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Designing smart, resilient cities for all

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Executive summary
RUGGEDISED aims to make an important contribution to improve the quality of life of citizens, reduce environmental impacts and to create a stimulating environment for sustainable economic development in three neighbourhoods in Rotterdam, Glasgow and Umea. Following this ambition, several quantitative and qualitative targets for the project were defined in the beginning. The monitoring and evaluation carried out in WP5 will assess, if, to what extent and how these targets will be met. This deliverable D5.1 describes how the monitoring and evaluation will be carried out during the lifetime of the project. The monitoring and evaluation needs to be tailored to the situation in the cities, embedded into other project activities and investigated from different perspectives.

The activities in WP5 will be guided by the following overarching research questions:
- Which information is necessary to understand the project impact?
- Which factors lead to a sustainable implementation?
- Which approach is necessary to describe an environment that enables the deployment of smart solutions?
- What is the contribution of the project to the overall transformation of the Light House Cities?
- Which information is necessary to determine whether a smart solution can be implemented by a follower city and estimate its potential impact?

In order to reach the different impact targets of the project and to support the replication in the best way the evaluation deals with different fields of assessment. The technical assessment of smart solutions and other interventions on district level will form the basis of the assessment. A deep insight into the specifications of what was implemented in RUGGEDISED enables further assessment of environmental and economic impacts. These quantitative methods will be accompanied by process evaluation and social assessment. Such comprehensive combination of quantitative and qualitative methods provides a big picture that is necessary for the innovation process that leads to replication of smart solutions.

To enable comparability among the different kinds of smart solutions in the three lighthouse cities and to allow for the assessment of complex infrastructure systems, assessment clusters have been defined:
- Energy efficiency interventions at district level
- Smart thermal grid
- Smart electricity grid
- Mobility solutions
- City-wide ICT infrastructures

The different assessment methods for each cluster are described including scope, inputs, outputs and planning. The methodology includes different fields of assessment within five clusters of smart solutions. However to show the overall impact of the project, the results of the different assessment streams need to be integrated in a common KPI list. It is based on the methodology of this guide and links its results with the overall impact targets as these have been outlined in the project proposal.

Assessment results and methodology will influence the implementation of monitoring devices coordinated in Task 5.2 towards implementation in lighthouse coordination work packages. Assessment results will also feed into discussions of the liaison group which will in return provide necessary feedback. Investment and business models assessment will be further utilised in the assessment of the upscaled deployment and business model innovation.

This deliverable is the main guidance for partners and methodological outline for the work package. A major purpose of this document is to provide a common framework and unify the approach before the implementation of the monitoring starts. Also the different perspectives used to assess the impacts of RUGGEDISED need to be aligned before any specialised assessment can start. This will allow for a proper compliance of results when it comes to support the replication of smart solutions at the end of the project.

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1. Introduction

RUGGEDISED aims to make an important contribution to improving the quality of life of citizens, reducing environmental impacts of activities and to creating a stimulating environment for sustainable economic development. Several quantitative and qualitative targets for the project were already defined during the proposal writing phase. These goals and targets can be found in the “Expected Impact” chapter of the Description of Work (DoW).

The monitoring and evaluation carried out in work package (WP) 5 will analyse, if, to what extent and how the project reaches its goals and objectives. Moreover, the results of monitoring and evaluation activities will provide information on the performance of the different technologies implemented in RUGGEDISED. This is especially important for replication within the city and to other cities.

The activities in WP5 will be guided by the following overarching research questions:

- Which information is necessary to understand the project impact?
- Which factors lead to a sustainable implementation?
- Which approach is necessary to describe an environment that enables the deployment of smart solutions?
- What is the contribution of the project to the overall transformation of the Lighthouse Cities?
- Which information is necessary to determine whether a smart solution can be implemented by a follower city and estimate its potential impact?

This document describes how the monitoring and evaluation will be carried out during the lifetime of the project. The assessment needs to be tailor-made to the situation in the cities, embedded into other project activities and investigate from different perspectives. Different aspects of the evaluation are explained:

- **What will be assessed?** The definition of scope along with the analysis of smart solution role in a particular infrastructure system resulted in the definition of assessment clusters. We describe these clusters in Chapter 2.

- **How will the evaluation be performed?** In order to reach the different impact targets of the project and support the replication in the best way the evaluation needs to be done from different perspectives: The approach for technical, environmental, economic, process and social impact assessment is outlined in Chapter 3.

- **What is the contribution of RUGGEDISED activities?** The project has set targets and will impact the development of districts but is also contributing to targets of the city. The envisaged impact of RUGGEDISED is the subject of Chapter 4.

- **How will the results be utilised?** Further use of results and their embedding in other developments of the projects are described in Chapter 5.

1.1 Purpose and target group

The intention of this manual is to define a common methodology for the monitoring and evaluation activities in WP5. This methodology should be applied by the three lighthouse cities – Umeå, Rotterdam and Glasgow - to ensure a proper impact assessment of the interventions carried out within the project. The document serves as a general guide for project partners involved in the monitoring and evaluation activities. It describes approaches to evaluate the performance of solutions, their impact and the overall impact of the project from different perspectives.

The guide clarifies the evaluation process and its scope, explains the background of data sets and harmonises outputs of the evaluation to show its relation to the overall impact. As an example, the intention of the present manual is not to describe in detail all matters related to installation of sensors etc. but the basics that need to be taken into account when the sensors’ deployment and monitoring activities are going to be planned. Therefore, D5.1 provides assistance and specifies the requirements and parameters for a monitoring and data collection process that fulfils what was stated as expected impact in the proposal. The

monitoring requirements are defined in order to enable a standardised analysis of the overall energy performance and the calculation of the Key Performance Indicators (KPI). This is defined by a bottom-up approach, starting from the individual units (buildings, small building integrated systems, e-cars) up to the city level. Data sets and inputs are specified per evaluation field and per cluster of solutions. In addition, this document is accompanied by "D5.2 Evaluation templates" that lists necessary data sets as these will be used in a particular city. Both documents will become the basis for the monitoring activities and evaluation of the project impact.

Target groups of D5.1 and D5.2 are project partners performing assessment in WP5 and partners involved in local implementation tasks of WPs 2, 3 and 4.

1.2 Drafting process and contribution of partners

The document was jointly written by partners involved in evaluation activities, and it has been checked and amended by experts from cities involved in the implementation of lighthouses. The overall approach has been set up by AIT and subsequently discussed with other research partners. The starting point was the outline of the impact of RUGGEDISSED in the project proposal together with the setup and design of smart solutions. To come up with a methodology, that also suits local setups and takes into consideration particularities of each smart solution, local monitoring workshops were held:

- on January 18 2017 in Umeå,
- on May 22 2017 in Rotterdam and
- on June 12 2017 in Glasgow.

These workshops were organised by AIT in cooperation with the local coordinator (Gemeente Rotterdam, Umeå Kommun and Glasgow City Council). Workshops were attended by all relevant local partners involved in the implementation. National research partners had a core role in these workshops due to their deep knowledge of the interventions and the conditions these are embedded in – TNO for Rotterdam, RISE for Umeå and University of Strathclyde for Glasgow. The result was an adaptation of the initial approach to allow for a tailor-made assessment while ensuring the overall consolidation of results. The methodology and planning for special fields of assessment (i.e. process assessment) were drawn by research organisations with the respective field of expertise in charge of these tasks:

- TNO for the assessment of the contribution to city strategies and process assessment,
- RISE for the assessment of business models,
- ISINNOVA for the assessment of activities in follower cities,
- AIT Center for Technology Experience for social impact assessment,
- AIT Center for Energy for technical, environmental, economic and process assessment.

Through their leading role in other work packages of RUGGEDISED these partners also ensure the alignment of the particular assessment with activities in these work packages.

1.3 Relation to other developments and alignment

Activities of WP5 are embedded into a complex system of activities of RUGGEDISED and therefore cannot be seen decoupled from the rest of the project. On top of that, the results of RUGGEDISED are planned to be exploited together with the results of other European lighthouse projects for replication purposes. Therefore alignment during the preparation of the evaluation approach was very important. In general two ways of alignment were required:

- Internal alignment with approaches and activities of other work packages,
- External alignment with frameworks on European level.

WP5 needs to be closely linked to the planning and implementation carried out in the lighthouse work packages WP2 (Rotterdam), WP3 (Umeå) and WP4 (Glasgow). In addition, there are strong links to work packages that cover parts of the assessment or tracking feeding into WP5:

- WP1 Cross-city implementation and innovation in the lighthouses,
- WP6 Enabling upscaled deployment and business model innovation,
- WP7 Replication to follower cities and knowledge transfer,

- WP8 Interaction with smart city projects and
- WP9 Communication and dissemination.

Smart Cities and Communities Information System (SCIS)

Another important reference point is the so-called Smart City Information System (SCIS). SCIS is an online platform that was initiated and funded by the European Commission to collect data from smart city demonstration projects. The cooperation with SCIS will ensure a wider replication of the RUGGEDISED results and a higher potential for replication from the exchange of data, experience and know-how on smart cities and an energy-efficient with similar projects under the same repository. The cooperation with SCIS also ensures the use of a standardized set of KPIs shared with other lighthouse projects throughout Europe.

For the purpose of alignment and cooperation, the following tools will be used[1]:
- "SCIS Technical Monitoring Guide", guide that sets a base for a standardized methodology of the evaluation and assessment related to different actions within the scope of SCIS.
- "SCSI Key Performance Indicator Guide", guide that defines relevant key performance indicators, together with the data requirements for their calculation
- SCIS self-reporting tool: SCIS has officially launched the self-reporting tool to collect the data from the demo-sites of the projects in scope of this initiative.

CITYkeys

The H2020 project CITYkeys developed and validated, with the aid of cities, key performance indicators and data collection procedures for the common and transparent monitoring as well as the comparability of smart city solutions across European cities (CITYkeys 2017). The CITYkeys KPI-framework[2] was therefore forwarded to local consortia and can be applied in the data management infrastructure of the municipality (ICT on city level).

[1] These documents are available at http://www.smartcities-infosystem.eu/library/resources/scis-essential-monitoring-guides

[2] KPIs are available at http://www.citykeys-project.eu/citykeys/cities_and_regions/Performance-measurement-framework

2. Scope and clustering of smart solutions

The smart solutions and other activities on district level have been screened and clustered to come to a consistent methodology for performing evaluation and calculating the project impact.

Smart solutions in RUGGEDISED cannot be seen as single interventions since these are part of an overall system. Also, not all smart solutions in Lighthouse Cities are of the same kind, which makes a comprehensive assessment difficult and does not allow for the aggregation of all impacts. Therefore the evaluation is based on clusters. The method for clustering is based on groups of smart solutions used in the project proposal – smart thermal grid, smart electric grid and e-mobility, ICT on city level.

Because these clusters do not cover all interventions performed within RUGGEDISED, a cluster for energy-efficiency interventions on building and district level has been added to cover building interventions. To ensure consistency in the assessment, also other measures to increase energy efficiency at building and district level have been added – innovative street lighting and smart waste management. In this regard two terms are used:

- Smart solution – Term commonly used by the RUGGEDISED project for technological implementation that answers a particular challenge of a lighthouse city. Smart solutions are commonly numbered in the RUGGEDISED project with a shortcut for the city with digit, i.e. R1.

- Intervention – Term commonly used by other Horizon projects and recommended by SCIS.[3] This term is used for all technological implementations that cannot be allocated to any smart solution but are necessarily performed within RUGGEDISED, i.e. all interventions related to building energy-efficiency.

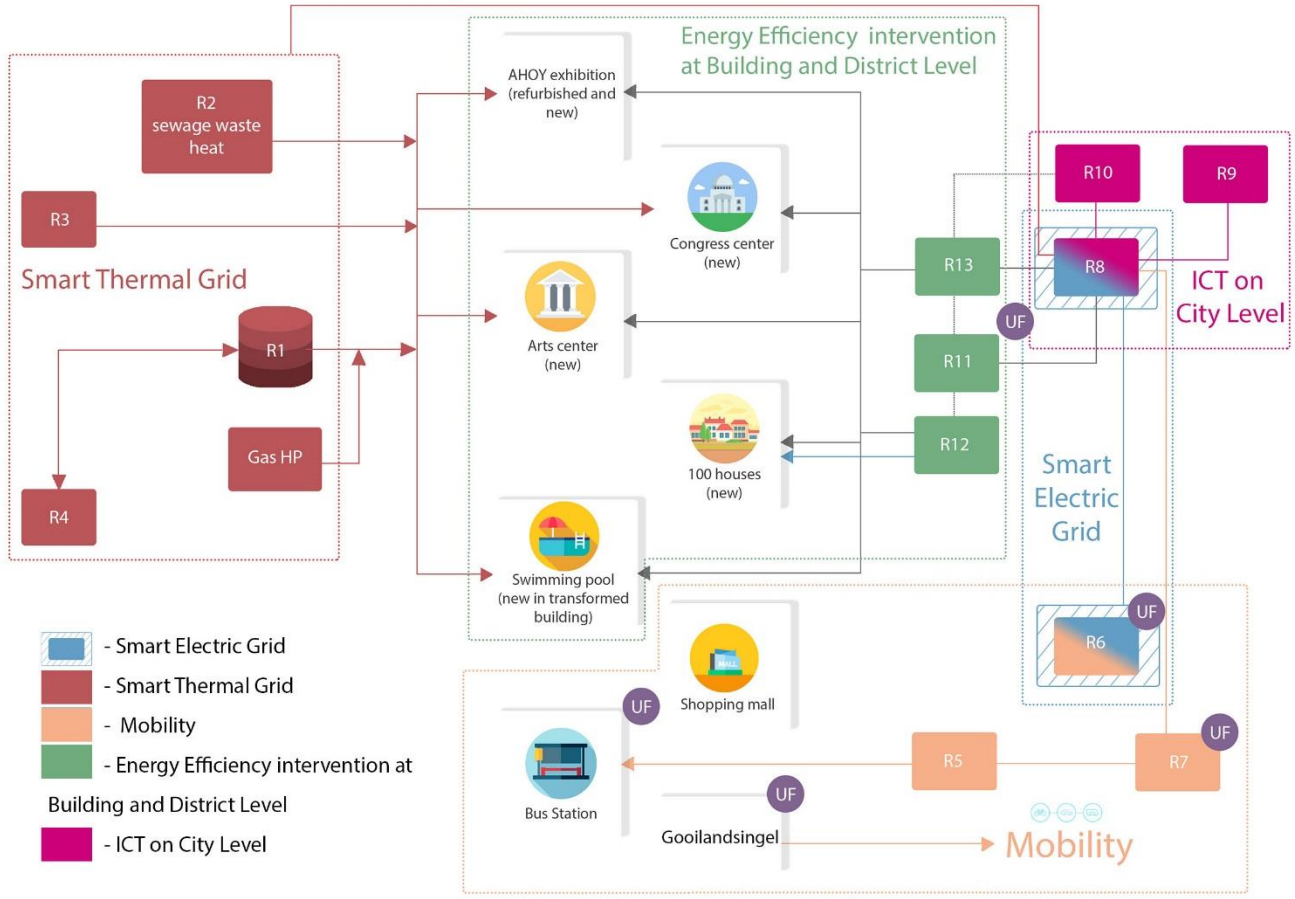
An overall assessment allows for the inclusion of synergetic effects between interventions. The method used covers overall impacts of solution cluster but needs to come up also with results for each smart solution. This is necessary in the case of e-mobility measures. In this case the overall impact and impact of each smart solution needs to be assessed. Therefore the cluster of smart electricity grid and e-mobility is split into two:

- Smart electricity and e-mobility - to assess the impact of the Smart Grid interventions.
- Mobility solutions containing the assessment of each mobility solution including e-mobility.

