IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

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Data model and management plan for integrated solutions

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Disclaimer

Executive summary

This document describes the IRIS data model and management plan for integrated solutions. The report is part of Task 9.2, which aims to define the monitoring infrastructure and develop a comprehensive data collection approach and model in order to coordinate and supervise the collection of information to the unified framework to be established in T9.3.

In this report an approach is defined where the translation is made between the KPIs and their calculation from D9.2, and the physical measurements as done in the integrated solutions. It describes the first steps of how each Key Performance Indicator (KPI), that is defined in D1.1 and D9.2, can be measured. This method is created and tested in close collaboration with the partners responsible from the integrated solutions. The most important feedback from these partners is acquired by having workshops in Utrecht, Gothenburg and Nice, where the calculation methods from D9.2 were applied to the integrated solutions. Further on the partners where invited to produce an overview of all measurements that are intended to take place in their demonstration sites, to investigate to what degree data for KPI calculation already sufficient and where extra measurements are required.

With the help of lessons learned from these workshops and examples from other smart cities projects, a common approach for data collection is given for each integrated solution. This approach includes a short description of the solution, a list of KPIs and their calculation method and a common data structure that will be utilized in the unified framework for harmonized data gathering, analysis and reporting. In this framework each monitored parameter from the integrated solutions is comprehensively described. This description is also an important basis for the input of data into the City Information Platform (CIP).

The deliverable also provides examples of best practices of how the approach from the former sections could be utilized for each integrated solution.

Even though this document provides a basis to proceed in defining the integrated solutions such that monitoring could take place as desired, the translation from each integrated solution to this method requires more guidance. For these reasons more workshops are planned at the start of 2019. With the lessons learned from these workshops, a guideline will be made to facilitate this translation as part of task T9.3.

With the help of this guideline, a harmonized description of each integrated solution can be developed and published in D9.4.

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List of Abbreviations and Acronyms

Abbreviation	Definition
CHP	Combined Heat and Power
CIP	City Innovation Platform
CITYkeys	Smart City performance measurement system (Project funded by the European Union HORIZON 2020)
DC	Direct Current
DER	Distributed Energy Resources
DH	District Heating
DHW	Domestic Hot Water
DNO	Distribution Network Operator
DR	Demand Response
DSM	Demand Side Management
DSOs	Distribution System Operators
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
ESCO	Energy Service Company
ESU	Energy Supply Unit
EU	European Union
EV	Electric Vehicle
FC	Follower City
ICT	Information and Communication Technologies
IS	Integrated Solution
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LH	Lighthouse
MHD	Maximum Hourly Deficit
MO	Market Operator
PM	Particulate Matter
PuT	Public Transport
PV	Photovoltaic
RES	Renewable Energy Sources
ROI	Return on Investment
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCIS	Smart Cities Information System (Project funded by the European Union HORIZON 2020)
TES	Thermal Energy Storage
TSP	Technology and Services Provider
TT	Transition Track
V2G	Vehicle to Grid
WP	Work Package

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1 Introduction

1.1 Scope and objectives and expected impact

Part of task T9.2, deliverable D9.3 reports on the IRIS data model and management plan for the Lighthouse Cities integrated solutions that are going to be evaluated and specifies formats and the initial architecture of data exchange. D9.3 is related to the definition of a detailed metering/monitoring methodology for each demonstration within the IRIS framework. It describes the first steps of how each Key Performance Indicator (KPI), that is defined in D1.1 and D9.2, can be measured.

The goal of this document is to develop:

- A data collection model: Contains the description of the data that will be collected for each integrated solution.
- A data collection approach: How the data will be collected for each integrated solution; it provides definitions on the (requirements for the) monitoring infrastructure.
- Relate KPIs with data: To give an overview of how the calculation of the KPIs of each integrated solution is defined.

This way the document provides a deeper insight in what the datasets, provided in the data management plan, consist of.

The information provided by this document is required for:

- Coordination and supervision of information collection.
- Uniformity and transparency of information collection.

By defining how the KPIs and the integrated solutions are related on a practical level, each partner is invited to have a closer look at their integrated solutions. This way, the approach to measure the KPIs, is defined at an early stage.

1.2 Contributions of partners

The main project partners in task T9.2 are UU, RISE and CERTH. UU, as the leader in T9.2, is responsible for coordinating the activities related to the definition of the data model and the Data Management Plan (DMP) for performance and impact measurement. RISE as the WP9 leader ensures that all activities are in line with other related WPs by maintaining communication with the respective WP leaders. Further on, the partners working within WP5 to WP7, provide detailed information from the integrated solutions that are presented in this document.

1.3 Relation to other activities

The definition of Key Performance Indicators has been harmonized with other European projects working on energy smartification of European cities as part of task T9.1. The main initiatives that have been consulted for the definition of the key performance indicators (KPIs) are SCIS and CITYkeys, although some

new indicators originate from the work conducted within the IRIS project. The use of SCIS and CITYkeys KPIs in IRIS will facilitate incorporation of all performance data into the SCIS throughout the project.

The description of KPIs and how to calculate them is provided by CERTH and RISE and defined in D1.1. The linkage between each integrated solution and the assigned KPIs is adopted from D9.2 where supplementary KPIs have been defined. The description of the integrated solutions is defined in D5.1, D5.2 D6.1, D6.2, D7.1 and D7.2.

The description of data creates an overview that will be utilized in the development of the City Information Platform (WP4).

1.4 Structure of the deliverable

Chapter 2 describes the methodology is of how this document has been developed. The workshops that took place with the LH city partners and the next steps for further development of task T9.3. Chapter 3 gives an approach to how each integrated solution should be described to give a detailed overview of how the connection between the KPIs as described in D9.2 is physically made for each integrated solution. Chapter 4 provides a few examples of how the generic approach could be filled in for some integrated solutions. A short conclusion of the work is given in chapter 5.

2 Methodology

The monitoring protocol for integrated solutions forms an important transition between the monitoring and evaluation schemes and definition of KPIs as described in D9.2 and the actual implementation of the monitoring program for the integrated solutions. A protocol which is accepted and supported by the partners performing the integrated solutions, can only be defined in close collaboration with these partners. Therefore, the methodology of defining this protocol is mainly based on the collaboration which is described in this chapter.

