Innovation Action

H2020-LC-SC3-SCC-1-2018

D5.3 - Evaluation procedure for PED actions

WP5; Task 5.1

November 2020 [M24]

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Document Information

Grant agreement	824418
Project title	Energy efficient pathway for the city transformation: enabling a positive future
Project acronym	MAKING-CITY
Project coordinator	Cecilia Sanz-Montalvillo (cecsan@cartif.es)- Fundación CARTIF
Project duration	1st December 2018 – 30th November 2023 (60 Months)
Related work package	WP 5 – Evaluation framework and social innovation
Related task(s)	Task 5.1 – Evaluation framework
Lead organisation	20-VTT
Contributing partners	01-CAR, 03-GRO, 4-TNO, 9-CGI, 13-OUK, 14-UOU, 32-R2M, 34-CAP
Due date of deliverable	30th November 2020
Actual submission date	4th December 2020
Dissemination level	Public

Date	Version	Submitted by	Reviewed by	Comments
17/06/2020	1.0	VTT	Jussi Rönty, Anne Immonen	Final initial version for submission
19/10/2020	1.1	VTT	Jussi Rönty	Update for comments
11/11/2020	1.2	VTT	Anne Immonen, Jussi Rönty	Updates on qualitative evaluation
04/12/2020	1.3	VTT	Jussi Rönty	Final review version
04/12/2020	2.0	VTT		Final version for submission

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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
GDPR	General Data Protection Regulation
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

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 frameworks.

The main objective of this deliverable is to describe the evaluation procedure and methods for measuring the performance and impacts of the MAKING-CITY project level interventions in the 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 previous deliverables, and the evaluation procedure described further in this report, will be used for the comparison of the project interventions to the baseline situation in WP2 (Oulu) and WP3 (Groningen), and later for the final impact assessment.

The first step carried out within this framework was the selection of a set of project level indicators that will allow measuring the impact of the project in each of the demonstration PED areas of the project. The KPI definitions and the methodology to calculate them have been reported in the "D5.2 - Project level indicators". Parallel, the city level indicators will be used in the evaluation to show to what extent overall policy goals have been reached in project cities. 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 indicators) and D5.4 (city level evaluation procedure).

The development of 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) will be incorporated into SCIS database. 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

WP5 aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. The MAKING-CITY evaluation framework considers two different but complementary levels for carrying out this evaluation: city and project level.

This report constitutes the Deliverable "*D5.15 - Evaluation procedure for PED actions - Initial version*" forming one of the main outcomes of the *"Task 5.1 Evaluation Framework*".

The main objective of this deliverable is to describe the procedure and methods for evaluating the success of MAKING-CITY project at PED demonstration level, identifying the specific PED actions and indicators that will allow measuring the outcome and impacts of the project in the PED areas in Oulu and Groningen. In this deliverable, the main set of project level indicators (KPIs) will be aligned with the project actions to ensure comprehensive base for monitoring and finally assess their impacts. The evaluation procedure for PED actions will be placed in line with the WP5 developments and the city level framework defined in *"D5.16 - City impact evaluation procedure - Initial version"*.

The set of project level indicators is in key role in the definition of the evaluation procedure but it has been needed to establish not only the best way to measure these indicators, but also how the results can be compared in order to identify correctly the impact of the implemented actions.

The defined procedure will also support Lighthouse cities in the establishment of strategic and technical goals for PEDs, since the methodology proposed will allow them to simulate different scenarios modifying the value of the indicators that have been included in the framework.

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
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

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.

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.

Deliverable nº	Relation
D5.10	Data collection and KPI calculation.
D5.11	Evaluation (city level, project level).

2 Evaluation framework at project level

WP5 "Evaluation framework and social innovation" aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. The scope of the monitoring protocol is 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 as indicated in Figure 1.
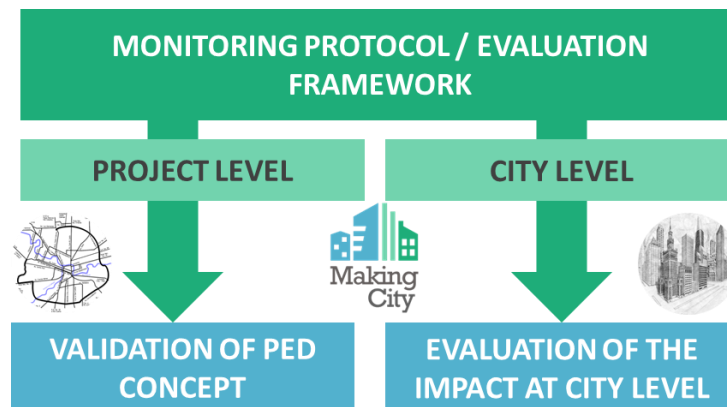
Figure 1: MAKING-CITY Evaluation Framework (source: D9.8)

This deliverable focuses on describing the procedure for the evaluation at project level based on the definitions of the project actions and the set of key performance indicators. Despite the difficulties in selecting the most appropriate key performance indicators to cover all project actions for achieving comprehensive evaluation, a good definition of the Evaluation Framework including "best practice" procedures can be very effective to obtain significant information for cities in order to improve their abilities and readiness for launching new actions for sustainability.

Demonstration projects enable the validation of the benefits and potential of the implementation of integrated solutions to improve key parameters that affect e.g. the environmental impact or the overall quality of life in the city. However, inside this context, the weakness related with upscaling and replicability of the solutions successfully deployed is commonly perceived. A real continuity of the urban transformation depends on the city commitment. This commitment can be constrained by several factors that can delay this city transformation and even in some cases, it can be jeopardised.

In order to define and establish the Smart City plans for the lighthouse and follower cities based on the replication potential of the interventions implemented in MAKING-CITY, it is necessary to start analysing the selected actions in an urban context in the earliest stage, i.e. identifying the opportunities and the barriers to the implementation of these actions. This will make it possible to study the feasibility of their implementation, but also to give priority to actions with a favourable context and to raise the barriers for other actions. At this point, a strong coordination with the lighthouse cities will be required to integrate useful information as open data e.g. within the ICT-city Platforms.

The demand side vs. supply side scenarios assessment should be based on a multi-criteria methodology evaluating the sustainability of the scenarios proposed under the three sustainable development dimensions: the economic, social, and environmental impacts of the different scenarios generated.

The reasoning for the impact-based evaluation (utilizing different type of indicators) in MAKING-CITY project is depicted by the Logic-model (Figure 2), 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).
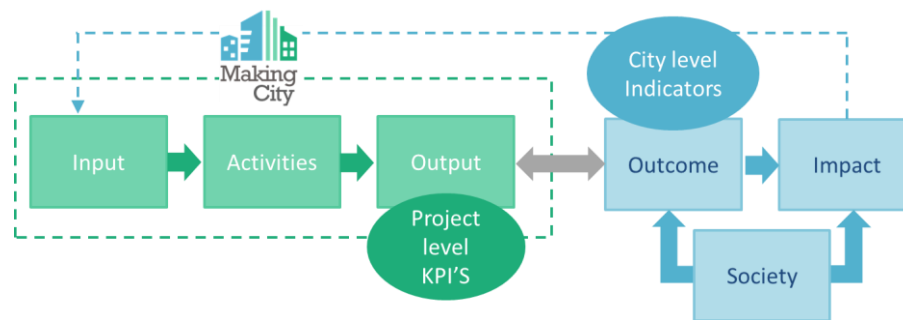
Figure 2: The Logic-model describes the steps from input to impact

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 aggregating the demonstration results up to the city level, would be irrelevant.

Therefore, in MAKING-CITY, the city level and project level evaluation (starting with indicators and KPIs) have been separated from each other. Only the main energy and environment related indicators are similar (comparable) in both levels. The city level is more concentrated on overall city level development targets (e.g. SECAP, long-term city strategies), whereas the project level aims to introduce new technologies for producing renewable energies and saving energy as much as possible and economically feasible. Both levels are important, but it is not that relevant to try to scale the PED level outcomes up to city level in this case. However, what could be up scaled, are the new technologies, business models and social innovations that can rise successfully up from the demonstrations. This is what cities could spread around in the planning of their smarter futures.
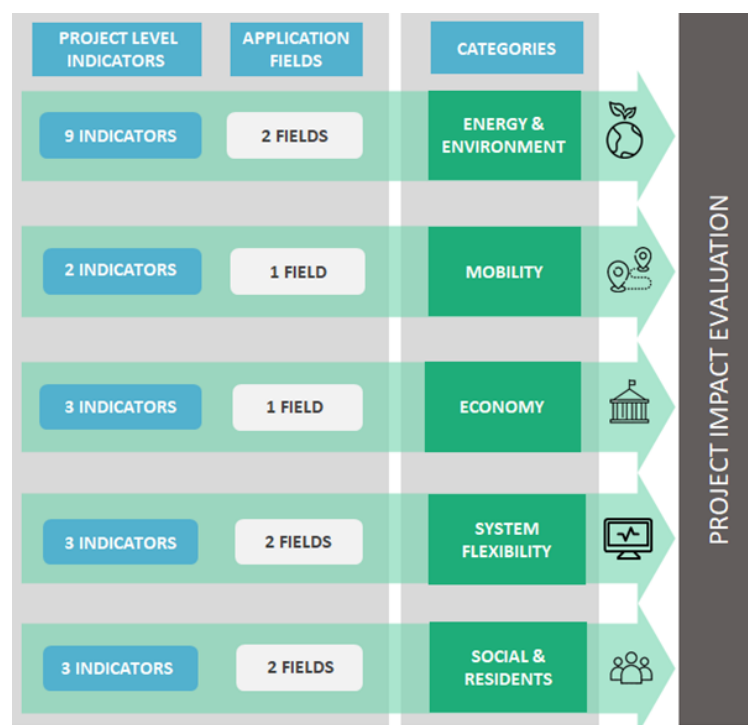
Figure 3: Levels of MAKING-CITY evaluation framework at project level

MAKING-CITY project has defined a set of project level indicators focused on monitoring the evolution of PED demonstration areas towards the targets. The project level indicators were defined in the 5.2 "Project Level Indicators" and they are also presented in the section 4 of this deliverable.

The project level evaluation framework consists of key performance indicators selected for evaluating the actions made in the demo areas on short- and medium-term. The project level can be considered as more technical than the city level concentrating not only assessing the level of sustainable energy planning but also the execution of the interventions in the PED areas. The evaluation procedure describes the methodology to assess project actions with the defined indicators. It consists of four steps:

- **Step I**: Selecting and defining the project level indicators in accordance with the PED actions, setting the objective for monitoring and impact assessment.

- **Step II**: Defining the baseline situation of the PED and calculating the indicator values at the beginning of the project (before the planned project level interventions).

- **Step III**: Monitoring the actions/action groups with key performance indicators during the monitoring phase of the project (following the indicators for the evaluation of progress).

- **Step VI**: Final calculation of the indicators at the end of the project for the final evaluation and impact assessment, where final values are obtained both per category and per application field.

This deliverable provides the methodological guidance for the evaluation procedure step by step on a general level. The actual indicator values for the baseline situation in PEDs will be calculated on initial values in M36 and reported in D2.2/3.2 (Baseline for Oulu/Groningen PED). Guidelines for the monitoring procedures will be presented in D5.6 (Guidelines for definition of Monitoring Programmes), and the actual monitoring will be reported in D5.7 and D5.8 (Monitoring Programmes).

The final evaluation of the achieved impacts - the impact assessment - and other benefits for both project and 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, considering existing KPIs and requirements for DAQ and GDPR.

2.1 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:

- **Evaluation at Project (PED) level (D5.3)**
  - o The objective is to evaluate the technical, environmental, economic and social impacts of the demonstration activities implemented in the two lighthouse (LH) cities.
  - o Project level indicators are defined in D5.2.
- **Evaluation at city level (D5.4)**
  - o 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 the eight cities of the project.
  - o City level indicators are defined in D5.1.

As shown in Figure 4, in total 40 indicators have been selected and classified in different categories, four in the case of the 20 city level indicators and five categories for the 20 project level ones. In order to evaluate the results and the impact of the project actions at both levels, it is necessary to establish a methodology to obtain the necessary data for calculating these indicators and carrying out the evaluation correctly.
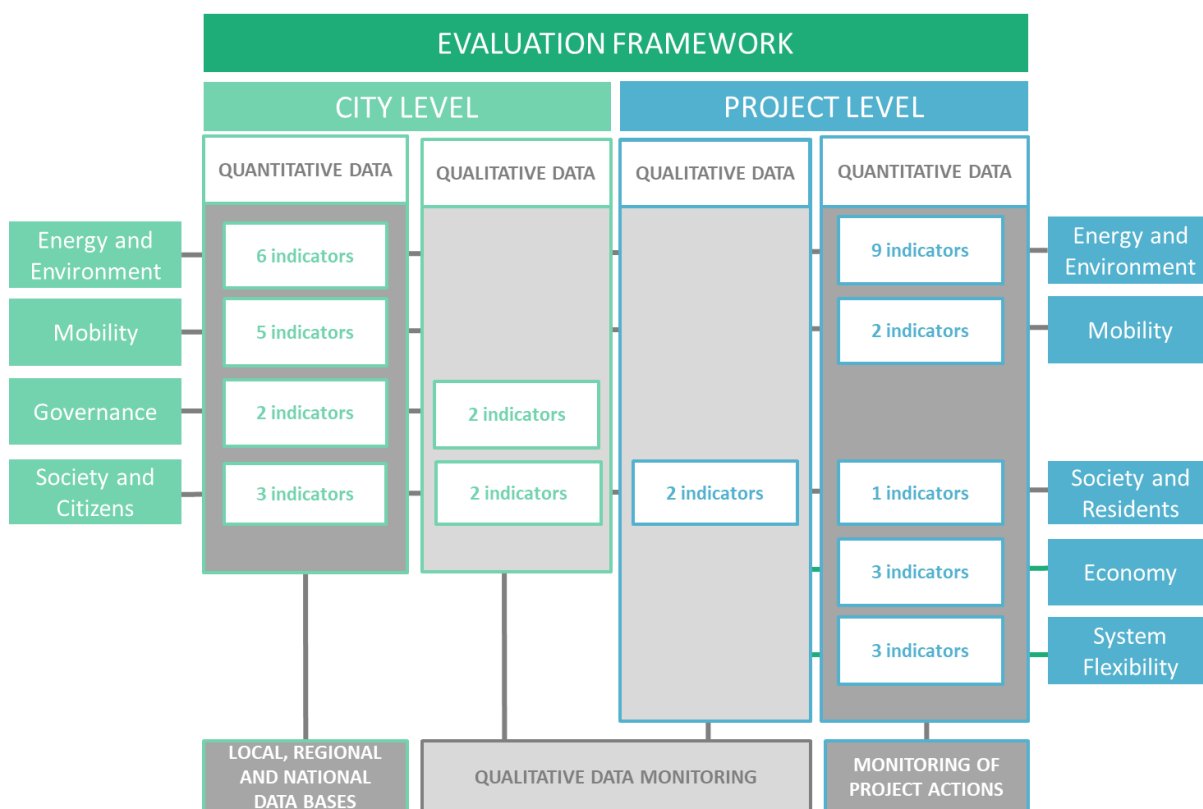
Figure 4: Classification of the defined indicators within the MAKING CITY evaluation framework

Although most of the indicators defined in the evaluation framework are quantitative, it should be mentioned that six of the proposed indicators are qualitative, so in these cases a specific methodology to obtain this information will be applied. More details about this methodology can be found in section 4.

