitted from the analysis:

- # of HEMS connected,
- # of EV connected,
- Smart lighting equipment connected,
- Recharging points equipment connected.

The description of the following KPI is open, since it depends on the setup:

- Total amount of data generated.

APPLICATION OF ICTs FOR THE CITIZEN

Number of services developed – The amount of services based on ICTs offered to citizens and third parties.

Unit: Number of services

Data sources/method: ICT system (web-page)

Input parameter	Unit	Data source
Service	number	ICT systen

Calculation: Count of services.

Reporting frequency and input data collection frequency: Once at the end of the project

Percentage of buildings connected – The percentage of buildings of pilot area connected to the system.

Unit: %

Data source/method: Housing associations/ICT system.

Input parameter	Symbol	Unit	Data source
Dwellings connected	D_c	Number	ICT system
Dwellings not connected	D_{nc}	number	ICT system

Calculation: D_c / D_{nc}

Reporting frequency and input data collection frequency: KPI is reported at the end of the project.

Open-Data sets available – Number of web service functions.

Unit: Number of data-sets/functions

Data sources/method: ICT system.

Input parameter	Symbol	Unit	Data source
Service functions	*SF*	Services	JSON

Calculation: Reported by JSON system.

Reporting frequency and input data collection frequency: KPI reported at the end of the project.

Other issues: One Local CIOP homepage will be developed and for data exchange with WP 6.

The following KPIs are omitted from the analysis:

- Types of services,
- Percentage of dwellings connected.

11.3.3 LCA

Objectives, methods and respective data sources involved in the evaluation of LCA in the city of Sonderborg are presented in Table 30. Table 31 presents the measures for retrofitting.

Sonderborg	
Objectives	Method and data sources
Evaluation in terms of LCA for - building retrofitting actions - integrated infrastructures - energy	CML-IA Ecological footprint method Cumulative energy demand methodology Life cycle inventory account Reference study period: 35 years

Table 30: LCA assessment objectives for Sonderborg

The LCA assessment consists of:

- Definition of baseline scenario and the evaluation of KPIs,
- Life cycle inventory,
- Definition of post-intervention scenario and evaluation of KPIs,
- Final reporting.

	Before retrofitting	**After retrofitting**
Passive measures	Expected replacement of façades due to maintenance incl. little or no envelope insulation.	Energy efficient retrofitting of façades incl. envelope insulation (including possibly other necessary replacement of façades due to maintenance).
	Expected replacement of roofs due to maintenance incl. little or no envelope insulation.	Energy efficient retrofitting of roofs incl. envelope insulation (including possibly other necessary replacement of roofs due to maintenance).
	Expected replacement of dormers due to maintenance.	Expected replacement of dormers due to maintenance.
	Expected replacement of ventilation systems due to maintenance	Expected replacement of ventilation systems due to maintenance
Active measures	The dwellings are connected to	The dwellings will be connected to the

(Integrated infrastructures)	the national electricity grid	national electricity grid
	The dwellings are connected to the local district heating network with a fuel mix of waste, natural gas and biomass	The dwellings will be connected to the district heating network with a future fuel mix
	No solar energy panels	Solar energy panels on roofs

Table 31: Measures for retrofitting Sonderborg

The LCA is done using a commercial software called SimaPro version 8.3, that includes the strongest database in the market (Ecoinvent version 3.3) and several environmental calculation methods. The data that was collected in the previous stage is modelled according to the different flows existing in the Ecoinvent database.

The input parameters for the indicators are described only for the first indicator (KPI), since the inputs are the same for all the Environmental indicators selected (Global warming, ecological footprint, etc.). The same set of indicators will also be used for final assessment (after the intervention), but the values may differ (i.e. windows, boilers, etc.).

Global warming potential (EI_1) – Index that attempts to integrate the overall climate impacts of a specific action. It relates the impact of emissions of a gas to that of emission of an equivalent mass of CO2. The duration of the perturbation is included by integrating radiative forcing over a time horizon (e.g., standard horizons for IPCC have been 20, 100, and 500 years). The time horizon thus includes the cumulative climate change and the decay of the perturbation. 100 years has been chosen for the LCA study.

Unit: kg CO_2 eq

Data source/method: CML methodology, IPCC 2013 GWP 100 years. CML-IA is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands. More information on: http://cml.leiden.edu/software/data-cmlia.html.

This method is an update of the CML 2 baseline 2000 and released by CML in April 2013 (version 4.2). The CML 2 baseline 2000 version can be found in the 'superseded' list. For most impact categories, substances have been added and removed and/or characterisation factors were updated, according to new scientific insight. Only the impact category Photochemical oxidation did not undergo any changes. The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into:

- A: Obligatory impact categories (category indicators used in most LCAs).
- B: Additional impact categories (operational indicators exist, but are not often included in LCA studies).
- C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA).

Input parameter	Unit	Data source
Conditioned area of the district (Sum of the surface of all the dwellings)	m^2	Housing associations

Input parameter	Unit	Data source
Description of the renovation actions for the next 35 years considering no SmartEnCity actions		
Façade area of the buildings in the district set for renovation (bricks, mortar and insulation material)	m^2	Housing associations
Roof area of the buildings in the district set for renovation (roof tiles and under roof)	m^2	Housing associations
Dormers in the district set for renovation (construction wood, windows and zinc cladding)	pcs	Housing associations
Ventilation systems in the district set for renovation	pcs	Housing associations
Description of façades set for renovation		
Bricks per façade area	kg/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Mortar per façade area	kg/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Insulation material per façade area	kg/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Destination after replacement (recycling/landfill/others)	-	Danish Building Research Institute / Ökobau.dat
Distance to final disposal/treatment	km	Danish Building Research Institute / Ökobau.dat
% that will be replaced according	%	Housing associations
Replacement origin (Distance from the new supplier)	km	Danish Building Research Institute / Ökobau.dat
Description of roofs set for renovation		
Roof tiles per roof area	kg/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Under roof (EPDM) per roof area	kg/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Destination after replacement (recycling/landfill/others)	-	Danish Building Research Institute / Ökobau.dat
Distance to final disposal/treatment	km	Danish Building Research Institute / Ökobau.dat
% that will be replaced according	%	Housing associations
Replacement origin (Distance from the new supplier)	km	Danish Building Research Institute / Ökobau.dat

Input parameter	Unit	Data source
Description of dormers set for renovation		
Construction wood per dormer	m^3/pcs	Housing associations
Window area per dormer	m^2/pcs	Housing associations
Glazing area per window area	m^2/m^2	Housing associations Danish Building Research Institute / Ökobau.dat
Zinc cladding per dormer	kg/pcs	Housing associations
Destination after replacement (recycling/landfill/others)	-	Danish Building Research Institute / Ökobau.dat
Distance to final disposal/treatment	km	Danish Building Research Institute / Ökobau.dat
% that will be replaced according	%	Housing associations
Replacement origin (Distance from the new supplier)	km	Danish Building Research Institute / Ökobau.dat
Description of ventilation systems set for renovation		
Ventilation control and wiring, central unit	pcs	Ecoinvent database
Destination after replacement (recycling/landfill/others)	-	Ecoinvent database
Distance to final disposal/treatment	km	Ecoinvent database
Replacement origin (Distance from the new supplier)	km	Ecoinvent database
Energy		
Thermal energy consumption from district heating (kWh/year, m^3 fuel/year, etc.) please be clear with the units (per m^2, per total district, etc.)	kWh/m^2y	Housing associations
Electricity energy consumption (kWh/year) please be clear with the units (per m^2, per total district, etc.)	kWh/m^2y	Housing associations

Calculation: In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Ecological footprint (EI_2) – The Ecological Footprint is defined as the area of productive land and water ecosystems required to produce the resources that the system needs and assimilate the wastes generated.

A measure of how much area of biologically productive land and water that an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption. Ecological Footprint is often referred to in short form as Footprint. "Ecological Footprint" and "Footprint" are proper nouns and thus should always be capitalized.

Unit: ha

Data source/method: Ecological footprint method. Method directly taken from Ecoinvent 2.0; Contact info: http://www.ecoinvent.org/contact/. Method published by Niels Jungbluth, ESU-services Ltd., Uster.

Calculation: Ecological Footprint (EF) = sum of time integrated direct land occupation and indirect land occupation. Normalisation is not a part of this method. Weighting: as each impact category is expressed in the same unit, a weighting factor of 1 is used for every impact category. For more information see the Database manual Version 1.01 (April 2009)- Added substance "Carbon dioxide" with a factor of 2.6722 to impact category "carbon dioxide".

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Use of renewable primary energy excluding energy resources used as raw material (RU_1) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non-renewable, as well as energy used for raw material and other uses.

Unit: MJ

Data source/method: Cumulative energy demand methodology. Method to calculate Cumulative Energy Demand (CED), based on the method published by ecoinvent version 2.0 and expanded by PRé Consultants for raw materials available in the SimaPro 7 database. Contact info: http://www.ecoinvent.org/contact/

Frischknecht R., Jungbluth N., et al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, www.ecoinvent.ch

- Wood is not included in this methodology due to the frequent use of wood as feedstock in Simapro.
- Normalization: it is not a part of this method.
- Weighting: Each impact category is given the weighting factor 1.

