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D5.2 - Project Level Indicators

WP5; Task 5.1

May 2020 [M18]

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Abbreviations and Acronyms

Acronym	Description
BEST	Building energy specification table
CITYkeys	Smart city performance measurement framework (CITYkeys). EU project that defined common indicator framework to assess the performance of smart city projects and smart cities in Europe.
CIVITAS	CIVITAS is a network of cities for cities dedicated to cleaner, better transport in Europe and beyond. CIVITAS stands for City VITAlity and Sustainability.
CONCERTO	EU initiative to demonstrate the optimisation of the building sector as whole communities is more efficient and cheaper than optimisation of each building individually.
DHW	Domestic Hot Water
DoA	Description of Action
EeB	Energy-efficient Buildings
EIP-OIP	European Innovation Partnership on Smart Cities and Communities: Operational Implementation Plan.
ESPRESSO	systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities (ESPRESSO). EU project to harmonise standardization approaches for smart city lighthouse projects.
EV	Electrical Vehicles
GHG	Greenhouse gas
KPI	Key Performance Indicator
LH	Lighthouse cities (Groningen and Oulu)
PED	Positive Energy District
PV	Photovoltaic
RES	Renewable Energy Sources
SCC	Smart Cities and Communities
SCIS	Smart Cities Information System
WP	Work Package

Executive Summary

Work package 5 aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. Robust monitoring and evaluation protocols including key performance indicators will be developed and implemented. Task 5.1 aims at the definition of the evaluation framework that will have a twofold scope in order to measure and assess the project activities at PED level (demonstration areas) and city level considering the main reference indicator frameworks defined by SCIS (Key Performance Indicator Guidelines) and CITYkeys (*D1.4 Smart city KPIs and related methodology – final*).

The purpose of this deliverable is to describe the process of selecting and defining a relevant set of project level indicators - "PED KPIs" - that will be used as high-level metrics to evaluate the performance and impacts of the technical and non-technical solutions implemented in the MAKING-CITY project interventions in the two lighthouse cities (Oulu and Groningen). The technical, environmental, economic and social goals of the project (as detailed in the "DoA") provide the frame for the evaluation procedure for common and transparent monitoring and assessment, as well as the comparability of smart city project actions across the cities. The key performance indicators defined in this report and the evaluation procedure described further in D5.3 will be later used for the comparison of the project interventions to the baseline situation in WP2 (Oulu) and WP3 (Groningen), and for the final impact assessment. A process of developing the evaluation framework including the project level indicators has been established and aligned with the city level developments described in *"D5.1 - City Level Indicators"*.

Starting from the definitions and links between smart city and smart city projects, indicators will be selected for tracking the progress, evaluating the projects in the demonstration areas and focusing on monitoring the evolution of a city district towards a smarter city as a whole. The development of KPIs and the evaluation framework interlinks with several other work packages and tasks. Within the present WP and in close collaboration with WP1, WP2, WP3, WP4 and WP8, links with (SCIS) Smart Cities Information System database will be established. All applicable design and performance data (i.e. KPIs, monitoring data and simulations) will be aligned with SCIS protocols and incorporated into the database. At this point, a strong coordination with the lighthouse cities will be required to integrate useful and relevant information as open data within the ICT-city Platforms.

1 Introduction

1.1 Purpose and target group

This report constitutes the Deliverable *"D5.2 - Project Level Indicators"* forming one of the main outcomes of the *"Task 5.1 Evaluation Framework*".

The main objective of this deliverable is to define a comprehensive set of key performance indicators as common metrics for the evaluation framework of MAKING-CITY project at project (PED) level, identifying the specific indicators that will allow measuring the outcome and impact of the project in the PED demo-areas in Oulu and Groningen. In this deliverable, the main set of project level indicators (KPI's) will be established being aligned with the WP5 developments and the main set of city level indicators defined in *"D5.1 - City Level Indicators"*.

1.2 Contribution partners

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

Table 1: Contribution of partners

Partner nº and short name	Contribution
01-CAR	ToC, KPI selection and definitions, peer-review
03-GRO	KPI selection and definitions
04-TNO	KPI definitions and typologies, Logic-model
09-CGI	KPI definitions
13-OUK	KPI selection and definitions
20-VTT	Leading contributor
32-R2M	Economic indicators
34-CAP	Social indicators

1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the MAKING-CITY Project and that should be considered along with this document for further understanding of its contents. The connections between the most relevant activities in relation to the specifications of the key performance indicators and the development of evaluation framework are further discussed in section 5.

Table 2: Relation to other activities in the project

Deliverable nº	Relation
D1.3	Tools for modelling energy demand, supply side, simulation of scenarios and estimation of impacts.
D2.1/D3.1	Oulu/Groningen PED interventions detailed design.
D2.2/D3.2	Baseline of Oulu/Groningen PED.
D2.3/D3.3	Simulation models of buildings, energy systems, storage and management of flows algorithms (Oulu/Groningen).
D2.4/D3.4	High performance buildings in Oulu/Groningen.
D2.5/D3.5	Smart Energy Systems in Oulu/Groningen.
D2.6/D3.6	Positive District Energy Flows (Oulu/Groningen).
D2.7/D3.7	Electric vehicles and charging stations roll-out strategy and analysis.
D2.8/D3.8	Adaptation of Oulu/Groningen ICT platform.
D2.9/D3.9	Services and Modules for Oulu/Groningen ICT Platform.
D4.2	Guidelines to calculate the annual energy balance PED (demand - consumption, energy flows, storage, RES). Guidelines to calculate PED primary energy balance.
D5.1	City level indicators. Evaluation framework consists of city level (D5.1) and project level (D5.2) indicators.
D5.3	Evaluation procedure for PED actions.
D5.4	City impact evaluation procedure.
D5.5	Data sets: Requirements, collection and protection.
D5.6	Guidelines for definition of Monitoring Programmes.
D5.7	Oulu Monitoring Programme.
D5.8	Groningen Monitoring Programme.
D5.9	ICT-City Platforms: common open specifications.
D5.10	Data collection and KPI calculation.
D5.11	Evaluation (city level, project level).

2 MAKING-CITY Evaluation framework

MAKING-CITY project is going to develop a large-scale demonstration of three Positive Energy Districts in two European cities, Groningen (Netherlands) and Oulu (Finland) where a rigorous monitoring and evaluation program will be deployed, with special attention to data collection, regulation (GDPR), evaluation framework and integration in a monitoring platform.

WP5 aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. Robust monitoring and evaluation protocols will be developed and implemented, including a full methodology for the monitoring and evaluation of the project actions and interventions that will allow the introduction of future data after the end of the project. Within the present WP and in close collaboration with WP1, WP2, WP3 and WP8, links with (SCIS) Smart Cities Information System database will be established.

The scope of the monitoring protocol will be twofold, firstly in order to measure the performance of the actions deployed to reach a validation of PED concept and secondly to evaluate the impact at city level.

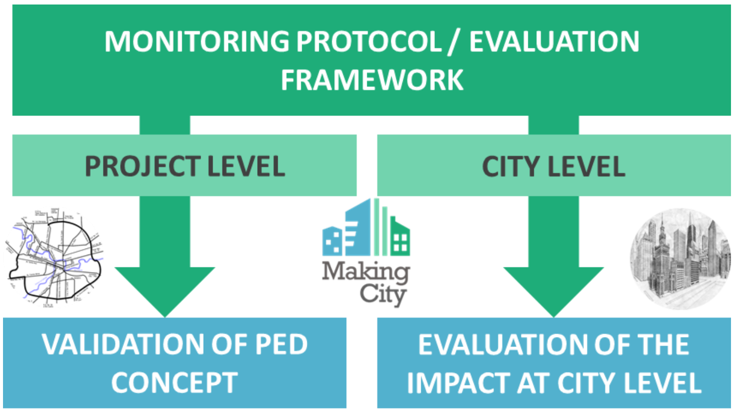

Figure 1: MAKING-CITY Evaluation Framework.

The city level indicators will be used to show to what extent overall policy goals have been reached, whereas project level indicators (PED KPIs) will be considered in the evaluation of the technical and non-technical actions in technical (energy, environment, ICT, mobility), economic and social aspects. The evaluation procedures will be used for the definition of the baseline scenarios in WP2 (Oulu) and WP3 (Groningen), and later on in monitoring of the actions/interventions and overall impact assessment.

2.1 Methodological approach

Task 5.1 aims at the definition of the evaluation framework in order to measure and assess the project activities at PED level (demonstration areas) and city level considering the indicator categories defined by CITYkeys (Smart City Indicators and related methodology), SCIS (Key Performance Indicators Guide) and other relevant reference frameworks (e.g. ESPRESSO, MAtchUP, mySMARTLife). The objective of the task is to select a set of Key Performance Indicators (KPIs) and data collection procedures for the common and transparent monitoring as well as the comparability of smart city actions across the cities.

Within Task 5.2 data sets and requirements for evaluating demonstrations will be defined based on the indicator selections from Task 5.1. The identification of the data sets will also be based on the previous work by CITYkeys and SCIS, and all the information related to these data sets will be included in the deliverable D5.5 that will be submitted by month 36. The data collection and KPI calculation will be carried out in WP2-Oulu (subtask 2.7.2) and WP3-Groningen (subtask 3.7.2). All relevant performance data (i.e. project level KPIs) will be incorporated into SCIS database. A strong coordination with the lighthouse cities will be required in order to integrate useful and useable information as open data within the ICT-city Platforms.

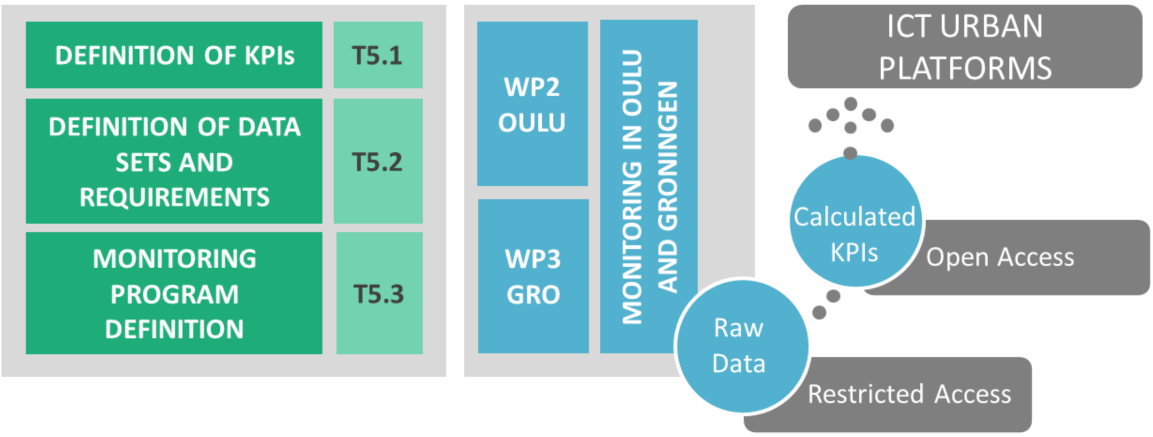

Figure 2: Definition of KPIs, data requirements and monitoring in tasks 5.1 – 5.3.