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 is 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 must 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.

2.2 Description of the PED actions

Project actions have been divided into four main categories (as described in DoA): **High performance buildings**, **Renewable energy systems online**, **Other technical actions** and **Non-technical actions**. The tables below break down the individual actions planned for PED areas in Oulu and Groningen.

At this point it is important to notice that some of the individual actions are subject to possible change or they can be re-defined during the course of the project. Hence, in the comprehensive evaluation process, it is more reasonable to concentrate on larger action categories and applications areas, and not so much on single actions. In many cases, it is not feasible to monitor actions at individual level, as they are usually part of some larger complex or entity, e.g. actions related to building retrofitting.

2.2.1 Oulu

Table 3: Actions related to high performance buildings in Oulu

HIGH PERFORMANCE BUILDINGS	
Action group	Related actions
Residential buildings retrofitting	A1: Residential building 1 (new insulation windows) (SIV)
New high-performance residential buildings	A8: Residential building 2 (SIV) A15: Residential building 3&4 (YIT)
New tertiary building	A19: New Arina mall (building 5) (ARI)
Smart building/ home energy controllers	A5: smart control in building 1 (VTT) & A13: smart control in building 2 (VTT) A7: visualisation units to study human behavior in building 1 (UOU) A14: visualisation units to study human behavior in building 2 (UOU) A26: wireless advanced control in Arina (VTT) A35: control system in local heating plant (OEN)

Table 4: Actions related to renewable energy systems onsite in Oulu

RENEWABLE ENERGY SYSTEMS ONSITE	
Action group	**Related actions**
Solar PV panels	A9: 10 kWp in building 2 (SIV) A23: 50 kWp in Arina (ARI) A30: 71 kWp in power plant (OEN)
Solar Thermal panels	A24: Hybrid heat collector in Arina (high pressurised CO2) (JET)
Heat pumps	A21: CO2 based heat pump in Arina (very high-performance COP 6) - 260 kW (ARI) A31: Advanced heat pump in the local heating plant (high COP 3.5) - 250 kWth (OEN)
Geothermal	A20: Geothermal energy in Arina (ARI)
Energy storage	A3: Phase transfer liquid heat tank in B. 1 – 200 kWh (SIV) A11: Phase transfer liquid heat tank in B. 2 – 200 kWh (SIV) A22: Phase transfer liquid heat tank in Arina – 300 kWh (JET) A28: Seasonal storage in Arina – 150 kWh (ARI) A33: Phase transfer liquid heat tank in local heating plant – 500 kWh (OEN)
Waste recovery	A2: Heat recovery system from AC and sewage water in building 1 (SIV) A10: Heat recovery system from AC and sewage water in building 2 (SIV) A16: Heat recovery system from AC in buildings 3&4 (YIT) A25: Heat recovery system in Arina (ARI) A32: Heat recovery from return pipeline to DHW (OEN)

Table 5: Other technical actions - Oulu

OTHER TECHNICAL ACTIONS	
Action group	**Related actions**
Building energy connectivity sharing	A4: Connection of building 1 to the DH (SIV) A12: Connection of building 2 to the DH (SIV) A17: Connect. of buildings 3&4 to the DH (YIT) A34: High speed data transfer network (VTT)
Impact on grids of EV charging points	A6: eCar parking in building 1 (SIV) A27:5 charging points for eCars in Arina (ARI)
IoT – Monitoring	A36: Smart lighting, power LED (OUK)

	A37: LoRa (Long Range) wireless network and activity sensors to optimize the lighting level (OUK)
District heating and cooling facilities	A29: Low-Temp regional transfer pipeline (OEN)

Table 6: Non-technical actions - Oulu

NON-TECHNICAL ACTIONS	
Action group	**Related actions**
Policy innovation	A38: New 2050 Oulu Vision (OUK) A39: SECAP monitoring and update of actions (OUK) A40: City Policies Update: taxes, subsidies (OUK) A41: Single window/desk for energy retrofitting (OUK) A42: PED Renaissance Strat. (OUK)
Business models	A43: Shared private-public investment models for sustainable energy consumption & production (ARI) A44: Business model for charging stations (OEN) A45: Energy efficient design of the real estate (VTT) A46: Smart City Crunching. Hackathon (OUK) A47: Demand management living lab (VTT)
New regulations / Standards	A48: Assessment of legal barriers & Solutions (OUK A49: Standardization of PED and energy balance in districts (OUK)
Social awareness actions	A50: Citizen and stakeholder engagement (OUK) A51: Education, Co-design and Co-creation in Oulu (OUK) A52: Local toolkit for renewable energy production and storage at the district scale (VTT) A53: Local toolkit for development of Near Zero Emission Buildings (VTT) A54: Thermographic and energy production mapping or end-user's engagement (OEN)
Capacity building actions	A55: City mentoring (OUK) A56: Policy forum on energy transition (OUK) A57: Collaboration with Covenant of Mayors Office to communicate SECAP experiences (OUK)

2.2.2 Groningen

Table 7: Actions related to high performance buildings in Groningen

HIGH PERFORMANCE BUILDINGS	
Action group	**Related actions**
Residential buildings high performance retrofitting	**NORTH** A1: Retrofitting of two multi-owner residential buildings- Nijeestee (7,400 m2) (NIJ) A2: Retrofitting of three terraced private houses (360 m2) (GPO)
New high perf. residential buildings	**SOUTHEAST** A3: New Powerhouse apartments (7,800 m2) (WAM)
Tertiary build. high perf. retrofitting	**SOUTHEAST** A4: Retrofitting of the office building Mediacentrale (14,400 m2) (WAM)
New high-performance tertiary build.	**NORTH** A5: New high-performance Energy Academy Europe (9,636 m2) (RUG) **SOUTHEAST** A6: New high-performance Sport Complex Europahal (5,315 m2) (GRO)
Smart building/home controllers	**NORTH & SOUTHEAST** A7: Advanced energy metering (SB, RUG) A8: Demand response/Smart Grid (CGI, RUG) A9: HeatMatcher for Nijeestee (TNO) A10: HeatMatcher for Mediacentrale (TNO)

Table 8: Actions related to renewable energy systems onsite in Groningen

RENEWABLE ENERGY SYSTEMS ONSITE	
Action group	**Related actions**
Solar PV panels	**NORTH** A11: PV in roofs and parking lot (600 kWp) (NIJ, GPO, WAR, GRO) A12: BIPV in Nijeestee (52.5 kWp) (NIJ) A13: BIPV in terraced houses (0.51 kWp) (GPO) SOUTHEAST A14: BIPV in Powerhouse (60 kWp) (WAM) A15: Floating solar pontoons (156 kWp) (GRO) A16: SolaRoad (70 kWp) (GRO)
Solar Thermal panels	**NORTH** A17: PVT in Nijeestee (50 kWp) (NIJ) A18: PVT in terraced houses (1.76 kWp) (GPO) A19: Ridge boiler in terraced houses (GPO) SOUTHEAST A20: PVT in Sport

	Complex (54.8 kWp) (GRO) A21: PVT in Mediacentrale (31 kWp) (WAM) A22: PVT in Powerhouse (54.8 kWp) (WAR))
Heat pumps	**NORTH** A23: Acoustic Air heat pump in terraced house (20 kW) (GPO) A24: Acoustic Hybrid heat pump in terraced house (5 kW) (GPO) A25: Geothermal heat pumps for Nijeestee (20 kW) (NIJ) SOUTHEAST A26: Geothermal heat pumps for Mediacentrale (45 kW) (WAM)
Geothermal	A27: Geothermal District Heating (GRO)
Energy storage	**NORTH:** A28: Neighbourhood electro storage facility-(600 kWh) (NIJ) A29: Thermal storage in Nijeestee (NIJ) **SOUTHEAST** A30: Thermal storage in Mediacentrale (WAM)
Waste recovery	**SOUTHEAST** A31: High pressure wastewater digester (250,000 kWh/yr) (GRO)

Table 9: Other technical actions - Groningen

OTHER TECHNICAL ACTIONS	
Action group	Related actions
Buildings energy connectivity, energy sharing	**NORTH & SOUTHEAST** A32: Modelling, simulation, adapting & validation of planned innovations (TNO)
Impact on grids of EV charg. points	**NORTH & SOUTHEAST** A33: 14 Smart charging stations (GRO) A34: Connection of the charging stations to the local demand response system (CGI)
ICT urban platform adaptation	A35: Open urban platform adaptation (GRO)
IoT – Monitoring	A36. Energy data monitoring of PED (CGI) A37: Integration of new services to the data platform (CGI) A38: Installation of IoT infra (TNO)
District heating &cooling facilities	**NORTH** A39: Adjust geothermal district heating for using low temperature (WAR) **SOUTHEAST** A40: Connection to the low temperature district heat (WAR)

Table 10: Non-technical actions - Groningen

NON-TECHNICAL ACTIONS	
Action group	Related actions
Policy innovation	A41: New 2050 Groningen Vision (GRO) A42. SECAP monitoring and update of actions (GRO) A43: City Policies Update (taxes, subsidies) (GRO) A44: Deployment and evaluation of energy zoning plans (GRO)
Business models	A45: Innovative business models development for PED (e.g: Energy Cooperative) (SEV, HUAS) A46: Open data business models (SEV, HUAS) A47: Blockchain. (CGI)
New regulations/standards	A48: Assessment of legal barriers & solutions (GRO) A49: Standardization of PED and energy balance in districts (GRO)
Social awareness actions	A50: Citizen social research (GRO) A51: Energy communities as part of the district energy transition strategy (GRO)
Capacity building actions	A52: City mentoring (GRO) A53: Policy forum on energy transition (GRO) A54: Collaboration with Covenant of Mayors Office to communicate SECAP experiences (GRO)

3 Indicator-based evaluation at project level

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 indicators will be aligned with project action in the following categories: **High performance buildings, Renewable energy systems onsite, Other technical actions** and **Non-technical actions**.

In the process of indicator-based evaluation, project level indicators will be utilized for tracking the overall progress of the demonstration areas, evaluating the outcome and impacts of the interventions and demonstrate the replication possibilities on the evolution of a city towards a smarter city.

3.1 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 must 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 regarding 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)

3.2 Alignment with existing knowledge on project evaluation procedures

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 (as the main reference) and CITYkeys, were selected as the starting point for the development of the evaluation protocols in MAKING-CITY, including indicators, monitoring and data integration approaches. In addition, other relevant smart city initiatives such as ESPRESSO, MAtchUP, mySMARTLife and Stardust, were taken into consideration as well.

The existing frameworks - starting from indicators - were 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

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

[2] https://civitas.eu

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

solutions between various projects. SCIS focuses on demonstration projects and not on entire cities. The defined indicators reflect this (SCIS, 2018a).

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 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).
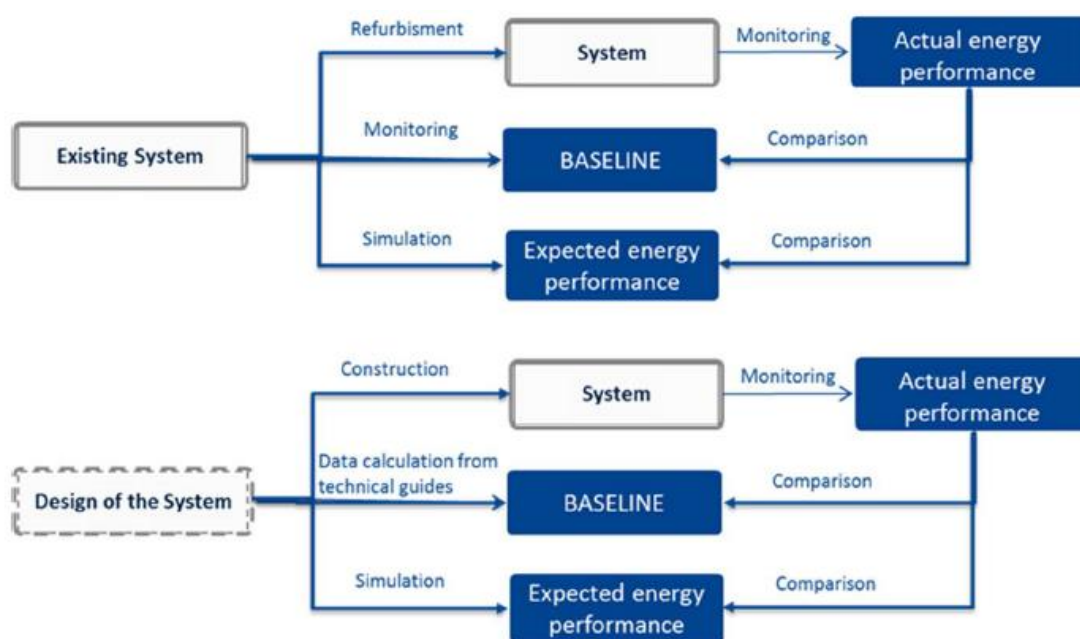
Figure 5: SCIS: Comparison of data on energy performance

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 can be found below.

For groups of buildings/systems SCIS highly recommends implementing a community energy management system (EMS) to facilitate data collection. Experiences and detected barriers in the project should be documented as lessons learned for future projects.

