IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

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Report on unified framework for harmonized data gathering, analysis and reporting

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0.1	18/12/2019	CERTH created the structure of the deliverable
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0.6	19/4/2019	All partners wrote Data Collection Framework (chapter 3)
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1.0	30/5/2019	Updated version based on comments and suggestions from internal reviewers
2.0	15/4/2020	New version including the description of the IRIS KPIs tool

Disclaimer

Executive Summary

The present document is the Deliverable D9.4 entitled as “Report on unified framework for harmonised data gathering, analysis and reporting”. The document depicts the research and study carried out within the Task 9.3 entitled as “Establishment of a unified framework for harmonised data gathering, analysis and reporting”. The main focus of the document is to provide the unified monitoring and evaluation framework that will allow smooth and integrated data gathering from all the Lighthouse (LH) cities, enabling the monitoring, post-processing, visualisation and permitting easy sharing and cooperation between the consortium partners.

Based on the work done in tasks 9.1 and 9.2 (presented in D9.2 and D9.3), the deliverable uses as input the data model and management plan created in D9.3 to create a unified methodology for KPIs related data collection, analysis and visualisation. Apart from the unified monitoring framework, D9.4 presents the IRIS KPIs tool that processes the collected data and calculates the Key Performance Indicators (KPIs). Moreover, the tool produces meaningful visualisations, which allow the evaluation of IRIS solutions and the comparison of different implementations within LH city as well as at a project level.

D9.4 analyses the data collection processes in the IRIS solutions’ heterogeneous fields (energy, mobility, ICT, and citizen engagement). The heterogeneous nature of those fields implies that data sources and means of data collection and storage might differ. In some cases, data are provided by systems that include smart meters, which automatically collect data and upload it to a repository. In other cases, they reside in another system’s repository and needs to be moved or copied. Data can also be collected by other methods such as questionnaires, interviews, direct observations, etc. and their results are registered in forms (electronic or paper).

The first part of the framework covers the data collection process. The deliverable presents the methodology for the collection of the various types of data required for the calculation of the KPIs in the IRIS LH cities. The data collection framework, which was created through a collaborative process within the IRIS LH cities, specifies the data requirements for each KPI. It includes templates for collecting the required information for the monitoring devices, the automatically generated data, and the manually collected data. The framework also contains the methodology for the KPIs that will be evaluated through data collected in the form of questionnaires. Finally, it presents the procedure for assessing the quality of the collected data.

The second part of the framework covers the calculation and visualisation of KPIs. It presents how the collected data will be analysed to produce each KPI and relevant visualisations. The data analysis and visualisation framework contains three layers: 1) The data acquisition layer, which contains the mechanisms that reliably record all related raw data in a valid format commonly agreed and standardised within the consortium, 2) the data analysis layer, which contains the tools able to filter and fuse data from heterogeneous sources and process them in an efficient and methodologically sound way, and 3) the dashboard layer, which produces the most appropriate visualisation diagrams for each KPI for meaningful representation of results. The implementation of data analysis and visualisation utilises the 6-step methodology that is presented through an example KPI.

The IRIS KPIs tool (available at http://monitoring.irissmartcities.eu) implements the unified monitoring framework and uses the collected monitoring data to calculate the KPIs’ values and to present the results. It interacts with the City Innovation Platform, which is the primary tool for data gathering from the IRIS demonstrations, to automatically collect monitoring data. Moreover, it supports the manual data entry of monitoring data and other static data that are required for KPIs calculations (i.e.

reference data, offline data and data collected using surveys). The tool includes interactive dashboards that allow users to monitor and evaluate their measures, and to compare the performance and impact of different demonstrations. The tool also supports the publishing of selected data to the City Innovation Platforms of LH cities and the SCIS self-reporting tool. The design and development of the tool are based on the analysis of similar tools created by CITYKeys and SCIS EU projects and on the latest developments in the fields of data visualisation and dashboard design.

The unified monitoring framework that is presented in this deliverable will be deployed during task 9.4 (Deployment of monitoring framework in LH cities) to all LHs with support from the technical partners from each LH. During that task, all the information that is required from the unified monitoring framework (i.e. data for the KPIs variables, measurement details, survey planning, etc.) will be collected in the three IRIS LH cities. The actual performance data collection and reporting will be carried out in task T9.5 (Overall evaluation and impact analysis for impact enhancement) starting month M25. During that task the unified framework and the KIPs tool will be evaluated and tested for easy maintenance to identify and restore flaws in data collection, ensuring performance, robustness and validity also after the end of the project so that future data can quickly be introduced into the SCIS.

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List of Acronyms and Abbreviations

Abbreviation	Definition
API	Application Programming Interface
CIP	City Innovation Platform
CITYkeys	Research project funded by the EU HORIZON 2020 programme. 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.
DOM	Document Object Model. The HTML DOM is an Object Model for HTML. It defines a) HTML elements as objects, b) properties for all HTML elements, c) methods for all HTML elements, and d) events for all HTML elements.
DSO	Distributed System Operator
ESCO	Energy Service Company
FC	Follower City
HTML	Hypertext Markup Language
HTML5 CANVAS	JavaScript charting library, which is pixel-based. The Canvas element is simply a large XY grid of pixels and gives the developer freedom to decide everything else. Canvas is good for high performance 2D graphics like games.
IS	Integrated Solution
ISO	International Standards Organization
ICT	Information and Communication Technology
JS	JavaScript
KPI	Key Performance Indicator
LH	Lighthouse
RES	Renewable Energy Sources
ROI	Return on Investment
SC	Smart City
SCIS	Smart Cities Information System. Launched with support from the European Commission, SCIS project focuses on energy, mobility & transport and ICT. SCIS allows for individual publishing of KPIs, best practices and lessons learned at the SCIS website.
SCIS SRT	SCIS Self Reporting Tool
SVG	Scalable Vector Graphics. SVG is a JavaScript charting library, which is DOM based. In SVG every object is part of the DOM. SVG is good for applications which draw objects like boxes, lines etc.
TT	Transition Track

1. Introduction

1.1. Scope, objectives and expected impact

The scope of this deliverable is to describe the unified framework for harmonised data gathering, analysis and reporting for all the IRIS demonstrations. This monitoring framework will allow smooth and integrated data gathering from all the Lighthouse (LH) cities, enabling the monitoring, post-processing, visualisation and permitting easy sharing and cooperation between the consortium partners. Apart from the unified monitoring framework, D9.4 presents the IRIS Key Performance Indicator (KPI)s tool that processes the collected data and calculates the KPIs. Moreover, the tool produces meaningful visualisations, which allow the evaluation of IRIS solutions and the comparison of different implementations within LH city as well as at a project level.

The IRIS KPIs tool will be connected through City Innovation Platform (CIP) to the online systems that automatically collect measurements from the IRIS demonstrations, to retrieve data required for KPIs calculations. Moreover, the tool allows manual data entry in case that the value of a variable is not captured automatically by a smart meter or is the result of a survey.

The unified monitoring framework will be deployed during task 9.4 (Deployment of monitoring framework in LH cities) to all LHs with support from the technical partners from each LH. During that task, all the information that is required from the unified monitoring framework (i.e. data for the KPIs variables, measurement details, survey planning, etc.) will be collected in the three IRIS LH cities.

1.2. Contributions of partners

The main project partners in task T9.2 are Centre for Research & Technology (CERTH), Utrecht University (UU) and Research Institutes of Sweden (RISE). CERTH, as the leader in T9.3, was responsible for coordinating the activities related to the creation of the unified monitoring framework and for designing and developing the IRIS KPIs tool. RISE as the WP9 leader ensures that all activities are in line with the other tasks of WP9. Both UU and RISE worked with LH cities of Utrecht and Nice to define the data collection framework. Civity (CIV) was involved in the connection of KPIs tool with the City Innovation Platform.

1.3. Relation to other activities

D9.3 is relying on information collecting from LH cities during the launch of the activities on each Transition Track (TT). It is also related to the development of CIP, as CIP is the main tool for data gathering in LH cities, in which data from some fields (i.e. building retrofitting, district heating, smart grid and smart mobility) will be collected and stored. Finally, D9.4 is integrated with the other activities of WP9 and especially to D9.3 Report on data model and management plan for integrated solutions and D9.5 Report on monitoring framework in LH cities and established baseline.

Table 1 depicts the relation of D9.4 to other activities (deliverables) developed within the IRIS project.

Table 1 Relation of D9.4 with other activities (deliverables)

Number	Title	Relation (Input/Output)
D4.4 [M12]	Document with technical solution reference architecture for CIP-components	Input used to connect the KPIs tool to the City Innovation Platform.
D4.6 [M30]	Integration of CIP in LH Cities	Output used to connect to the CIP, in each LH city, the monitoring equipment that is required to collect real time, high resolution data.
D5,6,7. 3,4,5,6,7 [M24]	Launch of the activities on each TT in Utrecht, Nice, Gothenburg	Input used for the creation of the data collection methodology.
D9.2 [M12]	Report on monitoring and evaluation schemes for integrated solutions	Input used for the creation of the data collection and data analysis methodologies.
D9.3 [M12]	Report on data model and management plan for integrated solutions	Input used for the creation of the data collection methodology. Input used for the design of the KPIs tool.
D9.5 (M24)	Report on monitoring framework in LH cities and established baseline	Output used to implement the unified framework in the three IRIS LH cities.
D9.6: (M38)	Intermediate report after one year of measurement	Output, as the actual performance data collection and reporting will be carried out in this deliverable. Moreover, the KPI tool will be used to calculate and visualize the KPIs in each LH city.
D9.6: (M60)	Report on evaluation and impact analysis for integrated solutions	Output, as the actual performance data collection and reporting will be carried out in this deliverable. Moreover, the KPI tool will be used to calculate and visualize the KPIs in each LH city.

1.4. Structure of the deliverable

The structure of this deliverable is as follows:

Chapter 1 is the introduction.

Chapter 2 presents the methodology followed to create the unified monitoring framework and the IRIS KPIs tool. The methodology consists of 1) the methodology for collecting indicators data, 2) the methodology for calculating KPIs and 3) the methodology for KPIs tool design and development.

Chapter 3 presents the data collection framework. This framework specifies the data requirements for each KPI and the methodology for data collection. It includes templates for collecting the required information for the monitoring devices, the automatically generated data, and the manual collected data. The framework also contains the methodology for the KPIs that will be evaluated through data collected in the form of questionnaires. Finally, it presents the procedure to evaluate the quality of the collected data.

Chapter 4 presents the data analysis and visualisation framework. This framework specifies how the collected data will be analysed to produce each KPI and relevant visualisations. The implementation of data analysis and visualisation utilises the 6-step methodology that is presented through an example KPI.

Chapter 5 presents the IRIS KPIs tool that implements the unified monitoring framework and uses the collected monitoring data to calculate the KPIs' values and to present the results.

Chapter 6 provides an overview of how D9.4 is linked with the forthcoming activities in the rest of WPs.

Chapter 7 presents the conclusions.

Chapter 8 contains the references to external sources used in the document.

Chapter 8 contains four Annexes. Annex 1 shows the form that is used in LH cities to interpreter each KPI. Annex 2 presents the IRIS KPIs to be used as a reference. Annexes 3 and 4 show some screenshots of similar tools, CITYKeys and SCIS, respectively.

2. Methodology

2.1. Methodology for collecting indicators data

The assessment of the different IRIS demonstrations within the LH cities will be undertaken through the inspection of various indicators showing the effectiveness of the implementations. To retrieve these defined KPIs for each demonstrator project, several parameters are of relevant importance to be measured. Monitoring of these measurements will take place during the operation of the integrated solutions. Cornerstone of the measurement procedure is the data collection. Data collection is the process of gathering information on specific variables following a systematic method that enables measuring and evaluating outcomes. The emphasis in the data collection process is put on ensuring accurate data collection.

In IRIS, data collection processes in heterogeneous fields (energy, mobility, ICT, and citizen engagement) need to be analysed. The heterogeneous nature of those fields implies that data sources and means of data collection and storage might differ. In some cases, data will be provided by systems that include smart meters, which automatically collect data and upload it to a repository. In other cases, they reside in another system's repository and simply needs to be moved or copied. Data can be also collected by other methods such as questionnaires, interviews, direct observations, etc. and their results are registered in forms (electronic or paper).

In some cases, data transformation is required so that the information can be used in analysis and evaluation. For example, instant data about electrical consumption provided by a smart meter might not be easy to interpret but the electrical energy consumed by a building during one month is relevant. This second value can be calculated from the information of several smart meters like the first one providing information during a whole month.

In this section, the methodology for the collection of the various types of data required for the calculation of the KPIs in the IRIS LH cities, will be presented. The collected data will be stored in the City Innovation Platform (CIP) and they will used by the IRIS KPI tool to calculate and visualise the KPIs.

2.1.1. Main concept

The feedback from the workshops as described in chapter 2 of D9.3, and workshops in smaller groups in Utrecht have led to a guideline that supports the partners of the integrated solutions in setting up their projects such that:

- KPI's that are being measured are well understood
- KPI's give a meaningful result
- The right data is being measured to calculate the required KPI's during implementation of the integrated solutions

An important part of this process is to have a close look at the KPI's that are projected for each integrated solution, the calculation method of the KPI's, and the expected results. By doing so:

- KPI's are defined and calculated such that an only one way of interpretation is possible. This way results from different projects and cities are homogenized.

- It is well understood what result the measurement of a KPI leads to.

Figure 1 gives a schematic representation of the process of interpreting and applying the KPI's to the integrated solutions.

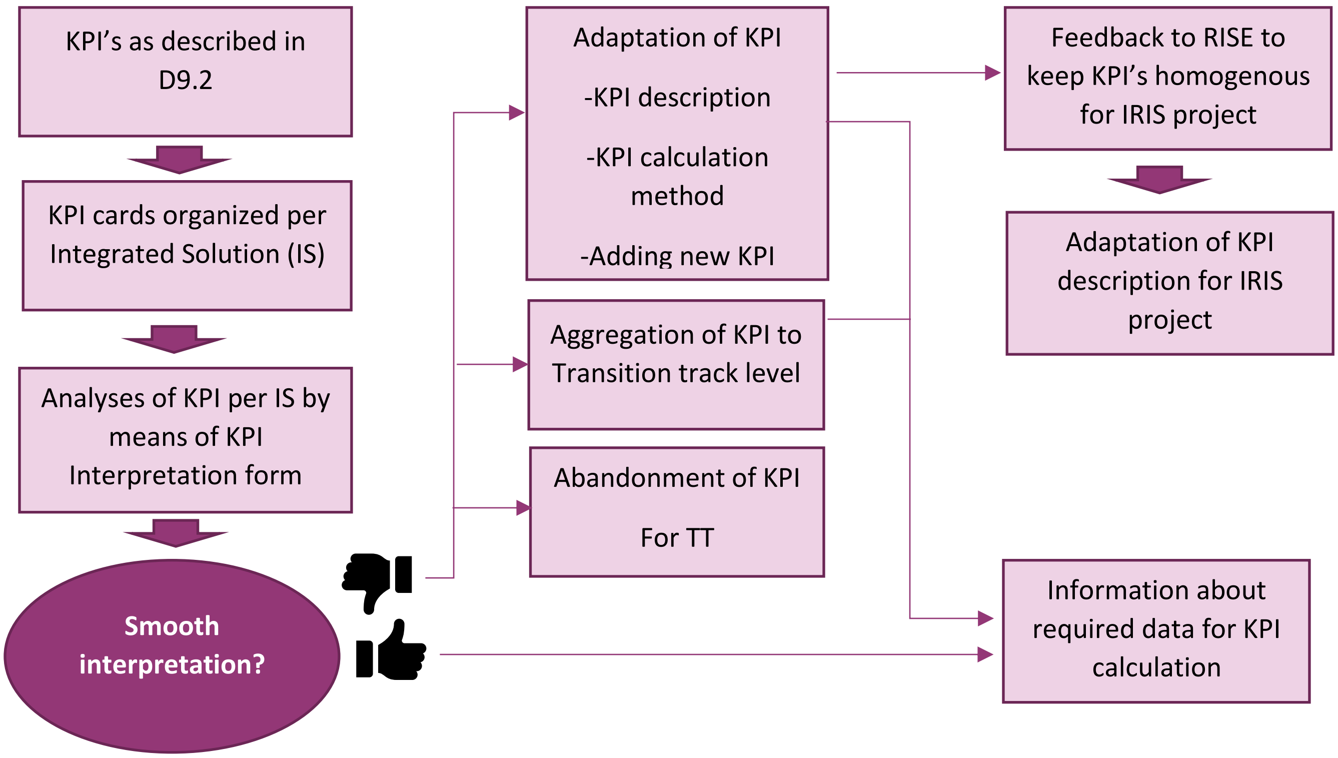


Figure 1 Schematic representation of KPI interpretation process

The interpretation starts with the KPIs as described in D9.2. To facilitate the work, for each integrated solution (IS) the KPIs that are projected to be measured are organized in a separate folder. Then the IS and the KPIs are analysed by means of the KPI interpretation form. An example of this form is provided in the Annex 1 – Form for interpretation KPIs.

In case of a smooth interpretation of a KPI for an Integrated Solution (IS), the interpretation form leads to a list of information which is required to calculate the KPI's during the project.

When interpretation does not happen smoothly, different options are possible:

- **Adaptation of the KPI**: This could either mean that the KPI description or the KPI calculation method will be changed. Adjustment of the KPI will happen in close contact with RISE, to make sure that KPI's remain homogenous for each city throughout the IRIS project. Alternatively, a new KPI could be added to the database.
- **Aggregation of the KPI to transition track (TT) level**: In some cases, integrated solutions are so much integrated in a transition track, that it's not possible or meaningless to distinguish the effect of the IS separately. In this case the KPI will be calculated for more solutions combined, at transition track level.
- **Abandonment of KPI**: In case a KPI cannot be measured both at IS and TT level, or measurement of the KPI is possible, but gives a meaningless result. Abandoning the KPI will be requested.

After adaptation of the KPI or aggregation of the KPI to transition track level, the interpretation form leads to a list of information which is required to calculate the KPI's during the project.

2.1.2. Automatic data collection

Part of the data collection in the IRIS demonstrations will be done using real time monitoring systems. These systems will use smart meters and other equipment to automatically collect measurements related to the demonstration's specific activities (e.g. energy consumption, generated energy, EV charging, etc.), and to produce the datasets that are needed for the calculation of specific indicators. The datasets are usually stored in the monitoring backend of the company that operates the monitoring system.

In the energy related demonstrations data are automatically collected at three different levels:

- At **District level**, information related to the district can be collected through the District energy management system (DEMS).
- At **Building level**, information will be collected through the Building Energy Management System (BEMS).
- At **Home level**, information will be collected by home devices, such as electrical smart meters, heat meters, thermostats, valves and other high efficiency smart appliances. The data are available through the Home Energy Management System (HEMS).

In the mobility related demonstrations, the calculation of the KPIs involves specific data collection, such as the final number of car-sharing users, the number of deployed vehicles in the respective area as well as the amount of yearly distance covered by an e-car shared vehicle in comparison to a privately owned one. All aforementioned collected data consist of the actual raw data which will be gathered and retrieved through various sensors situated either within the vehicles, such as the trip computers which record and display useful information, or within the Charging Stations. Furthermore, information retrieved from digital libraries and database of the demonstrations contribute to this collection of raw data. The latter will be processed in order for the required indicators to be established and finally evaluated.

Table 2 An example of data that can be collected automatically for the mobility related demonstrations.

Data Name	Description	Unit	Data Source
Final users involved	Final number of car sharing users	#	Membership Database
Driven Distance	Amount of travelled distance by car sharing fleet	Km	Trip Computer
Vehicle deployment	Number of vehicles deployed per area	# of Vehicles / Km^2	Database
Total EV & Solar Powered V2G Charging Stations	Number of EVs and solar powered V2G charging stations deployed in the area	Stations / Km^2 %	Database
Average Speed	Showing traffic and road congestion	Km/h	Trip Computer

Range	Remaining range at pickup and return showing efficiency	Km	Trip Computer
Driven Time	Amount of time the vehicle was driven	xxH. xxM	Trip Computer

In the ICT related demonstrations, the applications keep log files that can be used to extract the information needed to calculate the related KPIs.

In order to define a monitoring plan for each solution, a common data collection structure between the LH cities needs to be defined and also configured to the different city's replications, as it is briefly described in this chapter and further in detail later as well as in D1.1.

2.1.3. Data collection using surveys

In order to have an effective feedback rate from the surveys without exhausting the target audience, the IRIS surveys must be combined with already planned surveys to as large extent as possible. They can be combined both regarding different KPIs and tasks in the IRIS project, but also with other ongoing projects or annual surveys that have the same target group. It is preferable that the IRIS survey questions are integrated into the already planned everyday work to as large extent as possible. The surveys could be carried out through different channels depending on the solution evaluated, e.g. questions in apps developed in the project, annual surveys to residents etc. Therefore, planning when, with whom, and how the surveys will be carried out throughout the project is necessary. Finding out if any of the involved partners are already doing or planning surveys or other interaction with the target group is necessary and support from IRIS horizontal partners to plan and execute the surveys is crucial.

Creating surveys

Before designing the questions in a survey, it must be decided how the answers will be used and for what purpose. For instance, a survey on energy consumption relating to changes could be designed differently depending on whether the change is associated to behavioural or technical issues. The target group should also be considered when formulating the questions and answer alternatives. The purpose and use of results from the survey should set the questions.

Choosing method

Surveys are a useful tool to collect data from a broad crowd. Surveys can be collected by phone, internet, email, handed out paper, among other methods. The most common surveys have a fixed questionnaire with prespecified questions and a fixed set of response alternatives. Other methods that can be used are for example observation, in depth interviews, focus groups, panels and experiments. These methods can be chosen to collect data instead of surveys but are also a useful complement to surveys, to be able to achieve a deeper understanding of the result from a survey or answer follow-up questions that might arise. Complementing methods can also be of useful when planning a survey. For example, *In-depth interviews can be used to uncover issues that are important to include in the questionnaire, learn how potential respondents think about the topic, develop response alternatives and learn how the population might react to survey procedures. This can be especially useful when the population and/or topic are not familiar to the researcher.* (Czaja, 2005)

In-depth interviews are good for getting deep, detailed, complex information that does not work well in a survey. For example, if you want to know how residentials integrate with a new interface that should support them to lower their energy consumption, then in-depth interviews with a small number of residentials could be useful. But if you want to know if all residents are using the tool and know what behaviour to ask about, a survey will be more useful. In Table 3 some methods and their strengths and weaknesses in relation to surveys are described.

Table 3. Summary of how surveys relate to other data collection methods (Czaja, 2005).

Method	Strength vs surveys	Weakness vs surveys
Observations	Not subject to reporting bias	Can't measure mental states; not efficient for measuring infrequent behaviors
Depth interviews	Can probe freely and go into depth	Expensive, poor populations coverage
Focus groups	Can probe freely and go into depth; can see social dynamics	Expensive, poor populations coverage
Panels	Shows change over time	Expensive; a limited number of people will participate
Experiments	Strong test if causation	Difficult to do outside lab

Examples of survey questions

Below are a few sources that can be used when looking for questions or inspiration on how to shape questions and answers with Likert scale. These questions might not be the exact form that will be used in the IRIS project but can be of use when designing questions. There are many more good examples that can be found. The important thing is that the questions are easy to understand and that the answers will be relevant for the purpose of the survey.

European Social Survey

European Social Survey has examples of questions that are well tested and can be copied if suitable or just used as inspiration (European Social Survey, 2019). In the suggested questions are also examples of answers to choose from. There are different themes to look for inspiration from, for example concerning climate change. It also provides examples on how to formulate Likert scale question answers, as shown in Figure 2.

Figure 2. Example of survey question answer alternatives from European Social Survey; Likert scale in six steps, in addition, options Refusal, Don't know or No answer can be included.

World Values Survey

Another source that can be used for inspiration is World values survey, which also has well tested questions within different themes and several examples of how to frame answers according to the Likert scale.

Now, I would like to read some statements and ask how much you agree or disagree with each of these statements. For these questions, a 1 means that you "completely disagree" and a 10 means that you "completely agree." (*Code one number for each statement*):

V192. Science and technology are making our lives healthier, easier, and more comfortable.
Completely disagree Completely agree
1 2 3 4 5 6 7 8 9 10

V193. Because of science and technology, there will be more opportunities for the next generation.
Completely disagree Completely agree
1 2 3 4 5 6 7 8 9 10

V194. We depend too much on science and not enough on faith.
Completely disagree Completely agree
1 2 3 4 5 6 7 8 9 10

V195. One of the bad effects of science is that it breaks down people's ideas of right and wrong.
Completely disagree Completely agree
1 2 3 4 5 6 7 8 9 10

V196. It is not important for me to know about science in my daily life.
Completely disagree Completely agree
1 2 3 4 5 6 7 8 9 10

Figure 3 Example of questions from world value survey with answers according to the Likert scale with numbers from 1 to 10 (World Value Survey, 2019).