The project level (more technical than the city level) evaluation framework consists of indicators selected for evaluation of the actions made in the demo areas on short- and medium-term sustainable energy planning and execution by the lighthouse cities. The evaluation procedure describes the methodology to assess city actions with the defined indicators. It consists of four steps:

1. Selecting and defining the project level indicators
2. Defining the baseline situation in the PED area and calculating the indicator values at the beginning of the project (before the planned project level actions)
3. Monitoring the indicators during the course of the project (following the indicators for the evaluation of progress), and
4. Final calculation of the indicators at the end of the project for the final evaluation and impact assessment.

This deliverable provides the methodological guidance for the procedure. The project level indicators are selected and defined for evaluating the demonstration actions in the Lighthouse cities. The actual indicator values for the current situation in cities will be calculated on initial (baseline) values in M36. The evaluation of the achieved impacts - impact assessment - and other benefits of the city level actions and interventions will be performed at later stages of the project. Monitoring and evaluation protocols will be developed and implemented in the framework of WP5 with collaboration of the RTO partners of the project, taking into account existing KPIs and requirements for DAQ and GDPR. VTT and CGI are the partners in charge of leading the links with the Oulu and Groningen urban platforms respectively.

Figure 3: Coordination among lighthouse cities and other initiatives to define useful and usable information as open data within ICT city platforms.

2.2 Relation between project and city level evaluation

Before stating the specific objectives for the evaluation procedure, it is important to notice that indicator-based evaluation is carried out in the MAKING-CITY project both at project and city level for different purposes:

- D5.1: City level indicators
  - Joint effort with D1.2, with the aim of providing a method to make an advanced city diagnosis for measurement of progress in cities on the road to sustainability and energy smartness with the intention to guide the cities in the design of strategic plans to deploy innovative technologies in energy, mobility and ICT sectors. This framework will be applied in all of the eight cities of the project.
- D5.2: Project (PED) level indicators
  - The objective is to evaluate the technical, environmental, economic and social impacts of the demonstration activities implemented in the two lighthouse (LH) cities.

The indicators for assessing the **project level** serve the evaluation of the interventions in **PED demo-areas**. They indicate the difference the project has made, by comparing the situation without the project with the situation after the implementation of the project. As such, they can also serve to benchmark projects against each other.

The project level indicators can be divided into two main categories:

- Quantitative indicators or technical performance indicators (general technical, environmental and economic indicators), that are common for all demo-areas in lighthouse cities. These KPIs are mainly technology-specific indicators (energy, ICT/flexibility, mobility etc.), which may have different purposes in the specific objectives in each demo (such as smart control), and

- Qualitative indicators or non-technical indicators (social, citizen or resident related indicators), that are also common indicators for all demo-areas, but the measurement methodology can differ from each other depending on the prerequisites and the demography of the area.

The indicators for the **city level** are less technical than the project level indicators, focusing on monitoring the evolution of a city towards an even smarter city. In this case, specific focus in on energy and sustainability planning. The time component -"development over the years"- is an important feature. The city indicators may be used to show to what extent overall policy goals have been reached, or are within reach.

According to the DoA, specific objectives must be met in both Lighthouse cities in terms of energy production/consumption (new technologies highlighted) and GHG emission reduction due to the implementation of energy/environment, ICT, mobility and societal actions, in order to achieve **Positive Energy District (PED)** demo areas. These are the main targets that cities have in the project level and they need to be evaluated after two-three years of monitoring. The outcomes and impacts from the demo areas will be measured first at the PED level, and then estimated at the city level.

The objectives of these evaluation frameworks are somewhat different since the city level evaluation framework developed in WP1 and WP5 aims at medium- or long-term energy & sustainability planning based on efficient policy measures. Both lighthouse and follower cities have to adopt the evaluation process and calculate the indicators, while the project level evaluation framework in WP5 intends to assess the efficiency and benefits of the measures implemented in the demo areas of the LH-cities.

Demonstration projects enable the validation of the benefits and potential of the implementation of integrated solutions to improve key parameters that affect overall quality of life in the city. Ranging from the pure environmental ones, passing through those related with citizens' comfort and leading to those that allow a progress in the socioeconomic conditions as the promotion and attraction of talent, or new businesses yielding to and intensive job creation. These projects, in general financed with extra funds (with respect to conventional) should offer society an open pathway to the city transformation, where citizens and stakeholders' engagement are ensured and well structured.

The reasoning for the impact-based evaluation in MAKING-CITY project is depicted by the Logic-model (Figure 4), that describes the intended logic between the direct outputs and outcomes of the activities and interventions of the project (PED) level (short term effects) and the incurred impact on the city level (medium- or long-term effects).

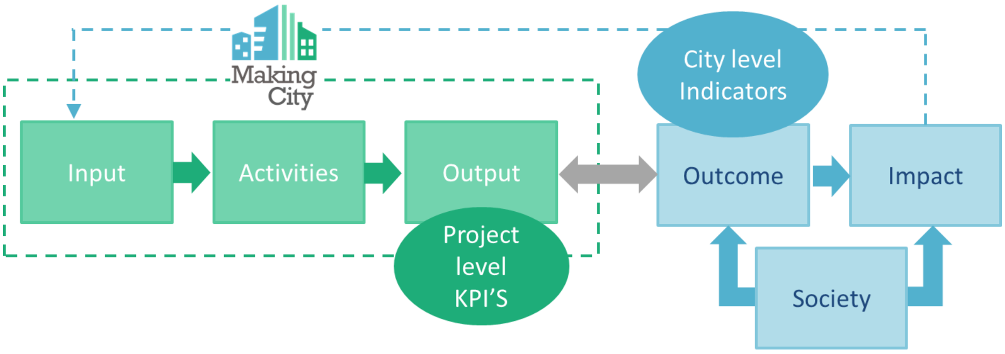

Figure 4: The Logic-model describes the steps from input to impact.

Despite this intended logical methodology, the reality in some of the smart city projects - including MAKING-CITY - is that the project level (PED area) represents just a demo-scale selection of mainly energy related actions and technologies, and upscaling the outputs/outcomes from this level into city level impacts, is not necessarily going to represent the real progress or even desired goals. It is of course possible to generate simulations of what would it be like, but in real world, cities are much more complex entities, and just aggregating the demonstration results up to the city level, would be somewhat useless.

2.3 Indicator typology for the evaluation of demonstration effects

Indicators can be used for various evaluation purposes. Indicators can be also classified into different types which can help to identify most useful indicators for specific use. This indicator typology consists of input, process, output, outcome and impact indicators, summarized shortly below.

Impact indicators are applicable to all kinds of projects in all contexts: For instance, an indicator in the framework could be 'the reduction in greenhouse gas emissions', whether by e.g. introducing electric vehicles or by insulating dwellings. The number of electric vehicles introduced or houses insulated, is then less relevant, making the indicator framework suitable for evaluation of many types of projects in different contexts.

Impact indicators also leave room for the cities to find their own solutions to achieve a certain performance, instead of prescribing the way they should reach that or the measures that have to be implemented. The latter ones have the risk to lower the possibility for innovative solutions to achieve the same goal, and might be outdated within a few years.

It is useful to use also output indicators, such as number of smart meters distributed, as they allow short-term evaluation of the effectiveness of the intervention through direct measures. On the other hand, outcome indicators, such as percentage of target population using a new app are needed as they help to monitor the extent to which the developed new solutions are reaching their target group.

These different indicator types can be defined as follows:

- Input indicators refer to the resources needed for the implementation of interventions, measuring the quantity, quality, and timeliness of resources. Policies, human resources, materials, financial resources are examples of input indicators.
- Process indicators measure whether planned activities took place. Examples include holding of meetings, conducting training courses, distribution of smart meters.
- Output indicators add more details in relation to the product ("output") of the activity, e.g. the number of smart meters distributed, the area of roof that has been isolated or the number of electric buses in the system.
- Outcome indicators measure intermediate results generated by outputs. Outcome indicators refer more specifically to the objectives of an intervention relating to the quantity and quality of the activities implemented. Often they are coverage indicators measuring the extent to which the target population has been reached, e.g. percentage of car owners using a parking app.
- Impact indicators measure the state with regard to a set city target (impact of policy), e.g. city's energy consumption, and can be used to evaluate for example the sustainability impacts of smart solutions.

This typology captures well the different phases of innovations. The indicator types can be grouped into types of evaluation purposes. Combined use of input and impact indicators helps to answer key questions such as, what benefits and value can a city achieve with its investments? And how process indicators can help in the diagnosis of why certain objectives were not reached. (Huovila, Bosch & Airaksinen, 2019)

3 Development of indicators for the project level evaluation

The evaluation framework will include boundaries of the integrated evaluation and specific approaches to assess the impact of the project actions and interventions in each one of the indicator categories selected for the project: **Energy & Environment**, **Mobility**, **Economy**, **System flexibility** (mainly technical, quantitative indicators) and **Society & Residents** (mainly non-technical, qualitative indicators).

The project level indicators will be selected and utilized for tracking the overall progress of the demonstration areas, evaluating the outcome and impacts of the interventions and focusing on monitoring the evolution of a city towards a smarter city.

3.1 Key performance indicators by target groups

According to CITYkeys, smart city project indicators serve decision making of different stakeholders in cities. Indicator outcomes, be it individual indicators or assessments based on multiple indicators should reach the relevant decision makers. The various parts of the indicators are aimed at decision makers on various levels. In addition to decision makers of cities, other relevant target groups can include e.g. policy makers, citizens, energy companies, service providers, housing associations, etc.

The indicators on project level have two primary target groups:

- Decision makers managing and businesses providing services for smart city projects; the ones who can use the indicators to learn about the relative success of smart city projects (how have they been performing technically and economically, what have been factors determining performance) in order to improve in the next projects, which requires integral in-depth knowledge of results and process of the project, and
- Decision makers in the city council, who need an insight in how the various projects they have decided upon, have been performing (also to be able to take better decision next time), for which a more aggregated overview may be more appropriate.

The project indicators can also be used in the design phase of a project: to give an impression on the expected performance based on design specifications, vis-à-vis already realized projects.

The smart city indicators equally have two primary target groups:

- Decision makers in the city council who need to follow the impacts of their smart city strategy over time, essentially answering the questions has the city become smarter and what has been the final result, and
- National governments and European bodies, to follow if their smart city policies have resulted in more attention for the overall aims (of reducing energy use and greenhouse gas emissions, increasing citizen participation, etc.). In addition, national government and European institutions tend to use indicators to compare cities.

It is clear that for users of the city indicators progress over time is important. Thus, the city indicators should be formulated in such a way that they can easily be included in the city's programme for gathering regular statistics. The outcome of the indicator process, in turn, should get a regular place in the planning processes of the city.

Other groups that are using both project and city indicators include educational and knowledge institutes, and businesses. For citizens the indicators may help to get a better understanding of complex projects and their impacts. (Bosch et al., 2017)

3.2 Existing knowledge on key performance indicators and the main references (SCIS, CITYkeys, ESPRESSO)

Most of the existing smart or sustainable city frameworks aim at evaluating the performance of cities, but there are not many indicator frameworks to evaluate the effects of smart city projects. Furthermore, among the existing project evaluation frameworks, many are domain specific focusing only on e.g. buildings, energy or transport (Neumann et al., 2015).