[3] See SCIS KPI-guide at http://www.smartcities-infosystem.eu/content/resources

2.1 Rotterdam

The interventions that are carried out in the city of Rotterdam are clustered and summarised in Figure 1.



R1 - Geothermal heat-cold storage and heat pumps
R2 - Thermal energy from waste streams
R3 - Surface water heat-cold collection
R4 - Pavement heat-cold collector
R5 - DC grid, PV and storage for mobility
R6 - Smart charging parking lots (e - hub)
R7 - Optimising the E-bus fleet of RET
R8 - Energy Management
R9 - 3-D City operations model
R10 - LoRa-network
R11 - Efficient and intelligent street lighting
R12 - Nerdalize eRadiator
R13 - Smart Waste Management
UF - User Feedback

Figure 1 Clusters for Rotterdam

The clusters for ROTTERDAM have been structured in the following way:

- **Energy efficiency interventions at building and district level:** The backbone of the interventions is the energy efficiency actions in the buildings included in the RUGGEDISED project. This includes both the construction of new buildings and the renovation and transformation of old ones. The reason why this is monitored is to fulfilled requirement of call description which mentioned increasing the energy efficiency at building and district level at least. In addition, the purpose of some buildings is going to be shifted – the change of a municipal office into a swimming pool and the art center on the old location of the swimming pool. In addition solutions R11, R12 and R13 are also part of this cluster since they focus on energy demand reduction at district level.

- **Smart thermal grid:** In the energy supply side, the smart solution identified as R1 to R4 have been clustered together in the action “smart thermal grid”.

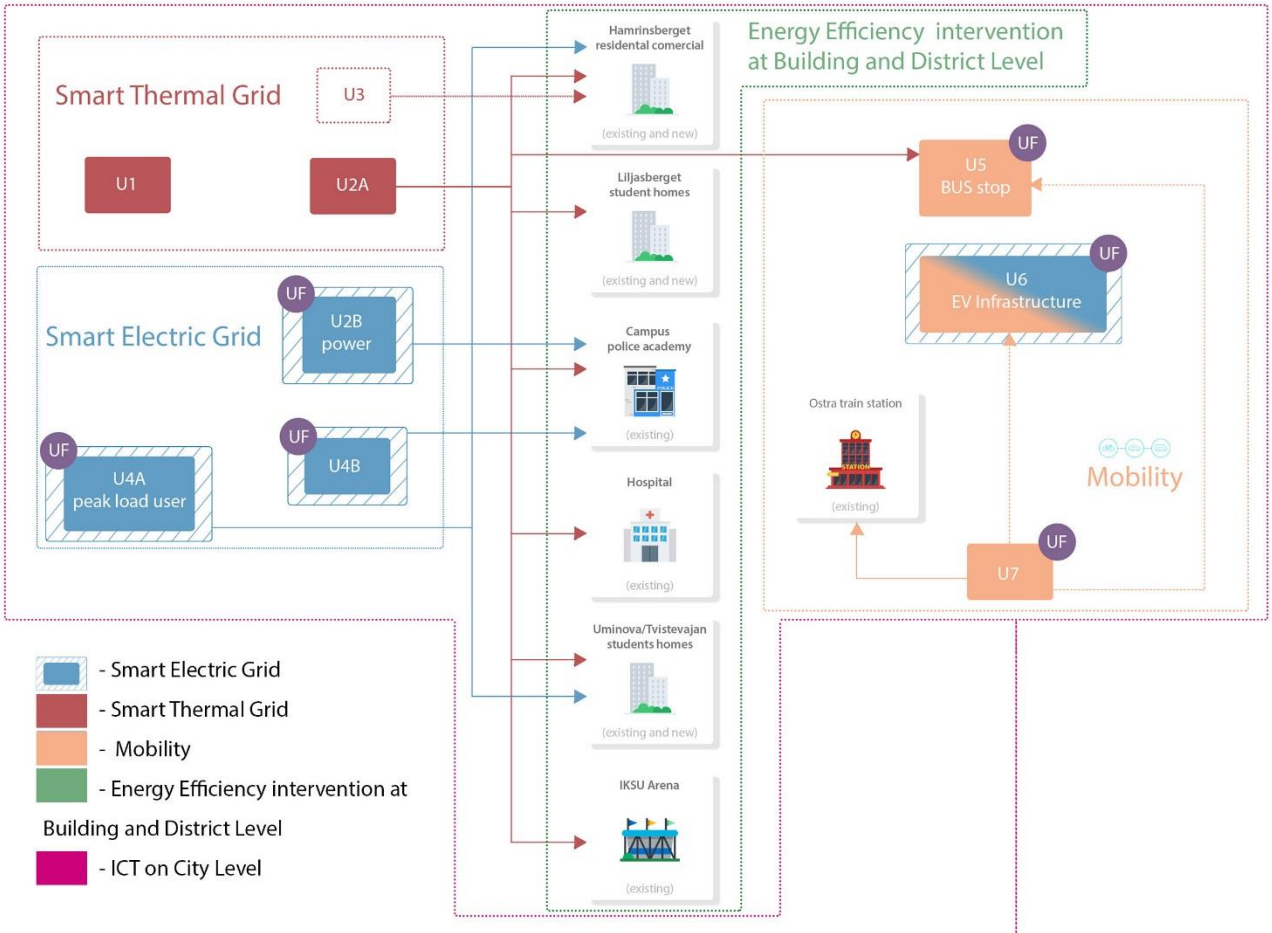
- **Smart electric grid:** To show the impact of smart grid interventions, measures R6 and R8 are assessed in this cluster.

- **Mobility solutions:** In the mobility side, the actions R5 to R7 have been clustered and will be assessed on the level of each solution as well as all together.

- **ICT on city level:** This cluster includes city-wide ICT infrastructure and consists of smart solutions R8, R9, and R10.

2.2 Umeå

Smart solutions and interventions on the district level are summarised in Figure 2.



U1 - Smart City connection to 100% renewable energy
U2 - Peak load variation management and power control
U3 - Geothermal heating/cooling storage exchange
U4 - Intelligent building control and end user involvement
U5 - Energy opimised electric BRT-station
U6 - E-charging hub/ charging infrastructure (e-bike, private car, taxi, car-share), storage and exchange, and optimisation of the integration of RES in the grid
U7 - Energy-efficient land use though flexible green parking pay off
U8 - Smart Open Data city Decision platform
U9 - Demand-side management
UF - User Feedback

Figure 2 Clusters for Umea

The clusters for Umea have been structured in the following way:

- **Energy efficiency interventions at building and district level:** The backbone of the interventions is the energy efficiency actions in the buildings included in the RUGGEDISED project. This includes both the construction of new buildings and the renovation of existing buildings.

- **Smart thermal grid:** Complementary to these actions to reduce the final energy demand of the buildings are the interventions on the energy supply side. Actions U1, U2A and U3 are clustered in the thermal grid cluster.

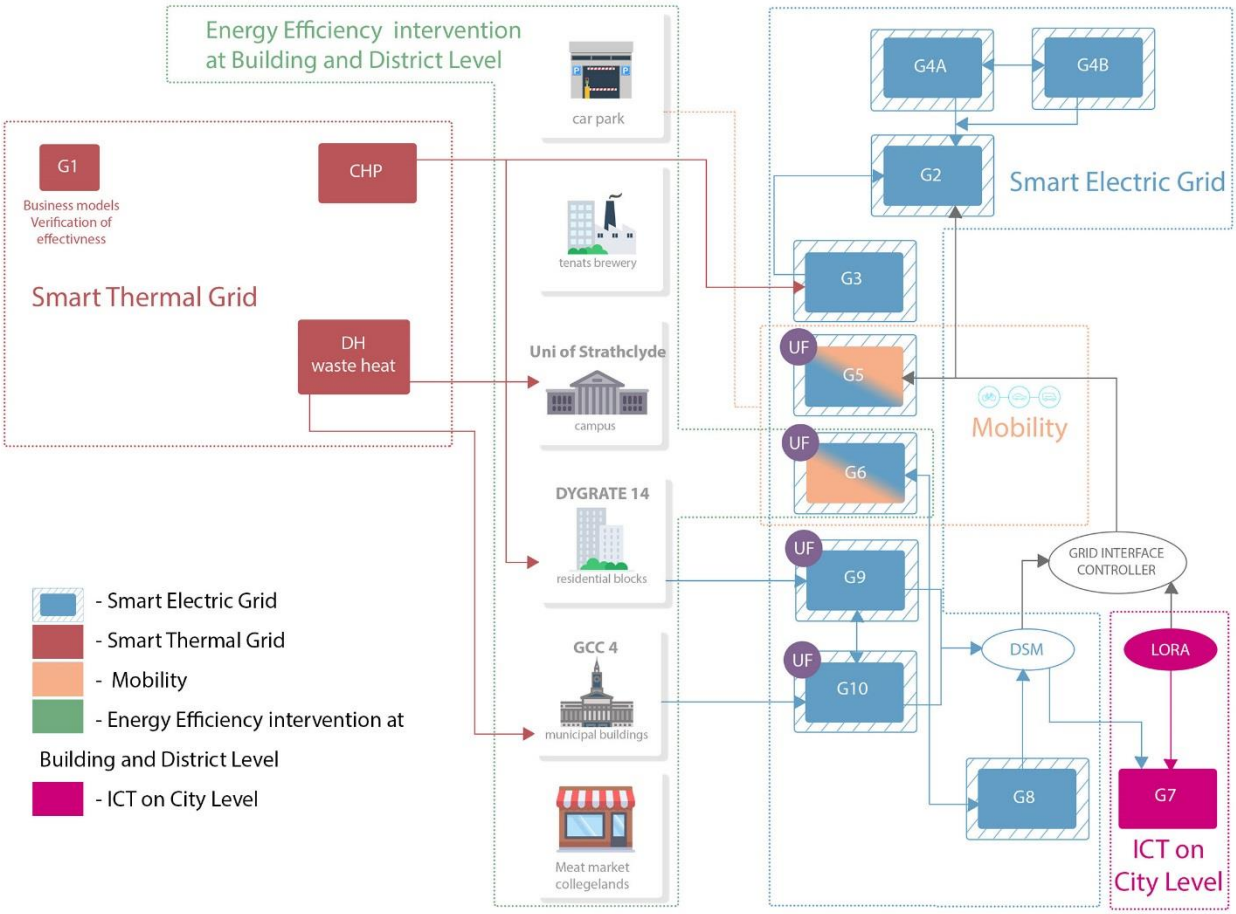
- **Smart electric grid:** U2B, U4A and U4B are clustered within the power grid cluster. The main objective is to reduce the use of primary energy and the CO_2 emissions as well as to balance the electric system. The measure U6 will also be included in the assessment of smart electricity grid to cover synergies between electrical grid and e-mobility.

- **Mobility solutions:** Smart solutions U5 to U7 will be assessed individually in the mobility cluster as well as all together.

- **ICT on city level:** This cluster includes city-wide ICT infrastructure and consists of smart solutions U8 and U9.

2.3 Glasgow

Smart solutions and interventions on the district level are summarised in Figure 3.



G1 - Heat and Cold exchange - Connection of buildings to district heating network
G2 - Battery storage technology as grid balancing mechanism & Supply of RES to EV charging and battery infrastructure
G3 - TCB CHP surplus power storage in EV Charging hub battery storage
G4 - Optimisation of the integration of near - site RES, potentially linked into battery storage
G5 - EV Charging hub in city centre car park
G6 - Intelligent LED street lights with integrated EV charging functionality, wireless communications network, and air pollution monitors
G7 - Smart open data Decision Platform/ central management system
G8 - Implementation of demand-side management technology in street lighting
G9 - Implementation of demand-side management technology in domestic properties
G10 - Implementation of demand-side management technology in non-domestic properties
UF - User Feedback

Figure 3 Cluster for Glasgow

The clusters for Glasgow have been structured in the following way:

- **Energy efficiency interventions at building and district level:** In the case of Glasgow, there is neither construction of new buildings nor renovation of old ones. This cluster will therefore include the assessment of street lighting (G6) leaving apart the demand side management measures with lighting (G8).

- **Smart thermal grid:** The only smart solution related to smart thermal grid is G1.

- **Smart electric grid:** The backbone of the smart solutions is based on Demand Side Management. Interventions also include storage and e-mobility. The cluster covers most of the smart solutions in Glasgow: G2, G3, G4, G5, G6, G8, G9 and G10.

- **Mobility solutions:** In addition to the assessment of e-mobility for the purpose of smart grid implementation, the following mobility solutions will be assessed separately: G5 and G6.

- **ICT on city level:** This cluster includes only smart solution G7. Other solutions will only be partly considered (ICT implementation focus).

3. Methodology

A proper assessment to show the impact of RUGGEDISED and support learning regarding replication requires the use of different perspectives. The methodology is a combination of quantitative and qualitative assessment methods. It needs to be applicable to a large variety of interventions as well as synergetic effects between them. The aim is to show the overall impact of the project but also of each solution. The different perspectives that will in the end provide a comprehensive picture of the impact of the project and of each smart solution are covered by different fields of assessment outlined below:

- Performance assessment – besides direct outcomes related to the increase in energy efficiency, the generation of renewable energy, the use of waste heat and the effects of demand side management are considered. This assessment builds a basis to calculate environmental and economic impact;
- Environmental assessment – includes consideration of carbon emissions and the assessment of the impact on air quality;
- Economic and business model assessment – includes assessment of the business environment and is accompanied by calculation of business-related indicators such as the payback period;
- Planning and implementation process assessment – is focused on structures of governance processes enabling the implementation of solutions;
- Social impact assessment – interventions directly affecting tenants, employees, visitors and their quality of life are subject to social impact assessment;
- Assessment of contribution to city strategies and targets – supports the replication within the city but also to other cities by assessing the relation and links between the implementation of the intervention and overall strategies on city level;
- Assessment of activities of follower cities – evaluates the improvement of capacity to replicate smart solutions and cooperation in follower cities of RUGGEDISED.

Where necessary the methodological fields are divided according to the assessment clusters defined in Chapter 2. Each methodological part includes the description of scope, the approach of the assessment, necessary inputs including source, outputs (i.e. KPIs) and planning as well as responsibilities.

3.1 Performance assessment of smart solutions

3.1.1 Cluster of solutions to increase the energy efficiency at building and district level

Scope: Assessment of energy efficiency interventions on buildings, street lighting and smart waste management within RUGGEDISED. This includes the construction of new buildings and the transformation and refurbishment of existing buildings, both interventions with a more ambitious energy efficiency approach than stated by national standard. In some cases, a refurbishment is being performed while the building gets a new function.
The following buildings are in the scope:

- Rotterdam
  - 100 zero energy residential buildings (new construction),
  - Arts centre (new construction),
  - Exhibition centre AHOY (new and refurbishment),
  - International congress centre (new construction),
  - Swimming pool (new in transformed building).
- Umeå
  - Hospital (refurbishment)
  - Student homes (new)
  - University building with laboratory (refurbishment)
- Glasgow
  - No energy efficiency interventions in buildings are foreseen. Building demonstrations are primarily used for demand side management interventions.

Regarding street lighting, the following is included:

- Rotterdam:
  - Efficient and intelligent street lighting (R11)
- Glasgow

- Intelligent LED street lights with integrated EV charging functionality, wireless communications network, and air pollution monitors (G6)
- Implementation of demand side management technology in street lighting (G8)

Regarding waste management, the following is included:

- Rotterdam:
  - Smart Waste management (R13)

Approach: According to the call and the objectives of the project, energy efficiency interventions are not allocated to smart solutions and therefore, they are not financed; however, since they are part of the district development with a significant impact for the project, their impact also needs to be shown. The baseline to calculate final energy savings in the case of new and refurbished buildings is the respective national standard (building code). This allows for showing the impact of highly innovative interventions in comparison to business as usual. Therefore, the situation before the interventions (in the case of refurbishment) is not taken into consideration but a comparable case.

