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Deliverable 1.1

Report on the list of selected KPIs for each Transition Track

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v0.9	21/6/2018	Add executive summary, next steps and conclusions by Tsarchopoulos P.
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Disclaimer

Executive Summary

The present document is the Deliverable "D1.1: Report on the list of selected KPIs for each Transition Track" of this IRIS project. D1.1. The document presents the work undertaken in Tasks 1 to 5 (Integration synergy on Transition Track #1, #2, #3, #4, #5) of WP1 towards the definition of the Key Performance Indicators (KPIs) repository that will be used for facilitating the monitoring phase of the demonstrated solutions, which will take place in WP9.

The scope of the deliverable is to determine the appropriate list of KPIs for the technology solutions proposed in IRIS by either gathering existing ones in the project's proposal that fit well to the requirements of the specific solutions, and/or introducing new ones, in order to assess more accurately the success level of each technology or methodology tested by the demonstrators. The definition of KPIs is conducted in accordance with other European projects leading the way towards energy smartification of European cities. Thus, most of the selected KPIs were developed within the SCIS [2] and CITYkeys [3] initiatives, which have created lists of KPIs for the evaluation of systems and technologies demonstrated in smart city projects.

The methodology for selecting the KPIs has been finalised in collaboration with key partners from the three LH cities, the five Transition Tracks leaders and RISE (leader in monitoring and evaluation activities). The selection process was based on many criteria including relevance, completeness, availability, measurability, reliability, familiarity, non-redundancy, and independence.

D1.1 created a holistic performance framework for the evaluation of the project's five Transition Tracks. The principal axis of this framework lies in the definition of the KPIs domains, namely technical, economic, environmental, social, ICT and legal. These six domains (or dimensions) are complementing each other and facilitate the holistic evaluation of the specific technical characteristics of a technology, its impact on the social and environmental surroundings, its feasibility from an economic point of view, its smart automation and interaction through an ICT platform and its availability concerning the legal infrastructure. Apart from the domains' definition, seven groups of stakeholders, which can be actively participating/represented in the evaluation of the solutions, were identified: 1) Distribution System Operators (DSOs), 2) Consumers (End-users), 3) Technology and Services Providers, 4) Policy-Making Bodies and Governance, 5) Citizens, 6) Representative Citizen Groups, and 7) Citizen Ambassadors. For each group, its objectives, interests and main role in demonstrated solutions were defined. Finally, the different levels of spatial aggregation that can be evaluated, which go from a single building to a whole district or city, were identified.

Each KPI is presented in a detailed table (KPI card) that contains the following elements: description (including justification), calculation formula, unit of measurement, measurement procedure, object(s) of assessment, involved stakeholders and responsible IRIS partner for data collection. The threshold and target will be calculated in D9.2 as both depend on the specific integrated solution and LH city where the KPI will be used. However, D1.1 provides the methodology for the definition of the threshold of each KPI. The document also provides guidance regarding the required data collection for the calculation of the KPIs by identifying the sources of primary (measurement-based) and secondary (model-based) data.

D1.1 is the first step towards the establishment of the monitoring infrastructure of the IRIS project. The list of KPIs, defined in D1.1, will be shared with D9.2, as D9.2 will go a step forward towards defining the necessary KPIs that will be used for the evaluation of each of the LHs and not only for the specific demonstrated solutions. The data model and management plan for integrated solutions will be delivered in month 12 within D9.3. The monitoring infrastructure will be completed in month 24 with the establishment of a unified framework for harmonised data gathering, analysis and reporting (T9.3) and the deployment of the monitoring framework in LH cities (T9.4).

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List of Acronyms and Abbreviations

Abbreviation	Definition
API	Application Programming Interface
BaU	Business as Usual
BESS	Battery Energy Storage System
BMS	Battery Management Systems
CBA	Cost Benefit Analysis
CE	Citizen Engagement
CHP	Combined Heat and Power
CIP	City Innovation Platform
CITYKeys	Smart City performance measurement system (Project funded by the European Union HORIZON 2020)
DCAT	Data Catalog Vocabulary
DER	Distributed Energy Resources
DHW	Domestic Hot Water
DNO	Distribution Network Operator
DR	Demand Response
DSM	Demand Side Management
DSOs	Distribution System Operators
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
EROI	Energy Return on Investment
ESCO	Energy Service Company
ESU	Energy Supply Unit
EU	European Union
EV	Electric Vehicle
FC	Follower City
ICT	Information and Communication Technologies
IS	Integrated Solution
ISO	International Organisation for Standardisation
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LH	Lighthouse
LSE	Load Serving Entities
LV	Low Voltage
MHD	Maximum Hourly Deficit

MO	Market Operator
MV	Medium Voltage
PM	Particulate Matter
PuT	Public Transport
PV	Photovoltaic
RES	Renewable Energy Sources
ROI	Return on Investment
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCIS	Smart Cities Information System (Project funded by the European Union HORIZON 2020)
SME	Small and Medium Enterprises
TES	Thermal Energy Storage
TSP	Technology and Services Provider
TT	Transition Track
V2G	Vehicle to Grid
WP	Work Package

1. Introduction

1.1 Scope and objectives of the deliverable

The European Energy Union of 2015 aims to ensure secure, affordable and climate-friendly energy for EU citizens and businesses among others, by bringing new technologies and renewed infrastructure towards decreasing household bills, creating more jobs and boost growth, for achieving a sustainable, low carbon and environmentally friendly economy, putting Europe at the forefront of renewable energy production and winning the fight against global warming.

With an increasing share of renewable energy sources in the coming decades, the generation of energy (electricity and thermal) will change drastically from present-day centralized production by gigawatt fossil-fuelled plants towards decentralized generation in cities. These will be mostly produced and distributed by local household and district level RES located (e.g. PV, wind turbines) systems, operating primarily in the level of micro-grids. With the intermittent nature of renewable energy, grid stress is a challenge. Therefore, there is a need for more flexibility in the energy system. Technology can be of great help in linking resource efficiency with flexibility in energy supply, and demand with innovative, inclusive and more efficient services for citizens and businesses. The realization of the European targets of further growth of renewable energy in the energy market, and the exploitation on a European and global level in a sustainable manner, require city planners, administrators, universities, entrepreneurs, citizens, and all other relevant stakeholders to cooperate and be the promoters/advocates of future EU cities development.

One of the main objectives of the IRIS project is to evaluate and optimize the operation of smart systems, operating on a district level and potentially cover the needs of a whole city, using as a basis Renewable Energy Sources (RES) as local energy provision source. RES solutions can feed both thermal/cooling and electrical needs, with interconnected grids. However, the current knowledge on how such grids should be designed to operate is limited and technological advancements and demonstrations activities need to be carried out, before the level of technological maturity reaches readiness level of nine (9) and the technology can be actually commercialized. Through demonstration activities, both thermal and electricity grids performance evaluation results, especially those oriented to the case of islandic conditions, can be used to mature the technology. Such results can also be extrapolated to the case of non-islandic conditions when the energy mixture is characterized by a high degree of RES.

Towards this objective, the selection of the most representative Key Performance Indicators (KPIs) is determined, which are used to evaluate certain technical characteristics of a technology, its impact on the social and environmental surroundings, its feasibility from an economic point of view, its smart automation and interaction through an ICT platform and its availability concerning the legal infrastructure.

As a result, the present deliverable aims to present the results of the work undertaken in Work Package 1 entitled as “Transition strategy five tracks to maximize integration synergy and replicability”, having considered the feedback of various stakeholders for each of the foreseen demonstrated solutions in the three Lighthouse cities and the four Follower ones. The Scope of the deliverable is to determine the appropriate list of KPIs for the technology solutions proposed in IRIS by either gathering existing ones in the project’s proposal that fit well to the requirements of the specific project, and/or proposing new ones, in order to assess more accurately the success level of each technology or methodology tested by the demonstrators, during and after the monitoring and data collection phases of the project.

A holistic evaluation of the proposed solutions requires various and sometimes competing interests of the relevant stakeholders (e.g. profit for the market operator vs cheap services for the consumer). The scalar quantification of solutions through the assessment criteria, being defined by the selected repository of KPIs, enables the comparison on a fair basis among the Business as Usual (BaU) technologies and the application of innovative ones.

1.2 Structure of the deliverable

As a first step, **section 2** presents the general idea to be followed, within the framework of IRIS project, and orients to the definition of the necessary Key performance Indicators (KPIs) that need to be determined, so that afterwards during the real actual demonstration and monitoring phases of the project, these are measured and quantified. The methodology to be followed lies on taking benefit of already existing know-how similar basis as those of CITYKEYS and SCIS. There is an agreement to that with the main IRIS partners, responsible both for the evaluation and monitoring of the various IRIS solutions (mainly in WP5, WP6 and WP7), with both the consideration of the FCs feedback (WP8) and that of the RISE for WP9, who are mainly dealing with the evaluation of the LHs as themselves and in connection with the whole IRIS project as a smart city.

Following that, since WP1 and WP9 are linked from the perspective of IRIS evaluation as a project, the specific Deliverable collaboration with the objectives of WP9 is explained, since the latter is the main WP responsible for the LHs overall evaluation. In the next subsection, the groups of stakeholders, which can be actively participating/represented in the evaluation of the solutions, are defined. A thorough description on the categorisation of the KPI repository into various domains (technical, environmental, economic, social, ICT and legal), using as a guide the aim that each group of KPIs is designed to serve, is following. Section 2 ends with the methodology for the definition of the threshold of each KPI, and a proposal for a gradually executed evaluation route (i.e. starting from the IS level and ending with the LH and FCs level), which in turn can enable the quantification and evaluation of all relevant IRIS city smartification solutions to be examined and demonstrated in detail on an overall European Level.

Section 3 describes the actual definition of the IRIS KPI repository, after this is being finalized in collaboration with the relevant key IRIS partners, i.e. the 3 LH demonstrators, the five (5) Transition Tracks responsible persons, the overall IRIS as a project evaluator and of course considering as well the opinion of the FCs, who need to take into consideration and solid understanding of the Solutions to be demonstrated during the IRIS project, so that IRIS can be of actual value for them. Each of the KPIs are enlisted into the various domains being described in section 2, in order to facilitate at a following step, the IRIS overall evaluation.

Section 4 deals with the required data collection for the calculation of the KPIs.

Section 5 defines the steps that have to be taken by the other Work Packages concerning the evaluation principles of the proposed technology solutions.

Section 6 provides the general conclusions derived by the process of IRIS KPI determination.

Section 7 includes the references.

Finally, in **section 8** there are two annexes. The first includes a separate card for each KPI with a description of the main characteristics of each of the selected KPIs. The second presents the selected KPIs per Integrated Solution and Transition Track.

1.3 Relation to Other Tasks and Deliverables

As D1.1 deals mainly with the selection of the KPIs that will be used for the evaluation and monitoring of the IRIS Integrated Solutions, the deliverable is strongly related to the tasks of WP1 (Transition strategy: five tracks to maximise integration synergy and replicability) and WP9 (Monitoring and evaluation). The associated tasks from WP1 are related to the definition of each Solution, while the related tasks in WP9 are related to the monitoring and evaluation of the demonstrated Solutions.

D1.1 is also related to WP5,6,7: Utrecht / Nice / Gothenburg City demonstration activities. In those work packages, the demonstration activities will take place and the data required for KPIs calculation will be collected. Furthermore, as the City Innovation Platform (CIP) is a key tool for data gathering, D1.1 is related to WP4: City Innovation Platform.

Finally, D1.1 is loosely related to WP3: Development of Bankable Business Models and Exploitation Activities as it contains a group of economic KPIs that will facilitate the creation and evaluation of business models for the IRIS solutions.

The following table presents the deliverables of WP1 and WP9 that are related to D1.1.

Table 1 – Deliverables that are strongly related to D1.1

Number	Title
D1.2	User, Business and Technical Requirements of T.T.#1 Solutions
D1.3	User, Business and Technical Requirements of T.T.#2 Solutions
D1.4	User, Business and Technical Requirements of T.T.#3 Solutions
D1.5	User, Business and Technical Requirements of T.T.#4 Solutions
D1.6	User, Business and Technical Requirements of T.T.#5 Solutions
D9.2	Report on monitoring and evaluation schemes for integrated solutions
D9.3	Report on data model and management plan for integrated solutions
D9.4	Report on unified framework for harmonized data gathering, analysis and reporting
D9.5	Report on monitoring framework in LH cities and established baseline
D9.6	Intermediate report after one year of measurement
D9.7	Report on evaluation and impact analysis for integrated solutions

During the deliverable's preparation phase, preliminary feedback was received from LH cities through the workshops organised by RISE (WP9 leader). This feedback lead to including new and deleting some of the already selected KPIs. However, this process will be continued in the framework of D9.2 that is due in month 12.

2. Methodology

2.1 Evaluation on an IRIS Solution and Transition Track level

The IRIS project tests in demo city environment specific technology solutions and social policies, with the active participation of citizens, which envisage the smartification of the energy grid with an increased RES penetration. Other technologies that are to be integrated include energy storage solutions, such as Battery Energy Storage System (BESS) and Thermal Energy Storage (TES) systems, and electric vehicles, which serve both mobility needs, but also potentially electricity grid requirements. The application of such type of solutions, being supported by their supervision of operation by smart platforms and control algorithms, both on building and district level are expected to boost the sustainability of current grids in terms of efficiency, especially when compared with their current status of operation. Specifically, the three first Transition Tracks enabling the transition towards reduced energy demand and increased shares of renewables and e-mobility in the urban energy and mobility systems aim at:

1. **IRIS Transition Track #1: Smart renewables and closed-loop energy positive districts:** Integrating (a) a high share of locally produced and consumed renewable energy at district scale, (b) energy savings at building level reducing the citizens' energy bill and (c) energy savings at district level. Demonstrated solutions integrate high renewables penetration like district scale PV and biomass for district heating, near zero energy housing retrofit, energy efficient low temperature district heating and smart public lighting that is energy efficient, powered by renewables and connected to the district energy system.
2. **IRIS Transition Track #2: Smart Energy Management and Storage for Grid Flexibility**: Integrating smart energy management and renewable energy storage for (a) maximum profits of renewable power/heat/gas, (b) maximum self-consumption reducing grid stress and curtailment, and (c) unlocking the financial value of grid flexibility. Demonstrated technical solutions include smart ICT to interconnect energy management systems at home, building and district level, and to integrate maximal renewables production (track 2), V2G storage in e-cars operated in car sharing systems (track 3) with additional stationary energy storage.
3. **IRIS Transition Track #3: Smart e-Mobility Sector**: Integrating electric vehicles and e-car sharing systems in the urban mobility system offering (a) local zero-emission mobility, (b) lower household mobility costs, and (c) smart energy storage in V2G car batteries. Demonstrated solutions include extensive deployment of (V2G) e-cars, exploitation of (V2G) e-cars in local car sharing systems, and district-wide smart (V2G) charging stations powered mainly by renewables.

In the light of such a fast transiting environment, the need for strategies that help cities smartly integrate technology solutions becomes more and more apparent. ICT indeed plays a pivotal role as enabler of smart integration, unlocking the synergy potential of divergent energy and mobility solutions and offering new meaningful insights and services thanks to the data generated by the integrated solutions. In that respect, IRIS includes a fourth Transition Track as well namely, the City Innovation Platform. This includes:

4. **IRIS Transition Track #4: City Innovation Platform (CIP):** Cutting edge information technology and data framework enabling (a) the above-mentioned solutions, maximizing cost-effectiveness of the integrated infrastructure. Next, the City Innovation Platform with open, standards-based application program interfaces (APIs) provides meaningful data and information services for households, municipality and other stakeholders, allowing for a Data Market with new business models. A common architecture, harmonized data models and a sustainable data governance plan ensure the interoperability and replicability of the solutions, transferring them from city to city. The City Data Market and the service

marketplace manage access to all data and services, with appropriate licenses and flexible pricing models in and across cities and allowing real time KPI monitoring and benchmarking of smart energy and mobility performances.

However, except for the technical sector, smart city projects should start from people - by focusing on citizen needs, embracing citizen-centric design and their search for an integral quality of life. To this end, IRIS include one additional Transition Track (#5), which focuses on Citizen Engagement, named as:

5. **IRIS Transition Track #5: Citizen engagement and Co-Creation**: This orient to design and demonstration of feedback mechanisms and inclusive services for citizens to achieve that they are intrinsically motivated to (a) save energy, (b) shift their energy consumption to periods with redundant renewables, (c) use electric vehicles and (d) change the vehicle ownership culture towards a use or common mobility assets culture. Demonstrated solutions include game-theory based engagement methods and instruments ranging from co-creating infotainment apps, local school campaigns, offering on the job training to students living in the district by partaking in the demo activities, competitive energy games using the home energy management system, energy ambassadors creating local energy communities, to crowd-funding creating a sense of being part of the solution.

Each Transition Track comprises a general sector of interest for which IRIS promotes certain solutions. Thus, each Transition Tracks consist of several IRIS Solutions (IS). For example, Transition Track #1 “Smart renewables and closed-loop energy positive districts” consists of the following IRIS Solutions (IS):

- **IS-1.1**: Positive Energy Buildings
- **IS-1.2**: Near zero energy retrofit district
- **IS-1.3**: Symbiotic waste heat networks

In this light, the assessment of new proposed technology solutions is a very important step towards the further development of smart grids; thus, the approach on this should be as holistic as possible. Taking this into account and attempting to address the needs of each individual stakeholder, who can take benefit of smart grid operation on an EU level, this assessment is proposed to be conducted by domain, i.e. in technical, environmental, economic, social, ICT and legal terms individually. Every energy system is operating in a synergetic environment and in this sense should be in position to meet as much as possible the various requirements imposed by the market operators and/or its potential customers.

The following Table provides the IRIS Transition Tracks, under each one numerous solutions are fitted, based on the aim they are designed and made to serve.

Table 2: The IRIS Transition Tracks along with their corresponding IRIS Solutions

Transitions Tracks	Integrated Solutions
#1 Smart renewables and closed-loop energy positive districts	**IS-1.1:** Positive Energy Buildings
	IS-1.2: Near zero energy retrofit district
	IS-1.3: Symbiotic waste heat networks
#2 Smart Energy Management and Storage for Energy Grid Flexibility	**IS-2.1:** Flexible electricity grid networks
	IS-2.2: Smart multi-sourced low temperature district heating with innovative storage solutions
	IS-2.3: Utilizing 2nd life batteries for smart large-scale storage schemes

#3 Smart e-Mobility Sector	**IS-3.1:** Smart Solar V2G EVs charging
	IS-3.2: Innovative Mobility Services for the Citizens
#4 City Innovation Platform (CIP)	**IS-4.1:** Services for Urban Monitoring
	IS-4.2: Services for City Management and Planning
	IS4.3: Services for Mobility
	IS-4.4: Services for Grid Flexibility
#5 Citizen engagement and Co-creation	**IS-5.1:** Co-creating the energy transition in your everyday environment
	IS-5.2: Participatory city modelling
	IS-5.3: Living labs
	IS-5.4: Apps and interfaces for energy efficient behaviour

2.2 Evaluation on a city level

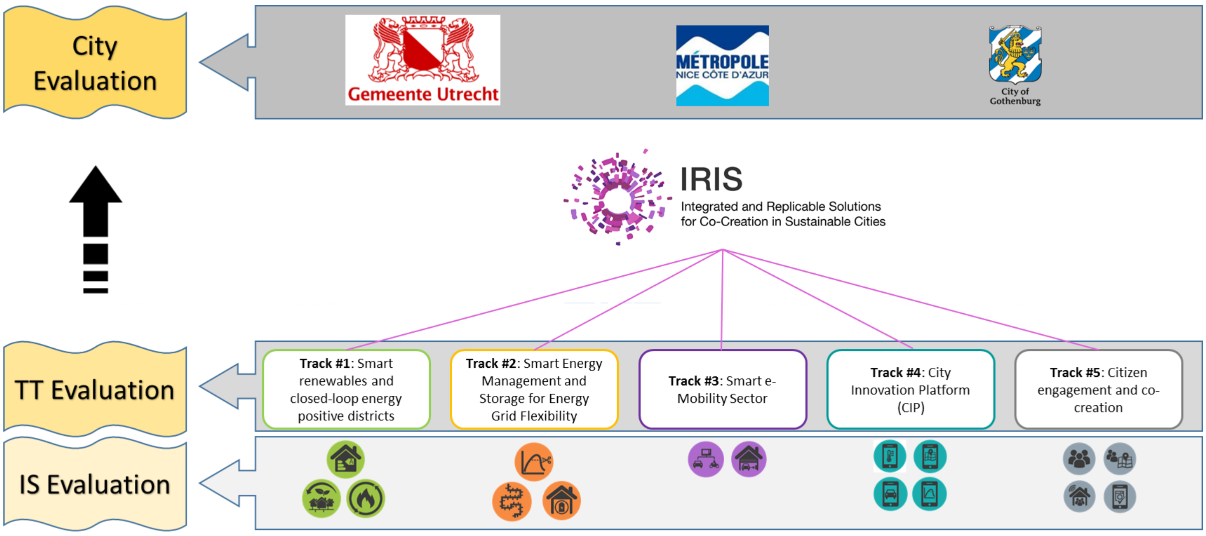
The IRIS Lighthouse and Follower cities, as well as all cities, islands and communities that take part in smart grid projects, aim at the smartification of their grids and the significant reduction of the environmental footprint of their energy mix. Regarding this, they either launch or participate in various projects (both research and commercial oriented ones), during which they develop, test and evaluate numerous smart technology solutions, aiming at their wide integration in their cities and their city life. This process towards their smartification is monitored via quantified indicators, just as the KPIs do, for the assessment of the various project solutions. The object of the evaluation is not only technological driven, but also a social one, since before any technology can be widely applied, first it needs to be evaluated positively by its end-users, which in most of the cases are the citizens themselves. The subject of implementation is the city itself, usually in the sense of what are the benefits it offers compared to the past serving the same goal solutions, focusing on the level of integration of the various technologies, as well as their quantified impact on the various stakeholders.

