# IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

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# Deliverable 9.7

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## Disclaimer

# Executive Summary

The purpose of this deliverable is to assess the effectiveness of the 59 pilot measures implemented in three cities (Utrecht, Nice and Gothenburg) as part of the IRIS project. The evaluation is carried out by using key performance indicators (KPIs) to measure whether the project impact goals have been achieved. This report is based on the work conducted in Work Package (WP) 9, "Monitoring and Evaluation", and utilizes the monitoring framework and baselines established in deliverable D9.5 to collect data and calculate KPIs. The KPI tool, which was created and presented in D9.4, is used to process and visualize the results of the data collected.

This deliverable is relevant for individuals involved in monitoring and evaluation of smart city projects, and the result chapters provide an overview of the performance of specific measures for those interested in implementing similar solutions. The report outlines the process of collecting data and evaluating KPIs in the IRIS project, which requires an iterative approach due to the need for continuous adjustments of the KPIs to better fit the measures, available data, and changes that occur throughout the project. The KPI selection process involved a dialogue with partners to ensure that all necessary parameters for the selected KPIs could be measured.

The IRIS KPI tool was developed to facilitate monitoring and evaluation of the initiatives in the three cities. Data can be transferred to the tool automatically or manually through a template, a process explained in this deliverable. However, data extraction and transfer into the KPI tool have been challenging due to the complexity of APIs and the lack of standards. Manual data collection and a systematic procedure involving partners were required for measures not connected to City Information Platform. The transferred parameters used for the evaluation are included in the Annex to ensure transparency in the evaluation process. The data collected and analysed in the KPI tool are available for download.

The process of adjusting KPIs to enable clear interpretation and consistent use, continued throughout the project. Qualitative KPIs were developed to capture measures aimed at citizen engagement and co-creation. As data collection progressed, it became apparent that additional information beyond the KPIs was required. KPIs are designed to track specific and measurable outcomes, which may not encompass the broader narrative and qualitative aspects of the measurement. As a result, using KPIs alone can give a narrow and oversimplified view of the impact of the initiative. To address this, two workshops were conducted with project partners, which aimed to encourage them to actively participate in the storytelling process and identify and provide additional information to improve the interpretability of the KPI results.

The results are presented in a chapter per city which is divided into sections per transition track that in turn presents the results at measure level. The highest level of detail can be obtained at the measure level but results are also aggregated up to transition track, city and project level. The impact targets set in the three cities have been achieved to varying degrees and details can be found in the result chapters of this deliverable together with explanations for the reasons why some are not reached. In general, it is worth mentioning that the COVID pandemic has affected the implementation and use of some measures. Furthermore, challenges when implementing new technologies, changes of to the scope and too ambitious targets are some of the reasons for not meeting the set targets. Valuable lessons learnt by the project partners and details beyond KPIs are given in the final report of the respective cities. At the IRIS

project level, the implemented PV installations have produced around 825 MWh of electricity per year, which is enough to cover the needs of 515 EU citizens in terms of household electricity. The production levels are evenly distributed among the three cities. Furthermore, the various measures included in the IRIS project are estimated to a achieve CO2 emission reduction of approximately 825 tonnes per year, equivalent to the emissions of 520 EU citizens. Intelligent mobility solutions, such as electric buses and cars, accounted for approximately 90% of this reduction. These results were also evaluated using alternative assumptions regarding emission factors which turned out to influence the results with up to 15 %. A sensitivity analysis was performed to demonstrate how different calculation methods and time resolutions affect the estimation of emissions related to the electricity grid. The study utilized data from a measure in the IRIS project that involved a combination of PVs and batteries. The results highlight the challenge of generalizing project outcomes and offer useful insights for upcoming EU projects.

The challenges encountered in the monitoring and evaluation process are summarised in the conclusions. Recommendations are provided based on the difficulties experienced in the IRIS project, particularly concerning data collection and KPIs. In addition to the recommendations for data collection in the IRIS project, there are other important considerations when monitoring and evaluating smart city initiatives. To ensure the success of these initiatives, projects should take a comprehensive and multifaceted approach to measurement that goes beyond KPIs. This involves supplementing quantitative data with qualitative data, stakeholder feedback, and other forms of information to provide a more nuanced understanding of impact.

Moreover, transparency in the monitoring and evaluation process is crucial for ensuring trust and interpretability. This can be achieved by clearly stating assumptions and targets when presenting results. In addition, organizing workshops with all partners involved in the project can promote a better understanding of the complex interplay between measurement narratives and KPIs.