As one of the main goals of smart city solutions is to improve efficiency of urban infrastructure and services by integration of different sectors, their assessment also requires a holistic evaluation framework. Therefore, the smart city lighthouse project assessment frameworks developed specifically for this purpose by the initiatives of the European Commission, i.e. SCIS (main reference), CITYkeys and ESPRESSO, were selected as the starting points to select the indicators, including monitoring and data integration approaches. In addition, other relevant smart city initiatives such as MAtchUP, Stardust and mySMARTLife, were taken into consideration as well.

The existing material was adapted and further developed as needed for MAKING-CITY purposes in order to align them with the evaluation goals, expected impacts and objectives of individual city actions.

3.2.1 SCIS

The **Smart Cities Information System (SCIS)** is a knowledge platform encouraging exchange of data, experience, know-how and collaboration on smart cities to ensure a high quality of life and a clean, energy efficient and climate friendly living environment for the citizens (SCIS, 2019). From the point of view of lighthouse projects, the most typical use of SCIS is its database as reporting of monitoring data to that database is mandatory for all.

SCIS also describes indicators in order to measure technical and economic aspects of energy, mobility and ICT related measures in projects. These should be applicable to European funded demonstration projects for Smart Cities and Communities (SCC), Energy Efficient buildings (EeB) and designated projects funded under the calls for Energy Efficiency (EE) (SCIS, 2018a). Through SCIS, project developers, cities, research institutions, industry, experts and citizens from across Europe come together to share best practices and lessons learnt from projects (SCIS, 2019). The implementation of SCIS indicators has been done through alignment with other initiatives and already existing indicator sets, such as EIP-OIP[1], CIVITAS[2] and CONCERTO[3]. The KPI indicator lists allow for comparability of solutions between various projects. SCIS focuses on demonstration projects and not on entire cities. The defined indicators reflect this (SCIS, 2018a).

The KPIs can be divided in two categories. A complete list of the core KPIs is provided in Table 3 (SCIS, 2018a).

- Core KPIs: those KPIs identified as the most relevant for SCIS and which should be implemented by the projects in scope of SCIS. Some of these KPIs may not apply to all projects.
- Supporting KPIs: relevant for SCIS and their use is recommended.

[1] https://www.smartcities.at/assets/Uploads/operational-implementation-plan-oip-v2-en.pdf

[2] https://civitas.eu

[3] https://www.concertoplus.eu/

Table 3: Core KPIs as defined in SCIS

Core KPIs	
General technical performance indicators	• Energy demand and consumption • Energy savings • Degree of energetic self-supply by RES
General environmental performance indicators	• Greenhouse Gas Emissions • Primary Energy Demand and Consumption • Carbon dioxide Emission Reduction
General economic performance indicators	• Total Investments • Grants • Total Annual costs • Payback period • Return on Investment (ROI)
General performance indicators for ICT related technologies	• Increased reliability • Increased Power Quality and Quality of Support (DSO + TSO) • Increased system flexibility for energy players • Reduction of energy price by ICT related technologies • Peak load reduction • Increased hosting capacity for RES, electric vehicles and other new loads • Consumers engagement
General performance indicators for mobility related technologies	• Energy consumption data aggregated by sector fuel • Kilometres of high capacity public transport system per 100 000 population • Passenger-kilometres public transport and private vehicle • Number of efficient and clean (biofuel and hydrogen) vehicles deployed in the area • Number of e-charging stations deployed in the area

Core KPIs	
	• Impact of ICT apps into mobility • Carpooling locations • Clean mobility utilization • Modal split

In SCIS, the current approach for data collection is through individual project data collection done by monitoring experts, and this information is periodically updated in the self-reporting tool (SCIS, 2018b). The aim of the data collection is to allow the comparison of results of the projects (SCIS, 2018a). In data collection, a distinction is made between new systems and renovations of existing systems. The evaluation process uses a bottom-up approach, collecting data from small Energy Supply Units (ESU), buildings and implemented mobility and ICT solutions at unit level. These are aggregated in cases where the objective is to evaluate the energy performance of a whole neighbourhood or city. Data quality in SCIS is ensured with:

- Compliance with SCIS data requirements
- Documentation on metadata (such as time of measurement, unit, application area...)
- Adjustments to apparently implausible data is discussed and checked with SCIS

Moreover, to ensure the quality, the measurement time for all energy flows should be the same, if possible, to allow easier comparison of data. Monthly metered values of energy consumption and energy generation are to be provided to SCIS. Data must be measured and not generated by theoretical calculations or any other synthetic way. Different energy flows should be differentiated in the measurements, e.g. space heating and domestic hot water. Endogenous effects (e.g. changes in building occupancy) should be differentiated from exogenous effects (e.g. weather) by providing supplementary or meta-data. The effects of climatic conditions are normalized in the data as described in the SCIS KPI Guide (SCIS, 2018a). Ideally, monitoring should take place several years in order for a building or other system to reach its optimal operation levels.

The monitoring phases are as follows:

1. Definition: Selection of KPI and monitoring concept, calculation of expected energy performance, definition of baseline
2. Implementation: Installation of metering, beginning of documentation
3. Monitoring: Data collection, analysis and comparison
4. Voluntary long-term monitoring

Energy performance is measured with reference to two points of comparison: baseline and expected energy performance.

The baseline is different for new and existing systems. It is important to meter energy consumption before refurbishment in projects that deal with existing buildings and systems. This data is then used for defining the baseline. For new buildings and systems, the baseline is determined based on the energy performance of similar systems representing state of the art or minimal requirements by law, i.e. buildings with similar purposes and sizes or mobility systems in similar districts or cities. The baseline for a project should be defined as follows:

- Refurbishment cases: one year of monitoring of the existing system. The building's energy consumption must be metered before the construction work starts, which will include final energy demand for heating, domestic hot water, cooling, and electrical appliances (kWh/month). In case metering is not possible, data from energy bills can be used to define the status before refurbishment.

- New-built cases: one year of synthetic data reflecting the typical scenario. This data has to be calculated according to regulations, technical guides or similar projects. The calculation can be also simulated as will be done in many cases.

In addition to the baseline, expected energy performance of the system or systems is predefined in planning phase based on simulation, modelling and calculations. This way, later deviations from design values can be detected.

For the calculation of indicators and the assessment of the energy-performance different sets of data are needed. These include baseline scenario, design data and monitoring data. The division into these three data sets will allow the comparison between:

- Design data and baseline scenario: improvement compared to the typical solution
- Monitoring data and baseline scenario: real improvement compared to the typical solution
- Monitoring data and design data: comparison of achieved performance against prediction, this can also be defined as a separate indicator (quality of prediction).

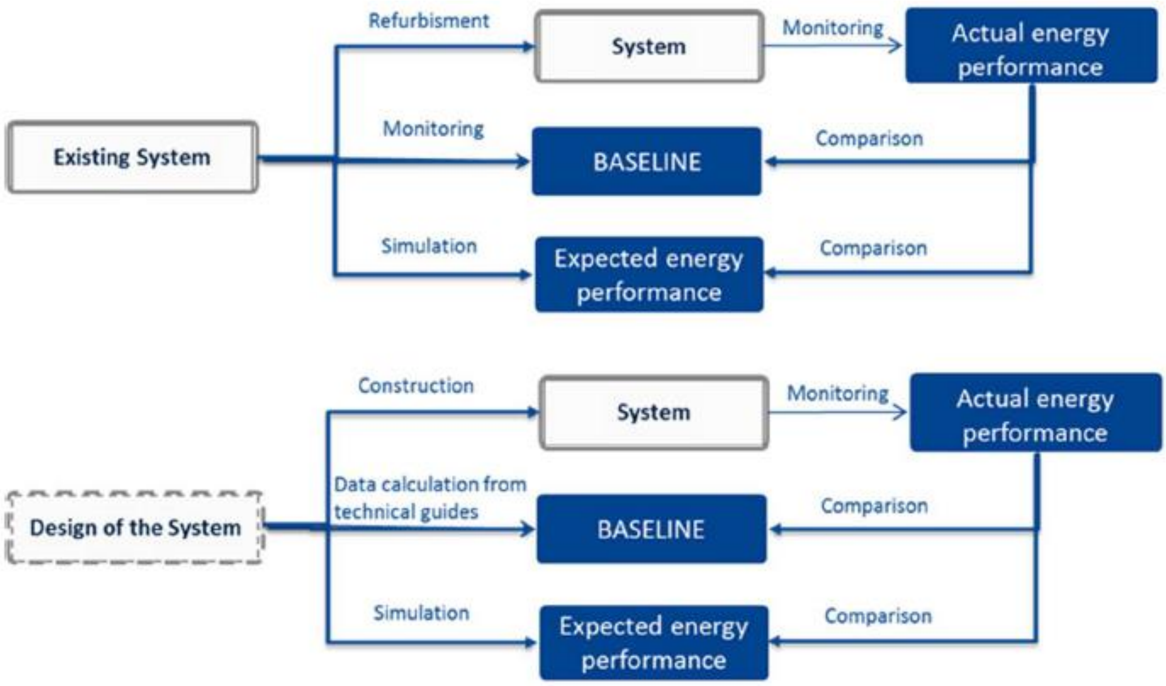

Figure 5: SCIS: Comparison of data on energy performance

The indicators defined in the SCIS KPI guide can also be calculated as a reduction or increase of, for example, the energy performance in comparison with the baseline or the designed data. A detailed explanation of each of the cases and guidelines for data needs, monitoring and evaluation can be found in later deliverables.

3.2.2 CITYkeys

The CITYkeys assessment method and the indicators (both city and project level) are to be used to evaluate the success of demo projects and the possibility to replicate the (successful) projects in other contexts. As follows from the smart city definition, success is determined by the transition across the entire ecological footprint of urban areas, simultaneously promoting economic prosperity, social aims and resilience to climate change and other external disturbances.

The extent to which smart city projects are able to have an effect on social, environmental and economic indicators forms the core of the evaluation. However, this is not enough to determine the success of a smart city project. Success is also determined by how projects have been - or will be - realised in various contexts.

The ability of individual smart city projects to be replicated in other cities and contexts determines its ultimate effect in achieving European goals with regard to energy and CO2 emissions. Under the Propagation category, smart city projects are evaluated to determine their potential for up scaling and the possibilities for application in other contexts.

A subdivision of the evaluation framework in impact categories allows for more flexibility than a subdivision in driving forces, actors or sectors. In addition, as smart city projects in various sectors all contribute to the same impacts there will be fewer double indicators (such as 'energy savings' or 'emission of carbon dioxide'). Indicators that are relevant for a specific sector can easily be in- or excluded depending on the type of project to be evaluated without disturbing the logic of the assessment.

Each of the major themes (people, planet, prosperity, governance and propagation) encompasses several specific policy goals. In many cases these are not all mentioned in a smart city strategy, but may be scattered over various policy documents in a city. For the design of the CITYkeys indicator framework we have arranged these policy goals under the major theme headings. For instance, under the theme People, subthemes conforming to policy ambitions are created (see Figure 6): increasing diversity and improving social cohesion, increasing safety, guaranteeing good education for every citizen, etc.