IRIS, as a project lasting only five (5) years cannot cover the necessary time frame needed for the evaluation of the various solutions to be demonstrated in the three (3) Lighthouse cities on a city level, since the demonstrations take place in specific buildings or premises, and do not cover the whole city territory. However, IRIS acts as a first strong promoter making initiatives towards this objective, proposing a restricted number of KPIs, that can be used as the base ground for the solutions evaluation, on a city level. Obviously, their monitoring will have to continue much longer after the end of IRIS, when the integration of the IRIS solutions will reach a higher level of maturity and penetration in the citizens' life.

Thus, the city-level evaluation starts from the IRIS Solutions (IS) level, and proceeds to the level of Transition Tracks, which when consolidated into a common and limited number of KPIs, the latter can be used to evaluate the city development in terms of smartness.

This process is depicted in Figure 1.

Figure 1 : On the road to city evaluation



2.3 Sharing with WP9 in order to align with monitoring & evaluation planning

After the corresponding KPI repository for the needs of ISs and of TTs is defined, the next step is to work on each KPI, to define its threshold. The current KPI repository is shared with WP9, which is responsible for the monitoring throughout the project. WP9 will determine the infrastructure needed for the actual data collection and quantification of the various parameters that will be needed for the measurement of the KPIs.

Firstly, the differentiation in the orientation of each of these two Deliverables needs to be clarified. D1.1 deals mainly with the selection of the KPIs that will be used for the evaluation and monitoring of the ISs being grouped in WP1 under the Transition Tracks (TT) and will actually be performed as part of WP5, WP6 and WP7.

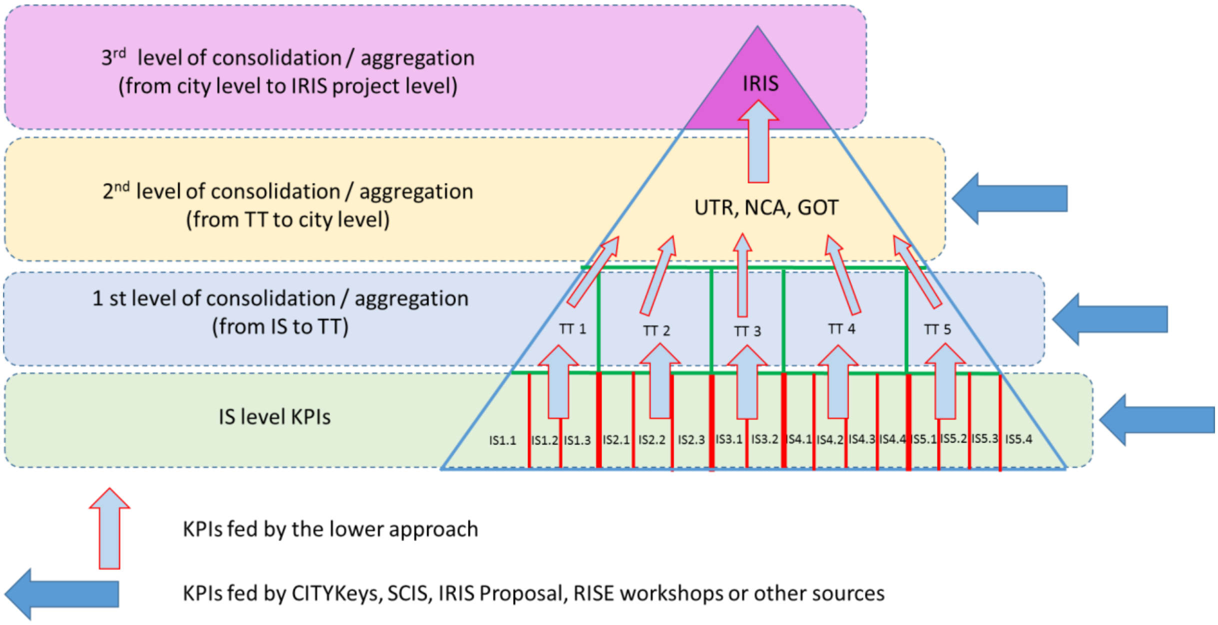
On the other hand, the orientation of D9.2 is to define the list of KPIs, not only for the solution demonstration activities, but to go a step forward towards defining the necessary KPIs including stakeholder recommended KPIs that will be used for the evaluation of each of the LHs in a time period, covering the IRIS project period and ending up to five (5) years, as an estimate, after its end. This is important as the outcome (positive, negative and its quantification) of the IRIS project on these LHs and Followers cities, will be made through this specific list of KPIs (project/city oriented). Except for that, it is part of D9.2 purposes, to describe how the monitoring activities of the solutions will be done, with the use of the selected KPIs (in WP1) and describe the full evaluation approach of the project.

In addition to that, as WP9 will provide the means for the evaluation of the LHs, some representative KPIs (e.g. those belonging to economic domain) can be consolidated to be used for the evaluation of the IRIS project itself, from a WP perspective. For example, a) those belonging to economic domain to evaluate WP3 scope, b) those belonging to ICT domain to evaluate WP4 scope, c) those belonging to social domain to evaluate WP3 scope as well. This can be done under the coordination of RISE, who lead T9.5 entitled as “Overall evaluation and impact analysis for impact enhancement”, also with the participation of the key IRIS partners based on their individual specialization.

To do that, one needs to think of the project structure. Following a top-bottom approach, this starts from the Project level, continues with the city level first and the Transition Tracks subsequently, ending at Solutions level. More or less like a pyramid. So, the decision is to start the evaluation following the exact opposite pathway, in the sense that we evaluate each solution, then we can evaluate each of the Transition Tracks and then through them each LH/FC and end with an evaluation of the IRIS project compared to others similar ongoing EC projects.

This structure is depicted in Figure 2.

Figure 2: The bottom-top KPI list aggregation of the IRIS evaluation framework



2.4 IRIS stakeholders' perspective

The inclusion of relevant stakeholders' opinion in decision-making, is considered to be of high significance, as the decision analysts by themselves cannot be aware of a problem to the level of detail and awareness that a relevant stakeholder can (no one knows better the needs and the other parameters of a problem than the people affected by and affecting it). For smart city projects, a sensible stakeholder categorization can include the following group of them, so that most of the stakeholders can be actively participating / represented in the evaluation of the solutions (from a first level) and of the city (to a final level).

The proposed groups of stakeholders include:

- **A. Distribution System Operators (DSOs)**
- **B. Consumers (End-users)**
- **C. Technology and Services Providers**
- **D. Policy-Making Bodies and Governance**
- **E. Citizens**
- **F. Representative Citizen Groups**
- **G. Citizen Ambassadors**

After having determined the stakeholder groups, the identification of the objectives for each stakeholder group should be named, followed, by each stakeholder group of interests and the main strategy envisioned to be followed, towards the overall IRIS project evaluation in terms of advancements and new expertise gained during its course. The seven stakeholders referred, try to represent all the stakeholder points of view concerning the development of smart grids and solutions.

A. Distribution System Operators (DSOs)

A DSO is responsible for the management and operation of the distribution network of electricity. To this end, the DSO is responsible for control rooms and various ICT systems for power distribution management and automation in the LV/MV grid electricity network. In addition, depending on the legislation of each country, a DSO or a DNO (Distribution Network Operator) might be responsible for energy consumption requests for reduction. Sometimes, in the competitive electricity market, the distribution of electricity is usually a monopoly controlled by the regulating authorities.

It is of high interest for the project to evaluate IRIS system performance from the DSO's point of view. The main aim of a DSO is the sustainability, reliability and flexibility of the system, the ability of the Distribution grid to reciprocate to the various consumer needs every single moment (industry and domestic-scale), or the ability to modify the load curve via peak shaving techniques.

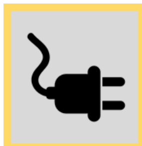
Similar to the DSOs, are the Distributors of heating/cooling mediums for heating/cooling purposes either of a district's or of a city's level consumers. Since this specific category of Distributors are not named with a standard format, we include them as part of DSOs, and when we refer to DSOs we actually imply either the electricity or the heating/cooling providers, dependent on the type of IRIS Solution, each time is the orientation

B. Consumers (End Users)

The role of the customer in the energy system can change from a passive user, simply using energy from the energy system, to an active participant in the energy system, reacting to signals in the market and delivering energy services to the grid and market participants. The citizen engagement has an enhanced role in the modern struggle for increased energy efficiency. Actually, one of the main objective of IRIS project is to ensure and promote the active participation of end users in market and grid operations; thus, special focus is delivered to the evaluation of End Users performance within the context of the project.

Concerning TT1 and TT2, the consumers can be sorted as *residential* and *non-residential,* if someone wants to examine end-user's role in the grid level in a more detail:

- *Residential consumers*: Their main interest is the reduction in the energy consumption, as well as in the energy price, with a probable environmental care about the electricity mixture. Residential consumers are willing to renovate their residences with energy solutions that finally lower the energy bills. Several questionnaires will be conducted in order to deal with the acquisition of local residents' point of view.



- *Non-residential consumers*: Their main interest is grid security and sustainability, as well as the provision of energy (electricity, thermal) for a low price, with a care for a socio-economic improvement concerning the local energy consumption. They include factories, facilities, offices and generally non-residential buildings, municipal or private, with high energy demand, usually in a fixed daily timetable.

Due to the variety of solutions in TT3, various consumers are identified in the mobility system.

The first group of consumers are the citizens, who in the electro-mobility and car-sharing solutions aim at making use of a common pool of electric vehicles for satisfying their mobility needs instead of owning their own car. In the other services (electric buses, tram priority and urban pulse services) the citizens receive the final benefit as less travel time or reduced pollution.

The second group of consumers are the public transport operators, which can upgrade their fleet of vehicles to electric ones or have priority at intersections.

C. Technology and Services Providers (TSPs)

In this category, the private sector composed of industry, technological companies and service providers including SMEs have a crucial role by connecting the IRIS eco-system and supporting the provision of the solutions in different ways.

ESCOs, Aggregators and retailers are interested in monitoring and analysing the behaviour of the end-users, in validating the operational credibility of the technological installations supporting alternative DR schemes, in identifying potential profile deviations, and in evaluating the impact of the benefits generated by the applied policies. Towards this direction, it is essential for the project to evaluate the impact of the different strategies (Demand Response, Storage and EV management) to the different market stakeholders.

Furthermore, the term '*prosumers'* refers to agents that both consume and produce energy at local level. The growth of small and medium-sized agents using solar photovoltaic panels, smart meters, vehicle-to-grid electric vehicles, home batteries and other 'smart' devices, induces the increase in flexibility in the electricity networks. As the number of prosumers increases, the electricity sector is likely to undergo significant changes over the coming years, offering possibilities for the greening of the system. However, demand reduction implications on the grid have not been implemented yet; managing a grid is mainly a fixed cost and as the use of the grid reduces, so the percentage cost of the grid maintenance increases and is undertaken by the remaining users of the grid.

Prosumers could be alternatively included in the end-user's category. On the other hand, they invest on energy, sometimes even having profit instead of paying for the energy they consume; thus, they tend to behave more like a market operator.

The main interest of a TSP is the profit in an energy venture, a fast payback period of the initial capital cost and a large investment lifetime. Various market operators will be asked for their opinion, beginning from the ones that own the largest share in the electricity mixture in each island, to small prosumers.

In TT1, the TSPs are responsible for executing and supervising the implementation of the solution. In some cases, their roles are also to promote citizen engagement in order to reach the appropriate business models. At district level, there are various types of market operators such as housing corporations who have experience in testing combined energy efficient solutions in buildings, companies manufacturing and suppling electrical equipment who deal with the implementation and exploitation of advanced devices and applications and municipal plants, which provide their installation and their equipment towards improving energy processes.

In TT2, the traditional utility operators and their expected new business roles are considered. ESCOs and DR Aggregators are the responsible organisations to manage the technology to perform DR and negotiate on behalf of their customers with the operator for the provided services.

In TT3, the role of the TSPs is to implement, maintain and run the solutions. They are

responsible for both the development and the commercial exploitation of the solutions in the market. They range from traffic management providers and vehicle manufacturers (usually large companies) dealing with the priority service and the electric vehicles respectively to service providers (usually SMEs) able to provide car-sharing services or dedicated apps.	

D. Policy-Making Bodies and Governance

The current regulators represent an important stakeholder group for which to consider, too. They are responsible for a normal and steady operation of the energy market, its gradual privatization, and they provide the basis of the regulatory framework, which is responsible for the determination of the quality standards and the basic rules. A clear and consistent vision for the smart grid has not been adopted by legislators or regulators. Even though there is a great discussion about individual technologies such as renewables or about specific energy issues (e.g. environmental impact), little progress about the overall vision for a modernized grid is detected. That strategy will integrate the appropriate technologies, solve the grid related issues, and provide the desired benefits to stakeholders and society[1]. IRIS project is established on the city environments of the three Lighthouse Cities, with their Municipalities coordinating the demonstration in each of them. In the TT1 closed-loop energy positive districts, the policy making and municipal authorities are responsible for providing installations and services towards the implementation of energy efficient solutions with main objective the socio-economic development of the district and the reduction of emissions (through utilization of renewables for electricity and waste resources for heating). In addition, the concept of IRIS project is promoting the active engagement of citizens in order to assure the proper use and exploitation of the applied technologies and solutions. In TT2, the municipality will be partly responsible concerning the citizen engagement regarding the application and success of the policies developed for the increase of the flexibility of the grid. The governance will be tested in its ability to get in touch and motivate a considerable number of end-users, mainly domestic and SMEs, in order to get engaged in the proposed IRIS solutions. In the mobility TT (TT#3), the policy making and governance authorities are responsible for providing mobility services to the citizens and keeping the pollution levels under desired thresholds. The IRIS solutions are supporting them in these objectives by reducing emissions in the urban regions (electro-mobility, priority to PuT, car-sharing schemes) while providing a communication channel with the citizens (urban pulse) for increasing their awareness and sensibility towards them.	

E. Citizens

These are the citizens who are residents of the target areas, some or all of whom may become consumers of the services being provided via IRIS. This group may also include non-residential citizens with other connections or interests within the target areas (e.g. citizens involved in similar initiatives in neighbouring areas).	

F. Representative Citizen Groups

These are groups of citizens within a neighbourhood or within the Lighthouse City who have a representative role within those areas. The groups can be formal, semi-formal or informal. The activities of these groups will vary substantially between cities. There is no minimum size for these groups.	

G. Citizen Ambassadors

These are individuals with a stronger interest in the issues and deployment of the Integrated Solutions, either residential or non-residential. These citizen ambassadors are characterised by a high level of engagement with the initiatives and with an active steering role in communicating with fellow citizens in the target areas.	

2.5 Domain presentation

The basic axis of the IRIS KPI framework lies on the definition of IRIS domains, namely technical, economic, environmental, social ICT and legal. These domains (or dimensions) are complementing each other to set the holistic performance framework.

The IRIS KPI domains are defined as:

- **KPIs measuring Technical Performance**, such as the energy consumption, the RES generation ratio, the peak load reduction etc.
- **KPIs measuring Economic Performance**, such as the average cost of energy consumption, the average estimation of cost savings etc.
- **KPIs of Environmental Performance**, such as CO2 emissions reduction
- **KPIs of Social Performance** such as the degree of users' satisfaction.
- **KPIs concerning the Performance of ICT** such as people following the advice of the Urban Pulse app, apps which enable the residents to monitor and analyse their energy and water consumptions, home energy management systems etc.
- **KPIs of Legal Performance**, such as the level of adaptation of electricity/heat integration in the legal framework, the legal barriers for usage of biofuels for energy exploitation purposes etc.

The current proposed domain categorization is not the only one that can be defined. There are other domain frameworks too, either close to the one presented (e.g. SCIS [2]), or quite different (e.g. CITYKeys [3]). IRIS proposes the one presented as a more holistic in studies for systems operation characterized by a medium to high TRL. The Legal domain is a new aspect that is presented in this study for the first time and many stakeholders demand it nowadays, given the condition that the current EU underpinning of solutions EU legislative framework is not uniform but fragmented across the various EU countries. The next table shows an example of the relevance between the specific domain categorization with the main questions that have to be posed for the evaluation of a technology solution (e.g. the second life batteries).

Table 3 : Selecting the KPIs domains

Questions for the evaluation of the 2nd life batteries implementation	Domain
Do they need maintenance often?	Technical
Is their cost per year higher than that of brand-new batteries?	Economic
Are there any CO_2 savings because of their implementation?	Environmental
Is the idea publicly accepted or are they not trusted?	Social

Do they correlate well with other components in a smart grid?	ICT
Is their use accepted by the legal framework?	Legal

Figure 3 : The IRIS methodology for KPI definition

2.5.1 Technical

KPIs in Technical Domain measure the effectiveness of a given solution with respect to the operating parameters and technical constraints acting on electricity/thermal grid and active/passive users, as well as the effectiveness of technology solutions concerning heating/cooling, electrification and mobility, on both a building and a district level. They identify and quantify the benefits that IRIS architecture offers to existing assets and on the quality of service provided to customers. Representative technical KPIs can be obtained by gathering the electrical metrics of the network (e.g. voltages/currents collected along feeders and active/reactive powers measured at the interface with the transmission system, number of e-charging stations and V2G vehicles deployed in the area, proportion of RES integration, share of waste heat network) and of customers and producers consumption profiles (e.g. active/reactive energy/power exchanged with the network, usage of the car-sharing vehicles, usage of solar energy, energy consumption for cooling, heating and hot water). In some cases, the KPIs need to be supported by numerical simulations on the basis of a thermal or an electricity grid model, representing the operation of a building or a district, and/or possible actual measurements collected during the grid operation (KPIs aiming at evaluating the technical performance of a particular asset e.g. batteries or the model-based evaluation of DER capacity in a local network) or by monitoring the flow path of symbiotic energy steams and measuring the thermal. The interest in these KPIs changes depending on the perspective of the various stakeholders, such as system operators (DSOs) that are mainly concerned about KPIs related to the MV/LV network operation, while customers are focused on KPIs assessing the performance of a new approach/strategy at their premises. However, other factors exist that could affect the relevance of the KPIs considered in the different situations, for example the regulatory framework in force, which could promote an improvement of the quality of service with reference to specific technical	

indexes (SAIDI/SAIFI), or business cases applying in each particular scenario, also in relationship with the target performances defined in the economic domain.

2.5.2 Environmental

KPIs in the Environmental Domain are important for understanding and evaluating the environmental impact of energy/storage, smart grid distribution, heating/cooling and mobility related solutions and are important for a smart system planning and operation.

In IRIS project, the environmental KPIs will be used to evaluate the efficiency of the IRIS solutions demonstrated in the pilots from the viewpoint of the expected environmental impact. For example, there are KPIs that refer to the operational phase (Noise and Pollen Pollution Exposure), as well as to the end-of-life phase (EROI). The main focus is on operational phase evaluation through the definition of KPIs that set the framework for day to day evaluation, while a Life Cycle Analysis (LCA) methodology can be applied for the determination of environmental aspects and potential impacts of a product or system from raw material extraction through production, use and disposal, while evaluating possible recycling routes following a Cradle-to-Cradle approach (e.g. a typical example for that includes the IS solution of second life batteries).

2.5.3 Economic

The economic performance evaluation takes into account the business efficiency of each application and usage scenario from the market stakeholder perspective. The three demonstrators offer different value propositions to IRIS stakeholders and thus, special focus should be delivered to the definition of KPIs that reflect this specific viewpoint. Among the objectives of the project is to provide market viable solutions, defining business oriented KPIs to evaluate the day-to-day performance of the IRIS tools and applications. For example, the residents of apartments would like to have a view of the economic benefit produced by their flexible consumption behaviour. They may be willing to sacrifice part of their comfort to achieve lower energy bills and they would like to know what the cost/benefit ratio is. Likewise, the business stakeholder (DR Aggregator) will like to know the actual benefit from the implementation of DR strategies in a portfolio of customers. Concerning the closed-loop energy positive districts, the local communities try to promote and support energy efficient measures and solutions targeting to economic and business development by reducing the electricity bills and engaging consumers to an energy sensitive attitude. With regards to mobility, the city is willing to reduce congestion and pollution as well as parking places, while the consumers are willing to increase the usage of the vehicles (the system operator) and to increase the availability of shared vehicles (the citizens).

Once again, the overall business and economic analysis is closely related to the definition of business stakeholders in the project, along with the selection of business models and associated scenarios to be examined at the demonstration sites of the project.

2.5.4 Social

The social aspects of energy projects were found to be the less popular among the employed KPIs in previous similar studies. However, one of the biggest problems area in general for Smart Cities in general is what is usually categorised as 'Social', as it turns out from the SCIS database, where the challenges around Energy are mostly in this

category (https://www.smartcities-infosystem.eu/lessons-learned/energy/social).

The chosen indicators reveal that attitudes towards energy are interrelated with demand response mechanisms [4] and such KPIs can be used to evaluate the extent up to which the end-users (citizens in most cases) are willing to participate and be self-motivated for further demonstration and application of the demonstrated solutions. This is a core aspect of the IRIS as the project aims at investigating the potential of end customers to actively participate in demand response schemes, for example.

Generally, the social performance domain visualizes the impact of a technology, scheme or policy to social factors like local wealth, unemployment, satisfaction, or even more specific like the effect on the use of public transport, the health care system etc.

A popular approach used in literature for expressing the social KPIs is the Likert scale, since it is a sensible way for quantifying a qualitative value. Partners responsible for such KPIs will determine target groups among the various stakeholders and pose them a question that need a Likert answer.