Monash University

Likert scale can be framed in many ways. Figure 4 presents another example, a survey from Monash University where they use different answering examples, involving not only your own perception but also how you perceive other groups awareness.

1. Stormwater Quality Management for Waterway Health

This section is focused on stormwater quality management from an environmental protection perspective.

1. In YOUR opinion, how important is advancing stormwater quality management practices across Melbourne to the following groups for protection of the receiving waterways?

	Very Low	Low	Average	High	Very High	I don't know
You						
Your Organisation						
The Community						
Current State Politicians						

Figure 4 Example of one of many surveys from Monash University (Monash University Online Questionnaire Survey, 2019).

2.1.4. Collection of reference data

Apart from data collected automatically and through surveys, reference data are necessary for the calculation of some KPIs. These data fall into the following two categories:

- **Building characteristics** such as number of inhabitants, total gross floor area, total heated net floor area, total cooled net floor area, etc.
- **Financial data** such as total investment costs, total operating costs, grants and subsidies, etc.
- **Financial parameters** such as local grid electricity price (€/kWh) and local gas price (€/kWh)

For a more concrete and robust assessment of the respective demonstrations that will allow the comparison between the different IRIS LH cities, not only data that are necessary for the KPIs' calculation are important, but also data regarding conditions through which the demonstrated activities were held or undertaken. This information can be retrieved through data referring to all-day weather conditions which in turn can be collected through historical weather data or even database libraries of weather forecast websites. The following climate parameters are required for each LH city (CONCERTO Premium, 2013):

- **Heating Degree Days ($HDD_{18/15}$):** The severity of the cold in a specific time period taking into consideration outdoor temperature and average room temperature (in other words the need for heating). For normalizing heating energy consumption in different climate conditions, the so-called "heating degree days" (HDD) are used and well established. The calculation of HDD relies on the base temperature, defined as the lowest daily mean air temperature not leading to indoor heating. The value of the base temperature depends in principle on several factors associated with the building and the surrounding environment. By using a general climatological approach, the base temperature is set to a constant value of 15°C in the HDD calculation.
- **Cooling Degree Days ($CDD_{18/22}$):** The severity of the heat in a specific time period taking into consideration outdoor temperature and average room temperature (in other words the need for cooling). For normalizing cooling energy consumption in different climate conditions, the so-called "cooling degree days" (CDD) are used. The calculation is analogue to the HDD and as it is applied to air-conditioning systems very often there is no distinction between ambient air temperature and room set temperature. The supply air with a specific set temperature has to be cooled down exactly at the time when the temperature of the ambient air temperature exceeds that value. According to the common use, the base temperature is defined as 18^{o}C.
- **Global solar radiation (GSR):** The total solar irradiation that hits a horizontal surface is called global radiation and it consists of the direct radiation and the diffuse radiation. The diffuse radiation emerges from reflection by clouds and dust or water particles. Solar radiation is a factor that influences the heating energy consumption as well as the ambient temperature. The unit is kWh/m^2 for radiation energy in a time period.

Furthermore, connected to the weather conditions are also information regarding traffic congestion, which can also be retrieved through online platforms and database such as Google Maps or other live traffic status platforms. Graphs or other schematically depicted information can assist in the presentation of these useful data, which in this case as well need to be collected by all LH cities.

2.2. Methodology for calculating KPIs

The general framework that is used for calculating KPIs can be summarized in the Figure 5 below.

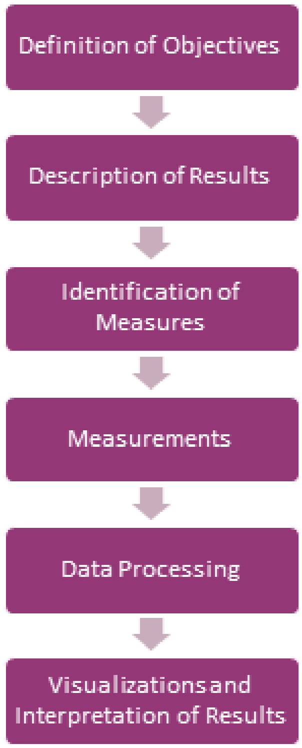


Figure 5 Steps for calculating KPIs

In more detail, each of the steps is described below.

STEP 1 Definition of Objectives: KPIs are based on objectives and they should exist solely to contribute to an objective. Taking an example with respect to mobility from D1.1, an objective could be the adoption of efficient vehicles in an area.

STEP 2 Description of the results: The objective that was defined before should be operationalized in tangible results. Furthermore, several issues need to be taken into consideration for the description of the results. Firstly, the results should be meaningful to the involved stakeholders. Moreover, it is important to consider and differentiate between monetary and socio-environmental results, while considering the entire area of interest beyond the one the service was implemented at. Thus, realistic behaviours will emerge that will provide insights into the impact of the services.

Continuing the example from step 1, the objective can be achieved if a percentage (a specific number) of the vehicles that circulate in an area belongs to the proposed service (it is efficient).

STEP 3 Identification of measures: Hence, the results that were described before, should be further defined as variables that can be measured. In this case, the measures could for example include users' ids that use efficient vehicles per day. In case no concrete variables can be defined, then the analyst should return either to the objectives or to the results and re-define them.

STEP 4 Measurements: It includes the collection of data of the appropriate variables. In general, the main components that are used in this step are the following:

- Sensors: They describe the set of instruments and tools that will measure the appropriate values that will be used for the calculation of the KPIs
- Records: They describe the actual values that will be measured/recorded by the sensors
- Databases: They describe the components that will be used for storing the measurements

STEP 5 Processing the Data: This step contains fusion and processing of the data that were collected in the previous step, probably from various sources. In addition, methodologies for calculating the KPIs should be harmonized across LH and FL cities. Finally, there is a strong need for harmonization of the conditions surrounding the measurements in order to obtain comparable results. Regarding these comparisons, additional issues need to be considered when analysing the data. These can be summarized into two groups: same-city and different-cities comparisons. These issues are:

- Same-city comparisons:
    - Comparisons should be performed for the same vehicle and driver (if possible). Thus, the real impact of the service can be measured
    - Comparisons should be done for the same periods of the day
- Different-cities comparisons:
    - The above apply for comparisons among different cities
    - Data should be normalized across the different cities in order to have meaningful comparisons on the same level of measurement
    - Common data formats should be used across the different cities.

For example, the aggregate number of users that circulate with environmentally friendly vehicles is the measure of the adoption of the proposed service in the area. To normalize the results across different areas, these variables can be further refined by calculating the number of circulating efficient vehicles per the total number of efficient vehicles per day.

STEP 6 Visualization and Interpretation of the Results: Data analysis results should be visualized in an intuitive and meaningful way, as to convey without complications the meaning of the results.

The results should be compared based on a pre-defined limit, which could either be a comparison baseline, a filter or a specific level of data aggregation. For example, an applied limit could include the results from a different period, or the ones generated from another area. Finally, these results should be interpreted qualitatively and if necessary, the whole process could start over.

Concrete examples of the above methodology are presented in section 4 of the present deliverable.

2.3. Methodology for KPIs tool design and development

For the calculation and visualisation of KPIs, a new tool will be developed that will integrate the monitoring data collected for the various IRIS demonstrations, calculate the KPIs and present the results to the local project's partners and other stakeholders' groups (Figure 6).

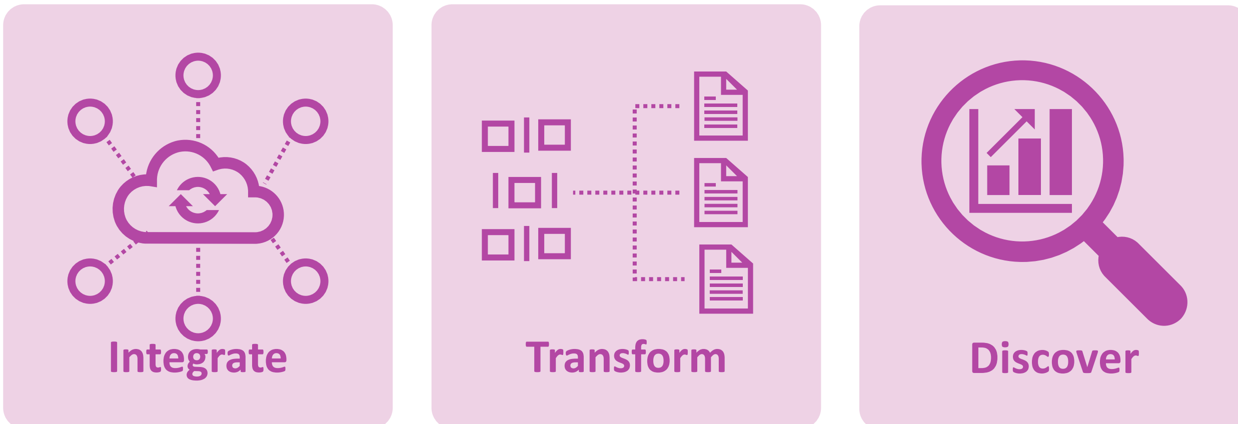


Figure 6 IRIS KPIs tool lifecycle

The KPIs tool will implement the steps 5 (processing the data) and 6 (Visualization and Interpretation of the Results) of the methodology for calculating the KPIs, which was presented in section 2.2. It will partially address the step 4 (Measurements), as the primary tool for monitoring data gathering will be the CIP. The KPIs tool will have manual (i.e. reference data, offline measurements, and data from surveys) and automatic (i.e. high-resolution data from smart meters) input modes.

The KPIs tool will include a dashboard and post-processor for visualization, permitting easy sharing and cooperation between the consortium partners responsible for the evaluation of the IRIS solutions and communication purposes for the general public. The design and development of the tool will be based on the analysis of similar tools used in other EU projects and on the latest developments in the fields of data visualisation and dashboard design. In addition, to decide on the specific functionality of the tool, three use cases will be analysed. The first concerning a KPI in which the required data collected automatically through CIP, the second concerning a KPI in which the required data is manually entered into the tool, and the third concerning a KPI in which the required data comes through user surveys.

2.3.1. Dashboards and data visualisation

Dashboards are analytics tools that give users a unified view of the most important data. They consolidate real-time information in a simple, easy-to-understand, and dynamic format (Logi Analytics, 2015). A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance (Few, 2007). Dashboards are especially useful when the aim is to compare multiple datasets at a time. There are two main types of dashboards (Bakusevych, 2018):

1. **Operational dashboards:** They provide the users a digital control room designed to help users be quick, proactive, and efficient. Operational dashboards aim to impart critical information quickly to users as they are engaged in time-sensitive tasks. Their main goals are to present data deviations to the user quickly and clearly, show current resources, their status (Figure 7).

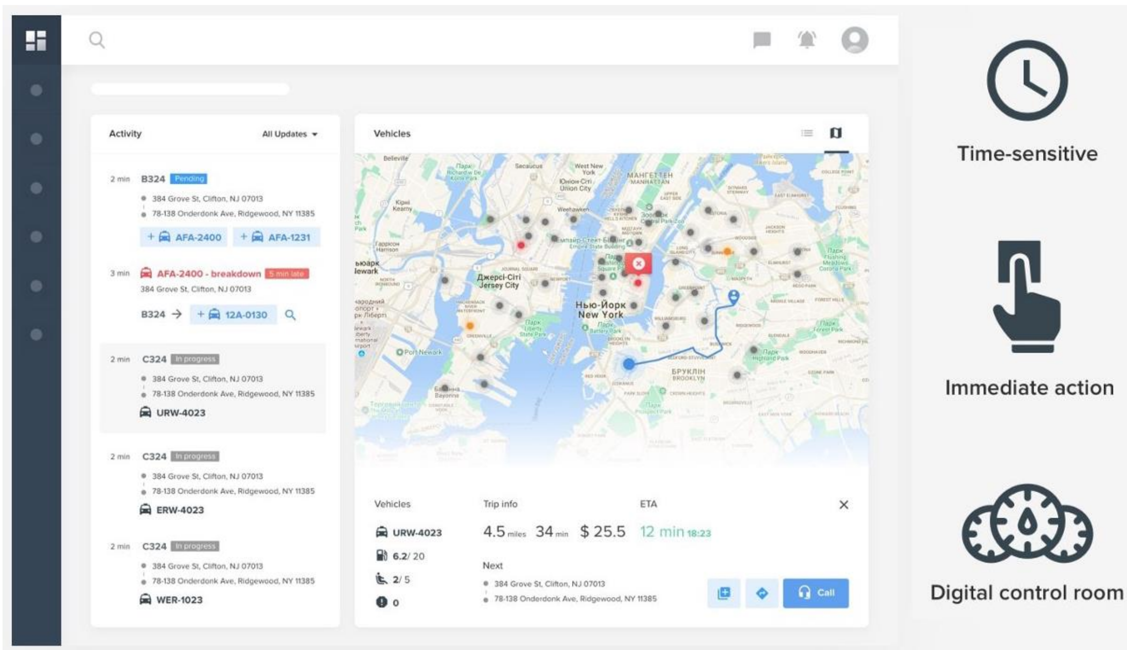


Figure 7 Operational dashboard (Bakusevych, 2018)

2. **Analytical dashboards:** They provide the users with at-a-glance information used for analysis and decision making and are less time sensitive and not focused on immediate action. Analytical dashboards aim to help users make the best sense of the data, analyse trends and drive decision

making (Figure 8).

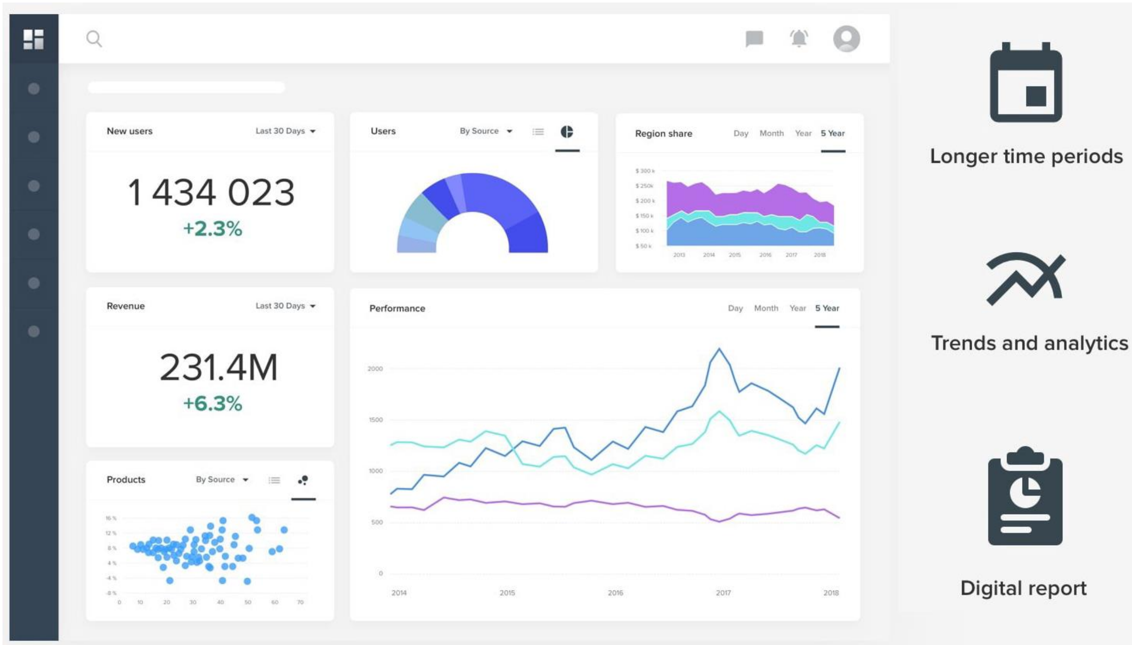


Figure 8 Analytical dashboard (Bakusevych, 2018)

The IRIS KPI tool will provide an analytical dashboard.

Literature review offers the fundamentals of the dashboard design. Many of these fundamentals are related to successful data visualisation. The design of the IRIS KPIs tool will be based on the following steps / guidelines (Juice, 2009), (Bakusevych, 2018) (Few, 2007):

Step 1: Define your audience. In the beginning of the process, the different types of users must be defined. The differentiation of the user groups is related to their different needs and consequently the different ways that will want to use the tool. IRIS KPIs tool users fall into two main categories:

- **Information consumers:** These users prefer to work with a predefined dashboard experience where they can regularly view, interact with, and personalize a preconfigured asset.
- **Content creators:** These users want the ability to choose the data they need and supplement those existing dashboards and reports with their own metrics.

The users of the IRIS KPIs tool will be defined through a number of use cases. Each use case will produce a number of user requirements.

Step 2: Chose the right representation for the data. Data visualisations are graphical representations of data and are used to simplify the understanding of sometimes complex information. It is a complicated task, especially on the IRIS case where multiple types of KPIs must be presented. The wrong choice of the chart type or inconsistencies to the most common type of data visualisation could confuse users or lead to data misinterpretation. The following chart selection guide (Figure 9) has been used for the selection of the most appropriate chart types for the IRIS KPIs visualisation.

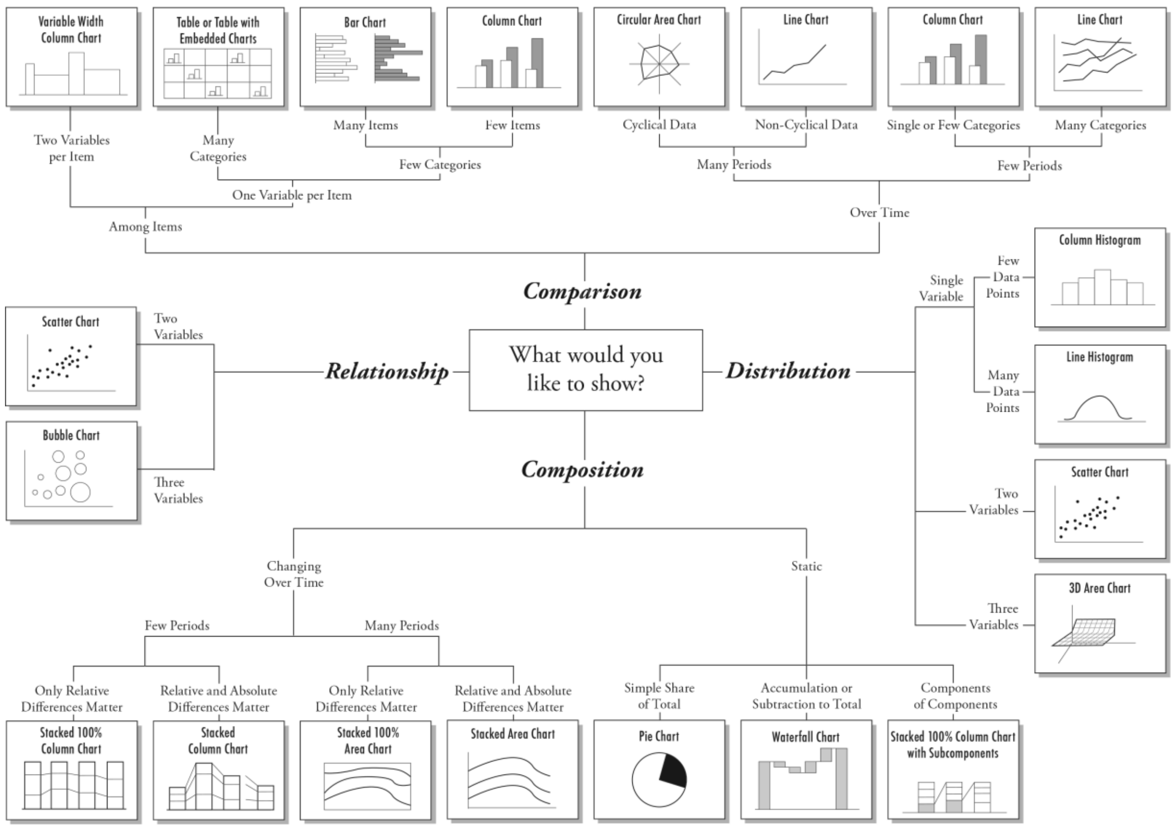
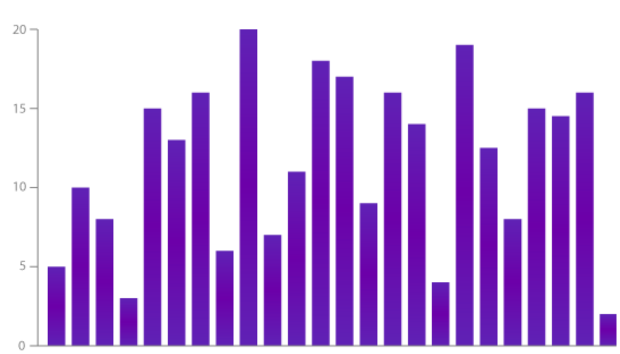


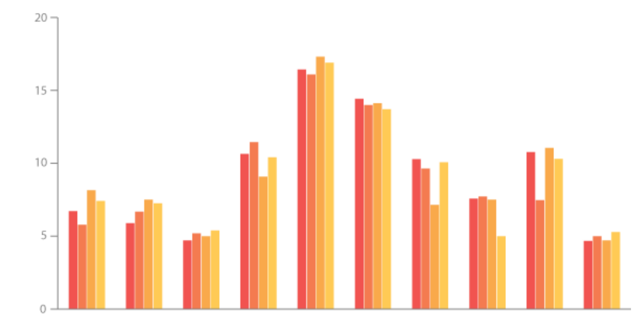
Figure 9 Chart Selector Guide (Abela, 2013)

For the IRIS KPIs tool, the focus will be on the comparison charts and performance charts. Comparison charts are used to compare values against each other. They show the differences in values, such as the difference between categories, or how values are changing over time. Performance charts provide a quick view of a performance measure. Looking at a performance chart, a user can quickly identify the measure value and whether the results are as expected or not. Table 4 presents the most common types of charts that will be used for KPIs tool dashboard (The Data Visualisation Catalogue , n.d.), (When to use what type of visualization, 2019).

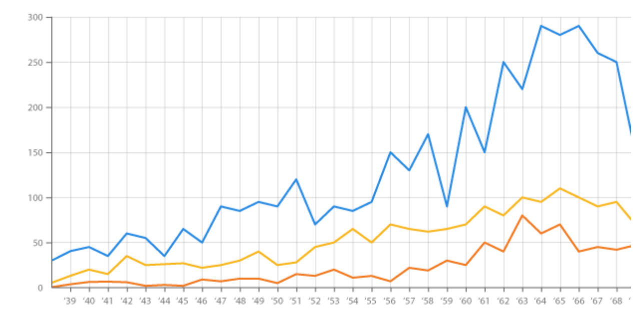
Table 4 Chart types for the IRIS KPIs tool dashboard

Bar Chart / Multi-set (or Grouped) Bar Chart	
	The bar chart is suitable for comparing multiple values. One axis of the chart shows the specific categories being compared and the other axis represents a discrete value scale. The multi-set bar chart is variation of a bar chart that is used when two or more data series are plotted side-by-side and grouped together under categories, all on the same axis. Like a Bar Chart, the length of each bar is used to show discrete, numerical comparisons amongst categories. Each data series is

<table>
<tr><td>



</td><td>assigned an individual colour or a varying shade of the same colour, in order to distinguish them. The multi-set bar chart is usually to compare grouped variables or categories to other groups with those same variables or category types.</td></tr>
<tr><td colspan="2">Line Chart</td></tr>
<tr><td>

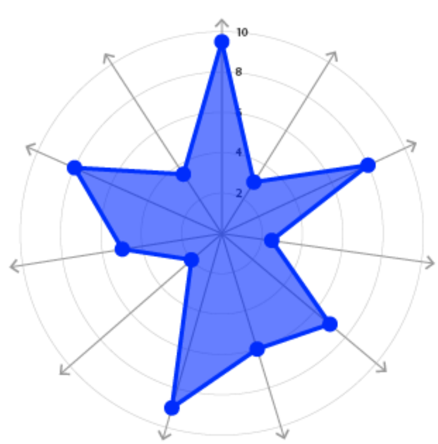


</td><td>

The line chart is used to show trends and analyse how the data has changed over time. Typically, the y-axis has a quantitative value, while the x-axis is a timescale or a sequence of intervals. Negative values can be displayed below the x-axis.

When grouped with other lines (other data series), individual lines can be compared to one another.

</td></tr>
<tr><td colspan="2">Radar (or Spider) Chart</td></tr>
<tr><td>

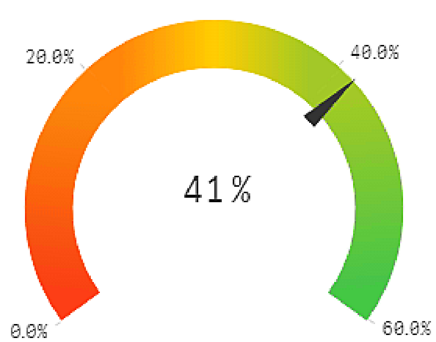


</td><td>

The radar chart is used to compare multiple quantitative variables. This makes it useful for seeing which variables have similar values or if there are any outliers amongst each variable. The radar chart is also useful for seeing which variables are scoring high or low within a dataset, making them ideal for displaying performance.