- For more information see the Database manual.
- Adaptations (August 2004, v1.01):
  - Added: Additional oil resources;
  - Water, barrage
  - Corrected values: Uranium ore, 1.11 GJ per kg, in ground; Uranium, 2291 GJ per kg, in ground; Uranium, 451 GJ per kg, in ground; Uranium, 560 GJ per kg, in ground.
  - Not included: Energy from hydrogen; Energy, recovered; Energy, unspecified; Oil; Steam from waste incineration.
- Other adaptations (March 2005, v1.02):
  - Sulphur removed.
- Other adaptations (August 2005, v1.03):
  - In impact category Non-renewable, fossil the characterisation value for "Gas, natural in ground" has been changed from 40,3 to 38.3 MJ LHV/m^3 following the ecoinvent 1.2 update.
- Other adaptations (February 2008, v1.04):
  - Minor adaptations in Unit names and Impact category names (capitals, points) for more consistency with other categories.
- Other adaptations (April 2008, v1.05):
  - Seven extra substance flows are added:
    - Energy, gross calorific value, in biomass, primary forest,
    - Geothermal converted,
    - Energy, solar, converted,
    - Energy, from hydrogen,
    - Energy, unspecified
  - The characterisation factor of Peat, in ground' raw biotic in IC non-renewable, fossil has a new characterisation factor = 9
- Other adaptations (November 2009, v1.06):
  - Created a new impact category: 'Non-renewable, biomass' and moved the substance 'energy, gross calorific value, in biomass, primary forest' to this new impact category.
- Other adaptations (March 2010, v1.07):
  - Weighting: The weighting factor of impact category non-renewable biomass was changed to 1.
- Other adaptations (August 2010, v1.08):
  - The quantity and unit of the single score is changed:
    - 1.07: Indicator (Pt)
    - v1.08: Energy (MJ)
- Other adaptations (August 2014, v1.09):
  - The following flows were added:
    - Coal, bituminous, 24.8 MJ per kg
    - Coal, hard, 30.7 MJ per kg
    - Gas, natural/kg
  - The factor for Methane was changed from 35.9 to 55.53 MJ/kg (the previous value was in MJ/m3, which is the incorrect unit).

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the cumulative energy demand methodology, the following KPIs will also be calculated:

Use of renewable primary energy resources used as raw material (RU_2) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy excluding energy resources used as raw material (RU_3) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Use of non-renewable primary energy resources used as raw material (RU_4) – Using the environmental indicator cumulative energy demand, it will be able to separate the primary energy in renewable and non- renewable, as well as energy used for raw material and other uses. Unit: MJ

Exported energy (OF_1) – Energy that is produced in the context of the district studied that can be exported from the system to other use out of the systems boundaries. Unit: MJ

Hazardous wastes disposed (WC_1) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC.

Unit: kg

Data source/method: Life cycle inventory account

Reporting frequency and input data collection frequency: Two reports will be developed. The first one considering the baseline and the second one after the retrofitting actions implementation and some monitoring time. Thus, the KPI will be calculated twice – the baseline and after the intervention.

Using the same methodology (life cycle inventory account), the following KPI will also be calculated:

Non-hazardous wastes disposed (WC_2) – Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Directive 2008/98/EC and Annex III to Directive 2008/98/EC. Unit: kg

11.3.4 Mobility

Objectives, methods and respective data sources involved in the evaluation of mobility in the city of Sonderborg are presented in Table 32Table 29.

Sonderborg	
Objectives	Methods and data sources

Assessing public transport system reliability, development of efficiency of mobility system and development towards increased clean fuels in mobility system.	Municipality National statistics Private recharging station companies

Table 32: Mobility assessment objectives for Sonderborg

Accuracy of timekeeping for public bus – Number and percentages of services arriving/departing on time.

Unit: Number, %

Data source/method: Meter.

Input parameter	Unit	Data source
Public bus departures	number	Municipality
Public bus departures on time	number	Municipality

Calculation: Departures on time/departures

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Vehicle fuel efficiency – Total energy consumed for the vehicles measured as a function of consumed fuel per unit of transport activity. This should be derived by vehicle type and fuel type.

Unit: MJ/vKm

Data source/method: Meter/standard vehicle efficiency factors.

Input parameter	Unit	Data source
Efficiency of personal cars	MJ/km	Municipality, standard vehicle efficiency factors
Efficiency of personal EV cars	MJ/km	Municipality, standard vehicle efficiency factors
Efficiency of public busses	MJ/km	Municipality, standard vehicle efficiency factors

Calculation: Fuel consumption by vehicles, Total distance completed by vehicles.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Total number of recharges per year (biogas and EV) – Total number of recharges during a year in the public and private charging stations. It will be required to infrastructure operator and vehicle owners in order to compare this indicator with energy consumption and distance travelled.

Unit: Number of recharges

Data source/method: Meter/standard vehicle efficiency factors.

Input parameter	Unit	Data source
Total number of recharges per year (EV)	number	Private recharging station companies
Total number of recharges per year (biogas)	number	Private recharging station companies

Calculation: Sum of recharges.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

Total kWh recharged in the EV charging stations (biogas and EV) – Number of kWh recharged during a year in the public and private charging stations. It will be required to infrastructure operator and vehicle owners to compare this indicator with energy consumption and distance travelled.

Unit: kWh

Data source/method: Meter.

Input parameter	Unit	Data source
Total kWh recharged in the EV charging stations (EV)	kWh	Private recharging station companies
Total kWh recharged in the EV charging stations (biogas)	kWh	Private recharging station companies

Calculation: Sum of recharged kWhs.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

11.3.5 Social acceptance

Objectives, methods and respective data sources involved in the evaluation of social acceptance in the city of Sonderborg are presented in Table 33.

Sonderborg	
Objective	Methods and data sources
Evaluation of the acceptance of tenants living in the district on SmartEnCity solutions implemented in the district renovated Evaluation of the gains in life quality of tenants living in the district retrofitted	Questionnaire Data measurement
Evaluation of the acceptance of tenants living in other districts of the city (citizens) on SmartEnCity solutions implemented in the district renovated	Questionnaire

Evaluation of the gains in life quality of tenants living in other districts of the city (citizens)	

Table 33: Social acceptance assessment objectives for Sonderborg

DISTRICT RENOVATED AND OTHER POTENTIAL DISTRICTS

- *Questionnaire*

Method	Questionnaire for district renovated and other potential districts
Materials (what?)	KPIs and related questions in the questionnaires directed to the residents of the district renovated are divided into five groups: 1) social background of a respondent, 2) environmental background of a respondent, 3) individual perceptions of residents (aka respondent), 4) economic value of the solution estimated by the respondent, 5) technical value of the solutions estimated by the respondent. For residents outside the district renovated group 4 and 5 will be changed to 4) economic value of solution anticipated by the respondent, 5) technical value of the solutions anticipated by the respondent. The questions will be close ended (multiple choice) or requiring short open-answer. Some of the answers use the Likert-scale (1 to 5). The questionnaire presented here has been designed in English, but for further distribution and implementation it needs to be translated to Danish.
Agents to involve (who?)	Target respondents are tenants living in areas that have been retrofitted and 5 similar departments. Total number of apartments to be retrofitted is 807. The estimated response rate is 15%.
Means (how?)	All apartments will receive a link to the online questionnaire. Channels of distribution of questionnaires: questionnaire will be distributed through website to the tenants from the district to be retrofitted and by phone to those tenants from other districts to be involved in the social acceptance evaluation.

Social background

KPI/element	Description of KPI	Question	Response
Individual characteristics			
Age of residents (% of categories)	The age of residents.	How old are you?	1) under 18 years old 2) 18–30 years old 3) 31–50 years of old 4) 51–65 years old 5) More than 65 years old
Highest level of completed education of inhabitants (% of categories)	The highest level of completed education of residents.	What is your highest level of completed education?	1) without studies 2) primary studies 3) secondary studies

			4) vocational education 5) university studies
Nationality (% of main nationality, % of foreigners)	The nationality data corresponds to (i) the percentage of main nationality and (ii) percentage of tenants born outside Denmark	Where were you born? (Country level)	Open answer
Net monthly income of the households (% of categories)	The net monthly income of the households.	What is the average net monthly income of the last year of your household?	1) less than 1,000 €, 2) between 1,001 and 2,000 €, 3) between 2,001 and 3,000 €, 4) between 3,001 and 4,000 €, 5) more than 4,000 €.
Characteristics of the dwelling			
Type of building (% of number of types)	The building types.	What is the type of your building where your household lives?	1) single house 2) semi-detached house 3) terraced house 4)line block building 5) tower block building 6) central patio building 7) non-residential building
Size of dwelling – heated area (% of categories)	The size of the dwelling corresponds to the surface in m^2.	What is the size of your dwelling?	1) less than 50 m^2 2) 51–70 m^2 3) 71–90 m^2 4) 91–110 m^2 5) more than 110 m^2
Accommodation time (% of categories)	The years of occupancy in the current home.	How long have you lived in your dwelling?	1) until 3 years 2) 4–6 years 3) 7–10 years 4) 11–20 years 5) more than 21 years