In case of street lighting, the baseline should be based either on the technical code[4], or the previous situation when there is no law available.

Inputs: Data necessary include the baseline, design and monitoring data per year per building. Except the monitoring data, all necessary data sets are available in BEST-sheets.

Table 1 Input data for the performance assessment of the energy-efficiency interventions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Gross conditioned floor area of each building [m^2]	Best-sheets	Best-sheets	N/A
Final space heating, domestic hot water, cooling energy and electricity demand for the baseline [kWh/m^2.yr]	National regulations	National regulations	N/A
Final space heating energy demand per building [kWh/m^2.yr]	Design/ simulation / best sheet	Design/ simulation / best sheet	N/A
Final domestic hot water energy demand per building [kWh/m^2.yr]	Design/ simulation / best sheet	Design/ simulation / best sheet	N/A
Final cooling energy demand per building [kWh/m^2.yr]	Design/ simulation / best sheet	Design/ simulation / best sheet	N/A
Final electricity energy demand per building [kWh/m^2.yr]	Design/ simulation / best sheet	Design/ simulation / best sheet	N/A
Installed capacity of street lighting [MW]	Municipality of Rotterdam	N/A	Glasgow City Council
Final electricity energy demand of the street lighting before the intervention [kWh/y]	Design/ simulation / best sheet	N/A	Design/ simulation / best sheet
Data collected after the implementation of interventions (months 48 – 60)			
Final space heating energy consumption per building [kWh/m^2.yr]	Monitoring devices	Monitoring devices	N/A
Final domestic hot water energy consumption per building [kWh/m^2.yr]	Monitoring devices	Monitoring devices	N/A
Final cooling energy consumption per building [kWh/m^2.yr]	Monitoring devices	Monitoring devices	N/A

[4] This is, the minimum requirements that the street lighting need to meet according to law.

Final electricity energy consumption per building [kWh/m^2.yr]	Monitoring devices	Monitoring devices	N/A
Heating degree days [# HDD]	Monitoring devices or weather databases	Monitoring devices or weather databases	N/A
Cooling degree days [# HDD]	Monitoring devices or weather databases	Monitoring devices or weather databases	N/A
Final electricity energy consumption of the street lighting after the intervention [kWh/y]	Monitoring devices / Municipality of Rotterdam	N/A	Monitoring devices / Glasgow City Council
Annual savings in fuel for waste collection [€]	Municipality of Rotterdam or municipal utility	N/A	N/A
Factors used (months 12 – 60)			
Primary energy factors of the electrical grid [kWh primary energy / kWh final energy]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Primary energy factors of the gas grid [kWh primary energy / kWh final energy]	Utility supplying the buildings	Umeå Energi	N/A
Primary energy factors of the city district heating (existing network) [kWh primary energy / kWh final energy]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council

Outputs: The results will be shown per annum and intervention, both at city and aggregated at project level. In accordance to the SCIS approach similar buildings will be grouped to be assessed in order to avoid calculation with no additional value (e.g. 100 net zero energy buildings in Rotterdam). These results will further be used for the calculation of environmental and economic impacts (carbon emission savings, payback period etc.). In addition, seven KPIs will be directly calculated as a sum per city / for the whole project:

- Final energy savings by building energy efficiency interventions [MWh/yr],
- Final energy reduction by building energy efficiency interventions [%],
- Final energy savings by street lighting interventions [MWh/yr],
- Final energy reduction by street lighting interventions [%],
- Final energy reduction by waste management interventions [%],
- Primary energy savings by building energy efficiency measures and street lighting [MWh/yr] (in order to provide results for SCIS),
- Primary energy demand reduction [%] (in order to provide results for SCIS).

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT; provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT; provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT; provision and collection of data: RISE, TNO and US].

3.1.2 Thermal energy grid cluster

Scope: The technical assessment focuses on showing the impact of interventions related to the thermal energy grid in RUGGEDISED to ensure [EC 2016: 110]:

- Increase significantly the share of renewable energies, their integration into the energy system, stimulate self-consumption, reduce curtailment to the minimum.
- Make the local energy system more secure, more stable and cheaper for the citizens and public authorities.

This includes all smart solutions in the cluster “Smart thermal grid” in section 2.

Approach: The interventions related to the thermal energy grid include several sub-systems (ICT, thermal network, exchangers). The impact of the individual subsystems cannot be assessed independently due to high amount of synergies and coupled effects of the individual interventions. For the purpose of the performance assessment – provide results for technical, environmental and economic impact – an overall assessment is more suitable. Therefore, an integrated approach for a global evaluation will be followed.

The evaluation of these measures will follow calculations outlined by SCIS [SCIS 2017]. The baseline is the situation before the intervention or business as usual.

The following clusters are included:

- Geothermal heat-cold storage and heat pumps (R1)
- Thermal energy from waste streams (R2)
- Surface water heat-cold collection (R3)
- Pavement heat-cold collector (R4)
- Energy management (R8)

- Umea
  - Smart city connection to 100% renewable energy (U1)
  - Peak load variation management and power control (U2)
  - Geothermal heating/cooling storage exchange (U3)
- Glasgow
  - Heat and cold exchange – connection of buildings to DH network (G1)

Individual assessment: although this is not possible in all cases, it is interesting to assess the individual interventions in detail additional and in parallel to the global assessment.

The following individual interventions are to be monitored:

- Heating-cooling exchange
  - Thermal energy from waste streams (R2)
  - Surface water heat-cold collection (R3)
  - Pavement heat-cold collector (R4)
  - Heat and cold exchange – connection of buildings to DH network (G1)
- Storage
  - Geothermal heat-cold storage and heat pumps (R1)
  - Peak load variation management and power control (U2)
  - Geothermal heating/cooling storage exchange (U3)
- Peak load variation
  - Peak load variation management and power control (U2)

Inputs: Data necessary include the baseline, design and monitoring data per year per system.

Table 2 Input data for the technical assessment of smart thermal grid solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Total capacity of the individual generation systems [kW; MW; in case of solar thermal→m2]	Eneco, Municipality of Rotterdam	Umeå Energi	Tennent Caledonian Brewery
Thermal peak load before the intervention [kW; MW]	Monitoring devices	Monitoring devices	Monitoring devices
Total input per energy carriers into the thermal grid before the intervention [kWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable thermal energy not injected before the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices

Data collected after the implementation of interventions (months 48 – 60)			
Thermal peak load after the intervention [kW; MW]	Monitoring devices	Monitoring devices	Monitoring devices
Total input per energy carriers into the thermal grid after the intervention [kWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of heating energy fed into the thermal storage [kW/yr; MW/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of cooling energy fed into the thermal storage [kW/yr; MW/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of heating energy extracted from the thermal storage [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of cooling energy extracted from the thermal storage [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable thermal energy not injected after the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices

Outputs: The results will be shown per annum and smart solution, both at city level and aggregated at project level. As it is stated above, individual interventions will be assessed when possible.
The results from the technical assessment will further be used for the calculation of environmental and economic impacts (carbon emission savings, payback period etc.). In addition, six KPIs will be directly calculated as a sum per city / for the whole project:

- Peak load reduction [%],
- Primary energy savings by cluster [MWh/yr], (in order to provide results for SCIS).
- Primary energy demand reduction [%], (in order to provide results for SCIS).
- Reduced energy curtailment of RES and DER [%],
- Degree of self-supply by RES [%] and
- Use of storage [kWh/yr].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.1.3 Smart electricity grid cluster

Scope: The technical assessment focuses on showing the impact of interventions related to the smart electrical grid to ensure [EC 2016]:

- “the rollout of electric vehicles in cities while containing the need for excessive upgrading of the electricity grid”,
- “Increase significantly the share of renewable energies and their integration into the energy system, stimulate self-consumption, reduce curtailment to the minimum”.

To assess such a complex issue, the implementation of smart grid solutions is evaluated by its effects on the urban energy system. Smart grid applications such as demand side management interventions allow for an increased integration of additional volatile generation units (e.g. PV) or consumption (e.g. e-cars) without the necessary upgrade of the grid. To do so it is necessary to calculate the increased hosting capacity for RES (e.g. PV) as well as the increased hosting capacity for e-cars. For this purpose, the

renewable electrical energy not injected as well as fed into the grid are monitored and assessed before and after the intervention to evaluate the positive effect of the smart electricity grid solutions.

This includes all smart solutions in the cluster “Smart electricity grid” in section 2.

Approach: The intervention related to the smart electricity energy grid includes several sub-systems (ICT, storage etc). The impact of the individual subsystems cannot be assessed independently due to high amount of synergies and coupled effects of the individual interventions. For the purpose of the performance assessment – provide results for technical, environmental and economic impact – an overall assessment is more suitable. Therefore, an integrated approach for a global evaluation will be followed.

The baseline is the situation before the intervention.

The following clusters are included:

- Rotterdam
  - Smart charging parking lots (e-hub) (R6)
  - Energy management (R8)
- Umea
  - Peak load variation management and power control (U2)
  - Intelligent building control and end user involvement (U4)

- Glasgow
  - Battery storage technology as grid balance mechanism and supply of RES to EV charging and battery infrastructure (G2)
  - TCB CHP surplus power storage in EV charging hub battery storage (G3)
  - Optimization of the integration of near – site RES, potentially linked into battery storage (G4)
  - EV charging hub in city centre car park (G5)
  - Intelligent LED street lights with integrated EV charging functionality, wireless communications network, and air pollution monitors (G6)
  - Implementation of demand side management technology in street lighting (G8)
  - Implementation of demand side management technology in domestic properties (G9)
  - Implementation of demand side management technology in non-domestic properties (G10)

Inputs: Data necessary include the baseline, design and monitoring data per year per system.

Table 3 Input data for the technical assessment of smart electrical grid solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Total capacity of the individual generation systems [kW; MW]	Eneco, Municipality of Rotterdam	Umeå Energi, Akademiska Hus	Siemens
Electrical peak load before the intervention [kW; MW]	Monitoring devices	Monitoring devices	Monitoring devices
Total input per energy carriers before the intervention [kWh/yr]	Monitoring devices	Monitoring devices devices	Monitoring devices
Renewable electrical energy fed into the grid before the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable electrical energy not injected before the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable electrical energy used on site before the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices

Data collected after the implementation of interventions (months 48 – 60)			
Electrical peak load after the intervention [kW; MW]	Monitoring devices	Monitoring devices	Monitoring devices
Total input per energy carriers after the intervention [kWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of electrical energy fed into the electrical storage [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Total amount of electrical energy extracted from the electrical storage [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable electrical energy fed into the grid after the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable electrical energy not injected after the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable electrical energy used on site after the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Factors used (months 12 – 60)			
Primary energy factors of the energy carriers used in the electrical grid [kWh primary energy / kWh final energy]	Municipality of Rotterdam, Eneco	Umeå Energi, Akademiska Hus	Siemens, Scottish Power Energy Networks

Outputs: The results will be shown per cluster per annum and smart solution, both at city level and aggregated at project level.

The results from the technical assessment will further be used for the calculation of environmental and economic impacts (carbon emission savings, payback period etc.). In addition, four KPIs will be directly calculated as a sum per city / for the whole project:

- Peak load reduction [%],
- Primary energy savings by cluster [MWh/yr], (in order to provide results for SCIS).
- Primary energy demand reduction [%], (in order to provide results for SCIS).
- Reduced energy curtailment of RES and DER [%],
- Degree of self-supply by RES [%] and
- Use of storage [kWh/yr].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available].
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.1.4 Mobility cluster

Scope: The technical assessment focuses on showing the impact of interventions related to mobility

This includes all smart solutions in the cluster “mobility” in section 2.

Approach: The interventions related to the mobility can be assessed independently.
The evaluation of these measures will follow calculations outlined by SCIS (SCIS 2017). The baseline is the situation before the intervention.

The following clusters are included:

- Rotterdam
  - DC grid, PV and storage for mobility (R5)
  - Smart charging parking lots (e-hub) (R6)
  - Optimising the e-bus fleet of RET (R7)
- Umea
  - Energy optimised electric BRT-station (U5)
  - E-charging hub/charging infrastructure (e-bike, private car, taxi, car-share) storage and exchange, and optimisation of the integration of RES in the grid (U6)
  - Energy-efficient land use though flexible green parking park off (U7)
  -
- Glasgow
  - Battery storage technology as grid balance mechanism and supply of RES to EV charging and battery infrastructure (G2)
  - EV charging hub in city centre car park (G5)
  - Intelligent LED street lights with integrated EV charging functionality, wireless communications network, and air pollution monitors (G6)

Table 4 Input data for the technical assessment of the mobility solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Nominal power of charging stations [kW; MW]	TEST-sheet	TEST-sheet	TEST-sheet
Number of Vehicles with Alternative Energy Carriers (Excl. Electricity) [#]	TEST-sheet	N/A	N/A
Number of Charging Stations [#]	TEST-sheet	TEST-sheet	TEST-sheet
Number of e-Hubs [#]	TEST-sheet	TEST-sheet	TEST-sheet
Number of e-vehicles before the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Data collected after the implementation of interventions (months 48 – 60)			
Number of e-vehicles after the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council

Outputs: The results will be shown per cluster per annum and smart solution, both at city level and aggregated at project level.

The results from the technical assessment will further be used for the calculation of environmental and economic impacts (carbon emission savings, payback period etc.).

- Number of e-vehicles after the intervention [#]
- Energy Savings by Mobility Measures, Total [kWh/yr]
- Number of Vehicles with Alternative Energy Carriers (Excl. Electricity) [#]
- Number of Charging Stations [#]
- Number of e-Hubs [#]

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]

- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.1.5 ICT on city level cluster

Scope: The technical assessment focuses on showing the number of open solutions, interoperability of 3rd party applications and integrated ICT systems.

Approach: The interventions related to ICT can be assessed independently.

The baseline is the situation before the intervention.

The following clusters are included:

- Rotterdam
  - Energy management (R8)
  - 3-D city operations model (R9)
  - LoRa-network (R10)
- Umea
  - Smart open data city decision platform (U8)
  - Demand-side management (U9)

- Glasgow
  - LORA
  - Smart open data decision platform/central management system (G7)

Table 5 Input data for the technical assessment of the ICT solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Number of open solutions before the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Number of applications for interoperability of 3rd parties before the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Number of integrated ICT systems before the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Data collected after the implementation of interventions (months 48 – 60)			
Number of open solutions after the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Number of applications for interoperability of 3rd parties after the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Number of integrated ICT systems after the intervention [#]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council

Outputs: The results will be shown per cluster per annum and smart solution, both at city level and aggregated at project level.

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first part of the project is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the last part of the project is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.2 Environmental impact assessment

3.2.1 Cluster of solutions to increase the energy efficiency at building and district level

Scope: Assessment of the environmental impact of the energy efficiency interventions on buildings, street lighting and smart waste management within RUGGEDISED. The interventions included were detailed in 3.1.

Approach: After the technical assessment, it is necessary to assess the environmental impact of these interventions. The scope of environmental impact assessment in RUGGEDISED was defined based on the call text and takes into account the expected environmental impacts mentioned there. Therefore, the environmental impact assessment will focus on carbon emissions and local air quality according to the call [EC 2016]. The project will certainly have additional environmental impacts, but given the goals and the limited resources of the project, these additional impacts will not be assessed.