Each variable value is plotted along its individual axis and all axes are arranged radially, with equal distances between each other, while maintaining the same scale. All the variables in a dataset are connected to form a polygon.

</td></tr>
<tr><td colspan="2">Gauge Chart</td></tr>
<tr><td>



</td><td>The gauge chart is used to show a single measure value and visualize how to interpret that value. The value together with segmenting and colour coding gives an instant indication of the performance within an area. It is important to set relevant max and min values to support the interpretation of the value. A reference line can be used to provide additional context.</td></tr>
</table>

Apart from the charts mention in Table 4, tables will also be used to present detailed data and precise values in addition to the visualizations of values. A table is excellent for presenting exact values rather than trends or patterns. The tables allow the users to compare individual values. Within a limited screen space, the user can drill down to the next level of detail and analyse the updated measure values. Moreover, they can be filtered and sorted in different ways.

Step 3: Build a Solid Layout. A good layout design enhances the tool's overall functionality effectiveness. Composition, typography, and colours are the building blocks of a good layout design.

Composition

A grid will be used to support the composition of the various components. The grid system helps align web page elements based on sequenced columns and rows. This column-based structure will facilitate the placement of text, KPIs charts, and functions in a consistent way throughout the design. Once we know what information the users of the tool need, the related data will be grouped next to each other. The visualizations will be tiered by size and position to highlight the most important pieces of information. Consistent sizes will be used for similar elements. Finally, special attention will be paid to decide on the most appropriate amount of data included in each web page; otherwise the users will be confused, and the power of tool's insights will be lost.

Typography

Typography helps to create a visual hierarchy with all the content displayed in a dashboard. Emphasis can be added using bold type or an accent colour. A Sans-serif font will be used for the body text while a Serif font will be used for the headlines. This combination is the most used in the webpages. Moreover, no more than three sizes of the selected font will be used in each webpage.

Colours

Colour is used in a dashboard to serve a particular communication goal. For instance, to highlighting something or to differentiating meaning. So, each colour should serve a purpose and should serve it effectively. Figure 10 presents an effective use of colours in KPIs' layout design that increases the users' understanding.

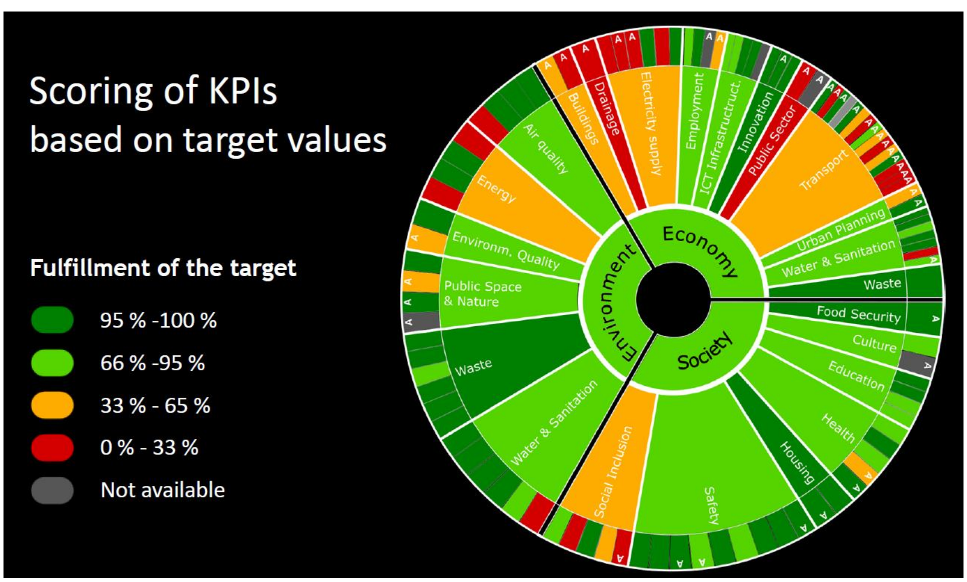


Figure 10 Effective use of colour in KPIs' layout design (U4SSC United for Smart Sustainable Cities, 2018)

2.3.2. JavaScript chart and visualisation libraries

The rapid development of the IRIS KPIs tool's interactive visualisations will be facilitated by a JavaScript chart or visualisation library. There are many libraries available that can be used. In order to understand which one (or a combination of them) would work best for the visualisation of the IRIS KPIs, the following factors will be taken into consideration (Majorek, 2019):

- Is the library available as an open source project or is it offered for free for non-profit or research organisations?
- Does the library support the chart presented in section 2.3.1 (i.e. bar charts, multi-set (or grouped) bar charts, line charts, radar (or spider) charts, and gauge charts)?
- Can the library handle large datasets? In general, libraries based on Scalable Vector Graphics (SVG) are usually better for smaller to medium datasets while Hypertext Markup Language (HTML)5 CANVAS based tools are more suitable for large datasets.
- Can the library be used for Web, mobile, or both?
- How popular is the library among the developers' community?

The following libraries fulfil to some extent the above-mentioned requirements (Saring, 2018).

D3.js (https://d3js.org/)

D3.js is the most popular (84K stars in GitHub) JavaScript library for visualizing data using web standards. D3 helps you bring data to life using SVG, Canvas and HTML. D3 combines powerful visualization and interaction techniques with a data-driven approach to Document Object Model (DOM) manipulation, giving user the full capabilities of modern browsers and the freedom to design the right visual interface for his data. Figure 11 presents some examples of D3.js charts. More examples are available at https://github.com/d3/d3/wiki/Gallery

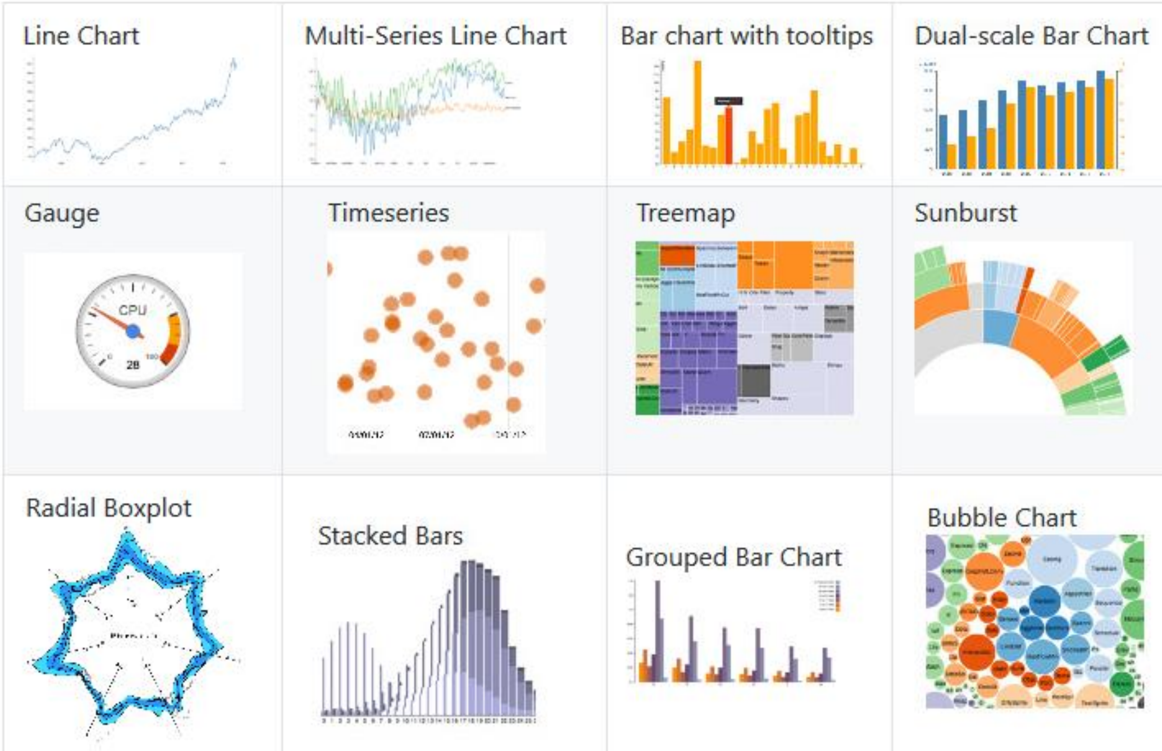


Figure 11 Example of charts created using D3.js library

The popularity of D3.js led to the development of libraries that extent the charting capabilities of D3.js.

NVD3 (http://nvd3.org/) offers high customizable, re-usable charts and chart components for d3.js. Figure 12 presents some chart components of NVD3. More examples are available at http://nvd3.org/ghpages/examples.html

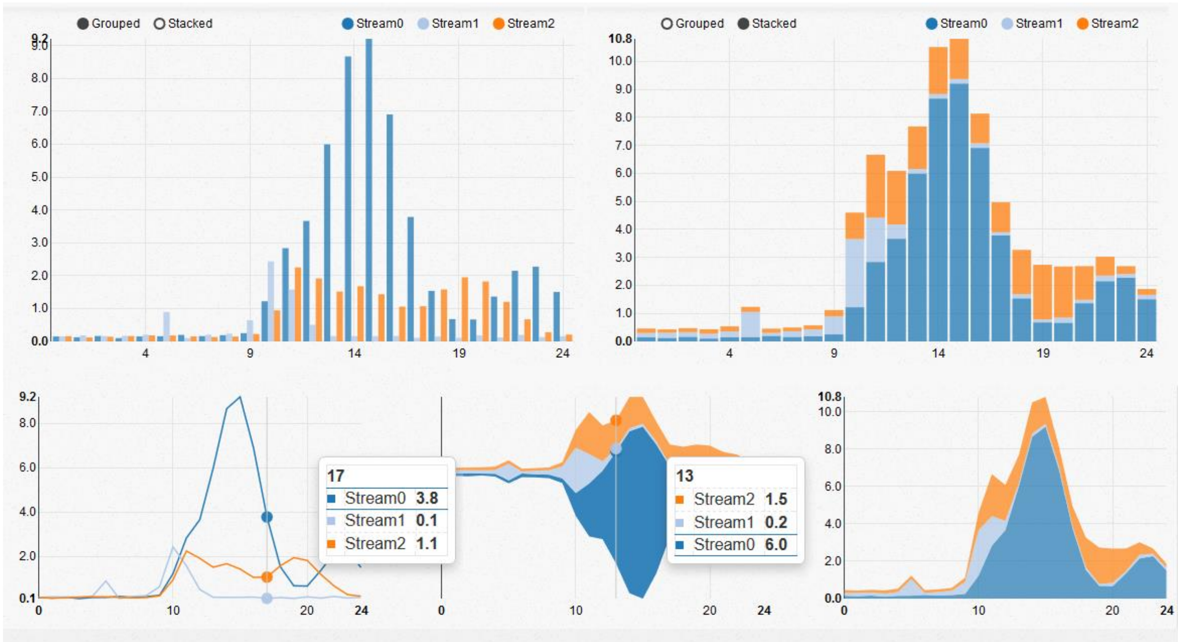


Figure 12 Examples of NVD3 chart components

C3.js (http://c3js.org) offers also D3-based reusable components that enable deeper integration of charts into web applications. Figure 13 presents some chart components of NVD3. More examples are available at https://c3js.org/examples.html

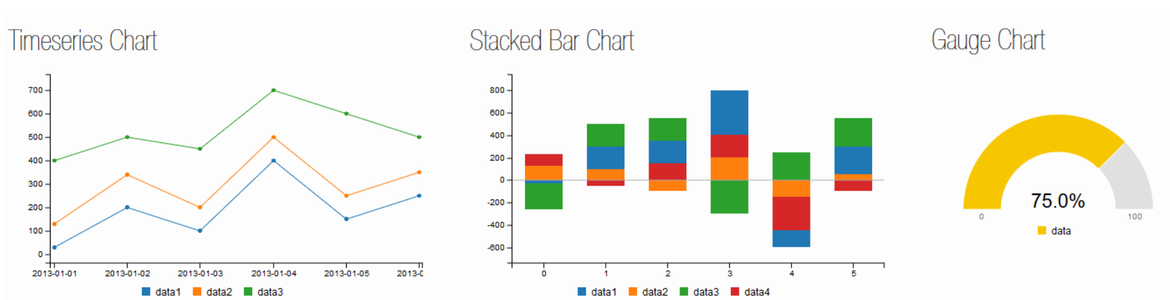


Figure 13 Examples of C3js chart components

ChartJS (https://www.chartjs.org/)

ChartJS is another very popular (43K stars in GitHub) library of open source HTML 5 charts for responsive web applications using the canvas element. It includes bar charts, line charts, area charts, linear scale, radar charts, and scatter charts. V.2 provides mixed chart-types, new chart axis types, and beautiful animations. Designs are simple and elegant with 8 basic chart types. Moreover, the developers can combine the library with moment.js (https://momentjs.com/) for time axis. Figure 14 presents some chart components of ChartJS. More examples are available at https://www.chartjs.org/samples/latest/

Figure 14 Examples of ChartJS chart components

Highcharts (https://www.highcharts.com/products/highcharts/)

Highcharts is a JavaScript SVG-based, multi-platform charting library that has been actively developed since 2009. It makes it easy to add interactive, mobile-optimized charts to web and mobile projects. Highcharts is a commercial solution which is offered for free for non-profit companies and organisations. The 1st version of SCIS tool uses the Highcharts library. Figure 15 presents some chart components of Highcharts.

Figure 15 Examples of charts created using Highcharts (https://www.highcharts.com/demo)

amCharts (https://www.amcharts.com)

amCharts is another very popular commercial JavaScript charting library, which is also available for free for non-profit companies and organisations. amCharts offers a simple yet powerful and flexible drop-in data visualization solution, which includes both charts and geographical maps. Figure 16 presents some chart types supported by amCharts. More examples are available at https://www.amcharts.com/demos/

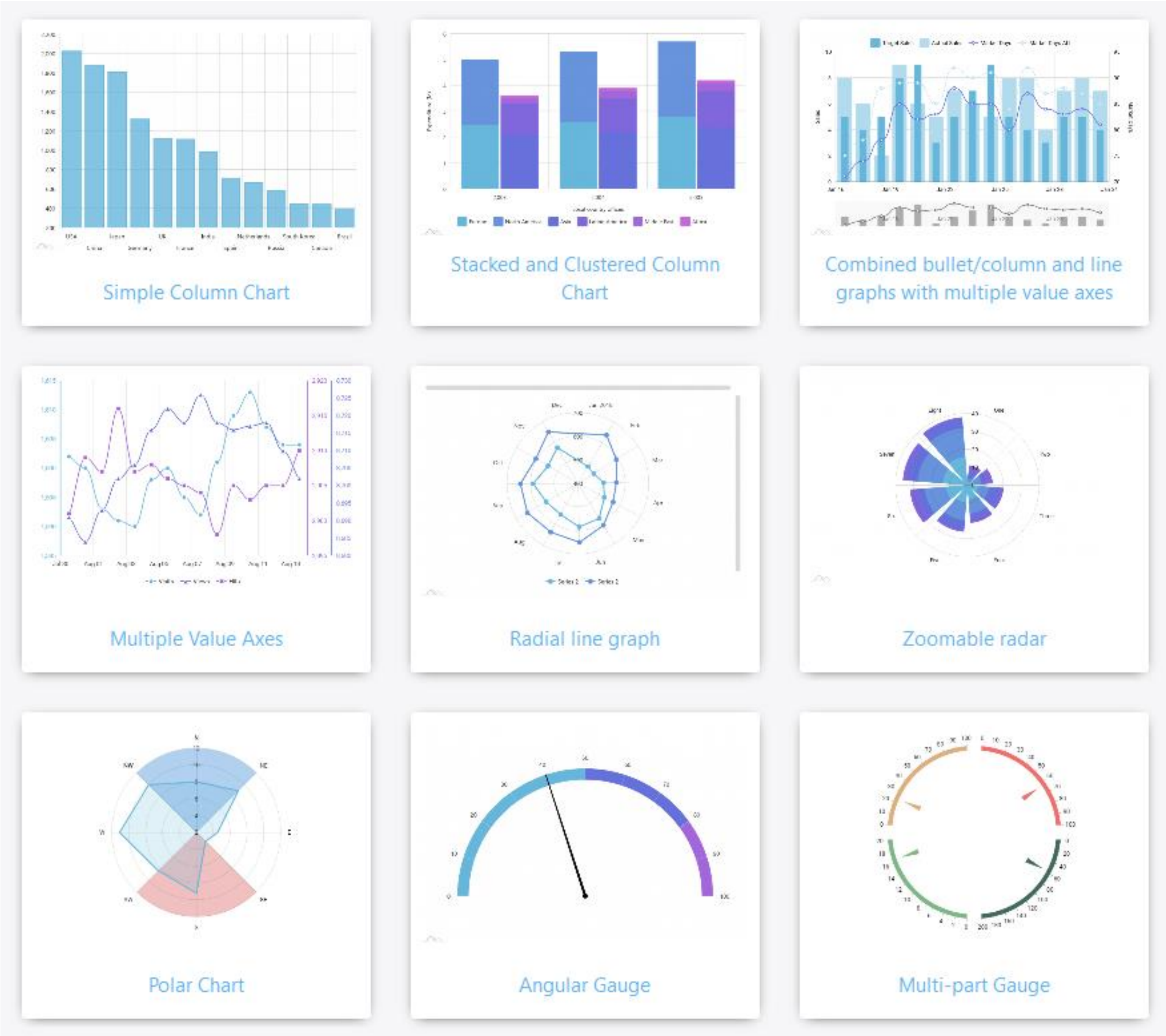


Figure 16 Examples of charts created using amCharts

2.3.3. Analysis of similar tools

The analysis of similar tools for CITYKeys and SCIS projects offers very useful input for the design and development of the IRIS KPIs tool. The following two sub-sections present the main characteristics of each tool.

CITYKeys KPI Tool

The CITYkeys project (http://www.citykeys-project.eu/) created a concrete concept of a performance measurement system for smart cities that can operate either on project level or on a city level. The main idea in CITYkeys is to offer both automatic and manual data collection methods for city and project level indicator values. For the manual mode, supported by web page interface, the values are stored to existing open data portal. On the automatic mode for CITYkeys data collection, the datasets are read via existing Application Programming Interfaces (APIs) and related indicator values are calculated by CITYkeys algorithms. Typically, these data collection APIs are REST based web services which CITYkeys dataset readers could read automatically without user interaction. (CITYKeys Project, 2016). Figure 17 presents an overview of the CITYkeys performance measurement system.

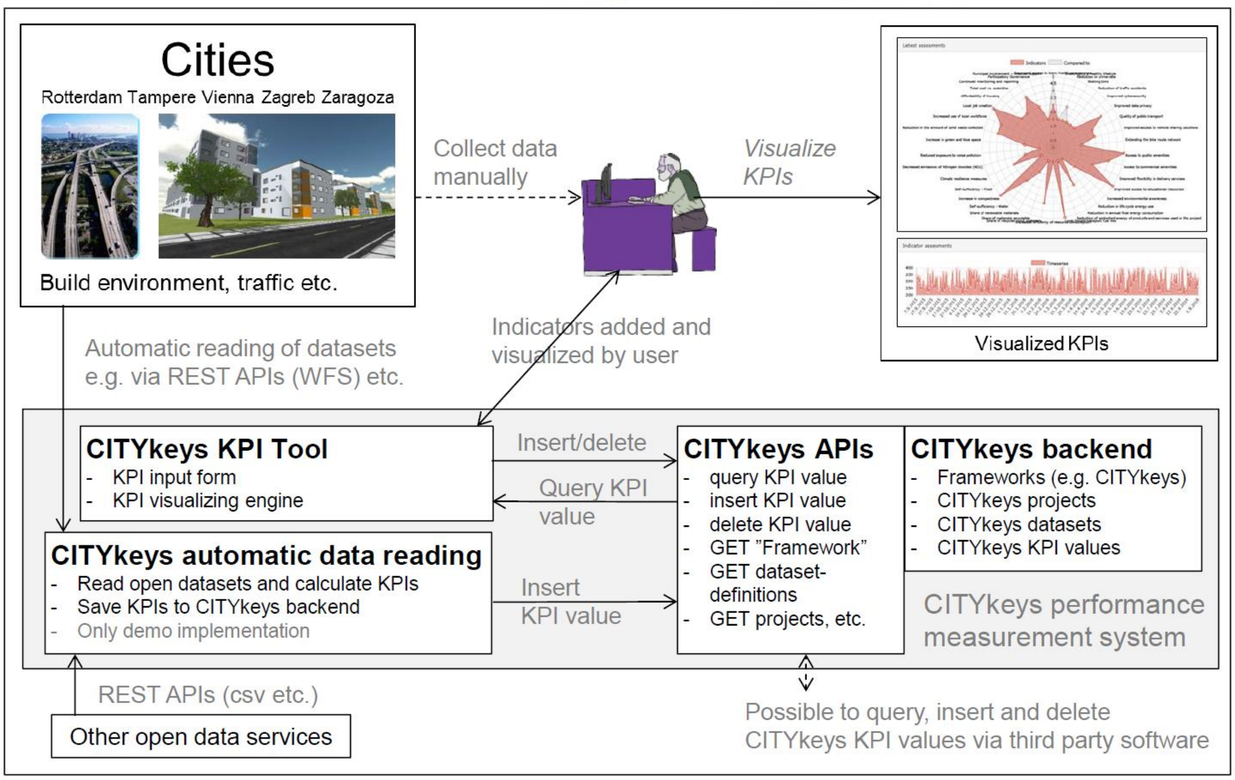


Figure 17 Overview of the CITYkeys performance measurement system (CITYKeys Project, 2016)

The CITYkeys project developed a prototype where only the manual collection method was implemented. CITYkeys prototype platform is available for testing at https://ba.vtt.fi/keystone/kpitool/ using the following credentials: username: demo - password: demo. The prototype provides a very good understanding of how a KPIs tool can present individual KPIs and the comparisons between different KPIs. Figure 0-18 and Figure 19 present two different visualisations produced by the tool, while Annex 3 presents screenshots of the tool.

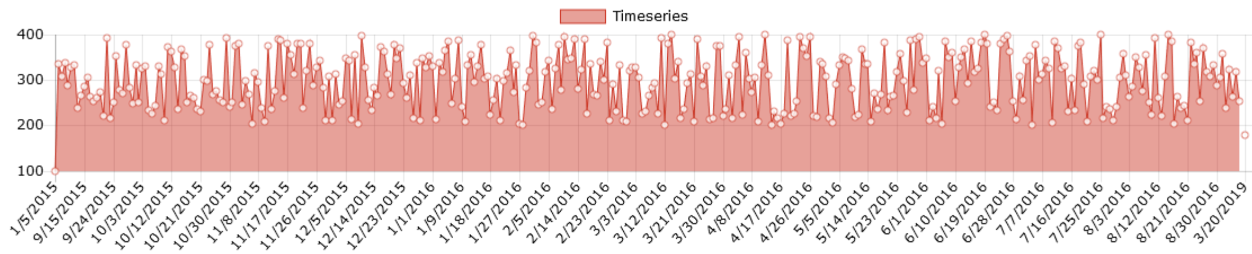


Figure 0-18 CITYKeys water consumption KPI visualisation.