People	Planet	Prosperity	Governance	Propagation
• Health	• Energy & mitigation	• Employment	• Organisation	• Scalability
• Safety	• Materials, water and land	• Equity	• Community involvement	• Replicability
• Access to (other) services	• Climate resilience	• Green economy	• Multi-level governance	
• Education	• Pollution & waste	• Economic performance		
• Diversity & social cohesion	• Ecosystem	• Innovation		
• Quality of housing and the built environment		• Attractiveness & competitiveness		

Figure 6: The CITYkeys indicator framework.

3.2.3 ESPRESSO

The third relevant horizontal EU indicative that developed solutions for common issues of all smart city lighthouse projects was **ESPRESSO - systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities** (2016-2017, http://www.espresso-project.eu/).

ESPRESSO project focused on the development of a conceptual Smart Cities Information Framework, which consists of a Smart City platform and a number of data provision and processing services to integrate data, workflows, and processes in applications relevant for Smart Cities within a common framework. To build this framework, the project identified relevant open standards, technologies, and information models in use or in development in the various sectors. It analysed potential issues caused by gaps and overlaps across standards developed by the various standardization organizations and provided guidelines on how to effectively solve those issues.

The most relevant results of ESPRESSO for MAKING-CITY purposes will be used when defining data requirements and the monitoring programme in T5.2 and T5.3, with links to development of urban ICT platforms in the lighthouse cities (T2.7).

From the various monitoring programmes and indicator frameworks mentioned above, we can select useful indicators and methods for the MAKING-CITY project, knowing that the developed methodology serves policy goals. In addition, it is needed to make further efforts to connect project level (PED zone) indicators to the same framework. The introduced Logic-model can be helpful in determining which indicators are relevant and useful for both city and project level evaluation.

4 Selected KPIs for evaluating the performance at project level

4.1 Process of indicator selection and definition

The process for the indicator selection and definition for project level has been an iterative working process between the contributors of Task 5.1. The detailed definitions and calculation methods have mainly been processed between VTT, TNO, CAR, CGI, R2M, CAP and the cities of Oulu and Groningen.

The indicator definitions and the logic behind the evaluation process have been discussed iteratively in the consortium meetings, telcos and face-to-face meetings with city representatives, universities and other technical partners. A draft of a framework template following the work conducted in WP5 with project level indicators was created to set the objectives of evaluation. In addition, the necessity to establish periodical communication between sectoral experts was identified. Therefore, specialized groups were established grouping the experts of different domains from different partner organisations. Regular mailing lists were set-up and telcos organised to discuss topical issues on these domains, mainly related to technical indicators and evaluation in general, but also other domain-specific issues. These telcos have been open for horizontal communication between the experts in the lighthouse and follower cities as well as technical partners, even if they are not partners working in WP5.

The definition of the project level evaluation framework (including the lighthouse city partners' contribution to identifying indicators) can be summarized into the following steps:

1. <u>Structuring the evaluation framework using KPIs</u>

VTT prepared the draft list of project level indicators. At this time *Energy & Environment, Mobility, Economy, System flexibility and Social & Residents* categories were established in order to discuss more in detail about the indicator selection, applicability, data availability and calculation methods.

2. <u>Defining the evaluation procedure</u>

This step included the matching of indicator framework with actions and interventions, and the definition of practical steps to collect the data, calculate the indicator values and report of the development. Methodological guidelines on evaluation procedures (data needs, baseline definitions, monitoring, impact assessment methods etc.) must be further discussed in collaboration between technical partners. This will be carried on in the following tasks and deliverables (e.g. D5.3, D5.4 and D5.5).

3. <u>Validation of indicators with partners involved in demonstrations</u>

The indicator proposal by VTT included the list of key performance indicators combining project level actions and interventions into high-level metrics as tools for the impact assessment, as well as the methodological definitions. Before the final validation, they must be reviewed by all partners involved in the demonstrations in terms of feasibility, relevance, evaluation boundaries, data sources and methodological approaches for calculations and baseline definitions (measurements, simulations etc.). In addition, the development of SCIS KPI protocols can have an impact on the final validation of the KPI definitions, calculation methodologies and evaluation boundaries.

4.2 Criteria for selecting indicators

In general, the key performance indicators at project level should express as precisely as possible to what extent an aim, a goal or a standard has been reached or even surpassed. Data that is not linked to standards or any specific goals of projects can be used as quantitative or qualitative background information, but this data is not suited for evaluative purposes. Often, however, various indicators are available to assess the progression towards a certain goal.

A set of predefined selection criteria (based on the criteria defined by the CIVITAS framework) has been used in the MAKING-CITY project. All selected indicators should follow the validation criteria.

Ideally, the key performance indicators are defined so that they are able to show a direct relationship of the energy related interventions with other relevant interventions in MAKING-CITY, energy sustainability being the main target of the project.

The set of criteria based on the CIVITAS framework (van Rooijen et al. 2013):

1. RELEVANCE; Each indicator should have a significant importance for the evaluation process. That means that the indicators should have a strong link to the subthemes of the evaluation framework, and a direct link with the project interventions.

Further the indicators should be selected and defined in such a way that the implementation of the smart city project will provide a clear signal in the change of the indicator value. Indicators that provide an ambiguous signal (if there is doubt on the interpretation of e.g. an increase in the indicator value) are not suited.

2. COMPLETENESS; The set of indicators should consider all relevant aspects of the implementation of smart city projects. Indicators can be selected according to the People, Planet, Prosperity and Governance themes (and for project indicators from the Propagation theme as well), which framework is fairly comprehensive in describing public policy goals.

3. AVAILABILITY; Data for the indicators should be easily available. As the inventory for gathering the data for the indicators should be kept limited in time and effort, the indicators should be based on data that either:
   - are available from the project leader or others involved in the innovation case that is being evaluated,
   - or can easily be compiled from public sources,
   - or can easily be gathered from interviews, maps, or terrain observations.

Indicators that require, for instance, interviews of users or dwellers are not suited as the large amounts of data needed are too expensive to gather. The same holds for indicators that require extensive recalculations and additional data, such as footprint indicators, and some financial indicators.

4. MEASURABILITY; The identified indicators should be capable of being measured, preferably as objectively as possible. However, for some indicator categories, quantitative measurability is limited. Social sciences provide approaches to deal with qualitative information in a semi-quantitative way (Abeyasekera, 2005). Data from simulations and models can be considered comparable to measured data in the case there is no possibility to utilize actual measurements.

5. RELIABILITY; The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.

6. FAMILIARITY; The indicators should be easy to understand by the users and non-experts as well. For a large number of indicators we have relied on indicators from existing indicator sets, which generally comply with this requirement. For new indicators a definition should be developed so that it has a meaning in the context of existing policy goals.

7. NON-REDUNDANCY; Indicators within a system/framework should not measure the same aspect of a subtheme.

8. INDEPENDENCE; Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation. As an example, the current energy

system is still largely based on fossil fuels, and there is a direct relation between a reduction in the use of energy and the reduction of the emission of carbon dioxide. This will lead to a certain extent to double counting the impact.

4.3 List of key performance indicators

The tables in the subsections below list and describe the project level indicators selected for the MAKING-CITY project. The KPIs have been divided into five main categories: **Energy & Environment**, **Mobility**, **Economy**, **System flexibility** and **Social & Residents**.

The starting point for selecting project level KPIs has begun with analyzing the scope, objectives and focal targets of the project; what type of indicators are actually needed to keep track on the performance of the PED areas, and what is most relevant in these particular cases. The next step was to analyze the BEST tables, the Impacts in the DoA, and the list of actions in the demos, comparing them to the main reference indicators systems. Several iteration rounds were performed between the contributors, in order to find optimal and solid selection of descriptive key performance indicators.

The links between the demonstration actions with the selected KPIs will be further described in *"D5.3 - Evaluation procedure for PED actions"* showing that all of the actions can be evaluated with the selected KPIs. In the case, where a demo decides to add an action not considered from the beginning, a new KPI could be required and its addition would be reported in *"D5.10 - Data collection and KPI calculation"*.

As a conclusion, SCIS, CITYkeys and other indicator frameworks have been considered as references, nevertheless only the most relevant and applicable KPIs have been selected to measure and follow the performance of the main targets in the MAKING-CITY project. In addition to these selected KPIs, it is also intended to incorporate other type of input/output parameters and measured data to the SCIS database, in the case they are considered as relevant information, and required by the SCIS self-reporting tool. All project level indicators will be considered to represent the entire PED demo area level. However, the calculation of some PED indicators require sub-division first to e.g. building level or system level calculations before combining them to the project area level as the final KPI calculation.

4.3.1 Energy & environment

Table 4: Energy indicators

PED Energy Profile		
Indicator	Source	Description
E1: Final energy consumption	SCIS	Annual final energy consumption divided for all uses and forms of energy (electricity/thermal/gas). **Transportation and public lighting excluded.** Buildings combined to area level. No separate apartments reported. Monitoring on the building level, but **final KPI on PED area level.** Final energy used in buildings defined as in the BEST tables: electricity for lighting, ventilation, space heating and cooling, hot water, for heat: heating, cooling and domestic hot water.
E2: Primary energy consumption	SCIS	This indicator corresponds with the primary energy consumed inside the PED boundaries that is the energy forms found in nature (e.g. coal, oil, gas, biomass, nuclear, wind, solar, hydro) which have to be converted (often with subsequent losses) to useable forms of energy. **Excluding transportation and public lighting.**

E3: Energy imported to PED	SCIS	The amount of electricity, thermal energy (district heating) and other energy sources (e.g. gas) **imported to the demonstration area** from outside the PED boundaries.
E4: Energy exported from PED	SCIS	The amount of electricity and thermal energy **exported outside the PED boundaries** from the demonstration area.
E5: RES production	SCIS, CITYkeys	Amount of **RES production inside PED boundaries**, and share (compared to final energy consumption in the area.) Divided into electricity (solar) and thermal energy (including geothermal, waste/excess heat etc. energy produced with heat pumps).
E6: PED energy balance	SCIS	The overall **primary energy balance of the PED** area considering demand-consumption, energy flows, storage, RES.
E7: Energy savings in the PED	SCIS	Total annual **saved primary energy in the PED** compared to situation without any interventions (baseline).

Table 5: Environmental indicators

Environmental effect		
Indicator	Source	Description
E8: GHG emissions	SCIS, CITYkeys	The GHG emissions (**converted to CO2-eq.**) generated over a calendar year by the same activities included in the primary energy related KPIs inside the PED boundaries.
E9: Reduction of emissions	CITYkeys	**Reduction of CO2-eq. emissions in the PED area** achieved by the project actions and interventions.

4.3.2 Mobility

Table 6: Mobility indicators

Mobility related technologies		
Indicator	Source	Description
M1: Number of public EV charging stations	SCIS	Number of EV charging station inside the PED that are available for the public use.
M2: Energy delivered for EV charging	SCIS	Energy consumption (energy delivered) by the EV charging stations in PED, and if available, the total number of charges, or the total charging time.