Environmental background

KPI/element	Description of KPI	Question	Response
Knowledge and environmental awareness on environmental problems			
Environmental	The knowledge and	How do you assess your awareness and	Scale from 1

awareness (average score, %)	awareness of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on global environmental problems. The following values are derived from the Special Eurobarometer 416 report: Attitudes of European Citizens Towards the Environment[32]	knowledge on the following global environmental problems? #1: Climate change #2: Air pollution #3: Water pollution (seas, rivers, lakes and underground sources) #4: The impact on our health of chemicals used in everyday products #5: The growing amount of waste #6: Depletion of natural resources #7: Agricultural pollution (use of pesticides, fertilisers, etc.) #8: Shortage of drinking water #9: Loss of extinction of species and their habitants and of natural ecosystems (forests, fertile soils) #10: Our consumption habits #11: Urban problems (traffic jams, pollution, lack of green spaces, etc.) #12: Land take (i.e. that more land is used to build roads or cities, and that cities expand into the surrounding countryside) #13: Noise pollution #14: Soil degradation #15: The spread of harmful non-native plants and animals (invasive species)	to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every problem separately.
Knowledge and benefits of the solutions implemented in energy efficient retrofit projects			
Knowledge about efficient energy measures (average score, %)	The level of knowledge of citizens (direct beneficiaries of the project as residents and drivers and other citizens) on the existing efficient energy measures at building level.	Have you heard about the following measures and benefits? #1: Insulation to decrease the thermal loss in cold climate and thermal gain in warm climate #2: Cheaper Lightning (new LED lightning systems) #3: Better Windows (less noise and more energy-efficient #4: Better ventilation (less noise and more energy-efficient) #5: Energy dashboards (see the Solar panels production and buildings consumption of energy)	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every measure and benefit separately.

Individual perception of residents

[32] http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_416_en.pdf

KPI/element	Description of KPI	Question	Response
Fairness and inclusiveness in the decision-making process: satisfaction with the project, with the level of information received, with the involvement degree			
Residents project satisfaction (average score, %)	The level of satisfaction of the dwelling's resident with regard to the project in general terms. The project is surrounded by technical solutions, information, costs, intervention phases and external conditions, among others.	How satisfied are you with the project?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction with the information accessibility (average score, %)	This KPI determines whether the residents with energy monitoring systems are satisfied with the access to such data.	How satisfied are you with the accessibility of information related to energy monitoring?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Residents involvement degree (average score, %)	% of people who feel involved during the intervention project life cycle.	How involved did you feel?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Residents involvement degree (average score, %) *KPI from Citizen Engagement*	Number of residents who felt involved in the decisions taken in the district.	How involved did you feel in the decisions taken in the district?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Economic value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the investment costs			
Satisfaction with the investment costs (average score, %)	Determines the level of satisfaction of the dwelling's residents with the investment costs. Investment costs are defined as the increase of rent.	How satisfied are you with the investment costs?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction level with the reduction in the energy bills			
Energy bill reduction (average score, %)	Reduction in the energy bills that is directly translated into money. Subjective measure.	How satisfied are you with the reduction in energy bill?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not

			at all (1)
Willingness to invest in further energy projects			
Further investments in energy related project (average score, %)	The percentage of inhabitants who would like to invest in further energy projects taking into consideration the results of the SmartEnCity one.	Given your present economic situation how willing are you to invest in further energy projects?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

Technical value of the solutions

KPI/element	Description of KPI	Question	Response
Satisfaction with the solution implemented as a whole			
Whole solution satisfaction (average score, %)	The percentage of the inhabitants who are satisfied with the solution vs raise in rent.	How satisfied are you with the solution implemented as a whole?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)
Satisfaction from the energy perspective (comfort)			
Comfort conditions (average score, %)	Another goal of this sort of projects is the comfort, even the most important from the end user together the reduction of the energy bills. Nevertheless, the comfort is, perhaps, the most subjective parameter because every person's comfort level differs from each other. In contrast to the subjective evaluation, the objective result gives the real performance compared to the National regulations which limit the maximum and minimum conditions associated to the building typology. Thus, the opinion of the owners can be compared with the regulations to obtain the real context.	What kind of comfort improvements have you experienced after the retrofitting? #1: Less drag from the windows #2: Better air quality in the apartment #3: Easier to regulate the warmth in the apartment #4 Noise reduction #5: General better comfort in the apartment	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every comfort condition separately.
Satisfaction from the energy perspective (energy savings satisfaction)			
Energy savings satisfaction (average score, %)	One of the main objectives of this kind of projects is the reduction of the energy consumption both at district and building and dwelling levels. However, from the social perspective, not only the numeric value is enough, but also the owners' opinion is required. In this way, the achievement of this KPI is done if more than the 60% of the people feel satisfied with the reached energy savings. Nevertheless, this result is compared with the objective KPI about energy savings, because both must be aligned so that	How satisfied are you with the energy savings? #1: Electricity #2: Heating	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1) Response required for every energy type

	the results would be consistent.		separately.
Satisfaction from aesthetic perception			
Aesthetical satisfaction (average score, %)	Aesthetical satisfaction of the solutions. The buildings aesthetical appearance after the retrofitting.	How satisfied are you with the aesthetics of the implemented solutions?	Scale from 1 to 5. Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)

- *Data measurements*

Data from the monitoring system can be used for assessing real parameters, providing the comparison of both survey and measurement methods a better knowledge of the real situation than each of them individually considered.

Parameter	Description	Data source
Heating	The total consumptions of heat in the buildings	ICT
Electrical consumption	The total consumptions of electricity in the buildings	ICT

11.3.6 Citizen engagement

In Sonderborg the strategy to be followed to engage the citizens in the process will be deployed in different steps. All tenants in the three housing associations will be invited for meetings where they will receive information about the specific plans for retrofitting and where they will be able to discuss about them. Additionally, there will be information available online at the websites of the housing associations. Citizen engagement will be assessed in three topics: 1) engagement strategy, 2) urban platform, and 3) project objectives of the district (Table 34).

Sonderborg	
Objective	Method and data sources
Evaluate the citizen engagement strategy through the perception of responsible of their design and residents. Evaluate the use of urban platform/web application. Evaluate the successful of the project objectives in the district.	Questionnaires Interviews Urban platform

Table 34: Citizen engagement assessment objectives for Sonderborg

CITIZEN ENGAGEMENT STRATEGY

Questions related to the perception of residents, users of services related to mobility actions and citizens are integrated and will be asked as part of the social acceptance questionnaires

for residents, mobility actions, citizens. The methodology has been described in section 11.3.5.

- **Objective: Evaluate the citizen engagement strategy through the perception of residents**

Residents involvement degree – Number of residents who felt involved in the decisions taken in the district / Number of residents who answered this question

Unit: %

Data source/method: Survey for residents living in retrofitted apartments.

Input parameter	Symbol	Unit	Data source
Respondents who felt involved	*R*	number	Survey for residents
Respondents who answered this question	*N*	number	Survey for residents

Calculation: (R/N)*100

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: The question uses Likert-scale from 1 to 5 (Extremely (5) – Very (4) – Moderately (3) – Slightly (2) – Not at all (1)). Respondents answering 3, 4 ot 5 on a scale of 1 to 5 are interpreted as residents who are considered to be well-involved.

Number of surveys fulfilled by residents/Number of residents informed about the citizen engagement actions – Residents are defined by the citizens who has participated in the decision proces.

Unit: % of the tenants in the involved departments (sum of all apartments)

Data source/method: Questionnaire.

Input parameter	Symbol	Unit	Data source
Respondent who considered to be well-informed	*R*	Number	Survey for residents
Respondent who answered this question	*N*	Number	Survey for residents

Calculation: R/N

Reporting frequency and input data collection frequency: The KPI is reported once after the survey has been carried out.

Other issues: Respondents answering 3, 4 or 5 on a scale of 1 to 5 are interpreted as residents who are considered to be well-informed.

The following KPI is not measured:

- Resident information satisfaction.

- **Objective: Evaluate the citizen engagement strategy through the perception of responsible of their design**

Perception of success or failure by actors involved about citizen engagement activities performed

The perception of the citizen engagement strategy will be evaluated through the members of the advisory board by a discussion/interview with the members. The group meets 3 times a year and could therefore evaluate once a year on the progress.

Unit: Interviews

Data source/method: Interview with the advisory board, qualitative assessment.

Reporting frequency and input data collection frequency: The KPI is assessed once at the end of the project.

CITIZEN ENGAGEMENT PLAN (URBAN PLATFORM)

- **Objective: Evaluate the use of urban platform (apps, added value services, social media and website) as part of the citizen engagement strategy by residents from district, mobility actors and citizens**

Number of citizens using web application – This indicator consists of the number of people (registered users and anonymous) who have connected to the website of the project in a time basis (daily, monthly).