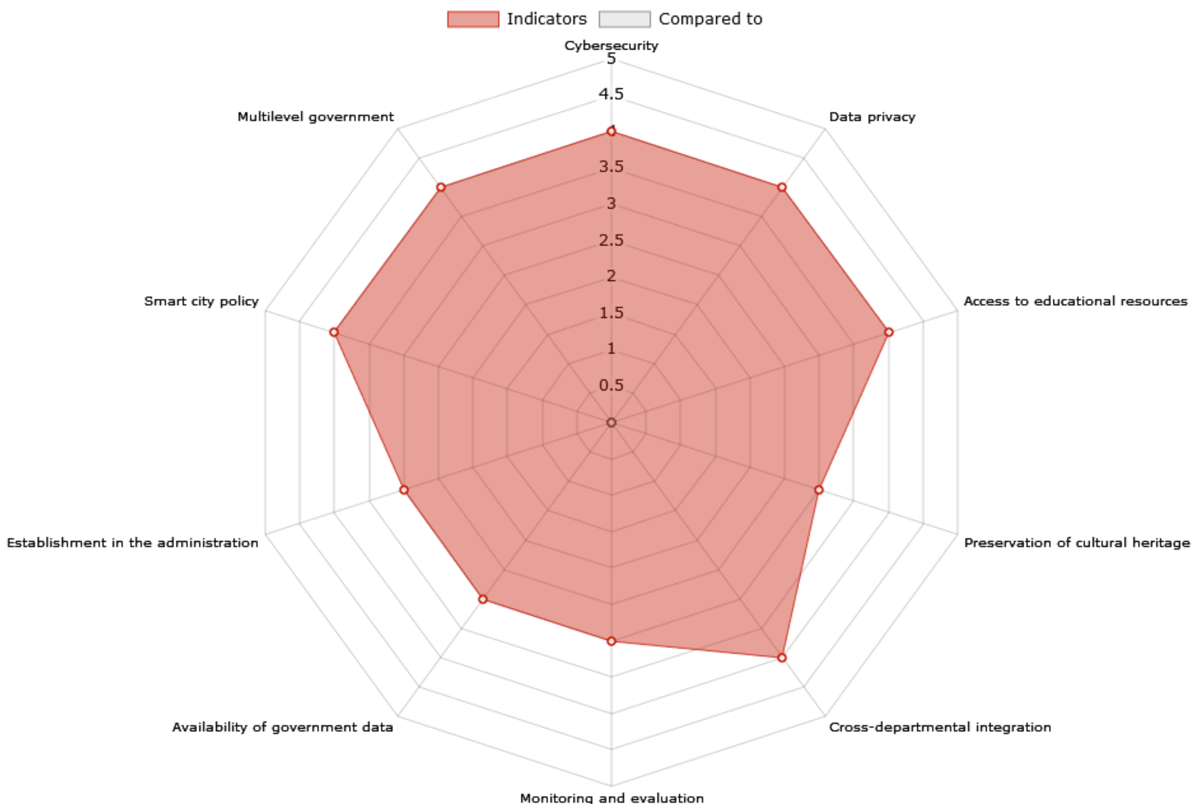


Figure 19 CITYKeys Visualisation and comparison of KPIs with Likert-scale values

SCIS Self Reporting Tool

The SCIS project (https://www.smartcities-infosystem.eu) created a tool that produces KPI visualisations based on data from European smart cities projects. The data available for the different projects were gathered and presented in a comprehensive way to understand the state of the art of the projects financed by the EU. The data is presented per demo site, with a colour and a label that clearly states the name of the demo site and the project. Different KPIs are available to be visualised. The tools is available at https://www.smartcities-infosystem.eu/kpi-visualisation. The following KPIs are supported:

- Final energy consumption in kWh/m^{2}a and MWh/year
- Primary energy reduction in MWh/a and kWh/m^{2}year
- CO2 emissions reductions in tonnes CO_2/a and kg CO_2 /m^{2}year

- Cost of savings in €/kgCO_2*year and €/kWh*year
- Total EC funding (€)
- Specific investment (€/m²)
- Investment - % EC funding compared to total investment of the demo site (€/€)
- Financial performance – payback period (years)

The available data can be grouped in different clusters in order to be better analysed (Climatic zone - HDD, Country, Type of intervention, and Programme). The user must select the category that will be used to group the data (for example, “countries”). Within this cluster, the user must select only the groups that he wants to visualise (for example, “Spain”, “Austria” for countries or HDD: “<1000” for Climatic zone - HDD). Moreover, the user can use advanced filters to select only the projects or demo sites he wants to visualise. Figure 0-20 shows an example of a KPI visualisation.

Figure 0-20 Example of visualisation produced from SCIS KPI visualisation tool

A new, improved version of the tool is under development from the SCIS project (SCIS Project, 2018). The SCIS self-reporting web-based tool aims to provide a tool for project coordinators to report on projects' relevant outputs and information and populate the SCIS database. The users of the self-reporting tool (project coordinators, for example), will use this tool to upload the relevant information on the different interventions carried out on his/her project: new and refurbished buildings, energy supply units (and their integration) as well as mobility and ICT actions. The information reported by the user will be stored in the

SCIS database. This information will be visualised as KPIs and it will be also available for stakeholders to be exported. The data entry is done at two levels:

1. At Demo Site level where the user provides general data about the demo site and create the "Fields of Action" which are relevant for the demo site, and
2. At Field of Action level where the user provides a) design data and b) monitoring data for all the "Fields of Action" which were created in the previous level.

The tool supports the visualisation of 27 SCIS KPIs (Table 5) (SCIS Project, 2018).

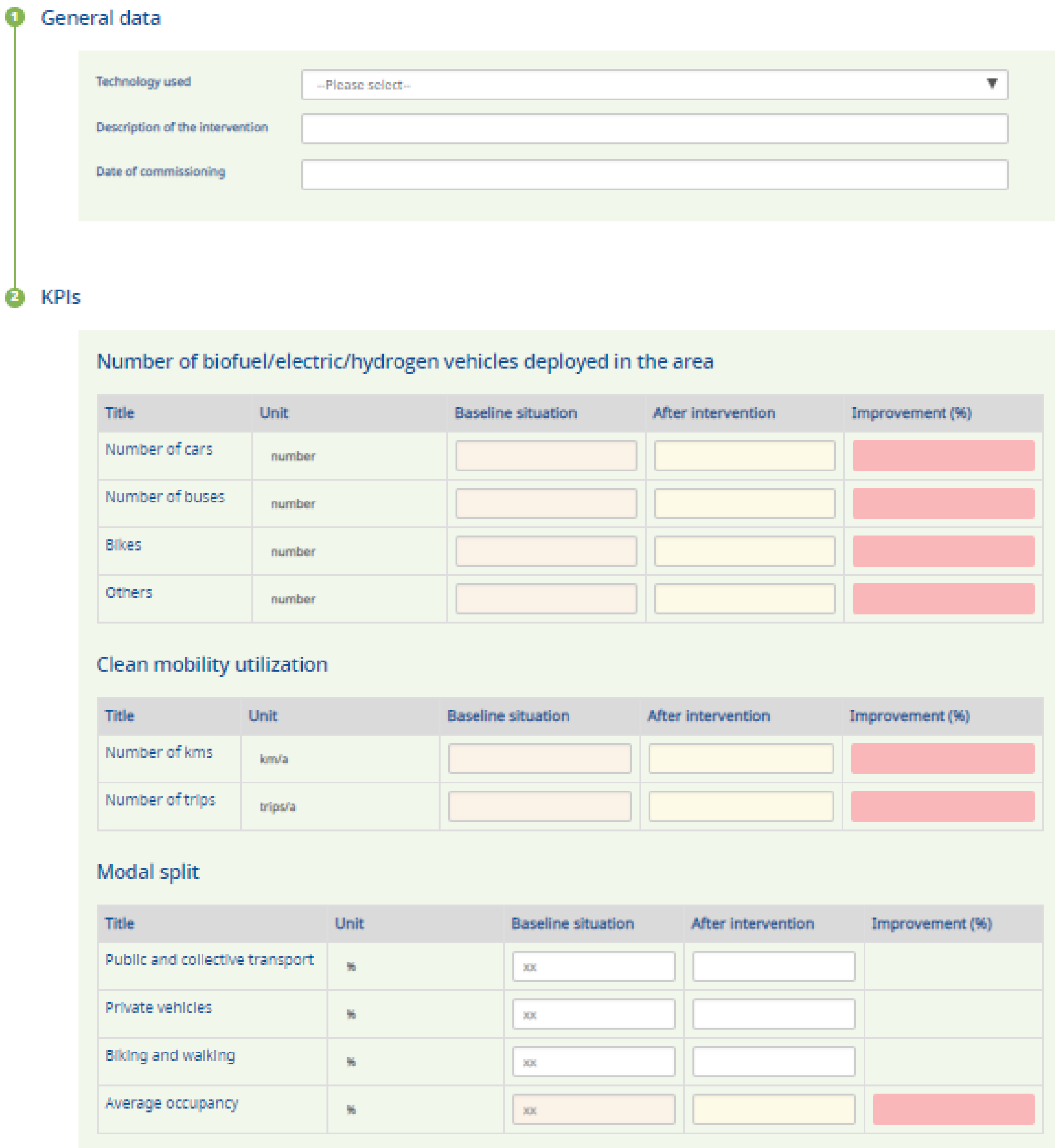
Table 5 – KPIS supported by the SCIS self-reporting tool

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

The SCIS tool supports different levels of aggregation (city, district, neighbourhood, implementation area…) through the following combinations:

- Building
- Set of buildings
- Energy supply unit
- Set of energy supply units
- Buildings + energy supply units
- ICT measures at the building level
- ICT measures at the energy supply unit level
- ICT measures at the neighbourhood / city level
- Mobility measures at the building level
- Mobility measures at the neighbourhood / city level

Figure 21 shows a screen of the SCIS serf-reporting tool. Annex 3 presents more screenshots of the tool.



1 General data

Technology used	--Please select--
Description of the intervention	
Date of commissioning	

2 KPIs

Number of biofuel/electric/hydrogen vehicles deployed in the area

Title	Unit	Baseline situation	After intervention	Improvement (%)
Number of cars	number			
Number of buses	number			
Bikes	number			
Others	number			

Clean mobility utilization

Title	Unit	Baseline situation	After intervention	Improvement (%)
Number of kms	km/a			
Number of trips	trips/a			

Modal split

Title	Unit	Baseline situation	After intervention	Improvement (%)
Public and collective transport	%	xx		
Private vehicles	%	xx		
Biking and walking	%	xx		
Average occupancy	%	xx		

Figure 21 Example of data entry in the SCIS serf-reporting tool

3. Data Collection Framework

This chapter presents in detail how the data required for the KPIs' calculation will be collected from the demonstrations. It presents the same examples as given in D9.3, but this time with additional information for data gathering.

3.1. KPI data requirements

This section will continue the work done in D9.3 chapters 4.x.2. Table 6 will be used which extent the table used in 9.3 by adding the data source.

Table 6 KPI data requirements

Name of indicator	Unit	Formula	Data Source
(17) Increased awareness of energy usage/Increased environmental awareness	Likert		• Smart meter • Survey • Simulation/ theoretical calculation • Other source

3.1.1. KPI data requirements Utrecht examples

Table 7 KPI data requirements for LH city Utrecht

Name of indicator	Unit	Formula	Data Source
Increased awareness of energy usage/Increased environmental awareness (17)	Likert	Not at all – 1 – 2 – 3 – 4 – 5 – very much	Survey
Energy savings (13)	(kWh/(m^2 year); MWh/(year))	$$ES_T = 1 - \frac{TE_C}{ER_T}$$ 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)].	Smart meter

		$$ES_E = 1 - \frac{TE_C}{ER_E}$$ 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)].	
Carbon dioxide Emission Reduction (5)	tonnes CO_2/year	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	Smart meter
Reduced energy costs for consumers (34)	Euro/m^2	$$COST_{REDUCTION} = \frac{COST_{R\&I} - COST_{BaU}}{COST_{BaU}}$$ COST = the electricity price at a given period of time	Smart meter
CO_2 reduction cost efficiency (7)	Euro/ton CO_2 saved per year	This indicator is calculated on an annual basis, taking the annual reduction in CO_2 emissions, and the annual costs of the project (which is the annualised investment plus current	Smart meter

		expenditures for a year). Note: Only the additional costs for energy/CO_2 related measures (to the extent discernible) are taken into account in the total costs' calculation.	
Degree of energetic self-supply by RES (10)	%	$$\mathrm{DE_T} = \frac{\mathrm{LPE_T}}{\mathrm{TE_C}}$$ DET = Degree of thermal energy self-supply based on RES LPET = Locally produced thermal energy [kWh/month; kWh/year] TEC = Thermal energy consumption (monitored) [kWh/(month); kWh/(year)] $$\mathrm{DE_E} = \frac{\mathrm{LPE_E}}{\mathrm{TE_C}}$$ DEE Degree of electrical energy self-supply based on RES LPEE Locally produced electrical energy [kWh/month; kWh/year] EEC Electrical energy consumption (monitored) [kWh/(month); kWh/(year)]	Smart meter

3.2. Monitoring Equipment and other sources of information

The tables described in D9.3 are adapted to include additional information about the measurements. Three new columns are defined:

- **Expected availability:** For the availability the following values are possible: open data, public, confidential, no data available.
- **Data accessibility:** Data accessibility is divided into three categories: 1) Data is available over common networking protocols without access constraints, 2) data is available online, but requires authentication, and, 3) data is not accessible online, or requires manual work to get data out from internal systems. Open data mostly satisfies the first category requirement, as it is also part of the open data definition that data should be accessible in machine readable format, at machine findable location.
- **Expected reliability:** The reliability of the data is divided into three categories: 1) High 2) Medium 3) Low

For those KPIs that will use data automatically collected, Table 8 will be used to collect details about the monitoring equipment and the expected measurements.

Table 8 Monitoring equipment for KPIs

KPI #	Variable (Data type)	Definition	Meter	Location	Expected availability	Collection interval	Expected reliability	Expected accessibility

A similar table will be use in case that data came from other sources (non-automatically) such as energy bills or statistical databases.

Table 9 Other sources of information for KPIs

Variable	Definition	Source	Type	Expected availability	Collection interval	Expected reliability	Expected accessibility

3.2.1. Monitoring equipment Utrecht examples

Table 10 presents the details of monitoring equipment that will be used in Utrecht.

Table 10 Monitoring equipment used in Utrecht (example)

Variable (Data type)	Definition	Meter	Location	Expected availability	Collection interval	Expected reliability	Expected accessibility
Solar_Toon	Actual energy solar energy production.	HEMS_1_Eneco Toon	In every apartment house, in the living room	Confidential	Yearly	High	2
CO2_Toon	Actual CO2 level	HEMS_1_Eneco Toon	In every apartment house, in the living room	Confidential	Yearly	High	2
Bat_storage	Actual energy storage	2. Battery Management System	In 2 apartment buildings, in the garage box	Confidential	Yearly	High	2
Solar_house	Energy generated by solar energy (input from the invertor)	3a. Electricity meter in fuse box (DIN-rail)	In every apartment house, in the fuse box	Confidential	Yearly	Low	3
Solar_inv	Energy generated by solar energy	Electricity meter in invertor	In every apartment house, in the electricity cabinet	Open	Yearly	High	1
Heat_distr	Heat power/flow	District heating meter	In every apartment house, in the central heating cabinet	Confidential	Yearly	High	2

3.3. KPIs based on Surveys

Table 11 to Table 13 presents the KPIs, which will be evaluated through data collected in the form of questionnaires.

Table 11. Solutions that will be evaluated using surveys in Utrecht.

Solutions using surveys as data source	Data point	Related KPI	Source	When to measure
V2G e-car sharing system 'We Drive Solar'(TT3)	Surveys/interviews concerning access to vehicle sharing solutions	Improved access to vehicle sharing solutions	LOM + UTR	Date to be set (First before M38)
Community building (TT5)	Environmental awareness	Increased environmental awareness	BOEX	Date to be set (First before M38)
	Satisfaction of involvement from the tenants	Local community involvement in planning/ implementation phase	BOEX	Date to be set (First before M38)
	Feeling of involvement in the community/ Social cohesion	Evaluation and co-creation	BOEX	Date to be set (First before M38)
Evaluation and co-creation (TT5)	Satisfaction of implementation of the EMS TOON	Evaluation and co-creation	BOEX	Date to be set (First before M38)
	Environmental awareness by using EMS TOON	Increased environmental awareness	BOEX	Date to be set (First before M38)
	Advantages of EMS TOON for end users (Likert or lowered energy bills)	Advantages for end users	BOEX	Date to be set (First before M38)
	Satisfaction of tenants/ How the home EMS TOON is perceived as easy or difficult to understand and use	Ease of use for end users of the solution	BOEX	Date to be set (First before M38)
Campaign using Smart lamp posts (TT5)	Environmental awareness by Campaign using Smart lamp posts	Increased environmental awareness	UTR	Date to be set (First before M38)
Campaign District school involvement (TT5)	Satisfaction of involvement in campaign from the students	Local community involvement in planning/ implementation phase	UTR	Date to be set (First before M38)
New Home & District Experience (TT5)	Satisfaction from tenants using the virtual reality platform	Ease of use for end users of the solution	BOEX	Date to be set (First before M38)

Table 12. Solutions that will be evaluated using surveys in Nice.

Solutions using surveys as data source	Data point	Related KPI	Source	When to measure
LEM (TT2)	Awareness of energy usage	Increased awareness of energy usage	EDF	Date to be set (First before M38)
The free-floating project (TT3)	Surveys/interviews concerning access to vehicle sharing solutions	Improved access to vehicle sharing solutions	VULOG	Date to be set (First before M38)
	Survey concerning ease of use for end users of the solution	Ease of use for end users of the solution	VULOG	Date to be set (First before M38)
SERVICE BLEU (TT5)	Satisfaction from users of SERVICE BLEU, how the app is perceived as easy or difficult to understand and use	Ease of use for end users of the solution	NCA	Date to be set (First before M38)
Smart Management of Peak Pollution (TT5)	Satisfaction from users of Smart Management of Peak Pollution	Ease of use for end users of the solution	VEOLIA	Date to be set (First before M38)
	Environmental awareness by using Smart Management of Peak Pollution	Increased environmental awareness	VEOLIA	Date to be set (First before M38)
CIVOCRACY (TT5)	Satisfaction from users of CIVOCRACY (Likert)	Ease of use for end users of the solution	NCA	Date to be set (First before M38)

Table 13. Solutions that will be evaluated using surveys in Gothenburg.

Solutions using surveys as data source	Data point	Related KPI	Source	When to measure
EC2B (TT3)	Survey concerning ease of use for end users of the solution	Ease of use for end users of	TRIV	Date to be set (First before M38)
	Surveys/interviews concerning access to vehicle sharing solutions	Improved access to vehicle sharing	TRIV	Date to be set (First before M38)
Spatial planning design contest for children and youths (TT5)	Satisfaction of the involvement in the Minecraft competition	Local community involvement in planning phase	GOT	Date to be set (First before M38)
Citizen engagement (smart city hub) (TT5)	Satisfaction of the open data	Accessibility of open data	GOT	Date to be set (First before M38)
Citizen engagement (Inclusive Life Competition) (TT5)	Satisfaction of citizen engagement challenge	Trialability	GOT	Date to be set (First before M38)
BIM (TT5)	Environmental awareness	Increased environmental awareness	HSB	Date to be set (First before M38)

Personal Energy Threshold (PET) (TT5)	Environmental awareness	Increased environmental awareness	HSB	Date to be set (First before M38)
	Satisfaction from the tenants using PET	Local community involvement in implementation phase	HSB	Date to be set (First before M38)

3.4. Data quality assessment

This section presents the procedure to evaluate the quality of data. According to (Askham, et al., 2013) there are six dimensions of data quality; completeness, uniqueness, timeliness, validity, accuracy and consistency. Depending on the type of data, different quality dimensions apply. The different dimensions of data quality assessment are presented below with a suggested approach to measure the quality.

The procedure to assess the data quality will be to:

- Identify critical data sets for each KPI, the required quality of data may differ between KPIs
- Determine what data quality dimensions are useful to assess the quality for each data set (see dimensions below)
- Define the range that indicates good or bad quality data for the chosen dimensions, this range may differ for different KPIs using the same data set depending on the data requirements of the KPI
- Apply the criteria to the data sets evaluated
- Review the results and decide whether the data quality is sufficiently good
- If possible, correct data of insufficient quality

3.4.1. Completeness

Completeness of data refers to the proportion of accessible data compared to the potential of 100% complete data. Depending on the data requirements of the KPI to be calculated, the data set could either be left as it is or corrected through imputation of data. Missing values can in some cases be corrected through interpolation.

3.4.2. Uniqueness

The dimension uniqueness refers to that the same data point should not be repeated more than once. If duplicates are discovered these need to be removed from the data set.

3.4.3. Timeliness

Timeliness refers to the degree to which data represent reality from the required point in time. For example, timeliness can in IRIS refer to that the energy use reported for a certain time period corresponds to the actual energy use for that period. The timeliness can be ensured through time stamps on the data received.

3.4.4. Validity

Data of the right format, type and range is considered valid. Depending on the type of data, allowed format and data range (minimum, maximum) can be decided. The validity of the data can be assessed through comparing the metadata or documentation of the data to the requirements. A percentage of valid to invalid data items can be used as a measurement of the data validity.

Another aspect of the validity is whether the data complies to Data Catalogue Vocabulary (DCAT) standards. The DCAT standard facilitates interoperability between data catalogues published online by describing a standard for metadata. When describing datasets through DCAT, the data is more easily discovered and enable applications to combine or search across multiple data catalogues. This aspect of data quality is not necessary for the evaluation of the project but is of value to the City Innovation Platform.

3.4.5. Accuracy

The accuracy of the data set describes how well the data corresponds to the “real world” object or event. This can be assessed for example by comparing the data to data from a reliable source. The accuracy relates very much to the validity of the data, data that is out of range could be inaccurate and should be further analysed.

3.4.6. Consistency

Consistency refers to that data describing the same object or event should not be different. The datasets should be compatible to previous data and presented in the same format.

4. Data Analysis and Visualisation Framework

This chapter presents how the collected data will be analysed to produce each KPI and relevant visualizations. The main workflow is as follows (Figure 22):

- Data acquisition layer: develop the mechanisms that reliably record all related raw data in a valid format commonly agreed and standardized within the consortium
- Data analysis layer: define the tools able to filter and fuse data from heterogeneous sources and process them in an efficient and methodologically sound way
- Dashboard layer: produce the most appropriate visualisation diagrams for each KPI for meaningful representation of results

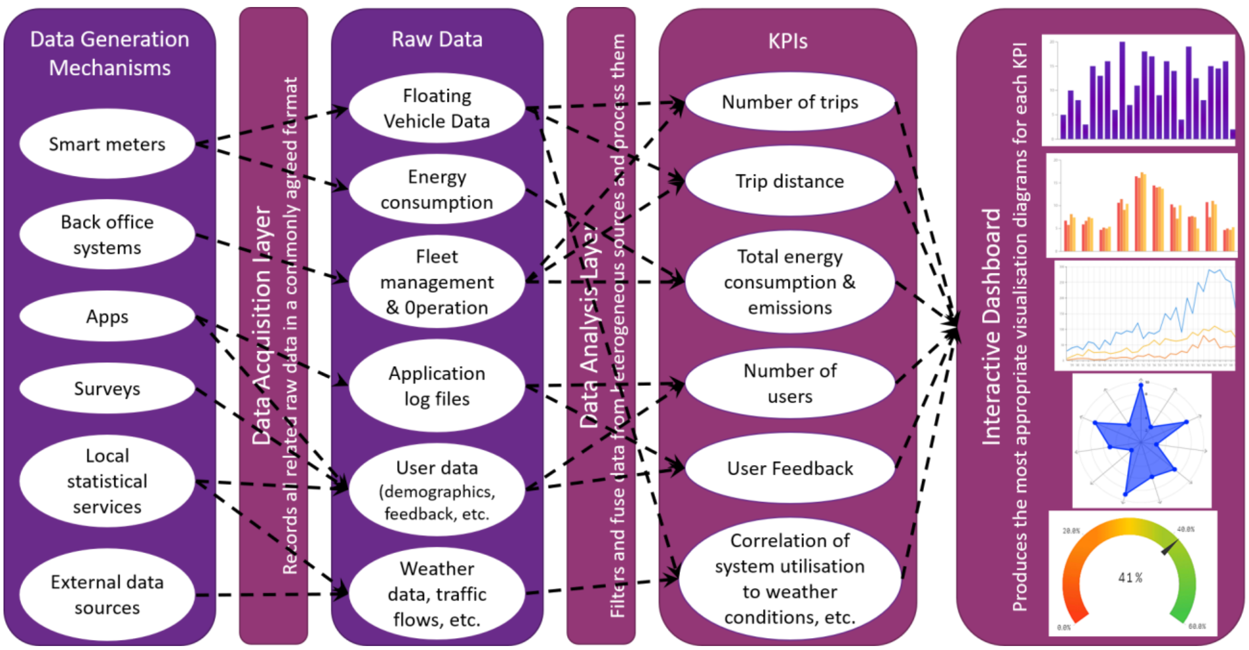


Figure 22 Workflow from generation of raw data to the production of visualizations

The implementation of data analysis and visualization utilizes the 6-step methodology defined in section 2.2. An example is presented below, concerning the KPI related to the yearly km made through the e-car sharing system instead of private conventional cars.

4.1. Data analysis

This section consists of the five first steps of the methodology applied to the KPI “yearly km made through the e-car sharing system instead of private conventional cars”.

STEP 1 Definition of Objectives: The objective of this indicator is to monitor the extent to which the EV sharing system is utilized. Obviously, this indicator is relative to city-specific measures like its total area, transportation network size, population and number of EVs offered to the public.

STEP 2 Description of the results: The level of adoption of the service is indeed critical for the involved stakeholders, with both financial and environmental impacts. It is important to accurately estimate the monetary effects on the end users and measure the environmental footprint of the EV sharing service in comparison to traditional mobility with privately owned vehicles.