4.3.3 Economy

Table 7: Economic indicators

Economic performance		
Indicator	Source	Description
C1: Total investments	SCIS	How much money is invested in total to PED interventions (entire development units). Subdivision of the sources (EU funding, (local) government funding, private investment by companies and other private investment.
C2: Payback time	SCIS	Economic payback period of investments (comprehensive system or unit, not single intervention).
C3: Economic value of savings	SCIS	Total investments combined with the output results (in terms of energy savings or reduction in GHG emissions (CO2-eq.)) on a project level, this KPI tells something about the effectiveness per saved amount of (primary) energy / reduced emissions, or contribution into new energy generation.

4.3.4 System flexibility

Table 8: Flexibility indicators

Performance based on flexibility		
Indicator	Source	Description
F1: System flexibility for energy players	SCIS	Flexibility of the whole energy system in PED by means of smart solutions. Demand response management and smart controls for the energy system. Additional flexibility capacity gained for energy players. KPI measures the progress brought by R&I activities relative to the new clusters and functional objectives, assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO.
F2: RES storage usage	MAtchUP	The combined usage of energy storage capacity in the PED area. The aim is to increase energy system flexibility with local energy storages for electricity and heat.
F3: Peak load reduction	SCIS/CITYkeys	The indicator is used to analyse the maximum power demand of a system in comparison with the average power. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. E.g., Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels.

4.3.5 Social & Residents

Table 9: Social indicators

Social indicators		
Indicator	Source	Description
S1: Energy poverty	CITYkeys	Percentage of households by definition (described further in the Annex), or energy bill as % of total household disposable income.
S2: Consciousness of residents	CITYkeys	Increased consciousness of residents of the area on the defined issues (project interventions, energy, environment, climate, personal/communal consumption, carbon footprint and handprint, etc.).
S3: Resident engagement / empowerment to climate conscious actions	CITYkeys	Appreciation of the benefits of project actions and interventions; Energy empowerment at home and in the community, engagement of residents to energy saving related actions, satisfaction and happiness of people towards the project.

5 Calculation of the project level indicators

This section provides general description and guidelines for the lighthouse cities and other stakeholders working with the PED interventions on the indicator definitions, data needs (main input parameters) and calculation methodology (formulas) for the determination of the project level KPIs. The detailed data needs and calculation specifications for some of the selected KPIs have not been presented in this report, since they are still under development in other deliverables (e.g. D4.2, D5.5.). Further description on how to utilize the selected key performance indicators and the evaluation framework for the impact assessment, what are the exact data needs, plans for data collection, monitoring and simulation procedures etc. will be further discussed in the deliverables:

- D1.3 (Tools for modelling energy demand, supply side, simulation of scenarios and estimation of impacts),
- D2.1/D3.1 (PED interventions detailed design),
- D2.2/D3.2 (Baseline of PED),
- D4.2 (Guidelines to calculate the annual energy balance PED (demand-consumption, energy flows, storage, RES)),
- D5.3 (Evaluation procedure for PED actions),
- D5.4 (City impact evaluation procedure),
- D5.5 (Data sets: Requirements, collection and protection),
- D5.6 (Guidelines for definition of Monitoring Programmes),
- D5.7 (Oulu Monitoring Programme) and
- D5.8 (Groningen Monitoring Programme)
- D5.10 (Data collection and KPI calculation)
- D5.11 (Evaluation (city level, project level))

The baseline situation of the demo-areas (without interventions) will be determined in M36 by the deliverables D2.2/D3.2. The baseline is determined by calculating/defining the initial values (measured or simulated) for the needed design data and selected indicators. Monitoring of the progress and the final calculation of indicators will follow at later stages of the project (D5.7/D5.8, D5.10). The final evaluation and impact assessment for both city and project level will be performed in D5.11.

Before the final validation of the KPIs, they have be thoroughly reviewed by the task groups developing the definitions, calculation methodologies, monitoring procedures etc. for different demonstration activities. In addition, the development of SCIS KPI protocols can have an impact on the final validation of the KPI definitions and calculation methodologies.

5.1 Calculation methodology and parameters

Following tables compile the KPI definitions, units, needed parameters and calculation formulas for the selected project level indicators. As a rule, the final evaluation level and boundaries for all KPIs is at the PED level, meaning that the calculated value of each indicator describes the situation at the entire demo-area level. However, within the calculations, many of the KPIs have to be first divided into building or energy system level.

As an example, the final energy consumption, is calculated by combining the consumptions of each renovated and new building (including all final energy demands and uses), energy consuming sub-systems (e.g. ground-source heat pumps), and other possible consumptions within the PED scope (excluding transportation and public lighting). The final figure then shows the situation at the PED level, and can be compared to the same KPI at different times during the monitoring period.

5.1.1 Energy & environment

Table 10: Calculation of energy indicators

PED Energy Profile		
Indicator	Unit	Definition and calculation parameters
E1: Final energy consumption	kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	Annual final energy consumption divided for all uses and forms of energy (electricity/thermal/gas). **Transportation and public lighting not included.** Buildings combined to area level. Separate apartments not reported. Monitoring on the building level, but final KPI on PED area level. Final energy used in buildings defined as in the BEST tables: electricity for lighting, ventilation, space heating and cooling, hot water, for heat: heating, cooling and domestic hot water. Measurement per time unit (e.g. minute): Meter reading (kWh) Usage per time unit = Meter reading t – Meter reading t1 Calculation formulas defined by SCIS: <u>At Building Level</u> • $E_d = \frac{TE_d + EE_d}{A_b}$ E_d Energy demand (simulated) TE_d Thermal energy demand (simulated) [kWh/ (month); kWh/ (year)] EE_d Electrical energy demand (simulated) [kWh/ (month); kWh/(year)] A_b Floor area of the building [m²] • $E_c = \frac{TE_c + EE_c}{A_b}$ $E1_c$ Energy consumption (monitored) TE_c Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year) MWh/(year)] EE_c Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year) MWh/(year)] A_b Floor area of the building [m²] <u>At District Level</u> $E_{district\ demand}$ Energy demand (simulated) of the district (buildings, excluding mobility & infrastructure) (weighted average over the buildings) • $E_{district\ demand} = \sum(E_d * A_b)/A_{total}$ Energy consumption (monitored) of the district (buildings, excluding mobility & infrastructure) (weighted average over the buildings) $E_{district\ consumption} = \sum(E_c * A_b)/A_{total}$
E2: Primary energy consumption	kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	The primary energy demand/consumption of a system encompasses all the naturally available energy that is consumed in the supply chains of the used energy carriers (e.g. coal, oil, gas, biomass, nuclear, wind, solar, hydro). To enable the comparability between systems, the total primary energy demand/consumption can be related to the size of the system (e.g. conditioned area) and the considered time interval (e.g. month, year). (Demand is

		here defined as "design consumption". Consumption is actual/monitored energy consumption). Calculation formulas defined by SCIS: <u>At Building Level</u> • $PE_d = \frac{TE_d \cdot PEF_T + EE_d \cdot PEF_E}{A_b}$ PE_d Primary energy demand (simulated) TE_d Thermal energy demand (simulated) [kWh/(month) ; kWh/(year)] EE_d Electrical energy demand (simulated) [kWh/(month) ; kWh/(year)] PEF_T Primary energy factor for thermal energy (weighted average based on source/fuel mix in production) PEF_E Primary energy factor for electrical energy (weighted average based on source/fuel mix in production) A_b Floor area of the building [m²] Formula: • $PE_c = \frac{TE_c \cdot PEF_T + EE_c \cdot PEF_E}{A_b}$ PE_c Primary energy consumption (monitored) TE_c Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)] EE_c Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)] PEF_T Primary energy factor for thermal energy (weighted average based on source/fuel mix in production) PEF_E Primary energy factor for electrical energy (weighted average based on source/fuel mix in production) A_b Floor area of the building [m²] <u>At District Level</u> $PE_{district\ primary\ demand}$ Primary energy demand (simulated) of the district • $PE_{district\ primary\ demand} = \sum PE_d$ $PE_{district\ primary\ consumption}$ Primary energy consumption (monitored) of the district. • $PE_{district\ primary\ consumption} = \sum PE_c$
E3: Energy imported to PED	kWh/15min(/day); kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	The amount of electricity, thermal energy (district heating) and other energy sources (e.g. gas) imported to the demonstration area from outside the PED boundaries. The resolution can vary from e.g. 15 minutes (can be applied for congestion management analysis) to hour or day. Aggregated to month and year reporting level. Longer timeslots are more suitable for detecting seasonal differences.
E4: Energy exported from PED	kWh/15min(/day); kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	The amount of electricity and thermal energy exported outside the PED boundaries from the demonstration area. The resolution can vary from e.g. 15 minutes (can be applied for congestion management analysis) to hour or day. Aggregated to month and year reporting level. Longer timeslots are more suitable for detecting seasonal differences.
E5: RES production	kWh/month; kWh/a; % of final energy consumption	Amount of RES production inside PED boundaries, and share/degree (compared to final energy consumption in the area). Divided into electricity (solar) and thermal energy (including geothermal, waste/excess heat etc. energy produced with heat pumps). The degree of energetic self-supply by RES is defined as ratio of locally produced energy from RES and the energy

		consumption over a period of time (e.g. month, year). DE is separately determined for thermal (heating or cooling) energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy. Calculation formulas defined by SCIS: • $DE_T = \frac{LPE_T}{TE_c} * 100$ DE_T Degree of thermal energy self-supply based on RES LPE_T Locally produced thermal energy [kWh/month ; kWh/year] TE_c Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)] **Formula:** • $DE_E = \frac{LPE_E}{EE_c} * 100$ DE_E Degree of electrical energy self-supply based on RES LPE_E Locally produced electrical energy [kWh/month ; kWh/year] EE_c Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)]
E6: PED energy balance	kWh/month; kWh/a; (surplus + or deficit -); %?	The overall primary energy balance of the PED area. Guidelines for the calculation of the annual energy balance in PEDs considering demand-consumption of the buildings, energy flows, storage, RES production, will be provided in D4.2.
E7: Energy savings in the PED	kWh/(m2a); %	Total annual saved primary energy in the PED compared to situation without any interventions (baseline). Calculated at building level and aggregated to PED level. This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. Energy savings can be calculated separately determined for thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings. % = ESt / ERt * 100 UoM kWh / m2a; kWh / a Calculation formulas defined by SCIS: $ES_T = ER_T - TE_C$ ES_T Thermal energy savings TE_c Thermal energy consumption of the demonstration-site [kWh/(m² year) MWh/(year)] ER_T Thermal energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year); MWh/(year)]. $ES_E = ER_E - EE_C$ ES_E Electrical energy savings EE_c Electrical energy consumption of the demonstration-site [kWh/(m² year) MWh/(year)] ER_E Electrical energy reference demand or consumption (simulated or monitored) of the demonstration-site [kWh/(m² year) MWh/(year)].