2.5.5 ICT

The Information and Communication Technology (ICT) domain could be concerned as one of the technology pillars of IRIS project since the City Innovation Platform is one of the IRIS Transition Tracks. Nevertheless, a smart city tends to connect the various energy operations, including generation and consumption, with a central energy management platform that interacts with citizens and generally all stakeholders. ICT is used as a KPI domain because it indicates the interoperability of the technology solution presented, its ability to correlate with the rest components of the energy grid, its capability for two-way interaction with the citizens.

The KPIs listed in the ICT domain refer to the City Innovation Platform mainly, regarding the monitoring and sensible control of the proposed technology solutions. This domain is appropriate for smart city projects regarding the implementation of new components in an existing smart grid.

2.5.6 Legal

KPIs in the Legal Domain, which mainly monitors the legislative background concerning the application of the proposed solutions. The specific domain is not commonly used, but it is of great importance in the R&I, since law-making bodies are often not flexible enough to follow the progress of technology, especially when these are related to strongly regulated/protected markets (energy and mobility). This is a serious problem, especially in EU, since most of the already mature technologies cannot be actually implemented and operate in real-life conditions, because there is not the necessary legal background, allowing their actual life operation. Even more important are the economic results. An immediate legislative support of a new technology can give a serious handicap for its developer and end-user in a world-wide market, where the exploitation of innovations is one of the most serious sources of profit. Generally, market operators (including DSOs and prosumers) need a steady legislation concerning their invested capital, and fast response concerning the legislative background of innovations.

The Legal KPIs evaluate mainly the governance in terms of legislative flexibility. This flexibility is difficult to be objectively quantified, so the subjective point of view of several stakeholders is needed, usually in the form a percentage scale.

2.6 Stakeholder-domain link approach

The presented evaluation approach for the definition of the IRIS KPI repository is based on the connection of each stakeholders' interest between each of the domains listed in the previous paragraph. The following table shows this connection for the case of Transition Track #2:

Table 4 : Connection between stakeholders and domains

	DSOs	Market Operators	Consumers (End users)	Policy Bodies and Governance
Technical domain	DSOs are mostly interested in ensuring an adequate level of quality of supply to the grid-connected customers, taking into consideration each of the specific grid characteristics. Critical peaks of demand should be avoided, constantly monitoring users' consumption to avoid grid breakdowns and efficiently addressing fraud challenges. In other words, DSOs are interested in the operational impact of any scenario to the grid conditions regarding grid sustainability and high-level electricity quality.	With reference to the technical domain, Market Operators (MOs) are interested in the various technologies available for power generation and storage, as well as to the proposed DR strategies. Technology performance is crucial for any investment decision. Moreover, a better exploitation of assets devoted to improving the regulating capabilities of Virtual Power Plant (e.g. energy storage systems) would reduce the required investment costs and increase the incomes. A high-level performance of the technologies or services provided gives an advantage in the market competition, since it requires less energy to deliver the same amount of service. The same applies to heating MOs, either in district level or technology providers, as well as to the mobility MOs who deliver the EVs in the modern city environment.	The quality of the power delivered is a matter of interest mainly to non-residential consumers. Especially factories and large workplaces can withstand neither power interruptions, nor large voltage variations or harmonics. Residential consumers are not as dependent to quality of service as the above, but certainly demand it. Concerning heating and cooling the end users demand steady provision of indoor climate at 18-24^{0}C throughout the year. Concerning mobility, the end-users tend to be hard at adopting new technologies like EVs.	Policy Bodies are interested in monitoring the contribution of the projects to the smart grid functions, which are directly related to Smart Grid policy objectives. These are among others, the Security and quality of supply, the connectivity and access to all categories of network users, the capacity of distribution grids to connect and bring electricity from and to users. Security and quality of supply is also the main objective concerning the technical characteristics of district heating. Regarding mobility, governance cares about the technical characteristics that provide social satisfaction through easiness in transportation.

	DSOs	Market Operators	Consumers (End users)	Policy Bodies and Governance
Economic domain	The main aforementioned concerns of the DSOs in the technical domain are also having an economic aspect, as any potential inefficiencies in the quality of supply to the grid customers, may cause significant charges from the side of the regulation authorities. Moreover, DSOs are responsible for proposing an energy strategy, giving directions about the future of the energy mixture, bearing in mind the overall cost.	Main goal of the Market operators is to maximize profit concerning the cost of the investment. This means that they care for all the economic aspects of any possible technology on which they could invest. They compete to sell DR services to the utility operator and provide compensation to consumers, in order to modify their preferable consumption pattern. In this respect, they will make use of economic indicators to identify operational needs, market opportunities or critical situations and deploy appropriate DSM strategies. Any available RES promotion paying policies (feed-in tariff, etc.) are under close observation as they play a decisive role in the overall feasibility of an investment. Real-time views for revenue protection, unexpected PV and solar loads identification are some of the metrics that would make sense for utilities in such case.	The main expectation of the residential consumers is a direct economic benefit either in the form of cost reduction or in terms of at hand compensation, depending on the DR schema category they participate, the heating/cooling services acquired, as well the final cost of mobility. Non-residential consumers also demand the lowest possible final cost, as the energy cost is one of the main factors that are included in the final cost of any kind of business, and thus is very important to the international competition.	From the perspective of policy makers, economic domain indicators should reflect the efficiency and quality of service achieved in electricity supply and grid operation. Measures of interest indicatively include: Demand side participation in electricity markets and in energy efficiency measures, societal CBA which goes beyond the costs and benefits incurred by the project promoter, as well as the monetary value of reduced CO_2 emissions, whereas the KPI analysis might just refer to the amount of CO_2 reduction expressed in tons.

	DSOs	Market Operators	Consumers (End users)	Policy Bodies and Governance
Environmental domain	DSOs are highly interested in knowing about the impact of new smart technologies on the environment, either when applied or when they replace conventional systems, since their electric grid, under supervision, influences the cities and citizens' quality of life much. Moreover, they need to confront with the current EU legislation policies promoting the low CO_2 technologies.	Market Operators are expected to apply schemes contributing in making electricity and heating/cooling aggregation smarter and more efficient (e.g. DR programs by LSEs or third-party energy aggregators). Environmental KPIs related to demand determine the quality of response from the customers. Many technology providers are advertised using the eco-friendly characteristics of the offered technologies and services. Moreover, the environmental indicators are necessary for the Market Operators to provide the environmental profile asked by both governance and end-users (market).	Both residential and commercial end-users are highly interested in knowing more about the environmental impact of any technology solution proposed. Environmental parameters are linked and to a certain extent reflect the, demographical, physical and contextual characteristics such as types of premises and profile of users, weather conditions all of which have an impact on the electricity and heating/cooling demands, as well as to the national/local characteristics, idiosyncrasies and legislation etc.	Governance is interested in the levels of electricity and heating/cooling sustainability and would like to monitor it in a quantified manner (including the reduction of greenhouse emissions and the environmental impact of electricity grid infrastructure). International agreements are directing the local energy policies which include the increase in RES penetration and the reduction of the CO_2 emissions.
Social domain	The social approach is necessary for the definition of the quality standards of the delivered services, as comfort and satisfaction are taken into serious consideration by the DSOs for the evaluation of their services.	Even more than the social approach of the DSOs, Market Operators (especially the utility-scale) depend on the social comfort and satisfaction by the delivered services, as it plays a crucial role in the determination of the marketing strategy to prevail the competition.	All kinds of consumers can be motivated to change their energy behaviour through different social approach techniques, especially if there is direct monetary benefit. It further allows them to understand and feel comfortable with the energy infrastructures at home (RES, batteries, smart-meters, etc.) and improve their energy attitude.	Governance is interested to the social approach in the filter of the general evaluation of its general policy that has to be acceptable to the highest possible population percentage.

	DSOs	Market Operators	Consumers (End users)	Policy Bodies and Governance
ICT domain	ICT plays the key role for the determination of a grid or city as smart. The DSO participates in the multiple interactions taking places in a ICT platform, but mainly as an observant. DSO would care for the ICT operation in order for the DR and DSM policies to reach to the end-users widely. ICT is a tool for the increase of citizen engagement, which enables DSO apply strategies for sustainability and RES penetration more easily.	The MOs have a serious impact on the ICT operation as it is the basic tool for communication with the end-users. ICT provides the field through which MOs can promote the DR policies along with the various billing techniques proposed in order to minimize the cost of energy. Thus, MOs have a high interest in the quality of the ICT services needed for an advanced and automatic interaction with the end-users.	The consumers, too, have a high interest in the level of ICT services. An easy access to the ICT services can help them avoid face-to-face contact every time they want to reconsider their strategy, or even pay a bill. A high-level interactive environment in the ICT platform is quite new in the modern cities and of wide acceptance.	The Governance has a secondary interaction with the ICT, like the DSO. Being an observant of the whole system, and mainly its impact in the society, governance care for the steadiness of an ICT platform regarding the increase of the citizen engagement in the applied energy policies, either concerning electricity or heating/cooling and mobility.

	DSOs	Market Operators	Consumers (End users)	Policy Bodies and Governance
Legal domain	Being responsible for the operation of the grid, DSOs would like to be free to apply the most suitable mix of technologies according to the demand. The legislative framework sets the barriers of the DSO's freedom to apply any new changes. On the other hand, laws are seriously based on the proposals of the Operators, although there are other additional perspectives that need to be taken into account.	Market operators are probably the most affected stakeholders by the legal domain. The various-size companies and enterprises, purchase technologies that have to cope with specific standards. The permission to use a technology, and sometimes the terms under which the market operates is pre-set by the legislative framework. A very serious point is the profitability of an investment. Generally, in the multinational market, the sooner an innovative technology is applied, the bigger market share it will acquire. That is why law-making bodies are often pressed by companies to adjust (or make it fit) the legislative framework according to the technology progress as soon as possible.	Consumers are the least involved in the legal domain. They seldom have to alter their position according to the changes in the legal framework, at least not as much as the market operators. End-users want the legal framework to help the market operation in such a way so as to provide the best possible relationship between price and quality.	Governance is the most related stakeholder with the legal domain. It could be said that the legal domain evaluates the governance, and specifically its ability to set up the rules of the market under which all the stakeholders can take benefit of.

2.7 Definition of KPI repository

As described in the previous paragraphs, the IRIS evaluation framework will assess the IRIS technology solutions according to their performance in their specific environments, and then try to derive more general conclusions moving from IS level towards city level, with Transition Tracks, which consolidate the various possible smart solutions in groups of them.

The use of quantitative indicators is valuable not only to describe/assess as accurately as possible individual characteristics of a technology, but also to evaluate them, in a simple and on a fair basis way, against other solutions of the same characteristics serving the same role. Such an approach facilitates the direct comparison of available technologies, designed for the same scope (in many aspects, as it will be evident subsequently from the text document). Key Performance Indicators (KPIs), in general, are methods/systems that measure the effectiveness of a project towards the achievement of its specific key objectives. The process of selecting KPIs also assist to clarify project objectives measures of success.

In general, indicators (and even more so KPIs) should express as precisely as possible to what extent an aim, a goal or a standard has been reached or even surpassed. Data that is not linked to standards or specific goals of projects, can be used as quantitative background information (e.g. Total Investments), but is not suited for evaluative purposes. Often, however, various indicators are available to assess the progression towards a certain goal. To achieve having a shortlist of indicators and following bilateral discussions with key partners from the three LH cities, a set of criteria was derived, using as a basis the CIVITAS framework [5], according to which each set of KPIs should be characterized by:

1. **RELEVANCE**: Each indicator should have a significant importance for the evaluation process. That means that the indicators should have a strong link to the subthemes of the framework. Furthermore, the indicators should be selected and defined in such a way that the implementation of the smart city project provides a clear signal in the change of the indicator value. Indicators that are influenced by other factors than the implementation of the evaluated project are not suited. Indicators that provide an ambiguous signal (if there is doubt on the interpretation of e.g. an increase in the indicator value) are equally not suited.
2. **COMPLETENESS**: The set of indicators should consider all aspects of the implementation of smart city projects. KPIs can be selected according to the People, Planet, Prosperity and Governance themes (and for project indicators also from the Propagation theme), which framework is fairly comprehensive in describing public policy goals.
3. **AVAILABILITY**: Data for the indicators should be easily available. As the inventory for gathering the data for the indicators should be kept as limited as possible, in time and effort, the indicators should be based on data that either:
    - are available from the project leader or others involved in the innovation case that is being evaluated;
    - or can easily be compiled from public sources,
    - or can easily be gathered from interviews, maps, or terrain observations.
    - Indicators that require, for instance, interviews of users or dwellers are not suited as the large amounts of data needed are too expensive to gather. The same holds for indicators that require extensive recalculations and additional data, such as footprint indicators, and some financial indicators. The current selection contains, however, a few footprint type indicators that might be expected to become common in the near future (e.g. the legal KPIs).
4. **MEASURABILITY**: The identified indicators should be capable of being measured, preferably as objectively as possible. For the majority of indicators in the ICT, Social and Legal domains, quantitative measurability is limited. Social sciences provide approaches to deal with

qualitative information in a semi-quantitative way [6].
5. **RELIABILITY**: The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.
6. **FAMILIARITY**: The indicators should be easy to understand by the users. For a large number of indicators IRIS has relied on indicators from existing indicator sets that generally comply with this requirement. For new indicators a definition has been developed that has a meaning in the context of existing policy goals.
7. **NON-REDUNDANCY**: Indicators within a system/framework should not measure the same aspect of a subtheme.
8. **INDEPENDENCE**: Small changes in the measurements of an indicator should not influence preferences assigned to other indicators in the evaluation. In general IRIS has kept to this principle but given the political attention for both improving energy efficiency and reducing carbon dioxide emissions, IRIS has included both indicators. As the current energy systems are still largely based on fossil fuels, there is a direct relation between a reduction in the use of energy and the reduction of the emission of carbon dioxide. This will lead to a certain extent to double counting the impact.

The IRIS project definition of KPIs is conducted in accordance with other projects enhancing the way towards the energy smartification of European cities. The need for a uniform monitoring of this process throughout Europe has led to initiatives promoting the cooperation and exchanging of know-how among European cities. Such initiatives as CITYkeys [3] and SCIS [2] have created platforms of interaction along with a list of KPIs, each for the evaluation of systems and technologies demonstrated in smart city projects.

The *Smart Cities Information System* **(SCIS)** focuses on the development of indicators to measure technical and economic aspects of energy related measures. These should be applicable to European funded demonstration projects for Smart cities and communities, energy efficient buildings and designated projects funded under the calls for energy efficiency.

SCIS is a knowledge platform to exchange data, experience and know-how, and to collaborate on the creation of smart cities, providing a high quality of life for its citizens in a clean, energy-efficient and climate-friendly urban environment. SCIS brings together project developers, cities, research institutions, industry, experts and citizens from across Europe.

Launched with support from the European Commission, SCIS encompasses data, experience and stories collected from completed, ongoing and future projects. Focusing on energy, mobility & transport and ICT, SCIS thus showcases solutions in the fields of energy-efficiency in buildings, energy system integration, sustainable energy solutions on district level, smart cities and communities and strategic sustainable urban planning.

Projects in the scope of SCIS are mostly co-funded by the European Commission, for example, the 12 Horizon 2020 Smart Cities and Communities (SCC1) projects (such as Triangulum, Sharing Cities, IRIS or Stardust), the 7th Framework Program projects CELSIUS and City-zen, and many more.

The overall goal is to foster replication. SCIS, therefore, analyses project results and experiences to:

- Establish best practices which will enable project developers and cities to learn and replicate.
- Identify barriers and point out lessons learned, with the purpose of finding better solutions for technology implementations and policy development.
- Provide recommendations to policy makers and policy actions needed to address market gaps.

Funded by the European Union HORIZON 2020 program, **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.

The CITYkeys project addressed the horizontal challenges: the current transition to low carbon, resource-efficient cities is moving slowly. Innovative and smart solutions are available but uptake in other cities is low, because the impacts of the smart city solutions are not objectively verified and because of lack of confidence that the solutions can also be applied in other contexts and cities. This project aimed to speed up the transition by facilitating and enabling stakeholders in projects or cities to learn from each other, create trust in solutions, and monitor progress, by means of a common performance measurement framework.

The tangible objectives of the CITYkeys project were to:

1) Develop and validate a performance evaluation system (go to page):
   - Harmonizing existing environmental, technological, economic and social indicators (KPIs) for Smart Cities and specifying missing indicators
   - Developing a prototype system for transparent data collection, KPIs calculation and visualization
   - Validating the performance measurement prototype system by the partner cities as test-cases
2) Build recommendations for the implementation of performance evaluation (go to page):
   - Developing recommendations for the implementation of the performance evaluation system in cities'
   - Policies and relevant decision-making processes.
   - Endorsing the results by the participating cities, through implementation of the prototype framework during the testing phase.
   - Identifying new business opportunities based on the project results.
   - Suggesting paths for the future development of a 'smart city index'.
3) Promote synergy between stakeholders and replicability of solutions (go to Smart City Index page):
   - Engaging citizens and stakeholders in contributing to the needs specification and feedback for validation.
   - Informing key stakeholders at local, regional, national, European and international level on the project results and outcomes.
   - Cooperating with other initiatives, projects and networks focused on Smart Cities solutions.
   - Carrying out networking and communication activities with the other projects funded under the FPand H2020 Smart Cities scope.
   - Providing a common data collection system which supports Lighthouse projects cooperation of cities and other involved stakeholders.

In order to achieve its objectives, CITYkeys was built on existing smart city and sustainable city assessment frameworks. The bases of the framework are the traditional sustainability categories People, Profit and Planet, but the performance measurement framework includes specific smart city KPIs that go beyond the traditional division into categories and measure the integration level and openness of the technological solutions. This allows the stakeholders to access and compare different solutions and planning scenarios impacting on the deployment of the most suitable ones (download CITYkeys indicators for smart cities projects and smart cities).

In this light, the majority of the IRIS project KPIs is mainly taken by the CITYKeys and SCIS KPI pools. Some KPIs, mostly the Legal ones, did not exist in previous literature. Specifically, the legal KPIs were firstly used in the **SMILE project** [7]. The list was discussed among the demonstrators in order to make the appropriate additions and adjustments according to the project needs. Finally, most of the KPIs for the integrated solutions of TT5 (Citizen engagement and co-creation) are based on recommendations from **EIP-SCC Manifesto on citizen engagement** [8]. The Manifesto is a result of the ongoing work of the Citizen Focus group in EIP-SCC.

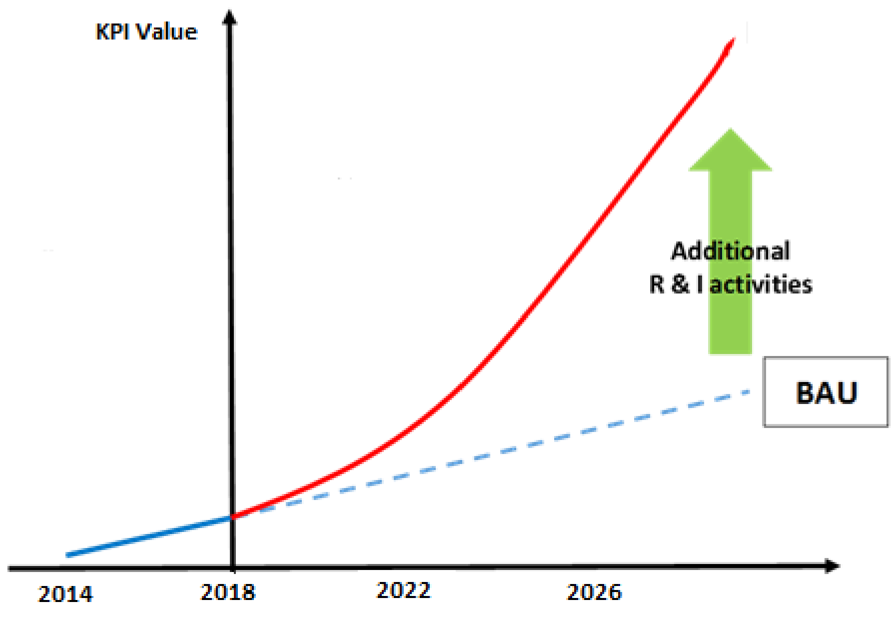
The first and most important criterion for the definition of KPIs by the demonstrators should be if this KPI can actually be measured or calculated in a way. It makes no sense to propose KPIs that we will not manage to be quantified. The second criterion is the importance of the specific KPI for their opinion as an ecosystem (taking into consideration the opinion of their relevant ecosystem stakeholders). These two parameters are enough for their prioritization, based on our experience. Especially for WP3 and WP4, the corresponding leading partners already know which of the available KPIs are of high importance compared to others, while to that respect RISE, who already has a feedback from the local workshops arranged already has a first point of view for each LH interest. This feedback taken by RISE and the demonstrators gave the final IRIS KPI repository reported in the present deliverable.

2.8 Threshold definition

After the final definition of the KPI repository, threshold definition is an important and sometimes difficult task, since it sets the quantified objectives of the project. Each KPI will finally acquire a value calculated throughout the monitoring of the project. The actual evaluation of the presented technology solution has to be done with the comparison of the KPI final value with a threshold that separates success to failure. This separation line can have the form of:

- **Baseline**: Baseline is a measurement taken in the beginning of the project. If the threshold is the baseline, then the scope is to check the difference in the actual result because of the implementation of the proposed technology solution.
- **Business as Usual (BaU)**: BaU is a more complex thresholds since it takes into consideration the change in the value of the KPI throughout the time period of the project, without the implementation of the tested technology solution. It takes into account the general tendency of the change in the KPI value. The BaU threshold comprises a more realistic view on the tested technology impact on its environment but is more difficult to be estimated.
- **Other threshold**: A threshold value could be defined by the evaluator, without it being either a baseline or a BaU. This could apply to KPIs that are not estimated in the past such as the legal KPIs or some social that are measured with the Likert Scale.

Figure 4 : A graphic explanation of the BaU threshold



Either way, the threshold is defined regarding the necessary literature survey. The demonstrators have the last word in the threshold determination since they are able to take into consideration the most aspects influencing the performance of the tested technology solutions in their city environment.