This report provides a basis for D9.4 “Report on unified framework for harmonized data gathering, analysis and reporting [M18]” which is related to task T9.3. As a variety of data sources will be used for the calculation of the KPIs (i.e. smart meters, utility bills, surveys, etc.) the creation of the unified framework for harmonized data gathering analysis and reporting, which is envisaged in D9.4, requires an understanding of the different data sets that will be available from the IRIS demonstrations. Moreover, as the monitoring system must handle data from various sources and different LH cities, a common data model for the KPIs is required to enable the homogeneous calculation of KPIs for the different LH cities. So, from the D9.4 perspective, the D9.3 must provide for information about what data should be collected and how for each KPI.

D9.3 at a first glance might have similarities with D9.1 and D9.8 - D9.11 (the data management plan and its updates). However, the data management plan D9.1 has its primary focus on the definition of datasets only, while D9.3 defines the variables within these sets, and how these variables determine the KPIs (see Figure 1).

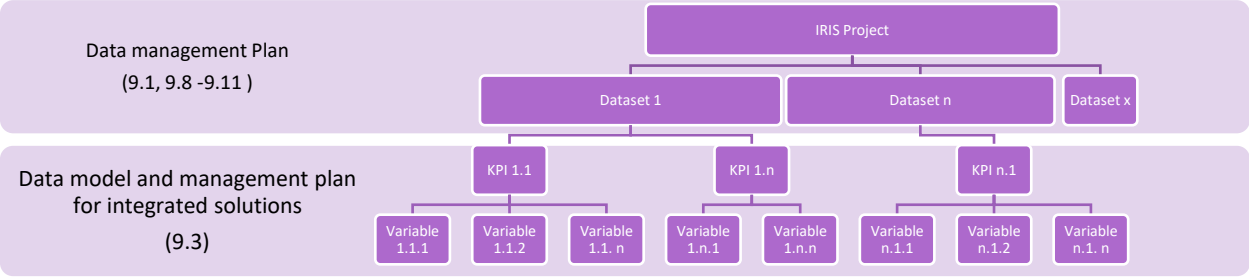

Figure 1 Difference between data management plan and D9.3

2.1 Development procedure

Figure 2 shows how the common approach for each integrated solution is being developed. The process starts with research among other projects (section 2.2). From this research an early approach was developed. This approach is tested with the partners performing the integrated solutions by means of a workshop (section 2.3). The feedback from this workshop leads to an update of the approach, which is being tested with another workshop (sections 2.4 and 2.5). This cycle is being repeated till an adequate approach and a guideline is defined which finally leads to the input of D9.4.

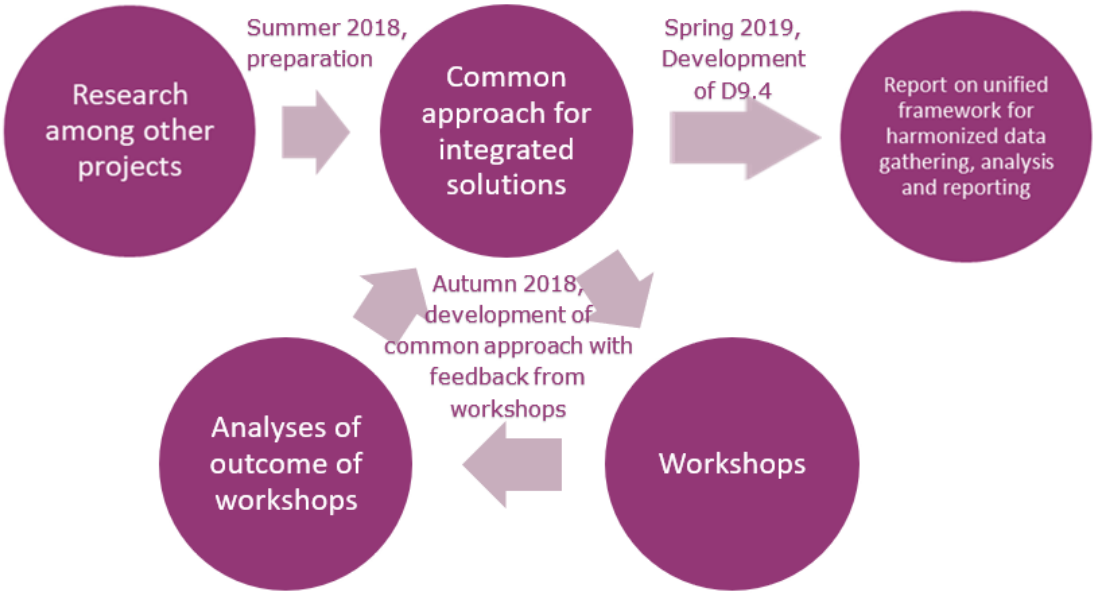

Figure 2 Methodology to reach a common approach for integrated solutions

2.2 Research among other projects

The first step in defining the contents of this document is taken by research among other comparable projects, such as the Smart Cities Projects; Celsius [1] and Ruggedised [2]. This research forms the basis of the common data structure (3.2) and the approach of describing each integrated solution (Chapter 3).

2.3 First workshop in Utrecht

To have the partners collaborate in defining the protocol, a workshop was held with the partners in Utrecht. This workshop took place early in October, soon after the delivery of D9.2.

2.3.1 Projected results

- To analyse the desired project outcomes of the partners.
- To take a step in synchronizing these desired outcomes with the project outcomes and KPIs listed in D9.2.
- To inform the partners about the approach of calculating the KPIs as described in D9.2.
- To investigate up to what degree this approach is understood by the partners.
- To take a first step in making an overview of how the projected measurements in the integrated solutions will provide the data that is required for calculating the KPIs.