Unit: Number of users

Data source/method: Info from the ICT system.

Calculation: Sum of users.

Reporting frequency and input data collection frequency: Annually, once a year the total count of users is collected.

Number of logins (monthly) in the web application – To measure the use of the ICT system, number of logins are measured and compared with the total of registered users to the system.

Unit: Number of logins

Data source/method: Info from the ICT system.

Input parameter	Symbol	Unit	Data source
Registered users	*U*	number	ICT system
Logins	*L*	number	ICT system

Calculation: Total number of logins.

Reporting frequency and input data collection frequency: Annually, once a year the total logins are reported.

Increase of new visitors in the web application – Percentage of increase (or decrease) in registered citizens, monthly. Increase is measured as new registered users to the system. New users are defined as new registered usernames to the system.

Unit: %

Data source/method: Info from the ICT system.

Input parameter	Symbol	Unit	Data source
New users	U_{new}	number	ICT system
Existing users	U_{ex}	number	ICT system

Calculation: $(U_{new} / U_{ex}) \times 100$

Reporting frequency and input data collection frequency: Annually.

Time spent on the web – Average time that people spend in the website. It could be measured monthly**.**

Unit: Time (minutes)

Data source/method: Info from the ICT system.

Input parameter	Symbol	Unit	Data source
Time spent on the web	*Ttime*	minutes	ICT system
Visitors using the website	*Visitors*	number	ICT system

Calculation: Ttime/Visitors

Reporting frequency and input data collection frequency: Annually.

Number of mobile app downloads in the framework of SmartEnCity

Unit: Number of downloads

Data source/method: Info from the ICT system.

Calculation: Sum of all downloads.

Reporting frequency and input data collection frequency: Annually.

The following KPIs (described in D7.3) will not be measured or are substituted:

- Number of mobile app downloads by residents from district,
- Number of visits (daily/monthly) in the web application,
- Number of active users of Apps,
- Quality of services/added value services.

CITIZEN ENGAGEMENT STRATEGY + PLAN (PROJECT OBJECTIVES IN DISTRICT)

- **Objective: To evaluate the success of project objectives: building refurbishment action and district heating with RES**

Number of dwellings retrofitted

Unit: Number of dwellings

Data source/method: Housing associations.

Reporting frequency and input data collection frequency: The KPI is reported after the retrofitting.

Number of buildings connected to the District Heating

Unit: Number of buildings

Data source/method: Housing associations.

Reporting frequency and input data collection frequency: The KPI is reported after connecting to the District Heating.

Number of residents benefited by the intervention

Unit: Number of residents

Data source/method: Housing associations.

Reporting frequency and input data collection frequency: The KPI is reported after the retrofitting.

Number of residents who were against project – This indicator intends to measure the level of rejection towards the project. It can be evaluated through the percentage of residents who voted against the retrofitting of buildings (and the percentage of residents who voted against to district heating). In addition, if any group is created as a platform against the project, it should include as number of people who took part of these platforms.

Unit: Number of tenants, % of tenants

Data source/method: Reports from tenants' meetings.

Input parameter	Symbol	Unit	Data source
Tenants against	T_a	number	logbook
Tenants in favour	T_f	number	logbook
Tenants living in department	T_t	number	logbook

Calculation: $T_a / T_t \times 100$

Reporting frequency and input data collection frequency: Once at the deciding residents meeting in each Department.

11.3.7 Economic performance

Economic performance will be measured for district renovation actions (Table 35). The data source for collecting data for economic assessment KPIs is questionnaire, but some of the KPIs will be estimated based on the collected data from questionnaires. The questionnaire is addressed to housing associations. In total, there will be estimated five KPIs (Table 36). KPI number 3 will be calculated for the baseline as well as for the final performance, other KPIs will be estimated as the final performance. Old costs must be calculated to the baseline of the project, since demo's partners must know what is the value of these costs before the beginning of the renovation.

To facilitate the calculation of the different KPIs, an Excel sheet has been prepared under D7.3 SmartEnCity Evaluation Protocols where the information with the indicators disaggregated is depicted in the annex of D7.3. The required data is indicated and when completing it, the Excel sheet gives the KPI resulting value.

Sonderborg	
Objective	Methods and data sources
Economic performance of district interventions	
Energy costs savings of tenants living in district (in comparison with the initial situation).	Questionnaire

Table 35: Economic performance assessment objectives for Sonderborg

Eq. #	KPI (unit)	Method	Input parameters of the KPI (unit)	Data source for the component
1	Resident costs (€/m^2)	Questionnaire	Investment (€)	Consultant
			Grant (€)	Consultant
			Total area (m^2)	Consultant
2	Grant rate (%)	Questionnaire	Investment (€)	Consultant
			Grant (€)	Consultant
3	Total annual costs (€/m^2)	Questionnaire	Total maintenance costs (€)	Consultant
			kWs uptake (kW)	Consultant
			kWs country price (€)	Consultant
			Total area (m^2)	Consultant
4	Total annual benefits for	Questionnaire	Old costs (€)	Consultant

Eq. #	KPI (unit)	Method	Input parameters of the KPI (unit)	Data source for the component
	residents (€/m^2)		Total annual costs (€/m^2)	Consultant
5	Cost saving rate (%)	Questionnaire	Total annual benefits for residents (€/m^2)	Consultant
			Old costs (€/m^2)	Consultant

Table 36: KPIs, input parameters and data sources for economic assessment

11.3.8 City indicators

The city indicators will provide an overall picture of the interventions and evaluate the impact by the project. The frequency to evaluate the city impacts and the baseline for different topics will be done before the intervention (estimated in D5.1 (M9) and D5.2 (M18)) and at the end of the project (M66).

Green background corresponds to impacts to be potentially evaluated as a result of the difference between the value of the indicators used in the city diagnosis made in D5.1 and the value of the intervention performance to be evaluated by the relevant KPIs.

Blue background corresponds to those impacts which require collecting new data by the consortium (maybe not available through the current or foreseen infrastructure).

The city diagnosis indicators are described in D5.1 and the data have already been collected. Data for KPIs for intervention and the final diagnosis need to be collected.

ENVIRONMENTAL INDICATORS FOR EVALUATING CITY IMPACTS

- **Impact: Energy savings in the city due to district renovation**

Indicator from city diagnosis

Residential buildings energy consumption per year – Residential consumption in the city for heating and electricity uses.

Unit: MWh/year

Data source/method: Geographical Energy Balance 2015.

Input parameter	Unit	Data Source
Heat consumption	MWh/year	Geographical Energy Balance 2015
Electricity consumption	MWh/year	Geographical Energy Balance 2015

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Other issues: End-use consumption (“Electricity” incl. electricity for heating and heat pumps).

Total building energy consumption in the city per capita *(including residential and non-residential uses)* – Residential + non-residential consumption in the city for heating and electricity uses.

Unit: kWh/year per inhabitant

Data source/method: Geographical Energy Balance 2015.

Input parameter	Unit	Data Source
Heat	kWh/year per inhabitant	Geographical Energy Balance 2015
Electricity	kWh/year per inhabitant	Geographical Energy Balance 2015

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Other issues: For Heat: end-use consumption (excl. industry); For Electricity: end-use consumption (excl. industry. "Electricity" incl. electricity for heating and heat pumps).

KPI for intervention

Energy savings due to district renovation *(Energy Assessment Protocol)*

Unit: kWh

Data source/method: ICT.

Input parameter	Symbol	Unit	Data Source
Total energy use after	TEU_a	kWh	ICT
Total energy use before	TEU_b	kWh	Energy company

Calculation: Total energy use after / Total energy use before

Reporting frequency and input data collection frequency: Annually once the retrofitting is complete.

- **Impact: Lower emissions of CO_2 in the city due to district renovation**

Indicator from city diagnosis

Emissions of residential and non-residential sectors (CO_2 equiv.) – Described as Global Warming Potential (GWP) per capita.

Unit: Tn equi. CO_2 / year capita

Data source/method: Geographical Energy Balance 2015.

Calculation: Emissions of residential and non-residential sectors / city population

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

CO_2 emissions savings due to district renovation *(Energy Assessment Protocol)*

Unit: t CO_2

Data source/method: Calculated by Danish Energy Management & Esbensen.

Input parameter	Symbol	Unit	Data Source
Total CO_2 emissions before retrofitting	TE_{br}	t CO_2	ICT
Total CO_2 emissions after retrofitting	TE_{ar}	t CO_2	ICT

Calculation: $TE_{br} - TE_{ar}$

Reporting frequency and input data collection frequency: Once at the end of the project.

- **Impact: Lower emissions of CO_2 in the city due to sustainable mobility actions**

Indicator from city diagnosis

Transport greenhouse gas emissions – Measure of the total greenhouse gas emissions (per capita) due to public and private transport.

Unit: t /(pers.·a)

Data source/method: Calculated from a national level Danish statistic, Geographical Energy Balance 2015

Calculation: Transport GHG emissions, in equivalent CO_2 units, generated over a calendar year.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

CO_2 emissions savings due to sustainable mobility actions *(Mobility protocol)*

Unit: T CO_2

Data source/method: Tide bus company, ICT from charging stations.