2.9 From Local to Global

The process of evaluation using KPIs is of great importance, as it indicates the degree of success of either a research innovation project or even a commercial one. All interested stakeholders can just take a look at the KPI values and acquire a good impression of the progress that is made. In that respect and to improve and strengthen the impact of solutions demonstrated, starting from the IRIS limited boundaries and expanding to EU level, the evaluation has to be done inductively (the part to whole approach). Such a route approach can also achieve the successful passage from the specific case studies to a more generalized scheme. That is the reason why the evaluations of each case study need to be generalized taking benefit of smaller-scale experience gained by similar to IRIS case studies towards a greater than IRIS scale.

In this light, everyone should have in mind to foresee an expanding character in the selected KPIs, so that the most important of them or appropriate consolidations of them into fewer can operate as a general framework for policy and business investment making, on a larger than each community level. A globalized evaluation of solutions, considering the needs primarily of the Governance from the side of stakeholders' perspective along with the inclusion of consolidated globalized KPIs in terms of the six (6) already defined KPI Domains, should form the basis for a holistic globalized evaluation platform.

Above the IS level of evaluation, an aggregation of the KPIs should take place in order to reach an evaluation at TT level. There is not any specific solid based scientific methodology that can do such a calculation. However, for at least most of the environmental, social, ICT and citizen engagement KPIs this can be done, as most of them are measured in Likert scale and, in the end, what counts is not absolute numbers, but the general feeling of the relevant stakeholders. This is also enhanced by the fact that numerous of the KPIs proposed in at least the level of TTs and city level are the same.

Although it is not among the objectives of the present Deliverable, the technology evaluation should be able to acquire more global characteristics. For example, the use of EVs as a method of storage and DSM in order to help the increase in RES penetration, is firstly used in the specific pilots of each island. The collective experience by all the pilots could give the directions for the integration in a larger scale, which could be that of a whole city. This could give additional experience according to its evaluation and show the way to a wider integration on larger grids, or even to the interconnected system. The final level of generalization is that of the EU who is close to a market grid unification according to the Target Model.

This generalised evaluation cannot be done in the close barriers of a single project. IRIS and similar other projects are under observation by EC since the conclusions can guide to tomorrow's European policies concerning the state-of-the-art application and the market rules. The use of KPIs from CITYkeys SCIS, and other European projects and initiatives facilitates the evaluation at a European level.

3. Defined KPIs per Domain

This section enlists the IRIS KPI repository for the evaluation of the IRIS Solutions.

In the IRIS project there are different levels of spatial aggregation which go from a single building to a whole district or city. The following table presents the different levels of aggregation that can be evaluated using the IRIS KPIs.

Table 5 : Different levels of evaluation (Source SCIS [2])

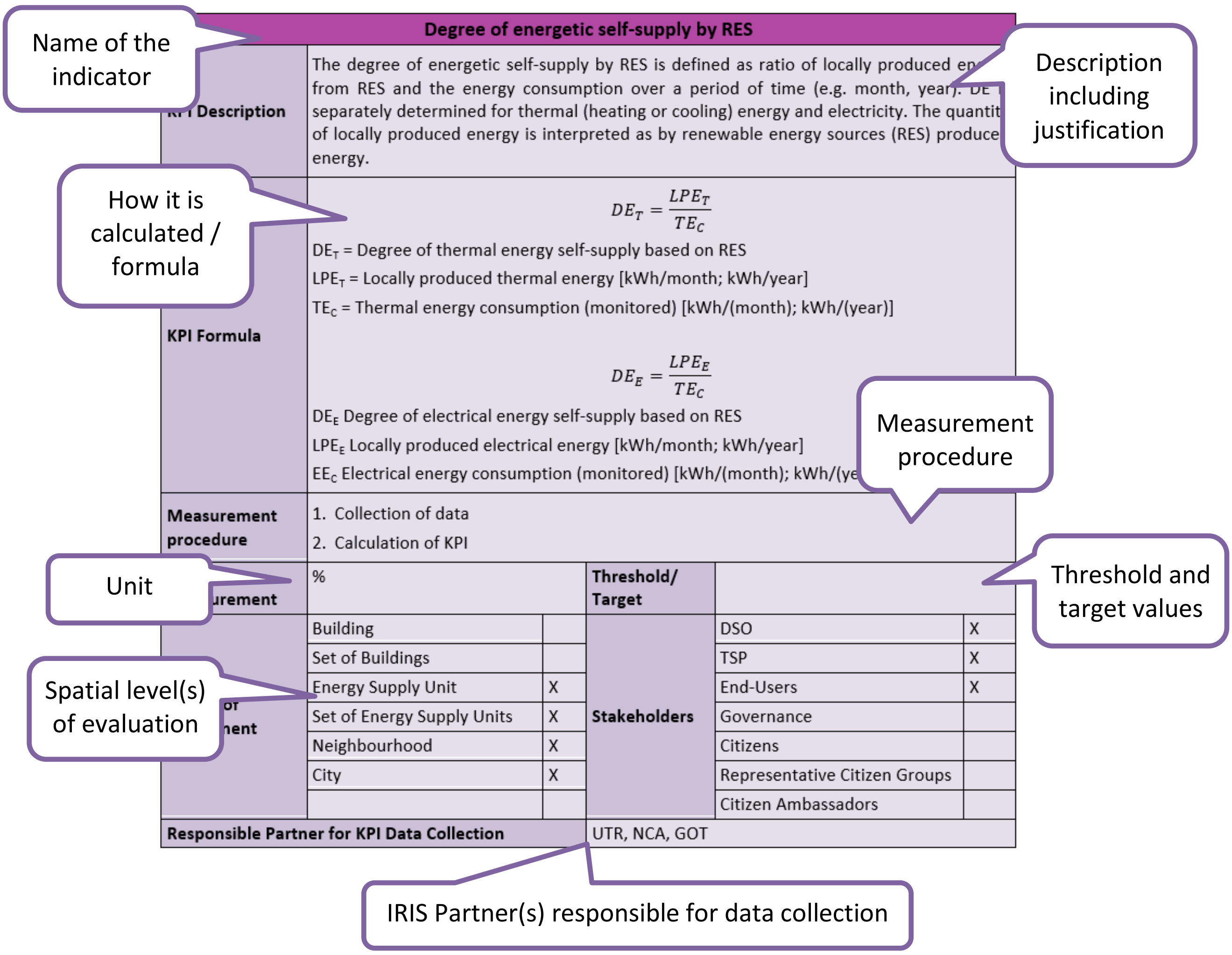
Area of evaluation	Description of the evaluation area
Building	It concerns the energy performance balance of: – The delivered energy required to meet the energy needs – The exported energy The delivered energy is to be expressed per energy carrier. If part of this delivered energy is allocated to energy export, it also needs to be specified in the data collection (e.g. gas fired CHP, where the electricity produced is not used in the building. In this case the corresponding amount of gas allocated to electricity production shall be specified in order to be able to calculate the energy performance of the building). At the building level the data required is (calculation procedure goes from the energy needs to the primary energy): – Energy needs per area of application (heating, cooling, DHW…) – Energy technologies supplying these energy needs – Energy storage units – Delivered energy to each energy supply units expressed per energy carrier
Set of Buildings	The assessment for a set of buildings is done by aggregation of building units. The indicators can then be calculated for the sum of the buildings as a group.
Energy Supply Unit (ESU)	At the Energy Supply Unit level, the approach followed is similar to the building level. Delivered energy per energy carrier and output energy allocated to energy carrier need to be specified. Additionally, and depending on the energy supply unit different indicators can be calculated. This assessment object refers to building integrated energy supply units as well as large-scale energy supply units.
Set of Energy Supply Units	The assessment for a set of ESU is done by aggregation of energy supply units. The indicators can then be calculated for the sum of the energy supply units.
Neighbourhood/City	The level of implementation area or neighbourhood is composed by the aggregation of different entities. The energy flows at this point need to be defined. The following information is required to define the energy system: – Energy carriers used at the implementation area level and the

Area of evaluation	Description of the evaluation area
	primary energy factors corresponding to this area – Demonstration units involved (buildings, energy supply units, storage units and distribution systems) – Delivered energy to each ESU and building allocated to the corresponding energy carrier – Output energy of each ESU and, if applicable, output energy exported out of the boundary allocated to the amount of delivered energy carrier – Energy flows between technologies and buildings (which ESU is supplying which building or ESU). Due to the complexity of these systems, indicators can only be calculated if a full set of data is available.
Nation	IRIS demonstrates in city environment. Nation level mainly concerns the legal performance indicators.

The following tables (Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11) presents the KPIs per domain.

In Annex 8.1 (KPI description cards) each indicator is presented in a detailed table (Figure 5).

Figure 5 - Description format of each KPI



Degree of energetic self-supply by RES					
KPI Description	The degree of energetic self-supply by RES is defined as ratio of locally produced en... from RES and the energy consumption over a period of time (e.g. month, year). DE ... separately determined for thermal (heating or cooling) energy and electricity. The quantit... of locally produced energy is interpreted as by renewable energy sources (RES) produce... energy.				
KPI Formula	$DE_T = \frac{LPE_T}{TE_C}$ DE_T = Degree of thermal energy self-supply based on RES LPE_T = Locally produced thermal energy [kWh/month; kWh/year] TE_C = Thermal energy consumption (monitored) [kWh/(month); kWh/(year)] $DE_E = \frac{LPE_E}{TE_C}$ DE_E Degree of electrical energy self-supply based on RES LPE_E Locally produced electrical energy [kWh/month; kWh/year] EE_C Electrical energy consumption (monitored) [kWh/(month); kWh/(ye...				
Measurement procedure	1. Collection of data 2. Calculation of KPI				
...urement	%		Threshold/ Target		
...of ...ent	Building		Stakeholders	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

3.1 Technical

Table 6 – List of technical KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference
Degree of energetic self-supply by RES Ref: SCIS	The degree of energetic self-supply by RES is defined as ratio of locally produced energy from RES and the energy consumption over a period of time (e.g. month, year). DE is separately determined for thermal (heating or cooling) energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy.	%	Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 2.1
Reduced energy curtailment of RES and DER Ref: SCIS	Reduction of energy curtailment due to technical and operational problems. The integration of ICT will have an impact on producers, as the time for curtailment will be reduced, and the operative range will be wider.	%	Energy Supply Unit Set of ESUs Neighbourhood City	2.1, 2.3
Average number of electrical interruptions per customer per year Ref: SCIS	The average number of electrical interruptions per customer per year shall be calculated as the total number of customer interruptions (numerator) divided by the total number of customers served (denominator).	Number /year	Neighbourhood City	2.1
Average length of electrical interruptions (in hours) Ref: SCIS	The average length of electrical interruptions shall be calculated as the sum of the duration of all customer interruptions in hours (numerator) divided by the total number of customer interruptions (denominator). The result shall be expressed as the average length of electrical interruptions in hours.	Hours	Neighbourhood City	2.1
Energy demand and consumption Ref: SCIS	The energy demand/consumption corresponds to the energy entering the system in order to keep operation parameters (e.g. comfort levels). The energy demand is based on the calculated (e.g. simulated) figures and the energy consumption is based on the monitored data. This indicator can be used to assess the energy efficiency of a system.	kWh/ (m^2month); kWh/ (m^2·year)	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 2.1, 2.2, 3.1, 3.2

KPI	Definition - Description	Units	Object of assessment	IS-reference
Energy savings Ref: SCIS, CITYKeys	This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. Energy savings may be calculated separately determined for thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings.	%	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2
Smart Storage Capacity	The smart storage capacity includes all the energy storage technologies integrated in the city smart grid containing electricity, heating and mobility. This KPI presents the impact of the project in the use of smart energy storage systems.	%	Set of ESUs Neighbourhood City	2.1, 2.2, 2.3
Battery Degradation Rate Ref: SMILE	The KPI illustrates the capacity losses of the batteries used in project, through use (some cycles) and through time (some years). The conclusions of this KPI concern the effectiveness of this technology, the need for maintenance and thus, gives useful data concerning the financial feasibility of its integration.	%	Energy Supply Unit Set of ESUs	2.3
Storage Energy Losses Ref: SMILE	This KPI illustrates the energy losses because of battery storage, including the added voltage transformations. The conclusions of this KPI concern the effectiveness of this technology and thus, gives useful data concerning the financial feasibility of its integration.	%	Building Set of Buildings Energy Supply Unit	2.3
Maximum Hourly Deficit Ref: CITYKeys	The Maximum Hourly Deficit (MHDx) indicates the maximum ratio of the difference between load and on-site renewable energy generation to load for each energy type. It is calculated taking the biggest value of those ratios calculated for each hour of the year, for those hours when local renewable supply is smaller than the demand.	Number	Building Set of Buildings Neighbourhood City	1.1, 1.2, 2.1
Technical Compatibility Ref: CITYKeys	This indicator aims to provide an indication of the technical compatibility of the smart city solution, meaning the extent to which the solution fits with current practices, administrative and existing technological standards/infrastructures.	Likert scale (No unit)		1.1, 1.2, 1.3

KPI	Definition - Description	Units	Object of assessment	IS-reference
Improved Interoperability Ref: CITYKeys	Interoperability is the ability of a system (or product) to work with other systems (or products) by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate effectively together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner without going into details.	Likert scale (No unit)	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 1.3, 3.2
Energy consumption data aggregated by sector fuel Ref: SCIS	Energy consumption of the mobility sector. It should be assessed for public transport (before and after) as well as for private vehicles (before and after).	GJ	Neighbourhood City	3.1, 3.2
Free Floating subscribers	The successful implementation of a free-floating car-sharing system mostly depends on the use of the vehicles, which is highly related to the service subscribers. This indicator will assess the increase in the number of subscribers to the free-floating car-sharing service.	Number	Building Set of Buildings Neighbourhood City	3.2
Yearly km are made through the e-car sharing system instead of private conventional cars	The key element of a car-sharing system is the usage of the system, not only in terms of users but in terms of kilometres. This indicator will assess the number of kilometres done using the car-sharing service.	km	Building Set of Buildings Neighbourhood City	3.2
Number of efficient vehicles deployed in the area Ref: SCIS	A car-sharing system needs a critical number (mass) of vehicles in order to be useful for the users. This indicator will assess the level of service offered by measuring the number of efficient vehicles in the area.	Veh/km^2	Neighbourhood City	3.1
Number of EVs charging stations and solar powered V2G charging stations deployed in	Charging infrastructure development is critical for the promotion of electromobility and the deployment of electric vehicles. This indicator will assess the level of service with regards to charging capabilities offered by measuring the number of electric vehicles charging stations deployed in the	stations/ km^2, %	Neighbourhood City	3.1

KPI	Definition - Description	Units	Object of assessment	IS-reference
the area	area. Additionally, it will measure the number of solar powered V2G stations comparing it with the total number of stations.			
Improved flexibility of service delivery following citizen feedback phases	This KPI measures the improved flexibility of service delivery following citizen feedback phase(s)	Likert scale (No unit)	Neighbourhood City	5.1, 5.2, 5.3, 5.4

3.2 Environmental

Table 7 – List of environmental KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference
Carbon dioxide Emission Reduction Ref: SCIS	CO_2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO_2 emissions are combustion processes related to energy generation and transport. CO_2 emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.	tones/year	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2
Increase in Local Renewable Energy Generation Ref: SCIS	The share of renewable energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator should account for the increase of the renewable energy generation due to the intervention.	%	Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.2, 2.3
Energy Return on Energy Investment Ref: SMILE	This indicator presents the efficiency of a technology or application as a whole, measuring the overall energy output throughout its lifetime compared to the energy needed for the aforementioned output, with the exception of the primary energy inputs for its construction.	No unit	Energy Supply Unit Set of ESUs	2.2

KPI	Definition - Description	Units	Object of assessment	IS-reference
Increased efficiency of resources consumption Ref: CITYkeys	This KPI will measure the percentage reduction in material consumption of the project.	% in tonnes	Building Set of Buildings Neighbourhood City	3.1, 3.2
Reduction in annual final energy consumption Ref: CITYkeys	This indicator will assess the final energy consumption of the project taking into account all forms of energy (e.g. electricity, gas, heat/cold, fuels) and for all functions (transport, buildings, ICT, industry, etc.). The final energy consumption is the energy actually consumed by the end-user.	%	Building Set of Buildings Neighbourhood City	1.1, 1.2, 1.3, 3.1, 3.2
Decreased emissions of Particulate matter Ref: CITYkeys	This KPI will measure the percentage reduction in PM10 and PM2,5 emissions achieved by the project.	%	Neighbourhood City	1.3, 3.1, 3.2
Decreased emission of oxides (NOx) Ref: CITYkeys	This KPI will measure the percentage reduction in NOx emissions (NO and NO2) achieved by the project.	%	Neighbourhood City	1.3, 3.1, 3.2
Noise pollution Ref: CITYkeys	Prolonged exposure to noise can lead to significant health effects. Urban environmental noise pollution relates a lot to noise caused by traffic. One of the advantages EVs offer is the reduction of noise pollution. This KPI will measure the noise levels before and after the activities of the project.	dB level, %	Neighbourhood City	3.1, 3.2

3.3 Economic

Table 8 – List of economic KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference

KPI	Definition - Description	Units	Object of assessment	IS-reference
Payback Ref: SCIS, CITYKeys	The payback period is the time it takes to cover investment costs. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period.	Years	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1,1.2,1.3, 2.2, 2.3, 3.1, 3.2
Return on Investment Ref: SCIS	The return on investment (ROI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total incomes/net profit and the total investment of the project, usually expressed in %.	%	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1,1.2,1.3, 2.2, 2.3, 3.1, 3.2
Reduction of energy cost Ref: SCIS	This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator. The KPI will measure the cost of the energy traded by an aggregator, both as a baseline and when ICT are implemented, e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower.	%	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.2, 2.1, 2.2, 2.3
Total Investments Ref: SCIS	An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. Within IRIS, total investments apply to the energy aspects of the system (e.g. high efficient envelope in a building) and exclude investments non-energy related (e.g. refurbishment of bathrooms).	€/m^2 or €/kW	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1,1.2,1.3, 2.1, 2.2, 2.3, 3.1, 3.2
Total Annual costs Ref: SCIS	The total annual costs are defined as the sum of capital-related annual costs (e.g. interests and repairs caused by the investment), requirement-related costs (e.g. power costs), operation related costs (e.g. costs of using the installation) and other costs (e.g. insurance). The total annual costs are related to the considered interval of time (year). To make different objects	€/year	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood	1.1,1.2,1.3, 2.1, 2.2, 2.3, 3.1, 3.2

KPI	Definition - Description	Units	Object of assessment	IS-reference
	comparable the same types of costs have to be included in the calculation.		City	
Financial benefit for the end-user Ref: CITYKeys	One dimension of value creation by the smart city project is the extent to which the project generated cost savings for end-users. Cost savings can be generated, for example, through a reduction in energy use, the generation of renewable energy on site, or reduction in housing costs.	€/ household/ year	Building Set of Buildings Neighbourhood City	1.1,1.2,1.3, 2.1, 2.2, 2.3, 3.1, 3.2
Grants Ref: SCIS	Grants are non-repayable funds that a grant maker, such as the government, provides to a recipient, e.g. a business, for ideas and projects to provide public services and stimulate the economy.	%	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.1,1.2,1.3
Fuel poverty Ref: CITYKeys	The indicator is derived from the UK definition, according to which households are considered as energy poor if their energy bill consumes 10% or more of the household income. This KPI will measure the change in percentage points of (gross) household income spent on energy bills.	%	Building Set of Buildings Neighbourhood City	1.1,1.2
CO2 reduction cost efficiency Ref: CITYKeys	Costs in euros per ton of CO2 saved per year. Many smart city projects are intrinsically aimed at reducing the amount of CO2 emitted during their lifetime. Those projects which prove to be able to significantly reduce their carbon footprint, whilst keeping the related costs at a minimum, are considered to be interesting projects for upscaling.	€/((ton of CO2) * year))	Building Set of Buildings Neighbourhood City	1.1,1.2,1.3, 3.1, 3.2
Stimulating an innovative environment Ref: CITYKeys	The extent to which the project is part of or stimulates an innovative environment. A project can stimulate an environment that enhances innovations, either by being part of it or by contributing to it.	Likert scale (no unit)	Neighbourhood City	1.2, 1.3, 3.2

KPI	Definition - Description	Units	Object of assessment	IS-reference
Awareness of economic benefits of reduced energy consumption	This KPI measures the awareness of economic benefits of reduced energy consumption	%	Neighbourhood City	5.1, 5.2, 5.3, 5.4

3.4 Social

Table 9 – List of social KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference
Consumers' engagement Ref: SCIS	The implementation of ICT solutions can also be related to the involvement of the users in the control over the energy use in the building.	Number	Building Set of Buildings Neighbourhood City	1.1, 1.2, 2.1, 2.3, 3.1, 3.2
Professional stakeholder involvement Ref: CITYKeys	The extent to which professional stakeholders outside the project team have been involved in planning and execution. In this context, relevant stakeholders may include: industry or business associations, local councils, government departments, politicians, environmental organisations, architects, project developers.	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.3, 3.1, 3.2
Social Compatibility Ref: CITYKeys	The extent to which the project's solutions fit with people's 'frame of mind' and do not negatively challenge people's values or the ways they are used to do things. If an innovation requires people to significantly think differently, and challenges assumptions or the ways how we normally are accustomed to do things, its implementation in society will be more difficult.	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.2, 2.3
Ease of use for end users of the solution Ref: CITYKeys	The extent to which the solution is perceived as difficult to understand and use for potential end-users. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 2.1