Chapter 4 of the SCIS Technical monitoring guide (SCIS, 2018c) provides instructions on what kind of data should be provided for various types of cases. This is supplemented by the SCIS Overview of required datasets (SCIS, 2018d), which lists the inputs to the SCIS reporting tool. These are categorized as follows for buildings and energy systems:

- General data on demo level includes environmental and climatic data (reported in reference, design and monitored values)

- General building data means technical information on the building, such as the floor area.

- Technical information on the building envelope mostly consisting of U-values

- General technical information for energy systems, such as energy output of the plant. For final energy generation, design and monitored values are reported.

- Energy carriers for the applied technologies (reference/baseline, design and monitored values)

- Economic information such as size of investment (reference, design and monitored values)

For mobility cases, the data is categorized as follows:

- Fuel consumption in public and private vehicles (before and after values)

- Kilometres of high-capacity public transport system (before and after values)

- Passenger-kilometres and vehicle-kilometres (before and after values)

- Number of efficient vehicles and e-charging stations

- Economic information such as size of investment (design and monitored values)

For ICT cases, the data is categorized as follows:

- Reliability meaning e.g. the number of power interruptions

- Integration meaning e.g. the level of demand response

- Consumers engagement meaning e.g. the number of final users

- Economic indicators such as the payback period

Energy in buildings and groups of buildings is measured in delivered energy. SCIS (2018c) uses definitions of the CEN standard EN 15603, accordingly energy performance of the building is the balance of:

- The delivered energy, which required to meet the energy needs and

- The energy that has been exported.

Delivered energy, as well as energy export, is defined as the energy that crosses the building boundary as is shown in Figure 6.

Figure 6: SCIS system boundary for building cases

For energy systems, the included issues are energy carriers, the energy supply and transformation units and the energy demand of the demonstration building or buildings. Energy flows must be presented. (SCIS, 2018c)
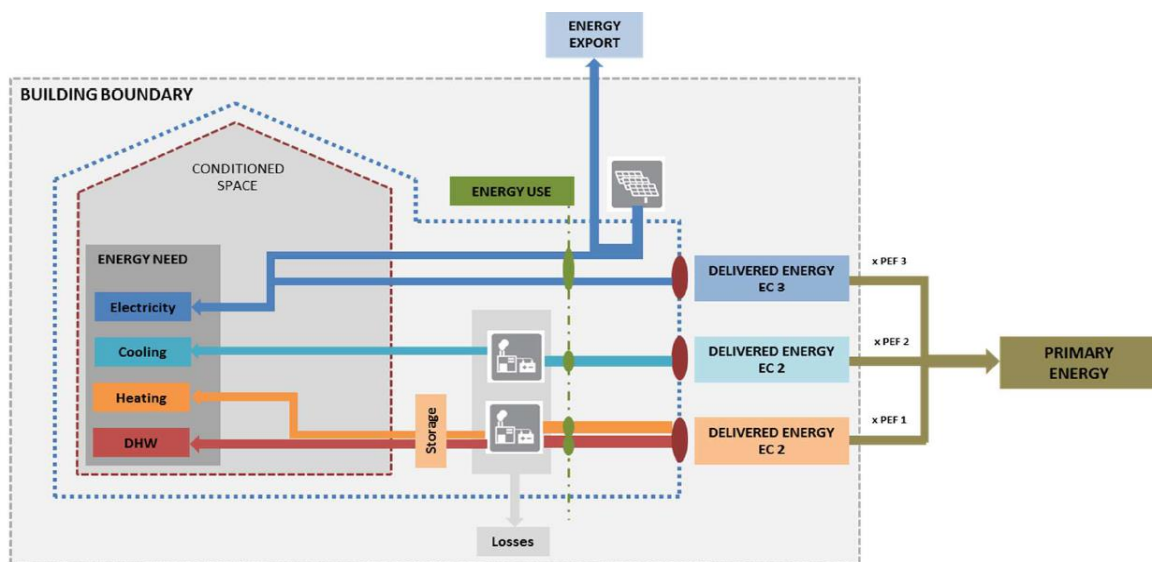
3.2.2 CITYkeys

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 can influence 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 regarding energy and CO_2 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 7): 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 7: The CITYkeys indicator framework

From the indicator frameworks and assessment methods mentioned above, we can select relevant indicators and evaluation protocols for MAKING-CITY, knowing that the developed methodologies serve policy goals of the project. In addition, it is needed to make further efforts to connect city and project level indicators to the same framework. The Logic-model introduced in section 2 can be used in determining which type of indicators are relevant and useful for both city and project level evaluation.

4 Procedure and methodology for the evaluation of PED performance in MAKING-CITY

4.1 Step I: Selection of Key Performance Indicators in accordance with PED actions

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**. On the other hand, project actions have been divided into four categories: **High performance buildings**, **Renewable energy systems online**, **Other technical actions** and **Non-technical actions**. The rough alignment of the indicators with the project actions to be monitored is presented in Figure 8.

The starting point for selecting project level KPIs has begun with analyzing the scope, objectives and focal target points of the project; what kind of indicators are needed to keep track on the performance of the PED areas, and what is most relevant in these cases. The next step was to analyze the BEST tables, the project objectives, and the list of PED actions and interventions, comparing them to the main reference indicators systems. In the comprehensive evaluation process, it is more reasonable to concentrate on larger action categories and applications areas, and not so much on single actions. In many cases, it is not feasible to monitor actions at individual level, as they are usually part of some larger complex or entity, e.g. actions related to building retrofitting.

Figure 8: Indicators aligned with the PED actions

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.

4.1.1 Energy & environment

Table 11: Energy indicators

PED Energy Profile		
Indicator	**Unit**	**Description**
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 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	kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	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	kWh/15min(/day); kWh/month; kWh/a; kWh/(m2month); kWh/(m2a)	The amount of electricity and thermal energy (district heating, gas and other sources) **imported to the PED area** from outside the PED boundaries.
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.
E5: RES production	kWh/month; kWh/a; % of final energy consumption	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	kWh/month; kWh/a; (surplus + or deficit -); %	The overall **primary energy balance of the PED** area considering demand-consumption, energy flows, storage, RES.
E7: Energy savings in the PED	kWh/(m2a); %	Total annual **saved primary energy in the PED** compared to situation without any interventions (baseline).

Table 12: Environmental indicators

Environmental effect		
Indicator	Unit	Description
E8: GHG emissions	kgCO2-eq/ (m2month); kgCO2-eq/(m2a) kgCO2-eq/(kWh a)	The GHG emissions (converted in 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	kgCO2-eq/a; %	**Reduction of CO2-eq. emissions in the PED area** achieved by the project actions and interventions.

4.1.2 Mobility

Table 13: Mobility indicators

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

4.1.3 Economy

Table 14: Economic indicators

Economic performance		
Indicator	Unit	Description
C1: Total investments	€/m2; €/kW(h)	How much money is invested in total to PED interventions. Subdivision of the sources (EU funding, (local) government funding, private investment by companies and other private investment.
C2: Payback time	Years	Economic payback period of (selected, most impactful?) investments.
C3: Economic value of savings	€ / saved kWh (or reduced kgCO2-eq)/a	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.

4.1.4 System flexibility

Table 15: Flexibility indicators

Performance based on flexibility		
Indicator	Unit	Description
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.
F2: RES 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.
F3: Peak load reduction	%; # of peaks (congestion), duration of peaks and size of peaks; MHDx maximum hourly deficit	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.

4.1.5 Social & Residents

Table 16: Social indicators

Social indicators		
Indicator	Unit	Description
S1: Energy poverty	% of households, or % share of income	Percentage of households by definition (described further in the Annex), or energy bill as % of total household disposable income.
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.).
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 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.

4.2 Step II: Baseline calculation

Baseline assessment refers to the procedure to assess the actual situation before the intervention takes place and which will be used to compare the effect of the intervention. This section provides general guidelines for assessing interventions within the technical application areas defined to be evaluated at project level (energy consumption, environmental effect, system flexibility etc.) which are intended to achieve either savings, to increase the share of renewable energy, or to gain other possible benefits that help PED areas moving towards the project objectives.

Baseline calculations differ depending on the application area. In each baseline calculation, the boundary for the analysis has to be clearly defined. For example, when the boundary of the analysis is at an existing building, a baseline refers to the actual situation before the refurbishment, when the intervention relates to improving the energy efficiency or service level of the building. For new building developments, the baseline refers to the business as usual practice, which can be derived e.g. from building regulations or by utilizing measured data from same type of buildings.

In these cases, methodologies such as IPMVP (EVO, 2012) can be directly applicable. IPMVP is a best practice methodology commonly used for measuring, computing and reporting savings achieved by energy efficiency projects at end user facilities. This protocol establishes how to perform the evaluation of e.g. energy savings by comparing measured consumption before and after implementation of energy actions making suitable adjustment for changes in conditions. IPMVP will be further discussed in section 4.4 as the methodology for executing the final impact assessment at the end of the monitoring period.

4.2.1 New buildings

For new buildings, there are no existing data to which against the comparison is made. Baseline shall be based on the energy performance of similar buildings without implementing the interventions mentioned in the project plan. One year of synthetic data will reflect the typical scenario. The data has to be calculated according to regulations, technical guides or similar projects. The calculation can be also simulated as will be done in some cases.

4.2.2 Renovated buildings

For refurbished buildings, it is essential to meter all the needed energy performance metrics before any renovation actions are made. In this case, baseline shall be pure metrics calculated from one year before renovation actions without weather corrections. This 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.

4.2.3 Calculation methodology and parameters

The detailed data needs and calculation specifications for some of the selected KPIs are not 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:

- 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)),
- D5.5 (Data sets: Requirements, collection and protection),
- D5.6 (Guidelines for definition of Monitoring Programmes),
- D5.7/D5.8 (Oulu & Groningen Monitoring Programmes),
- D5.10 (Data collection and KPI calculation)
- D5.11 (Evaluation (city level, project level))

The baseline situation of the demo-areas (before 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.

4.3 Step III: Monitoring the progress

Monitoring programme concentrates on monitoring all the incoming and outgoing energy flows for each building of the district and for the whole district separately. Monitoring must handle all the energy types that flows to building/district at own pipes separately (e.g. electricity from grid or thermal energy from district heating pipes or gas from gas pipes).

These are the main guidelines, but it is natural that in real life there might be deviations from this guideline. For example, it may be possible that not all the buildings can be monitored due to GDPR regulations or some buildings or public infra such as public lighting misses metering. However, if there occur any deviations from this main guideline, all the deviations should be documented.

4.3.1 Monitoring phases of quantitative data

SCIS Technical monitoring guide defines four monitoring phases (SCIS, 2018b):

1. Definition
2. Implementation
3. Monitoring
4. Voluntary long-term monitoring

Monitoring concept used in MAKING-CITY shall follow these phases, but it reformulates the third phase to cover also simulation of energy flows that cannot be directly monitored. There are two identified cases which prevents the direct monitoring. Firstly, there may be cases where in some buildings there are no possibility to install meters. Therefore, the performance of these buildings shall be simulated instead of real metering. Secondly, some energy efficient solutions planned in this project are based on intelligent control of energy systems that is not possible to be implemented for the whole monitoring period. Monitoring programmes for Oulu and Groningen will be described in D5.7 and D5.8.

Overall picture of monitoring phases is given in Figure 9. Next subsections shall cover the phases with more details.
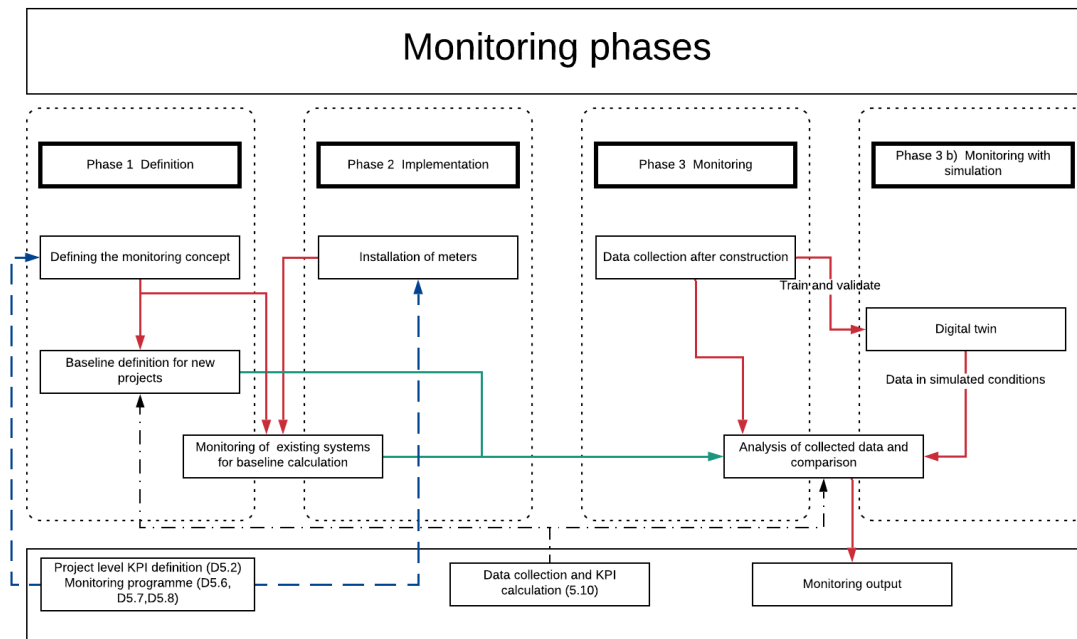
Figure 9: Monitoring phases of quantitative data.

4.3.1.1 Phase 1 - Defining the monitoring concept

In this step, it is fundamental to identify the requirements that are needed to calculate KPIs. Moreover, all the energy related KPIs are based on baseline. Therefore, setting baseline and calculating the baseline performance is essential part of this phase. Exact baseline calculations shall be presented in deliverables 2.2 and 3.2.

Baseline comparison mechanism depends on two separate issues. First, it depends on whether the building is a renovation building or a new one. Second, it depends whether system can be fully monitored, partially monitored or not monitored at all. If the system can be partially monitored, partial monitoring data is collected to form a simulation model (digital twin) of the system. After that, the digital twin is used to simulate the whole monitoring data.