Input parameter	Symbol	Unit	Data Source
Total CO_2 emissions from public and private transport in reference year (2016)	*CHGtotal2016*	tons	Danish Statistic
Total CO_2 emissions from public and private transport in current year	*CHGtotal201x*	tons	Danish Statistic

Calculation: GHGtotal 2016 – GHGtotal 201x

Reporting frequency and input data collection frequency: Annually.

- **Impact: Increase in the use of RES in the city due to district renovation**

Indicator from city diagnosis

Percentage of total energy consumed in the city derived from renewable sources – Defined as "percentage of total energy derived from renewable sources" (see D5.1).

Unit: %

Data source/method: Geographical Energy Balance 2015.

Calculation: Total renewable energy consumption in the city/gross inland consumption in the city.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Total renewable energy consumption in the city – Energy derived from energy renewable sources.

Calculation: Not possible to calculate.

- **Impact: Increase in the production of RES in the city due to district renovation**

Indicator from city diagnosis

Final energy produced in the city per year

Unit: MWh/year

Data source/method: Geographical Energy Balance 2015.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

KPI for intervention

Share of renewable energy *(Energy Assessment Protocol)* – Total share of renewable energy sources in a complex energy supply system. More specifically: The share of renewable energy produced in the retrofitted departments.

Unit: %

Data source/method: ICT system.

Input parameter	Symbol	Unit	Data Source
Total electricity by renewable	RES_p	kWh	ICT
Total electricity demand	*TED*	kWh	ICT

Calculation: RESp / TED

Reporting frequency and input data collection frequency: Annually after retrofitting.

- **Impact: Number of dwellings/buildings retrofitted due to SmartEnCity project**

Final diagnosis

Number of dwellings/buildings retrofitted – The number of dwellings and buildings retrofitted in the project (see also section. 11.3.6).

Unit: Number of dwellings

Data source/method: Housing associations.

Input parameter	Unit	Data Source
Buildings	number	Housing associations

Calculation: Sum of dwellings.

Reporting frequency and input data collection frequency: The KPI is reported after the retrofitting.

Number of buildings connected to the District Heating

Unit: Number of buildings

Data source/method: Housing associations.

Reporting frequency and input data collection frequency: The KPI is reported after connecting to the District Heating.

- **Impact: New sustainable vehicles (EV) in the city due to SmartEnCity project**

Indicator from city diagnosis

Electric vehicles by category (cars, taxis, motorbikes, e-bikes, last mile logistic, bus)

Unit: % electric vehicles by category

Data source/method: Danish Electric Vehicle Alliance, ProjectZero.

Input parameter	Unit	Data Source
Electric private cars	%	Danish Electric Vehicle Alliance, ProjectZero
Electric taxis	%	Danish Electric Vehicle Alliance
Electric motorcycles	%	Danish Electric Vehicle Alliance

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

Number of new EV in the city – the number of new EV in the city acquired by the project and the total EV in the city also from other initiatives since the project could influence in promoting these actions.

Not estimated, since not part of the SmartEnCity project in Sonderborg.

- **Impact: New sustainable vehicles (biogas buses) in the city due to SmartEnCity project**

Indicator from city diagnosis

Biogas buses – biogas public buses.

Unit: Number of biogas buses

Data source/method: Sonderborg Municipality.

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

Biogas buses – The number of new Biogas buses in the city acquired by the project and the total biogas buses in the city also from other initiatives since the project could influence in promoting these actions.

Unit: Number of biogas public buses.

Data source/method: Grant Agreement, Sonderborg municipality.

Input parameter	Unit	Data Source
New biogas buses acquired by the project	number	Grant Agreement
Biogas buses from other initiatives	number	Sonderborg Municipality

Calculation: Sum of the total number of biogas public buses.

Reporting frequency and input data collection frequency: Reported after the implementation of the intervention.

- **Impact: Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project**

Indicator from city diagnosis

Number of public EV charging stations *(initially it was required to count only public EV charging stations)* – Total number of public EV charging stations in the city.

Unit: Number of EV charging stations

Data source/method: www.ladekortet.dk

Reporting frequency and input data collection frequency: Reported in the city diagnosis.

Final diagnosis

Number of (public) EV charging stations – The number of new EV charging infrastructures acquired by the project and total EV infrastructures in the city also from other initiatives since the project could influence in promoting these actions.

Unit: Number of EV charging stations

Data source/method: Danish Electric Vehicle Alliance.

Input parameter	Unit	Data Source
New EV charging infrastructures acquired by the project	number	Grant Agreement
EV infrastructures in the city also from other initiatives	number	Sonderborg Municipality

Calculation: Sum of the total number of EV charging stations.

Reporting frequency and input data collection frequency: Reported after the implementation of the intervention.

- **Impact: Increase in the use of EV charging infrastructures due to the project**

Indicator from city diagnosis

Total kWh recharged in the EV charging stations – Number of estimated kWh recharged during a year in the public EV charging stations

Unit: kWh

Data source/method: Data not available.

KPI for intervention

Total kWh recharged in the EV charging stations (biogas and EV) – Number of kWh recharged during a year in the public and private charging stations. It will be required to infrastructure operator and vehicle owners to compare this indicator with energy consumption and distance travelled.

Unit: kWh

Data source/method: Meter.

Input parameter	Unit	Data Source
Total kWh recharged in the EV charging stations (EV)	kWh	Private recharging station companies
Total kWh recharged in the EV charging stations (biogas)	kWh	Private recharging station companies

Calculation: Sum of recharged kWhs.

Reporting frequency and input data collection frequency: KPI reported for the baseline and final performance. Data collected twice – in baseline year and in final performance year.

ECONOMIC INDICATORS FOR EVALUATING CITY IMPACTS

- **Investment mobilized for the renovation of the district**

Total investment of the district from local and regional public funding, EC funding and private funding" (e.g. dwellings' owners, energy companies, social housing companies, etc.). It should be specified for each type of fund.

Unit: €

Data source/method: Questionnaire for housing associations and energy companies.

Input parameter	Unit	Data Source
Private funding (housing associations, energy companies)	€	Questionnaire
Regional public funding (housing associations, energy companies)	€	Questionnaire
EC funding (housing associations, energy companies)	€	Questionnaire

Calculation: Sum of funding by funding type.

Reporting frequency and input data collection frequency: Once after the implementation of the intervention – at the end of the project.

Other issues: Channels of distributing will be by mail a link to the questionnaires or by letter. Questions addressed are "What are the investment costs by funding type in: #1: Investments in RES; #2: EV charging stations; #3: energy retrofitting; #4: retrofitting along whit the energy retrofitting". Investment types are defined as "private funding", "EC funding" and "regional public funding".

11.4 Parameters for quality checks and surveillance

11.4.1 Vitoria-Gasteiz

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Energy assessment						
Described in the further steps						
ICT						
Described in the further steps						
LCA						
Global warming potential	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	No thresholds set since KPI values are checked manually after the calculation	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in the software used to calculate the LCA KPI values. Thus, manual check is implemented	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Ecological Footprint						
Use of renewable primary energy excluding energy resources used as raw material						
Use of renewable primary energy resources used as raw material						
Use of non-renewable primary energy excluding energy resources used as raw material						
Use of non-renewable primary energy resources used as raw material						
Exported energy						
Hazardous wastes disposed						
Non-hazardous wastes disposed						
Mobility						
Described in the further steps						
Social Acceptance						
Questionnaire for district renovated						
Age	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository	0.0…100.0	Thresholds for detecting out of range values for answers that require a selection from predefined categories are defined by the limited set of possible answer choices	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range "-1" will be inserted to indicate the missing value. Manual check applied for the cases
Education level						
Nationality						
Income						
Type of building						
Dwelling size						
Ownership						
Accommodation time						

Environmental awareness Awareness of environmental problems in the city			0.0…100.0 for % of categories, 1.0…5.0 for average score			
Knowledge about efficient energy measures						
Residents project satisfaction						
Satisfaction with the information accessibility						
Residents information satisfaction						
Residents involvement degree						
Satisfaction with time plan for execution of actions						
Satisfaction with the communication and dialogue with decision makers						
Satisfaction with the investment costs						
Satisfaction with the access to financing						
Satisfaction with the payback period						
Energy bill reduction						
Further investments in energy related projects						
Whole solution satisfaction						
Comfort conditions						
Energy savings satisfaction						
Aesthetical satisfaction						
Citizen Engagement						
Described in the further steps						
Economic Performance						
Described in the further steps						
City indicators (KPIs for intervention and final assessment)						
Described in the further steps						