KPI	Definition - Description	Units	Object of assessment	IS-reference
	solution.			
Advantages for end-users Ref: CITYKeys	The extent to which the project offers clear advantages for end users. The advantage can take many forms, for instance cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2
Advantages for stakeholders Ref: CITYKeys	The extent to which the project offers clear advantages for stakeholders. This advantage could, for example, be ease of management or reduced maintenance costs. It is presumed that solutions which have a higher level of advantages to stakeholders will be more likely to be adopted and invested in than solutions which have negative or no advantages to the investors themselves.	Likert scale (no unit)	Building Set of Buildings Energy Supply Unit Set of ESUs Neighbourhood City	1.2, 1.3, 3.1, 3.2
People reached Ref: CITYKeys	Percentage of people in the target group that have been reached and/or are activated by the project. A Smart City project is usually most successful if the entire target group of a service participates. The effort the project will make towards reaching the full extent of its target group can vary and with it the size of the target audience.	%	Neighbourhood City	1.2, 3.1, 3.2
Thermal comfort Ref: SMILE	The quality of the delivered heating/cooling service is certainly a matter of technical aspects that can be measured with quantified technical indicators, but also a matter of the opinion of the service receivers.	Likert scale (no unit)	Building Set of Buildings Neighbourhood	2.2
Increased environmental awareness Ref: CITYKeys	Awareness of environmental problems is important for creating support for environmental projects and programs. This indicator, therefore, assesses the extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment.	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 1.3, 3.1, 3.2
Increased consciousness of	The extent to which the project has contributed in increasing consciousness of citizenship. Consciousness of citizenship is the awareness (consciousness)	Likert scale (no unit)	Neighbourhood City	1.1, 1.2, 3.1, 3.2

KPI	Definition - Description	Units	Object of assessment	IS-reference
citizenship Ref: CITYKeys	of one's community, civic rights and responsibilities and as such contributes to the sense of community.			
Increased participation of vulnerable groups Ref: CITYKeys	Vulnerable and other groups whose opinions or contributions are not reflected well enough in our society (like women, minorities and the disabled), require special attention to be included in the community, thereby enhancing social cohesion and diversity and tapping into underdeveloped social capital.	Likert scale (no unit)	Neighbourhood City	1.1, 1.2
Local job creation	One of the pillars of the smart city projects is to improve the economy by reducing costs and energy, but also by fostering the local economy and the local eco-systems. This indicator will assess the creation of direct jobs from the implementation and operation of the IRIS solutions.	#	Building Set of Buildings Neighbourhood City	3.1, 3.2
Local community involvement in the implementation phase Ref: CITYKeys	The extent to which residents/users have been involved in the implementation process.	Likert scale (no unit)	Neighbourhood City	5.1, 5.2, 5.3, 5.4
Increased citizen awareness of the potential of smart city projects	This KPI measures the increased citizen awareness of the socio-cultural potential of smart city projects.	Likert scale (no unit)	Neighbourhood City	5.1, 5.2, 5.3, 5.4
Number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens	This KPI measures the number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens	Number	Neighbourhood City	5.1, 5.2, 5.3, 5.4
Provision of a localised multi stakeholder co-	This KPI measures the provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen Engagement activities.	Number	Neighbourhood City	5.1, 5.2, 5.3, 5.4

KPI	Definition - Description	Units	Object of assessment	IS-reference
creation and co-production Field Guide for Citizen Engagement activities	This is the direct aim of the Citizen Engagement approach developed in IRIS project. By modularising the process and making available advice and tools, we anticipate that the platform will grow during the lifetime of the project and provide a valuable resource.			
Participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities	This KPI measures the participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities	Number	Neighbourhood City	5.1, 5.2, 5.3, 5.4

3.5 ICT

Table 10 – List of ICT KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference
Peak load reduction Ref: SCIS	Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system.	%	Building Set of Buildings Neighbourhood City	2.1
Number of costumers that are positive about how energy systems are controlled Ref: SCIS	All the end-users involved in the project demonstrations are asked whether they are satisfied with the provided services including the ICT system. This is done with a Yes/No question and the value of the indicator is given by the percentage of the end-users that stated that they were satisfied.	%	Building Set of Buildings Neighbourhood City	2.1
Reliability Ref: SCIS	Avoiding failures revert on higher reliability, meaning fewer stops on the normal operation of the building and associated systems. With the application of ICT measures it is possible to correct a potential misbehaviour of the system and avoid unexpected stops. This indicator will be measured as: • Ratio of power interruptions avoided in a year • Ratio of power quality issues avoided in a year	%	Energy Supply Unit Set of ESUs Neighbourhood City	1.1, 1.2, 1.3, 3.1, 3.2
Increased system flexibility for energy players Ref: SCIS	This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention. Stability refers to the maintaining of voltage and frequency of a given power system within acceptable levels.	%, W/€	Neighbourhood City	1.2, 2.1
Increased hosting capacity for RES, electric vehicles and other new	This KPI is intended to give a statement about the additional loads that can be installed in the network, when R&I solutions are applied, and compared to the BAU scenario.	%	Neighbourhood City	3.1

loads Ref: SCIS				
Impact of ICT apps into mobility	Impact of ICT apps into switching from non-sustainable mobility into sustainable mobility, this is, change on modal split.	%	Neighbourhood City	3.2
Developer engagement	This KPI measures the use of open datasets by developers. Developers are important stakeholders in the open data market. It is important to gain insight in the variety, importance and value of data used and not used by the developers.	Number	City	4.1, 4.2, 4.3, 4.4
Data safety	Number of blocked malicious hacking attempts. The nature of the web environment is hostile. There are a lot of agents trying to exploit vulnerabilities in any software system. From DDoS to someone taking control of the servers, the risks are diverse. This KPI is intended to give a statement about the safety of data in the IRIS applications.	Number	City	4.1, 4.2, 4.3, 4.4
Data loss prevention	Lost datapoints in a period. Managing data brings a lot of opportunities but also some safety issues. To know if data has been stolen, leaked or otherwise distributed it is important that monitoring is in place.	Number	City	4.1, 4.2, 4.3, 4.4
Usage of open source software	This KPI is intended to give a statement about how easy it is to connect systems. The use of open source software means less possibilities of vendor lock-in and more space for communities to develop together smart city solutions. It also lowers the software costs.	Likert scale (no unit)	City	4.1, 4.2, 4.3, 4.4
Expiration date of open data	Percentage of outdated datasets on a city platform per timeframe. Open data can become outdated and obsolete, which acts negatively on the attractivity of using data from platforms. By monitoring the expiration dates of the data, the owner gets a message to renew or remove the datasets.	%	City	4.1, 4.2, 4.3, 4.4
Quality of open data	Percentage of data that uses DCAT standards. The quality of open data is better if is standardized. Processes get easier when data standards are applied. The DCAT standard allows municipal	%	City	4.1, 4.2, 4.3, 4.4

	employees to produce data in a standardized way.			
Platform downtime	Downtime per timeframe. To run a stable platform, monitoring is required to fix bugs and quickly improve the software environments.	Minutes / (selected timeframe)	City	4.1, 4.2, 4.3, 4.4
Open data-based solutions	Number of services based on open data. To gain insight of the use of open data, mapping the applications developed based on the open data is vital.	Number / (month, year)	City	4.1, 4.2, 4.3, 4.4
Number of active 'touch-points' identified where citizens have a degree of agency and interaction with solution	This KPI measures the number of active 'touch-points' identified where citizens have a degree of agency and interaction with solution. This is the basis for distinguishing between communication and CE activities and for prioritising and mapping suitable activities to each IS.	Number	Neighbourhood City	5.1, 5.2, 5.3, 5.4

3.6 Legal

Table 11 – List of legal KPIs

KPI	Definition - Description	Units	Object of assessment	IS-reference
Green Building self-consumption Legal Framework Compatibility	The indicator presents the level of suitability of the legal framework for the integration of self-consumption RES generation solutions in buildings.	Likert Scale (No unit)	City	1.1, 1.2
Symbiotic waste heat Legal Framework Compatibility	The indicator presents the level of suitability of the legal framework for the integration of symbiotic waste heat solutions.	Likert Scale (No unit)	City	1.3, 2.2
Energy flexibility policies Legal Framework Compatibility	The indicator presents the level of suitability of the legal framework for the integration of energy flexibility policies such as incentives for peak-shaving.	Likert Scale (No unit)	City	2.1, 3.1
Smart EVs Legal Framework	The indicator presents the level of suitability of the legal framework for the integration of private EVs and public transport EVs in the city mobility	Likert Scale	City	3.1

Compatibility	policies.	(No unit)		
City platform Legal Framework Compatibility	The indicator presents the level of suitability of the legal framework for the integration of a web city platform for the energy management and citizen engagement. The mentioned suitability takes into account not only whether the platform is permitted, but also what measurements are taken in order to maintain system security and privacy.	Likert Scale (No unit)	City	4.1, 4.2, 4.3, 4.4
Change in rules and regulations	It shows the extent to which the project is able to change the context in which they were applied, by providing a different interpretation of existing rules and regulations.	Likert Scale (No unit)	City	1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2
Measure extent to which privacy by design has been ensured	This KPI measures the extent to which privacy by design has been ensured. Trust is paramount to the adoption of smart city solutions, which must fully respect individual freedom and the right to privacy by integrating the concepts of privacy by design including citizen consent in smart cities projects.	Number	City	5.1, 5.2, 5.3, 5.4

4. Data Control

4.1 Primary (measurement-based) data

The collection of data by the different pilots is crucial for the calculation of the IRIS KPIs, as well as its overall evaluation in terms of the different pilots and its replication ability. In most cases, the data is described by its units and the time point/period it refers to. The data source directs to the methodology used for the data collection. The most usual cases are described below:

Existing web services

Online data, both real time and historical can be collected from online services via web-service API. One of the more common examples is environmental data such as temperature that is often needed for energy efficiency or demand calculations. Moreover, existing web-services will provide all the information needed in order to evaluate the legislative background concerning the quality standards of the three grids, as well as the market operation rules.

Smart meters

Some sites may already have meters or data loggers installed that are already connected or provisioned to connect and send data to the network via a dedicated network interface. These meters can be easily connected and configured to send data files into a pre-defined web address that can then be accessed online by users or automatic web services. In some cases, such meters cannot be accessed directly, but need to be accessed via a web service that is included as part of the solution. In such case, data can be accessed online manually from a website and exporting the data or using some type of API. Some of the more advanced utilities have also deployed smart meters at the utility input and are enabling user access to the meter data.

In other generation sites, smart meters will have to be applied and, along with existing equipment of the premises, in order to provide exact information about the electricity generation, especially in RES power plants.

On the other hand, there is the alternative of simple *energy meters*. These meters/analysers are used for metering but not necessarily for billing. They are often coupled with analytical tools to help users/operators analyse the consumption profiles.

The determination between smart meters and simple energy meters is depending on several criteria like connectivity, sampling frequency and accuracy.

The data acquired either way will be mostly in a compatible form.

Plug-level meters

They will be used in pilots to measure the current signal in EVs. The aspects taken into consideration are mainly the need for a remote access, an open API, as well as the necessity to use a smart plug which will allow a larger maximum current than that needed for charging.

Utility bills

Historical and highly delayed data is provided by utility bills. This data is, of course, interval data for very long intervals (months). However, collecting this historical data can provide good benchmarks for initial calibration. This data is provided in different formats by different utilities and in most cases, needs to be manually collected and organized in files, or even better to be gathered by the local electricity utility in computer files.

Battery Management Systems (BMS) and EV charging platforms

BESS and charging platforms for EVs and boats are some of the main technology solutions tested. Data needed for their evaluation will be gathered by smart metering in place and connected with the management platform.

Grid power quality analyser

A grid power quality analyser shares the basic functions of a smart meter, in terms of measuring the consumption of energy with information such as active, reactive and apparent power, power factor, network frequency, harmonic distortions, voltage and current, allowing, at the same time, bidirectional communication of the data obtained using cellular networks (i.e., 3G, GSM and GPRS) or Wi-Fi.

One difference between smart-meters and grid power quality analysers is the sample frequency. Typically, smart meters sample data every few seconds or minutes. However, the control of voltage and frequency levels in distribution points need real time information about these quantities, thus the need for such equipment.

Supervisory control and data acquisition (SCADA)

A very important source of data is SCADA as will provide all the relative data for the DSO. The values provided are various including plenty of the electricity qualitative and quantitative characteristics like voltage, active/reactive/apparent power, frequency etc. Moreover, the data is separated by very short time intervals (from 1 to 15 minutes; the latter is required by most of the current standards and EU based national legislation rules), so a quite exact impression can be given in order to evaluate accurately.

4.2 Secondary (model-based) data

Except for the raw measurements associated with the real-time operation of the IRIS platform, many additional parameters, not easy to be measured, will need to be determined for the calculation of IRIS KPIs. These data consist of the configuration parameters and normalization factors that will enable the model-based KPIs calculation. These values are of high importance and their actual use within our calculations is:

- To reflect factors that can be considered constant throughout the overall IRIS approach without introducing bias to our evaluation results.
- To represent values, selected taking into account the conditions/parameters of the EU market or the pilot countries (retailer energy prices).
- To derive factors, which allow someone to normalize KPI values so as to support further comparative analysis (installed capacity).
- To be factors and configuration parameters associated with different business models and contractual agreements; of high interest within the IRIS framework (feed-in tariffs).

The configuration data values are to be extracted from the audit process at pilot infrastructures of the IRIS project. In some cases (e.g. retailer or market prices), dynamically updated values will be considered and thus interfaces with external service providers (e.g. energy markets) will be defined.

In summary, the IRIS performance framework can form, with the introduction of such data, a holistic approach for the estimation of indicators based on a priori estimations and a posteriori measurement values. This separation of work mandates for the adoption of both Measurement-based and Model-based metrics and therefore, both types of KPIs have been selected for the performance evaluation of the project. The KPIs will be fed with raw data originated from a variety of devices, systems or web sources, coupled with or validated against technical references, where appropriate, for calibration and/or testing purposes.

5. Next steps (in cooperation with WP5-WP7, WP9)

D1.1 provides the appropriate list of Key Performance Indicators, which should be used to evaluate the technical solutions proposed in the IRIS project. This list of KPIs is shared with WP9, which is responsible for the monitoring throughout the project. WP9 will determine the infrastructure needed for the actual data collection and quantification of the various sizes that will be needed for the measurement of the KPIs. Moreover, WP9 deliverables will describe how the monitoring activities of the solutions will be done and will define the full evaluation approach of the project.

Subsection 2.3 (Sharing with WP9 in order to align with monitoring & evaluation planning) explains in detail the connection between D1.1 and the activities in WP9, especially with D9.2. To summarise, the D9.2 will expand the list of KPIs that is selected in D1.1 for the specific demonstrated solutions and will go a step forward towards defining the necessary KPIs that will be used for the evaluation of each of the LHs in a time period, covering the IRIS project period and ending up to five (5) years, as an estimate, after its end.

After the final definition of the KPI repository in D9.2, LH cities should define the thresholds for each KPI. The process of threshold definition, an important and sometimes difficult task, is explained in subsection 2.8 (Threshold definition).

D9.3: Report on data model and management plan for integrated solutions, which will be also delivered in month 12, is strongly related to D1.1 and D9.2 as it will define the monitoring infrastructure and will develop a comprehensive data collection approach and model in order to coordinate and supervise the collection of information.

The establishment of the monitoring infrastructure will be completed in month 24 with the establishment of a unified framework for harmonised data gathering, analysis and reporting (T9.3) and the deployment of the monitoring framework in LH cities (T9.4). The unified framework will allow smooth and integrated data gathering from all the LH cities, enabling the monitoring, post-processing, visualisation and permitting easy sharing and cooperation between the consortium partners.

The results of the monitoring process will be reported firstly in month 38 in D9.6: Intermediate report after one year of measurement. This deliverable will provide early results on the impact of actions carried out in the LHs. Based on the initial KPIs defined and through continuous analysis and evaluation of the results, along with the impact analysis, this deliverable will give an early indication on the effective potential of each integrated solution and technology implemented in the LHs. The final report on the impact of all actions carried out in the LH cities will be available on month 60 in D9.7: Report on evaluation and impact analysis for integrated solutions.

6. Conclusions

D1.1 is the first step towards the establishment of the monitoring infrastructure of the IRIS project. The deliverable presents the work undertaken in Tasks 1 to 5 (Integration synergy on Transition Track #1, #2, #3, #4, #5) of WP1 for the definition of the Key Performance Indicators repository that will be used for facilitating the monitoring phase of the IRIS integrated solutions.

The selection of the appropriate KPIs for the IRIS integrated solutions is based on existing ones in the project's proposal that fit well to the requirements of the specific solutions, and/or on new ones in order to assess more accurately the success level of each technology or methodology tested by the demonstrators. The definition of KPIs is conducted in accordance with other European projects dealing with the energy smartification of European cities. Thus, most of the selected KPIs were developed within the SCIS [2] and CITYkeys [3] initiatives, which have created lists of KPIs for the evaluation of systems and technologies demonstrated in smart city projects. The support of SCIS and CITYkeys KPIs will facilitate the incorporation of all performance data into the SCIS.

The creation of the KPIs repository is based on a detailed methodology that is finalised with RISE (the leader of WP9: monitoring and evaluation), key representatives of LH cities and the leaders of the five Transition Tracks. The selection process was based on many criteria including relevance, completeness, availability, measurability, reliability, familiarity, non-redundancy, and independence.

The deliverable presents a holistic performance framework allowing the evaluation of the specific technical characteristics of a technology, its impact on the social and environmental surroundings, its feasibility from an economic point of view, its smart automation and interaction through an ICT platform and its availability concerning the legal infrastructure. The three pillars of the IRIS performance framework for the integrated solutions are:

1. **KPI Domains:** Technical, Economic, Environmental, Social, ICT, and Legal.
2. **Stakeholders Groups:** Distribution System Operators (DSOs), Consumers (End-users), Technology and Services Providers, Policy-Making Bodies and Governance, Citizens, Representative Citizen Groups, and Citizen Ambassadors.
3. **Object(s) of Assessment:** Building, Set of Buildings, Energy Supply Unit, Set of Energy Supply Units, Neighbourhood, City

Each KPI is presented in a detailed table (KPI card) that contains all the requisite information for its calculation. The deliverable provides guidance regarding the required data collection by identifying the sources of primary (measurement-based) and secondary (model-based) data. Moreover, it provides the methodology for the definition of the threshold of each KPI. The threshold will be calculated in D9.2 by LH cities as it depends on the specific integrated solution and the city that this KPI will be used.

The work done in D1.1 will be used in D9.2 that is due in month 12. D9.2 will go a step forward by defining the necessary KPIs that will be used for the evaluation of each of the LH cities and not only for the specific demonstrated solutions. D1.1 will also feed the D9.3, which will create the data model and the management plan for integrated solutions.