2.3.2 Methodology

- Inviting the project partners to write down what they want to investigate/ learn from the integrated solutions that they are part of on Post-its. Sharing and discussion about these outcomes and short analysis to determine if and where these outcomes are in line with the projected KPIs for the IS (60 minutes).
- Analysing the calculation/ definition of one KPI (in this case: Increase in local energy production) as described in D9.2 (45 minutes).
- What is required for a proper functioning of the IS, is reviewed regarding the following aspects:
    - What do we want to measure in the system?
    - Where in the system do the measurements take place?
    - On what scale do these measurements take place (how many meters / how often)
    - When will the measurements take place?
    - Is this done by existing meters? Should new meters be installed?
    - Who owns / supplies the data?
    - Are there any restrictions to unlock the data?
    - In what format is the data available?
    - Could the data be implemented in the CIP? How?
    - What (else) is required to calculate a KPI from the data?
    - Any other aspects to add to this list?
- Make a schematic drawing of one of the demonstration sites, to create an overview of what kind of measurements are projected to take place (60 minutes).

2.3.3 Outcome

- As time was limited, not every integrated solution and KPI could be analysed thoroughly. Nevertheless, it was helpful for us and the partners to see where desired project outcomes of the partners meet with the desired IRIS project outcomes. Further important observations:
    - Desired project outcomes of partners and the KPIs are not always in line, but this is also not a requirement for the project to succeed.
    - Partners should critically analyse how project outcomes and KPIs meet their requirements, and if necessary, reconsider the KPIs as defined in D9.2.
    - Taking this step invited the partners to ...

- Thoroughly analysing the particular KPI lead to quite some discussion. Even though the KPIs and how to calculate them are extensively described in D9.2, certain definitions are still subject to interpretation. Therefore:
    - The KPIs as described in D9.2 require specific translation for each IS.
    - To be able to compare and analyse project results, the calculation of KPIs for each IS should be clearly described.
    - To harmonize the project results between different partners or ISs collaboration between these parties and several iterations are necessary.
- Making the schematic drawing of the measurements gave a clear overview of where measurements are projected in the demonstration site (Figure 3, Figure 4, more detailed in Annex 1)
    - This step clarified where different IS's and partners could share results.
    - It defines a basis to explore where additional measures should be taken to acquire the proper data for calculation of the KPIs.

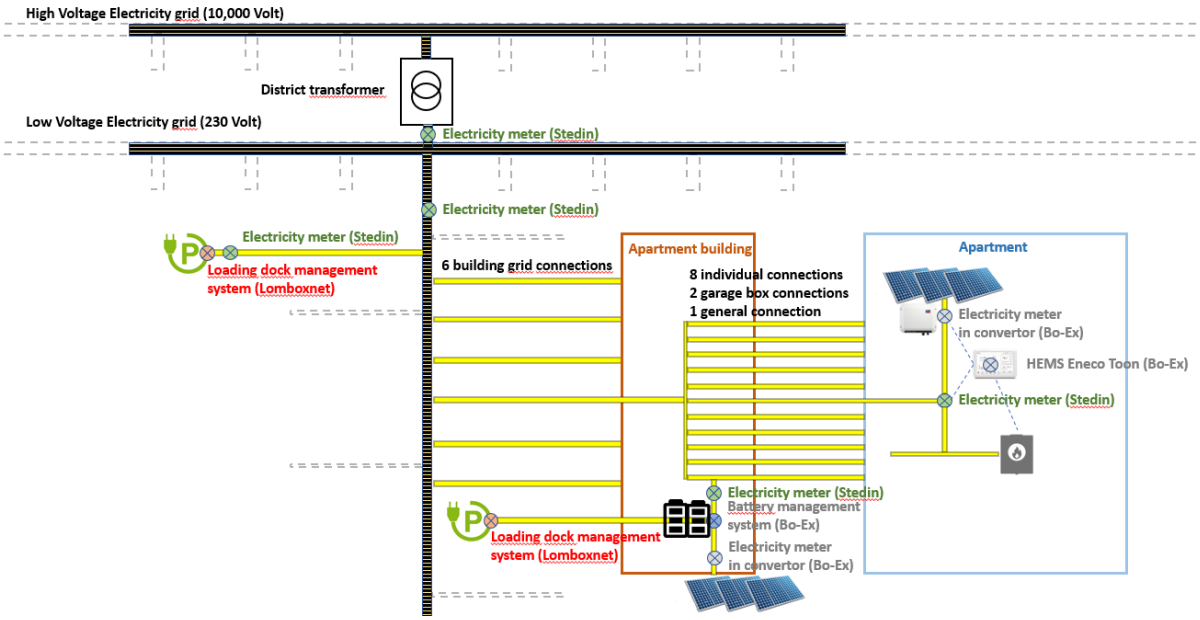

Figure 3 Schematics of the existing or planned electricity monitoring in the Utrecht demonstration site