These baseline comparison concepts for each of these cases are presented in the Figures 10, 11 and 12 below.
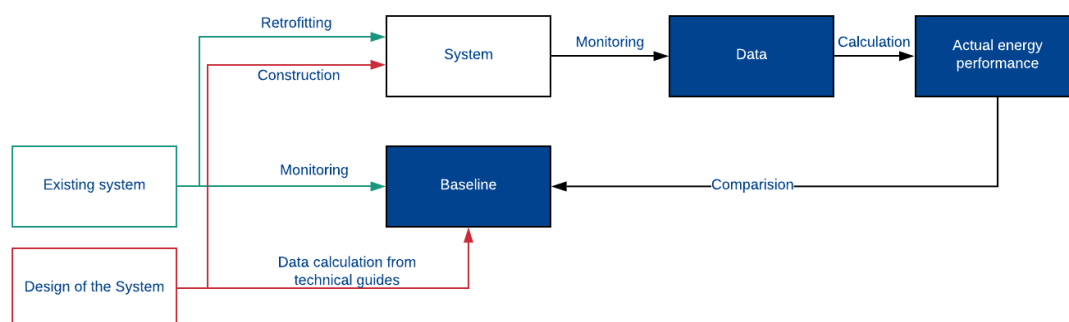
Figure 10: Performance validation when all the measures can be monitored. Green lines are present for retrofitting buildings and red ones for new ones.
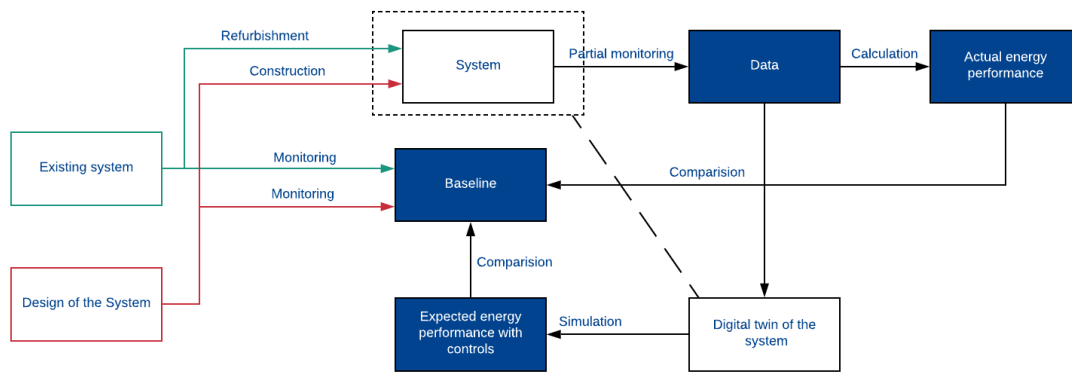
Figure 11: Performance validation when the system can only be partially monitored. Green lines are present for retrofitting buildings and red ones for new ones.
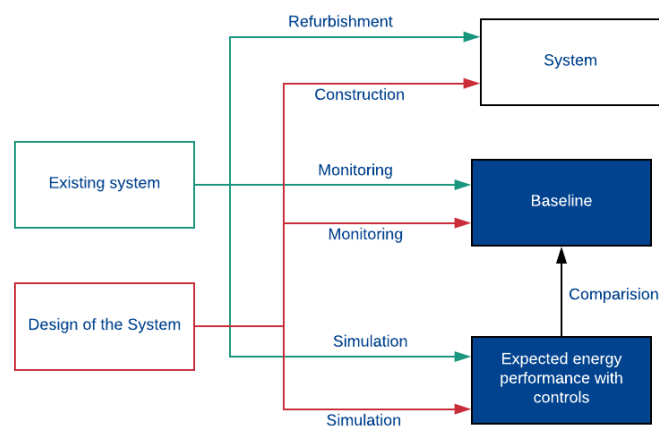
Figure 12: Performance validation if the system cannot be monitored due to missing meters. Green lines are present for retrofitting buildings and red ones for new ones.

Baseline assessment refers to the procedure to assess the actual situation before the intervention takes place and which will be used to compare the effect of the intervention. This section focuses on guidelines for specific interventions within the energy scope, which are intended to achieve energy savings or to increase the share of renewable energy once the boundary for the analysis is clearly defined. Baseline calculations differ whether we are dealing with a new or renovation building. In these cases, methodologies such as IPMVP (EVO, 2012) can be directly applicable. For example, when the boundary of the analysis is at the building a baseline refers to the actual situation before the refurbishment, when the intervention relates to existing buildings and to the business as usual practice (e.g. building regulations) for new building developments.

- For new buildings, there are no existing data to which against the comparison is made. Baseline shall be based on the energy performance of similar buildings without implementing the interventions mentioned in the project plan.
- For renovated buildings, it is essential to meter all the needed energy performance metrics before any renovation actions are made. In this case, baseline shall be pure metrics calculated from one year before renovation actions without weather corrections.

4.3.1.2 Phase 2 - Implementation

A different approach during phase 2 is applied to new constructions and to retrofitting projects:

1. Projects based on existing systems: The monitoring must start before the implementation of measures since real data from the existing system has to be collected for further comparisons for at least one year. Once this data has been collected and the construction and renovation measures start, the next steps are similar to new construction projects. It may also be possible that the requested data to calculate a KPI is available without new data collection pipeline.

2. New construction projects: From the monitoring concepts and requirements previously defined, a plan for the sensor installations must be prepared, based on the concept definition of phase 1.

There are three building blocks in monitoring architecture that need attention to get robust working monitoring implementation:

- Energy meters: Energy meters are the first part of data collection pipeline. For selecting the proper energy meters to be installed, an attention should be paid that the energy meters meet time and energy resolution specified in D5.5.
- Reading process: Reading process reads the meters and sensors and sends them to an external server. In this process, again attention needs to be paid to the meter and sensor reading frequency such that time resolution requirements are fulfilled.
- Server and Database: Finally, the collected data is saved to database in some server either in cloud or in own premises. The data collection pipeline should be monitored in the server such that data breaks would be noted with minimal delay and the reason identified and corrected as quickly as possible.

The real implementation may be totally different and more complex, but they most probably contain these building blocks in any case. Data collection pipeline does not work if any of these components fail.

4.3.1.3 Phase 3 - Monitoring

The objective of Phase 3 is to measure real energy performance for each individual building and the whole district. For KPIs the energy performance shall be monitored during two consecutive years. However, there are two cases identified that prevents direct monitoring:

1. In some buildings, metering equipment are not possible or feasible to be installed.

2. Some advanced energy optimization techniques require dynamic control of energy management system that is possibly be done only for very limited time frame.

These cases must be handled with indirect monitoring.

The following basic principles on monitoring the monitoring should be noted:

- Monitoring the monitoring process: The whole monitoring process should be monitored to get good quality of data. It is good practice to toggle automatic alarms to database such that if data flow stops to database engineers would get immediate feedback to solve the issue.
- Simulating the energy behaviour without monitoring: Description of simulations is needed in the case the buildings cannot be monitoring.

4.3.1.4 Phase 4 - Long term monitoring

It is recommended that monitoring would be continued also after the project phase. However, due to various reasons it may not be possible. If the monitoring is not continued after the project, the reasons shall be explained in deliverables D5.7 and D5.8.

4.3.2 Monitoring phases of qualitative data

Monitoring of qualitative data consists of the following phases (as depicted in Figure 13):

1. Context definition
2. Selecting the techniques, approaches, and tools
3. Collecting the data
4. Analyzing the data
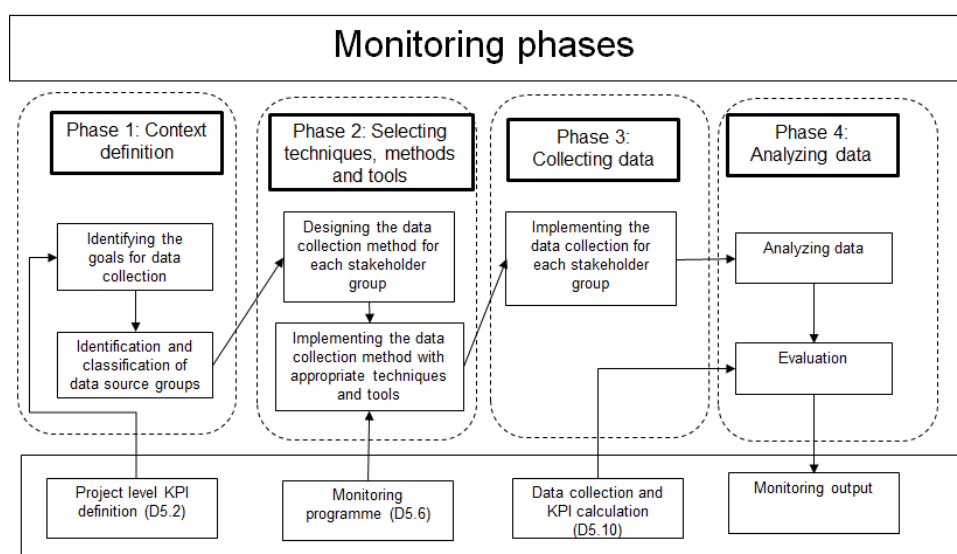
Figure 13: Phases and steps of qualitative monitoring.

4.3.2.1 Phase 1 - Definition of monitoring context

In the first phase, it is important to identify the requirements that are needed to reach the value for the indicators. Project level KPI definition (D5.2) document is used to assists in definition of goals for the data collection.

All the required data may not be able to be collected from the same data source. Therefore, it is important to identify all the required data sources. In the case of qualitative data, these data sources mean people, i.e. stakeholders, that are relevant in the context of the monitored target. Different kinds of stakeholders are classified to the different groups. For each group, the minimum and maximum number of stakeholders must be defined.

For each stakeholder group, the goals for the data collection must be defined.

The qualitative data indicators include:

S1: Energy poverty

S2: Consciousness of residents

S3: Resident engagement / empowerment to climate conscious actions

The data collection must obtain the data that is required to form values for these indicators.

4.3.2.2 Phase 2 - Selecting the techniques, approaches, and tools

The goals for the data collection for each stakeholder group (defined in the previous phase) guide the design of the content for the data collection. The selection of methods depends on a) the stakeholder groups, b) the amount of responses required, c) the ability to ask predetermined questions. Closed-ended questions have a limited set of possible answers, whereas open-ended questions enable respondents to describe their thoughts and opinions more freely. The questions enable to obtain data required for the calculation of the pre-defined indicators.

Surveys enable standardized data collection, ensuring that the same data is collected from each respondent. Surveys can be roughly divided into two categories: questionnaires and interviews.

- Questionnaires: Questionnaires provide an efficient way to collect information from multiple stakeholders quickly. They can force users to select from choices, rate something or have open ended questions allowing free-form responses.
- Interviews: There are three types of interviews - unstructured, structured, and semi-structured. In structured interviews, the analyst uses a predetermined set of questions. The success depends on knowing the right questions, when they should be asked, and who should answer them. In unstructured interview there is no agenda or list of questions. Semi-structured interview is a combination of the structured and unstructured.

Different kind of survey must be prepared for each stakeholder group. The survey must include a common part that is the same for all respondents, but some parts of the survey may vary, for example, due to the different regulations of different countries, different kind of situations in the cities, or different types of buildings/residents.

The questionnaire can be implemented in different formats:

- Questionnaire in PDF format
- Online form
- Online platform

Online form enables to reach the questionnaire easily through a direct web link. The link itself can be made available in several ways; through social media (Facebook/Twitter), websites and e-mails. A web-based questionnaire also enables to select the questions based on the answers; the next question is determined by the answer given. This kind of questionnaire also enables easy classification and reporting of results.

Generally, it is up to the cities to decide how they reach the residents for the data collection. Some cities may already have a technical platform to reach their people, and the people may already be familiar with it. All kind of residents may not be able to be reached via Internet. For example, older people may not have access to the Internet, they may not have a computer, or they cannot use or do not want to use smart phones. Reaching these people may be difficult. A printed questionnaire sent via traditional mail may be a better choice. A personal interview may also be an alternative. However, the interviews are often time-consuming.

4.3.2.3 Phase 3 - Collecting the data

The collection of qualitative data from the residents will be performed in 2 phases:

The first data collecting phase is implemented right in the beginning. The purpose is to research residents' current status, consumption behaviour, expectations, motives for changes in their behaviour, etc.

The feedback data collection is implemented in the later phase of the project, collecting detected and actual results; what are the concrete changes, how satisfied and pleased the people are and how succeeded the goals of the project were.

4.3.2.4 Phase 4 - Analyzing the data

Quantitative methods can be used to analyse the responses to the closed-ended questions (e.g. Yes/NO or numbers from 1 to 5), described as percentages or as numbers (Likert scale). The answers obtained from the open-ended questions can be analysed using qualitative data analysis methods, such as the constant comparative method, open coding, etc. For example, content analysis method (Bengtsson, 2016) enables to parse and present data in words and themes, and finally to identify the common characteristics among the responses. Data collection and KPI calculation (D5.10) document assists in achieving values for the qualitative indicators.