7. References

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2. Antonio Garrido Marijuan, G.E., Sebastian Moller Smart Cities Information System: Key Performance Indicator Guide v.2.0. 2017.
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5. Rooijen, T.v. and N. Nesterova Applied framework for evaluation in CIVITAS PLUS II. 2013.
6. Abeyasekera, S., Methods in Development Research; Combining Qualitative and Quantitative Approaches. 2005. p. 97-106.
7. Smart Islands Energy System (SMILE) project: http://www.h2020smile.eu/
8. EIP-SCC Citizen Focus, Inclusive Smart Cities: a European Manifesto on Citizen Engagement, 2016

8. Annex

8.1 KPI description cards

8.1.1 Technical

Degree of energetic self-supply by RES					
KPI Description	The degree of energetic self-supply by RES is defined as ratio of locally produced energy from RES and the energy consumption over a period of time (e.g. month, year). DE is separately determined for thermal (heating or cooling) energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy.				
KPI Formula	$$DE_T = \frac{LPE_T}{TE_C}$$ DE_T = Degree of thermal energy self-supply based on RES LPE_T = Locally produced thermal energy [kWh/month; kWh/year] TE_C = Thermal energy consumption (monitored) [kWh/(month); kWh/(year)] $$DE_E = \frac{LPE_E}{TE_C}$$ DE_E Degree of electrical energy self-supply based on RES LPE_E Locally produced electrical energy [kWh/month; kWh/year] EE_C Electrical energy consumption (monitored) [kWh/(month); kWh/(year)]				
Measurement procedure	1. Collection of data 2. Calculation of KPI				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Reduced energy curtailment of RES and DER	
KPI Description	Reduction of energy curtailment due to technical and operational problems. The integration of ICT will have an impact on producers, as the time for curtailment will be reduced, and the operative range will be wider. This indicator can be measured as the percentage of GWh electricity curtailment from DER reduction of R&I solution compared to BaU for a period of time, i.e. a year.
KPI Formula	$$Reduction\ of\ EnI = \frac{EnI_{baseline} - EnI_{R\&I}}{EnI_{baseline}} \cdot 100$$ EnI = Energy not Injected

Measurement procedure	1. Calculation/determination of baseline 2. Data collection 3. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Average number of electrical interruptions per customer per year					
KPI Description	The average number of electrical interruptions per customer per year shall be calculated as the total number of customer interruptions (numerator) divided by the total number of customers served (denominator). The result shall be expressed as the average number of electrical interruptions per customer per year.				
KPI Formula	$$N_{EIav} = \frac{N_{CItot}}{N_{Ctot}}$$ NEIav = Average number of electrical interruptions per customer per year NCItot = Total number of customer interruptions NCtot = Total number of customers served				
Measurement procedure	1. Collection of data 2. KPI calculation				
Unit of Measurement	#/year		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Average length of electrical interruptions (in hours)</th></tr>
<tr><td>KPI Description</td><td colspan="5">The average length of electrical interruptions shall be calculated as the sum of the duration of all customer interruptions in hours (numerator) divided by the total number of customer interruptions (denominator). The result shall be expressed as the average length of electrical interruptions in hours. Electrical interruptions shall include both residential and non-residential.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$D_{EIav} = \frac{D_{CItot}}{N_{CItot}}$$
DEIav = Average length of electrical interruptions in hours
DCItot = Sum of the duration of all customer interruptions in hours
NCItot = Total number of customer interruptions</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Collection of data</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Hours</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="2">Energy demand and consumption</th></tr>
<tr><td>KPI Description</td><td>The energy demand/consumption corresponds to the energy entering the system in order to keep operation parameters (e.g. comfort levels). The energy demand is based on the calculated (e.g. simulated) figures and the energy consumption is based on the monitored data. To enable the comparability between systems, the total energy demand/consumption is related to the size of the system and the time interval. This indicator can be used to assess the energy efficiency of a system.</td></tr>
<tr><td>KPI Formula</td><td><u>At Building Level</u>
$$E_d = \frac{TE_d + EE_d}{A_d}$$
E_d = Energy demand (simulated)
TE_d = Thermal energy demand (simulated) [kWh/ (month); kWh/ (year)]
EE_d = Electrical energy demand (simulated) [kWh/ (month); kWh/(year)]
A_b = Floor area of the building [m^2]
$$E_C = \frac{TE_C + EE_C}{A_b}$$
$E1_C$ = Energy consumption (monitored)
TE_C = Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)]
EE_C = Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)]
A_b = Floor area of the building [m^2]</td></tr>
</table>

	At district level $$E_{district\ demand} = \sum E_d$$ $$E_{district\ consumption} = \sum E_c$$				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	kWh/ (m²·month); kWh/(m²·year)		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Energy savings	
KPI Description	This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. ES may be calculated separately determined for thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings.
KPI Formula	$$ES_T = 1 - \frac{TE_C}{ER_T}$$ ES_{T} = Thermal energy savings TE_{C} = Thermal energy consumption of the demonstration-site [kWh/(m^2 year)] ER_{T} = Thermal energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m^2 year)]. $$ES_E = 1 - \frac{TE_C}{ER_E}$$ ES_{T} = Electric energy savings TE_{C} = Electric energy consumption of the demonstration-site [kWh/(m^2 year)] ER_{T} = Electric energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m^2 year)].
Measurement procedure	1. Data collection 2. KPI calculation
Unit of Measurement	% | **Threshold/ Target** |

Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Smart Storage Capacity					
KPI Description	Viewing the need for an increase in the RES penetration in the energy mix, energy storage is essential due to the fuzziness in the generation using RES. The smart storage capacity includes all the energy storage technologies integrated in the city smart grid containing electricity, heating and mobility. This KPI presents the impact of the project in the use of smart energy storage systems.				
KPI Formula	$$Storage\ capacity\ installed = \frac{SCI_{R\&I} - SCI_{baseline}}{SCI_{baseline}} \cdot 100$$				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Battery Degradation Rate	
KPI Description	The various battery storage systems, including BESS, 2nd life batteries and EVs, are essential for the flexibility of energy grids using increased amounts of electricity deriving by RES. The KPI illustrates the capacity losses of the batteries used in project, through use (some cycles) and through time (some years). The conclusions of this KPI concern the effectiveness of this technology, the need for maintenance and thus, gives useful data concerning the financial feasibility of its integration.
KPI Formula	$$BDR_c = \frac{BC_n - BC_0}{n \cdot BC_0} \cdot 100$$ $$BDR_Y = \frac{BC_Y - BC_0}{Y \cdot BC_0} \cdot 100$$ BDR_C= BDR per cycle

	BDR_Y= BDR per year BC_0= initial battery capacity BC_n= battery capacity after n cycles n= number of cycles Y= number of years				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood			Citizens	
	City			Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Storage Energy Losses					
KPI Description	The various battery storage systems, including BESS, 2nd life batteries and EVs, are essential for the flexibility of energy grids using increased amounts of electricity deriving by RES. This KPI illustrates the energy losses because of battery storage, including the added voltage transformations. The conclusions of this KPI concern the effectiveness of this technology and thus, gives useful data concerning the financial feasibility of its integration.				
KPI Formula	$$SEL = \frac{E_{input} - E_{output}}{E_{input}} \cdot 100$$ E_{input} = the energy input in a piece of energy storage equipment E_{output}= the energy output of a piece of energy storage equipment				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units			Governance	
	Neighbourhood			Citizens	
	City			Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Maximum Hourly Deficit</th></tr>
<tr><td>KPI Description</td><td colspan="5">Smart city projects encouraging local renewable energy generation need to deal with balancing supply and demand over the day, over the week and over seasons. Peaks in production of renewable energy and peaks in consumption patterns often do not coincide.
The Maximum Hourly Deficit (MHDx) indicates the maximum ratio of the difference between load and on-site renewable energy generation (including energy retrieved from local storage to cover the load) to load for each energy type. It is calculated taking the biggest value of those ratios calculated for each hour of the year, for those hours when local renewable supply is smaller than the demand.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">For:
t_1 = 0 hours
t_2 = 0 hours
dt = 1 hour
G = energy generation
L = load
If:
$$\int_{t_1}^{t_2} G_x(t)\,dt < \int_{t_1}^{t_2} L_x(t)dt$$
Then:
$$MHDx = Max\left[\frac{\int_{t_1}^{t_2}[L_x(t) - G_x(t) + S_x(t)]\,dt}{\int_{t_1}^{t_2} L_x(t)dt}\right]$$
S_x = the storage discharge rate (negative value)</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection
2. Calculation of KPI</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="5">Technical Compatibility</th></tr>
<tr><td>KPI Description</td><td colspan="4">This indicator aims to provide an indication of the technical compatibility of the smart city solution, meaning the extent to which the solution fits with current practices, administrative and existing technological standards/infrastructures.</td></tr>
<tr><td>KPI Formula</td><td colspan="4">The indicator provides a qualitative measure and is rated on a five-point Likert scale:
No technical compatibility – 1 — 2 — 3 — 4 — 5 — Very high
1. No technical compatibility: the solution needs many and major adjustments to current (infra)structures and/or practices for its implementation.
2. Low compatibility: the solution requires some major adjustments to current (infra)structures and/or practices for its implementation.
3. Moderate: some adjustments to current (infra)structures and/or practices are necessary to implement the solution.
4. High: only minor adjustments (think of a different type of plug, a specific internet connection, etc.) are needed to implement the solution.
5. Very high: no adjustments to current (infra)structures and/or practices are needed, the solution can immediately be implemented.</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Data Collection
2. Calculation of KPI</td></tr>
<tr><td>Unit of Measurement</td><td>No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building | X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings | X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit | X</td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units | X</td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood | X</td><td>Citizens</td><td></td></tr>
<tr><td>City | X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="2">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

Improved Interoperability	
KPI Description	Interoperability is the ability of a system (or product) to work with other systems (or products) by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate effectively together (ISO/TS 37151). While the term was initially defined for information technology or systems engineering services to allow for information exchange, a broader definition takes into account social, political, and organizational factors that impact system to system performance. Different levels of interoperability can be distinguished. When two or more systems are able to communicate with each other, this is called syntactic interoperability. Semantic interoperability is when the systems are also capable of interpreting the information exchanged in order to produce useful results. Cross-domain interoperability exists when organizations or systems from different domains interact in information exchange, services, and/or goods to achieve their own or common goals. The indicator assesses the improvement in interoperability in a qualitative manner without going into details.
KPI Formula	Likert scale

	Not at all - 1 – 2 – 3 - 4- 5 – Excellent 1. Not at all: the project does not increase interoperability. 2. Poor: the project does little to increase interoperability. 3. Somewhat: the project somewhat increases interoperability. 4. Good: the project increases interoperability sufficiently. 5. Excellent: the project increases interoperability extensively.				
Measurement procedure	1. Data Collection 2. Calculation of KPI				
Unit of Measurement	No Unit		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Energy consumption data aggregated by sector fuel					
KPI Description	Energy consumption of the mobility sector. It should be assessed for public transport (before and after) as well as for private vehicles (before and after).				
KPI Formula	$Reduction\ of\ EnC = \frac{EnC_{baseline} - EnC_{R\&I}}{EnI_{baseline}} \cdot 100$ EnC = $Energy\ Consumption$				
Measurement procedure	1. Data Collection 2. Calculation of KPI				
Unit of Measurement	GJ		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	x
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	x
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Free Floating subscribers					
KPI Description	The successful implementation of a free-floating car-sharing system mostly depends on the use of the vehicles, which is highly related to the service subscribers. This indicator will assess the increase in the number of subscribers to the free-floating car-sharing service.				
KPI Formula	Number of final users involved				
Measurement procedure	1. Data collection				
Unit of Measurement	#		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA		

Yearly km are made through the e-car sharing system instead of private conventional cars					
KPI Description	The key element of a car-sharing system is the usage of the system, not only in terms of users but in terms of kilometers. This indicator will assess the number of kilometers done using the car-sharing service				
KPI Formula	Number of kilometres done by the car-sharing fleet				
Measurement procedure	1. Data collection				
Unit of Measurement	km		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Number of efficient vehicles deployed in the area					
KPI Description	A car-sharing system needs a critical number (mass) of vehicles in order to be useful for the users. This indicator will assess the level of service offered by measuring the number of efficient vehicles in the area.				
KPI Formula	Vehicles deployed / area				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	Veh/km2		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Number of EVs charging stations and solar powered V2G charging stations deployed in the area					
KPI Description	Charging infrastructure development is critical for the promotion of electromobility and the deployment of electric vehicles. This indicator will assess the level of service with regards to charging capabilities offered by measuring the number of electric vehicles charging stations deployed in the area. Additionally, it will measure the number of solar powered V2G stations comparing it with the total number of stations.				
KPI Formula	Total stations deployed/area; V2G stations deployed / area; (solar powered V2G stations deployed/total stations deployed) * 100				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	stations/km2, %		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Improved flexibility of service delivery following citizen feedback phases</th></tr>
<tr><td>KPI Description</td><td colspan="5">This KPI measures the improved flexibility of service delivery following citizen feedback phase(s)</td></tr>
<tr><td>KPI Formula</td><td colspan="5"></td></tr>
<tr><td>Measurement procedure</td><td colspan="5">Each stakeholder group to provide feedback on flexibility of service delivery as initial benchmark.
Each stakeholder group to provide feedback on flexibility of service delivery annually.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Likert scale (No unit)</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">HKU</td></tr>
</table>

8.1.2 Environmental

Carbon dioxide Emission Reduction	
KPI Description	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. CO_2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO_2 emissions are combustion processes related to energy generation and transport. CO_2 emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.
KPI Formula	The emitted mass of CO_2 is calculated from the delivered and exported energy for each energy carrier: $$m_{CO_2} = \sum(E_{del,i}K_{del,i}) - \sum(E_{exp,i}K_{exp,i})$$ $E_{del,i}$ = the delivered energy for energy carrier i $E_{exp,i}$ = the exported energy for energy carrier i $K_{del,i}$ = the CO_2 coefficient for delivered energy carrier i $K_{exp,i}$ = the CO_2 coefficient for exported energy carrier i The indicator is calculated as the direct (operational) reduction of the CO_2 emissions over a period of time. The result may be expressed as a percentage when divided by the reference CO_2 emissions. To calculate the direct CO_2 emissions, the total energy reduced, can be translated to CO_2 emission figures by using conversion factors for different energy forms as described in below tables: **National and European emission factors for consumed electricity (Countries of IRIS LH and FCs) (source: Covenant of Mayors).**

Country	Standard emission factor ($t\ CO_2/MWh_e$)
Spain	0.440
Finland	0.216
France	0.056
Greece	1.149
Netherlands	0.435
Sweden	0.023
Romania	0.701
EU-27	**0.460**

Standard Emission factors for fuel combustion – most common fuel types (IPCC, 2006)

Type	Standard emission factor [t CO_2/MWh]	LCA emission factor [t CO_2-eq/MWh]
Motor Gasoline	0.249	0.299
Gas oil, diesel	0.267	0.305
Residual Fuel Oil	0.279	0.310
Anthracite	0.354	0.393
Other Bituminous Coal	0.341	0.380
Sub-Bituminous Coal	0.346	0.385
Lignite	0.364	0.375
Natural Gas	0.202	0.237
Municipal Wastes (non-biomass fraction)	0.330	0.330
Wood [a]	0 – 0.403	0.002[b] – 0.405

Measurement procedure	1. Data collection 2. KPI calculation 3. Comparison with national emissions factor				
Unit of Measurement	tones/(year)		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increase in Local Renewable Energy Generation	
KPI Description	The share of renewable energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator should account for the increase of the renewable energy generation due to the intervention. In case biomass is used to generate energy, the transport distance is limited to 100 km. Renewable energy shall include both combustible and non-combustible renewables (ISO/DIS 37120, 2013). Noncombustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. The combustible renewables and waste (CRW) consist of biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes), municipal waste (waste produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste.
KPI Formula	$$LREG = \frac{ERES_{R\&I} - ERES_{BaU}}{EC}$$ LREG = Annual Local Renewable Electricity Generation ERES = Annual electricity generated by RES EC = Annual Electricity consumption $$LRHG = \frac{HRES_{R\&I} - HRES_{BaU}}{HC}$$

	LRHG = Annual Local Renewable Heating/Cooling Generation ERES = Annual Heating/Cooling generated by RES EC = Annual Heating/Cooling consumption				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Energy Return on Energy Investment					
KPI Description	This indicator presents the efficiency of a technology or application as a whole, measuring the overall energy output throughout its lifetime compared to the energy needed for the aforementioned output, with the exception of the primary energy inputs for its construction				
KPI Formula	$EROI=\frac{E_{out}}{E_{in}}$ E_{out}= Energy delivered (kWh) E_{in}= Primary energy required for the delivery of the energy above (kWh)				
Measurement procedure	1. Data collection 2. Simulation 3. KPI calculation				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood			Citizens	
	City			Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increased efficiency of resources consumption					
KPI Description	Percentage reduction in material consumption of the project.				
KPI Formula	The increased efficiency of resource consumption resulting from measures taken in the project is calculated as: $$E_{RC} = \frac{C_{MB} - C_{MF}}{C_{MBF}} \cdot 100$$ E_{RC} = Percentage reduction in material consumption of the project C_{MB} = Baseline material consumption of the project [t] C_{MF} = Final material consumption of the project [t] C_{MBF} = Baseline final material consumption [t]				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	% in tonnes		**Threshold/ Target**		
Object of assessment	Building	x	**Stakeholders**	DSO	
	Set of Buildings	x		TSP	x
	Energy Supply Unit			End-Users	x
	Set of Energy Supply Units			Governance	x
	Neighbourhood	x		Citizens	
	City	x		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Reduction in annual final energy consumption	
KPI Description	Reduced and effective energy use can create substantial savings and can enhance security of the energy supply. Reducing the energy consumption also reduces greenhouse gas emissions and the ecological footprint, which contribute to combating climate change and achieve a low carbon economy. (ISO 37120, 2013) This indicator shall assess the final energy consumption of the project taking into account all forms of energy (e.g. electricity, gas, heat/cold, fuels) and for all functions (transport, buildings, ICT, industry, etc.). The final energy consumption is the energy actually consumed by the end-user. This in contrast with primary energy use, the energy forms found in nature (e.g. coal, oil and gas) which have to be converted (with subsequent losses) to useable forms of energy, a more common indicator for evaluating energy consumption. When moving towards a renewable energy system, however, measuring the primary energy consumption loses its value. A reduction in primary energy consumption, for example by increasing the production of renewable energy, does not directly lead to a reduction in final energy consumption.
KPI Formula	The percentage of the decrease in energy consumption caused by the project is calculated as: $$REC_{AF} = \frac{E_{Btot} - E_{Atot}}{E_{Btot}} \cdot 100$$ REC_{AF} = Percentage of the decrease in energy consumption caused by the project EBtot = Total use of energy per year (kWh) on-site or within the project boundaries before the project EAtot = Total use of energy per year (kWh) on-site or within the project boundaries after

	the project EBtot = Total use of energy per year (kWh) on-site before the project The indicator expresses the perceptual reduction of energy consumption due to actions taken within the project. To facilitate the calculation of the total energy consumption, the indicator can be broken down into energy consumption of various sectors: buildings, transport, industry, public services, etc. This can, of course, be further subdivided, for example for 'buildings', in residential buildings, commercial buildings and public buildings, or for 'transport' in public and private transport. All forms of energy need to be taken into account, including electricity consumption, natural gas or thermal energy for heating and cooling and fuels. These will be given in different units of energy (kWh, GJ, m3), but they all have to be calculated or converted to kWh of energy in order to be able to sum up the separately calculated energy consumptions and achieve the total energy consumption of the project. Note for Residential building consumption: As total energy consumption may vary considerably per household (or per user of the building) in some cases this indicator may be restricted to energy for heating, cooling, and hot water provision. These data can be more easily gathered, also in a planning stage.				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Decreased emissions of Particulate matter	
KPI Description	Fine particulate matter can cause major health problems in cities (ISO/DIS 37120, 2013). According to the WHO, any concentration of particulate matter (PM) is harmful to human health. PM is carcinogenic and harms the circulatory system as well as the respiratory system. As with many other air pollutants, there is a connection with questions of environmental justice, since often underprivileged citizens may suffer from stronger exposure. The evidence on PM and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad but are predominantly to the respiratory and cardiovascular systems. Percentage reduction in PM10 emissions achieved by the project.
KPI Formula	$$percentage\ change\ in\ PM10\ emissions = \left(\frac{PM10\ emissions\ \left(\frac{kg}{yr}\right)\ after\ project}{PM10\ emissions\ \left(\frac{kg}{yr}\right)\ before\ project} \times 100 \right)$$ Since data for PM2.5 is not readily available, levels are often calculated on the basis of

	PM10 emission and this is reported as a separate indicator. If a reduction in PM10 emissions cannot be found in project reports or elsewhere, a conversion method can used to calculate the PM2,5 emissions in kg from the amount of final energy consumption in the project.				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Decreased emission of oxides (NOx)					
KPI Description	Nitrogen oxides (NO and NO2) are major air pollutants, which can have significant impacts on human health and the environment (ISO/DIS 37120, 2013). NO contributes to ozone layer depletion and, when exposed to oxygen, can transform into NO2. NO2 contributes to the formation of photochemical smog and at raised levels can increase the likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. NO2 chemically transforms into nitric acid and contributes to acid rain. Nitric acid can corrode metals, fade fabrics, and degrade rubber. When deposited, it can also contribute to lake acidification and can damage trees and crops, resulting in substantial losses. Percentage reduction in NOx emissions (NO and NO2) achieved by the project.				
KPI Formula	$$percentage\ change\ in\ NOx\ emissions = \left(\frac{NOx\ emissions\ \left(\frac{t}{yr}\right)\ after\ project}{NOx\ emissions\ \left(\frac{t}{yr}\right)\ before\ project} \times 100 \right)$$ NOx emissions can be derived from energy use if not directly available. The level of NOx emissions is varying depending mainly on the energy generation technology and type of fuel. It would be most convenient to use an average ratio number specific to the combustion process and fuel (e.g. Energy production from coal or diesel combustion engines). $$\boldsymbol{Energy\ produced\ \times NOx_{ratio}\ (kWh\ \times NOx/kWh)}$$				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of	%		**Threshold/**		

Measurement			**Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Noise pollution					
KPI Description	Prolonged exposure to noise can lead to significant health effects. Urban environmental noise pollution relates a lot to noise caused by traffic. One of the advantages EVs offer is the reduction of noise pollution. This KPI will measure the noise levels before and after the activities of the project.				
KPI Formula	The indicator is measured in level of decibels (dB) which means that the reduction can be calculated as: (dB level before/dB level after) * 100				
Measurement procedure	• Measurements (noise level should be measured at the object receiving the noise) • Interviews				
Unit of Measurement	dB level, %		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City			Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

8.1.3 Economic

Payback					
KPI Description	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators.				
KPI Formula	Economic payback, EPP, type A static: $EPP = \frac{EPI_{BR}}{m}$ m can be calculated as average annual costs in use savings (€/a) $m = TAC_{after} - TAC_{before}$ Type B dynamic: $EPP = \frac{ln(m \cdot (1+i)) - ln(EPI_{BR} - EPI_{BR} \cdot (1+i) + m)}{ln(1+i)} - 1$ Type C dynamic with energy price increase rate: $EPP = \frac{ln(m \cdot (1+i)) - ln(EPI_{BR}(1+p) - EPI_{BR} \cdot (1+i) + (1+p)m)}{ln(1+i) - ln(1+p)} - 1$ EPI_{BR} (€) = Energy-related investment i (%) = Discount rate p (%) = Energy price increase rate				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	Years		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Return on Investment				
KPI Description	The return on investment (ROI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total incomes/net profit and the total investment of the project, usually expressed in %.			
KPI Formula	$$ROI_T = \frac{\sum_{t=1}^{T}(In_t - TA_{after_t}) - (I_{BR} - I_{ER})}{I_{BR} - I_{ER}}$$ ROI_T = Return on Investment [%] T = Duration of the economic analysis period: T=10, 15 and 20 [yr]			
Measurement procedure	1. Data collection 2. KPI calculation			
Unit of Measurement	%		**Threshold/ Target**	
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Reduction of energy cost				
KPI Description	This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator. The KPI will measure the cost of the energy traded by an aggregator, both as a baseline and when ICT are implemented, e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower.			
KPI Formula	$$COST_{REDUCTION} = \frac{COST_{R\&I} - COST_{BaU}}{COST_{BaU}}$$ COST = the electricity price at a given period of time			
Measurement procedure	1. Data collection 2. KPI calculation			
Unit of Measurement	%		**Threshold/ Target**	
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Total Investments</th></tr>
<tr><td>KPI Description</td><td colspan="5">An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system is defined as cumulated payments until the initial operation of the system. The investment in the refurbishment of an existing system is defined as cumulated payments until the initial operation of the system after the refurbishment.
Within SCIS, total investments apply to the energy aspects of the system (e.g. high efficient envelope in a building) and exclude investments non-energy related (e.g. refurbishment of bathrooms).</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$EPI_{ER} = \frac{I_{ER}}{A_d}$$
EPI_{ER} = Total investment for all the interventions related to energy aspects in the district per conditioned area [€/m^2]
I_{ER} = Total investment for all the interventions related to energy aspects [€]
A_d = Total floor area of the system renovated [m^2]</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection
2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">€/m^2 or €/kW</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="2">Total Annual costs</th></tr>
<tr><td>KPI Description</td><td>The total annual costs are defined as the sum of capital-related annual costs (e.g. interests and repairs caused by the investment), requirement-related costs (e.g. power costs), operation related costs (e.g. costs of using the installation) and other costs (e.g. insurance). These costs (can) vary for each year.
• Capital related costs encompass depreciation, interests and repairs caused by the investment.
• Requirement-related costs include power costs, auxiliary power costs, fuel costs, and costs for operating resources and in some cases external costs.
• Operation-related costs include among other things the costs of using the installation and costs of servicing and inspection.
• Other costs include costs of insurance, general output, uncollected taxes etc.
The total annual costs are related to the considered interval of time (year). To make different objects comparable the same types of costs have to be included in the calculation.</td></tr>
<tr><td>KPI Formula</td><td>$$TAC_i = C_E + C_{O\&M} + C_F$$
TAC_i = Total annual energy cost of the system after the intervention (i.e. energy, operation</td></tr>
</table>