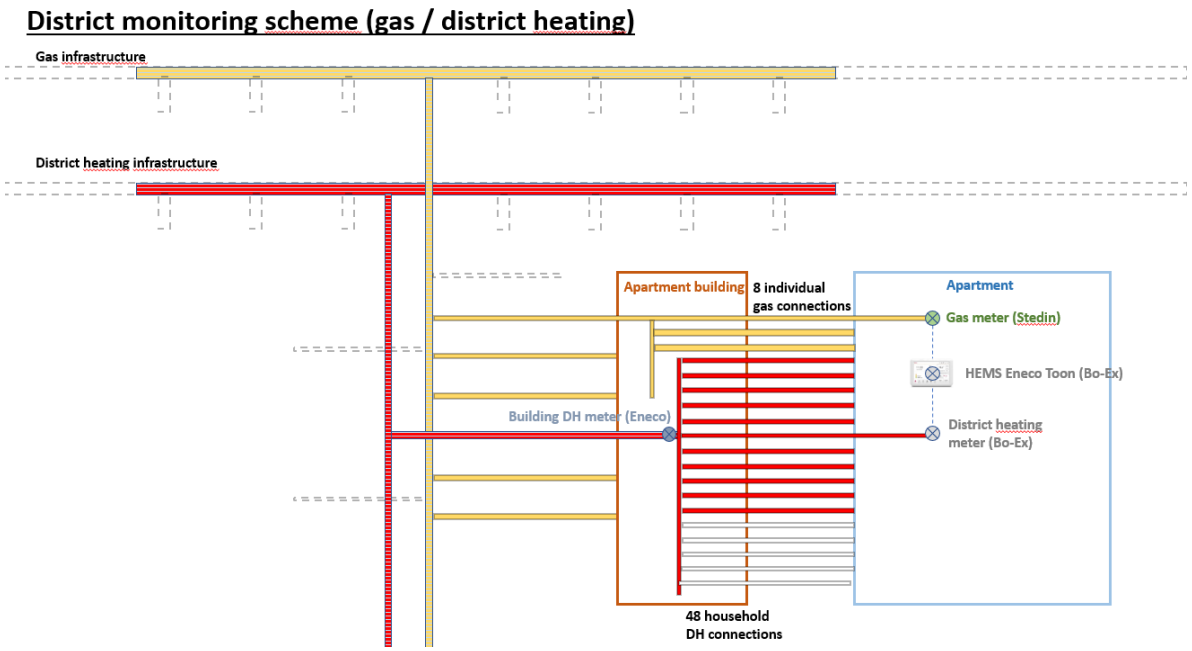

Figure 4 Schematics of the existing or planned gas / district heating monitoring in the Utrecht demonstration site

2.4 Workshop at the IRIS consortium meeting in Nice

The workshop at the plenary meeting in Nice was not as comprehensive as the one in Utrecht, due to the limited time frame. Therefore, only the third step of the first workshop in Utrecht was taken. Also, more time was spent in introducing the methodology described in D9.2.

2.4.1 Projected results

- Get the partners of the LHs started with critically analysing their integrated solutions and linking these with the KPIs.
- Find out in what stage the LH cities are, so next steps in the project will be in line with the needs of the partners.

2.4.2 Methodology

- The contents and approach of D9.2 where presented in a 20-minute presentation.
- The projected contents of D9.3 and how to achieve them where introduced.
- The approach of the workshop in Utrecht was explained, together with its results.
- Partners where invited to get together as lighthouse cities, choose one demonstration site and create an overview of what measurements are projected to take place.
- Results of this exercise where briefly presented to each other.

2.4.3 Outcome

- The workshop was a good start in showing what input is expected from the cities to reach a proper KPI calculation.
- The general impression of the workshop was that, like in Utrecht, guidance is required to make a translation between D9.2 and the physical situation of the integrated solutions.
- Partners are very much interested and open in receiving guidance and help in setting up their approach.
- Generally speaking, partners are in a stage where projects are not completely defined in detail yet. Giving room and time to optimize their monitoring approach.
- The workshop lead to another meeting and productive discussion where a stronger connection with WP4 (the City Information Platform) was made.

2.5 Second workshop Utrecht

The second workshop in Utrecht is a follow up of the first one. It is based on the experiences from the former workshops and planned at the end of November.

2.5.1 Projected results

- Find out to what degree the common data structure (section 3.2) meets the requirements of the partners.
    - Is it clear how to utilize the structure?
    - Are there subjects missing / unnecessary?
- Take a second step in making an overview of how the projected measurements in the integrated solutions will provide the data that is required for calculating the KPIs.
- Learn how to set up a common approach to support the other LH cities in this process.

2.5.2 Methodology

- The workshop continues with the schemes that where created in workshop 1.
- The partners are invited to do some homework before the session:
    - Find the specifications of the meters that where defined in the scheme.
    - Fill in the 'common data structure' (Section 3.2) for these measurements.
- The homework will be discussed at the start of the session.
- How to get from a KPI to the actual data in an IS will be analysed / discussed with the whole group for at least 2 KPIs (a, presumably, simple and a more complicated one):
    - Increased awareness of energy usage (connected to the HEMS / TOON integrated solution)
    - Energy savings
- Examples of topics for discussion are:
    - What is required for a proper functioning of the IS, is reviewed regarding the aspects as stated in 2.3.2
    - Are we able to calculate / realize the KPI?
    - Are the existing measurements (Figure 3) sufficient? Is more data required?
    - Does the KPI meet the requirements of the project partners?
    - Does the KPI meet the requirements of the IRIS project?
    - Can all data which is used to calculate the KPI be published in the CIP?

2.5.3 Outcome

As the workshop has not been held yet, the outcome will be described in the update of this document D9.4. The outcome of this workshop will be used as input for the next steps.

2.6 Next steps

Introductory workshops have also been held in Gothenburg, and are planned to proceed as part of task 9.3. With the combined outcome of the workshops and best practices of other projects a guideline will be set up to support all LH partners in the process. This guideline will be developed in close cooperation with the lighthouse cities and incorporate harmonized data gathering. New workshop sessions for this procedure will be held in the beginning of 2019. Besides inviting the partners from the IS's in these sessions, also the partners from WP4 (City Information Platform) will also collaborate, to have a smooth integration of their work in this process.

3 Approach for each integrated solution

To retrieve the defined KPIs for each demonstrator project, several parameters are of relevant importance to be measured. The monitoring of these measurements will take place during the operation of the integrated solutions. In order to define a monitoring plan for each solution a common structure is defined, as described in this chapter.

3.1 Description of the integrated solution

For each integrated solution within the framework of the IRIS project, a specific section is written. Each section is divided into subsections which give:

- A short description of the integrated solution
- A schematic diagram of the setup (if necessary)
- A list of KPIs which will be evaluated by the integrated solution
- A case specific translation/ interpretation of the KPI (if required)
- A list of parameters to be measured within the integrated solution
- A detailed table based on the Common data structure (Table 1) where the details of each measured parameter are represented.

3.2 Common data structure

The template as shown in Table 1 identifies relevant categories of information to be collected during the operation of the integrated solutions. For less technical parameters, for example parameters measured more from a financial or societal approach, it might not be possible to fill in certain categories. When this is the case for a whole dataset, columns could be deleted from the template table.

The following sections provide guidance in what information to provide in each column in Table 1. The basis for this structure is related to the data model of the Celsius smart cities project [3] and the FIWARE data models [4]. As an example, one row is filled with expected type of information.