Table 11: Calculation of environmental indicators

Environmental effect		
Indicator	**Unit**	**Definition and calculation parameters**
E8: GHG emissions	kgCO2-eq/ (m2month); kgCO2-eq/ (m2a) kgCO2-eq/ (kWh a)	The GHG emissions (kgCO2-eq.) generated over a calendar year by the same activities included in the primary energy related KPIs inside the PED boundaries. The greenhouse gas, particulate matter, NOx and SO2 emissions of a system correspond to the emissions that are caused by different areas of application. In different variants of this indicator the emissions caused by the production of the system components are included or excluded. SCIS only excludes these emissions. To enable the comparability between systems, the emissions can be related to the size of the system (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. month, year). The greenhouse gases are considered as unit of mass (tones, kg.) of CO2 or CO2 equivalents. Calculation formulas defined by SCIS: District Level: $GGE = \frac{TE_c \cdot GEF_T + EE_c \cdot GEF_E}{A_b}$ GGE Greenhouse gas emissions for buildings TE_c Thermal energy consumption (monitored) of the demonstration site [kWh/ (month); kWh/ (year)] EE_c Electrical energy consumption (monitored) of the demonstration site [kWh/ (month); kWh/ (year)] GEF_T Greenhouse gas emission factor for thermal energy (weighted average based on thermal energy production source/fuel mix) (kg CO2eq/kWh consumed) GEF_E Greenhouse gas emission factor for electrical energy (weighted average based on electricity production source/fuel mix) (kg CO2eq/kWh consumed) A_b Floor area of the building [m^2]
E9: Reduction of emissions	kgCO2-eq/a; %	Reduction of CO2-eq. emissions in the PED area achieved by the actions and interventions. Calculated at building / energy system level and aggregated to PED level. Calculation formula defined by SCIS: The emitted mass of CO2 is calculated from the delivered and exported energy for each energy carrier: $m_{CO_2} = \sum(E_{del,i} K_{del,i}) - \sum(E_{exp,i} K_{exp,i})$ Where $E_{del,i}$ *is the delivered energy for energy carrier i* into object of assessment; $E_{exp,i}$ *is the exported energy for energy carrier i* out of object of assessment; $K_{del,i}$ *is the CO2 emission coefficient for delivered energy carrier i;* $K_{exp,i}$ *is the CO2 emission coefficient for the exported energy carrier i.* The indicator is calculated as the direct (operational) reduction of the CO2 emissions over a period of time. The result may be expressed as a percentage when divided by the reference CO2 emissions. To calculate the direct CO2 emissions, the total energy reduced, can be translated to CO2 emission figures by using conversion factors for

5.1.2 Mobility

Table 12: Calculation of mobility indicators

Mobility related technologies		
Indicator	Unit	Definition and calculation parameters
M1: Number of public EV charging stations	# of installed stations	Total number of installed EV charging stations or points for the electric vehicles that are available for the public. Please specify the also the type and capacity. Amount before the intervention and after the intervention.
M2: Energy delivered for EV charging	kWh/month; kWh/a; charging time; # of charges	Monitored energy consumption (energy delivered) by the EV charging stations in PED, and if available, the total number of charges, or the total charging time. Usage: charging time of stations per time unit Usage # charges

5.1.3 Economy

Table 13: Calculation of economic indicators

Economic performance		
Indicator	Unit	Definition and calculation parameters
C1: Total investments	€/m2; €/kW(h)	How much money is invested in the actions and interventions in the PED area, and subdivision of the sources (EU funding, (local) government funding, private investment by companies and other private investment sources. The calculation includes total investments of each development unit (e.g. investments of a renovated building includes also those investments that are part of the total solution, not only the project interventions). An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system is defined as cumulated payments until the initial operation of the system. The investment in the refurbishment of an existing system is defined as cumulated payments until the initial operation of the system after the refurbishment (grants are not subtracted). Within SCIS, total investments apply to the energy aspects of the system (e.g. high efficient envelope in a building) and exclude investments non-energy related (e.g. refurbishment of bathrooms). To be meaningful, within SCIS, also the investments for a business as usual case is taken into account. Calculation formulas defined by SCIS:

		$$EPI_{BR} = \frac{I_{BR}}{A_d}$$ EPI_{BR} Total investment for all the interventions related to energy aspects in the district per conditioned area [€/m²] I_{BR} Total investment for all the interventions related to energy aspects [€] A_d Total floor area of the system renovated [m²] $$EPI_{ER} = \frac{I_{ER}}{A_d}$$ EPI_{ER} Total investment for all the interventions related to energy retrofitting (in the district) per conditioned area [€/m²] I_{ER} Total investment for all the interventions related to energy retrofitting [€] A_d Total floor area of the district renovated [m²] (subscript ER means energy retrofitting, subscript BR means building retrofitting)
C2: Payback time	Years	Economic payback period of the investment for a comprehensive system or unit, not single intervention (e.g. building level renovations, solar PV-system, new holistic concept). The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators. Calculation formulas defined by SCIS: Economic payback, EPP, type A static $$\mathrm{EPP} = \frac{EPI_{BR}}{\mathrm{m}}$$ M can be calculated as average annual costs in use savings (€/a) $$\mathrm{m} = \mathrm{TAC_{after}} - \mathrm{TAC_{before}}$$ Type B dynamic $$\mathrm{EPP} = \frac{\ln(\mathrm{m}\cdot(1+\mathrm{i})) - \ln(EPI_{BR} - EPI_{BR}\cdot(1+\mathrm{i}) + \mathrm{m})}{\ln(1+\mathrm{i})} - 1$$ Type C dynamic with energy price increase rate $$\mathrm{EPP} = \frac{\ln(\mathrm{m}\cdot(1+\mathrm{i})) - \ln(EPI_{BR}\cdot(1+\mathrm{p}) - EPI_{BR}\cdot(1+\mathrm{i}) + (1+\mathrm{p})\cdot\mathrm{m})}{\ln(1+\mathrm{i}) - \ln(1+\mathrm{p})} - 1$$ EPI_{BR} (€) Energy-related investment i (%) Discount rate p (%) Energy price increase rate i should be unequal to p
C3: Economic value of savings	€ / saved kWh (or reduced kgCO2-eq)/a	Invested euros for the interventions (comprehensive system or unit, not single intervention) versus the amount

		of saved energy or reduced/avoided kgCO2-eq. aggregated to the PED level. Total investments combined with the output results (in terms of energy savings or reduction in GHG emissions (CO2-eq.)) on a project level, this KPI tells something about the effectiveness per saved amount of (primary) energy / reduced emissions, or contribution into new energy generation.

5.1.4 System flexibility

Table 14: Calculation of system flexibility indicators

Performance based on energy flexibility		
Indicator	Unit	Definition and calculation parameters
F1: System flexibility for energy players	%; kWh; Likert?	Flexibility of the whole energy system in PED by means of smart solutions. Demand response management and smart controls for the energy system. Additional flexibility capacity gained for energy players. KPI measures the progress brought by R&I activities relative to the new clusters and functional objectives, assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO. This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention. Stability refers to the maintaining of voltage and frequency of a given power system within acceptable levels. Calculation formula defined by SCIS: $\Delta SF = \frac{SF_{SG} - SF_{Baseline}}{SF_{Baseline}} * 100$ *SF* is the amount of load capacity participating in demand side management [MW]. ΔSF is the percentage improvement.
F2: Energy storage usage	%; kWh	The combined usage of energy storage capacity in the PED area. The aim is to increase energy system flexibility with local energy storages for electricity and heat. Energy Storage usage: Charging time + Discharging time / Time available * 100% Time available can be on day / month or year basis For congestion management (dis)charging power is also relevant.
F3: Peak load reduction	%; # of peaks (congestion),	The indicator is used to analyse the maximum power demand of a system in comparison with the average power.

	duration of peaks and size of peaks; MHDx maximum hourly deficit	With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. E.g., Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power. Calculation formula defined by SCIS: $\% = (1 - \frac{P_{peak,R\&I}}{P_{BAU}})*100$

5.1.5 Social & Residents

Table 15: Calculation of social indicators

Social and resident related indicators		
Indicator	Unit	Definition and calculation parameters
S1: Energy poverty	% of households, or % share of income	A significant part of a household's income is consumed by housing costs and related expenditures. As such, both are determinants of the extent to which households are at risk of poverty or deprivation. As a large share of the European housing stock consists of buildings in desperate need of refurbishment, particularly in lower income low-energy-efficiency buildings with residents living in fuel poverty, the key to alleviate fuel poverty is to renovate the stock into more energy efficient buildings. Percentage of households by definition, or Energy bill as % of total household disposable income. ((Energy costs before project)/(Gross household income)×100%) - ((Energy costs after project)/(Gross household income)×100%) = percentage point change in income spent on energy
S2: Consciousness of residents	Likert scale: No consciousness – 1 – 2 – 3 – 4 – 5 – High consciousness	Increased consciousness of residents of the area on the defined issues (project interventions, energy, environment, climate, personal/communal consumption, carbon footprint and handprint, etc.). Communal consciousness and social coherence are the foundations of a healthy and democratic society (ITU). Civic consciousness is the people's awareness of their civic rights and responsibilities, their role in the community and their

		involvement in its holistic development, thereby increasing social capital (Ng, 2015). This includes: 1. Personal identity and citizenship: awareness, pride, obedience to the law, equality 2. National identity: respect for the national authorities, belief in the current political system, development of the country 3. Moral consciousness: being a good citizen in public and private, trusting that others are too 4. Ecological consciousness: awareness of the finite nature of resources, thinking about environmental consequences of actions 5. Social citizenship: family values and virtues, actively concerned with others at home and abroad
S3: Resident engagement / empowerment to climate conscious actions	Likert scale: No engagement – 1 – 2 – 3 – 4 – 5 – High engagement	Appreciation of the benefits of project actions; Energy empowerment at home, satisfaction, happiness of people. The indicator provides a qualitative measure and is rated on a five-point Likert scale: No increase – 1 — 2 — 3 — 4 — 5 — High increase 1. No increase: The project has not increased civic/resident engagement. 2. Small increase: The project has increased civic/resident engagement with regards to one of the five factors mentioned. 3. Some increase: The project increased civic/resident engagement with regards to two of the factors mentioned. 4. Significant increase: The project has increased civic/resident engagement with regards to three of the factors mentioned. 5. High increase: The project has increased civic/resident engagement with regards to four or more of the factors mentioned. Note: during the testing phase it will be seen whether it is possible to measure actual impact of projects on civic/resident engagement, or that we may need to rephrase the indicator to just include actions taken by the project to increase civic/resident engagement.

6 Conclusions

In the process to become a smart city, establishing reliable metrics for the smart city project is a key point to support cities to identify strengths and weaknesses and consequently set priorities for action. For this reason, PED demonstration areas in Oulu and Groningen were aligned in order to establish a common set of project level indicators useful for the diagnosis of outcome and impacts of project level actions and for the identification of the future needs and priorities.

Task 5.1 aims at the definition of the evaluation framework in order to measure and assess the project activities at both **city** and **project level** considering the indicator categories defined by SCIS (Key Performance Indicators Guide, SRT - Self Reporting Tool etc.), CITYkeys (Smart City Indicators and related methodology), and other relevant reference frameworks (ESPRESSO, MAtchUP, mySMARTLife etc.). The objective of the task is to select a set of Key Performance Indicators (KPIs) and data collection procedures for the common and transparent monitoring as well as the comparability of smart city actions across the cities.

This deliverable describes the process of developing the evaluation framework concentrating on the selection of the project level indicators (KPIs) that have been established and aligned in cooperation with the two Lighthouse cities. The main set of indicators as targets for the developments in short- or medium-term.