The baseline to calculate CO_2 energy savings is the final energy demand assessed in 3.1 and the characteristics of the local electrical and gas grid as well as standards boilers. This allows for showing the impact of highly innovative interventions to business as usual. Therefore, the situation before the interventions (in the case of refurbishment) is not taken into consideration but a comparable case.

In case of street lighting, the baseline takes the final energy demand from 3.1 and the electrical grid.

Inputs: Data necessary include the baseline, design and monitoring data per year.

Table 6 Input data for the environmental assessment of energy-efficiency solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected after the implementation of interventions (months 48 – 60)			
Monitored final energy savings per building and type of energy [MWh/yr.]	KPI generated by technical performance assessment in months 48 and 60 (AIT)		N/A
Monitored final energy savings for street lighting [MWh/yr.]	Technical performance assessment (AIT)	N/A	Technical performance assessment (AIT)
Factors used (months 12 – 60)			
CO_2 factors of the electrical grid [g CO_2 / kWh final energy]	Municipality of Rotterdam	Umeå Energi, Akademiska Hus	Siemens, Scottish Power Energy Networks
CO_2 factors of the fuel used by the waste management [g CO_2 / kWh final energy]	Municipality of Rotterdam	N/A	N/A

Outputs: The results will be shown per smart solution and per annum and smart solution, both at city level and aggregated at project level.

Two KPIs will be directly calculated as a sum per city / for the whole project:

- CO_2 savings [tonnes CO_2/yr],
- CO_2 reduction [%].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.2.2 Thermal energy grid cluster

Scope: Assessment of CO_2 saving and rise of sustainability due to the interventions on the thermal grid. The interventions and the clusters included were detailed in 3.1.

Approach: After the technical assessment, it is necessary to assess the environmental impact of these interventions. The evaluation of these interventions will follow calculations outlined by SCIS (SCIS 2017). The baseline to calculate primary energy savings is the total thermal energy supply by the thermal grid, the characteristics of the gas grid as well as standards boilers. This allows for showing the impact of highly innovative interventions in comparison to business as usual. Therefore, the situation before the interventions is not taken into consideration but a comparable case.

Inputs: Data necessary include the baseline, design and monitoring data per year.

Table 7 Input data for the environmental assessment of the smart thermal solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Total input per energy carriers into the thermal grid before the intervention [kWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Renewable thermal energy not injected before the intervention [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Data collected after the implementation of interventions (months 48 – 60)			
Input of energy carriers into the thermal grid [kWh/yr; MWh/yr;]	Monitoring devices	Monitoring devices	Monitoring devices
Output of the thermal grid [kWh/yr; MWh/yr;]	Monitoring devices	Monitoring devices	Monitoring devices
Factors used (months 12 – 60)			
CO_2 factors of the energy carriers used in the thermal grid [g CO_2 / kWh final energy]	Municipality of Rotterdam, Eneco	Umeå Energi	Tennent Caledonian Brewery

Outputs: The results will be shown per cluster per annum and smart solution, both at city level and aggregated at project level.

Two KPIs will be directly calculated as a sum per city / for the whole project:

- CO_2 savings [tonnes CO_2/yr],
- CO_2 reduction [%].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.2.3 Smart electric grid cluster

Scope: Assessment of primary and CO_2 saving due to the interventions on the electric grid. The interventions and the clusters included were detailed in 3.1.

Approach: After the technical assessment, it is necessary to assess the environmental impact of these interventions. The baseline to calculate primary energy savings is the total electrical energy supply by the thermal grid and the characteristics of the electrical grid. This allows for showing the impact of highly innovative interventions in comparison to business as usual. Therefore, the situation before the interventions is not taken into consideration but a comparable case.

Inputs: Data necessary include the baseline, design and monitoring data per year.

Table 8 Input data for the environmental assessment of the smart electric grid solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected after the implementation of interventions (months 48 – 60)			
Input of energy carriers into the electrical grid [kWh/yr; MWh/yr;]	Monitoring devices	Monitoring devices	Monitoring devices
Output of the electrical grid [kWh/yr; MWh/yr;]	Monitoring devices	Monitoring devices	Monitoring devices
Factors used (months 12 – 60)			
CO_2 factors of the energy carriers used in the electrical grid [g CO_2 / kWh final energy]	Municipality of Rotterdam, Eneco	Umeå Energi, Akademiska Hus	Siemens, Scottish Power Energy Networks

Outputs: The results will be shown per cluster per annum and smart solution, both at city level and aggregated at project level.
Four KPIs will be directly calculated as a sum per city / for the whole project:

- CO_2 savings [tonnes CO_2/yr],
- CO_2 reduction [%].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]
- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.2.4 Mobility cluster

Scope: The technical assessment focuses on showing the impact of interventions related to mobility, especially those related to CO_2 emission reduction and the improvement of the local air quality by the reduction of the following items:

- CO_2,
- NO_x,
- PM_{10} and
- SO_2.

This includes all smart solutions in the cluster "mobility" in section 3.1.

Approach: After the technical assessment, it is necessary to assess the environmental impact of these interventions. The baseline to calculate the savings is the substitution of conventional cars - powered by fossil fuels.

The baseline cannot be easily directly monitored, but more likely would be calculated indirectly from the following data:

- Characteristics of the fuel that powers the conventional cars: % of cars that use diesel, gasoline or other fuels.
- Characteristics of the car: year of construction.
- Output of the charging stations before the interventions [kWh/yr; MWh/yr]

Inputs: Data necessary include the baseline and monitoring data per year.

Table 9 Input data for the environmental assessment of the mobility solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Vehicles typology [year, fuel characteristics] in the city as %.	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Distance driven by conventional cars [person.km/yr]	Municipality of Rotterdam	Municipality of Umea	Glasgow City Council
Output of the charging stations before the interventions [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Data collected after the implementation of interventions (months 48 – 60)			
Output of the charging stations after the interventions [kWh/yr; MWh/yr]	Monitoring devices	Monitoring devices	Monitoring devices
Factors used (months 12 – 60)			
Factors to calculate content of pollutants per type of car [grams pollutant / vehicle*km]	JRC-report "Emission factors for new and upcoming technologies in road transport"		

Outputs: The results will be shown per cluster. Four KPIs will be directly calculated as a sum per city / for the whole project:

- CO_2 savings [tonnes CO_2/yr],
- SO_2 savings [g SO_2/yr],
- NO_x savings [g NO_x/yr],
- PM_{10} savings [g CO_2/yr].

Planning and responsibilities:

- Months 12 - 24: Before implementation - collection of baseline and design data, first calculations and provision to SCIS [calculation and collection: AIT, provision of data: RISE, TNO and US in case data is not available]

- Months 36 - 48: One year after the finalisation of the implementation the data from the first year of monitoring is being assessed. These preliminary results are included into the draft of D5.4 at month 48. [calculations: AIT, provision and collection of data: RISE, TNO and US]
- Months 48 - 60: At the end of the project: data from the second monitoring year is collected and assessed. Results are available in D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US].

3.3 Economic and business-model assessment

3.3.1 Business model assessment related to all clusters

Scope: Business-related process evaluation includes the assessment of the development of new business models for Smart Cities solutions. Starting from a traditional and hierarchic form of supply and demand of energy, towards increased emphasis on collaboration and sharing, it is essential and insightful to study how new business models for sustainable energy solutions are developed.
In Ruggedised, the following Business Models will be developed:

Table 10 List of business models

No.	Smart solution and related business model
R1, R2, R3, R4	Smart thermal grid
R5	DC grid, PV and storage for mobility
R6	Smart charging parking lots
R7	Optimizing the E-Bus fleet of RET
U1	Smart City connection to 100% renewable energy
U3	Geothermal heating / cooling storage exchange
U7	Energy-efficient land use through flexible green parking payoff
G1	Heat and cold exchange / connection of buildings to district heating network
G3	TCB CHP surplus power storage and EV Charging hub battery storage

Approach: RISE works today with studying the above mentioned transition and the formation of new forms of business models within several sectors of society and will lead this task. It will be closely linked to WPs 1 and 6 and provide a qualitative assessment and feedback on the process of creating these models and the drivers and barriers for upscaling and replication.

The business cases for the solutions in WP 2-4 are assumed to be complex. They will not be designed in the traditional way with a producer of a product or service and a passive consumer. Rather, the roles of producer, distributor and consumer will be less clear and the values behind the business models need to be redefined in order to assess and capture all kinds of value for all stakeholders in the exchange.
Because of its complexity, the assessment of the business models will not be a clear cut study on financial profitability, but on the process of elaborating these models and in particular the barriers that will be encountered.

RISE currently work in many different projects related to system innovation, circular solutions, value chain governance and integrated system solutions. In many of the projects new business models must be developed and analysed in order to include as many aspects of the innovative solutions as possible. In some cases this is very concrete work developing business model canvases and finding new ways to measure output and spill-over effects from the innovative solutions.

In other cases the business models are equally important, but not always the starting point in the process of developing innovative solutions. In these cases there is usually a common view of a possible innovation

and the benefits and costs associated for the stakeholders to the change the innovation will lead to. When the innovation is getting more concrete a useful approach is to study the plausible business models for the innovation from the perspective of the barriers they encounter.

These barriers can be divided into five categories; Institutional, Organisational, Technological, Behavioural and Market. The solutions in the project and each plausible business models will be studied from the perspective of these barriers. The purpose is to understand what business models are the best suitable and how they must be modified to fit the new solutions.

The business models presented by the cities will initially be consolidated and analyzed with the business model canvas method. The focus of the analysis is to find out where and how the sustainable value is captured or developed in the business model.

Typically the new and sustainable value is captured or developed by changes in five areas of the business models. The areas of changes could be in the value chain, the customer interface, the value proposition, the financial model or in some cases in new intellectual property rights. There can also be a combination of changes from these areas of the business model canvas.

Each of these areas of change could encounter barriers in the implementation of the new business model. These barriers will be analyzed with the model of barriers to sustainable business models.

The performance indicators for the pilots are set by each pilots needs and targets. The added performance evaluation is the ability to create a suitable business model and the organizations ability to overcome the barriers to that business model. In the analysis of the barriers there is a scale of how substantial or difficult the barriers are. The scale is normative and will be developed for the set of pilots. By measuring the strength (or height) of the barriers initially and after deployment of the pilots there will be an understanding of the difficulties and the performance in overcoming the difficulties. This could be extra important in the case business models fail. There should be correlation between the strength of the barriers and the fail or success rate of the pilots. It will also be possible to see if the ability to overcome the barriers is enough to move the pilots with strong barriers to successful pilots.

Inputs: Assessment of business models in a Smart Cities concept is primarily a qualitative one. Information will be gathered based interviews and questionnaires. The business models for the Smart Solutions will also be mapped towards their potential of change (from individual technology or service towards systemic change) and their potential of innovation (from incremental to radical).

Outputs: 2-3 Smart solutions from each Lighthouse City will be chosen to be studied in depth and RISE will follow the process of developing these models throughout the implementation phase, by written communication, phone and physical meetings.

Planning and responsibilities: The methodology will be specified between months 12 and 18. Afterwards the assessment will be incorporated into WP6-activities. By month 47 a summary of the findings will be delivered. The reporting of results will be a provided into D5.5.

The analysis of the value capture and possible barriers will be done in the phase of planning or initiating the business models and again closer to the end of the project. The analysis will help create understanding of which business models are viable, what barriers are encountered, how they can be overcome by the pilots and at the end how successful business models can be created.

After the first phase of analysis the pilots will be better informed about the possible value development and the potential barriers they will encounter in the development and deployment of the pilots. This will make it possible to at an early stage adapt the business model to barriers or by other means try to overcome them. The first phase will also create a benchmark to compare pilots in early stages of the development with each other and with their own development over time.

The second stage will consolidate the learnings from the pilots and inform the partners and stakeholders to the project what barriers are substantial or possible to overcome for the different types of business models.

These activities will be performed by RISE and coordinated within WP6.

3.3.2 Cluster of solutions to increase the energy efficiency at building and district level

Scope: Energy efficiency measures at building and district level include energy efficiency interventions in buildings, energy-efficient street lighting and smart waste management. Building interventions include new and refurbished buildings in Umeå and Rotterdam. Only innovative parts - investments and operational costs for the implementation beyond the building code requirements - are being assessed.

Approach: Results will accompany business model generation. For the calculation dynamic payback period will be used. The formula given by SCIS (SCIS 2017: 18) will be adapted: instead of energy-related investment the innovative share of investment will be used. This is given by the difference of construction investments in the building per square meter and standard investment per square meter indicated by the respective construction company in charge of the building. In case this value cannot be indicated, average value on national level from literature will be used. In difference to technical performance assessment that uses gross conditioned area, gross floor area will be used for the calculation of the relative amounts. This value needs to be collected in addition to the collection for the purpose of the technical performance assessment.

Smart street lighting will be assessed by using dynamic payback period through a comparison with standard solution that would be deployed by the city. The calculation will be performed per installed capacity (MW or kW). Smart waste management calculation will also follow dynamic payback period taking into account the investment in the solution and annual savings coming from reduced fuel costs.

Inputs:

Table 11 Input data for the economic assessment of energy-efficiency interventions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Gross floor area of each building [m^2]	Municipality of Rotterdam	Municipality of Umeå	N/A
Installed capacity of street lighting [MW]	Municipality of Rotterdam	N/A	Glasgow City Council
Data collected after the implementation of interventions (months 48 – 60)			
Monitored total final energy savings per building [MWh/yr.]	KPI generated by technical performance assessment in months 48 and 60 (AIT)		N/A
Total investment per building [€]	Municipality of Rotterdam	Municipality of Umeå	N/A
Total investments in a standard building [€/m^2]	Construction company of a particular building	Construction company of a particular building	N/A
Monitored total final energy savings for street lighting [MWh/yr.]	Technical performance assessment (AIT)	N/A	Technical performance assessment (AIT)
Total investment for street lighting [€]	Municipality of Rotterdam	N/A	Glasgow City Council
Investments in a standard solution of street lighting [€/MW]	Municipality of Rotterdam	N/A	Glasgow City Council
Annual savings in operational costs (fuel) for waste collection [€]	Municipality of Rotterdam	N/A	N/A
Investment in smart waste management system [€]	Municipality of Rotterdam	N/A	N/A

Factors used (months 12 – 60)			
Thermal and electric energy price for residential and commercial buildings [€/kWh]	Utility supplying the buildings	Umeå Energi	N/A
Electricity price for lighting [€/MWh]	Municipality of Rotterdam	N/A	Glasgow City Council
Discount rate [% p.a.]	Single discount rate will be selected for all buildings, e.g. 3%		

Outputs: Two kinds of indicators are foreseen to as output of the investment assessment. Certain indicators are used as a support of business model development and for the provision to SCIS. These indicators are marked as such. Payback periods cannot be aggregated on the project level and are thus used per smart solution. The following indicators are foreseen as a result of these calculations:

- payback period expressed in years per building - this number will be used as an indicator to support business model generation (indicator for SCIS);
- total investments in construction per lighthouse city;
- total investments in construction per m^2;
- payback period expressed in years per installed capacity of street lighting (indicator for SCIS);
- payback period of smart waste management (indicator for SCIS).

Planning and responsibilities: Respective parties will be identified and informed during the preparation of D5.3 (until month 24). These calculations require outputs of the technical performance assessment (energy savings). Sheet for calculations will be prepared by AIT within Task 5.4 until month 48. Calculations (based on monitoring data) and their interpretations will be available at the end of the project.

3.3.3 Thermal energy grid cluster

Scope: Thermal energy generation units installed as part of smart solutions of the district heating network in each of the lighthouse cities. In Rotterdam and Umea this will include also storage. In case the solution is only to be developed as a business model, the monitoring data will be replaced with design or simulation data used also for the technical specification of the particular device.