4.4 Step IV: Final calculation and impact assessment

Final calculation of indicators and impact assessment of the project interventions (post-intervention evaluation) will be performed at the end of the monitoring period of the project, by utilizing standardized evaluation methodology IPMVP (International Performance Measurement and Verification Protocol). For clarity, this section focuses on evaluating the improvements in energy efficiency. However, IPMVP can be also utilized for other application areas. Figure 14 shows an example of a baseline and its projection after the retrofitting has been finalized, showing higher theoretical energy use if the EMCs were not implemented, when compared to the measured energy use. Comparison is made for the same set of conditions, as the baseline energy has been adjusted correspondingly.
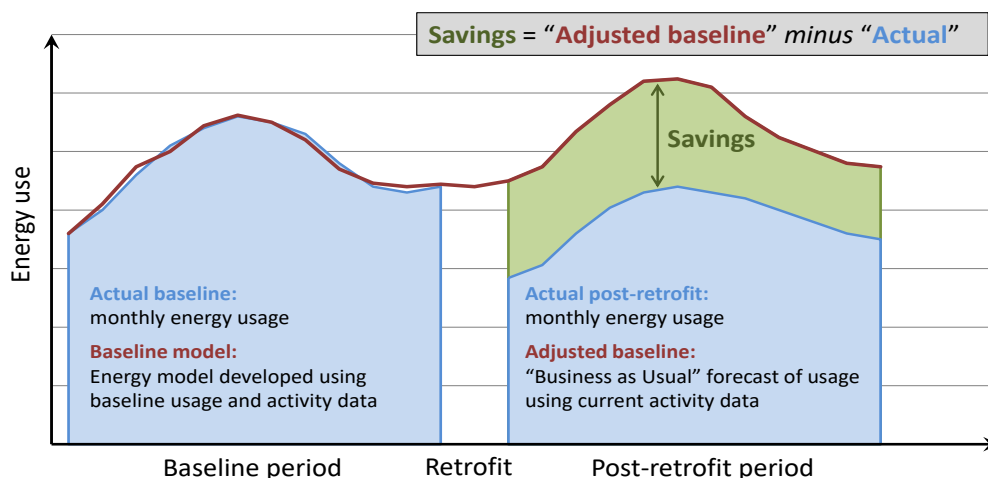
Figure 14: IPMVP evaluation method (EVO, 2012)

IPMVP is a "best practice" methodology commonly used for measuring, computing and reporting savings achieved by energy efficiency projects at end user facilities. This protocol establishes how to perform the evaluation of energy or other savings by comparing measured consumption before and after implementation of the actions/interventions making suitable adjustment for changes in conditions. Thus, the period prior to the implementation of the improvement measures is selected and the current situation is measured in order to define the "baseline period". Once these measures are applied, a suitable period of time is determined, and the energy use is once again measured in order to define the "post-retrofit" performance period. Then, the comparison of baseline period and reporting period is done following this general M&V equation:

$$\text{Savings} = \text{Baseline period energy} - \text{Reporting period energy} +/- \text{Adjustments}$$

The adjustment term shown in the equation should be computed from identifiable physical facts and in this case, proceed to perform an adjusted of the baseline energy.

Appropriate adjustments shall be done by taking into account changes in the existing conditions and calculate the Adjusted-baseline Energy. Adjustments include routine adjustments and non-routine adjustments.

Routine adjustments refer to the so-called Independent Variables, which are parameters expected to change regularly and have a measurable impact on the energy use of a system or facility. The most common independent variable related to building energy consumption is the outdoor temperature; other variables include building occupancy and schedule. Routine-adjustments are usually done by developing valid mathematical models including factors derived from regression analysis correlating energy to one or more than one independent variables, such as outdoor temperature, degree-days, occupancy, etc.

Non-routine adjustments refer to the so-called Static Factors, which have an influence in the energy consumption but are not usually expected to change. In the case of buildings, such Static Factors can include:

- Amount of space that is heated or air conditioned.
- Building envelope characteristics, such as new insulation, windows, doors, air tightness, etc.
- Changes in the equipment of the building (type, amount, or its use profile).
- Occupancy profiles.
- Indoor environmental conditions, such as temperature and humidity set points, light levels, ventilation rate, etc.

4.4.1 Post-intervention evaluation

The evaluation of the technical objectives at project level will be done taking the technological monitoring guide from SCIS as the main reference, whereas the approach to evaluate energy savings is based in Measurement and Verification (M&V) concept. Additionally, IPMVP has been chosen as reference for setting energy performance in buildings and energy infrastructures. To proceed successfully to the final evaluation of all the categories defined in the project level, it is required to follow the evaluation steps described in this deliverable.

The definition of the objects of assessment is a crucial step since they will be the functional units on which to measure the improvement. They can be defined for a single building, a set of buildings, an energy supply unit, a set of energy supply units as well at neighborhood/city scale. To define these boundaries, it is important to identify the energy carriers used as well as the energy supply and

transformation units that cover the energy demands of the demonstration area and the exported units.

Another crucial step is to establish a baseline for evaluating the change and the improvement on the system due to the energy efficiency measures. Baseline is defined as an agreed set of parameter values describing the system and its ex-ante KPIs.

A first set of calculated KPIs will be obtained as an outcome of this baseline definition, in order to be further compared with the KPIs obtained from the monitoring process for the post-intervention assessment. Consequently, the baseline must gather, whenever possible, the same parameters that will be measured in the monitoring phase to ensure verifiable post-intervention process. Specific M&V plans are required to be developed in each demo-site in order to adapt the IPMVP protocol to each building, energy system or the entire district.

Monitoring data for post-intervention evaluation is required preferably for at least two years in order to demonstrate the energy performance and other impacts of the implementation area. Therefore, it is important to collect all sampled data at the same time period in a consistent way. During the first year of monitoring, the data collection process is important for the analysis and optimization of the operating system. Afterwards it is possible to check the actual consumption against expected, calculated data and to analyze and evaluate the energy performance.

In case of refurbishments it is possible to compare the data collected/metered before refurbishment against the data metered after refurbishment. On other hand, climate factors shall be monitored by metering equipment at a proper rate. These datasets should be collected for baseline and during the monitoring period for the post-intervention evaluation.

Finally, after the monitoring period has been completed, the final evaluation and impact assessment will be carried out and reported in Deliverable 5.11 - Evaluation (both city and project level).

Conclusions

In the process to become a smart city, establishing reliable metrics for the smart city project is in a key role 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 evaluation 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, CITYkeys, 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 evaluation of smart city actions across the cities.

The project level evaluation framework consists of key performance indicators selected for evaluating the actions made in the demo areas on short- and medium-term. The project level can be considered as more technical than the city level concentrating not only assessing the level of sustainable energy planning but also the execution of the interventions in the PED areas. The evaluation procedure describes the methodology to assess project actions with the defined indicators. It consists of four steps:

- **Step I**: Selecting and defining the project level indicators in accordance with the PED actions, setting the objective for monitoring and impact assessment.

- **Step II**: Defining the baseline situation of the PED and calculating the indicator values at the beginning of the project (before the planned project level interventions).

- **Step III**: Monitoring the actions/action groups with key performance indicators during the monitoring phase of the project (following the indicators for the evaluation of progress).

- **Step VI**: Final calculation of the indicators at the end of the project for the final evaluation and impact assessment, where final values are obtained both per category and per application field.

This deliverable provides the methodological guidance for the evaluation procedure step by step on a general level. It aims to describe the process for post-intervention evaluation concentrating on the project level actions and indicators (KPIs) that have been established and aligned in cooperation with the two Lighthouse cities.

Starting from the definitions and links between smart city and smart city projects, indicators were selected as the backbone of the evaluation protocol for tracking the progress, assessing the impacts 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) will be incorporated into SCIS database.

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Annex A: Detailed description of the PED actions

Oulu

HIGH PERFORMANCE BUILDINGS	
Residential buildings high performance retrofitting	
Action 1: Residential building 1 (Sivakka) new insulation windows.	Leader: SIV The building is a rental house, currently populated, and includes 56 apartments distributed in 7 floors and the basement. The total area is 2,900 m2 and the volume is 8,930 m3. The energy consumption before the renovation is 414 MWh/year (357 MWh for heating and 57 MWh in electricity). The retrofitting actions will focus on the building envelope within new insulation windows. The annually estimated energy consumption after this renovation is 240.7 MWh (heat+electricity), which means 83 kWh/m2yr, below the Finnish goal of 140 kWh/m2yr for renovation buildings.
New high performance residential buildings	
Action 8: Residential building 2.	Leader: SIV A new rental building will be constructed (total area 5,300 m2), consisting in 50 apartments distributed in 7 floors. It will be built according to the latest energy specifications, so the annually estimated consumption is 414.3 MWh (heat+elecricity), which means 78 kWh/m2yr, large below the Finnish reference for category C buildings (120 kWh/m2yr).
Action 15: Residential buildings 3&4.	Leader: YIT 2 new residential buildings will be built according to the latest regulations. The 2 buildings will be equal and include 45 apartments distributed in 7 floors with an area of 2500 m2. Annually estimated consumption is 197.5 MWh (heat+elecricity), which means 79 kWh/m2yr, large below the Finnish reference for category C buildings (120 kWh/m2yr).
New high performance tertiary buildings	
Action 19: New Arina mall (building 5).	Leader: ARI The shopping mall will be commissioned by October 2018 and will be built to meet very low 228.5 kWh/m2yr total consumption. It will have a total area of 2,000 m2, distributed in a single floor. The Arina will have a singular heating and cooling system based on heat pump and geothermal energy, connected to the district heating, with a thermal energy storage tanks (phase transfer liquid) and PV panels in the roof. A special type of low temperature hybrid heat collectors will provide extra heat even in cold winter temperatures. The mall also houses an advanced control system based on wireless sensors and charging points for eCars.
Smart building/home energy controllers	
Actions 5&13: Smart control in buildings 1&2.	Leader: VTT The buildings will be fitted with a wireless sensor network which monitors indoor air quality (Temperature, humidity, CO2, pressure) and operates heating, ventilation and lighting. It also monitors the energy consumption (heat and electricity) and operates as a demand response control unit. The data from the consumption will be collected to a common database with the local high speed network (Action 34).

Action 7&14: Visualisation units to study human behavior regarding the Energy consumption in buildings 1&2.	Leader UOU 106 display modules (PDA) will be installed in buildings 1&2 to assess how human behavior is affected by different information from the system. People living in the SIV buildings will have very comprehensive information of the local resources and energy balance. The assessment of human behavior in terms of energy usage from both groups of people will be carried out.
Action 18: Smart control in buildings 3&4.	Action 18: Smart control in buildings 3&4. Leader: VTT The buildings will be fitted with a wireless sensor network which monitors indoor air quality (T, humidity, CO2, pressure). The control system will optimize the energy consumption (heat and electricity) and also collect necessary data for verification and performance analysis with the local high speed network (Action 34).
Action 26: Wireless advanced control in Arina.	Leader: VTT The Arina (Action 19) will be fitted with a wireless sensor network which monitors indoor air quality (T, humidity, CO2, pressure) and operates heating, ventilation and lighting by means of a smart power management unit.
Action 35: Control system in local heating plant.	Leader OEN The control system of the local heating plant is combining the heat production on site with the production available from the Arina (Action 19). It also manages the storages on different buildings and makes production planning taking in the weather information and estimated consumption of the inhabitants on the area. The heat production can be adjusted to match to consumption or if needed a surplus heat can be delivered also outside the area.

RENEWABLE ENERGY SYSTEMS ONSITE	
Solar PV panels	
Action 9: 10 kWp in building 2.	Leader: SIV 10 kWp PV panels will be made by new materials (flex cell). They will be installed on the roof of the building 2 (Action 8). Flex cell is an innovative material developed by VTT. During the MAKING-CITY Project, the durability and production capacity of this material will be tested on the site.
Action 23: 50 kWp in Arina.	Leader: ARI 50 kW of conventional silicon crystal panels (275 m2) will be used to supply power to the CO2-based high-efficiency heat pump in Arina (Action 21).
Action 30: 71 kWp in power plant.	Leader: OEN 71 kW of conventional silicon crystal panels (400 m2) will be assembled to supply electricity from RES to the local heating plant (Action 31).
Solar Thermal panels	
Action 24: Hybrid heat collector in Arina.	Leader: JET Low temperature heat collectors will be used in Arina (Action 19) to collect heat even from very low temperatures (-20ºC). The normal vacuum tube type of heat collector is able to harvest energy only when the sun is shining. A new type of heat collector is using high pressurized CO2 to collect heat also in the night time. The new collector is made by open end technology and can collect heat from radiation and from surrounding air. This type of heat collector is

efficient because it collects energy 24 hours a day.

Geothermal

Action 20: Geothermal energy in Arina.	Leader: ARI In Arina (Action 19), heat dwells are located under the parking area (Action 28). During summer, the heat in the dwells is increasing by 20ºC (up to 20 - 25ºC) and this temperature is needed in the winter period. The heat pump system is able to take back the heat with a good COP down to +10ºC. This temperature is reached in January - February. From February onwards extra heat is also available from solar heat collectors (Action 24) on the roof of the supermarket.

Heat pumps

Action 21: CO2 based heat pump in Arina.	Leader: ARI In Arina (Action 19), a very innovative 260 kWth heat pump will use CO_2 instead of Freon, achieving COP 6. Compared to conventional heat pumps based on Freon, CO_2 is a better environmental option and has also good properties for the system (not aggressive compound, cheap, lower vapour temperature). The only problem related to the use of CO_2 is the higher pressure in the system up to 100 bars. This means that all components in the cooling systems must be redesigned and tested properly.
Action 31: Advanced heat pump in the local heating plant.	Leader: OEN The heat pump system (250 kWth) is matched to give a very high COP of 3.5 on the specified temperature range. Heat pumps are not doing very well over a range of 60ºC rise between input and output. This is avoided by dropping the secondary circuit temperature to 60ºC and working over the comfortable 30 - 40ºC temperature difference in the primary circuit. The heat pump is optimized to operate on this narrow temperature range and thus gives very good efficiency rate. The input is coming from the cold water return pipeline of the regional heating (Action 32).