STEP 3 Identification of measures: The specific variable to be calculated for this objective is the total kilometres covered with EVs from the sharing system instead of private conventional cars, within a year.

STEP 4 Measurements and storage of the data: Data recorded from different sources will be fused to extract the desired measure (Figure 22). The main source is the Global Navigation Satellite System (GNSS) enabled on-board sensors which accurately log vehicle kinematics data with high temporal frequency. At a minimum level, those sensors record a vehicle's coordinates, instantaneous speed (both magnitude and orientation) and corresponding timestamps. Such datasets are commonly known as Floating Car Data (FCD). The second source is the mobility service provider. The operator monitors the EV fleet for operational and management purposes, consequently its back office can serve as a complementary database.

The high logging frequency of FCD is known to produce data with great granularity, in real-time (velocity) and volume directly proportional to the number of electric vehicles. Those two are the most common characteristics of what is nowadays called 'Big-Data'. The most reliable and robust mean for storing the FCD is to utilize databases optimized for huge volumes of structured data or adopt Big Data technologies utilizing cloud-based services, known for their scalability.

STEP 5 Processing the data: This step is implemented after the database is populated with trip records from all the EVs that belong to the car sharing system. For each vehicle and each completed trip, the distance is derived by processing the sequence of GNSS pulses of the vehicles (which include timestamps and vehicle coordinates).

The results of this procedure continuously populate a table, where each row corresponds to one EV completed trip. The vehicle ID, user ID, IRIS test site, date and length of trip are recorded. Such details are crucial for the analysts who need to perform customized aggregation of records according to specific needs, for example temporal aggregation of trips within specific time periods or aggregation of trips from a certain type of EV. Each city can design the mechanisms to gather trip data into this structure, all following commonly agreed specifications.

Furthermore, the derived indicators can be normalized regarding specific information of each test city. This way, comparisons of results among different cities, time periods and type of vehicles are meaningful and straightforward. For example, the total km travelled with EVs in each city should be normalized by the total number of available EVs to derive an indicator of total km per EV. In a similar fashion, the total km can be normalized by the total number of people with access to the system to formulate an indicator describing travelled distance per person.

This normalization should be also done at city level, for example by dividing the total distance by the average distance travelled in the city by conventional vehicles, in which case will generate a dimensionless indicator (a pure number without measurement units) and therefore comparable among different cities. In addition, other measures can be used for normalizing the indicators, such as the "diameter" of the city, the number of inhabitants, the car ownership, the modal share of Put and many others.

4.2. Data visualisation

This section consists of the final step of the methodology, concerning visualizing and interpreting the results of data analysis.

STEP 6 Visualization and Interpretation of the results: In this step, the results of data processing are visualized. A first graph is a simple bar chart with the non-normalised total km of distance travelled with EVs from the sharing system per city, which provides with an initial, general view of the comparative adoption of the system. This plot can be used for large periods and therefore see the evolution of the usage of the system, or for averaging the values per day and showing the usage of the system within the week (it will be interesting to see if the system is mostly used during weekdays for short-work-home trips or during the weekends for long-leisure trips). A pie chart can be also created, with each slice corresponding to a test city and its size proportionate to the percentage of km travelled to this city. Furthermore, the normalized indicators can be used to generate the same visualizations for relative comparisons amongst the km per EV and km per citizen of the involved cities.

More diagrams are created to present results at city level. The dates of the trips are recorded, therefore the distribution of distance travelled with respect to time provides with insights on the evolution of the system in time. In the case of different types of EVs offered within a city, a pie chart demonstrates the percentage share of each type regarding distance travelled.

A huge advantage of the visualization tool is its interactivity. The user can define certain parameters to produce customized visualizations. As an example, finer-grained distribution plots can be generated with results grouped by hour, weekday, month or even season to uncover the association between driven distance and specific time periods. Moreover, the user can filter the data according to the IRIS site, date periods, types of EV etc., before the graphs are produced.

Finally, for the mobility use case it will be interesting to identify from the data collected and the indicators estimated the different user profiles in each city making use of the car-sharing and electric vehicles services. These profiles will consist of socio-economic characteristics as well as service usage indicators, consisting of number of trips per week (differentiating between weekdays and weekends), the average distance and duration, the pick-up and drop-off locations and many others. In order to illustrate how a profile will look like, two possible profiles are provided below (Table 14):

Table 14 User profile characteristics for the mobility TT

Characteristics	User profile 1	User profile 2
Gender	Non-relevant	Non-relevant
Age	20-30	30-45
Number of trips per week	10 (2 every weekday)	1 (during the weekend)
Average distance	5 km	200 km
One way or round trips?	One way	Round trip

From the above results it can be concluded that in the IRIS city x there are two types of users, one using the system for going every day from home to work and back, and one using the service for a long trip during the weekend, most probably with the family.

Some visualization examples are presented in the following figures and graphs. Figure 23 presents the volume of traffic flows between 8 locations, and Figure 24 is a heatmap designating the busiest road network spots.

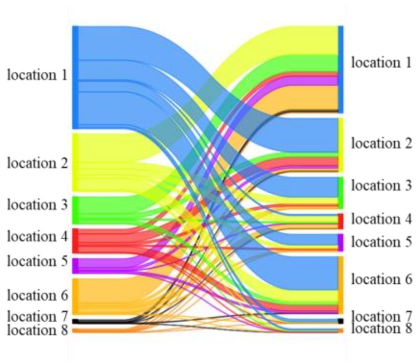


Figure 23 Data flows example diagram

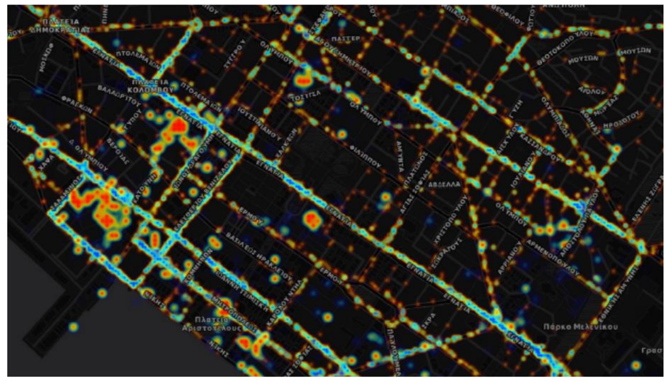


Figure 24 Heatmap example diagram

Figure 25 shows the number of trips that started and ended from the same station of a bike sharing platform, and the bikes balance.

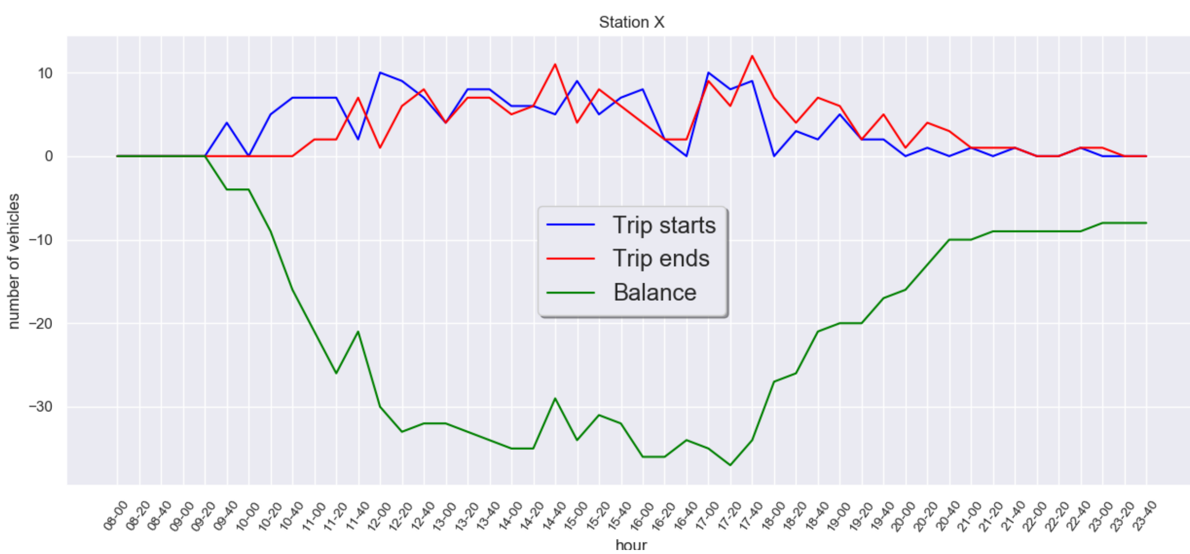


Figure 25 Example Diagram presenting trips starts, ends and balance of bike sharing station

Figure 26 shows a summary of statistics and indicators extracted from this system's utilization data.

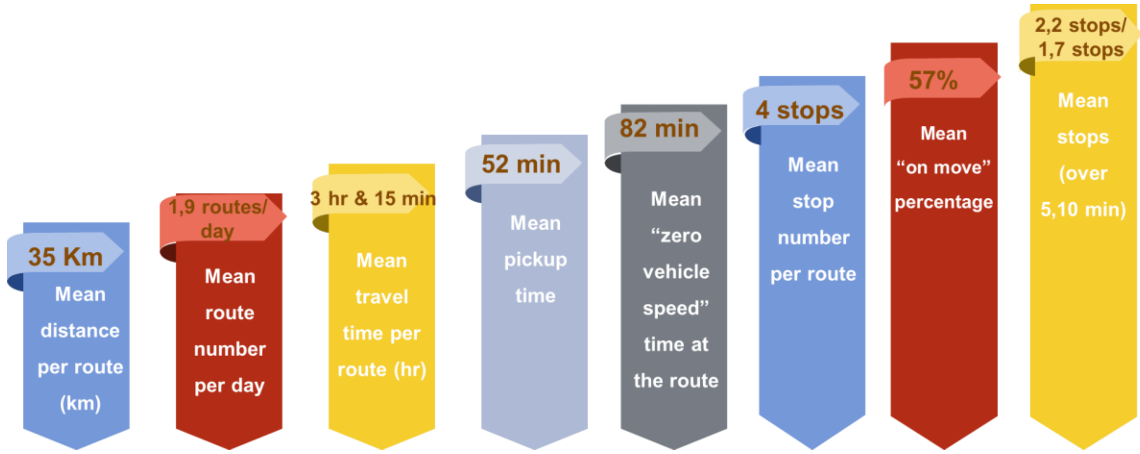


Figure 26 Summary of main trip indicators

User feedback will also be recorded from surveys, and Figure 27 provides a presentation of results from a 5-point scale Likert type questionnaire.

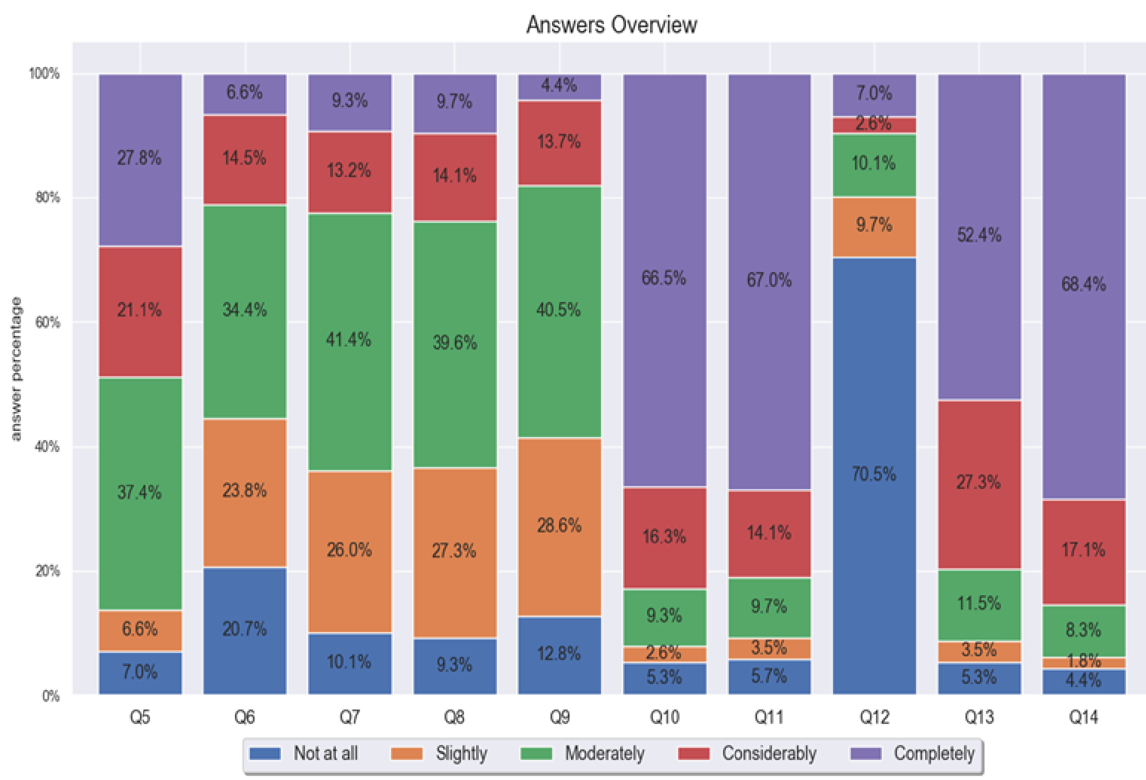


Figure 27 Example diagram presenting a summary of questionnaire's results

5. IRIS KPIs Tool

5.1. Overview

The IRIS KPI tool is available at http://monitoring.irissmartcities.eu. The tool is a platform that can store, manage, process, visualise and share project monitoring data from the three LH cities. The tool captures monitoring data from various sources and uses these data to calculate the KPIs that have been selected in each demonstration.

The monitoring data from the IRIS demonstrations are captured through an automated or manual way. The automated process involves a connection between the KPIs tool and the online backend of the organisation that collects and stores the monitoring data in each demonstrator (KPI data owner). This connection is facilitated by the IRIS City Innovation Platform (CIP). The manual process allows certified users to log in and upload a file with monitoring data. The KPI tool backend analyses and models the collected data, calculates the KPIs and visualises them in an interactive web-based Monitoring Dashboard to indicate the measured performance of an intervention compared to the targeted impact. The IRIS partners, as well as the general public, can access the dashboard, in order to view, monitor and compare the performance of the three LH cities. Moreover, the calculated KPIs can be stored in the CIP of each LH city. The collected data can be also used to feed the Smart Cities Information System Self Reporting Tool (SCIS SRT).

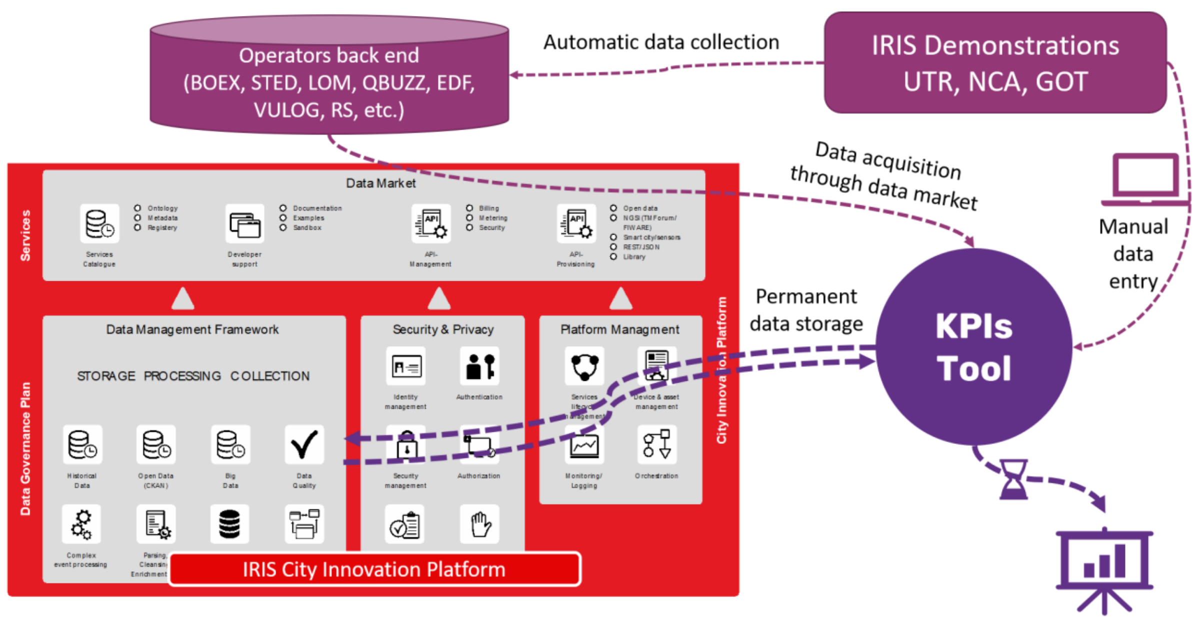


Figure 28 Schematic diagram presenting the connection of the IRIS KPIs tool with CIP and LH cities' demonstrations

The current version of the KPIs tool is a prototype that calculates and visualises all KPIs. There is an ongoing collaborative process with the KPI data owners and the other project partners to customise the tool according to their preferences and requirements. This process will ensure that the KPIs tool will effectively support the project's monitoring, evaluation and impact assessment procedures. In the following subsections present the KPIs tool in detail.

5.2. Use Cases – Core Functionality

The IRIS KPIs tool supports the project's monitoring activities and the overall evaluation and impact analysis of the interventions in the LH cities. It presents to the KPIs at different levels of detail, i.e. measure (demonstrator), Transition Track, LH city and, finally, IRIS project. The functionality of the tool emerged from the needs and requirements of the users. There are three types of users:

(1) The administrator: The administrator has full access to all components, configures and manages them and performs all the required technical actions ensuring smooth operations of the tool. Regarding the KPI Monitoring Dashboard, the administrator creates the different views that present the KPIs and selects the chart that is the most suitable for each KPI.

(2) The IRIS user: The IRIS user represents three types of IRIS partners:

1. Partners that are involved in the interventions in LH cities (LH cities Site Managers, TT leaders and local partners in general). These partners want to monitor and evaluate their measures, and also to compare the performance and impact of their implementations against similar measures implemented in the other LH cities.
2. Partners from Fellow cities. These partners want to identify interventions with the most significant impact in order to replicate them in their cities.
3. Partners that are involved in the horizontal WPs (monitoring and evaluation, business modelling, project management). These partners want data so that to evaluate the results, create bankable business models, follow the project implementation, etc.

The IRIS user is the typical user of the tool. (S)he can see the numerical values of the KPIs but also performance data (i.e. the numerical values of the variables that are used in the calculation of each KPI). Moreover, the IRIS user can see the numerical values of KPIs at different levels of spatial aggregation (i.e. IRIS project, LH city, Transition Track, Measure, Building / District / System). The following views are available for the IRIS user:

- **IRIS Project View**
    - KPIs at the RIS level (consolidated)
    - KPIs per LH city (consolidated at the city level)
    - KPIs per TT (and city)
- **LH City View**
    - KPIs at the city level (consolidated)
    - KPIs at the TT level (consolidated)
- **Transition Track View**
    - KPIs at the TT level (consolidated)
    - KPIs at the Measure (Demonstrator) level
- **Measure View**
    - KPIs of the measure
- **Building / District / System View**
    - KPIs for the Building / District / System
- **KPI View**
    - Value at IRIS Level
    - Value at LH City Level

- Value at Transition Track Level
- Value at Measure Level
- Building

To be able to evaluate each measure against the expected impact, for each KPI apart from the numerical value, the tool also displays the target value.

The IRIS user can access the KPI Monitoring Dashboard using a username and a password.

(3) **General Public:** This type of user represents anyone interesting in the results of the IRIS project. The visitor of http://monitoring.irissmartcities.eu can use the KPI tool without a user account but with limited functionality compared to the IRIS user. The following views are available for the public user:

- **IRIS Project View**
- **LH City View**
- **Transition Track View**
- **Measure View**

Apart from the limitations in the level of spatial detail, the public user will experience similar functionality with the IRIS user.

Based on the needs of the specific users, the following capabilities are required from the IRIS KPIs tool:

- **Collect monitoring data automatically and manually:** The tool must collect monitoring data from the demonstrations in the IRIS LH cities. The tool should collect data automatically from the databases of the organisations that hold the monitoring data. Moreover, a manual way should be available for the LH cities to post data, in case that monitoring data are not available online. The CIP Data Market component automatic facilitates the automatic collection of data.
- **Calculate KPIs values for various aggregation levels:** The tool must calculate the KPIs not only at the measure level but also for the different aggregation levels (i.e. TT, LH city, IRIS project). The calculation follows the KPIs formulas available in the KPIs cards. The way that the KPIs is aggregated in the different levels is presented in D9.5.
- **Present KPIs values and monitoring data:** The tool must facilitate users to evaluate the impact of the IRIS solutions. Thus, various dashboards should be available, presenting KPIs values at different levels of spatial aggregation, their evolution over time, and the contribution of each measure in the KPI value.
- **Export KPIs values and monitoring data:** The tool must export data to the CIP of each LH city to be available to the local ecosystem. Moreover, it should support the process of adding IRIS monitoring data in SCIS Self Reporting Tool.

5.3. High-level architecture

To support the required functionality, the IRIS KPIs tool is developed around five components that collect, store, analyse, present and export monitoring data from the IRIS demonstrations. Figure 29 presents the high-level architecture of the KPIs tool. The components are presented in detail in section 5.5.

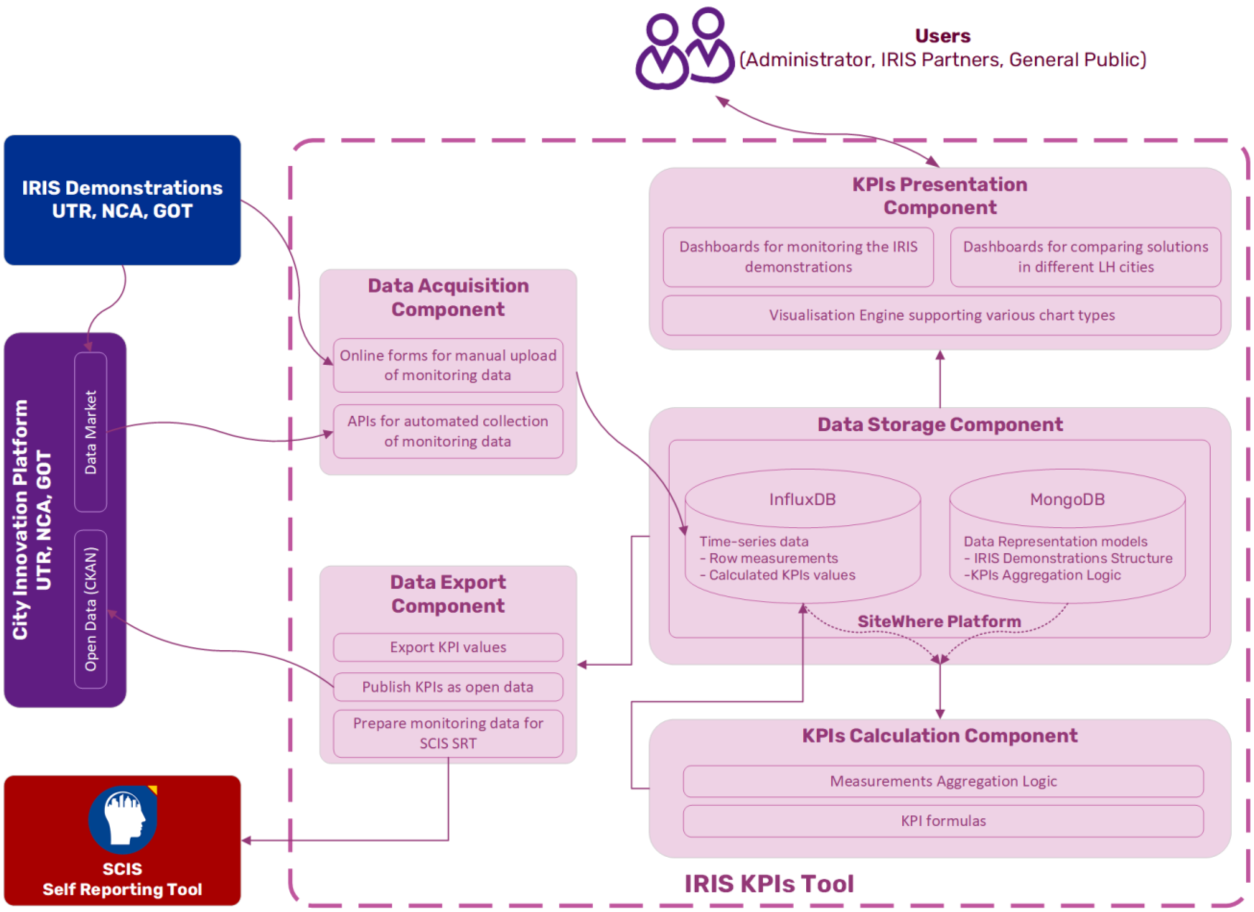


Figure 29 – IRIS KPIs tool high-level architecture

5.4. Data Models

A set KPIs has been defined by the consortium, for the evaluation of the LH cities performance in terms of technical, environmental, economic, social and ICT aspects. For the calculation, visualization and monitoring of those KPIs in accordance to the different project levels (City, Transition Track, etc.) a set of data models, as well as a relational model, have been defined.