Data set

Figure 1 shows the relation between the datasets in the data management plan and the measured variables in this document. Please specify in this cell to which dataset the variables are related. In case the measured variables are part of more than one dataset, please specify all of them.

KPI(s)

Specify to what KPI(s) the measured data is related. The KPIs are numbered in alphabetical order as listed in Annex 2.

Data type

Define the type of main physical parameters to be measured and recorded such as: Electric energy consumption / production, temperatures, water / gas flows etc. Besides these technical parameters, also

other parameters such as tariffs, emissions, pollution particles etc. could be given. Where possible, keep this typology in line with the data types mentioned in the "Description format of each KPI", as mentioned in D1.1. A full, readable and distinguishable short name should be provided here. Which can be abbreviated in the next cell).

Data Variable name

The KPI formulas in D1.1 provide abbreviations for different variables leading to the KPIs. Where possible similar abbreviations will be used for each data variable name.

As large amounts of data will be collected, possible mistakes could happen due to mixing up variables. Especially when similar variables are measured at different locations for example. Therefore, each measured parameter will have a specific identification name that distinguishes it from other variables. Part of this name could also be for example the location of the measurement.

Units of measurement

Define which units are being used. Try to keep units uniform, for example when electrical energy is measured in kWh, try to use the same unit for electrical energy in the whole dataset.

Location of measurement

Similar measurements can take place at different locations.

- On larger scale: When similar integrated solutions take place in different cities
- On small scale: When similar units are being measured at different locations within the same project.

Monitoring equipment

Indicate here what equipment will be used for monitoring. Further on provide information about

- The accuracy of the implemented monitoring equipment
- A possible estimation of (un)certainty of the gathered data due to other (external) effects.

Recording frequency

The recording frequency depends on the purpose of each solution and the associated KPIs that are evaluated by monitoring. Define what frequency suits your situation and indicate the recording frequency (hourly, daily, yearly….) for each measurement here.

Start of measurements

In some cases, similar datasets can be provided for different timeframes within the project. Specify at what date / time the measurements of each variable starts.

End of measurements

Specify at what date / time the measurements of each variable ends.

Comments

This section can be used to

- Add extra information that is relevant for the measurements, which is not covered by the other columns
- Keep track of unusual situations, such as (temporal) failures, calibrations tests of equipment etc.

Table 1 Common data structure used for the information collection during the operation of the integrated solutions

Data Set	KPI	Data Type	Data Variable name	Units of measurement	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start of measurements	End of measurements	Comments
The data set as represented in the DMP to which the data belongs	*KPI('s) that are related to the data*	*The parameter that is being measured*	*An abbreviation for the variable*	*What unit is being measured ?*	*Where the measurements take place*	*What is used to measure the data? How accurate is this?*	*How often the data is recorded*	*Time-stamp of the first measure-ment of the dataset*	*Time-stamp of the last measure-ment of the dataset*	*Further info*
1	KPI1.2	Annual energy consumption	E_c	kWh	Utrecht, building X	Smart meter, 1% accuracy	Once per year	1-1-2019, 0:00CET	31-12-2019, 24:00CET	example

Apart from the above entities that will be collected during the operation of the integrated solutions, the data model of the Key Performance Indicator will also contain entities, which will be used to store information that is required or produced during calculation and visualisation of the KPI. Table 2Table 2 present the extra entities of the KPI data model:

Table 2 Additional entities of the KPI data model

Name	Description	Type	Examples of values
calculationFrequency	How often the KPI is calculated	Text	hourly, daily, weekly, monthly, yearly, quarterly, bimonthly, biweekly
calculationMethod	The calculation method used	Text	manual, automatic, semiautomatic
calculationFormula	For informative purposes, the formula used for calculating the indicator	Text	
calculationPeriod	KPIs period of time	Structured value	Period start DateTime – Period end DateTime
kpiValue	The value of the KPI	Any type	
dateNextCalculation	Date on which a new calculation of the KPI should be available	DateTime	
dateExpires	The date on which the KPI will be no longer necessary or meaningful	DateTime	
updatedAt	Last update date of the KPI data	DateTime	
aggregationLevel	The level at which the KPI is calculated	Text	IS, TT, LH city, IRIS project
KpiThreshold	The threshold for this KPI	Any type	
kpiTarget	The target for this KPI	Any type	

4 Examples

The examples in this chapter give an impression of how integrated solutions could be described by making use of the approach described in the former chapter. Even though real integrated solutions are being used, the data given in these examples do not give a representation of the actual final situation and are only examples.

4.1 Home Energy Management Systems (HEMS) TOON

4.1.1 Description of the integrated solution

The Eneco Toon® (hereafter Toon) is an existing device (7`` display) with proven technology (Figure 5). The main objective of the Toon is to provide information of the energy usage of a household. Since a couple of years, the Toon is already installed in many houses and apartments in The Netherlands, for clients and non-clients of Eneco. The user interface and hardware of the Toon have been adjusted frequently. Other functionalities were added, such as:

- Amount of energy produced by PV panels
- Monthly energy bill
- Spoilage checker
- Weather forecast

Figure 5 The Eneco Toon with a screenshot of the app

Eneco will be involved in the PoR stage and design process for the apartment buildings. The PoR of the Toon and linked applications depends on the possibilities to adjust the software of the Toon and/or linked applications. Eneco will therefore also be partner in the citizen engagement activities in TT#5.

4.1.2 Evaluated KPIs and calculation method

Table 3 List of KPIs evaluated with the Home Energy Management System

KPI	Unit	Definition	Formula
Increased awareness of energy usage/Increased environmental awareness	Likert	The extent to which the project has used opportunities for increasing awareness of energy use	Not at all – 1 – 2 – 3 – 4 – 5 – very much

4.1.3 Monitored parameters

To evaluate how TOON increases the awareness of energy use, data will be collected in the form of questionnaires. In order to have an effective feedback rate from the surveys without over asking the target audience, surveys will be combined as much as possible.