11.4.2 Tartu

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Energy assessment						
Energy demand	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis (before and after renovation)	Monthly	60...300 kWh/m^2·a	Buildings main heat meter [0...40 kWh/m^2·month], Dwellings electricity meter and buildings general electricity meter [0.5...10 kWh/m^2·month], Buildings main gas meter [0...5 kWh/m^2·month], Buildings PV panels electricity on-site consumption [0...5 kWh/m^2·month]	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Delivered energy (for buildings)	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis (before and after renovation)	Monthly	40...300 kWh/m^2·a	Buildings main heat meter [0...40 kWh/m^2·month], Dwellings electricity meter and buildings general electricity meter [0...10 kWh/m^2·month], Buildings main gas meter [0...5 kWh/m^2·month]	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Primary energy (for buildings)	Once as the data are inserted in the repository	Monthly, once as the data are inserted in the repository	3000...11000 MWh/a (for all renovated buildings)	Delivered energy per energy carrier [0...55 kWh/m^2·month], Exported energy per energy carrier [0...5 kWh/m^2·month], Primary energy factor for delivered energy carrier [0.1...3], Primary energy factor for exported energy carrier [-], Floor area of the building [35000...45000 m^2]	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 equivalent (for buildings)	Once as the data are inserted in the repository	Yearly	1000...4000 tCO_{2e}/a (for all renovated buildings)	Electricity CO_2 equivalent [0....1500 tCO_2e/a], Heat CO_2 equivalent [0...1000 tCO_2e/a], Gas CO_2 equivalent [0...200 tCO_2e/a],	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Density of energy demand	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0...50 kWh/m^2·a	Tartu district heating area [10...40 km^2], Heat energy consumption of Tartu district heating area [400...800 GWh/a]	NA	Manual checks are implemented. Thus, no data correction procedures are implemented
Peak load and load profile of electricity demand	Once as the data are inserted in the repository	Monthly	0…3000 kW (for all renovated buildings)	Load profile (average usage/normal usage) [0...3000 kW], Peak load [0...3000 kW]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Peak load and load profile of thermal (heating/cooling) energy	Once as the data are inserted in the	Monthly	0...5500 kW (for all renovated buildings)	Outside temperature [-35...+35 °C], Heating Degree Days [0...1000 HHD per	If up to 25% of buildings data are missing, the KPI and	Manual checks are implemented. Thus,

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
demand	repository			month at 17° $t_{balance}$], Load profile (base power in heating season) [0...5500 kW], Peak load [0...5500 kW]	input parameters are calculable/estimable (e.g. using units per m^2)	no data correction procedures are implemented
Degree of congruence of calculated annual final energy demand and monitored consumption	Once as the data are inserted in the repository	Yearly	0...30%	Final energy demand of building I based on annual data of year [0...55 kWh/m^2·a], Final energy consumption of building I based on annual data of year [0...55 kWh/m^2·a	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Degree of energetic self-supply	Once as the data are inserted in the repository	Yearly	0...30%	Renovated buildings PV panels annual production, Renovated buildings annual electricity consumption [5...50 kWh/m^2·a], Renovated buildings annual energy consumption [40...300 kWh/m^2·a],	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Share of renewable energy	Once as the data are inserted in the repository	Yearly	0...50%	Renovated buildings PV panels annual production, Renovated buildings annual electricity consumption, Renovated buildings annual energy consumption	If up to 25% of buildings data are missing, the KPI and input parameters are calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Efficiency	Once as the data are inserted in the repository	Monthly, once as the data are inserted in the repository	0...100%	PV panels production, Direct solar radiation, PV panels efficiency, Heat unit heat exchangers efficiency (hot water, heating), Ventilation heat recovery efficiency	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus. no data correction procedures are implemented
Internal air temperature	Once as the data are inserted in the repository	Monthly	18...23°C	Internal temperature [18...30°C]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Heat quantity for set point achievement	Once as the data are inserted in the repository	Monthly	10...20 kW per 1 degree of temperature change (for all renovated buildings)	Dwelling/one building's dwellings average temperature [18...30°C], Heating energy used by dwelling/building [0...40 kWh/m^2·month]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Thermal comfort	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	Dependent on the comfort topic: -2.0…2.0 1.0...5.0 -3.0...3.0	Dependent on the comfort question: -2…2 1...5 -3...3	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range "-1" will be inserted to indicate the missing value. Manual check applied
ICT						
Response time	Annually	Annually	0 … INF	0 … INF	NA	NA
Scalability	Annually	Annually	0 … INF	0 … INF	NA	NA

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Extensibility	Annually	Annually	0 … INF	0 … INF	NA	NA
Storage capacity	Annually	Annually	0 … INF	0 … INF	NA	NA
Hours of maintenance	Annually	Annually	0 … INF	0 … INF	NA	NA
Non-expected hours offline	Annually	Annually	0…24h*days in year	0…24h*days in year	NA	NA
# of HEMS connected	Annually	Annually	0…5000	0…5000	NA	NA
# of BEMS connected	Annually	Annually	0…5000	0…5000	NA	NA
# of EV connected	Annually	Annually	0…100	0…100	NA	NA
# of mobility equipment connected	Annually	Annually	0…1500	0…1500	NA	NA
Total amount of data generated	Annually	Annually	0 … INF	0…INF	NA	NA
Recharging points equipment connected	Annually	Annually	0…10	0…10	NA	NA
Smart lighting equipment connected	Annually	Annually	0…500	0…500	NA	NA
Number of services developed	Annually	Annually	0 … INF	0 … INF	NA	NA
Types of services	Annually	Annually	0 … INF	0 … INF	NA	NA
Percentage of dwellings connected	Annually	Annually	0.0 … 100.0%	Total number of dwellings in pilot area: 1759 Number of dwellings in pilot area connected to platform: 0…Total number of dwellings in pilot area	NA	NA
Percentage of buildings connected	Annually	Annually	0.0 … 100.0%	Total number of buildings in pilot area: 42 Number of buildings in pilot area connected to platform: 0…42	NA	NA
Open-Data sets available	Annually	Annually	0 … 100	0…100	NA	NA
LCA						
Global warming potential	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	No thresholds set since KPI values are checked manually after the calculation	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in the software used to calculate the LCA KPI values. Thus, manual check is implemented	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Ecological Footprint						
Use of renewable primary energy excluding energy resources used as raw material						
Use of renewable primary energy resources used as raw material						
Use of non-renewable primary energy excluding energy resources used as raw material						
Use of non-renewable primary energy resources used as raw material						
Exported energy						
Hazardous wastes disposed						

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Non-hazardous wastes disposed						
Mobility						
Average occupancy (electric bikes)	Annually	Annually	0…INF	EV (electric bike): 0….700, Number of rentals: 0…INF, Period to cover: days in specific month	NA	NA
Accuracy of timekeeping for public bus	Annually	Annually	0…INF, 0.0…100.0	Total departures: 0…INF, Total departures within allowed time of delay or ahead of schedule: 0…INF <= Dep total	NA	NA
CO_2 emission by travelled distance	Annually	Annually	0…INF	Distances travelled: 0…INF, Emissions CO_2 by km: 0…INF	NA	NA
Total number of recharges per year (EV)	Annually	Annually	0…INF	0…INF	NA	NA
Total kWh recharged in the EV charging stations (EV)	Annually	Annually	0…INF	0…INF	NA	NA
Social Acceptance						
Questionnaire for residents, mobility, and citizens						
Age	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	16…115	16…115	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range "-1" will be inserted to indicate the missing value. Manual check applied
Gender			0.0…100.0 for % of categories	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices		
Highest level of completed education of inhabitants						
Primary language of communication						
Net monthly income of the households						
Employment						
Size of the household			1.0…INF	1…INF		
Environmental awareness			0.0…100.0 for % of categories, 1.0…5.0 for average score	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices		
Awareness of environmental problems in the city						
Knowledge about efficient energy measures						
Residents						
Size of dwelling – heated area	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	1.0…100.0	1.0…100.0	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range "-1" will be inserted to indicate the missing value. Manual check applied
Size of dwelling – number of rooms			1.0…10.0	1…10		
Ownership structure			0.0…100.0 for % of categories	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices		
Accommodation time						
Residents project satisfaction			0.0…100.0 for % of	Categorical data: The thresholds for		

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Satisfaction with the information accessibility			categories, 1.0…5.0 for average score or dependent on the comfort topic: -2.0…2.0, -3.0...3.0	detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices		
Resident information satisfaction						
Involvement degree						
Resident consultation satisfaction						
Satisfaction with time plan for the execution of actions						
Satisfaction with the communication and dialogue with decision makers						
Satisfaction with the investment costs						
Satisfaction with the payback period						
Energy bill reduction						
Further investments in energy related projects						
Whole solution satisfaction						
Comfort conditions						
Energy savings satisfaction						
Aesthetical satisfaction						
Mobility						
Acquaintance with the project	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0…100.0 for % of categories	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range “-1” will be inserted to indicate the missing value. Manual check applied
Use of mobility services						
Service user’s project satisfaction			0.0…100.0 for % of categories, 1.0…5.0 for average score			
Willingness to purchase/invest in new EV						
Further investments in energy related projects						
Whole solution satisfaction						
Comfort conditions						
Citizens						
Citizens’ project satisfaction	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0…100.0 for % of categories, 1.0…5.0 for average score	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices.	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range “-1” will be inserted to indicate the missing value. Manual check applied
Citizen information satisfaction						
Further investments in energy related projects (individual perspective)						
Further investments in energy related projects						
Whole solution satisfaction						