The relational model between the IRIS defined entities was built according to D9.2 and the ongoing work of D9.5. An example of the relational model of Nice, with an emphasis in TT1, is given in the following figure.

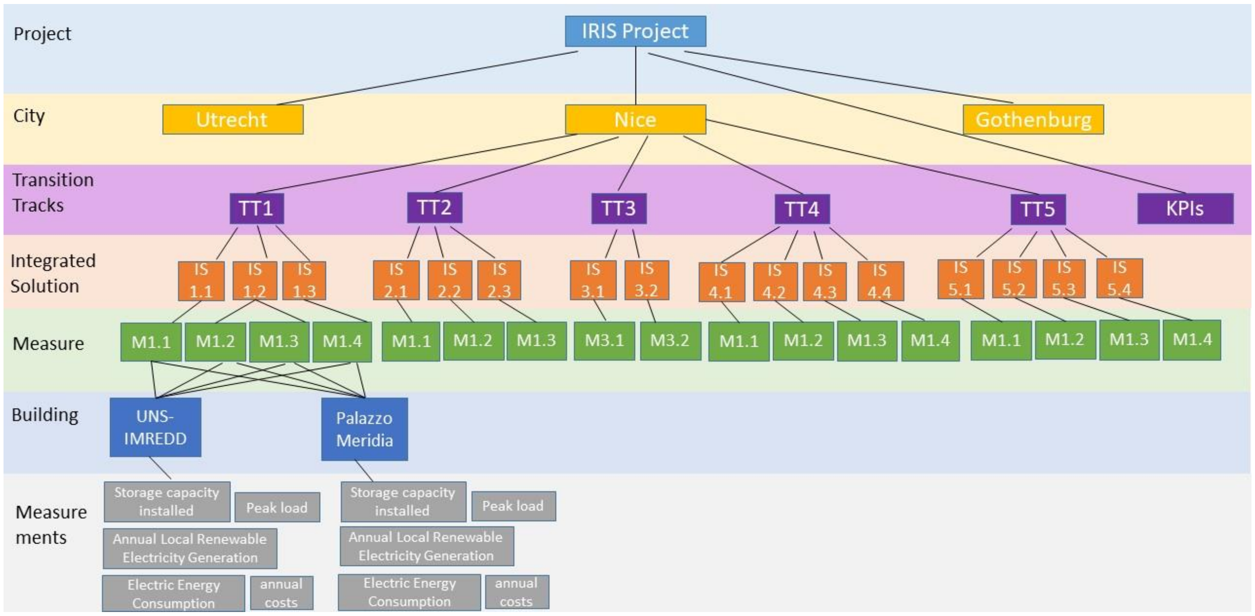


Figure 30 - Relational model: TT1 Nice example

The respective structure in the KPI Tool is as follows. The figures show the Buildings, the Measures and the Integrated Solutions that belong to the TT1 of Nice.

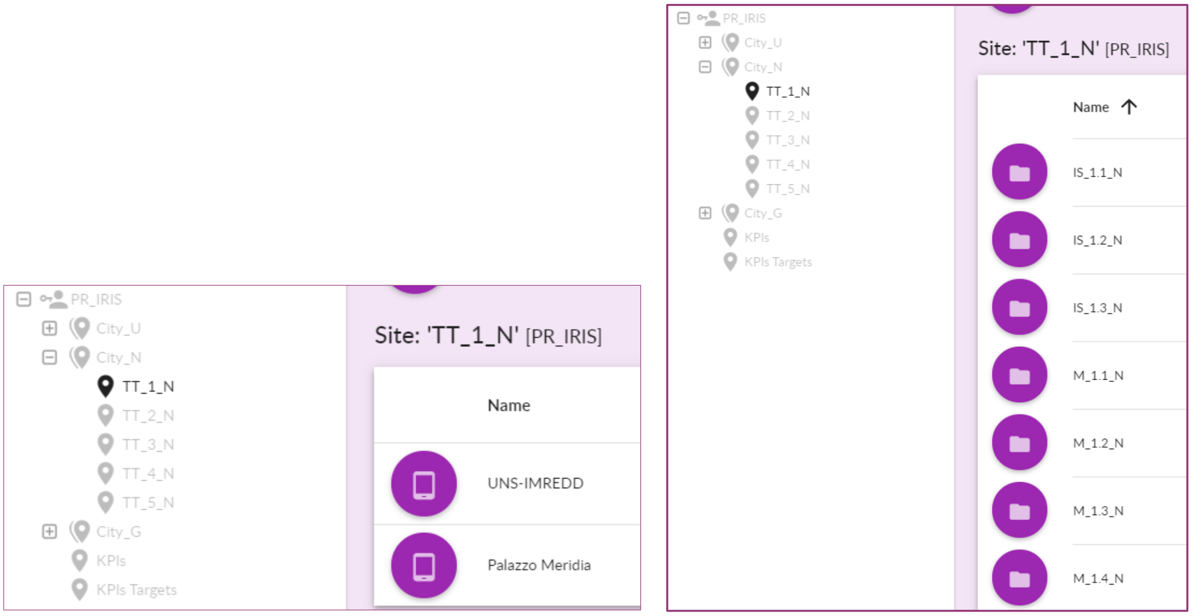


Figure 31 Relational model in the KPI tool

Two types of data models have been specified for the lowest level entities of the relational data model. One type is assigned to the entities that provide the raw measurements for the KPIs calculation, which could be a Building, a District or a System, in general. The second type is assigned to the KPIs and specifies the different aggregation levels for which they should be calculated. The two-model type can be seen in the following figure.

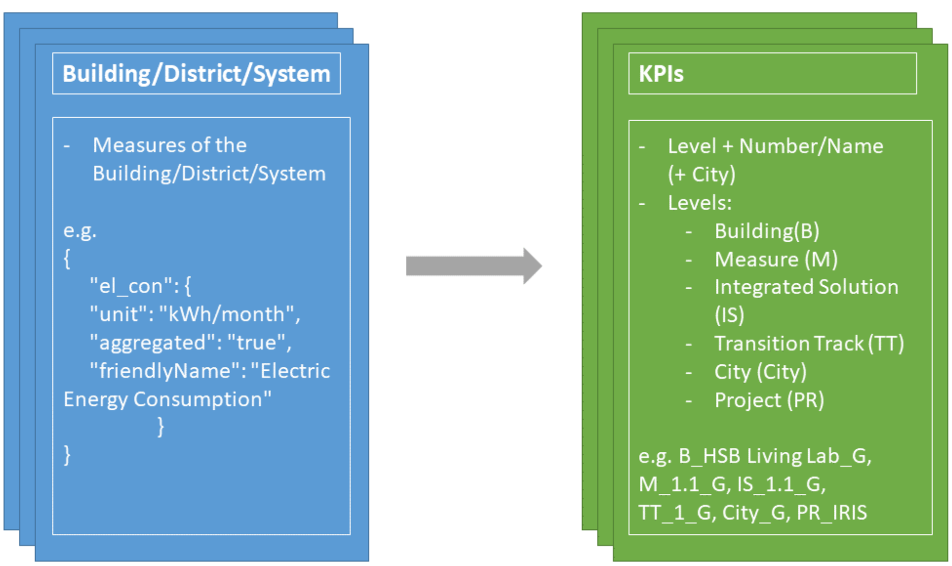


Figure 32 The two types of data models

In the KPI Tool, we have specified different models for the different types of Building according to the measurements that each one provides. The same principle applies for the KPIs. For each KPI, we have specified a different data model, which specifies the different project entities for which the KPI applies.

For example, the specification for the type of Buildings in TT1 of Gothenburg describes a number of measures that they provide for the calculation of the KPIs that they support.

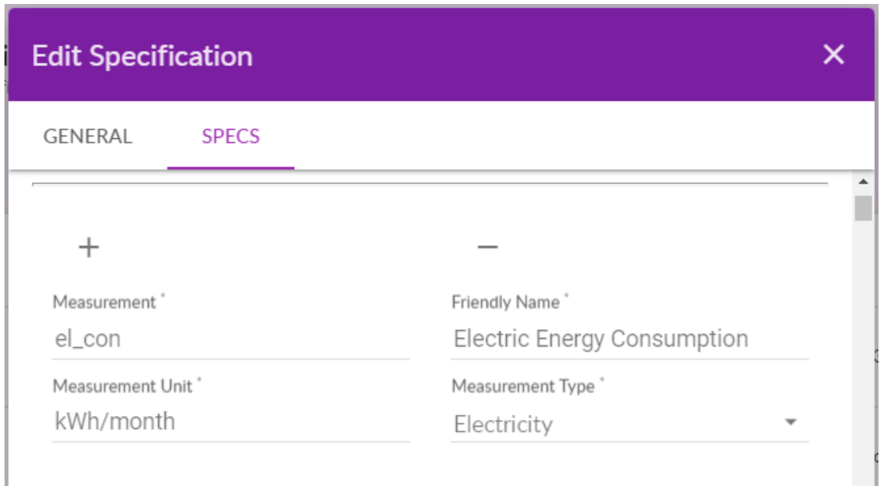


Figure 33 Specifications of the data model of Buildings in Gothenburg

5.5. Implementation of the Technical Components

The five different components that comprise the KPI Tool architecture will be described in detail, under this section.

5.5.1. KPI Tool Server

The KPI Tool's server is the central component of the system. It is responsible for the handling of all data, like the measurements coming from the LH cities, the calculated KPIs and the structure of the different IRIS project levels. The server is based on a platform that has been developed by CERTH/ITI, primarily for the purposes of IoT applications, the pragma.IoT platform[1]. The pragma.IoT platform offers frontend and backend capabilities, exploiting features from another open-source IoT platform, called SiteWhere[2]. The basic SiteWhere functionality that is used is the RESTful services, which allow an external entity to create, view, update, or delete entities in the system.

The IRIS entities have been mapped to the SiteWhere entities, in order to convert the platform to a KPI monitoring tool for the IRIS LH cities and potentially the follower cities. A NoSQL database, MongoDB[3], is used to store those entities and their relations, that basically refer to the Data Models that have been described in section 5.3, as for example, the relation between the Measures of an Integrated Solution that belongs to a specific Transition Track of a particular City. On the other hand, the raw measurements from the LH cities as well as the calculated KPIs for all the different levels of the project are stored in an open-source, SQL-like, time-series database (TSDB), InfluxDB[4], which is optimized for fast, high-availability storage.

In order to access the IRIS entities and their values, the tool offers, as previously mentioned, a set of RESTful APIs, with basic authentication and a Swagger-like documentation page, that allow the basic CRUD operations (create, read, update, delete) to the respective entities. The APIs are used by all the following components which are described in sections 5.5.2-5.5.5, in order to read or store information to the databases.

5.5.2. KPIs calculation engine

This component, as its name suggests, is responsible for the calculation of the values of the KPIs. Each cycle of calculation includes the following steps for the different levels of calculation of each KPI:

```
# define year
for each KPI:
    for each level of calculation:
```

[1] pragma.IoT https://pragma-iot.com/

[2] SiteWhere https://sitewhere.io/en/

[3] MongoDB https://www.mongodb.com/

[4] InfluxDB https://www.influxdata.com/

- ✓ retrieve the lowest level entities that participate in this level
- ✓ retrieve the raw measurements that are needed for the KPI's calculation from each of the lowest level entities, for the specific year of calculation
- ✓ perform the calculation, according to the pre-defined formula
- ✓ save the result to the appropriate level of the KPI

The above procedure is implemented in Python scripting language and includes the respective calls to the RESTful APIs that were described in section 5.5.1. Moreover, the KPIs calculation has been further grouped according to the type of the KPI, e.g. the calculation of the KPIs which have percentage (%) unit require the aggregation of the individual measurements of each building for the numerator and the denominator, before performing the division, in order to calculate the aggregated KPI value for an upper level e.g. the city level. On the other hand, there are KPIs that their aggregate value could be a simple sum of the values of the KPIs from the lower levels. In general, we have identified the following groups:

- ✓ Percentage, e.g. energy savings, peak load reduction, people reached
- ✓ Likert scale, e.g. increased awareness of energy usage, advantages for end-users
- ✓ sums, e.g. CO2 emission reduction

The above categorization also affects the way that they are visualized in charts, as it will be described in the following section.

5.5.3. KPI Monitoring Dashboard

The KPI Monitoring Interface is the main component that can be accessed by the consortium as well as the externals, in order to view, monitor and compare the performance from the three LH cities. It is a web interface implemented in HTML/CSS/JavaScript (AngularJS) and is based on the pragma.IoT platform's interface, which provides the related functionality for the communication with the backend. It works in a modularized way, which allows the administrator to create different views (dashboards) which can be filled with different types of widgets so that it is fully customizable according to needs.

The interface allows a plenty of widgets, as line, bar, doughnut, pie and many more types of charts, as well as numeric widgets. For the course of this task, we have implemented three extra types of widgets in order to address the needs for KPIs visualization. More specifically, we have added the ability to add:

- ✓ customizable text widgets with title and paragraph section, in order to allow the grouping of the KPIs in each dashboard (Technical, Environmental, Economic, Social, ICT) and give some information for each group
- ✓ combined bar-line charts in order to visualize and compare the actual KPI values with the target values
- ✓ and horizontal bar charts for the visualization of Likert scale KPIs

For the visualization of the KPIs, we have used dummy data in order to demonstrate the capabilities of the KPIs monitoring interface. In the following figure, the dashboard for KPIs that are aggregated in the project's level is displayed. As it can be seen we have used a combined bar-line chart for the visualization of the KPI per year in comparison to its yearly targets and a gause chart for displaying its latest value comparing to the year's target. In cases that a target is not available for the specific KPI or level, the bar chart and the numeric widget could be used instead as it can be seen in Figure 34.

Figure 34 IRIS Project KPIs

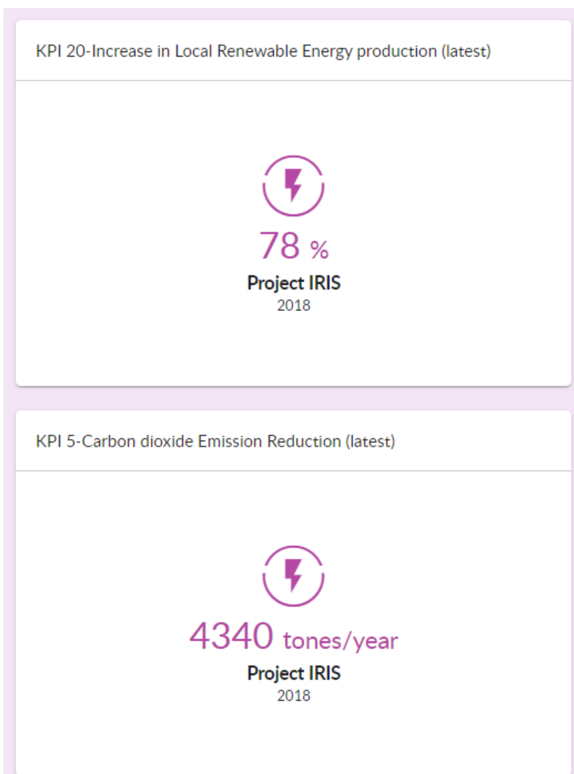


Figure 35 Numeric Widget

The KPI Dashboard allows the user to navigate through different dashboards from the main menu, presenting the different set of KPIs grouped under 3 main categories as of:

- ✓ The IRIS Project as a whole
- ✓ per Transition Track
- ✓ Per different Lighthouse City

so that the user can easily navigate to the part that he/she is mostly interested to monitor. In the following figure, the Transition Tracks dashboard is displayed, where the user can view the contribution of each transition track for a KPI.

Figure 36 KPIs per TT

In the next figure, the Transition Track 1 dashboard is displayed. Here the user can see the KPIs which are aggregated for this level and observe the contribution of each city in this track. A palette of colours based on each city's basic colour has been used in order to enable a comprehensive colour-mapping per city.

Figure 37 KPIs for TT1

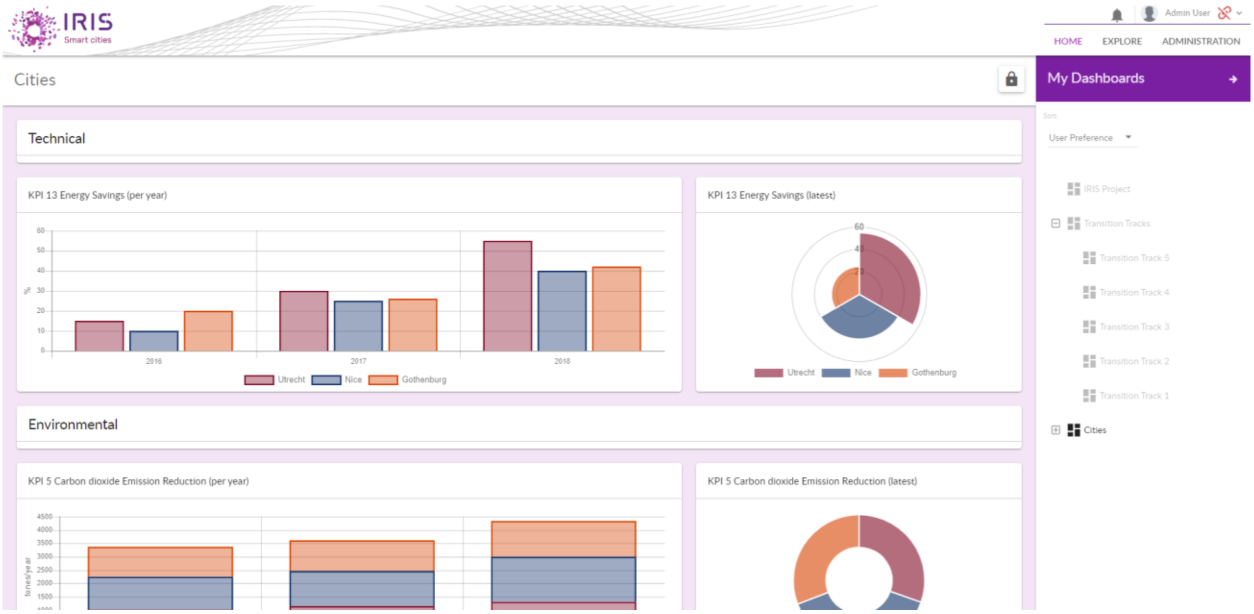


Figure 38 KPIs per City

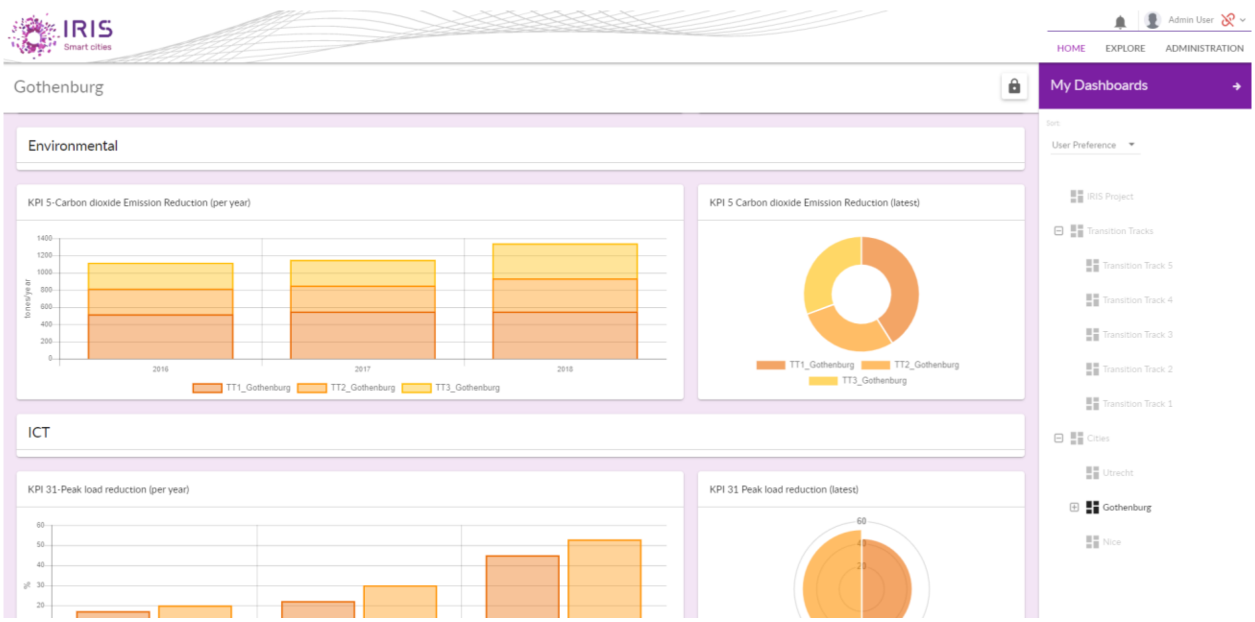


Figure 39 KPIs for Gothenburg City

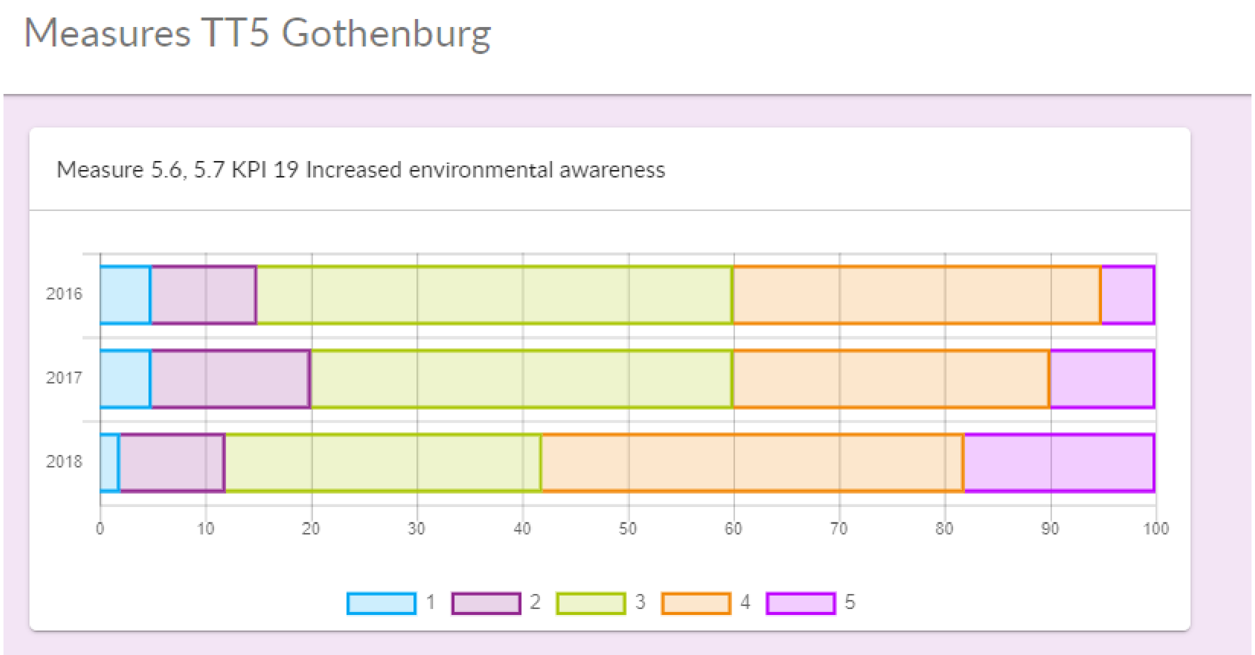


Figure 40 Horizontal chart for Likert scale KPIs

5.5.4. Provision of Data

There are two different ways to support the provision of data from the low-level entities to the KPI Tool, referring to the data being measured or extracted at the Buildings, Districts or Systems level. Such data could vary from energy measurements, costs to answers retrieved through structured/Likert-scale questionnaires etc. and they can be provided to the tool either:

- ✓ **Automatically** through API integration with the Data Market of the CIP. In this case, measurements available to the CIP will be forwarded to the KPI Platform (through the Data Market) and stored in the KPI Tool server's database through RESTful APIs. This procedure could be performed in a monthly or yearly basis or be event-driven (to be detailed within WP4 activities).
- ✓ **Manually** be the Smart City Coordinators In order to allow the provision of data in an off-line manner, a set of templates will be created (1e.g. in an Excel or tabular format), so that the LH cities can provide data that cannot be provided automatically (through the CIP). The filled forms will then be uploaded to the KPI Platform (in a monthly or yearly basis), so that they can be parsed by the application and store respective values in the KPI Tool server's database.