Table 4 - Monitored parameters of the home energy measurement system

Data Set	KPI	Data Type	Data Variable name	Units of measure-ment	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start	End	Comments
	17	Effect on environmental awareness Toon	Aw_Toon	Likert	At residence	Survey	3	01-2019	08-2021	The survey will be part of a larger survey

4.2 Energy savings as a result of refurbishing towards near zero energy building

4.2.1 Description of the integrated solution

Currently the apartment buildings experience high heat losses due to poor insulation. As part of the refurbishment activities to increase energy efficiency the following measures will be implemented:

- New window frames and glazing (double or triple glazing);
- Insulation of outer walls and the ground floor ceiling;
- Improvement of chinks (especially at the connection of the façade with the window frames);
- Mechanical ventilation (with natural or mechanical supply).

A schematic representation of the IS with the measurements is given in Annex 1.

4.2.2 Evaluated KPIs and calculation method

Table 5 List of KPIs measured with

KPI	Unit	Definition	Formula
Energy savings (13)	(kWh/(m2 year); MWh/(year))	The reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period.	$ES_T = 1 - \frac{TE_C}{ER_T}$ ES_T = Thermal energy savings TE_C = Thermal energy consumption of the demonstration-site [kWh/(m^2 year)] ER_T = Thermal energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m^2 year)]. $ES_E = 1 - \frac{TE_C}{ER_E}$ ES_T = Electric energy savings TE_C = Electric energy consumption of the demonstration-site [kWh/(m^2 year)] ER_T = Electric energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m^2 year)].
Carbon dioxide Emission Reduction (5)	tonnes CO_2/year	Reduction of emissions of carbon dioxide related to measure.	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

KPI	Unit	Definition	Formula
Reduced energy costs for consumers (34)	Euro/m2	Reduction in cost for energy consumption on an aggregated level, based on energy savings and current energy prices.	$COST_{REDUCTION} = \frac{COST_{R\&I} - COST_{BaU}}{COST_{BaU}}$ COST = the electricity price at a given period of time
CO_2 reduction cost efficiency (7)	Euro/ton CO_2 saved per year	Costs in euros per ton of CO_2 saved per year	This indicator is calculated on an annual basis, taking the annual reduction in CO2 emissions, and the annual costs of the project (which is the annualised investment plus current expenditures for a year). Note: Only the additional costs for energy/CO2 related measures (to the extent discernible) are taken into account in the total costs' calculation.
Degree of energetic self-supply by RES (10)	%	Ratio of locally produced energy from RES and the energy consumption over a period (e.g. month, year)	$\mathrm{DE_T} = \frac{\mathrm{LPE_T}}{\mathrm{TE_C}}$ 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)]

4.2.3 Monitored parameters

Table 6 Monitored parameters of integrated solution Energy savings as a result of refurbishing towards near zero energy building

Data Set	KPI	Data Type	Data Variable name	Units of measurement	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start	End	Comments
HEMS_1_Eneco Toon	10	Actual energy solar energy production. .	Solar_Toon	kWh	In every apartment house, in the living room	Operational platform for energy usage, solar energy and heating with multiple sensors.	< 1 second metering	12-2019	08-2021	
HEMS_1_Eneco Toon	10	Actual CO2 level	CO2_Toon	ppm	In every apartment house, in the living room	Operational platform for energy usage, solar energy and heating with multiple sensors.	< 1 second metering	12-2019	08-2021	
2. Battery Management System	10, 5	Actual energy storage	Bat_storage	kWh	In 2 apartment buildings, in the garage box	Energy Management System	< 1 second energy metering	12-2019	08-2021	Reporting every 4 seconds
3a. Electricity meter in fuse box (DIN-rail)	10, 7, 13	Energy generated by solar energy (input from	Solar_house	kWh	In every apartment house, in the fuse box	kWh-meter	Every 200ms (accuracy of 1%)	12-2019	08-2021	

Data Set	KPI	Data Type	Data Variable name	Units of measurement	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start	End	Comments
		the convertor)								
3b. Electricity meter in invertor	10, 5	Energy generated by solar energy	Solar_inv	kWh	In every apartment house, in the electricity cabinet	kWh-meter	50Hz, 60Hz;±5Hz	12-2019	08-2021	Application for the tenants
4. District heating meter	10, 7, 13	Heat power/flow	Heat_distr	GigaJoule	In every apartment house, in the central heating cabinet	Flow meter	< 1 second flow metering	12-2019	08-2021	Reporting once per week

4.3 HSB Living Lab

HSB Living Lab is a unique 3rd generation Living Lab where some 40 students and researchers live. The Living Lab is a test bed for new science and technologies that will enable tomorrow's sustainable housing and living. The building has been designed in a modular fashion to enable larger of smaller parts (such as facade elements) to be easily exchanged. A multi-sensor system of over 2 000 sensors and 15,000 metres of data cable monitor the tenants and their environment on a 24/7 basis. Built-in sensors monitor comfort conditions, for instance temperature, moisture and light conditions and therefore control of the insulation function can be managed with a few buttons. 540 electricity meters are installed to measure the energy consumption of various devices and on all electrical outlets in the house while a Bluetooth based location system of 54 position tags provides information about windows and door openings, place and time of washing clothes etc.

4.3.1 Description of the integrated solution(s)

As part of IRIS, HSB will mainly work with three specific integrated solutions connected to the HSB Living Lab:

- Demonstration of how Building Integrated Photovoltaics (BIPV) can be used in façade renovation process for easy and economical retrofits and renovations
- Visualization of real-time data in a BIM (Building Information Modelling) based 3D Virtual Reality Environment for optimisation of a building's energy infrastructure, including PV and storage facilities
- Personal Energy Threshold (PET), to motivate actively engaged users to change their energy consumption behaviour. This tool will integrate real-time data on energy production and consumption (availability and demand), and thus enable end-users in their homes to actively contribute to peak shaving in smart energy networks by providing them with alternatives on how to modulate their energy needs.