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Aesthetical satisfaction						
Citizen Engagement						
Resident information satisfaction	Once as the data are inserted in the database	Once as the data are inserted in the repository	0.0…100.0%	Respondents who answered this question: 0…the number of distributed questionnaires; Respondents who considered to be well-informed: 0…the number of respondents who answered this question	NA	NA
Citizen information satisfaction				Respondents who answered this question: 0…the number of distributed questionnaires; Respondents who considered to be well-informed: 0…the number of respondents who answered this question		
Resident consultation satisfaction				Respondents who answered this question: 0…the number of distributed questionnaires; Respondents who considered to be well-consulted: 0…the number of respondents who answered this question		
Involvement degree				Respondents who answered this question: 0…the number of distributed questionnaires; Respondents who considered to be involved: 0…the number of respondents who answered this question		
Response rate for surveys				Surveys distributed: 0…the number of distributed questionnaires, surveys filled: 0…the number of distributed questionnaires		
Perception of success or failure by actors involved about citizen engagement activities performed	NA	-	NA	-	NA	NA
Number of activities carried out for informing citizens (incl. residents) about the project	Once as the data are inserted in the database	Once as the data are inserted in the database	0…INF	0…INF	NA	NA
Number of residents involved in the citizen engagement actions (residents, mobility actions) carried out	Once as the data are inserted in the database	Once as the data are inserted in the database	0…INF	0…INF	NA	NA
Number of citizens (registered users) using web application	Annually	Monthly	0…INF	Number of unique registered users: 0…Total number of registered users (input parameter for one month).	NA	NA

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
				Sum of users over the time-period: 0…INF Time-period in months: 12		
Number of visits (daily/monthly) (in the web application)	Monthly	Monthly	0…INF	0…INF	NA	NA
Increase of new visitors in the web application	Monthly	Monthly	0.0…100.0	New registered users: 0…INF, Old registered users: Total number of users registered before	NA	NA
Time spent on the web	Annually	Monthly	0…INF	Total time spent on the website by all visitors: 0…INF Total number of visitors: 0…INF	NA	NA
Number of Apps developed in the framework of SmartEnCity	Annually	Annually	0…INF	0…INF	NA	NA
Number of mobile app downloads	Annually	Monthly	0…INF	0…INF	NA	NA
Number of active users of Apps	Annually	Annually	0…INF	0…Registered users	NA	NA
Number of active users of Apps in the category of citizens	Annually	Annually	0…INF	0…Registered users	NA	NA
Quality of services/added value services	Annually	Annually	0.0…100.0 for % of categories, 1.0…5.0 for average score	Categorical data: The thresholds for detecting out of range values for questions that require a selection from predefined categories are defined by the limited set of possible answer choices.	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	NA (if value missing "-1" is inserted for the raw data)
Number of dwellings retrofitted	Once as the data are inserted in the database	-	700...900 dwellings	-	NA	NA
Number of residents benefitted by the intervention	Once as the data are inserted in the database	-	0…2500 residents	-	NA	NA
Economic Performance						
District renovation						
Resident costs	Once as the data are inserted in the database	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0...400 €/m^2	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in Excel file used to calculate the Economic Assessment KPI values. Thus, manual check is implemented.	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Grant rate			0.0…100.0 %			
Total annual costs			5...20 €/m^2·a			
Total annual benefits for residents			0...15 €/m^2·a			
Cost saving rate			0.0…100.0%			
Mobility						
Total annual costs	Once as the data are inserted in the database	Once as the data are inserted in the repository (if the raw data are inserted in	0…INF	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in Excel file used to calculate the Economic Assessment KPI values.	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Benefit by uptake savings			0…INF			
Benefits			0…INF			
Cost of saving a kg of CO_2			0…INF			

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
		the repository)		Thus, manual check is implemented.		
Citizen engagement						
Investment	Once as the data are inserted in the database	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in Excel file used to calculate the Economic Assessment KPI values. Thus, manual check is implemented.	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Grant rate			0.0…100.0%			
Total annual costs			0…INF			
City indicators (KPIs for intervention and final assessment)						
Energy savings due to district renovation	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis	Monthly	40...70%	Buildings main heat meter (before, after) [0...40 kWh/m^2·month], Dwellings electricity meter and buildings general electricity meter (before, after) [0.5...10 kWh/m^2·month], Buildings main gas meter (before, after) [0...5 kWh/m^2·month], Buildings PV panels electricity on-site consumption [0...5 kWh/m^2·month	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 emissions savings due to district renovation	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis	Monthly	<50%	Electricity CO_2 equivalent [0....1500 tCO_2e/a, Heat CO_2 equivalent [0...1000 tCO_2e/a, Gas CO_2 equivalent [0...5 kWh/m^2·month	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 emissions savings due to sustainable mobility actions	Annually	Annually	0….INF	Total CO_2 emissions from public and private transport in reference year: 0…INF Current year: 0…INF	NA	NA
Increase of renewable energy usage	Once as the data are inserted in the repository	Monthly	0...800 MWh/a	Renewable energy on-site usage by SmartEnCity buildings (PV panels) 0...800 MWh/a	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Increase of renewable energy production	Once as the data are inserted in the repository	Monthly	750...1250 MWh/a	Renewable energy production by SmartEnCity buildings (PV panels) 750...1250 MWh/a	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Number of dwellings/buildings retrofitted	Once as the data are inserted in the repository	Once as the data are inserted in the repository	700...900 dwellings/20...22 buildings	Dwellings, Buildings [700...900 dwellings, 20...22 buildings]	NA	NA
Number of buildings in the city that demand a retrofitting or to include energy efficient measures	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…1500 buildings	Number of buildings in the city that demand a retrofitting or to include energy efficient measures [0…1500]	Data from Registry of Buildings and surveys is incomplete - The result is obtained by interpolating and	NA

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
					estimating that data	
The number of EV	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0...1500	EVs acquired by the project: TBD Total EV in the city from other initiatives: 0…1000	NA	NA
Biogas buses	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0.0...100.0%	Biogas buses from project: TBD Biogas buses from other initiatives: 0…100	NA	NA
Number of (public) EV charging stations	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	EV charging infrastructures from project: 5 EV charging infrastructures from other initiatives: 0…INF	NA	NA
Total kWh recharged in the EV charging stations	Annually	Annually	0…INF	0…INF	NA	NA
Total investment of the district from local and regional public funding, EC funding and private funding (e.g. dwellings' owners, energy companies, social housing companies, etc.).	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	0…INF	NA	NA
Total number of jobs created	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	0…INF	NA	NA
Number of jobs created in terms of professional specialization	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	Positions requiring higher education: 0…INF Jobs not requiring higher education: 0…INF	NA	NA
Total number of new services offered by companies due to district renovation, mobility actions and citizen engagement actions during the whole project	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	0…INF	NA	NA
Existence of plans/programs to promote energy efficient buildings	Once as the data are inserted in the database	-	Selection from a predefined value: Yes or NO	-	NA	NA
Existence of plans/programs to promote sustainable mobility						

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Existence of regulations for development of energy efficient districts						
Existence of regulations for development of sustainable mobility						
Existence of public incentives to promote energy efficient districts						
Existence of public incentives to promote sustainable mobility						
Involvement of the administration on smart city projects	Once as the data are inserted in the repository	-	1.0…5.0	-	NA	NA
Multilevel government	Once as the data are inserted in the repository	-	1.0…5.0	-	NA	NA