Approach: For the calculation dynamic payback period will be used. The formula given by SCIS (SCIS 2017: 18) will be adapted: instead of energy-related investment the innovative share of investment will be used. This is given by the difference of investments in an intervention divided by capacity and standard investment for large-scale gas thermal plant. In case this value cannot be indicated, average value on national level from literature will be used. Operational and maintenance costs as well as revenues will not be differentiated. Should the differentiation in single smart solutions not be possible for any reason, the calculations will be performed on thermal grid level.

Inputs:

Table 12 Input data for the economic assessment of smart thermal grid solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected after the implementation of interventions (months 48 – 60)			
Investment [€]	Eneco	Umeå Energi	Tennent Caledonian Brewery
Revenue from heat sales [€/MWh]	Eneco	Umeå Energi	Tennent Caledonian Brewery
Revenue from cooling sales [€/MWh]	Eneco	Umeå Energi	Tennent Caledonian Brewery
Operational and maintenance costs [€/MWh]	Eneco	Umeå Energi	Tennent Caledonian Brewery

Monitored use of thermal storage [MWh/year]	Eneco	Umeå Energi	N/A
Standard investment [€/MW]	Eneco	Umeå Energi	Tennent Caledonian Brewery
Grants received [€]	Municipality of Rotterdam	Municipality of Umeå	Glasgow City Council
Annual generated thermal energy [MWh]	Result of technical performance assessment by AIT		
Capacity [MW]	Result of technical performance assessment by AIT		
Factors used (months 12 – 60)			
Discount rate [% p.a.]	Single discount rate will be selected for all interventions, e.g. 3%		

Outputs: Two kinds of indicators are foreseen to as output of the investment assessment. Certain indicators are used as a support of business model development and for the provision to SCIS. These indicators are marked as such. Payback periods cannot be aggregated on the project level and are thus used per smart solution. The following indicators are foreseen as a result of these calculations:

- payback period expressed in years per intervention - this number will be used as an indicator to support business model generation (indicator for SCIS);
- total investments in the intervention;
- total investments in the intervention per MW (indicator for SCIS);
- share of the investment that is covered by grants in % (indicator for SCIS).

Planning and responsibilities: The approach will be further discussed with local stakeholders in charge of the implementation (Eneco, Umeå Energi and Glasgow City Council). This is necessary since also business models are being developed and any calculation needs to support the deployment of the respective business model. Discussion on concrete assessment and monitoring devices are scheduled for months 12 – 24. The subsequent implementation by AIT will include the installation or identification of monitoring devices. Assessment (AIT) will be possible after month 48 when first monitoring data will be available.

3.3.4 Smart electric grid cluster

Scope: Smart solutions assessed by this evaluation framework involve smart grid solutions to increase the hosting capacity of the grid (e.g. demand-side management), deployment of solutions for e-cars and renewable energy sources providing electric energy (PV and wind turbines). These interventions are all located on low-voltage grid and allow to fulfil the following aspect of the expected impact of RUGGEDISED [EC 2016: 110]:

Ensure the rollout of electric vehicles in cities while containing the need for excessive upgrading of the electricity grid.

Certain smart solutions in the RUGGEDISED cities focus on the municipal e-bus fleet. Since e-buses are connected to medium-voltage grid, these interventions are not within the scope of this assessment and will be assessed under mobility-related impacts.

Approach: The main targets of smart grid implementation in the urban environment is to increase the hosting capacity for e-cars. This confronts two approaches:

- Hosting capacity is increased by improving the infrastructure with a bigger installation (wiring, storage systems etc.).
- Hosting capacity is increased by a smarter use of the existing infrastructure.

To calculate the payback period, a baseline needs to be defined according to the assumption:

What will be the cost of a conventional grid upgrade to match the increase of hosting capacity for e-cars used for the comparison to the conditions achieved by the ICT-solution of RUGGEDISED?

The focus of the work related to the development of ICT-KPIs is to estimate what is the increased capacity of the grid for e-cars enabled through the ICT-development. We assume that, if no ICT solutions are implemented, no additional deployment of e-vehicles will be possible without grid infrastructure upgrade (storage, wiring etc.). A direct comparison between the cost of upgrading the grid to host new e-vehicles and the upgrade with smart solutions to host the same amount of e-vehicles results in the calculation of the payback period.

Inputs:

Table 13 Input data for the economic assessment of smart electric grid solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Nominal power of charging stations [kW]	TEST-sheet	TEST-sheet	TEST-sheet
Number of e-cars before implementation [#]	Municipality of Rotterdam	Municipality of Umeå	Glasgow City Council
Data collected after the implementation of interventions (months 48 – 60)			
Total investment in smart grid solutions incl. DSM [€]	Eneco, Municipality of Rotterdam	Umeå Energi, Akademiska Hus	Siemens
Estimated investment associated to the conventional increase of hosting capacity in the infrastructure [€]	Eneco, Municipality of Rotterdam	Umeå Energi	Scottish Power Energy Networks
Electricity use by e-cars [MWh]	Eneco, Municipality of Rotterdam	Umeå Parkerings, Umeå Energi	Scottish Power Energy Networks
Factors used (months 12 – 60)			
Electricity price [€/kWh]	Eneco, Municipality of Rotterdam	Umeå Energi	Scottish Power Energy Networks
Discount rate [% p.a.]	Single discount rate will be selected for all interventions, e.g. 3%		

Outputs: Prior to a deep analysis of costs, we assume that the investment on smart grid solution might be lower than the investments on a physical grid upgrade. In this case, the KPI used will be:

- Direct reduction of investments [in €]

Should there be no direct reduction than the following KPI will be used:

- Payback period [in years]

These indicators will be provided to SCIS. Additionally the following indicator will be used:

- Total investment in smart grid solutions incl. DSM [€].

Planning and responsibilities: The approach will be further discussed by AIT with local stakeholders in charge of the implementation (Eneco, Umeå Energi, Akademiska Hus, Siemens and Glasgow City Council). This is necessary since also business models are being developed and any calculation needs to support the deployment of the respective business model. Discussion on concrete assessment and monitoring devices are scheduled for months 12 – 24. The subsequent implementation will include the installation or identification of monitoring devices. Assessment (AIT) will be possible after month 48 when first monitoring data will be available.

3.3.5 Mobility cluster

Scope: All mobility interventions in lighthouse cities where monitoring or other quantification of performance is possible. This includes:

- Rotterdam

  - DC-grid, storage and PV for bus-stop (R5);
  - Smart charging parking lots (R6);
  - Optimisation of the bus fleet (R7);
- Umeå
  - Pre-heated bus-stops (U5);
  - E-charging hub (U6);
  - Green parking payoff (U7);
- Glasgow
  - E-charging hub in the car park (G5);
  - E-charging at the street (G6).

Approach: E-mobility interventions for cars (solutions R6, U6, G5 and G6) will be assessed with a dynamic payback calculation taking into account the investment in the charging infrastructure, sales on electricity (price per kWh and monitored final energy consumption in kWh) to cars and operational and maintenance costs per year. Smart solutions for public transport will be assessed by taking into account the investment into the solution compared to business-as-usual. In the case of R5 this will be conventional charging facility without electrical storage based on grid connection (AC), in the case of U5 the use of electric bus without pre-heated bus-stop causing losses at average stops per year will be used. Difference in investment to a standard solution is not necessary in this case, standard value will only be used to calculate savings. Green parking payoff needs to be discussed during the design of the business model since the calculation is strongly dependent on the business setup used.

Inputs:

Table 14 Input data for the economic assessment of mobility solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Investment in a conventional solution for bus charging [€]	Eneco, RET	N/A	N/A
Standard electricity use of a charging point for e-bus [kWh]	Eneco, RET	N/A	N/A
Data collected after the implementation of interventions (months 48 – 60)			
Investment in the solution [€]	Eneco, RET	Umeå Parkerings, Umeå Energi	Glasgow City Council
Monitored electricity use of charging points / hubs [MWh/yr.]	KPI generated by technical performance assessment in months 48 and 60 (AIT)		
Annual operational and maintenance costs [€]	Eneco, RET	Umeå Energi	Glasgow City Council
Factors used (months 12 – 60)			
Electricity price for e-charging [€]	Eneco, RET	Umeå Energi	Scottish Power Energy Networks
Electricity price for e-charging of a bus [€]	Eneco, RET	Umeå Energi	N/A
Discount rate [% p.a.]	Single discount rate will be selected for all interventions, e.g. 3%		

Outputs: Two kinds of indicators are foreseen to as output of the investment assessment. Certain indicators are used as a support of business model development and for the provision to SCIS. These indicators are marked as such. Payback periods cannot be aggregated on the project level and are thus used per smart solution. The following indicators are foreseen as a result of these calculations:

- Payback period of a particular solution [in years] (KPI for SCIS),
- Total investments [€].

Planning and responsibilities: Data for e-bus charging and a standard investment for the solution are foreseen to be collected before the implementation starts. Local monitoring coordinator will be in charge with the assistance of the municipality. Data known after the implementation of the solution (investments and operational/maintenance costs) will be collected together with the factors to be used in the calculation (prices at a given time) by the respective monitoring coordinators for each of the lighthouses.

3.3.6 ICT on city level cluster

Scope: The economic assessment for city-wide ICT on city level focuses only on the amount of investments necessary to setup smart solutions. Economic assessment of smart solutions for building energy management systems and demand-side management is included in smart electric grid cluster.

Approach: The overall investment for all smart solutions is aggregated per lighthouse city.

The following clusters are included:

- Rotterdam
  - Energy management (R8)
  - 3-D city operations model (R9)
  - LoRa-network (R10)
- Umea
  - Smart open data city decision platform (U8)
  - Demand-side management (U9)

- Glasgow
  - LORA
  - Smart open data decision platform/central management system (G7)

Table 15 Input data for the economic assessment of the ICT on city level solutions

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected after the implementation of interventions (months 48 – 60)			
Investment in the solution [€]	Municipality of Rotterdam, Future Insight	Municipality of Umeå, SME in charge of implementation	Glasgow City Council

Outputs: The results will be shown per annum and per smart solution, both at city level and aggregated at project level. The corresponding RUGGEDISED KPI is:

- Investments in ICT [€].

Planning and responsibilities:

- Months 12 - 24: Before implementation – partners in charge will be informed about the necessity to provide this information [AIT].
- Months 36 - 60: One year after the finalisation of the implementation the data from the first part of the project is being assessed. These preliminary results are included into the draft of D5.4 at month 48, corrected values (if applicable) into D5.4 final version. [calculations: AIT, provision and collection of data: RISE, TNO and US]

3.3.7 General economic and demographic impacts on district level

Scope: Additional indicators were proposed to lighthouse cities in order to measure indirect impact of the demonstration activities on district level. This includes indicators assessed by municipalities before and in course of the project. The assessment includes indicator acquisition for simple macro- and microeconomic indicators to show the extent to which the implementation influenced households, businesses and employment.

Approach: Direct acquisition of indicators available at the municipality. Predicted indicators are acquired before the implementation starts. Actual indicators are acquired after the implementation finished. Employment and residency indicators include amounts resulting from statistical assessment for a particular district that are checked at the end of the project. Household-related indicators are compared towards a baseline acquired before the implementation starts. The result is a difference between the target and baseline value.

Inputs

Table 16 Input data for general economic and demographic impacts

Data point [unit]	Source Rotterdam	Source Umeå	Source Glasgow
Data collected before the implementation of interventions (months 12 – 36)			
Residents in district [#]	Predicted value (Municipality of Rotterdam)	Predicted value (Municipality of Umeå)	Predicted value (Glasgow City Council)
Employees or visitors in district [#]	Predicted value (Municipality of Rotterdam)	Predicted value (Municipality of Umeå)	Predicted value (Glasgow City Council)
Persons directly involved [#]	Predicted value (Municipality of Rotterdam)	Predicted value (Municipality of Umeå)	Predicted value (Glasgow City Council)
Jobs created directly [#]	Predicted value (Municipality of Rotterdam)	Predicted value (Municipality of Umeå)	Predicted value (Glasgow City Council)
Jobs created indirectly [#]	Predicted value (Municipality of Rotterdam)	Predicted value (Municipality of Umeå)	Predicted value (Glasgow City Council)
Energy bill per household in refurbished buildings [€/yr]	Target value and baseline (Municipality of Rotterdam)	Target value and baseline (Municipality of Umeå)	Target value and baseline (Glasgow City Council)
Maintenance costs per household in refurbished buildings [€/yr]	Target value and baseline (Municipality of Rotterdam)	Target value and baseline (Municipality of Umeå)	Target value and baseline (Glasgow City Council)
Total housing costs per household in refurbished buildings [€/yr]	Target value and baseline (Municipality of Rotterdam)	Target value and baseline (Municipality of Umeå)	Target value and baseline (Glasgow City Council)
Disposable income of citizens in district [€/month]	Target value and baseline (Municipality of Rotterdam)	Target value and baseline (Municipality of Umeå)	Target value and baseline (Glasgow City Council)
Discretionary income of citizens in district [€/month]	Target value and baseline (Municipality of Rotterdam)	Target value and baseline (Municipality of Umeå)	Target value and baseline (Glasgow City Council)
Data collected after the implementation of interventions (months 48 – 60)			
Residents in district [#]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Employees or visitors in district [#]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Persons directly involved [#]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Jobs created directly [#]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Jobs created indirectly [#]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Total investment [€]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Total funding for investment [€]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Energy bill per household in refurbished buildings [€/yr]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)

Maintenance costs per household in refurbished buildings [€/yr]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Total housing costs per household in refurbished buildings [€/yr]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Disposable income of citizens in district [€/month]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)
Discretionary income of citizens in district [€/month]	Actual value (Municipality of Rotterdam)	Actual value (Municipality of Umeå)	Actual value (Glasgow City Council)

Outputs: The following indicators do not require calculation. They will be checked after the implementation.

- Residents in district [#]
- Employees or visitors in district [#]
- Persons directly involved [#]
- Jobs created directly [#]
- Jobs created indirectly [#]

An indicator requested by EC through the SCIS data requirements is calculated as division of funding and total investments (it will be calculated for each city and for the whole project):

- Leverage effect of EU-funding [%]

Indicators for the assessment of the impact on households will be calculated as the difference compared to baseline and expressed as an average value in %:

- Reduction in the energy bill per household in refurbished buildings [average increase in %]
- Decrease in the maintenance costs per household in refurbished buildings [average increase in %]
- Decrease in total housing costs per household in refurbished buildings [average increase in %]
- Change in the disposable income of citizens in district [average increase in %]
- Change in the discretionary income of citizens in district [average increase in %]

Planning and responsibilities: KPI requirements have been provided by AIT to local lighthouse coordinators (Municipality of Rotterdam, Municipality of Umeå and Glasgow City Council). Target values have been collected as well. Baseline will be requested by AIT between months 12 and 24. A second request will follow after the end of the implementation between months 48 and 54 by AIT. Subsequently, AIT will perform calculations and report in D5.5.

3.4 Planning and implementation process assessment

Scope: Assessment of planning, design, procurement and implementation phases of smart solutions in lighthouse cities. For the purpose of this assessment clusters of solutions as outlined in Chapter 2 will be the object of analysis.

Approach: The aim of this task is to evaluate the performance of planning and implementation processes related to the smart solutions which will be implemented in the three light house cities.

What needs to be considered in order to allow for a smooth process for planning and implementation of smart solutions?