4.3.2 Evaluated KPIs and calculation method(s)

Table 7 List of KPIs measured with HSB Living Lab integrated solution BIPV

KPI	Unit	Definition	Formula
Carbon dioxide Emission Reduction	tonnes CO_2/year	Reduction of emissions of carbon dioxide related to measure.	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

KPI	Unit	Definition	Formula
Reduced energy costs for consumers	Euro/m2	Reduction in cost for energy consumption on an aggregated level, based on energy savings and current energy prices.	$COST_{REDUCTION} = \frac{COST_{R\&I} - COST_{BaU}}{COST_{BaU}}$ COST = the electricity price at a given period of time
CO_2 reduction cost efficiency	Euro/ton CO_2 saved per year	Costs in euros per ton of CO_2 saved per year	This indicator is calculated on an annual basis, taking the annual reduction in CO2 emissions, and the annual costs of the project (which is the annualised investment plus current expenditures for a year). Note: Only the additional costs for energy/CO2 related measures (to the extent discernible) are taken into account in the total costs' calculation.
Degree of energetic self-supply by RES	%	Ratio of locally produced energy from RES and the energy consumption over a period (e.g. month, year)	$\mathrm{DE_T} = \frac{\mathrm{LPE_T}}{\mathrm{TE_C}}$ 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)]
Increase in local renewable energy production	% in kWh	Ratio of produced energy from renewable production over a period (e.g. month, year)	$LREG = \frac{ERES_{R\&I} - ERES_{BaU}}{EC}$ LREG = Annual Local Renewable Electricity Generation ERES = Annual electricity generated by RES EC = Annual Electricity consumption

4.3.3 Monitored parameters

Table 8 Monitored parameters of HSB Living Lab integrated solution BIPV

Data Set	KPI	Data Type	Data Variable name	Units of measurement	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start	End	Comments
	5	Electricity consumption before (BaU) and after measure		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Continuously, frequency of 1 s	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and measuring data
	7	Same as KPI 1.5		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Continuously, frequency of 1 s	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and measuring data
	7	Investment cost of measure		SEK / EUR	Gothenburg, HSB Living Lab	-	Once	N/A	N/A	Investment cost extracted from report (already in place)
	10	Locally produced electrical energy (- kWh to grid)		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Monthly	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and measuring data
	10	Electrical energy consumption		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Monthly	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and

Data Set	KPI	Data Type	Data Variable name	Units of measurement	Location of measurement	Monitoring equipment and data accuracy	Recording frequency	Start	End	Comments
										measuring data
	20	Locally produced electrical energy		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Monthly	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and measuring data
	20	Electrical energy consumption		kWh	Gothenburg, HSB Living Lab	Smart meter, 2 % accuracy	Monthly	1-10-2017, 0:00CET	31-9-2021, 24:00CET	Equipment already in place and measuring data

5 Output to other work packages

D9.3 sets a standard for data collection of the integrated solutions. This standard harmonizes how these integrated solutions, which are part of WP5, 6 and 7, will be described and analysed. Following the approach of in this document, facilitates these work packages in:

- Creating an overview of the measurements that are planned to take place in their integrated solutions.
- Making a connection with the KPIs and calculation methods as described in D9.2 and their physical measurements.
- Finding out where more data or other measurements are required for proper KPI calculation.
- Providing feedback where KPIs need adjustment.

The overview of data which is being gathered by the integrated solutions, provides input for WP4. (Open) data from WP5, 6 and 7 can be made available in the City information platform (CIP). This gives a structured database with proper background information where all IRIS partners can make use. It also provides insight in other business opportunities that could arise from the Integrated Solutions (WP3) and for replication as part of WP8.

6 Conclusions

In this document an approach is given to obtain a detailed description of each integrated solution, together with an overview of the physical measurements and a detailed KPI calculation. This approach is developed in collaboration with the IS partners by means of a series of workshops. The workshops where held with the partners in Utrecht, Nice and Gothenburg. One of the main objectives of these workshops was to determine what is required to link the approach for KPI calculation, as described in D9.2, with the physical demonstration sites of the integrated solutions.

The result of these workshops showed that making a detailed description of each integrated solution is an important task that requires some serious effort. It has led to the approach described in this document which defines a basis to specify and define the process of data collection in the integrated solutions.

More workshops are planned to proceed as part of T9.3. With the combined outcome of the workshops and best practices of other projects, a guideline will be set up to support all LH partners in the process. This guideline will also incorporate harmonized data gathering. Partners from WP4 (City Information Platform) will collaborate in this process, to have a smooth integration of their work.

With the help of this guideline, a harmonized description of each integrated solution can be developed and published in D9.4 to facilitate the unified framework for harmonized data gathering, analysis and reporting.

7 References

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[3] Celsius Smart Cities, "D 4.2 Common monitoring methodology and data structure" 2013 [Online] Available: https://smartcities-infosystem.eu/sites/default/files/celsius_common_monitoring_methodology_and_data_structure.pdf [Accessed 9-8-2018]

[4] Fiware, "Fiware Data Models, Key Performance Indicator" 2018 [Online] Available: https://fiware-datamodels.readthedocs.io/en/latest/KeyPerformanceIndicator/doc/spec/index.html [Accessed 9-8-2018]