11.4.3 Sonderborg

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Energy assessment						
Energy demand	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	60...300 kWh/m^2·a	Buildings main heat meter [0...200 kWh/ m^2/year], Dwellings electricity meter and buildings general electricity meter [0...100 kWh/ m^2/year], Buildings PV panels electricity on-site consumption	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Delivered energy (for buildings)	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	40...300 kWh/m^2·a	Buildings main heat meter [0...200 kWh/ m^2/year], Dwellings electricity meter and buildings general electricity meter [0...100 kWh/ m^2/year]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Primary energy (for buildings)	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	3000...11000 MWh/a (for all renovated buildings)	Buildings main heat meter [0...200 kWh/ m^2/year], Dwellings electricity meter and buildings general electricity meter [0...100 kWh/ m^2/year	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Primary energy (for energy supply units)	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	400000…800000 MWh/year (district energy supply in municipality)	Energy Balance (municipality), energy meters and national primary energy factors: [Wind power 0…70000 MWh/year, Solar (photovoltaics) 0...30000 MWh/year, Solar (thermal) 0…50000 MWh/year, Geothermal 0…15000 MWh/year, Heating oil (boilers) 0…15000 MWh/year, Natural gas (boilers) 0…150000 MWh/year, Biomass (boilers) 0…250000 MWh/year, Heating oil (CHP) 0…10000 MWh/year, Natural gas (CHP) 0…50000 MWh/year, Biomass (CHP) 0…50000 MWh/year, Waste (CHP) 0…350000, Electricity (heating element) 0…50000 MWh/year]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 equivalent (for buildings)	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	1000...4000 tCO_{2e}/a (for all renovated buildings)	Electricity CO_2 equivalent [0....1500 t CO_2e/year], Heat CO_2 equivalent [0....1500 t CO_2e/year]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 equivalent (for energy supply units	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	Electricity production in municipality: 0.0…0.5 Tonnes CO_2/MWh District heating production in municipality: 0.0…0.5 Tonnes CO_2/MWh	Electricity CO_2 equivalent [0....150000 t CO_2e/year], District heating CO_2 equivalent [0....100000 t CO_2e/year]	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Density of energy demand	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	50000…200000 kWh/building	, District heating consumption of buildings set for retrofitting in Sonderborg district heating area 50000…200000 kWh/building	NA	Manual checks are implemented. Thus, no data correction procedures are implemented
Peak load and load profile of electricity demand	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	0…3000 kW (for all renovated buildings)	Load profile (average usage/normal usage), Peak load	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Degree of congruence of calculated annual final energy demand and monitored consumption	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	0...30%	Final energy demand of building I based on annual data of year, Final energy consumption of building I based on annual data of year	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Degree of energetic self-supply	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	0...30%	Renovated buildings PV panels annual production, Renovated buildings annual electricity consumption, Renovated buildings annual energy consumption	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Share of renewable energy	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	0...50%	Renovated buildings PV panels annual production, Renovated buildings annual electricity consumption, Renovated buildings annual energy consumption	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Efficiency	Once as the data are inserted in the repository: KPIs for baseline and final performance	Annually	0...100%	PV panels production, Direct solar radiation, PV panels efficiency, Heat unit heat exchangers efficiency (hot water, heating), Ventilation heat recovery efficiency	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
Thermal comfort	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0…100.0 for % of categories, 1.0…5.0 for average score	Thresholds for detecting out of range values for answers that require a selection from predefined categories are defined by the limited set of possible answer choices	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range "-1" will be inserted to indicate the missing value. Manual check applied for the cases
ICT						
Response time	Annually	Annually	0 … INF	0 … INF	NA	NA
Scalability	Annually	Annually	0.0...100.0%	NA	NA	NA
Extensibility	Annually	Annually	0 … INF	0 … INF	NA	NA
Storage capacity	Annually	Annually	0 … INF	0 … INF	NA	NA
Hours of maintenance	Annually	Annually	0 … INF	0 … INF	NA	NA
Non-expected hours offline	Annually	Annually	0…24h*days in year	0…24h*days in year	NA	NA
# of BEMS connected	Annually	Annually	0 … INF	0 … INF	NA	NA
# of mobility equipment connected	Annually	Annually	0 … INF	0 … INF	NA	NA
Total amount of data generated	Annually	Annually	0 … INF	0…INF	NA	NA
Number of services developed	Annually	Annually	0 … INF	0 … INF	NA	NA
Percentage of buildings connected	Annually	Annually	0.0 … 100.0%	Total number of buildings in pilot area: 45, Number of buildings in pilot area connected to platform: 0…Total number of buildings in the pilot area	NA	NA

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Open-Data sets available	Annually	Annually	0 … INF	0 … INF	NA	NA
LCA						
Global warming potential	Once as the data are inserted in the repository: KPIs for baseline and final diagnosis	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	No thresholds set since KPI values are checked manually after the calculation	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in the software used to calculate the LCA KPI values. Thus, manual check is implemented	Manual checks are implemented. Thus, no interpolation procedures are implemented	Manual checks are implemented. Thus, no data correction procedures are implemented
Ecological Footprint						
Use of renewable primary energy excluding energy resources used as raw material						
Use of renewable primary energy resources used as raw material						
Use of non-renewable primary energy excluding energy resources used as raw material						
Use of non-renewable primary energy resources used as raw material						
Exported energy						
Hazardous wastes disposed						
Non-hazardous wastes disposed						
Mobility						
Accuracy of timekeeping of public bus	Annually	Annually	0…INF	0…INF	NA	NA
Vehicle fuel efficiency	Annually	Annually	0…INF	0…INF	NA	NA
Total number of recharges per year (biogas and EV)	Annually	Annually	0…INF	0…INF	NA	NA
Total kWh recharged in the EV charging stations (biogas and EV)	Annually	Annually	0…INF	0…INF	NA	NA
Social Acceptance						
Age	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0…100.0%	Thresholds for detecting out of range values for answers that require a selection from predefined categories are defined by the limited set of possible answer choices	For raw data NA. KPI can still be calculated, although there is a need to assess the (item) non-response rate	If the value is out of range “-1” will be inserted to indicate the missing value. Manual check applied for the cases
Highest level of completed education						
Nationality						
Net monthly income of the households						
Type of building						
Size of dwelling – heated area						
Accommodation time						
Environmental awareness			0.0…100.0 for % of categories, 1.0…5.0 for average score			
Knowledge about efficient energy measures						
Residents project satisfaction						

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Satisfaction with the information accessibility						
Residents information satisfaction						
Residents involvement degree						
Satisfaction with the investment costs						
Energy bill reduction						
Further investments in energy related project						
Further investments in energy related project						
Comfort conditions						
Energy savings satisfaction						
Energy savings satisfaction						
Citizen Engagement						
Residents involvement degree	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0.0…100.0%	Respondents who answered this question: 0…the number of distributed questionnaires Respondents who considered to be involved: 0…the number of respondents who answered this question	NA	NA
Number of surveys fulfilled by residents/Number of residents informed about the citizen engagement actions	Once as the data are collected	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0.0…100.0%	Respondents who answered this question: 0…the number of distributed questionnaires Respondents who considered to be well-informed: 0…the number of respondents who answered this question	NA	NA
Perception of success or failure by actors involved about citizen engagement activities performed	NA	-	NA	-	NA	NA
Number of citizens using web application	Annually	Annually	0…INF	0…INF	NA	NA
Number of logins (monthly) in the web application	Annually	Annually	0…INF	0…INF	NA	NA
Increase of new visitors in the web application	Annually	Annually	0.0….100.0%	0…INF	NA	NA
Time spent on the web	Annually	Annually	0…INF	0…INF	NA	NA
Number of mobile app downloads in the framework of SmartEnCity	Annually	Annually	0…INF	0…INF	NA	NA

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
Number of dwellings retrofitted	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	0…INF	NA	NA
Number of buildings connected to the District Heating	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	0…INF	NA	NA
Number of residents benefited by the intervention	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	0…INF	NA	NA
Number of residents who were against project	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	Total number of residents: ~1700 Residents against: 0…Total number of residents	NA	NA
Economic Performance						
Resident costs	Once as the data are inserted in the repository	Once as the data are inserted in the repository (if the raw data are inserted in the repository)	0…INF	No thresholds are set since the input data for the calculation of KPIs are checked manually before inserted in the Excel file used to calculate the Economic Assessment KPI values. Thus, manual check is implemented.	NA	NA
Grant rate			0.0…100.0%		NA	NA
Total annual costs			0…INF		NA	NA
Total annual benefits for residents			0…INF		NA	NA
Cost saving rate			0.0…100.0%		NA	NA
City indicators (KPIs for intervention and final assessment)						
Energy savings due to district renovation	Once as the data are inserted in the	Annually	0…INF	Buildings main heat meter (before, after), Dwellings electricity meter and buildings general	If up to 25% of buildings data are missing, the KPI	Manual checks are implemented.

KPIs by protocol	Frequency of quality checks		Thresholds		Interpolation	Data correction
	KPI	Input parameters	KPI	Input parameters		
	repository			electricity meter (before, after), Buildings main gas meter (before, after), Buildings PV panels electricity on-site consumption	is calculable/estimable (e.g. using units per m^2)	Thus, no data correction procedures are implemented
CO_2 emissions savings due to district renovation	Once as the data are inserted in the repository	Annually	0…INF	Electricity CO_2 equivalent, Heat CO_2 equivalent, Gas CO_2 equivalent	If up to 25% of buildings data are missing, the KPI is calculable/estimable (e.g. using units per m^2)	Manual checks are implemented. Thus, no data correction procedures are implemented
CO_2 emissions savings due to sustainable mobility actions	Annually	Annually	0…INF	0…INF	NA	NA
Share of renewable energy	Annually	Annually	0.0…100.0%	Renovated buildings PV panels annual production	NA	NA
Number of dwellings/buildings retrofitted	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	0…INF	NA	NA
Number of buildings connected to the District Heating	Once as the data are inserted in the repository	Annually	0…INF	Sonderborg district heating	NA	NA
Biogas buses	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	0…INF	NA	NA
Number of (public) EV charging stations	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	0…INF	NA	NA
Total kWh recharged in the EV charging stations (biogas and EV)	Once as the data are inserted in the repository	Annually	0…INF	Private recharging station companies	NA	NA
Total investment of the district from local and regional public funding, EC funding and private funding" (e.g. dwellings' owners, energy companies, social housing companies, etc.).	Once as the data are inserted in the repository	Once as the data are inserted in the repository	0…INF	0…INF	NA	NA