5.5.5. Data export

The KPI Tool will also support the exportation of the KPIs values in suitable formats (e.g. CSV, XML), in order to support open data access for the IRIS project. A web application with a simple UI will be implemented in order to allow people from any domain to select the KPIs they would like to export as well as the format they will be presented.

6. Output to other work packages

Table 14 presents the way that the other work packages will use the outcomes of the D9.4

Table 15 – Use of D9.4 outcomes to other work packages

WP	Deliverable	Use of D9.4 output
WP4	D4.6 (M30) Integration of CIP in LH Cities	The monitoring equipment in each LH city that is required to collect real time, high resolution data will be accessed through the CIP. The relevant data will become available to KPIs tool through the platform. Moreover, the static data that are required for calculating the KPIs will be stored in the platform.
WP9	D9.5 (M24) Report on monitoring framework in LH cities and established baseline	All the information that is required from the unified monitoring framework (i.e. data for the KPIs variables, measurement details, survey planning, etc.) will be collected in the three IRIS LH cities
	D9.6: (M38) Intermediate report after one year of measurement	The actual performance data collection and reporting will be carried out. The KPI tool will be used to calculate and visualize the KPIs in each LH city.
	D9.7: (M60) Report on evaluation and impact analysis for integrated solutions	The actual performance data collection and reporting will be carried out. The KPI tool will be used to calculate and visualize the KPIs in each LH city.

7. Conclusions

This deliverable provides the IRIS unified monitoring and evaluation framework and the IRIS KPIs tool. The current version of the deliverable presents the unified framework and the methodology for the design and development of the IRIS KPIs tool. The final version of D9.4 that is due to month 24 (September 2019) will present the IRIS KPIs tool. The unified monitoring and evaluation framework combined with the KPIs tool 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.

Based on the work done in tasks 9.1 and 9.2 (presented in D9.2 and D9.3), the deliverable used as input the data model and management plan from D9.3. It analyses the data collection processes in the IRIS solutions' heterogeneous fields (energy, mobility, ICT, and citizen engagement), as the heterogeneous nature of those fields implies that data sources and means of data collection and storage might differ. In some cases, data are provided by systems that include smart meters, which automatically collect data and upload it to a repository. In other cases, they reside in another system's repository and needs to be moved or copied. Data can also be collected by other methods such as questionnaires, interviews, direct observations, etc. and their results are registered in forms (electronic or paper). The analysis led to the creation of a unified methodology for KPIs related data collection, analysis and visualisation.

The first part of the monitoring and evaluation framework covers the data collection process. The deliverable presents the methodology for the collection of the various types of data required for the calculation of the KPIs in the IRIS LH cities. This methodology, which created through a collaborative process within the IRIS LH cities, specifies the data requirements for each KPI. Templates were created to collect the required information for the monitoring devices, the automatically generated data, and the manually collected data. The framework also contains the methodology for the KPIs that will be evaluated through data collected in the form of questionnaires. Finally, it presents the procedure to evaluate the quality of the collected data.

The second part of the framework covers the calculation and visualisation of KPIs. It is based on a six-step process in which the collected data will be analysed to produce each KPI and relevant visualisations. The data analysis and visualisation framework contains three layers: 1) The data acquisition layer, which contains the mechanisms that reliably record all related raw data in a valid format commonly agreed and standardised within the consortium, 2) the data analysis layer, which contains the tools able to filter and fuse data from heterogeneous sources and process them in an efficient and methodologically sound way, and 3) the dashboard layer, which produces the most appropriate visualisation diagrams for each KPI for meaningful representation of results. The implementation of data analysis and visualisation is presented through an indicative KPI.

The IRIS KPIs tool (available at http://monitoring.irissmartcities.eu) implements the unified monitoring framework and uses the collected monitoring data to calculate the KPIs' values and to present the results. It interacts with the City Innovation Platform, which is the primary tool for data gathering from the IRIS demonstrations, to automatically collect monitoring data. Moreover, it supports the manual data entry of monitoring data and other static data that are required for KPIs calculations (i.e. reference data, offline data and data collected using surveys). The tool includes interactive dashboards that allow users to monitor and evaluate their measures, and to compare the performance and impact of different demonstrations. The tool also supports the publishing of selected data to the City Innovation Platforms of LH cities and the SCIS self-reporting tool. The design and development of the tool are based on the analysis of similar tools created by CITYKeys and SCIS EU projects and on the latest developments in the fields of data visualisation and dashboard design.

The unified monitoring framework that is presented in this deliverable will be deployed during task 9.4 (Deployment of monitoring framework in LH cities) to all LHs with support from the technical partners from each LH. During that task, all the information that is required from the unified monitoring framework (i.e. data for the KPIs variables, measurement details, survey planning, etc.) will be collected in the three IRIS LH cities. The actual performance data collection and reporting will be carried out in task T9.5 (Overall evaluation and impact analysis for impact enhancement) starting month M25. During that task the unified framework and the KIPs tool will be evaluated and tested for easy maintenance to identify and restore flaws in data collection, ensuring performance, robustness and validity also after the end of the project so that future data can quickly be introduced into the SCIS.

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9. Annexes

9.1. Annex 1 – Form for interpretation KPIs

INSTRUCTIONS:

- Open the file of the *transition track*. This file describes which KPIs belong to which *integrated solution* in this transition track.
- Open the KPI-card file and read the description of this KPI.
- For the interpretation, take the *integrated solution* as reference.
- To interpret the KPI, fill out this table. Note: It is not necessary to answer the question in the given order. Feel free to jump around in the table. Use the table as a means to help in the interpretation of the KPI.

Step	Question	Answer
1.	Which *integrated solution* is focussed on?	
2.	Which KPI is focussed on?	
3.	Does the description of the KPI fit to the *integrated solution*?	❍ Yes, go to step 5 ❍ No, go to step 4
4.	Adjust the description of the KPI	
5.	At what timescale do we want to know this KPI?	❍ Per second ❍ Per hour ❍ Per day ❍ Per week ❍ Per month ❍ Per year ❍ Otherwise, …………

6.	At what spatial scale do we want to know this KPI?	❍ Per individual ❍ Per group of individuals ❍ Per dwelling(s) ❍ Per apartment building(s) ❍ Per district ❍ Otherwise, …………
7.	Describe the delineation in space and time of this KPI	
8.	Is the KPI formula correct?	❍ Yes, go to step 10 ❍ No, go to step 9
9.	Adjust the KPI formula	
10.	Remarks about the KPI formula	
11.	What is the baseline of this KPI? Tip: Baseline is described in deliverable D5.1 for all integrated solutions	
12.	Which type of measurement is needed to determine the KPI?	❍ Data or measurements of an existing meter ❍ Data or measurements of a new meter ❍ Data from databases ❍ Survey ❍ Otherwise, ………

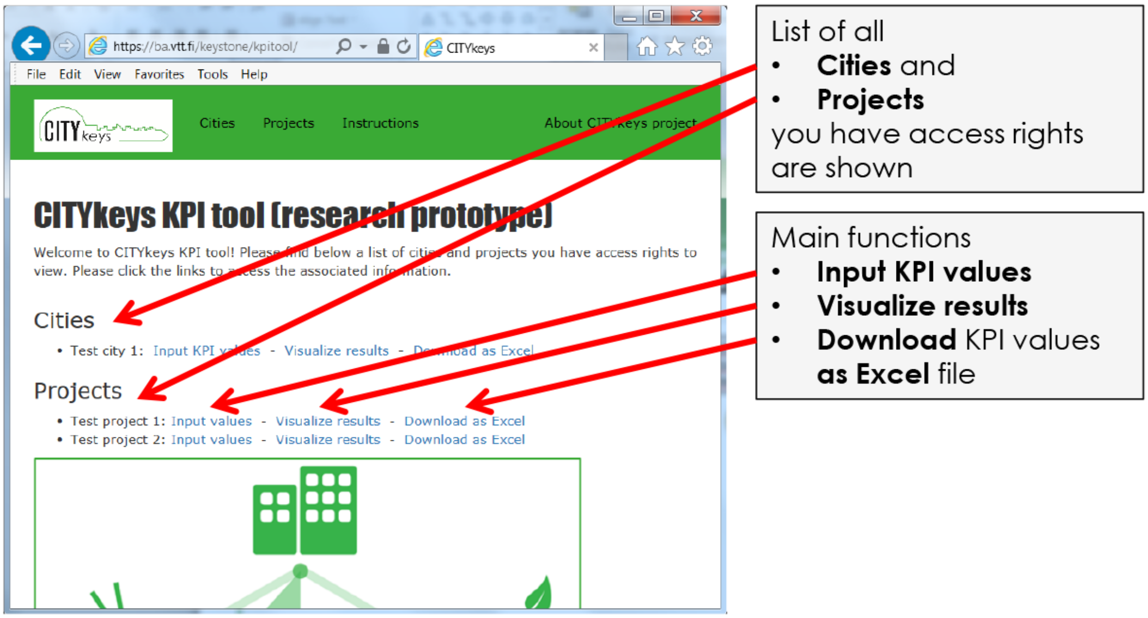
13.	Describe the type of measurements needed for the KPI	
14.	Where is measured for this KPI? Tip: use the monitoring schedule and name the meter and whose meter it is	
15.	When is measured for this KPI?	
16.	Who can provide the data?	
17.	Are there restrictions to unlock the data?	
18.	In what format is the data available?	
19.	Is it easy to link to the City Innovation Platform?	
20.	Who is responsible for KPI?	
21.	Who calculates the KPI?	
22.	Do a trial calculation of the KPI based on the project plan. Save your calculation! Explanation: Assume that 100% of the project plan is implemented and calculate the KPI based on that implementation. Is the result of the calculation a useful outcome? Is it realistic?	Describe in words what the outcome of the KPI says:
23.	Remarks	

9.2. Annex 2 – KPI Numbering

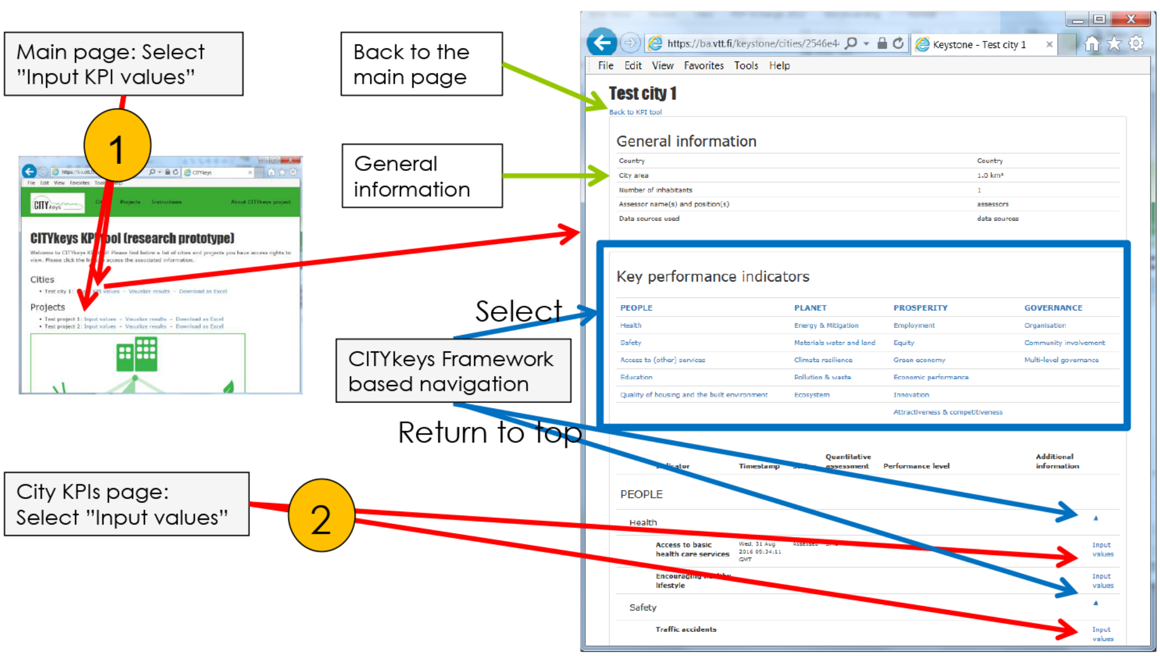
KPI #	KPI name	KPI #	KPI name
1	Accessibility of open data	24	NOx emission
2	Access to vehicle sharing solutions for city travel	25	Number of connected urban objects
3	Advantages for end-users	26	Number of e-charging stations deployed in the area
4	Battery Degradation Rate	27	Number of efficient vehicles deployed in the area
5	Carbon dioxide Emission Reduction	28	Number of Free-Floating subscribers
6	Carbon monoxide emission reduction	29	Open data-based solutions
7	CO2 reduction cost efficiency	30	Participatory governance
8	Data loss prevention	31	Peak load reduction
9	Data safety	32	People reached
10	Degree of energy self-supply by RES	33	Platform downtime
11	Developer engagement	34	Reduced energy cost for costumers
12	Ease of use for end users of the solution	35	Reduced energy curtailment of RES and DER
13	Energy savings	37	Reduction in annual final energy consumption by street lighting
14	Expiration date of open data	38	Reduction in car ownership among tenants
15	Fine particulate matter emission	39	Reduction in driven km by tenants and employees in the district
16	Improved access to vehicle sharing solutions	41	Share of RES in ICT power supply
17	Increased awareness of energy usage	42	Storage capacity installed
18	Increased consciousness of citizenship	43	Trialability
19	Increased environmental awareness	44	Usage of open source software
20	Increase in Local Renewable Energy production	45	User engagement
21	Increased system flexibility for energy players/stakeholders	46	Yearly km driven in e-car sharing systems
22	Local community involvement in the implementation phase	47	Quality of open data
23	Local community involvement in the planning phase		

9.3. Annex 3 – CITYKeys KPI Tool – Screenshots

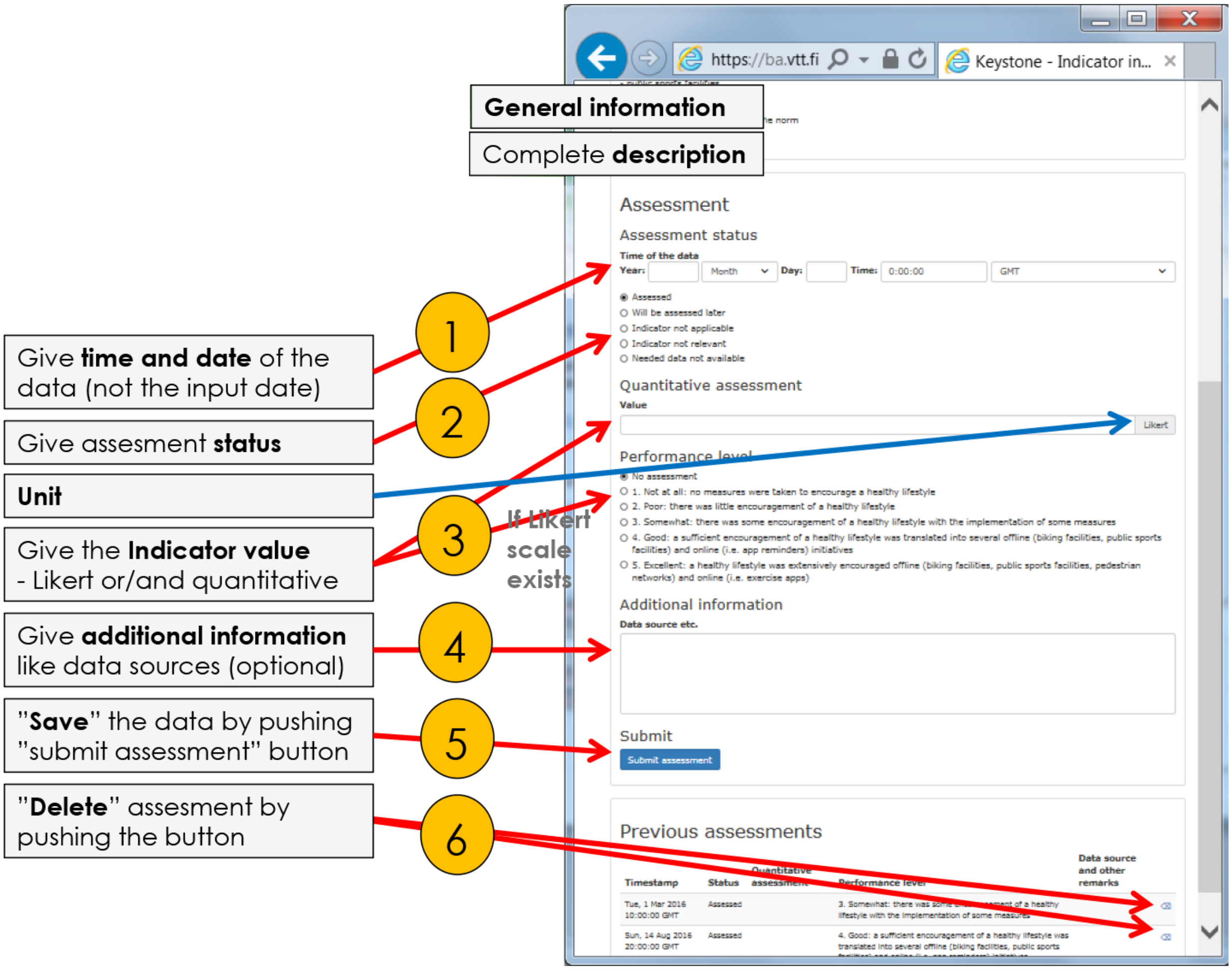
The following screenshots present the functionality of CITYKeys KPI tool (CITYKeys Project, 2016).



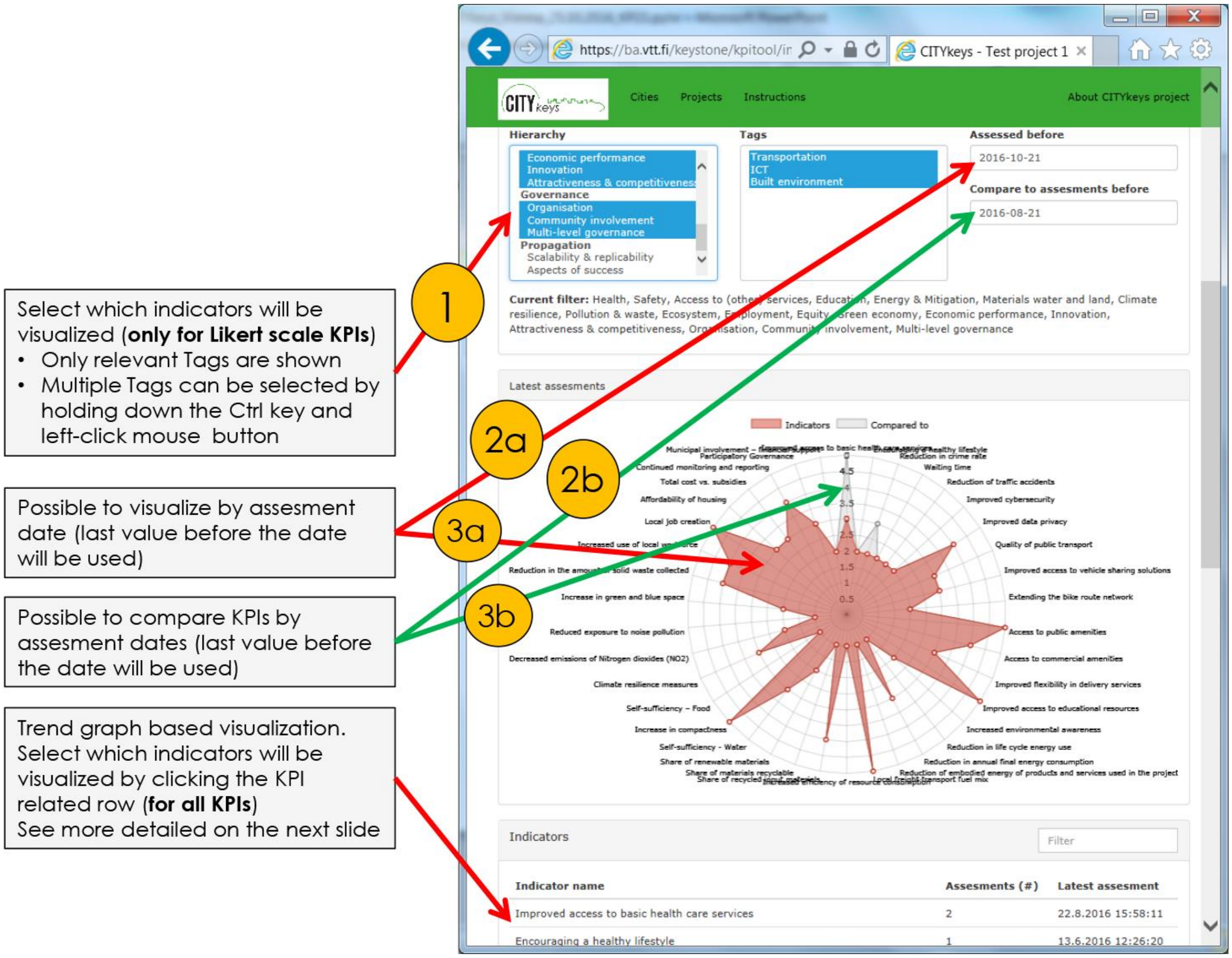
Screenshot 1 CITYkeys KPI tool: main page



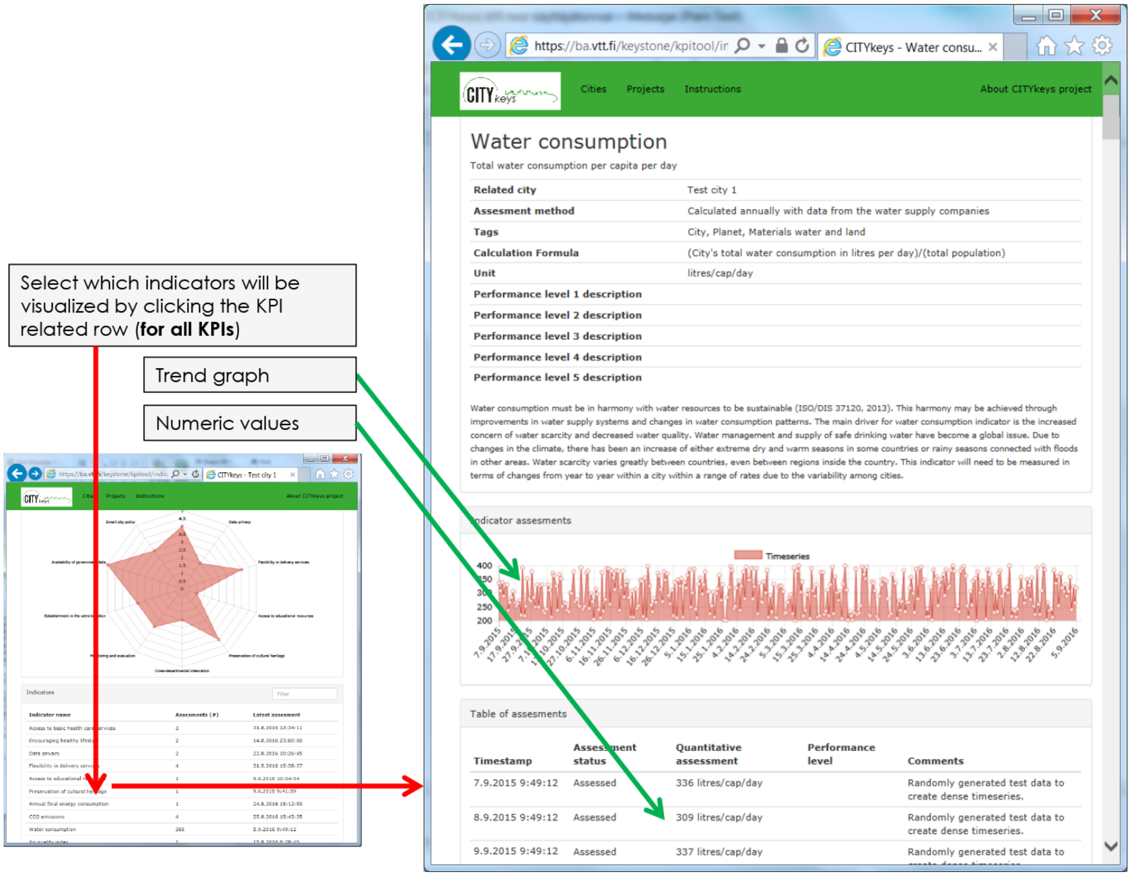
Screenshot 2 Input Project Indicators (1/2)