Annex 1. Schematics of Utrecht demonstration site

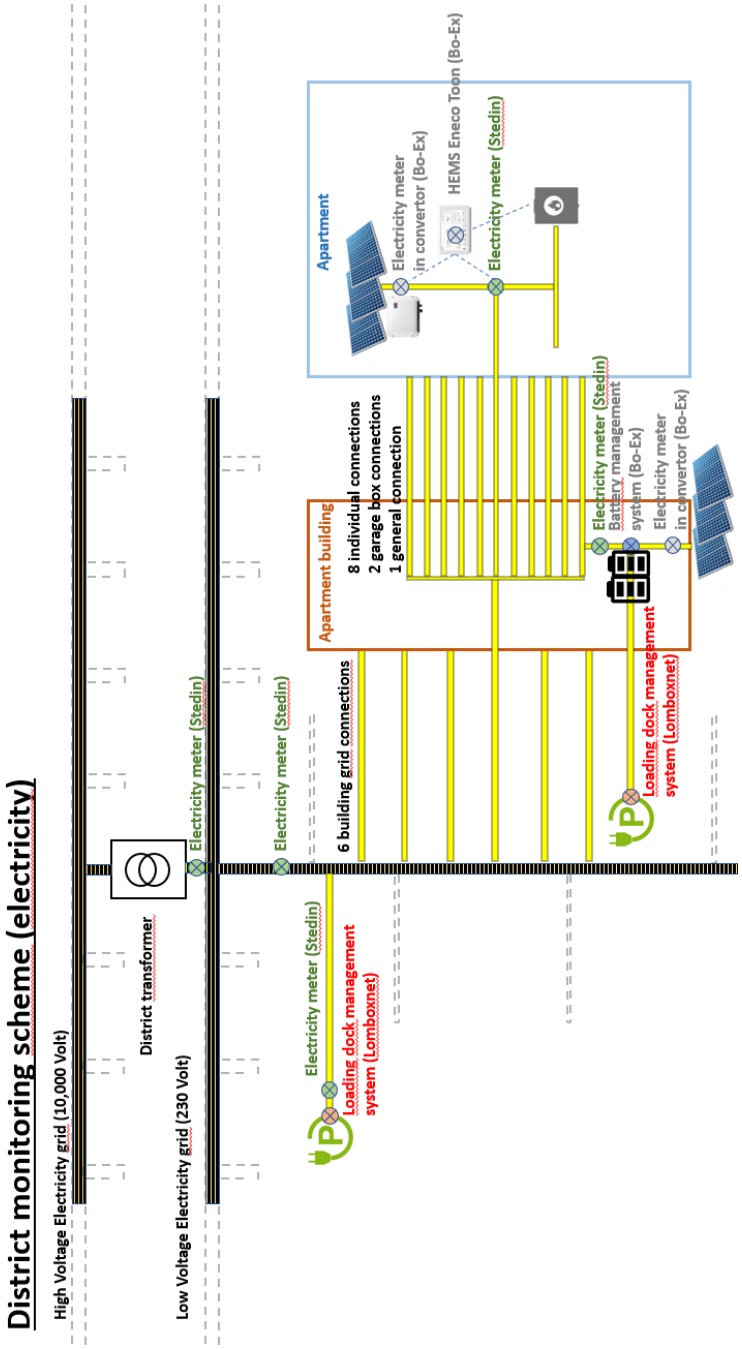

Figure 6 Detailed schematics of the existing or planned electricity monitoring in the Utrecht demonstration site

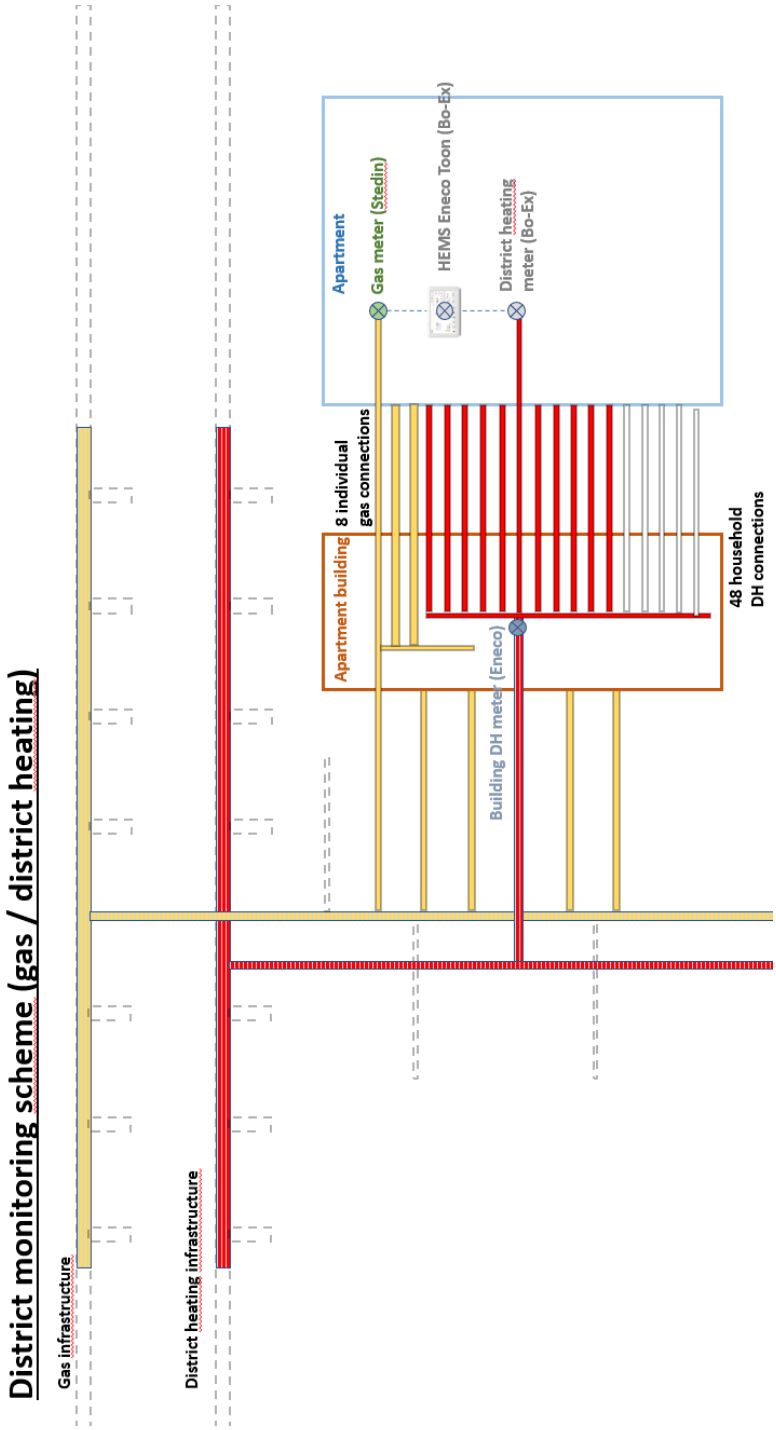

Figure 7 Detailed schematics of the existing or planned gas / district heating monitoring in the Utrecht demonstration site

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		