The comparability of solutions between the three cities is seen as essential for replication. The clusters defined in Chapter 2 will be assessed individually. Smart solutions will be assessed along the following set of questions:

- What kind of process was established in order to implement the smart solutions? Does this include elements not used before?
- Who are the involved stakeholders and which role in which phase do they play?
- What were obstacles and barriers in the process that needed to be solved?
- How were these barriers overcome?
- What were the lessons learned for future implementation?
- How can the process or method be replicated in other cities?

Table 17: Stakeholder Responsibility for defined Clusters

Cluster		Rotterdam	Umea	Glasgow
Energy Efficiency at Building and District Level	Buildings	Municipality/ Building owners/ construction company	Municipality/ Building owners/ construction company	
	Street lighting	Municipality		Municipality
	Waste management	Municipality		
Smart *Thermal Energy* Grid	Smart thermal grid	Eneco + Municipality	Umea Energi	Tennenat Cal. Brewery + Municipality
	Thermal storage	Eneco + Municipality	Umea Energi	Tennenat Cal. Brewery + Municipality
Smart Electric Grid	Smart Electric Grid	Eneco + Municipality	Umea Energi + Akademiska Hus	Municipality + Siemens
	Electric storage	Eneco + Municipality		Municipality + Siemens
Mobility	E-cars	Enerco + RET	Municipality + Umea Energi	GCC
	E-bus	Enerco + RET		
ICT on city level	ICT on city level	Municipality of Rotterdam/ Future Insight	Municipality	GCC

The main results of the telephone interviews on the managerial and organisational innovations will be fed into a specific session with the Liaison Groups (WP1) as to validate and complement the conclusions. The discussion in the Liaison Groups will also be directed towards the institutionalisation of the managerial and organisational innovations: Which ones were institutionalised? How? What was the specific role of planning processes? Were the innovations taken up in a certain planning processes (energy, mobility, spatial planning, etc.)? How? Conclusions from the Liaison Groups discussion will be taken up in the evaluation report.

Inputs: Information will be mainly gathered in interviews and workshops with the city coordinators and key stakeholders. The focus will lie on smart solutions from a management and organisational point of view. Further relevant information includes involved stakeholders and their role, barriers and obstacles as well as lessons learned.

Outputs: As detailed description will be outlined along with mapping of the organisational structure that is needed / in place in order to implement smart solution in Umea, Glasgow and Rotterdam. The results from the organisational evaluation will feed into Task 1.4 – Documentation of Lighthouse City experiences. The result should especially help to better describe the processes presenting the different stages of planning, procurement, and implementation and monitoring in the three cities.

Planning: A detailed methodology including the outline of interviews will be defined between months 12 and 18 by AIT. Two surveys are planned. The first one should be done before the implementation starts between months 19 and 24. A second survey after the implementation between months 51 and 55 will provide information on deviations from the initial planning. Activities will be performed by AIT. The involvement of local coordinators from all three lighthouse cities is necessary for conducting the interviews.

3.5 Social impact assessment

Scope: Social impact will be assessed for each lighthouse city's urban development project as well of those smart solutions which have a visible interface to their users within the limits of the targeted district. In addition, respondents are inquired about the awareness and role with regard to the RUGGEDISED project.

Approach: In order to evaluate the perceived impact of the different interventions and smart solutions featured by the RUGGEDISED project on stakeholders' (dweller, commuter, students, etc.) Quality of Life (QoL) and acceptance, a comprehensive feedback questionnaire will be distributed in each lighthouse city. The stakeholder feedback data obtained via the questionnaire will be used to quantify the social impact of different smart solutions by gauging user opinions, expectations and perceptions and comparing their statistics over time. The questionnaire is supposed to be filled out by representative samples from each relevant stakeholder group (residents, commuters, visitors, etc.) of the demonstration areas targeted in each lighthouse city. The questionnaire consists of four parts. Beyond questions about a subject's demographic background, perceived impact is inquired on three different levels: L1) Impact of the city's urban development project on Quality of Life (QoL), L2) Awareness and perceived impact of the RUGGEDISED project, and L3) Acceptance of smart solutions.
For all three levels, subjects answer to specific questions on expected or perceived impact (social, economic, mobility, etc.) by means of Likert scale ratings. Furthermore, a difference is made between perceived impact on the individual person vs. estimated impact on other people belonging to the subject's community or neighborhood.

As regards assessment of acceptance of smart solutions (L3), only those smart solutions that have a visible effect or interface to the user are evaluated. To provide understandable concepts to respondents, smart solutions are aggregated as four clusters (see also Section 2): electric vehicle charging infrastructure, smart mobility support (new e-bus fleets, heated bus stops, etc.), demand-side energy management for building control, and intelligent and efficient street lighting.

The templates represent questionnaires to be filled out a large number of users (>200 for each stakeholder group)[5] in the two campaigns in the different lighthouse cities. The target groups will be defined together with each lighthouse city based on relevance and exposure of audience groups to the planned interventions in the respective demonstration areas[6]. For example, in Umeå, primarily students of Umeå University will be targeted, while in Glasgow, employees of the Glasgow City Council and members of the University of Strathclyde will provide their feedback. The purpose of this design is to enable a statistically reliable comparison of social impact over time for the well-defined, most relevant citizen stakeholder groups rather than for a complete representative cross-section of the city population. After each campaign, the results data from all returned questionnaires will be validated and aggregated for further statistical analysis.

Inputs: Input to the process is the raw data from participant responses to the questionnaire from each campaign in each lighthouse city.

Outputs: The following outputs are foreseen as result of the social impact assessment:
- Statistical analysis of the questionnaire results data
- Interpretation of the statistical results analysis

Planning and responsibilities: Survey campaigns (= data collection and results analyses) are to be performed two times throughout the project in order to enable comparison between before-implementation and after-implementation situations in the target district in each lighthouse city. Note that this monitoring of social impact will be implemented together with the organizational monitoring for efficiency reasons, as described in Deliverable D5.2. The results enable post-evaluation of processes (T5.5.11) as well as impact assessment (T5.6). The following work will happen in two major phases:

- Clarification and preparation of the survey campaigns with the three light house cities – this includes the detailed design of the social impact survey campaigns (including definition of target groups and data formats) and the actual responsibilities and structures for executing them. In this context, AIT will provide a LimeSurvey instance of the questionnaires for each lighthouse city. Each city (local coordinator, with advice from local research organizations) will be responsible for questionnaire

[5] In order to obtain a valid quote random sample, a sufficiently large share of each targeted population needs to participate in the survey. Subject participation thus represents a risk that needs to be monitored during campaign execution.

[6] The key here is that respondents must be citizens truly affected by the developments in the targeted demonstration areas. This is to be ensured by taking geography into account when advertising the surveys as well as by integrating checks (like a clickable map) in the survey to make sure that respondents truly live or commute in the respective target district.

translation to the local language, adding the city-specific introduction and participant briefing, and pre-testing[7] the questionnaire. This phase will be finished by month 18.

- Actual monitoring of social impact – The actual survey campaigns are to be performed two times throughout the project in order to enable comparison between before-implementation and after-implementation conditions in each lighthouse city. In this sense, the first survey campaign will run from month 19 until month 25, while the second survey campaign will run from month 35 until month 41. Note that the monitoring of social impact will be implemented together with the organizational monitoring for efficiency reasons. During the survey campaigns, AIT will host the different instances of the questionnaires on a LimeSurvey server. Each lighthouse city (local coordinator, with advice from local research organizations) will be responsible for advertising the survey, ensuring that a sufficiently large number of respondents of the target groups participates in the survey[8], and that results data is provided in the right format and quality according to the guidelines[9] specified in the previous phase. AIT will then analyse the survey results data in order to quantify social impact of the different implementations. The results will be will be used for the final assessment of the lighthouse cities (D5.5).

All activities will happen in cooperation with local coordinators of lighthouse cities and local research partners. The impact questionnaire templates will be the basis for the work in task 5.5 Process evaluation.

3.6 Assessment of the contribution to city strategies and targets

Scope: Within RUGGEDISED the Lighthouse cities are experimenting with the implementation of smart solutions in particular districts of the city. The assessment of the contribution to city strategies and targets focuses on how lessons learned from the RUGGEDISED project are translated into relevant planning strategies of the Lighthouse cities, and especially on the EU prescribed Sustainable Energy Action Plans (SEAPs) and the cities' digital strategies or smart city strategies.

Approach: A three steps approach will be followed.

As a baseline the SEAPs of the Lighthouse cities are analysed. This analysis aims to qualitatively describe the perspective of the Lighthouse cities on 'smart cities' in general, on the districts that are involved in RUGGEDISED in particular, and on the smart solutions that are being implemented.

Q1) How well embedded are the Lighthouse districts in the SEAPs and is it possible to recognise the interaction of the Lighthouse districts with the existing SEAPs?

SEAPs are written at the scale of the city as a whole. Therefore the Lighthouse city districts should have a place in existing SEAPs. During the implementation of the smart solutions, we will focus on the interaction between the SEAPs and the measures in the Lighthouse districts. The way in which measures that have proven to be successful at the district level are deployed to other districts of the Lighthouses (and are thus being mentioned in the SEAP[10]) shows the upscaling ambitions and learning capacity of the Lighthouse cities and their partners. Indicators are (1) the number of revisions and the adjustments of the SEAP that include successful smart solutions from the Lighthouse districts and (2) the way in which these smart solutions are being modified in the SEAP according to the lessons learned by the Lighthouse cities (discussed in the Liaison Groups and Innovation Platforms).

[7] Based on the feedback of the pre-testing, AIT provide an improved LimeSurvey questionnaire instance for the actual campaign.

[8] Each city will need to monitor survey participation of each target group and in case of problems decide on corrective action in close coordination with AIT.

[9] The guidelines for survey data storage and exchange will be developed until month 18. They will address survey data structure, format, quality and timing of transfers.

[10] "The SEAP should not be regarded as a fixed and rigid document, as circumstances change, and, as the ongoing actions provide results and experience, it may be useful/necessary to revise the plan on a regular basis." From: Covenant of Mayors (2010). How to develop a SEAP.

Furthermore, other relevant planning documents, digital strategies and smart strategies of the Lighthouse cities are checked from the start of the project.

Q2) How are the lighthouse districts and their smart solutions "framed" and embedded in the relevant other documents and strategies of the Lighthouses?

The smart city strategies and digital strategies of the Lighthouse cities will be analysed in a similar way as the SEAPs. If information on the Lighthouse district and the smart solutions cannot be found in these strategies and plans, then the people developing these documents will be interviewed as to find out how the Lighthouse districts and the related actions will be embedded and what expectations exist on what the smart solutions will deliver for this strategies in the future.

In analogy with the monitoring of the SEAPs, indicators are (1) the number of revisions of the relevant planning documents, smart city strategies and digital city strategies and (2) the extent to which experiences with the implementation of smart solutions influence the city strategies.

Q3) How do the implementation experiences influence the city strategy?

The information regarding the influence of RUGGEDISED experiences on the SEAPs and other smart and digital city strategies together with the summarised information on the impact from D5.5, is taken up in the draft deliverable D5.6.

This draft is then validated in an intensive collaborative 2-day workshop with the involved people from all three Lighthouse cities. The members of the Liaison groups are invited as a 'core group' to this workshop. In interactive sessions we will facilitate the discussion between the cities on the impact of RUGGEDISED, city strategy alignment and policy embeddedness. During the workshop the participants are invited to explicitly reflect on the impact of RUGGEDISED (smart solutions and experiences). The discussion is geared towards conclusions about the way in which the city could (and should) improve the relevant strategies in the future. This will foster the impact of RUGGEDISED beyond the scope of the project's duration.

In conclusion:

Inputs: Information will be collected in the relevant documents, through interviews and during a two-day workshop. Documents to be analysed will be different per city, but in general:

- the Sustainable Energy Action Plans (SEAPs);
- sustainability program
- digital strategy or smart city strategy;
- links of smart solutions and interventions on district level to strategies;
- impact of smart solutions and interventions on district level to strategies.

Outputs:
D5.6 will outline the impact of RUGGEDISED (smart solutions and experiences) on the Lighthouse cities' SEAPs and other relevant plans and strategies. In addition it will also go beyond the project duration providing conclusions about the way in which the city could improve relevant strategies in the future.

Planning and responsibilities: Task 5.6 runs month 55-60. However, earlier preparation is recommended. The planning foresees the following stages:

- Month 6 – 18: Provision of SEAPs and smart city strategy by each of the three municipalities (ROT, UMEA, GCC);
- Months 18 – 24: Initial assessment of strategies (TNO);
- Months 48 – 55: Preparing draft 5.6 by assessment of links between solutions and strategies, interviews where necessary(TNO);
- Month 55 (approx.): Workshop in line with WP1-planning (TNO);
- Month 60: Final version of D5.6 (TNO).

3.7 Assessment of activities of follower cities

Scope: The impact evaluation in follower cities assesses effects and activities in Parma, Gdansk and Brno (1) focussing on the improvement of the level of cooperation in the city governance and on the increase of capacity on smart cities topics thanks to RUGGEDISED-activities with the aim to (2) enable an environment for the replication of solutions implemented by lighthouse cities.

Approach: Our approach is aligned with ongoing activities of WP7. Objectives that have been given to improve cooperation and capacity will be explained by effect indicators that are derived from activity indicators (targets) assessed during the performance of WP7. There are two kinds of activity indicators:

- Fulfilment of criteria with given quality level and amounts, e.g. three running and permanent local governing groups. These indicators will be planned over the period of the project duration and their fulfilment checked on a regular basis, in most cases annually. Deviations will be subject to explanation.
- Improvement compared to a baseline expressed as a percentage – these indicators will be measured via a short questionnaire using a Likert-scale. The questionnaires are aimed at assessing the cooperation as well as the capacity level. The targets groups of these questionnaires are: people working in the municipality as well as external stakeholders that are taking part in the foresight process and local smart cities activities. The baseline will be set in the report D7.1 Initial replication assessment which is due month 19. The second query will be performed at the end of the project. The difference will be compared to target and deviations explained. Details on this methodology will be provided in due time to the fellow cities and will be reported in the Initial Replication Assessment.

Inputs: The values (see also red-marked values in Table 18) of indicators outlined in the project proposals need to be revised to correspond to the needs of follower cities' stakeholders and be in line with the current planning of follower cities. Discussions to do so will happen before baselines are being discussed with coordinators of follower cities.

Outputs: The targets set in the fellow cities) relate to the objectives set out by the work plan of WP7, which is in charge of the replication efforts of RUGGEDISED. The three follower cities seek to pave the way for smart solutions replication through:

- The improvement of the level of cooperation among the relevant stakeholders taking part in the local smart city projects. These indicators are measured in terms of number of meetings of the local governing groups and the number of estimated participants to each meeting (number of involved stakeholders, already identified, times the number of attending individuals). All three cities have already running forms of governance that will be enhanced in RUGGEDISED through knowledge exchange of local practice and adoption of co-creation approaches. Accordingly, the 3 follower cities estimate an improvement of the level of satisfaction with the local cooperative processes. This indicator is a local expert estimation measured as an increase percentage over the 2016 baseline.

- The improvement of the level of capacity necessary to effectively replicate the selected smart solutions after the end of the project. This dimension is assessed through the delivery of a number of key planning documents (the Smart City Vision, the Roadmap to Implementation, and the Replication and investment Plan) as well as the acquisition of organisational and technical competence transferred from the lighthouse cities and necessary for the actual smart solutions deployment. Capacity improvement is a local expert estimation measured as an increase percentage over the 2016 baseline.