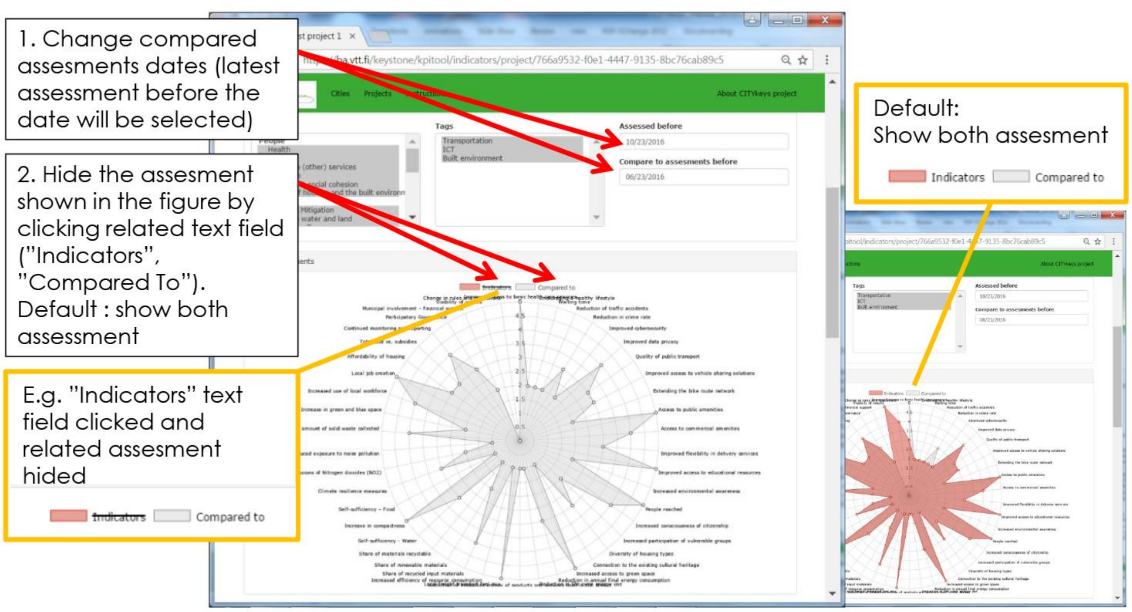
Screenshot 3 Input Project Indicators (2/2)



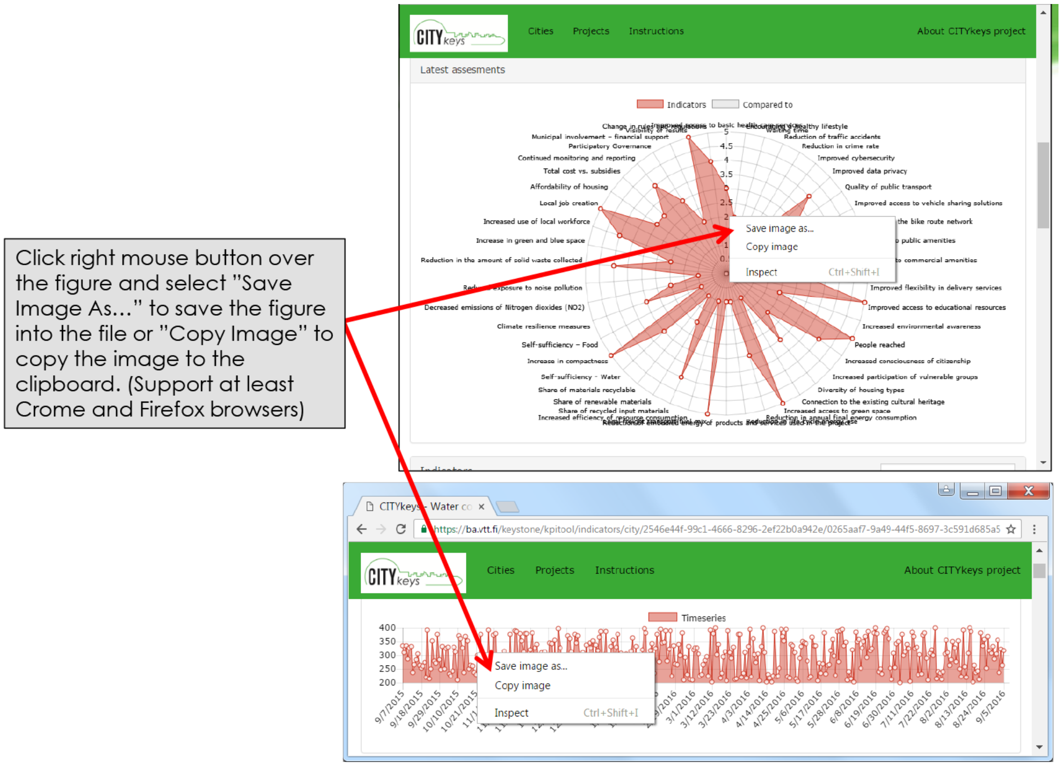
Screenshot 4 Visualizing KPIs (1/2)



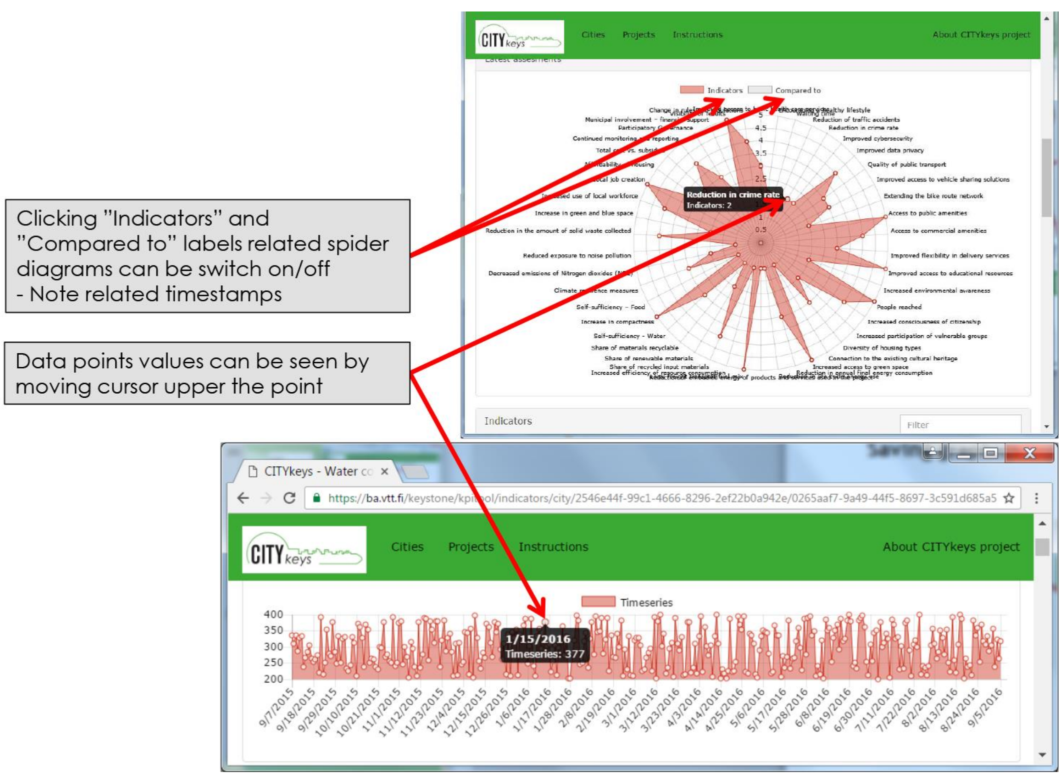
Screenshot 5 Visualizing KPIs (2/2)



Screenshot 6 Comparison of the assessments



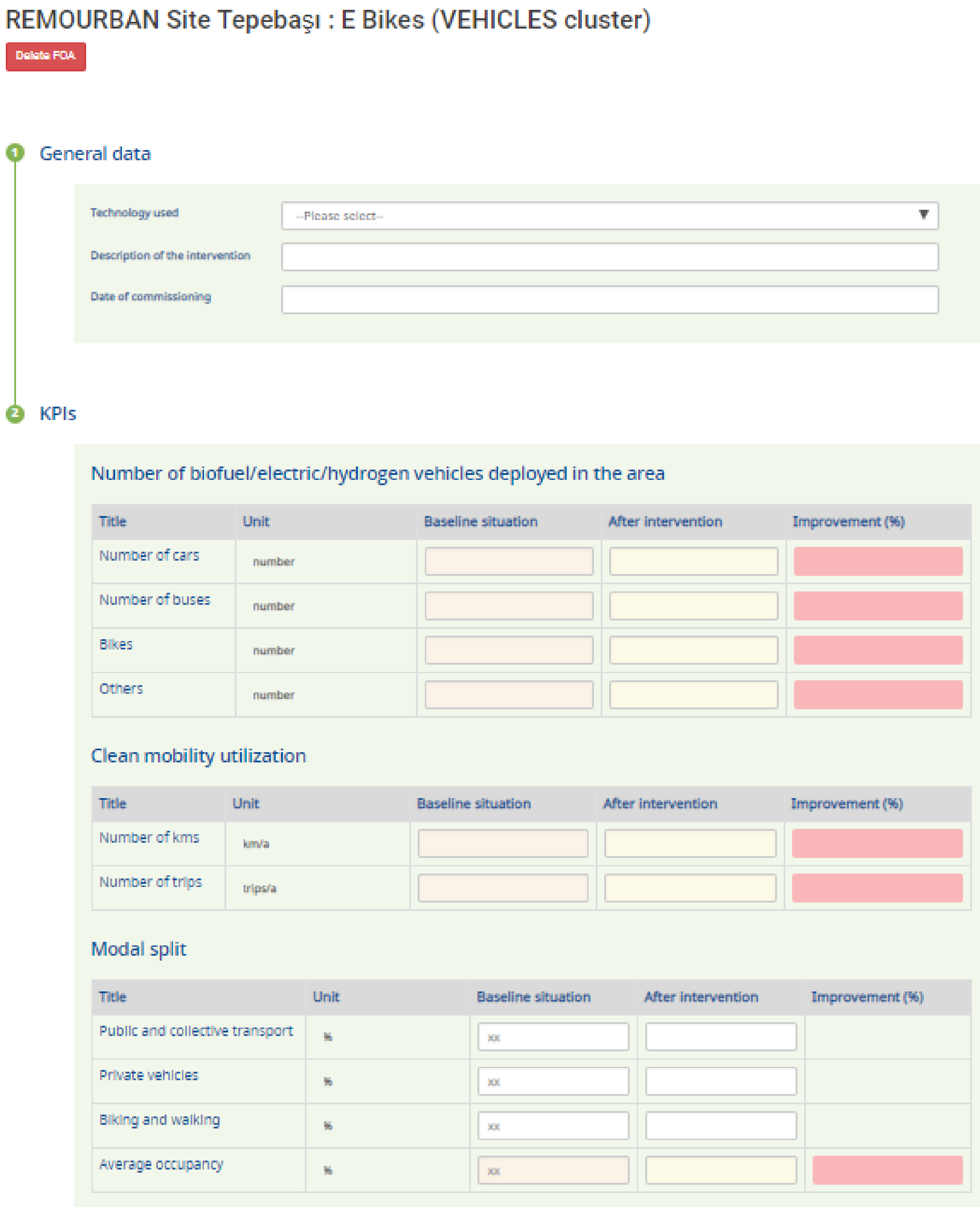
Screenshot 7 Saving images



Screenshot 8 Visualizing tips

9.4. Annex 4 – SCIS Self-reporting tool – Screenshots

The following screenshots present the functionality of SCIS self-reporting tool (SCIS, 2019)



REMOURBAN Site Tepebaşı : E Bikes (VEHICLES cluster)

Delete FOA

1 General data

Technology used	--Please select--
Description of the intervention	
Date of commissioning	

2 KPIs

Number of biofuel/electric/hydrogen vehicles deployed in the area

Title	Unit	Baseline situation	After intervention	Improvement (%)
Number of cars	number			
Number of buses	number			
Bikes	number			
Others	number			

Clean mobility utilization

Title	Unit	Baseline situation	After intervention	Improvement (%)
Number of kms	km/a			
Number of trips	trips/a			

Modal split

Title	Unit	Baseline situation	After intervention	Improvement (%)
Public and collective transport	%	xx		
Private vehicles	%	xx		
Biking and walking	%	xx		
Average occupancy	%	xx		

Screenshot 9 Field of Actions example: Mobility & Transport – Vehicles (1/2)

Energy consumption

Title	Unit	Baseline situation	After intervention	Savings (%)
Final Energy Consumption	kWh/a	xxxxxx		

Environmental KPI

Title	Unit	Baseline situation	After intervention	Savings (%)
Total CO2 Emissions	kgCO2eq/a			
Total Primary Energy Demand	kWh/a	xxxxxx		

Economic KPI for the mobility action

Title	Unit	Intervention
Total Investments (excl. VAT)	€	xxxxxxxx
Grants	€	xxxxxxxx
Net energy savings/value of improvements	€/a	xxxxxxxx
Total Operating costs	€/a	xxxxxxxx
Dynamic Payback Period	a	
Return on Investment	%	xx

Social KPIs

Citizens directly involved	
Number of jobs created	

Screenshot 10 Field of Actions example: Mobility & Transport – Vehicles (2/2)

TEST-Mobility E-mobility: 20181126 Rudy 2 (INFRASTRUCTURE cluster)

1 General data

Technology used	Bidirectional charging
Description of the intervention	Installation of 2 bidirectional chargers and vehicles
Date of commissioning	

2 KPIs

Energy consumption data aggregated by sector fuel (GJ)

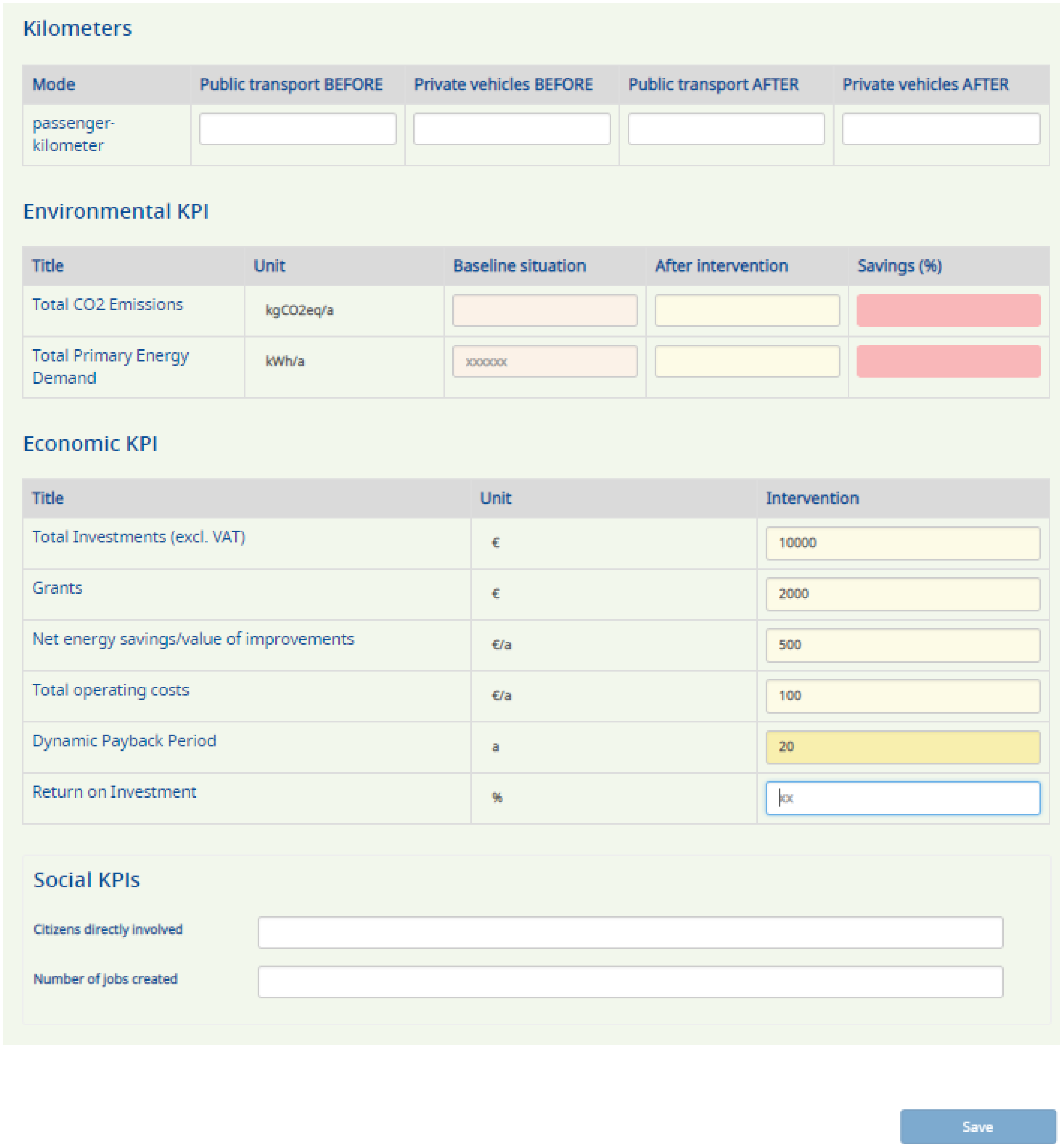
Mode	Public transport BEFORE	Private vehicles BEFORE	Public transport AFTER	Private vehicles AFTER
LPG				
Motor Spirit				
Kerosene - Jet Fuels				
Diesel Oil				
Heavy Fuel Oil				
Natural gas				
Biodiesel				
Electricity - grid				
Electricity - RES				

Transport system

Improvement	Unit	Baseline situation	After intervention	Improvement (%)
New e-hub/charging/fueling stations	outlets	0	2	Infinity
Deployment of bicycle lanes and pedestrian roads	km			
Deployment of public transport system	km/100000 inhabitant			
New car sharing/car pooling locations	spaces			

Save

Screenshot 11 Field of Actions example: Mobility & Transport – Infrastructure (1/2)



Kilometers

Mode	Public transport BEFORE	Private vehicles BEFORE	Public transport AFTER	Private vehicles AFTER
passenger-kilometer				

Environmental KPI

Title	Unit	Baseline situation	After intervention	Savings (%)
Total CO2 Emissions	kgCO2eq/a			
Total Primary Energy Demand	kWh/a	xxxxxx		

Economic KPI

Title	Unit	Intervention
Total Investments (excl. VAT)	€	10000
Grants	€	2000
Net energy savings/value of improvements	€/a	500
Total operating costs	€/a	100
Dynamic Payback Period	a	20
Return on Investment	%	xx

Social KPIs

Citizens directly involved

Number of jobs created

Save

Screenshot 12 Field of Actions example: Mobility & Transport – Infrastructure (2/2)

TEST-Mobility E-mobility: 20181126 (ICT cluster)

1 General Data

Description of the intervention	Installation of 100 smart lampposts
Thematic field of ICT Intervention	City level
Type of ICT Intervention (City level)	Smart lampposts
Date of commissioning	2020

2 KPIs

Demand Side Management

Title	Unit	Baseline situation	After intervention	Improvement (%)
Reliability in terms of power interruptions	number/a			
Power Quality and Quality of Supply (DSO+TSO): Time needed for awareness of grid faults	minutes			

Infrastructure

Title	Unit	Baseline situation	After intervention	Improvement (%)
Amount of smart lampposts	number	10	110	1000

Focus on Energy Savings

Title	Unit	Baseline situation	After intervention	Improvement (%)
Flexibility from energy players by increase of load capacity participating in demand side management	MW			
Energy price (averaged over a year)	€/kWh	xx.zz		
Peak load level	MW			
RES and DER hosting capacity	MW			
Hosting capacity for electric vehicles and other new loads	MW			

Save

Screenshot 13 Field of Actions example: ICT (1/2)

Consumers engagement

Title	Unit	Baseline situation	After intervention	Improvement (%)
Number of end users involved	#			
Number of people with increased ability to manage their energy consumption	#			

Environmental KPI

Title	Unit	Baseline situation	After intervention	Savings (%)
Total CO2 Emissions	kgCO2eq/a			
Total Primary Energy Demand (due to the ICT measure implemented)	kWh/a	xxxxxx		

Economic KPI

Title	Unit	Intervention
Total Investments (excl. VAT)	€	xxxxxxxx
Grants	€	xxxxxxxx
Annual value of improvements	€/a	xxxxxxxx
Total operating costs	€/a	xxxxxxxx
Dynamic Payback Period	a	
Return on Investment	%	xx

Social KPIs

Citizens directly involved	
Number of jobs created	

Save

Screenshot 14 Field of Actions example: ICT (2/2)

TEST-Mobility E-mobility: 20181126 E Storage (ELECTRICAL STORAGE cluster)

1 General data

Date of commissioning	2019

2 KPIs

Technical KPIs

Title	Unit	Value
Maximum charging/discharging power	kW	1000
Storage volume	m³	30
Electrical storage capacity	kWh	1200
Roundtrip efficiency	%	90
Energy density	kWh/kg	
Discharge time (in use)	hr	20000
Cycles in lifetime	cycles	3000

Environmental KPIs

Title	Unit	Demonstration power plant (calculated)	Demonstration power plant	Savings (SCIS calculation)	Reference value
Total CO2 Emissions	kgCO2eq/a				
Total Primary Energy Demand	kWh/a		xxxxxx		

Please, provide the savings of your system compared with a system of reference. This system should be based in BAU (e.g. gas boiler for heating) and be designed to produce the same output as the reported technology (e.g. the input should be different due to different performance ratios). If no savings are entered, SCIS provides calculation of savings from BAU baseline.

Screenshot 15 Field of Actions example: Energy System Integration – Electricity storage (1/2)

Economic KPI for the Energy System Integration Unit

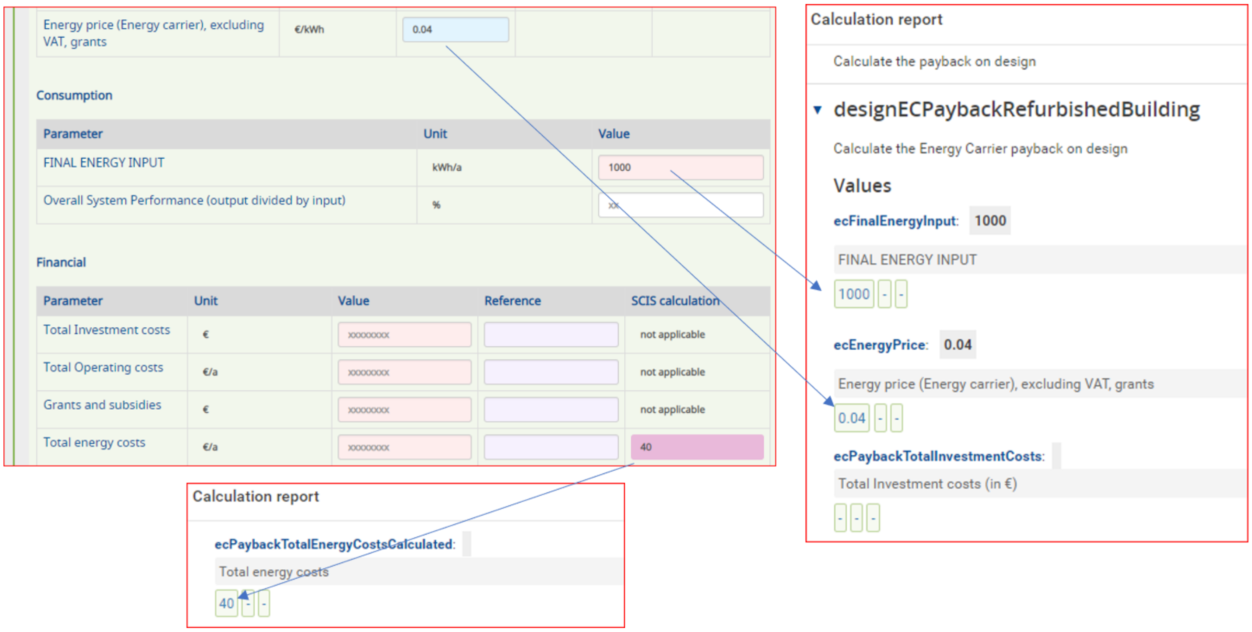
Title	Unit	Value	Reference value	SCIS calculation
Total Investments (excl. VAT)	€	500000	0	
Grants	€	200000	0	
Energy sales revenues for electricity	€/a	6000	0	
Energy sales revenues for delivered heating energy	€/a	0	0	
Energy sales revenues for delivered cooling energy	€/a	0	0	
Total Operating costs per year	€/a	xxxxxxxx		
Dynamic Payback Period	a			50
Return on Investment	%	xx		

Social KPIs

Citizens directly involved	
Number of jobs created	
Gross floor area in m² served by the new system in m2	

Save

Screenshot 16 Field of Actions example: Energy System Integration – Electricity storage (2/2)



Screenshot 17 Guidance to the calculations is available by right-clicking an entry cell