Thermal energy storage systems

Actions 3&11: Phase transfer liquid heat tanks in buildings 1&2.	Leader: SIV In building 1 (Action 1) and building 2 (Action 8), heat tanks are planned to have a capacity of 200 kWh (delta T 50ºC). The volume of this kind of heat tank with water is typically 3500 L. The temperature range for operation is from 30ºC to 80ºC and this makes the use very difficult. In MAKING-CITY Project, conventional water will be replaced by a fluid with a phase transfer temperature of 60ºC, so the whole capacity of the heat tanks will be available on a narrow temperature range (from 55ºC to 65ºC). This makes these components an ideal solution to be used together with heat pumps and low temperature heat distribution networks.
Action 22: Phase transfer liquid heat tanks in Arina.	Leader: JET In Arina (Action 19), a phase transfer liquid heat tank will have a capacity up to 300 kWh (5000 L). The operating temperature is between 50ºC - 60ºC. This tank is used together with the heat pump (Action 21) and high pressure heat collector on the roof (Action 24). The heat tank is reducing the peak capacity for heat and also serves as a short term storage in 24 hours operating cycle. It will also reduce the duty cycles of heat pumps in the winter time when they are used for heat generation.
Action 28: Seasonal	Leader: ARI Heat dwells are located under the parking area of Arina (Action 19). There are 10 dwells and 250 m deep. Each dwell can supply about 10-15 kWh

storage in Arina.	making the peak up to 150 kWh. The storage capacity is about the same, but the long term capacity depends of the soil & structure (sand, clay, rock etc.). A pipeline connects these dwells to the supermarket cooling/heating system. The cooling energy of the freezers and cold storages (i.e. heat) is used in the heating of the building when this is needed. If heating is not necessary, this energy goes to the surrounding buildings with the LT regional heating pipeline. If this heating is not needed the heat is stored either in the (local) heat tanks for short storage or to the heat dwells for long term storage. The supermarket has got a heat surplus for 10 months of the year. During the coldest winter period the heat dwells are used to give extra boost to the heating system of the building.
Action 33: Phase transfer liquid heat tank in local heating plant.	Leader: OEN The local heating plant (Action 31) will have a local storage for heat (estimated capacity 500 kW). This storage can be used in several ways. In spring and autumn the heat pump will operate with solar power and produce heat. The extra heat not consumed in the daytime can be stored and fed into the system in the night. This storage works together with the other storages in the buildings (1, 2 and 5). In the summer the power plant can also feed energy to the neighbouring areas. The other option is to stop heat generation and feed the solar energy (electricity) to the buildings. In this scenario the Arina supermarket (Action 19) is feeding the heat to the pipeline
A Waste heat recovery	
Actions 2&10&16: Recovery system from AC and sewage water in buildings 1 to 4.	Leader: SIV (A2&A10), YIT (A16) The heat recovery system from AC and sewage water will be based on heat pump technology. Estimated net energy saving is 2-3 kW of heat /apartment daily and this heat can be used to domestic hot water or heating.
Action 25: Heat recovery in Arina.	Leader: ARI The heat recovery system in Arina (Action 19), is based on combined cooling/heating cycle. When cooling the cold storages the heat pump produces heat equal to the amount of cooling + electricity used for the pump operation. This energy is not evaporated to open air but is used for heating and hot water production. When needed, the heat energy is stored to the heat dwells. It can be restored in the winter time when extra heat is needed in the building.
Action 32: Waste heat recovery from return pipeline to DHW.	Leader: OEN Combined with Action 31, heat recovery is done by using the return pipeline of the regional heating. This pipeline carries the cold water back to the thermal power plant of the city. The water temperature is low but it still contains energy. The water is led through a big low temperature heat exchanger and heat pump primary input is connected to this. The same technique can be used to harvest energy from seawater of river if there is one nearby

OTHER TECHNICAL ACTIONS	
Buildings energy connectivity for energy sharing	
Actions 4&12&17: Connection of buildings 1 to 4 to the DH.	Leader: SIV (A4&A12), YIT (A17) Low temperature heat exchangers will be installed in the buildings to provide the connection to the LT local pipeline. If these components fail, the buildings would be cold in winter and there will not be sufficient amount of domestic hot water. Local heat storages in buildings 1 and 2 (Actions 3&11) will be installed to prevent this situation, cut down the peak load and offer recovery time for the heat distribution system.
Action 34: High speed data transfer network.	Leader: VTT This network will cover the whole area, it is used both for control and data aggregation. The data network will be used in order to control both electricity and heat management. It also serves the people by delivering online data of the energy balance thus improving the energy awareness of the inhabitants (Actions 5, 13, 18 and 26). Third function of this network is to store data for learning, verification and documentation purposes.
Impact on grids of EV charging points	
Action 6: eCar parking in building 1.	Leader: SIV In building 1 (Action 1) the eCar parking area is having 10 charging stations for eCars. The facility will be located in the close walking distance from SIV and YIT buildings. Half of these are reserved for public use (car sharing and eCar charging) others can be rented for eCar private owners who need a parking facility. SIV will be responsible to build the parking facility and OEN to build the charging stations and taking care of the facility and management. The facility will be part of the local energy system. Local electricity will be used to charge when possible.
Action 27: 5 charging points for ECars in Arina.	Leader: ARI 5 eChargers for public cars will be deployed in the Arina (Action 19). The charging points are mid speed, which means that a normal eCar having 30 kW battery capacity can be charged in 3-4 hours.
IoT – Monitoring	
Action 36: Smart lighting, power LED.	Leader: OUK A new lighting system of the area will be installed in order to reduce the energy consumption. The technology deployed will be high power LED. The lighting control will be smart, so it will dim the lighting scene when no activity is detected on the area. Power supply may cut down to 50% of the maximum. Ambient lighting sensors are also used to keep track on the daylight so the lighting will adapt to the daylight as well.
Action 37: LoRa wireless network and activity sensors to optimize the lighting level.	Leader: OUK Power LED will be combined with smart lighting controller using LoRa (Long Range) wireless network (50 controllers) and activity sensors (50 units) to optimize the lighting level in evening and night time. LoRa based sensor network is used to have seamless control over the "private" and city owned lighting systems. The idea is to send control signals over the area to ensure safe travel and adequate level of lighting in all circumstances. Wireless activity sensors will also be used to provide intelligent control for the lighting
District heating and cooling facilities	
Action 29: Low Temp regional	Leader: OEN This system, that will operate with Action 31, uses lower temperatures (<60ºC) compared to regional heating (<110ºC) in heating and hot

transfer pipeline.	water production. Lower temperature means better economy in production, less losses in distribution and lower cost in building the distribution pipelines (plastic instead of steel piping). Using the lower temperature will also improve the COP of heat pumps. The extra investment in supplies (more powerful heat exchangers – Actions 4, 12 and 14), heating system) is paid back by the savings in energy cost.

NON-TECHNICAL ACTIONS	
Policy innovation	
Action 38: New 2050 Oulu Vision.	Leader: OUK Oulu will face the challenge of developing the long term 2050 vision, to guarantee a seamless city transformation, from planning to implementation and further upscaling. Working with this 30-years-ahead plan will require the use of appropriate tools to support the city in the planning process, in the implementation and in the evaluation and monitoring phases throughout their whole plan's lifetime. In order to better organise cities' activities, a specific Oulu Urban Planning department will be proposed in advance, to foster internal coordination. Once created, the extended tools for modelling the demand-side and supply-side in combination with impact estimation procedures will be integrated in the decision making procedures.
Action 39: SECAP monitoring and update of actions.	Leader: OUK Oulu is the only Finnish city that has signed the Covenant of Mayors, Mayors Adapt and Covenant of Mayors for Climate & Energy. Furthermore, Oulu is one of the first 21% of European cities with results already monitored (report in year 2017). Oulu Municipality is committed to continue the process of monitoring and updating their brand new SECAP, following the commitments acquired to the new CoMs for Climate and Energy. This monitoring and update will be based on the monitoring of the actions and the Upscaling plan respectively. All the insights acquired during this process will be shared with CoM Office.
Action 40: City Policies Update: taxes, subsidies.	Leader: OUK Throughout the whole project, discussions in expert panels consisting in SME, industry, public authorities, science and research institution representatives will be made, to prepare fertile ground for these new policies in Oulu. Oulu will discuss the subsidies and loans policy on the national level with the Ministry of the Environment and the Housing Finance and Development Centre of Finland to target more subsidies and funds to energy-efficient construction projects.
Action 41: Single window/desk for energy retrofitting.	Leader: OUK A new platform that comprises a major simplification of the refurbishment process concerning technical, administrative and funding aspects will be implemented to reach a high potential for local individual initiatives. The idea is to create a support system labelled by Oulu that offers professional help to citizens how to optimize the heating system in residential and non-residential housing and advice how to use solar energy.
Action 42: PED Renaissance Strategy.	Leader: OUK City of Oulu will adopt, based on the existing solutions and lessons learned from MAKING-CITY interventions, a model and strategy for district-level energy renovation for Oulu. The model considers technical interventions as well as urban planning interventions like densification and mobility planning. Results

	of this action will be considered in the Action 45
Business models	
Action 43: Shared private-public investment models for sustainable energy consumption and production.	Leader: ARI. Different residential and commercial buildings will be used as demonstrators of innovative business models. The data collected on performance, saving and other related benefits (e.g. jobs generation) together with the real case definition of joint public-private investments along the different actions implemented will be abstracted to provide business models to be replicated and scaled up by other districts (or cities). For instance, the Arina shopping centre will be analysed as an ambitious and complex business ecosystem in which public private (shared) clean energy investments and savings/benefits will be translated to new agreements and/or policies to reward responsible consumption, renewable energy and circular economy.
Action 44: Business model for charging stations.	Leader: OEN Grid bottlenecks that will become a challenge in urban areas can be reduced or even avoided via the integration of charging stations into the PED (Actions 6 and 27). A modular platform enables customer specific Apps with individual business models. Storage batteries can assist in improved load management of supplier and possibly improve economics of charged electricity by making use of time periods with excess supply and/or without local grid bottlenecks. Charging station can also be used as flexible components for demand/response control of electricity in the local grid.
Action 45: Energy efficient design of the real estate.	Leader: VTT Development of a business model for energetic transformation of the real estate with guarantee of energy cost savings. The implementation will consist on the analysis of current energy state of existing buildings followed by the definition of actions and finally the large scale modernization of building energy technologies with energy-saving contracts, monitoring, controlling, energy consulting and performance optimization.
Action 46: Smart City Crunching. Hackathon.	Leader: OUK It will be held a hackathon for developing further ideas for a Smart City ranging from business solutions for sustainable mobility, smart energy etc. Attention will be paid to tourism, environmental issues and retail. Open Data will form a crucial input in the form of traffic data, data from tourist organization and retailers/central super malls.
Action 47. Demand management living lab.	Leader: VTT Demand management is one of the most important of the total efficiency issues affecting energy use. It is also easier for social acceptance as long as affirmative financial and economic business cases can be demonstrated. Demand management in building energy utilization is recognized as a leading energy efficiency intervention with user friendly interfaces of consumption, creating the energy saving behaviour. The same is true for EV's and charging and the user in this case is fleet managers and individual citizens. The living lab will once again be a testing ground for the social acceptability of technical solutions as well as testing of the technical solutions themselves
New regulations / Standards	
Action 48: Assessment of legal barriers &	Leader: OUK Research on current barriers for the implementation of PED and identify solutions, facilitators and recommendations to overcome the legal and regulatory barriers as well as to guarantee the data security and protection.

Solutions.	
Action 49: Standardization of PED and energy balance in districts.	Leader: OUK This action aims to deploy the concept of positive energy blocks in a standardized concept as well as the calculation of the annual energy balance through the primary energy factors, taking into account local and country level specificities.
Social awareness actions	
Action 50: Citizen and stakeholder engagement.	Leader: OUK A user-centric approach will be followed in all the MAKING-CITY Project. For that, the smart city services will be codesigned with citizens, guaranteeing that the implemented innovations respond to their needs. Education and transparency about city plans is needed for effective participation. From one side, the city should delimit the extent of the input required from the community. A model for citizens' active participation in public life will be developed at the beginning of the project. This model will turn citizens into active actors of the sustainable change of the city via social networking (Facebook, LinkedIn, twitter, YouTube), city app, public consultations and participative workshops in the neighbourhood (social media strategy) in line with the overall dissemination, communication and citizens' engagement activities foreseen in the project (WP1, 2, 6, 7 and 8). In all this process, special attention will be paid to include in this entire process vulnerable people living in the district, in order to guarantee that they also participate and share their opinion. With this aim, printed materials, FAQs, and in-person visits will be developed to neighbours to explain the project and to empower them.
Action 51: Education, Co-design and Co-creation in Oulu.	Leader: OUK An important part of the engagement processes will be based on the analysis of the data collected from the PED. The data obtained will contribute to the understanding of the consumer behaviour of their citizens and offer workshops and awareness raising campaign to change their actions to sustainable behaviours. These trainings will be offered to different profiles (children, young people, families, business owners, CEOs, etc.) in different settings (schools, universities, chamber of commerce, etc.). Other training activities will be developed to engage with young and unemployed inhabitants and former workers from the construction sector living in the district to develop their eco-construction and refurbishment skills, with a special emphasis on the energy efficiency towards high-performance or near zero emission construction. Furthermore, a social innovation activity like an innovation camp will be delivered. A dedicated 1-2 day event will be organised during the last six months of the project to boost engagement, raise awareness and help solve the challenges that European cities are experiencing when implementing PEDs. This "Innovation Camp" will gather policy-makers, city representatives, technology providers, local citizens and other stakeholders that are considered necessary, such as representatives from the project's 6 follower cities. They will work together, share experiences and perspectives, and provide input to co-design a toolkit aimed at the project's follower cities and other cities that are considering the implementation of PEDs. This action will connect clearly with the refurbishment of building 1 (Action 1), that will be used as well as opportunity to

involve the trainees in the restauration of their neighbourhood and provide economic (jobs) and social benefits (inclusion). The impact of the training in the participants' behaviour will be assessed.   Finally, co-creation spaces will be organized, where co-design processes will be launched to ensure that citizens are the core of the urban energy transition and to ensure that the PED concept is a valid pathway for the citizens (and stakeholders). These co-creating processes will be linked with events with high interest in the neighbourhood to attract participation. Virtual tools will be additionally implemented to support the citizen participation processes. This strategy will be strongly linked with the policy actions.