	& maintenance, financial) for year *i* [€/year] C_E Total annual cost of the system supply [€/year] $C_{O\&M}$ Total annual cost of the operation and maintenance of the facility [€/year] C_F Total annual financing cost, if applies [€/year]				
Measurement procedure	1. Data collection 2. Simulation 3. KPI calculation				
Unit of Measurement	€/year		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Financial benefit for the end-user					
KPI Description	One dimension of value creation by the smart city project is the extent to which the project generated cost savings for end-users. Cost savings can be generated, for example, through a reduction in energy use, the generation of renewable energy on site, or reduction in housing costs. To achieve costs savings, initial investments or other costs might be required, e.g. when purchasing a more efficient heating installation. These costs have to be expressed as yearly costs to be able to determine the real annual cost savings due to the project. Direct revenue created by the project is included in this calculation as avoided costs.				
KPI Formula	Financial benefit = $\text{TotalCost}_{ref} - \text{TotalCost}_{R\&I}$				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	€/household/year		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Grants					
KPI Description	Grants are non-repayable funds that a grant maker, such as the government, provides to a recipient, e.g. a business, for ideas and projects to provide public services and stimulate the economy. In order to receive a grant, an applicant must submit a proposal or an application to the potential funder. This could be either on the applicant's own initiative or in response to a request for proposal from the funder.				
KPI Formula	$$G_{rBR} = \frac{G_{BR}}{I_{BR}}$$ G_{rBR} Share of the investment in building retrofitting that is covered by grants [%] G_{BR} Total grants received for the building retrofitting of the district [€] I_{BR} Total investment for all the interventions related to building retrofitting [€] $$G_{rER} = \frac{G_{ER}}{I_{ER}}$$ G_{rER} Share of the investment in energy retrofitting that is covered by grants [%] G_{ER} Total grants received for the energy retrofitting of the district [€] I_{ER} Total investment for all the interventions related to energy retrofitting [€]				
Measurement procedure	1. Data Collection 2. KPI Calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	X
	Energy Supply Unit	X		End-Users	X
	Set of Energy Supply Units	X		Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Fuel poverty	
KPI Description	A significant part of a household's income is consumed by housing costs and related expenditures. As such, both are determinants of the extent to which households are at risk of poverty or deprivation. As a large share of the European housing stock consists of buildings in desperate need of refurbishment, particularly in lower income low-energy-efficiency buildings with residents living in fuel poverty, the key to alleviate fuel poverty is to renovate the stock into more energy efficient buildings. Avoiding energy poverty has therefore become an important policy aim in many European countries, for example in the UK, in Austria and in Germany. The indicator is derived from the UK definition, according to which households are considered as energy poor if their energy bill consumes 10% or more of the household income (DECC, 2013). The assessor may need to determine a hypothetical baseline in case of a new construction development. Change in percentage points of (gross) household income spent on energy bills.

KPI Formula	$$\text{percentage poitn change in income spent on energy} = \left(\frac{\text{Energy costs before project}}{\text{Gross household income}} \cdot 100\% - \frac{\text{Energy costs after project}}{\text{Gross household income}} \cdot 100\%\right)$$ Note: The energy costs include all building related energy, i.e. for heating/cooling, warm water and electricity.				
Measurement procedure	1. Data Collection 2. KPI Calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

CO2 reduction cost efficiency					
KPI Description	Many smart city projects are intrinsically aimed at reducing the amount of CO2 emitted during their lifetime. Those projects which prove to be able to significantly reduce their carbon footprint, whilst keeping the related costs at a minimum, are considered to be interesting projects for upscaling. Costs in euros per ton of CO2 saved per year.				
KPI Formula	This indicator is calculated on an annual basis, taking the annual reduction in CO2 emissions, and the annual costs of the project (which is the annualised investment plus current expenditures for a year). Note: Only the additional costs for energy/CO2 related measures (to the extent discernible) are taken into account in the total costs calculation.				
Measurement procedure	1. Data Collection 2. KPI Calculation				
Unit of Measurement	$€/((ton\ of\ CO2)\cdot y)$		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	X
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Stimulating an innovative environment</th></tr>
<tr><td>KPI Description</td><td colspan="5">A project can stimulate an environment that enhances innovations, either by being part of it or by contributing to it. An important element of an innovative environment (or innovation ecosystem) is the coupling and close cooperation of business, government and knowledge institutes, the so called triple helix (stanford.edu).
The extent to which the project is part of or stimulates an innovative environment.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Likert scale
Not at all — 1 — 2 — 3 — 4 — 5 — Excellent
1. Not at all: the project is not part of and does not stimulate an innovative environment.
2. Poor: the project is somewhat part of an innovative environment.
3. Somewhat: the project is part of and somewhat stimulates an innovative environment.
4. Good: the project is part of and stimulates an innovative environment.
5. Excellent: the project is an essential part of and stimulates an innovative environment</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data Collection
2. KPI Calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="6">Awareness of economic benefits of reduced energy consumption</th></tr>
<tr><td>KPI Description</td><td colspan="5">This KPI measures the awareness of economic benefits of reduced energy consumption.</td></tr>
<tr><td>KPI Formula</td><td colspan="5"></td></tr>
<tr><td>Measurement procedure</td><td colspan="5">Each stakeholder group to provide quantitative feedback on existing awareness of benefits of reduced energy consumption as initial benchmark.
Each stakeholder group to provide quantitative feedback on increased awareness of benefits of reduced energy consumption annually.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td>X</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td>X</td></tr>
</table>

Responsible Partner for KPI Data Collection	HKU

8.1.4 Social

Consumers' engagement					
KPI Description	The implementation of ICT solutions can also be related to the involvement of the users in the control over the energy use in the building. A variety of measures can be implemented, from the installation of metering systems to give the user feedback, to the involvement of the user in the management of their energy consumption. In case that these measures can be allocated to an energy demand reduction, this indicator will be shown.				
KPI Formula	• Number of final users involved • Number of people with increased capacity				
Measurement procedure	1. Data collection				
Unit of Measurement	#		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Professional stakeholder involvement	
KPI Description	The extent to which professional stakeholders outside the project team have been involved in planning and execution. In this context, relevant stakeholders may include: industry or business associations, local councils, government departments, politicians, environmental organisations, architects, project developers.
KPI Formula	Likert scale No involvement — 1 — 2 — 3 — 4 — 5 — High involvement 1. **No involvement**: apart from the project team no other professional stakeholders outside the project team are involved. 2. **Inform**: a select group of professional stakeholders is informed about the project plan. Consultation, however, is merely intended at seeking acceptance amongst these stakeholders. 3. **Advise**: the project plan is presented to professional stakeholders (representatives of industry, local councils, environmental organizations), who are invited to ask questions, provide feedback and give advice. Based on this input the planners may alter the project plan. 4. **Partnership**: in a number of sessions professional stakeholders are involved in developing the project plan. Stakeholders are able to effectively influence the planning process. 5. **High involvement**: a fully integrated planning process, whereby a wide range of professional stakeholders are actively involved on an almost day-to-day basis in developing the project plan and advising on its implementation.

Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Social Compatibility					
KPI Description	The extent to which the project's solutions fit with people's 'frame of mind' and do not negatively challenge people's values or the ways they are used to do things. If an innovation requires people to significantly think differently, and challenges assumptions or the ways how we normally are accustomed to do things, its implementation in society will be more difficult.				
KPI Formula	Likert scale: Not at all – 1 — 2 — 3 — 4 — 5 — Very high 1. **Not at all**: the solution differs to such a degree from the usual way of doing things and/or from existing norms and values, that it is almost impossible for people to accept the solution. 2. **Low**: the solution requires considerable changes in the current way of doing things, and/or requires a change in norms and values. 3. **Moderate**: the solution has certain aspects that differ from the usual way of doing things which users (or others involved) will need to get accustomed to but requires no major changes in norms or values. 4. **High**: the solution is largely compatible with the current way of doing things, or with existing norms and values. Only slight adjustments are needed. 5. **Very high**: the solution does not differ from the usual way of doing things in operational sense and is fully consistent with existing norms and values.				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Ease of use for end users of the solution					
KPI Description	The extent to which the solution is perceived as difficult to understand and use for potential end-users. End-users are conceptualised as those individuals who will be using/working with the solution. Some solutions or innovations are perceived as relatively difficult to understand and use while others are clear and easy to the adopters. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution.				
KPI Formula	Likert Scale Very difficult – 1 — 2 — 3 — 4 — 5 — Very easy 1. **Very difficult**: users need extensive and sustained instructions to understand the solution and without these the solution cannot be understood or used. 2. **Fairly difficult**: users need to be well instructed to be able to understand and use the solution properly. Considerable time is required to familiarize themselves with the solution. 3. **Slightly difficult**: users have to invest some time to understand the solution and get accustomed to working with it. Some time is needed before the solution has become fully familiar to end users. 4. **Fairly easy**: a small investment in time is required of the end users to understand the solution and get accustomed to it, but they are fairly quickly familiar to work with it. 5. **Very easy**: the solution is as easy to understand and use.				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Advantages for end-users	
KPI Description	The extent to which the project offers clear advantages for end users. The advantage can take many forms, for instance cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.
KPI Formula	Likert Scale No advantage– 1 — 2 — 3 — 4 — 5 — Very high advantage 1. **No advantage**: The project does not offer clear advantages for end users. The technologies or principles applied in the project are not at all beneficial to end users. 2. **Little advantage**: The project offers very little advantage to end users. The vast majority of the technologies/principles offer an indirect and insignificant advantage to end users.

	3. **Some advantage**: The project offers some advantage to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project. 4. **High advantage**: The project offers a high advantage to end users who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive effect on end users. 5. **Very high advantage**: The project offers a very high advantage to end users as the applied technologies/principles have a direct and an extremely positive effect on end users (e.g. cheaper housing costs, increased comfort, increased quality of the living environment etc.).				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

People reached					
KPI Description	A Smart City project is usually most successful if the entire target group of a service participates. For example, if all electrical car owners join in optimizing their battery use to improve the energy system efficiency of the district. In addition, a high score on people reached can be seen as a signal of increased community engagement due to the project. The effort the project will make towards reaching the full extent of its target group can vary and with it the size of the target audience. Therefore, this effort and target audience have to be clearly defined before assessing the indicator. Percentage of people in the target group that have been reached and/or are activated by the project				
KPI Formula	(number of citizens reached/total number of citizens considered as the total target group of the project) * 100%				
Measurement procedure	1. Data collection 2. KPI calcualation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Advantages for stakeholders</th></tr>
<tr><td>KPI Description</td><td colspan="5">While some smart city projects offer a clear advantage to those using or working with the smart city solution, some innovations offer a clear advantage to those investing in project. This advantage could, for example, be ease of management or reduced maintenance costs. It is presumed that solutions which have a higher level of advantages to stakeholders will be more likely to be adopted and invested in than solutions which have negative or no advantages to the investors themselves.
The large-scale implementation of an electric public transport system, with public transportation running on ‘green energy’, for instance, generates no significant additional advantage to those using the solution. However, the city proliferates itself by introducing large-scale low-carbon transit options that will make the city more sustainable and known internationally.
The extent to which the project offers clear advantages for stakeholders.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five-point Likert scale:
No advantage– 1 — 2 — 3 — 4 — 5 — Very high
1. No advantage: The project does not offer clear advantages to any of the stakeholders. The technologies or principles applied in the project are not at all beneficial to stakeholders.
2. Little advantage: The project offers very little advantage to stakeholders. The vast majority of the technologies/principles offer an indirect and insignificant advantage.
3. Some advantage: The project offers some advantage to stakeholders who, to a certain extent, experience direct benefits from the technologies/principles applied in the project.
4. High advantage: The project offers a high advantage to stakeholders who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive effect on stakeholders.
5. Very high advantage: The project offers a very high advantage to stakeholders as the applied technologies/principles have a direct and an extremely positive effect on stakeholders.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection
2. KPI calcualation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>x</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>x</td></tr>
<tr><td>Set of Buildings</td><td>x</td><td>TSP</td><td>x</td></tr>
<tr><td>Energy Supply Unit</td><td>x</td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td>x</td><td>Governance</td><td>x</td></tr>
<tr><td>Neighbourhood</td><td>x</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>x</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

Thermal comfort					
KPI Description	The quality of the delivered heating/cooling service is certainly a matter of technical aspects that can be measured with quantified technical indicators, but also a matter of the opinion of the service receivers. Locals living/working in residences/offices with the proposed heating techniques will be asked about the thermal result of the introduced technology.				
KPI Formula	Likert scale Truly uncomfortable – 1 — 2 — 3 — 4 — 5 — Very satisfying				
Measurement procedure	There are many approaches for the measurement of the thermal comfort indicator. Since the purpose is not to greatly focus on the details that make the quality difference between the various heating/cooling techniques, the measurement will be conducted with a simple survey to the end-users. 1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City			Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increased environmental awareness	
KPI Description	Awareness of environmental problems is important for creating support for environmental projects and programs. This indicator, therefore, assesses the extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment. The extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment.
KPI Formula	Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – very much 1. Not at all: opportunities to increase environmental awareness were not taken into account in the project communication. 2. Poor: opportunities to increase environmental awareness were slightly taken into account in the project communication. 3. Somewhat: opportunities to increase environmental awareness were somewhat taken into account in the project communication, at key moments in the project there was attention for this issue. 4. Good: opportunities to increase environmental awareness were sufficiently taken into account in the project communication, the project utilized many possibilities to address this issue in their communications. 5. Excellent: opportunities to increase environmental awareness were taken into account in the project communication, the project utilized every possibility to address this

	issue both in online and offline communications.				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	No Unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increased consciousness of citizenship					
KPI Description	Consciousness of citizenship is the awareness (consciousness) of one's community, civic rights and responsibilities and as such contributes to the sense of community. At the very least, it means that the individual is aware of what is going on around him. Ideally, it would mean that the individual is involved in the life of the community --understanding his role in the community -- seeking to contribute when he is able to do so. The extent to which the project has contributed in increasing consciousness of citizenship.				
KPI Formula	The indicator provides a qualitative measure and is rated on a five-point Likert scale: No increase – 1 — 2 — 3 — 4 — 5 — High increase 1. None: The project has made no effort to increase civic consciousness. 2. Little: The project has made a small effort to increase civic consciousness. 3. Somewhat: The project has developed some initiatives to increase civic consciousness. 4. Significant: The project has executed several activities to increase civic consciousness. 5. High: increasing civic consciousness was (one of) the main goals of the project and it has done substantial effort to enhance it.				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	No Unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	x
	Set of Energy Supply Units			Governance	x
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increased participation of vulnerable groups

KPI Description	Vulnerable and other groups whose opinions or contributions are not reflected well enough in our society (like women, minorities and the disabled), require special attention to be included in the community, thereby enhancing social cohesion and diversity and tapping into underdeveloped social capital. One can think of many ways to increase this participation, for instance: I. Physical, e.g. improved accessibility for wheelchairs II. Digital, e.g. facilitating online access or providing information pages online III. Financial, e.g. financial aid to participate in sports or cultural activities IV. Organisational, e.g. through quotums on participation of underrepresented groups (for example in the workforce, although this is considered controversial by some)				
KPI Formula	The indicator provides a qualitative measure and is rated on a five-point Likert scale: No at all – 1 — 2 — 3 — 4 — 5 — Excellent 1. Not at all: the project has not increased participation of groups not well represented in society. 2. Poor: the project has achieved little when it comes to participation of groups not well represented in society. 3. Fair: the project has somewhat increased the participation of groups not well represented in society. 4. Good: the project has significantly increased the participation of groups not well represented in society. 5. Excellent: Participation of groups not well represented in society has clearly been hugely improved due to the project.				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	No Unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	x
	Set of Energy Supply Units			Governance	x
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Local job creation					
KPI Description	One of the pillars of the smart city projects is to improve the economy by reducing costs and energy, but also by fostering the local economy and the local eco-systems. This indicator will assess the creation of direct jobs from the implementation and operation of the IRIS solutions.				
KPI Formula	Number of jobs created				
Measurement procedure	1. Data collection				
Unit of Measurement	#		**Threshold/ Target**		
Object of	Building	X	**Stakeholders**	DSO	

assessment	Set of Buildings	X		TSP	
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Local community involvement in the implementation phase						
KPI Description	The extent to which residents/users have been involved in the implementation process. As residents' beliefs, needs, preferences and expectations towards sustainable living environments have a strong influence on project performance, public involvement during the implementation stage is essential to provide developers with input to ensure that the project will perform as intended. Moreover, a growing body of literature is exemplifying the importance of civil society/community participation in sustainable urban planning and execution, for example by means of smart city projects, to bring together information, knowledge and skills from diverse backgrounds to articulate the often ambiguous targets of smart cities and to create a sense of ownership over the outcomes					
KPI Formula	The indicator provides a qualitative measure and is rated on a five-point Likert scale: No involvement – 1 — 2 — 3 — 4 — 5 — High involvement 1. Not at all: No community involvement. 2. Inform and consult: The more or less completed project is announced to the community either for information only, or for receiving community views. The consultation, however, is mainly seeking community acceptance of the project. 3. Advise: the project implementation is done by a project team. Community actors are invited to ask questions, provide feedback and give advice. Based on this input the planners may alter the project. 4. Partnership: community actors are asked by the project planners to participate in the implementation process. The local community is able to influence the implementation process. 5. Community self-development: the project planners have empowered community actors to manage the project implementation and evaluate the results.					
Measurement procedure	1. Data collection 2. KPI calculation					
Unit of Measurement	No Unit		**Threshold/ Target**			
Object of assessment	Building		**Stakeholders**	DSO		
	Set of Buildings			TSP		
	Energy Supply Unit			End-Users	X	
	Set of Energy Supply Units			Governance		
	Neighbourhood	X		Citizens	X	
	City	X		Representative Citizen Groups	X	
				Citizen Ambassadors	X	
Responsible Partner for KPI Data Collection			HKU			

Increased citizen awareness of the potential of smart city projects					
KPI Description	This KPI measures the increased citizen awareness of the socio-cultural potential of smart city projects.				
KPI Formula					
Measurement procedure	Each stakeholder group to provide quantitative feedback on citizen awareness of the potential of smart city projects as initial benchmark. Each stakeholder group to provide quantitative feedback on citizen awareness of the potential of smart city projects annually.				
Unit of Measurement	% (Social, cultural, political, economic variables)		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	X
	City	X		Representative Citizen Groups	X
				Citizen Ambassadors	X
Responsible Partner for KPI Data Collection			HKU		

Number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens					
KPI Description	This KPI measures the number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens				
KPI Formula					
Measurement procedure	Each LH to provide quantitative feedback on the number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens as initial benchmark. Each LH to provide quantitative feedback on the number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens annually.				
Unit of Measurement	Number		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			HKU		

Provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen

Engagement activities					
KPI Description	This KPI measures the Provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen Engagement activities. This is the direct aim of the Citizen Engagement approach that is developed in the IRIS project. By modularising the process and making available advice and tools, we anticipate that the platform will grow during the lifetime of the project and provide a valuable resource.				
KPI Formula	Number of co-creation objects added to Field Guide				
Measurement procedure	Each stakeholder group to provide quantitative feedback on number of relevant objects added to Field Guide annually.				
Unit of Measurement	Number		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	X
				Citizen Ambassadors	X
Responsible Partner for KPI Data Collection			HKU		

Participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities					
KPI Description	This KPI measures the participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities Regarding this suggestion (measuring the co-creation of local/micro KPIs), this is something that could be considered as a structured outcome from the diverse local activities. It also helps us to close the feedback loop, as it were. This is not to over-emphasise the importance of such outcomes (they will after all take some time to locate and describe), but as part of a larger process this could be something we might suggest including within other projects.				
KPI Formula	Number of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities				
Measurement procedure	Each stakeholder group to provide quantitative feedback on number of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities as a benchmark. Each stakeholder group to provide quantitative feedback on number of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities annually.				
Unit of Measurement	Number		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	

	Set of Energy Supply Units			Governance	
	Neighbourhood			Citizens	X
	City			Representative Citizen Groups	X
				Citizen Ambassadors	X
Responsible Partner for KPI Data Collection			HKU		