It is also important to budget sufficient time for continuous discussion with project partners on monitoring and evaluation throughout the project. Updating and adjusting KPIs over time is an ongoing process, and projects should allocate sufficient time and resources for this task. Projects should also consider using percentual changes instead of absolute numbers as targets and periodically review and revise targets to ensure their continued relevance and accuracy throughout the project.

By following these recommendations, projects can improve their data collection and monitoring and evaluation processes and provide a more complete and nuanced understanding of the impact of their initiatives.

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# List of Abbreviations and Acronyms

| Abbreviation | Definition |
|---|---|
| AC | Alternating Current |
| APIs | Application Programming Interfaces |
| AWL | A Working Lab |
| BAU | Business As Usual |
| BESS | Battery Energy Storage Systems |
| BIM | Building Information Model |
| BIPV | Building Integrated Photovoltaics |
| CIM | City Information Model |
| CIP | City Innovation Platform |
| CITYkeys | Smart City performance measurement system (Project funded by the European Union HORIZON 2020) |
| COP | Coefficient of performance |
| CTP | Chalmers Teknik Park |
| DC | Direct Current |
| DEMS | District Energy Management System |
| DER | Distributed Energy Resources |
| DHCN | District Heating Cooling Network |
| DoA | Description of Action |
| DSO | Distribution System Operator |
| DSM | Demand Side Management |
| EC2B | Easy to be |
| EMSs | Smart Energy Management System |
| EPC | Energy performance contracting |
| EPBG | Energy Performance Building Gap |
| EV | Electric Vehicle |
| EVCI | Electric Vehicle Charging Infrastructure |
| FC | Follower City |
| FPM | Fine particulate matter emission |
| GA | Grant Agreement |
| GDPR | General Data Protection Regulation |
| GOT | Gothenburg |
| HEMS | Home Energy Management System |
| HP | Heat Pump |
| ICT | Information and Communication Technology |
| IL | IRIS project level |

| | |
|---|---|
| IMREDD | Institut Méditerranéen du Risque de l'Environnement et du Développement Durable |
| IRR | Internal Rate of Return |
| IS | Integrated Solution |
| ISO | International Standards Organization |
| KPI | Key Performance Indicator |
| LCL | Lighthouse City Level |
| LC | Lighthouse City |
| LCA | Life Cycle Assessment |
| LEMS | Load Estimation and Management System? |
| LH | Lighthouse |
| LHV | Lower Heating Value |
| lm | Lumen |
| M | Measure |
| MaaS | Mobility as a Service |
| ME | Citizen Engagement (Sw. "Medborgarengagemang") |
| MVP | Minimal Viable Product |
| NCA | Nice Côte d'Azur |
| NZEB | Near Zero Energy Building |
| OCPP | Open Charge Point Protocol |
| PCM | Phase Change Materials |
| PDS | Public Delegation of Service |
| PEB | Positive Energy Building |
| PED | Positive Energy District |
| PET | Personal Energy Threshold |
| POC | Proof of concept |
| PV | Photovoltaic |
| REC | Real Estate Core |
| RES | Renewable Energy Sources |
| ROI | Return of Investment |
| RVO | Rijksdienst Voor Ondernemend Nederland |
| SC | Smart City |
| SCIS | Smart Cities Information System (Project funded by the European Union HORIZON 2020) |
| SOC | State Of Charge |
| STT | Solution level |
| T | Task |
| TES | Thermal Energy Storage |
| TSO | Transmission System Operator |
| TT | Transition Track |
| UC | Use Case |

| | |
|---|---|
| UNS | University of Nice |
| UTA | Urban Transport Authority |
| UTR | Utrecht |
| USEF | Universal Smart Energy Framework |
| USI | Utrecht Sustainability Institute |
| V2G | Vehicle to Grid |
| WP | Work Package |

# 1 Introduction

The IRIS project implemented approximately 59 pilot measures in the lighthouse cities of Utrecht, Nice, and Gothenburg, across five different IRIS transition tracks: TT1 Renewable and Energy Positive District, TT2 Flexible Energy Management and Storage, TT3 Intelligent Mobility Solutions, TT4 Digital Transformation and Service, and TT5 Citizen Engagement and Co-creation.

This Deliverable provides an evaluation and impact analysis of these measures, utilizing Key Performance Indicators (KPIs) to assess their impacts. The process of revising and developing the KPIs and adjusting the related parameters for harmonization, as well as the process of collecting the data is also described. A Sensitive analysis is included to highlight the complexity of the evaluation process, the impact of assumptions on the results and the importance of transparency.