Action 52: Local toolkit for renewable energy production and storage at the district scale.	Leader: VTT Actions of RES production and storage will be promoted (at different scales) for the citizens and institutions in Oulu. Best practices will be identified and a toolkit will be developed for the development of local renewable energy production and self-consumption projects adapted to each specific context. The tool will analyse the best business cases in renewable energy production, storage and will provide a decision support process to promote these actions. The Municipality will act as the information exchange medium in this topic.
Action 53: Local toolkit for development of Near Zero Emission Buildings.	Leader: VTT Best practices will be identified and a toolkit will be developed on the development of near Zero Emission Building adapted to the local context to comply with the requirement of the EU regulation on NZEB by 2020. The analysis will not only identify and describe best practices in building and retrofitting, but will also provide a simple decision support tool based on clear social, environmental, technological and economic criteria, detailing possible funding sources to develop such projects. These guidelines will be translated to the local authority for their integration in the local planning documents and regulation.
Action 54: Thermographic and energy production mapping or end-users engagement.	Leader: OEN This engagement action will used smart energy auditing based on aerial thermographic mapping and sustainable energy production at district scale to engage household on retrofitting and new RES projects based on their own house/building characteristics. First, an aerial thermographic survey of the district will be performed to have a visual and personalized assessment of heat losses from the different buildings of the neighbourhood in an efficient way. Apart from that, a map of potential energy production in the district will be developed. These maps will provide to each end-user a picture of his house with colours indicating heat losses in a very impacting way and complemented with the potential energy generation from RES. All this data will be integrated into the Urban Platform. Individual information campaigns will be launched, based on the individual building information will be realized to engage with local stakeholder on energy efficiency issue based on individual and personalized tailored information
Capacity building actions	
Action 55: City mentoring.	Leader: OUK In the course of WP1, and partially in WP8, the most important insights acquired during the project execution in Oulu will be selected for a mentoring campaign that will be promoted among the rest of cities participating in the project (Groningen, Bassano del Grappa, Trenčín, Kadıköy, Vidin, Lublin and León). This action aims at fostering the activities of the existing energy working group of the municipality, integrated by staff of different services, to take advantage of the project to develop their capacity in terms of energy innovation

	though the exchange with other partner cities. Not only the Municipality, but also other members of Oulu local team will be selected as mentors so that they can explain in detail their experience and guide about the application of these topics that were identified in the other cities.
Action 56: Policy forum on energy transition.	Leader: OUK The outcomes from the different recommendation on energy policy analysis developed in the policies updated in the actions described above will be delivered to local decision makers and stakeholders (incl. citizen) through the development of local policy forum on energy transition where the experiences learned from the project will be transmitted to a wider audience at city scale. Moreover, municipality staff will communicate these insights in international forums.
Action 57: Collaboration with Covenant of Mayors Office to communicate SECAP experiences.	Leader: OUK As explained in Action 39, Oulu will monitor and update the SECAP. During this process, guidelines to support cities in this monitoring and update process, which will be based on the upscaling and replication plans will be developed. Oulu, as Groningen will offer collaboration to Covenant of Mayors Office, for which one of its main objectives is the encouragement of mentoring activities within the cities participating in the initiative.

Groningen

HIGH PERFORMANCE BUILDINGS	
Residential buildings high performance retrofitting	
Action 1: Retrofitting of two multi-owner residential buildings- Nijeestee (7,400 m2).	Leader: NIJ Two multi-owner social residential high rise buildings of 108 apartments (3748 m2 each) from the seventies will be retrofitted, insulating the façades, floor and roof. The insulation of the façades will be combined with BIPV (22.5 kWp in building 1 and 30 kWp in building 2) (Action 12). To increase the electricity production with RES, 50 kWp PV panels will be placed in the parking lot roofs of building 1 (Action 11). These buildings are planned to be connected to a low temperature district based on RES (Action 27) with extra support of a geothermal heat pump (20 kW) (Action 25). 50 kWp of PVT panels (Action 18) will be installed in each building. In order to optimize the heat balance, a 'HeatMatcher' concept (Action 9) will be applied in order to combine this low temperature heat with the PVT, the new heat pump and the buffer (Action 29). Smart controllers will regulate the temperature of both buildings and also energy monitoring and demand/response will be also installed (Actions 7- 8). An electricity storage facility (600 kW) (Action 30) will help to store the excess of electricity produced. Next to Highrise 1 flats, 4 smart charging stations will be installed (Action 33).
Action 2: Retrofitting of three terraced private houses	Leader: GPO Three terraced houses, built around sixties/seventies and with an average area around 120 m2, will be retrofitted on the basis of three different concepts. The first house will have an installation of 3.53 kWp of PV panels (Action 11) on roof and 0.51 kWp of BIPV (Action 13) on façade and will combine

(360 m2).	1.76 kWp of PVT panels (Action 19) with an acoustic air heat pump for thermal production (20 kW) (Action 23). To maximise the performance of the whole system, low temperature radiators will be installed to ensure a perfect operation. The second terraced house that has already 314 kWp of PV panels will be connected to the district heating grid. Finally, the third terraced house will incorporate a ridge boiler in the roof (Action 19) for the thermal demand of the house to support the acoustic hybrid heat pump (5 kW) (Action 24). This house also counts with 1.6 kWp of PV panels in the roof. Demand/response smart controls and a domotic system which includes a smart LED lighting will be incorporated (Actions 7- 8).
New high performance residential buildings	
Action 3: New Powerhouse apartments (7,800 m2).	Leader: WAM This newly building complex contains a combination of apartments and office buildings (7,800 m2) that will be ready by the end of 2018. The complex will have a heating system based on a geothermal heat pump (300kW), connected to the district heating (A27) with support of 54.8 kWp of PVT (Action 22). It is an energy efficient building, which from aesthetic purposes does not allow solar panels on the roof. However, 60 kWp of BIPV (Action 14) will be implemented to cover the electricity demand. Additionally, the wastewater installation will be modified to enable the collection of wastewater with a high content of digestible materials (Action 31). Finally, for the purpose of energy monitoring and demand/response smart controls will be installed (Actions 7- 8)
Tertiary buildings with high performance retrofitting	
Action 4: Retrofitting of office building-Mediacentrale (14,400 m2).	Leader: WAM The Mediacentrale was built in the 1930s as an energy plant and was repurposed as office building in 2005. The retrofitting of this building of 14,400 m2 consists of insulation of roof, floor, façade, new HR+++ glass and the installation of smart thermostats for temperature control (Action 7). Furthermore, the ventilation system and lightning will be upgraded. 209 kWp of PV panels will be installed on the roof and on the parking lot (Action 11) whereas 31 kWp of PVT panels will be placed in the roof (Action 21). A geothermal heat pump (45 kW) will contribute to cover the heat demand of the building (Action 26). A 'HeatMatcher' concept (Action 10) will combine district heating (Action 27) with the PVT, the new heat pump and the buffer (Action 29) to optimise the energy production and consumption of the building. For the purpose of energy monitoring and demand/response smart controls will be installed (Actions 7- 8). The wastewater installation will be modified to enable the collection of wastewater with a high content of digestible materials (Action 31). Next to the building, 10 smart charging stations will be installed (Action 33).
New high performance tertiary buildings	
Action 5: New high performance Energy Academy Europe (9,636	Leader: RUG This new positive energy tertiary building is located at the Zernike Campus Groningen and was completed in 2016, being the most sustainable teaching building in the Netherlands due to a BREEAM Rating Outstanding score of 89.62%. This building (totalling 9,636 m2) has a particular design for the use of natural sources: a large solar roof (1,600 solar panels), a solar chimney that

m2).	allows the ventilation of the building by natural drafts and a system for the reuse of the rainwater. Furthermore, a heap pump uses the terrestrial temperature to provide heat in winter and coolness in the summer, being the first Dutch building to be fitted with a heat pump with the new friendly environment and ozone-neutral coolant HFOR1234ze(E). For the optimisation of the energy production and consumption, smart controls will be installed (Actions 7- 8).
Action 6: New high performance Sport complex Europahal (5,315 m2).	Leader: GRO This energy positive sports complex (5,315 m2) is planned to be built in 2018. The complex includes class rooms and catering facilities and will have a heating system based on a heat pump (250kW) and geothermal energy connected to district heating (Action 27). 335 kWp of PV Panels (1900 m2) (Action 11) and 54.8 kWp of Solar Thermal panels (Action 20) will be installed on the roof. In order to increase the energy production with solar energy, 180 very innovative Floating Solar pontoons (156 kWp) will be installed in the channel behind the building (Action 16) as well as an innovative SolaRoad, consisting on a dedicated bike lane (Action 17) with solar panels integrated (70 kWp). Additionally, the wastewater installation will be modified to enable the collection of wastewater with a high content of digestible materials to be used in a new innovated high-pressure digester to produce directly green gas (Action 31). For the purpose of energy monitoring and demand/response, smart controls will be installed (Actions 7- 8).
Smart building/home energy controllers	
Action 7: Advanced energy metering.	Leader: SB, RUG The monitoring equipment to be installed in the 6 buildings (Action 1, A3, A4, A5, A6) and 3 houses (Action 2) that take part of both PEDs NORTH and SOUTHEAST and will consist on smart meters connected to the building. These will be also connected to several sensors and will be used to measure the energy consumption (electricity, gas, heat) and production (electricity and heat) at real time. For controlling the energy flexibility within the buildings/houses the monitoring equipment will be connected to the demand response system in the Positive Energy Districts using the EFI protocol.
Action 8: Demand response/Smart Grid.	Leader: CGI, RUG To match the intermitted energy production and the consumption and reduce curtailment within the two Positive Energy Districts, a smart grids solution for both PED's based on their island solution will be realized. Using the available energy flexibility within the PEDs (e.g storage, time shifting etc.) the solution will optimise the energy production and consumption within the PEDs. The flexibility of the buildings and houses is communicated through the advanced energy metering from Action 7 using the EFI protocol. For the terraced houses this system is combined with a smart LED lighting plan, including domotics for control. CGI will be in charge of buildings corresponding with Actions 1, A2, A3, A4, A6 whereas RUG will be responsible of Action 5 (Energy Academy Europe).
Action 9: HeatMatcher for Nijeestee.	Leader: TNO This solution is an innovative smart thermal grid controller to coordinate multiple energy producing and consuming components to determine the optimal balance between producers and consumers of heat and cold. The HeatMatcher concept will be implemented in the two buildings of Nijeesteee

	(Action 1) to combine the thermal flows of geothermal district heating (Action 27), PVT (Action 17), heat pumps (Action 25) and thermal storage (Action 29).
Action 10: HeatMatcher for Mediacentrale.	Leader: TNO This solution is similar to Action 9, but in Mediacentrale (Action 4) and it will combine the thermal flows of PVT (Action 21), heat pump (Action 26) and heat storage (Action 30) of this building.

RENEWABLE ENERGY SYSTEMS ONSITE	
Solar PV panels	
Action 11: PV in roofs and parking lot (600 kWp).	Leader: NIJ, GPO, WAR, GRO PV panels will be installed in the roof surface of buildings and parking lots in four buildings of both districts. Buildings that will incorporate PV in Groningen North are: Nijeestee High-rise building 1 (Action 1) and one of the terraced houses (Action 2), whereas Mediacentrale (Action 4) and Sport Complex Europahal (Action 6) will be the buildings that will include PV in Groningen Southeast. PV-power generated will be preferably used for self-consumption. In the Sport Complex it will contribute to the energy demand of the buildings which are part of the PED Southeast. The PV power for each building is approximately: Nijeestee High-rise (parking lot roof of building 1: 50 kWp), terraced houses roof (3.14 kWp), Mediacentrale (building roof: 77.6 kWp, parking lot roof: 131.1 kWp, Sport Complex (building roof: 335.3 kWp). Total surface of PV panels in parking lots will be 800 m2 and 2,600 m2 in buildings. PV-plant in Nijeestee is equipped with electrical power storage (Action 30).
Action 12: BIPV in Nijeestee (52.5 kWp).	Leader: NIJ Given the restrictions to install PV panels in the Nijeestee buildings (Action 1), BIPV will be placed in façade of both buildings as additional source to electricity production. In total 350 panels will be installed with a PV power of 52.5 kWp (building 1: 150 panels- 22.5 kWp and building 2: 200 panels-30 kWp).
Action 13: BIPV in terraced houses (0.51kWp).	Leader: GPO 0.51 kWp of BIPV (7 m2) will be installed on roof terrace fence of the terraced house (Action 2) that previously was not equipped with any PV facilities. These panels will be a complement of the PV panels (Action 11) to be also installed during the retrofitting of the house.
Action 14: BIPV in Powerhouse (60 kWp).	Leader: WAM In the new Powerhouse building (Action 3) 400 BIPV panels will be implemented to reduce the electricity demand. These panels will occupy 664 m2 and will have PV power of 60 kWp.
Action 15: Floating solar pontoons (156 kWp).	Leader: GRO A very innovative solution will be installed in the channel behind the building Sport Complex (Action 6), consisting on 180 floating solar pontoons (156 kWp) to maximise the solar energy production in this block. These very innovative doubled-sized floating panels will make full use of the reflecting properties of the water allowing the usage of two-sided solar panels increasing the yield of solar power.
Action 16: SolaRoad (70	Leader: GRO The existing bicycle lane located in front of Sport Complex Europahal (Action 6) will be improved with a bike lane with solar panels

kWp).	integrated in the surface that will be able to produce approximately 60,000 kWh/yr. The SolaRoad will be also connected to a smart grid to use the energy as smart as possible and will have a surface of 600 m2.
Solar Thermal panels	
Action 17: PVT in Nijeestee (50 kWp).	Leader: NIJ In Groningen North, 50 kWp of PVT will be placed in both Nijeestee buildings (Action 1). After the retrofitting of these residential high-rises, a total of 200 hybrid panels will be installed. The thermal energy production of building 1 will be controlled by the "HeatMatcher concept" (Action 9) that will be able to balance the energy production of all the thermal systems of the building (geothermal district - heat pump, PVT and buffer).
Action 18: PVT in terraced houses.	Leader: GPO In one of the terraced houses (Action 2), 1.76 kWp of hybrid panels will be placed to support the air heat pump (Action 23) in the production of thermal energy and the PV (Action 11) and BIPV (Action 13) to cover the electricity needs of the house.
Action 19: Ridge boiler in terraced houses.	Leader: GPO This solution consists of a special form of a solar water heater. This is a convex solar collector that is mounted on the ridge of a roof, covering the whole length of the house. This makes that the system can produce warm water all day, despite of the orientation of the roof. One ridge boiler will be placed in one terraced houses (hybrid house) (Action 2) to increase the share of thermal energy on site.
Action 20: PVT in Sport Complex (54.8 kWp).	Leader: GPO A photovoltaic thermal hybrid solar collector will be mounted in the Sport Complex (Action 6) to contribute to the production of an excess of electricity in this building and to cover the thermal needs of building. The size of this solution is 218 m2 and 54.8 kWp.
Action 21: PVT in Mediacentrale (31 kWp).	Leader: WAM These panels will have a PV power of 31 kWp and will contribute to the thermal and electricity needs of the office building (Action 4).
Action 22: PVT in Powerhouse (54.8 kWp).	Leader: WAR With a PV power of 54.8 kWp, the purpose of these panels is to contribute as support of geothermal DH during the summer periods for covering the thermal demands of the new building (Action 3).
Heat pumps	
Action 23: Acoustic Air heat pump in terraced house (20 kW).	Leader: GPO To prevent noise pollution and increase acceptability, an innovative heat pump that operates silently will be implemented in one of the terraced houses. This air heat pump of 20 kW will produce the heat needed for the all-electric house that will count with the support of PVT (Action 18) that will be also installed.
Action 24: Acoustic Hybrid heat pump in terraced house (5 kW).	Leader: GPO A hybrid heat pump will be installed in one of the terraced house (Action 2) to cover the thermal demand (75% of the heat will be produced with electricity and 25% of the heat will be produced by green gas). This heat pump will avoid the production of noise and will count with ridge boiler (Action 19) to cover the heat demand of the building.