In total, 20 key performance indicators were selected from five main categories, which are:

1. Energy & Environment (7+2 KPIs)
2. Mobility (2 KPIs)
3. Economy (3 KPIs)
4. System flexibility (3 KPIs)
5. Social & Residents (3KPIs)

Starting from the definitions and links between smart city and smart city projects, indicators were selected for tracking the progress, evaluate the projects in the demonstration areas and focusing on monitoring the evolution of a city district towards a smarter city as a whole. Within the present WP and in close collaboration with e.g. WP2, WP3 and WP4, links with (SCIS) Smart Cities Information System database will be established. All applicable design and performance data (i.e. KPIs, monitoring data, simulations) will be aligned with SCIS protocols and incorporated into the database.

For these purposes, this report provides the methodological guidance of the procedure for the lighthouse cities to define the calculation methodology and needed parameters for the project level indicators. The KPIs are selected and defined for evaluating the actions and interventions in the demo areas of the lighthouse cities. The actual indicator values for the current situation in cities will be calculated on the basis of this project report on initial (baseline) values at M36 (based on D2.2 and D3.2). The evaluation of the achieved impacts - impact assessment - and other benefits of the city level actions and interventions will be performed at later stages of the project.

Before the final validation of the KPIs, they must be thoroughly reviewed by the task groups developing the definitions, calculation methodologies, monitoring procedures etc. for different demonstration activities. In addition, the development of SCIS KPI protocols can have an impact on the final validation of the KPI definitions and calculation methodologies. These changes would be reported in D5.10 – 'Data collection and KPI calculation'.

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Annex A: Description of the project level indicators

Energy & environment

E1: Final energy consumption	PED energy profile
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	Annual final energy consumption divided for all uses and forms of energy (electricity/thermal/gas). **Transportation and public lighting are not included**. Building level combined to area level. No separate apartments reported. Monitoring on the building level, but final KPI on PED area level. Final energy used in buildings defined as in the BEST tables: electricity for lighting, ventilation, space heating and cooling, hot water, for heat: heating, cooling and domestic hot water. The final energy demand/consumption corresponds to the energy entering the system in order to keep operation parameters (e.g. comfort levels). The energy demand is based on the calculated (e.g. simulated) figures and the energy consumption is based on the monitored data. To enable the comparability between systems, the total energy demand/consumption is related to the size of the system and the time interval. This indicator can be used to assess the energy efficiency of a system.
Unit	kWh/month; kWh/a; kWh/m2a
Calculation	Simulated or monitored final energy consumption (heat + electricity + gas) at building level; aggregated to PED level. $Ec = \frac{TEc + EEc}{Ab}$ Ec = Final energy consumption/demand (monitored/simulated) TEc = Thermal energy consumption/demand (monitored/simulated) [kWh/(month) ; kWh/(year)] EEc = Electrical energy consumption/demand (monitored/demand) [kWh/(month) ; kWh/(year)] Ab = Floor area of the building [m2]
Data requirements and guidelines for assessment	
Evaluation boundaries	PED excluding transportation and public lighting.
Data sources and availability	Primarily metering, simulations if necessary. Collecting data from monitoring equipment (or energy bills) provided by the project owner, calculations or simulations provided by the planning consultant, in case energy provider is involved in the project the data can be obtained from this source as well;

	consumption data of public facilities can be provided by the municipal utility or municipal department responsible for operation, supervision or statistics. Impact assessment is done before the implementation and after that on yearly basis.
Calculation interval	Monthly, annually.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	Continuous energy metering.
References	SCIS

E2: Primary energy consumption	PED energy profile
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	The primary energy demand/consumption of a system encompasses all the naturally available energy that is consumed in the supply chains of the used energy carriers. To enable the comparability between systems, the total primary energy demand/consumption can be related to the size of the system (e.g. conditioned area) and the considered time interval (e.g. month, year). (Demand is here defined as "design consumption". Consumption is actual/monitored energy consumption.) In SCIS, energy consumption is reported at three phases: for refurbished buildings (baseline, (design), monitoring) and for new buildings (reference energy consumption based on regulations and similar buildings, design demand based on simulations, and monitored consumption).
Unit	kWh/month; kWh/a; kWh/m2a
Calculation	Simulated or monitored primary energy consumption (heat + electricity + gas) at building level; aggregated to PED level. $PEc = \frac{TEc * PEFt + EEc * PEFe}{Ab}$ PEc = Primary energy consumption/demand (monitored/simulated) TEc = Thermal energy consumption/demand (monitored/simulated) [kWh/(month) ; kWh/(year)] EEc = Electrical energy consumption/demand (monitored/demand) [kWh/(month) ; kWh/(year)] PEFt = Primary energy factor for thermal energy (weighted average based on source/fuel mix in production)

	PEFe = Primary energy factor for electrical energy (weighted average based on source/fuel mix in production) Ab = Floor area of the building [m2]
Data requirements and guidelines for assessment	
Evaluation boundaries	PED excluding transportation and public lighting.
Data sources and availability	Primarily metering and statistics, simulations if necessary. Can be derived from KPI E1 together with primary energy factors (based on fuel mix of energy sources). Primary energy factors used with reference to source and year should be accompanied with the assessment.
Calculation interval	Monthly, annually.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	Continuous energy metering.
References	SCIS

E3: Energy imported to PED	PED energy profile
Calculation level	PED
Description	The amount of electricity, thermal energy (district heating) and other energy sources (e.g. gas) imported to the demonstration area from outside the PED boundaries.
Unit	kWh/15min(/day); kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)
Calculation	The resolution can vary from e.g. 15 minutes (can be applied for congestion management analysis) to hour or day. Aggregated to month and year reporting level. Longer timeslots are more suitable for detecting seasonal differences.
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Energy company data.
Calculation interval	.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.

References	SCIS

E4: Energy exported from PED	PED energy profile
Calculation level	Buildings; energy systems; PED
Description	The amount of electricity and thermal energy (district heating etc.) exported outside the PED boundaries from the demonstration area.
Unit	kWh/15min(/day); kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)
Calculation	The resolution can vary from e.g. 15 minutes (can be applied for congestion management analysis) to hour or day. Aggregated to month and year reporting level. Longer timeslots are more suitable for detecting seasonal differences.
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Energy company data.
Calculation interval	.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

E5: RES production	PED energy profile
Calculation level	Energy system; PED
Description	Amount of RES production inside PED boundaries, and share/degree (compared to final energy consumption in the area.) Divided into electricity (solar) and thermal energy (including geothermal, waste/excess heat etc. energy produced with heat pumps).
Unit	kWh/month; kWh/a; % of final energy consumption; % change
Calculation	The degree of energetic self-supply by RES is defined as ratio of locally produced energy from RES and the energy consumption over a period of time (e.g. month, year). DE is separately determined for thermal energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy.

	In order to calculate the % change, the degree of energetic self-supply by RES (thermal and electrical together and separately) before the intervention is compared to the degree of energetic self-supply by RES after the intervention. Calculation formulas defined by SCIS: • $DE_T = \frac{LPE_T}{TE_c} * 100$ DE_T Degree of thermal energy self-supply based on RES LPE_T Locally produced thermal energy [kWh/month ; kWh/year] TE_c Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)] **Formula:** • $DE_E = \frac{LPE_E}{EE_c} * 100$ DE_E Degree of electrical energy self-supply based on RES LPE_E Locally produced electrical energy [kWh/month ; kWh/year] EE_c Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)]
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Metering.
Calculation interval	High resolution advisable, reporting monthly and annually.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

E6: PED energy balance	PED energy profile
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	The overall primary energy balance of the PED area. The total combined final energy consumption of the buildings and systems vs. the energy production inside the PED area at a given time period. Transportation and public lighting are excluded from the calculation. "Positive Energy Districts are energy-efficient and energy-flexible urban areas which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems."
Unit	kWh/month, kWh/a (surplus + or deficit -)
Calculation	Detailed guidelines to calculate the annual primary energy balance of PED (demand - consumption, energy flows, storage, RES), is described in D4.2.

Data requirements and guidelines for assessment	
Evaluation boundaries	PED excluding transportation and public lighting.
Data sources and availability	Metering.
Calculation interval	.
Baseline	Baseline definition in D4.2.
Monitoring	.
References	SCIS

E7: Energy savings in the PED	PED energy profile
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	Total annual saved primary energy in the PED compared to situation without any interventions (baseline). Risk: increased energy consumption because of additional services is not made visible: Definition of the service consumed is the key.
Unit	kWh/m2a; %
Calculation	$Percentage\ change = \frac{Energy\ use\ after - Energy\ use\ before}{Energy\ use\ before}$ x 100% Energy use is measured in kWh.
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Metering, simulation.
Calculation interval	Annually.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

E8: GHG emissions	Environmental effect
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	The GHG emissions (CO2-eq.) generated over a calendar year by the same activities included in the primary energy related KPIs inside the PED boundaries. The greenhouse gas, particulate matter, NOx and SO2 emissions of a system correspond to the emissions that are caused by different areas of application. In different variants of this indicator the emissions caused by the production of the system components are included or excluded. SCIS only excludes these emissions. To enable the comparability between systems, the emissions can be related to the size of the system (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. month, year). The greenhouse gases are considered as unit of mass (tones, kg.) of CO2 or CO2 equivalents.
Unit	kg CO2eq/ (m2month); kg CO2eq/ (m2a)
Calculation	Calculation formula defined by SCIS. $\mathrm{Total}_{\mathrm{GHG}_{\mathrm{emission}}} = \sum_{i}^{z} \mathrm{energy}_{\mathrm{carrier(i)}} \cdot \mathrm{GHG}_{\mathrm{factor}} * final\ energy\ input_{energy\ carrier(i)}$ z=number of energy carriers
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Metering.
Calculation interval	Monthly, annually.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	Energy metering.
References	SCIS

E9: Reduction of emissions	Environmental effect
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	Reduction of CO2-eq. emissions in the PED area achieved by the actions and interventions.

	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. CO2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO2 emissions are combustion processes related to energy generation and transport. CO2 emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.
Unit	% and tons of CO2-eq/m2
Calculation	The difference between CO_2 emissions (tons of CO_2 equivalent) after and before the project are calculated with the formula: $$Percentage\ change = \frac{CO2\ emissions\ after - CO2\ emissions\ before}{CO2\ emissions\ before}$$ CO_2 emissions are calculated as the emitted mass of CO_2, as a sum from delivered and exported energy for each energy carrier: m_CO_2 = sum (E_delivered energy for energy carrier*K_CO2 emission coefficient for delivered energy carrier) - sum (E_exported energy for carrier * K_CO2 emission coefficient for delivered energy carrier).
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Can be derived from energy consumption with help of emission factors based on fuel mix of energy source. To calculate the direct CO2 emissions, the total energy reduced, can be translated to CO2 emission figures by using conversion factors for different energy forms. Standard emission factors are provided for European countries by Covenant of Mayor and internationally by IPCC. Emission factors used with reference to source and year should be accompanied with the assessment.
Calculation interval	Monthly, annually.
Baseline	Note: For new initiatives, there will be not a saving because there is no baseline situation. Actual savings versus saving to a reference number (simulated baseline).
Monitoring	.
References	SCIS, CITYkeys

Mobility

M1: Number of public EV charging stations	PED mobility profile
Calculation level	Energy system; PED
Description	Total number of installed EV charging stations or points for the electric vehicles that are available for the public. Please specify the also the type and capacity.
Unit	# of installed stations
Calculation	Total number of installed EV charging stations or points for the electric vehicles that are available for the public. Please specify the also the type and capacity. Amount before the intervention and after the intervention.
Data requirements and guidelines for assessment	
Evaluation boundaries	PED.
Data sources and availability	Data easily available.
Calculation interval	At the beginning and at the end of the monitoring period.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

M2: Energy delivered for EV charging	PED mobility profile
Calculation level	Energy system; PED
Description	Energy consumption of the EV charging in PED, or the total number of charges, or the total charging time. TBD which one is the best indicator.
Unit	kWh/month; kWh/a
Calculation	The amount of energy delivered by the public EV charging stations, or the # of charges
Data requirements and guidelines for assessment	
Evaluation boundaries	PED.
Data sources and availability	Energy meters and ICT systems. Data availability depends on the system operator.