This deliverable is relevant for those working with monitoring and evaluation and the result chapters provides an overview of the performance of specific measures relevant for those interested in implementing similar solutions.

The collected data is available in the annex or for downloading in the KPI tool, where the KPIs of the evaluated measures also can be found.

## 1.1 Scope, objectives and expected impact

Work Package (WP) 9, Monitoring and Evaluation, aims to assess the extent to which the IRIS project has achieved its objectives in each Lighthouse (LH) city, as well as overall. To accomplish this, WP9 monitors and evaluates the performance of various measures demonstrated in the LH cities. This evaluation is valuable for those interested in replicating the solutions in other cities.

This Deliverable, D9.7 *Report on evaluation and impact analysis for integrated solutions,* is a result of task 9.5 *Overall evaluation and impact analysis for impact enhancement*. The scope of this deliverable is to present the outcomes of the demonstration activities in the three LH cities and the impact of actions for the IRIS project. It also aims to evaluate the effectiveness of the implemented measures in achieving the project impact targets outlined in the Grant Agreement or by the partners. Additionally, this deliverable seeks to provide insights into the monitoring and evaluation process involved in the project and highlight the lessons learned that could be beneficial to others working on similar initiatives.

The objectives of this deliverable are to provide an overview of the outcomes achieved in the IRIS project and the challenges encountered in using KPIs for evaluation, as well as to emphasize the importance of transparency in the evaluation process.

The findings and insights presented in this report will inform and guide future efforts to develop sustainable and energy-efficient solutions in urban areas. The results will be available to a wider audience, including researchers, and stakeholders, to support the replication and scaling-up of successful measures and to inform decision-making processes in the field of sustainable urban development. By sharing the lessons learned and best practices from the IRIS project, the expected impact is to contribute to the overall goal of reducing carbon emissions and improving the quality of life in cities across Europe and beyond.

The transferred parameter used for the evaluation is included in the Annex to ensure transparency in the evaluation process. The data collected and analyzed using the KPI tool are also available for downloading. The visualization of the collected data in the KPI tool allows for the evaluation and comparison of different measures, both at LH city and project levels.

## 1.2 Contributions of partners

Deliverable D9.7 *Report on evaluation and impact analysis for integrated solutions* has been authored by Research Institutes of Sweden (RISE), Centre of Research & Technology (CERTH) and Utrecht University (UU). RISE, as the leader in task 9.5 and WP9 leader, has coordinated the activities related to the monitoring and evaluation work. UU, CERTH and RISE have worked on establishing the necessary data to collect for each KPI, in close collaboration with the leaders of the demonstrators of each LH city (Utrecht, Nice and Gothenburg). Furthermore, CERTH and the partners of WP4, the City Innovation Platform (CIP), contributed to establishing the connection of the KPI tool with these platforms.

## 1.3 Relation to other activities

D9.7 *Report on evaluation and impact analysis for integrated solutions of measurement* builds on the work done in task 9.3 *Establishment of unified framework for harmonized data gathering, analysis and reporting,* task 9.4 *Deployment of monitoring framework in LH cities* and task 9.5 *Overall evaluation and impact analysis for impact enhancement.*

Deliverable D9.7 builds on the work done in WP9, mainly a continuation of the work presented in D9,6 *Intermediate report after one year of measurement*. The report uses a framework for monitoring that was developed in D9.*5* [1] and the IRIS Key Performance Indicators (KPI) tool, which processes the collected data and calculates the KPIs presented in D9.4[2]. The tool can be connected to the online systems in each LH city through the City Innovation Platform (CIP) for automatic transfer of data required for KPI calculations. In cases where measures are not connected through the CIP, manual data entry is allowed.

D9.7 relies on data collected from the LH cities (Utrecht, Nice and Gothenburg) of each Transition Track (TT). The five different transition tracks in the IRIS project are TT1 Renewable and energy positive district, TT2 Flexible energy management and storage, TT3Intelligent mobility solutions, TT4 Digital Transformation and Service, TT5 Citizen Engagement and co -creation.

It is worth noting that the results presented in D9.7 are a collaborative effort of the WP9 team and the partners involved. The work of the WP9 team relies on input and engagement from the partners, not only for the data but also regarding additional information and details about the measures such as changes made. Therefore, this deliverable has a clear relation to the final deliverable of each LHC (D5.9, D6.9 and D7.9).

D9.7 is also related to the development of the CIP, as the data from some fields (i.e. building retrofitting, district heating, smart grid and smart mobility) for the LH cites are gathered and stored in the CIP.

The table below summarizes the interrelation between these deliverable and other deliverables.