Action 25: Geothermal heat pumps for Nijeestee (20 kW).	Leader: NIJ The Nijestee high-rise buildings will count with a geothermal heat pump of 20 kW connected to a geothermal district heating. A storage buffer will optimise the operation of the heat pump by storing large amount of excess energy as hot water, being all the thermal production controlled by applying the "HeatMatcher" solution (Action 9).
Action 26: Geothermal heat pumps for Mediacentrale (45 kW).	Leader: WAM The geothermal heat pump (45 kW) to be installed in Mediacentrale will use the temperature of the ground to cover part of the heating demand of the building. In some cases it is needed to balance the amount of heat, that's why the heat pump, the buffer and the existing PVT will be connected to the "HeatMatcher concept" (Action 10).
Geothermal	
Action 27: Geothermal District Heating	Leader: GRO Two District Heating based on RES are located in NORTH and SOUTHEAST areas and will be the main responsible to supply thermal energy to the buildings which take part of both PEDs. For this purpose, specific connections among the DH and the buildings will be realized (Actions 39-40).
Energy storage systems	
Action 28: Neighbourhood electro storage facility (600 kW)	Leader: NIJ An electrical storage facility of 600 kW will be installed in Nijesteeflat 2 (Action 1) as part of the smart grid in order to store the solar power generated until the moment in which is most beneficial for the user and the system.
Action 29: Thermal storage in Nijeestee.	Leader:NIJ The surplus of thermal energy produced in the residential buildings Nijeestee (Action 3), the geothermal heat pump (Action 25) and PVT (Action 17) will be stored in two buffers to be placed in each one of the buildings until is used to supply energy needs of building during peaks of thermal demand.
Action 30: Thermal storage in Mediacentrale.	Leader: WAM This solution is similar to Action 9, but in this case the buffer will be installed in Mediacentrale (Action 4) to store the thermal flows of PVT (Action 21) and geothermal heat pump (Action 26).
Waste recovery	
Action 31: High pressure waste water digester (250,000 kWh/yr).	Leader: GRO The waste from the catering facility from the Sport Complex Europahal (Action 6) and the waste water from Sport Complex Europahal, Powerhouse (Action 3) and Media Centrale (Action 4) will be collected and digested under high pressure in a new innovative high-pressure digester to produce a surplus of 250.000 kWh/yr as green biogas that will be delivered through the gas pipeline. The biogas digester is a specially designed reactor which contains bacteria that process the leftover food and waster water. The wastewater installation of the three buildings will be designed and modified to enable the collection of wastewater with a high content of digestible materials.

OTHER TECHNICAL ACTIONS	
Buildings energy connectivity for energy sharing	
Action 32: Modelling, simulation, adapting & validation of planned innovations	Leader: TNO Simulation of the planned innovations will be done in order to observe how and to what extent the existing energy measures are able to achieve the goal of creating a PED in each district. The selected units (houses/buildings) will be modelled as well as the underlying network topology in each district and the result will be combined with the information available regarding energy demand patterns of the units involved as well as the energy production that is made available either to the PED or is produced within the PED. Based on the results of the simulations the planned activities for the interventions will be fine-tuned to optimise the PED NORTH and SOUTHEAST.
Impact on grids of EV charging points	
Action 33: 14 Smart charging stations.	Leader: GRO Smart charging stations will be placed within both districts and will be connected to the demand and response model. The parking lot of Nijestee flat 1 (Action 1) in the North will count with 4 smart charging poles, installing other 10 smart charging points at the building Mediacentrale (Action 4) in the Southeast area.
Action 34: Connection of the charging stations to the local demand response system.	Leader: CGI The 14 smart charging stations foreseen (Action 33) will be used for demand response and smart grid management. Since the EV park can add significant capacity to the local flexibility market for electricity, a charge-point interactive management system (CiMS) will be used to provide full-scale EV charge point management capabilities. This will be delivered as a Software as a Service (SaaS). Within the project an open protocol will allow to connect the EV capacity as source of flexibility in de the local DR system.
ICT urban platform adaptation	
Action 35: Open urban platform adaptation.	Leader: GRO The municipality of Groningen is connected to the Civity Dataplatform which is a wide used open data platform in the Netherlands. The most important goal of this platform is to share and use the potential of (open) data by governmental, commercial and knowledge institutes. Dataplatform is based on CKAN, FIWARE and Drupal software (open source) which allows the downloadable of datasets as well as programmatic access by API's (also IoT API's). To ensure the findability of the datasets, the metadata and download link is automatically harvested by national open data sites and subsequently publicised. There are no technical restrictions preventing the input of data (possibly after conversion) from the project into this platform. Within MAKING-CITY project, data integrity, authorisation and privacy will be embedded in the platform. Measures that guarantee data protection and security will be integrated from the start of the project to comply with privacy legislation (GDPR). Data access will be implemented on using different user authorisation levels. Data collected from PEDs will be aggregated for monitoring and data analysis.
IoT – Monitoring	
Action 36. Energy data	Leader: CGI The urban platform will monitor the data collected from measuring equipment installed in buildings with the aim to evaluate the performance and

monitoring of PED.	impacts of solutions implemented in both PEDs in the energy sector through specific indicators. With this objective, the information will be aggregated for the calculation of KPIs and the values will be available for the city planners, policy makers and decision makers to help them in the definition of strategies to upscale the concept of PED in other places of the city.
Action 37: Integration of new services to the data platform	Leader: CGI New services will be developed and integrated in the Groningen Urban platform to use and share the results generated in the project related to the monitoring of PEDs. These services will be focused in the improvement of the city operation and in the investment and planning of positive energy buildings.
Action 38: Installation of IoT infra	Leader: TNO This action will jointly integrate the necessary systems that allow for project-wide monitoring and controlling the available appliances and devices that are part of the pilots.
District heating and cooling facilities	
Action 39: Adjust geothermal district heating for using low temperature.	Leader: WAR The geothermal district heating network in Groningen NORTH (Action 27) is currently a high temperature network. To connect the retrofitted buildings to a low temperature heating network instead of gas, the existing heating network has to be adjusted. An innovated mix injection will be used to control the supply temperature to the apartments of Nijestee buildings (Action 1) as well as one of the terraced houses (Action 2).
Action 40: Connection to the low temperature district heat	Leader: WAR In the Southeast area a collective low temperature heat grid (Action 27) will be connected to a ground source heat pump of the Powerhouse (Action 3) and the Sport complex (Action 6). A Wall Connector with wheatstone bridge will be installed for this purpose.

NON-TECHNICAL ACTIONS

Policy innovation	
Action 41: New 2050 Groningen Vision.	Leader: GRO Developing a long term 2050 vision is a challenge for Groningen which currently has a 2035 vision to become energy neutral. Therefore for working with this 30-years-ahead plan the city must guarantee a seamless city transformation, from planning to implementation and further upscaling and will require the use of appropriate tools to support the city in this planning process, in the implementation and in the evaluation and monitoring phases throughout their whole plan's lifetime. In order to better organise cities' activities, a specific Groningen Urban Planning department will be proposed in advance, to foster internal coordination. Once created, the extended tools for modelling the demand-side and supply-side in combination with impact estimation procedures will be integrated in the decision making procedures. In addition, since there is a clear synergy between the new long term city vision and the continuous processes of implementation and monitoring of the SEAP/SECAP, the municipality

	of Groningen will use the insights on this to the new city vision 2050.
Action 42: SECAP monitoring and update of actions.	Leader: GRO The current version of the Sustainable Energy Action Plan is active since 2015 joining the city of Groningen to the Covenant Of Mayors in 2017 with a target of reduction of 70% for the year 2030. Currently the city is one of the first 51 medium size EU cities with SECAP approved and has as commitment to continue the process of monitoring and updating their brand new SECAP, following the commitments acquired to the new CoMs for Climate and Energy. This monitoring and update will be based on the monitoring of the actions and the Upscaling plan respectively.
Action 43: City Policies Update (taxes, subsidies).	Leader: GRO Based on all the developments in the MAKING-City Project several recommendations on the city policies will be proposed. The first one is related to redesign the taxes structure based on conditions obtained from the energy efficiency actions. A second update will define new schemes for public subsidies and loans to foster private investments in energy efficiency; once analysed the economic, environmental and social impact of the actions implemented in MAKING-City. Throughout the whole project, discussions in expert panels consisting in SME, industry, public authorities, science and research institution representatives will be made, to prepare fertile ground for these new policies in Groningen.
Action 44: Deployment and evaluation of district energy plans.	Leader: GRO As a result of combining the energy transition ambition with the current and future needs, preferences and limitations of the city expressed at district level, it will result the so-called district energy plans (EZPs). Rather than a one-size-fits-all approach that characterises the energy transition plans that cities (or countries) usually make, these district energy plans are innovative as they take into account local circumstances on both supply as well as demand sides. These plans are, at the moment, in different phases of development. We will develop a generic template DEP and implement two district energy plans for the districts North and Southeast. For the districts where these district energy plans are not yet made research will determine the optimal transition goals. These districts we selected are representative of the entire city, thereby enabling optimal replication of the project results.
Business models	
Action 45: Innovative business models development for PED (e.g: Energy Cooperative)	Leader: SEV-HUAS Research and further development of business models for the development of the PED concept in Groningen (taking PED North & Southeast as examples). Effective business models for different types of districts and solutions will be defined to make these business cases more attractive for private investments. This action allows a joint approach for building refurbishment and to finance, install, own, operate and maintain the onsite energy generation projects. A prime example are the Terraced houses where an energy cooperative representing citizens is aggregating demand and production of green energy. This specific business model has a wide replication potential (in Groningen and other cities).
Action 46: Open data	Leader: SEV-HUAS Exploitation of data and API generated in Groningen will be analysed. The urban platform will be able to collect, aggregate and analyse data

business models.	related to smart homes, smart buildings and energy systems.
Action 47: Blockchain.	Leader: CGI Development and roll out of billing & reconciliation concepts. This new billing structure will be studied and redesigned. In principle, a blockchain based solution (ICT Automatisering) will be studied.
New regulations / Standards	
Action 48: Assessment of legal barriers & solutions.	Leader: GRO Research on current legal barriers for the implementation of PED and identify solutions, facilitators and recommendations to overcome the legal and regulatory barriers as well as to guarantee the data security and protection.
Action 49: Standardization of PED and energy balance in districts.	Leader: GRO This action aims to deploy the concept of positive energy blocks in a standardized concept as well as the calculation of the annual energy balance through the primary energy factors, taking into account local and country level specificities.
Social awareness actions	
Action 50: Citizen social research.	Leader: GRO Several strategies to ensure the acceptance of the energy solutions to be implemented in the neighbours will be analysed in order to select those that better fit the profile of the citizens and stakeholders to be involved in the process of co-creation. This action includes aggregated research and recommendations
Action 51: Energy communities as part of the district energy transition strategy.	Leader: GRO A citizen engagement strategy will be deployed to foster a co-creation process and make citizens participants of the PED definition process by collecting needs and opinions and using innovative methodologies in the activities to be arranged. This action will connect clearly with the various refurbishment actions of the Making City project in the city of Groningen and contribute to the involvement of different residents with the associated social benefits (inclusion). Grunneger Power, in close collaboration with local citizen communities, will lead this transition process and will communicate PED actions in the district.
Capacity building actions	
Action 52: City mentoring.	Leader: GRO In the course of WP1, and partially in WP8, the most important insights acquired during the project execution in Oulu and Groningen will be selected for a mentoring campaign that will be promoted among the rest of cities participating in the project (Bassano del Grappa, Trenčín, Kadıköy, Vidin, Lublin and León). This action aims at fostering the activities of the existing energy working group of the municipality, integrated by staff of different services, to take advantage of the project to develop their capacity in terms of energy innovation though the exchange with other partner cities. Not only the Municipality, but also other members of Oulu and Groningen local team will be selected as mentors so that they can explain in detail their experience and guide about the application of these topics that were identified in the other cities.

Action 53: Policy forum on energy transition.	Leader: GRO The outcomes from the different recommendation on energy policy analysis developed in the policies updated in the actions described above will be delivered to local decision makers and stakeholders (incl. citizen) through the development of local policy forum on energy transition where the experiences learned from the project will be transmitted to a wider audience at city scale. Moreover, municipality staff will communicate these insights in international forums.
Action 54. Collaboration with Covenant of Mayors Office to communicate SECAP experiences.	Leader: GRO As explained in Action 42, Groningen will monitor and update the SECAP acquiring also insights that can be shared with CoM Office. In addition, all the learning gained in the 2050 vision can be provided as guidance packages on how to develop new plans or adapting SEAP to SECAP or upgrading SECAP as well as guidelines to re-define them from the monitoring of the execution of the long-term plans.

Annex B: 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	$Percentage\ change = \frac{Energy\ use\ after - Energy\ use\ before}{Energy\ use\ before} \times 100\%$
	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.
	$$Total_{GHG_{emission}} = \sum_{i}^{z} energy_{carrier(i)} \cdot GHG_{factor} * final\ energy\ input_{energy\ carrier(i)}$$ 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 $$EPP = \frac{EPI_{BR}}{m}$$ M can be calculated as average annual costs in use savings (€/a) $$m = TAC_{after} - TAC_{before}$$ Type B dynamic $$EPP = \frac{\ln(m \cdot (1+i)) - \ln(EPI_{BR} - EPI_{BR} \cdot (1+i) + m)}{\ln(1+i)} - 1$$ Type C dynamic with energy price increase rate $$EPP = \frac{\ln(m \cdot (1+i)) - \ln(EPI_{BR} \cdot (1+p) - EPI_{BR} \cdot (1+i) + (1+p) \cdot m)}{\ln(1+i) - \ln(1+p)} - 1$$ 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