Calculation interval	Monthly reporting.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

Economy

C1: Total investments	Economic performance
Calculation level	New buildings; renovated buildings; energy systems; PED
Description	How much money is invested in the actions and interventions in the PED area, and subdivision of the sources (EU funding, (local) government funding, private investment by companies and other private investment sources. The calculation includes total investments of each development unit (e.g. investments of a renovated building includes also those investments that are part of the total solution, not only the project interventions). An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system is defined as cumulated payments until the initial operation of the system. The investment in the refurbishment of an existing system is defined as cumulated payments until the initial operation of the system after the refurbishment (grants are not subtracted).
Unit	€/m2; €/kW(h)
Calculation	Calculation formulas defined by SCIS: $$EPI_{BR} = \frac{I_{BR}}{A_d}$$ EPI_{BR} Total investment for all the interventions related to energy aspects in the district per conditioned area [€/m²] I_{BR} Total investment for all the interventions related to energy aspects [€] A_d Total floor area of the system renovated [m²] $$EPI_{ER} = \frac{I_{ER}}{A_d}$$ EPI_{ER} Total investment for all the interventions related to energy retrofitting (in the district) per conditioned area [€/m²] I_{ER} Total investment for all the interventions related to energy retrofitting [€] A_d Total floor area of the district renovated [m²] (subscript ER means energy retrofitting, subscript BR means building retrofitting)
Data requirements and guidelines for assessment	
Evaluation boundaries	PED.
Data sources and availability	Data from project partners making investments.
Calculation interval	.
Baseline	.
Monitoring	.
References	SCIS

C2: Payback time	Economic performance
Calculation level	System or unit level; PED
Description	Economic payback period of the investment for a comprehensive system or unit, not single intervention (e.g. building level renovations, solar PV-system, new holistic concept). The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators.
Unit	Years
Calculation	Calculation formulas defined by SCIS: Economic payback, EPP, type A static $\mathrm{EPP} = \frac{EPI_{BR}}{\mathrm{m}}$ M can be calculated as average annual costs in use savings (€/a) $\mathrm{m} = \mathrm{TAC}_{\mathrm{after}} - \mathrm{TAC}_{\mathrm{before}}$ Type B dynamic $\mathrm{EPP} = \frac{\ln(\mathrm{m} \cdot (1+\mathrm{i})) - \ln(EPI_{BR} - EPI_{BR} \cdot (1+\mathrm{i}) + \mathrm{m})}{\ln(1+\mathrm{i})} - 1$ Type C dynamic with energy price increase rate $\mathrm{EPP} = \frac{\ln(\mathrm{m} \cdot (1+\mathrm{i})) - \ln(EPI_{BR} \cdot (1+\mathrm{p}) - EPI_{BR} \cdot (1+\mathrm{i}) + (1+\mathrm{p}) \cdot \mathrm{m})}{\ln(1+\mathrm{i}) - \ln(1+\mathrm{p})} - 1$ EPI_{BR} (€) Energy-related investment i (%) Discount rate p (%) Energy price increase rate i should be unequal to p .
Data requirements and guidelines for assessment	
Evaluation boundaries	.
Data sources and availability	Investments, metering.
Calculation interval	.

Baseline	.
Monitoring	.
References	SCIS

C3: Economic value of savings	Economic performance
Calculation level	System or unit level; PED
Description	Invested euros for the interventions (comprehensive system or unit, not single intervention) versus the amount of saved energy or reduced/avoided kgCO2-eq. aggregated to the PED level. Total investments combined with the output results (in terms of energy savings or reduction in GHG emissions (CO2-eq.)) on a project level, this KPI tells something about the effectiveness per saved amount of (primary) energy / reduced emissions, or contribution into new energy generation..
Unit	€ / saved kWh (or reduced kgCO2-eq)/a
Calculation	Investments per the amount of saved energy (or reduced/avoided kgCO2-eq.)
Data requirements and guidelines for assessment	
Evaluation boundaries	PED.
Data sources and availability	Investments, metering.
Calculation interval	.
Baseline	.
Monitoring	.
References	SCIS

System flexibility

F1: System flexibility for energy players	Energy flexibility
Calculation level	Energy system; PED
Description	Flexibility of the whole energy system in PED by means of smart solutions. Demand response management and smart controls for the energy system. Additional flexibility capacity gained for energy players. It measures the progress brought by R&I activities relative to the new clusters and functional objectives, assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO.
Unit	% / kWh / Likert?
Calculation	This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention.
Data requirements and guidelines for assessment	
Evaluation boundaries	.
Data sources and availability	Monitoring.
Calculation interval	.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	.
References	SCIS

F2: Energy storage usage	Energy flexibility
Calculation level	Energy system; PED
Description	The combined usage of energy storage capacity in the PED area. The aim is to increase energy system flexibility with local energy storages for electricity and heat. For congestion management (dis)charging power is also relevant.
Unit	kWh, %

Calculation	The combined Energy Storage usage in PED: Charging time + Discharging time / Time available * 100% Time available can be on day / month or year basis
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Energy metering. Can be also simulated.
Calculation interval	High resolution advisable.
Baseline	Baseline definitions in D2.2/D3.2.
Monitoring	Continuous metering if possible.
References	MAtchUP

F3: Peak load reduction	Energy flexibility
Calculation level	Buildings; energy systems; PED
Description	The peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). The indicator is used to analyse the maximum power demand of a system in comparison with the average power. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. E.g., Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. The indicator is used to analyse the maximum power demand of a system in comparison with the average power. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. E.g., Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels.
Unit	%
Calculation	Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g., Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. The indicator is used to analyse the maximum power demand of a

	system in comparison with the average power. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. $$\%\ change = \frac{Peak\ demand\ before - Peak\ power\ demand\ after}{Peak\ power\ demand\ before}\ \text{x}\ 100\%$$
Data requirements and guidelines for assessment	
Evaluation boundaries	PED
Data sources and availability	Monitoring and simulations.
Calculation interval	Minute, 15 minutes, 30 minutes, 1 hour?
Baseline	The peak demand before the aggregator implementation. Baseline definitions in D2.2/D3.2.
Monitoring	Continuous metering.
References	SCIS, CITYkeys, MAtchUP

Social & Residents

S1: Energy poverty	Social indicators
Calculation level	Households in average level; PED average
Description	Access to clean and affordable energy is fundamental to improving quality of life and is a key imperative for economic development. In this case, energy poverty is determined by the percentage of income spent on energy. It is well established that households that are poor spend a higher percentage of their income on energy than households that are wealthier. Empirical studies indicate that such percentages can range from about 5% or less to close to 20% of cash income or expenditure. When energy is above 10% of income, it will begin to have an impact on general household welfare. The problem is that when households are forced to spend as much as 10% of cash income on energy they are being deprived of other basic goods and services necessary to sustain life.
Unit	% of households, or % share of income.
Calculation	Percentage of households by definition, or percentage share of energy bill as % of total household disposable income.
Data requirements and guidelines for assessment	

Evaluation boundaries	PED area residents per household.
Data sources and availability	Statistical analysis or survey.
Calculation interval	At the beginning and at the end of the monitoring period.
Baseline	Baseline determined at the beginning of the monitoring period.
Monitoring	At the beginning and at the end of the monitoring period.
References	IEA, UNDP, EC, World Bank

S2: Consciousness of residents	Social indicators
Calculation level	Household; PED
Description	Increased consciousness of residents of the area on the defined issues (project interventions, energy, environment, climate, personal/communal consumption, carbon footprint and handprint, etc.). Communal consciousness and social coherence are the foundations of a healthy and democratic society (ITU). Civic consciousness is the people's awareness of their civic rights and responsibilities, their role in the community and their involvement in its holistic development, thereby increasing social capital (Ng, 2015). This includes: 1. Personal identity and citizenship: awareness, pride, obedience to the law, equality 2. National identity: respect for the national authorities, belief in the current political system, development of the country 3. Moral consciousness: being a good citizen in public and private, trusting that others are too 4. Ecological consciousness: awareness of the finite nature of resources, thinking about environmental consequences of actions 5. Social citizenship: family values and virtues, actively concerned with others at home and abroad
Unit	Likert scale
Calculation	Likert scale: No consciousness - 1 - 2 - 3 - 4 - 5 - High consciousness.
Data requirements and guidelines for assessment	

Evaluation boundaries	PED area residents per household.
Data sources and availability	Surveys, inquiries.
Calculation interval	At the beginning and at the end of the monitoring period.
Baseline	Baseline determined at the beginning of the monitoring period.
Monitoring	Using surveys, questionnaires etc. at the beginning and at the end of the monitoring period.
References	CITYkeys

S3: Resident engagement / empowerment to climate conscious actions	Social indicators
Calculation level	Household; PED
Description	Appreciation of the benefits of project actions and interventions; Energy empowerment at home, engagement of residents to energy saving related actions, satisfaction and happiness of people towards the project. The indicator provides a qualitative measure and is rated on a five-point Likert scale: No increase – 1 — 2 — 3 — 4 — 5 — High increase 1. No increase: The project has not increased civic/resident engagement. 2. Small increase: The project has increased civic/resident engagement with regards to one of the five factors mentioned. 3. Some increase: The project increased civic/resident engagement with regards to two of the factors mentioned. 4. Significant increase: The project has increased civic/resident engagement with regards to three of the factors mentioned. 5. High increase: The project has increased civic/resident engagement with regards to four or more of the factors mentioned.
Unit	Likert scale
Calculation	Likert scale: No increase in engagement - 1 - 2 - 3 - 4 - 5 - High increase in engagement.
Data requirements and guidelines for assessment	
Evaluation boundaries	PED area residents per household.

Data sources and availability	Surveys, inquiries. During the testing phase, it will be seen whether it is possible to measure actual impact of projects on civic/resident engagement, or that we may need to rephrase the indicator to just include actions taken by the project to increase civic/resident engagement.
Calculation interval	At the beginning and at the end of the monitoring period.
Baseline	Baseline determined at the beginning of the monitoring period.
Monitoring	Using surveys, questionnaires etc. at the beginning and at the end of the monitoring period.
References	CITYkeys