8.1.5 ICT

Peak load reduction					
KPI Description	Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power.				
KPI Formula	$PL_{REDUCTION} = \left(1 - \frac{P_{peak,R\&I}}{P_{BaU}}\right) * 100$				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	X
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Number of costumers that are positive about how energy systems are controlled					
KPI Description	All the end-users involved in the project demonstrations are asked whether they are satisfied with the provided services including the ICT system. This is done with a Yes/No question and the value of the indicator is given by the percentage of the end-users that stated that they were satisfied.				
KPI Formula					
Measurement procedure	• Definition of the actual phrasing of the question posed. • Undertaking of the survey. • Analysing the results.				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building	X	**Stakeholders**	DSO	
	Set of Buildings	X		TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Reliability</th></tr>
<tr><td>KPI Description</td><td colspan="5">Avoiding failures revert on higher reliability, meaning fewer stops on the normal operation of the building and associated systems. With the application of ICT measures it is possible to correct a potential misbehaviour of the system and avoid unexpected stops. In SCIS, the indicator will be measured as:
• Ratio of power interruptions avoided in a year
• Ratio of power quality issues avoided in a year
The failures can be caused by e.g. of grid congestion.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$Reliability = \frac{Number\ of\ failures\ avoided}{Total\ number\ of\ failures + number\ of\ failures\ avoided} \cdot 100\%$$</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection
2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>x</td></tr>
<tr><td>Energy Supply Unit</td><td>x</td><td>End-Users</td><td>x</td></tr>
<tr><td>Set of Energy Supply Units</td><td>x</td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>x</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>x</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="4">Increased system flexibility for energy players</th></tr>
<tr><td>KPI Description</td><td colspan="3">Additional flexibility capacity gained for energy players. It measures the progress brought by R&I activities relative to the new clusters and functional objectives, assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO.
This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention.
Stability refers to the maintaining of voltage and frequency of a given power system within acceptable levels.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">$$\Delta SF = \frac{SF_{R\&I} - SF_{BAU}}{P_{peak}}$$
SF is the amount of load capacity participating in demand side management [W].
It can also be expressed related to cost as:
$$SFAC = \frac{System\ flexibility}{Cost}$$</td></tr>
<tr><td>Measurement procedure</td><td colspan="3">1. Data collection
2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td>%, W/€</td><td>Threshold/ Target</td><td></td></tr>
</table>

Object of assessment	Building		**Stakeholders**	DSO	x
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Increased hosting capacity for RES, electric vehicles and other new loads					
KPI Description	This KPI is intended to give a statement about the additional loads that can be installed in the network, when R&I solutions are applied, and compared to the BAU scenario.				
KPI Formula	This improvement can be quantified by means of the following percentage: $$EHC_{\%} = \frac{HC_{R\&I} - HC_{BAU}}{HC_{BAU}} \cdot 100\%$$ EHC: the enhanced hosting capacity of new loads when R&I solutions are applied with respect to BAU scenario. HC: the additional hosting capacity of new loads applied with respect to currently connected generation (GW or MW).				
Measurement procedure	1. Data collection 2. KPI calculation				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	x
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	x
	Set of Energy Supply Units			Governance	
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Impact of ICT apps into mobility			
KPI Description	Impact of ICT apps into switching from non-sustainable mobility into sustainable mobility, this is, change on modal split.		
KPI Formula	Modal split of sustainable mobility solutions (after) – modal split of sustainable mobility solutions (before)		
Measurement procedure	1. Data collection 2. KPI calculation		
Unit of Measurement	%	**Threshold/ Target**	

Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	x
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	x
	Neighbourhood	X		Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Developer engagement					
KPI Description	Developers are important stakeholders in the open data market. It is important to gain insight in the variety, importance and value of data used and not used by the developers. This KPI measures the use of open datasets by developers.				
KPI Formula	Number of API calls per month				
Measurement procedure	Monitoring of API- calls with software. The CIP will keep detailed usage statistics.				
Unit of Measurement	#		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Data safety					
KPI Description	The nature of the web environment is hostile. There are a lot of agents trying to exploit vulnerabilities in any software system. From DDoS to someone taking control of the servers, the risks are diverse. This KPI is intended to give a statement about the safety of data in the IRIS applications.				
KPI Formula	Number of blocked malicious hacking attempts				
Measurement procedure	The CIP will keep detailed usage statistics.				
Unit of Measurement	# per unit /months/ years		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X

	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Data loss prevention					
KPI Description	Managing data brings a lot of opportunities but also some safety issues. To know if data has been stolen, leaked or otherwise distributed it is important that monitoring is in place. This KPI is intended to give a statement about the ability of CIP to prevent data loss.				
KPI Formula	Lost datapoints in a period.				
Measurement procedure	The CIP will keep detailed usage statistics. Monitoring access to critical files in relation with the malicious attacks, closely monitor if duplicate files are available on the web that originally are exclusively available on internal servers.				
Unit of Measurement	Number of lost datapoints per timeframe.		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Usage of open source software					
KPI Description	The use of open source software means less possibilities of vendor lock-in and more space for communities to develop together smart city solutions. It also lowers the software costs. This KPI is intended to give a statement about how easy it is to connect systems.				
KPI Formula	How easy is it to connect systems				
Measurement procedure	Survey				
Unit of Measurement	Likert scale (no unit)		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	

				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Expiration date of open data					
KPI Description	Open data can become outdated and obsolete, which acts negatively on the attractivity of using data from platforms. By monitoring the expiration dates of the data, the owner gets a message to renew or remove the datasets.				
KPI Formula	Percentage of outdated datasets on a city platform per timeframe				
Measurement procedure	Statistics from CIP.				
Unit of Measurement	% of obsolete data on city dataplatform per timeframe		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Quality of open data					
KPI Description	The quality of open data is better if is standardized. Processes get easier when data standards are applied. The DCAT standard allows municipal employees to produce data in a standardized way.				
KPI Formula	Percentage of data that uses DCAT standards.				
Measurement procedure	Manual monitoring/ research to calculate the number of standardized datasets.				
Unit of Measurement	%		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Platform downtime					
KPI Description	To run a stable platform, monitoring is required to fix bugs and quickly improve the software environments.				
KPI Formula	Downtime per timeframe.				
Measurement procedure	The CIP will keep detailed usage statistics.				
Unit of Measurement	Minutes / (selected timeframe)		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Open data-based solutions					
KPI Description	To gain insight of the use of open data, mapping the applications developed based on the open data is vital. This KPI is intended to give a statement about the easy of use of open data from external developers.				
KPI Formula	Number of services based on open data.				
Measurement procedure	Manual monitoring/ research in CIP databases.				
Unit of Measurement	Number / (month, year)		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Number of active ‘touch-points’ identified where citizens have a degree of agency and interaction with solution</th></tr>
<tr><td>KPI Description</td><td colspan="5">This KPI measures the number of active ‘touch-points’ identified where citizens have a degree of agency and interaction with solution.
This is the basis for distinguishing between communication and CE activities and for prioritising and mapping suitable activities to each IS</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of active ‘touch-points’ identified where citizens have a degree of agency and interaction with solution.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">Each stakeholder group to provide quantitative feedback on number of active ‘touch-points’ identified where citizens have a degree of agency and interaction with solution as a benchmark.
Each stakeholder group to provide quantitative feedback on number of active ‘touch-points’ identified where citizens have a degree of agency and interaction with solution annually.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Number</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">HKU</td></tr>
</table>

8.1.6 Legal

<table>
<tr><th colspan="5">Green Building self-consumption Legal Framework Compatibility</th></tr>
<tr><td>KPI Description</td><td colspan="4">The indicator presents the level of suitability of the legal framework for the integration of self-consumption RES generation solutions in buildings.</td></tr>
<tr><td>KPI Formula</td><td colspan="4">Likert Scale
Not compatible – 1 — 2 — 3 — 4 — 5 — Fully compatible
1. No permission: The legal framework firmly prohibits the integration of the proposed technology solution.
2. Legal barriers: The legal framework leaves very little space for the integration of the proposed technology making it almost impossible.
3. Unclear legal platform: The legal framework has not taken into account the proposed technology solution, making it unclear whether its integration is allowed or not.
4. Legal permission: The legal framework generally approves of the integration of the proposed technology solution. Some special guidelines are out of date making possible a legal lack of support.
5. Full legal support: The legal framework fully approves the integration of the proposed technology solution.</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Undertaking of the survey
2. Analysis of the results</td></tr>
<tr><td>Unit of Measurement</td><td>No unit</td><td></td><td>Threshold/ Target</td><td></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO | X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP | X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users | X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance | X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="2">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="2">Symbiotic waste heat Legal Framework Compatibility</th></tr>
<tr><td>KPI Description</td><td>The indicator presents the level of suitability of the legal framework for the integration of symbiotic waste heat solutions.</td></tr>
<tr><td>KPI Formula</td><td>Likert Scale
Not compatible – 1 — 2 — 3 — 4 — 5 — Fully compatible
1. No permission: The legal framework firmly prohibits the integration of the proposed technology solution.
2. Legal barriers: The legal framework leaves very little space for the integration of the proposed technology making it almost impossible.
3. Unclear legal platform: The legal framework has not taken into account the proposed technology solution, making it unclear whether its integration is allowed or not.
4. Legal permission: The legal framework generally approves of the integration of the proposed technology solution. Some special guidelines are out of date making possible a legal lack of support.
5. Full legal support: The legal framework fully approves the integration of the proposed</td></tr>
</table>

	technology solution.				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	X
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Energy flexibility policies Legal Framework Compatibility					
KPI Description	The indicator presents the level of suitability of the legal framework for the integration of energy flexibility policies such as incentives for peak-shaving.				
KPI Formula	Likert Scale Not compatible – 1 — 2 — 3 — 4 — 5 — Fully compatible 1. **No permission**: The legal framework firmly prohibits the integration of the proposed technology solution. 2. **Legal barriers**: The legal framework leaves very little space for the integration of the proposed technology making it almost impossible. 3. **Unclear legal platform**: The legal framework has not taken into account the proposed technology solution, making it unclear whether its integration is allowed or not. 4. **Legal permission**: The legal framework generally approves of the integration of the proposed technology solution. Some special guidelines are out of date making possible a legal lack of support. 5. **Full legal support**: The legal framework fully approves the integration of the proposed technology solution.				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="5">Smart EVs Legal Framework Compatibility</th></tr>
<tr><td>KPI Description</td><td colspan="4">The indicator presents the level of suitability of the legal framework for the integration of private EVs and public transport EVs in the city mobility policies.</td></tr>
<tr><td>KPI Formula</td><td colspan="4">Likert Scale
Not compatible – 1 — 2 — 3 — 4 — 5 — Fully compatible
1. No permission: The legal framework firmly prohibits the integration of the proposed technology solution.
2. Legal barriers: The legal framework leaves very little space for the integration of the proposed technology making it almost impossible.
3. Unclear legal platform: The legal framework has not taken into account the proposed technology solution, making it unclear whether its integration is allowed or not.
4. Legal permission: The legal framework generally approves of the integration of the proposed technology solution. Some special guidelines are out of date making possible a legal lack of support.
5. Full legal support: The legal framework fully approves the integration of the proposed technology solution.</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Undertaking of the survey
2. Analysis of the results</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO | X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP | X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users | X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance | X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="2">UTR, NCA, GOT</td></tr>
</table>

<table>
<tr><th colspan="2">City platform Legal Framework Compatibility</th></tr>
<tr><td>KPI Description</td><td>The indicator presents the level of suitability of the legal framework for the integration of a web city platform for the energy management and citizen engagement. The mentioned suitability takes into account not only whether the platform is permitted, but also what measurements are taken in order to maintain system security and privacy.</td></tr>
<tr><td>KPI Formula</td><td>Likert Scale
Not compatible – 1 — 2 — 3 — 4 — 5 — Fully compatible
1. No permission: The legal framework firmly prohibits the integration of the proposed technology solution.
2. Legal barriers: The legal framework leaves very little space for the integration of the proposed technology making it almost impossible.
3. Unclear legal platform: The legal framework has not taken into account the proposed technology solution, making it unclear whether its integration is allowed or not.
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5. Full legal support: The legal framework fully approves the integration of the proposed technology solution.</td></tr>
</table>

Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

Change in rules and regulations					
KPI Description	It shows the extent to which the project is able to change the context in which they were applied, by providing a different interpretation of existing rules and regulations (at local - city planning, zoning- or national-, -spatial law, energy laws- level). The change in local rules has an important signaling function which can inspire a new interpretation of the rules in other locations, paving the way for repetition of the urban innovation or for similar innovations.				
KPI Formula	Likert scale: No impact– 1 — 2 — 3 — 4 — 5 — High impact 1. No impact: the project has not, at any level, inspired changes in rules and regulations. 2. Little impact: the project has led to a localised discussion about the suitability of the current rules and regulations. 3. Some impact: the project has led to a public discussion, leading to a change in rules and regulations. 4. Notable impact: the project has led to a public discussion, leading to a change in rules and regulations. This in its turn has sparked a discussion amongst other administrations about the suitability of the current rules and regulations. 5. High impact: the project has led to a public discussion, leading to a change in rules and regulations. This in turn has inspired other administrations to reconsider their rules and regulations.				
Measurement procedure	1. Undertaking of the survey 2. Analysis of the results				
Unit of Measurement	No unit		**Threshold/ Target**		
Object of assessment	Building		**Stakeholders**	DSO	X
	Set of Buildings			TSP	X
	Energy Supply Unit			End-Users	X
	Set of Energy Supply Units			Governance	X
	Neighbourhood			Citizens	
	City	X		Representative Citizen Groups	
				Citizen Ambassadors	
Responsible Partner for KPI Data Collection			UTR, NCA, GOT		

<table>
<tr><th colspan="6">Measure extent to which privacy by design has been ensured</th></tr>
<tr><td>KPI Description</td><td colspan="5">This KPI measures the extent to which privacy by design has been ensured.
Trust is paramount to the adoption of smart city solutions which must fully respect individual freedom and the right to privacy by integrating the concepts of privacy by design including citizen consent in smart cities projects.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of active privacy by design measures implemented.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">Each stakeholder group to provide quantitative feedback on Number of active privacy by design measures implemented as a benchmark.
Each stakeholder group to provide quantitative feedback on Number of active privacy by design measures implemented annually.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Number</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">HKU</td></tr>
</table>

8.2 KPIs per Integrated Solution and Transition Tracks

8.2.1 T.T. #1: Smart renewables and closed-loop energy positive districts

	Positive Energy Buildings	Near zero energy retrofit district	Symbiotic waste heat networks
Technical	Energy demand and consumption	Energy demand and consumption	Energy savings
	Energy savings	Energy savings	Technical compatibility
	Degree of energetic self-supply by RES	Degree of energetic self-supply by RES	Improved interoperability
	Maximum Hourly Deficit	Maximum Hourly Deficit	
	Technical compatibility	Technical compatibility	
	Improved Interoperability	Improved interoperability	
Environmental	Carbon dioxide Emission Reduction	Carbon dioxide Emission Reduction	Carbon dioxide Emission Reduction
	Increase in Local Renewable Energy Generation	Increase in Local Renewable Energy Generation	Increase in Local Renewable Energy Generation
	Reduction in annual final energy consumption	Reduction in annual final energy consumption	Reduction in annual final energy consumption
			Decreased emissions of Particulate matter
			Decreased emissions of Nitrogen oxides
Economic	Total Investments	Total Investments	Total Investments
	Grants	Grants	Grants
	Total Annual costs	Total Annual costs	Total Annual costs
	Payback	Payback	Payback
	Return on Investment (ROI)	Return on Investment (ROI)	Return on Investment (ROI)
	Fuel poverty	Fuel poverty	CO2 reduction cost efficiency
	CO2 reduction cost efficiency	CO2 reduction cost efficiency	Financial benefit for the end user
	Financial benefit for the end user	Financial benefit for the end user	Stimulating an innovative environment

	Positive Energy Buildings	Near zero energy retrofit district	Symbiotic waste heat networks
		Reduction of energy cost	
		Stimulating an innovative environment	
Social	Professional stakeholder involvement	Professional stakeholder involvement	Professional stakeholder involvement
	Advantages for end-users	Advantages for end-users	Advantages for end-users
	Increased environmental awareness	Increased environmental awareness	Increased environmental awareness
	Increased consciousness of citizenship	Increased consciousness of citizenship	Social compatibility
	Increased participation of vulnerable groups	Increased participation of vulnerable groups	Advantages for stakeholders
	Ease of use for end users of the solution	Ease of use for end users of the solution	
	Social compatibility	People reached	
	Consumers engagement	Advantages for stakeholders	
		Social compatibility	
		Consumers engagement	
ICT	Reliability	Reliability	Reliability
		Increased system flexibility for energy players	
Legal	Change in rules and regulations	Change in rules and regulations	Change in rules and regulations
	Green Building self-consumption Legal Framework Compatibility	Green Building self-consumption Legal Framework Compatibility	Symbiotic waste heat Legal Framework Compatibility

8.2.2 T.T. #2: Smart Energy Management and Storage for Grid Flexibility

	Flexible electricity grid networks	Smart multi-sourced low temperature district heating with innovative storage solutions	Utilizing 2nd life batteries for smart large-scale storage schemes

	Flexible electricity grid networks	Smart multi-sourced low temperature district heating with innovative storage solutions	Utilizing 2nd life batteries for smart large-scale storage schemes
Technical	Degree of energetic self-supply by RES	Energy demand and consumption	Battery Degradation Rate
	Reduced energy curtailment of RES and DER	Energy savings	Storage energy losses
	Average number of electrical interruptions per customer per year	Smart Storage Capacity	Smart Storage Capacity
	Average length of electrical interruptions (in hours)		Reduced energy curtailment of RES and DER
	Energy demand and consumption		
	Energy savings		
	Smart Storage Capacity		
	Maximum Hourly Deficit		
Environmental	Carbon dioxide Emission Reduction	Carbon dioxide Emission Reduction	Increase in Local Renewable Energy Generation
	Increase in Local Renewable Energy Generation	Increase in Local Renewable Energy Generation	Financial benefit for the end-user
Economic	Reduction of energy cost	Payback	Payback
	Total Investments	Return on Investment	Return on Investment
	Financial benefit for the end-user	Reduction of energy cost	Reduction of energy cost
	Total Annual costs	Total Investments	Total Investments
		Financial benefit for the end-user	
		Total Annual costs	Total Annual costs
		Energy Return on Energy Investment	

	Flexible electricity grid networks	Smart multi-sourced low temperature district heating with innovative storage solutions	Utilizing 2nd life batteries for smart large-scale storage schemes
Social	Consumers’ engagement	Social Compatibility	Consumers’ engagement
	Professional stakeholder involvement	Advantages for end-users	Professional stakeholder involvement
	Social Compatibility	Thermal comfort	Social Compatibility
	Ease of use for end users of the solution		Advantages for end-users
	Advantages for end-users		
ICT	Peak load reduction		
	Number of costumers that are positive about how energy systems are controlled		
	Increased system flexibility for energy players		
Legal	Energy flexibility policies Legal Framework Compatibility	Symbiotic waste heat Legal Framework Compatibility	
	Change in rules and regulations	Change in rules and regulations	

8.2.3 T.T. #3: Smart e-Mobility Sector

	Smart Solar V2G EVs charging	Innovative Mobility Services for the Citizens
Technical	Energy demand and consumption	Energy demand and consumption
	Energy savings	Energy savings
	Energy consumption data aggregated by sector fuel	Improved interoperability
	Number of EVs charging stations and solar powered V2G charging stations deployed in the area	Energy consumption data aggregated by sector fuel
	Number of efficient vehicles deployed in the area	Free Floating subscribers
		Yearly km are made through the e-car sharing system instead of private conventional cars
Environmental	Carbon dioxide Emission Reduction	Carbon dioxide Emission Reduction
	Noise pollution	Noise pollution
	Increased efficiency of resources consumption	Increased efficiency of resources consumption
	Reduction in annual final energy consumption	Reduction in annual final energy consumption
	Decreased emissions of Particulate matter	Decreased emissions of Particulate matter
	Decreased emissions of Nitrogen oxides (NOx)	Decreased emissions of Nitrogen oxides (NOx)
Economic	Total Investments	Total Investments
	Total Annual costs	Total Annual costs
	Payback	Payback
	Return on Investment (ROI)	Return on Investment (ROI)
	CO2 reduction cost efficiency	CO2 reduction cost efficiency
	Financial benefit for the end user	Financial benefit for the end user
		Stimulating an innovative environment

	Smart Solar V2G EVs charging	Innovative Mobility Services for the Citizens
Social	People reached	People reached
	Professional stakeholder involvement	Professional stakeholder involvement
	Advantages for end-users	Advantages for end-users
	Advantages for stakeholders	Advantages for stakeholders
	Consumers engagement	Consumers engagement
	Increased environmental awareness	Increased environmental awareness
	Increased consciousness of citizenship	Increased consciousness of citizenship
	Local job creation	Local job creation
ICT	Reliability	Reliability
	Increased hosting capacity for RES, electric vehicles and other new loads	Impact of ICT apps into mobility
Legal	Change in rules and regulations	Change in rules and regulations
	Smart EVs Legal Framework Compatibility	
	Energy flexibility policies Legal Framework Compatibility	

8.2.4 T.T. #4: City Innovation Platform (CIP)

	Services for Urban Monitoring / Services for City Management and Planning / Services for Mobility / Services for Grid Flexibility
ICT	Developer engagement
	Data safety
	Data loss prevention
	Usage of open source software
	Expiration date of open data
	Quality of open data
	Platform downtime
	Open data-based solutions

8.2.5 T.T. #5 Citizen engagement and co-creation

	Co-creating the energy transition in your everyday environment / Participatory city modelling / Living labs / Apps and interfaces for energy efficient behaviour
Technical	Improved flexibility of service delivery following citizen feedback phases
Economic	Awareness of economic benefits of reduced energy consumption
Social	Increased environmental awareness
	Local community involvement in the implementation phase
	Increased citizen awareness of the potential of smart city projects
	Number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens
	Provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen Engagement activities
	Participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities
ICT	Number of active 'touch-points' identified where citizens have a degree of agency and interaction with solution
Legal	Measure extent to which privacy by design has been ensured