Table 18 Evaluation framework for follower cities

Link	Objectives	Outcomes (effect indicator)	Targets (activity indicator)
Improvement of the cooperation	Create physical and virtual environments for stakeholder and community interaction and involvement in the follower cities	Local smart city cooperation (institutions, utilities, industries, businesses, civil society)	• 3 running and permanent local Governing Groups • 10 local Governing Groups meetings each attended by 40 individual participants in Brno • 13 local Governing Groups meetings each attended by 12 individual participants in Gdansk • 15 local Governing Groups meetings each attended by 40 individual participants in Parma
			• Overall satisfaction with the level of local cooperation (calculated in % improvement over 2016 baseline).

Link	Objectives	Outcomes (effect indicator)	Targets (activity indicator)
			○ Brno: 30% ○ Gdansk: 20% ○ Parma: 30%
Improvement of the capacity	Define the vision and the path to smart solutions replication	Long-term and tactic planning	• Adoption of 1 strategic Vision and 1 Roadmap to implementation in Brno • Adoption of 1 strategic Vision and 1 Roadmap to implementation in Gdansk • Adoption of 1 strategic Vision and 1 Roadmap to implementation in Parma
	Acquire the necessary competences to replicate the smart solutions	Local and inter-project capacity building	• 6 Replication Workshops, each attended by 4 experts in Brno, 4 in Gdansk, and 4 in Parma
			• 6 Governance Workshops, each attended by 20 individual participants in Brno, 20 individual participants in Gdansk, and 50 individual participants in Parma
			• 3 intensive Study Tours, each attended by 4 experts from Brno, 4 from Gdansk and 4 from Parma
			• 1 international Study Tour attended by 4 experts from Brno, 4 from Gdansk and 4 from Parma
			• Overall perception of improved smart city capacity thanks to project activities (calculated in % improvement over 2016 baseline): ○ Brno: 20% ○ Gdansk: 20% ○ Parma: 40%
	Deliver Replication and Investment Plans	Detailed planning of smart solutions replication	• Adoption of 1 Replication and Investment Plan in Brno • Adoption of 1 Replication and Investment Plan in Gdansk • Adoption of 1 Replication and Investment Plan in Parma

Planning and responsibilities: The implementation foresees three stages:

1. Months 12 - 19: Targets will be revised by ISINNOVA based on discussions with follower cities' coordinators. Afterwards baselines will be set by a query sent to stakeholders of follower cities. A plan for tracking of criteria fulfilment will be established and reported in the "Initial Replication Assessment" (M19).
2. Months 26 – 44: Within activities of WP7 the implementation will be tracked and recorded. Results will be documented in D7.3 Intermediate Replication Assessments (M44).
3. Months 44 – 60: A second query with city stakeholders will be performed. Final assessment of activities will be done together with explanations on deviations. Results will be summarised in D5.7 Monitoring report on measures to maximise the impact.

ISINNOVA is responsible for the entire process. Fellow cities will provide their support in this activity.

4. Impact

The impact section of the proposal gives a first overview on the expected impacts across the Lighthouse cities and presented a preliminary list of quantitative indicators, which will be followed up in the monitoring process to assess the key expected impacts identified by each Lighthouse city. The proposed solutions are expected to result in:

- 182,000 m² of high efficient buildings, with a reduction of 3,700 t CO_2;
- 4,760 MW of newly installed renewable capacity in the districts that amount to 3,800 t CO_2;
- Savings over 1,800 t CO_2 thanks to e-mobility actions;
- 80 charging stations and 11 large e-hubs in order to ensure the roll-out of electric vehicles;
- direct benefits for more than 200 thousand citizens
- 1 billion EUR investments in the Lighthouse areas creating
- 1,900 new jobs only from the investments.

The methodology followed different assessment perspectives within five clusters of smart solutions. However to show the overall impact in a city or for the whole project the results of the different assessment streams need to be integrated in a common KPI list. This list summarises the overall impact of the project. It is based on the methodology of this guide and links its results with the overall impact targets as these have been outlined in the project proposal. The assessment will be subject to the work of Task 5.4 and will result in the Overall assessment of lighthouse projects in D5.5.

The following objectives of the lighthouse call have been taken as a bases to determine the impact of RUGEDISED:

- O1) Increase the energy efficiency on district scale at least;
- O2) Increase significantly the share of renewable energies, their integration into the energy system, stimulate self-consumption, reduce curtailment to the minimum;
- O3) Increase local air quality;
- O4) Reduce the technical and financial risks in order to give confidence to investors for investing in large scale replication;
- O5) Make the local energy system more secure, more stable and cheaper for the citizens and public authorities;
- O6) Ensure the roll-out of electric vehicles in cities while containing the need for excessive upgrading of the electricity grid);
- O7) Reduce transport based CO2 emissions , on the basis of CO2 intensity of the European electricity grid of 540 CO2/kWh (coherent with TEST format);
- O8) Create stronger links and active cooperation between cities in a large number of Member States with a large coverage of cities with different size, geography, climatic zones and economical situation

Table 19 Key performance indicators of RUGGEDISED

Key Performance Indicators

Indicators	Number of Smart Solutions Glasgow	Target Glasgow	Number of Smart Solutions Rotterdam	Target Rotterdam	Number of Smart Solutions Umea	Target Umea	Objectives of call	
General Assessement of Building								
New Built Floor Area, Residential[m²]		0	R1 - R13	13000	U4	0		
New Built Floor Area, Tertiary Buildings[m²]		0	R1 - R13	61193	-	0		
Refurbished Floor Area, Residential[m²]		0		-	-	0		
Refurbished Floor Area, Tertiary Buildings[m²]		0	R1 - R13	18691	U4B	36033		
Floor Area Of Buildings With DSM[m²]	G9, G10	52000	R1 - R13	92884	U2, U9	265000		
Refurbished Floor Area, Total[m²]		0	R1 - R13	18691	U2, U9	TBA		
Performance Assessment								
Energy Efficiency Interventions at Building and District Level Cluster								
Energy Savings by Building Efficiency Measures[MWh/yr]	n/a	0	All Buildings	7969	All Buildings	2316	O1	O5
Energy Demand Reduction[%]	n/a	0	All Buildings	25	All Buildings	39	O1	O5
Final Energy Savings by street lighting interventions[MWh/yr]	G6,G7,G8		R11		-		O1	O5
Final Energy reduction by street lighting interventions[%]	G6,G7,G8		R11		-		O1	O5
Final Energy Savings by waste management interventions[MWh/yr]	n/a		R13	TBC	n/a			
Primary energy savings by building energy efficiency measures and street lighting [MWh/yr]	G6 - G8		R11		n/a		Provide information to SCIS	
Smart Thermal Grid Cluster								
Installed RES Capacity Heating[MW]		0	R1 - R13	0.3	-	4	O2	O5
Floor Space to be Connected to District Heating[m²]	G1	40696	R1 - R13	79884	Possibly U4	0	O1	O5
Share of RES (excl excess heat) in District Heating[%]		0	R1 - R13	40	U1	90	O2	
Electricity Generated by RES[kWh/yr]	G4	192000	R1 - R13	1935101	U5, U6	88000	O2	O5
Peak demand reduction [%]	n/a		R1-R4; R8		U2		O5	
Thermal Energy Generated[kWh/yr]	G1	5087769	R1 - R13	948333	U1	0		
Thermal Storage Energy Used[MWh/yr]		0	R1 - R13	1632	U3	5000	O5	
Primary energy savings by cluster [MWh/yr]	G1		R1-R4; R8		U1-U3		Provide information to SCIS	
Primary energy demand reduction [%]	G1		R1-R4; R8		U1-U3		Provide information to SCIS	
Reduced energy curtailment of RES and DER [%],	G1		R1-R4; R8		U1-U3		O2	O5
Degree of self-supply by RES [%]	G1		R1-R4; R8		U2-U3		O2	O5
Smart Electric Grid Cluster								
Electricity Storage[MWh]		TBC	R1 - R13	0.56	-			
Installed RES Capacity Electricity[MW]	G4	0.02	R1 - R13	2.13	U5, U6	0.09		
Primary energy savings by cluster [MWh/yr]	G8-G10		R5; R8		U2; U4		Provide information to SCIS	
Primary energy demand reduction [%]	G8-G10		R5; R8		U2; U4		Provide information to SCIS	
Reduced energy curtailment of RES and DER[%]	G8-G10		R5; R8		U2; U4		O2	O5
Peak demand reduction[%]	G8-G10		R5; R8		U2; U4		O5	
Degree of self-supply by RES [%]	G8-G10		R5; R8		U2; U4		O2	O5
Storage Energy Used[MWh/yr]	G8-G10		R5; R8		U2; U4		O5	
Mobility cluster								
Number of e-vehicles after the intervention	G3, G5, G6	18	R5-R7	4 (bus)	U5, U6	23 (bus), 20 (taxi)	Provide information to SCIS	
Number of Vehicles with Alternative Energy Carriers (Excl. Electricity)[#]		0	R1 - R13	2 (bus, hydrogen)	U5, U6	-	O7	
Number of Charging Stations[#]	G3, G5, G6	15	R1 - R13	25	U6	21	O6	O7
Number of e-Hubs[#]	G3, G5, G6	1	R1 - R13	1	U6	1	O6	O7
Energy Savings by Mobility Measures, Total [kWh/yr]		78		150		1631	O6	O7
ICT on city level cluster								
Open Solutions[#]	G2, G3, G4, G5, G6, G7, G8, G9, G10	15	R1 - R13	3	U8	6	Provide information to SCIS	
Interoperability 3rd Party Applications[#]	G2, G3, G4, G5, G6, G7, G8, G9, G10	10	R1 - R13	1	U4,U5,U7, U8	4	Provide information to SCIS	
Integrated ICT systems[#]	G2, G3, G4, G5, G6, G7, G8, G9, G10	7	R1 - R13	1	U2, U4 (2),U5,U6 ,U8, U9	7	Provide information to SCIS	

Key Performance Indicators

Indicators	Number of Smart Solutions Glasgow	Target Glasgow	Number of Smart Solutions Rotterdam	Target Rotterdam	Number of Smart Solutions Umea	Target Umea	Objectives of call	
Environmental Impact Assessment								
CO_2 Reduction Achieved by Energy Supply Measures, Total[t/yr]	96	G4, G1	1442	R1 - R13	210	U5, U6		
Energy Efficiency Interventions at Building and District Level Cluster								
CO_2 Reduction Achieved by Building Efficiency Measures[t/yr]	n/a	0	All Buildings	3215	All Buildings	377	O3	
CO_2 Reduction by Energy Measures[t/yr]	n/a	872	All Buildings	4657	All Buildings	774	O3	
CO_2 Saving street lighting[t/yr]	G6 - G8		R11		n/a		O3	
CO_2 Reduction street lighting [t/yr]	G6 - G8		R11		n/a		O3	
Smart Thermal Grid Cluster								
CO_2 savings [tonnes CO_2/yr]	G1	96	R1-R4; R8	1442	U1-U3	210	O3	
CO_2 reduction [%]	G1		R1-R4; R8		U1-U3		O3	
Smart Electric Grid Cluster								
Primary energy savings [MWh/yr]	G2-G6; G8-G10		R5; R6; R8		U2; U4		Provide information to SCIS	
primary energy demand reduction [%]	G2-G6; G8-G10		R5; R6; R8		U2; U4		Provide information to SCIS	
CO_2 savings [tonnes CO_2/yr]	G2-G6; G8-G10		R5; R6; R8		U2; U4	187	O3	
CO_2 reduction [%]	G2-G6; G8-G10		R5; R6; R8		U2; U4		O3	
Mobility Cluster								
CO_2 savings [tonnes CO_2/yr]	G2; G5; G6		R5-R7		U5-U7		O4	O3
SO2 savings [g SO_2/yr]	G2; G5; G6	18	R5-R7	435	U5-U7	375	O4	O3
NO_x savings [g NO_x/yr]	G2; G5; G6	58	R5-R7	1420	U5-U7	1223	O4	O3
PM_{10} savings [g CO_2/yr]	G2; G5; G6	10	R5-R7	226	U5-U7	195	O4	O3
General Economic and Demographic Impacts On District Level								
Residents in Selected Areas[#]		~1500 residents & ~1700 students	R1 - R13	1224	U1-U9	3000		
Employees and Daily Visitors in Selected Areas[#]		21000 students, ~8500	R1 - R13	2631 employees, 108000 daily visitors	U1-U9	52000		
Persons Directly Involved[#]	G1-G10	19	R1 - R13	225				
Average Reduction Of Energy Bill per Household in Refurbished Buildings[€/yr]	G1, G9	TBC	R1 - R13	268119 (Total)	U4	n/a		
Average Reduction In Maintenance Costs per Household in Refurbished Buildings[€/yr]	G1, G10	TBC	R1 - R13	-	U4	n/a		
Average Reduction In Total Housing Cost Per Household in Refurbished Buildings[€/m^2yr]	G1, G11	0	R1 - R13	-	U4	n/a		
Individual Cost for Living (Focus on Energy/Housing & Transportation) for Citizens[€/month]	G1, G12	n/a	R1 - R13	729	U4	659		
New Business Models Developed and Validated [#]	G1	2	R1 - R13	TBA	U1, U3, U4, U7	3		
Jobs Created (Directly)[#]	G1-G10	TBC	R1 - R13	130	U1-U9	TBA		
Jobs Created (Indirectly)[#]	G1-G10	TBC	R1 - R13	300	U1-U9	TBA		
Disposable Income of Citizens in Lighthouse Districts[€/month]		TBC	R1 - R13	26200 (Total)	U1-U9	1328		
Discretionary Income of Citizens in Lighthouse Districts[€/month]		TBC	R1 - R13	22200 (Total)	U1-U9	813		
Investment In Construction Solutions [Million €]		0	R1 - R13	335.0	U4, U5	TBA		
Investment In Energy Solutions [Million €]	G1, G2, G3, G4	0.98	R1 - R13	7.2	U1, U2, U3, U9	TBA		
Investment In Mobility Solutions [Million €]	G5	0.32	R1 - R13	0.8	U5, U6, U7	TBA		
Investment in ICT[Million €]	G7	0.08	R1 - R13	1.7	U4, U6, U8	TBA		
Investment, total[Million €]	G1-G10	1.38	R1 - R13	9.7	U1-U9	TBA		
Leverage effect of EC funding[%]			R1 - R13	3.5	U1-U9	TBA		

5. Utilisation of results

The methodology, necessary data sets and related indicator definitions will be used in different work packages of RUGGEDISED:

- **WP5:** This deliverable is the main guidance for partners and methodological outline for the work package. Since there are several risks related to the usage of different formats, national standards and lack of partner commitment, a major purpose of this document is to provide a common framework and unify the approach before the implementation starts. Also the different perspectives used to assess the impacts of RUGGEDISED need to be aligned before any specialised assessment can start. This will allow for a proper compliance of results when it comes to support the replication of smart solutions at the end of the project. The structure of this document will be used as basis to structure the major deliverable of WP5 D5.5 Assessment of lighthouse projects at the end of the project.

- **WP2, WP3 and WP4:** Results and methodology will influence the implementation of monitoring devices coordinated in Task 5.2 towards implementation in lighthouse coordination work packages. To deal with risks related to deviation of outcomes from the desired targets continuous assessment in Task 5.4 is foreseen and will be fed back to lighthouse work packages. Most importantly this document should provide basic guidance to partners involved in local implementation activities on how to set up local information and data collection before or during the implementation of interventions and smart solutions.

- **WP1:** Assessment of WP5 will feed into discussions of the liaison group set up in Task 1.2. This will provide important feedback necessary to streamline the outcomes of WP5. Results from the various fields of assessment will accompany results summarised in the documentation of lighthouse city experiences in Task 1.4.

- **WP6:** Outcomes of the assessment but most importantly the economic and business assessment will be fed into WP6-work. This will include payback period calculation that usually accompanies the business outline of innovative solutions and to assess the long-term upscaling potential and energy system effects of smart solutions performed in Task 6.4.

- **WP7:** The methodology and indicator framework for activities in follower cities will be provided to WP7. Activities will be monitored in WP7 and provided back to WP5, Task 5.7 at the end of the project. Through alignment in WP1, follower cities and research organisations working in WP7 will also provide feedback on information and data outputs of WP5 to ensure the outcomes support the replication of smart solutions. The outputs need to be understandable to those performing replication.

- **WP8:** WP5 covers parts of WP8 activities related to the alignment of assessment results (i.e. KPIs). It also produces data and other information that need to be provided to the Smart Cities and Communities Information System.

- **WP9:** WP5 provides data, indicators and other outcomes that are being used to disseminate results of RUGGEDISED and its solutions. Main channel for these activities will be bundling of information related to experiences about smart solutions collected within WP1. In addition, data structure and privacy issues have been and will be provided in updates to Task 9.8 Data management. These are documented in a data management plan. This tool will be used to structure data that are also used by WP5 to be provided to public inventories for data of projects.

6. Risk Register

Related risks from project's Risk & mitigation sheet that are included in Steering Group Work package planning have been transferred to Table 20. This includes risks related to WP5 but also other risks related to the subject of the present document. The solutions to overcome the risks were re-evaluated based on the present document and on current developments.

Table 20 Risks related to WP5-activities

Risk	What is the risk	Level of risk[11]	Solutions to overcome the risk
R8	Different cities use different monitoring methodologies and metrics. Incomparable datasets produced. Difficulty in generating relevant monitoring data for projects and underestimation of time required to acquire data.	2	The purpose of this document is to unify monitoring methodologies and metrics. This is done to ensure a calculation of an overall impact of RUGGEDISED is possible and outcomes are aligned with initiatives where RUGGEDISED provides data.
R9	Too much data to process	2	Data sets were defined according to minimum requirements that are necessary to know to assess performance or impact.
R10	Insufficient involvement of stakeholders with effect on demonstration actions	3	Monitoring workshops were held to involve local stakeholders into the evaluation activities and make them aware of the necessity of data provision.
R13	Measures prove not to achieve the energy savings goals and replication potential as set up by the project and call text	2	The purpose of Task 5.4 Continuous analysis is to assess interventions and solutions in due course and make stakeholders aware in an early stage.
R15	Different procedures and metrics exist regarding data collection and measurement in the energy, ICT, transport and infrastructure sectors.	2	The evaluation methodology considers also synergetic effects between infrastructures. The comprehensive assessment developed for this purpose ensures metrics are aligned.
R16	LHCs experience difficulties collecting the required data and the overall progress of the WP is affected.	3	This issue is checked during the definition of data sets. Person or organisation in charge is defined. In addition, the issue will be subject to deliverable D5.3 Maintenance plan at month 18.
R17	Smart city solution are often hampered by inconsistent standards, even within the same city, and regulations (especially across countries)	3	D5.1 uses unified methodology given by SCIS. National or local differences are being re-calculated by local research partners to the common framework.
R18	The implementation of smart solutions and analysis of their transferability and scalability potential require continues commitment from all participating cities and their local partners to guarantee success of implementation and access to knowledge and data to identify upscaling potentials and evaluate solutions.	3	With regards to the commitment to evaluation local monitoring workshops have been held to actively involve local partners into evaluation activities. Teleconferences and intensive communication have been used to ensure commitment of partners involved in other related work packages.
R20	The smart solutions included in RUGGEDISED cover a wide range of applications in the energy, building and transport sector, included hardware and software, as well as different business and management options and open data solutions.	N/A	A combination of comprehensive evaluation methodology considering synergies as well specific assessment of smart solutions for the replication purposes ensure a proper assessment of such a complex system.
New risk	Replacement of smart solutions or buildings affecting monitoring and evaluation activities	1	The assessment will be adapted as soon as information is available. Discussion with concerned stakeholders and local coordinator will be established. Subsequently, assessment will be adapted accordingly.

[11] Risk level: 1 = high risk, 2 = medium risk, 3 = Low risk

New risk	Delay in the implementation of a smart solution is affecting monitoring and evaluation activities.	1	Since assessment activities are scheduled after the implementation, delays might affect the duration of the project. Therefore WP5 will be actively engaged in the discussion concerning the delay of implementation. The discussion needs to involve partner in charge of smart solution, local coordinator and project coordinator. An advice of the European Commission is essential in any case and will be requested. The decision needs to be performed by either the Steering Group or General Assembly.
New risk	Social impact survey campaigns are implemented inconsistently across different cities, leading to incomparable datasets and results.	2	Deliverables D5.1 and D5.2 clearly specify survey methodologies and questionnaires. Survey implementation by cities will be monitored. This should ensure consistent evaluation of the social impact of the project.
New risk	Number of respondents to social impact surveys are too low for obtaining statistically significant and valid results.	2	Questionnaire design will be optimized for maximum ease of use and low effort for respondents. Campaign implementation and participation will be monitored, with corrective actions to be taken in close coordination with the implementing cities.

7. References

CITYkeys Website: Main; http://www.citykeys-project.eu/ [last access 29.8.2017]

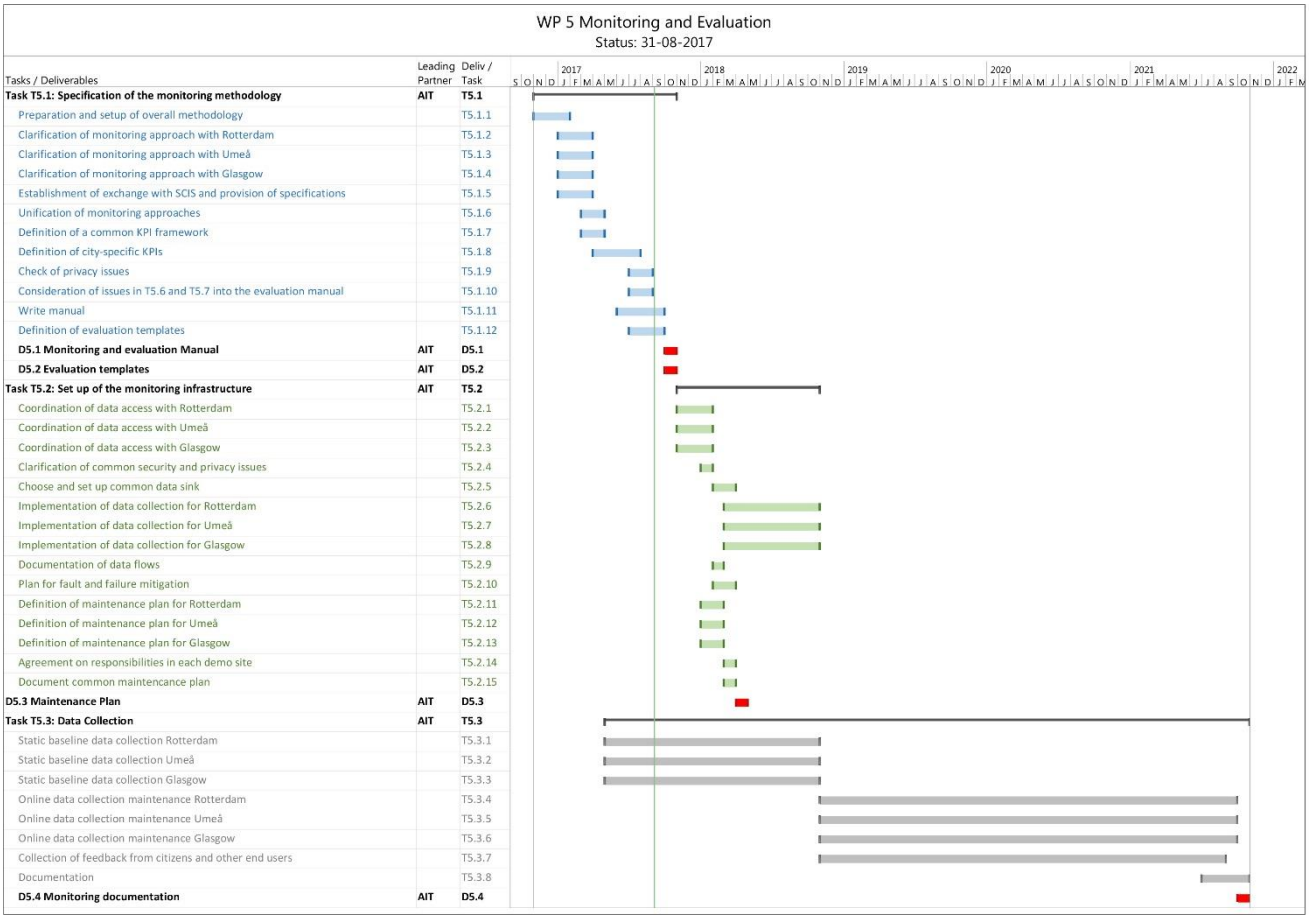
Smart Cities Information System: Key performance indicator guide. Version 2; February 2017; http://www.smartcities-infosystem.eu/sites/default/files/document/scis_kpi_guide.pdf [last access 29.8.2017]

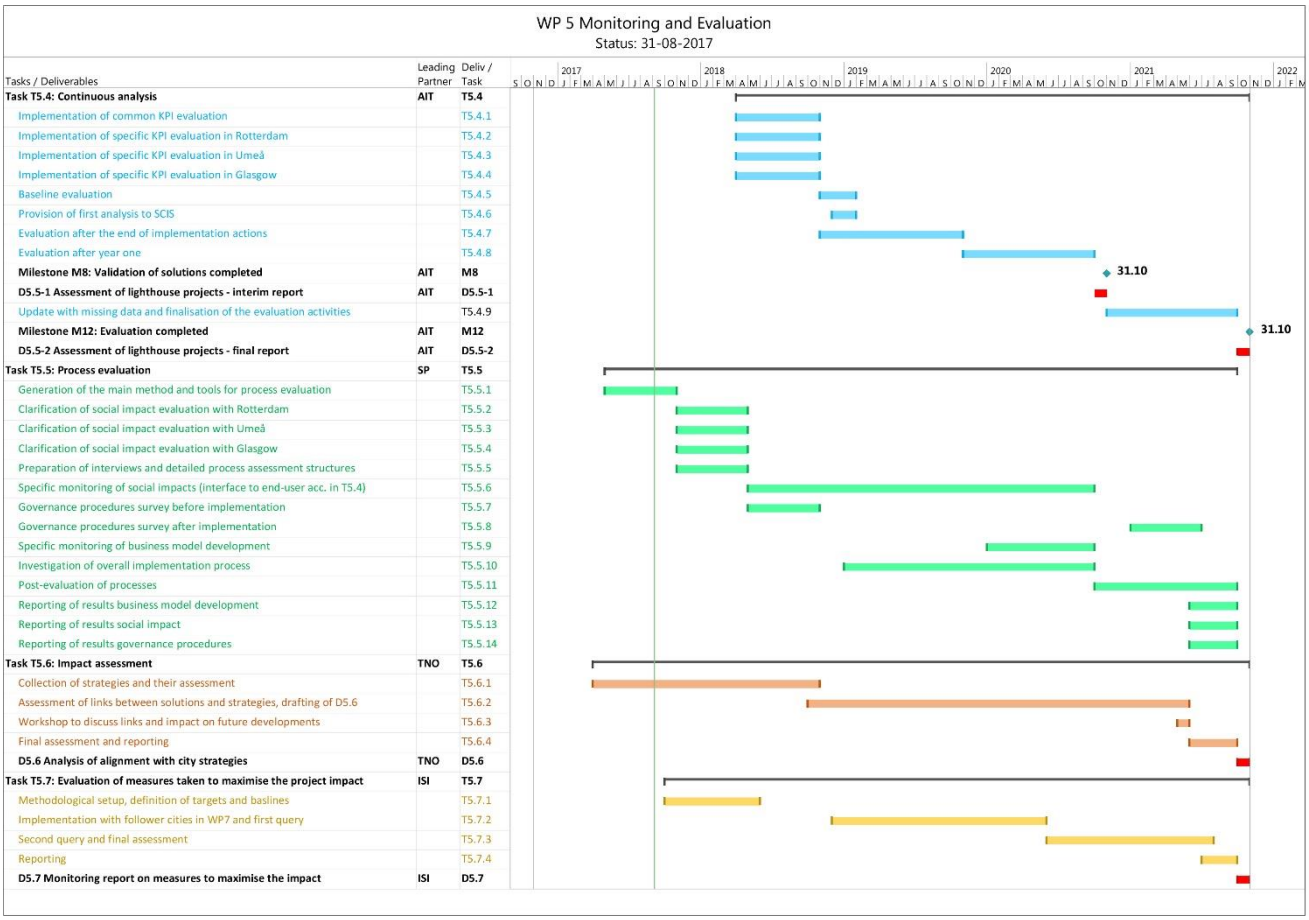
Smart Cities Information System: Technical monitoring guide. Version 1; 2016; http://www.smartcities-infosystem.eu/sites/default/files/document/technical-monitoring-guide_2016.pdf [last access 29.8.2017]

Horizon 2020: Work programme 2016 – 2017. 17. Cross-cutting activities; http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-focus_en.pdf [last access 1.9.2017]

8. Appendix

GANTT-chart




WP 5 Monitoring and Evaluation
Status: 31-08-2017
Tasks / Deliverables
Leading Partner
Deliv / Task
2017
2018
2019
2020
2021
2022
Task T5.4: Continuous analysis AIT T5.4
Implementation of common KPI evaluation T5.4.1
Implementation of specific KPI evaluation in Rotterdam T5.4.2
Implementation of specific KPI evaluation in Umeå T5.4.3
Implementation of specific KPI evaluation in Glasgow T5.4.4
Baseline evaluation T5.4.5
Provision of first analysis to SCIS T5.4.6
Evaluation after the end of implementation actions T5.4.7
Evaluation after year one T5.4.8
Milestone M8: Validation of solutions completed AIT M8
31.10
D5.5-1 Assessment of lighthouse projects - interim report AIT D5.5-1
Update with missing data and finalisation of the evaluation activities T5.4.9
Milestone M12: Evaluation completed AIT M12
31.10
D5.5-2 Assessment of lighthouse projects - final report AIT D5.5-2
Task T5.5: Process evaluation SP T5.5
Generation of the main method and tools for process evaluation T5.5.1
Clarification of social impact evaluation with Rotterdam T5.5.2
Clarification of social impact evaluation with Umeå T5.5.3
Clarification of social impact evaluation with Glasgow T5.5.4
Preparation of interviews and detailed process assessment structures T5.5.5
Specific monitoring of social impacts (interface to end-user acc. in T5.4) T5.5.6
Governance procedures survey before implementation T5.5.7
Governance procedures survey after implementation T5.5.8
Specific monitoring of business model development T5.5.9
Investigation of overall implementation process T5.5.10
Post-evaluation of processes T5.5.11
Reporting of results business model development T5.5.12
Reporting of results social impact T5.5.13
Reporting of results governance procedures T5.5.14
Task T5.6: Impact assessment TNO T5.6
Collection of strategies and their assessment T5.6.1
Assessment of links between solutions and strategies, drafting of D5.6 T5.6.2
Workshop to discuss links and impact on future developments T5.6.3
Final assessment and reporting T5.6.4
D5.6 Analysis of alignment with city strategies TNO D5.6
Task T5.7: Evaluation of measures taken to maximise the project impact ISI T5.7
Methodological setup, definition of targets and baslines T5.7.1
Implementation with follower cities in WP7 and first query T5.7.2
Second query and final assessment T5.7.3
Reporting T5.7.4
D5.7 Monitoring report on measures to maximise the impact ISI D5.7

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