*Table 1: List of relation to other activities*

| Deliverable Number | Title | Relation (Input/Output) |
|---|---|---|
| **D4.6** | 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** | Launch of the activities in each TT in Utrecht, Nice, Gothenburg | Input used for description of the monitoring methodology and listing of all variables to be measured. |
| **D9.2** | Report on monitoring and evaluation schemes for integrated solutions | Input used for the creation of the data collection and data analysis methodologies. |
| **D9.3** | Report on data model and management plan for integrated solutions | Input used for the creation of the data collection methodology. |
| **D9.4** | Establishment of a unified framework for harmonized data gathering, analysis and reporting | Input used for the creation of the data collection methodology. |
| **D9.6** | Intermediate report after one year of measurement | Output, as the actual performance data collection and reporting was carried out in this deliverable. Moreover, the KPI tool was used to calculate and visualize the KPIs in each LH city. |
| **D9.11** | Fourth and final update of the Data Management Plan | Output, the information for all data variables provides the basis for the data input of the data management plan. |
| **D5,6,7. 9** | Final report on lighthouse demonstration activities | Input used for description of the monitoring methodology and listing of all variables to be measured. Output in form of update KPI list and final results of KPIs |
| **D8.4 – D8.12** | Replication plans of follower cities, European level replication guidelines | Output used for monitoring and evaluation of IRIS replicable solutions. |

## 1.4 Structure of the deliverable

The structure of this deliverable is as follows:

**Chapter 1:** Introduction including the scope, objectives and expected impact of the report are described. Relation to the other work packages in the IRIS project are given and measures excluded from this deliverable are listed.

**Chapter 2:** Methodology describing the methods used to obtain the presented results.
**Chapter 3:** Revision of KPIs gives an overview of the modifications made to the original KPIs, harmonization of parameters and aggregation of KPIs.

**Chapter 4:** The results for the included measures in the Lighthouse city Utrecht.
**Chapter 5:** The results for the included measures in the Lighthouse city Nice
**Chapter 6:** The results for the included measures in the Lighthouse city Gothenburg

**Chapter 7:** The results that are aggregated to IRIS project level
**Chapter 8:** Sensitivity analysis on assumptions regarding $CO_2$ emission factors
**Chapter 9:** Conclusions, challenges with monitoring and recommendation

## 1.5 Excluded from deliverable

Regrettably, some measures in the LH cities have not been incorporated into this deliverable due to several reasons. Below is a list of the excluded measures for each LH city, accompanied by a brief explanation for the reason.

### 1.5.1 Utrecht

In total, 21 measures in Utrecht are excluded from this deliverable. A brief explanation to the exclusion is given in Table 2 while more details can be found in the deliverables of the LH city D.5.9 *Final report on Utrecht lighthouse demonstration activities* [3].

*Table 2: Overview of measures excluded Utrecht with a short explanation to the reason.*

| Measure Number | Measure title | Explanation |
|---|---|---|
| **Transition Track 1 Renewables and Energy Positive Districts** | | |
| **Measure 2** | Low temperature district heating | Implementation of measure delayed |
| **Measure 6** | AC/DC home switchboxes | Measure only partly implemented |
| **Transition Track 2 Flexible Energy Management and Storage** | | |
| **Measure 1** | Solar V2G charging points for e-cars/e-vans (demand driven) | Use case not appropriate for KPI calculation |
| **Measure 2** | Solar V2G charging point for e-buses | Use case not appropriate for KPI calculation |
| **Measure 4** | EMSs- Smart Energy Management System | Use case not appropriate for KPI calculation |
| **Transition Track 4 Digital Transformation and Services** | | |
| **Measure 1** | Monitoring E-Mobility with LoRa network | No KPIs |
| **Measure 2** | Smart Street Lighting with multi-sensoring | No KPIs |
| **Measure 3** | 3D Utrecht City Innovation Model | No KPIs |
| **Measure 4** | Monitoring Grid Flexibility | No KPIs |
| **Measure 5** | Fighting Energy Poverty | KPI calculated in TT1 |
| **Transition Track 5 Citizen Engagement and Co-Creation** | | |
| **Measure 5** | XR Experience | No data due to preliminary end of demonstration |

### 1.5.2 Nice

In total 3 measures in Nice are not included in this deliverable. More details on the reasons are given in the deliverables of the LH city D6.9 *Final report on Nice lighthouse demonstration activities* [4].

*Table 3: Overview of measures excluded in Nice with a short explanation to the reason.*

| Measure Number | Measure title | Explanation |
|---|---|---|
| **Transition Track 1 Renewables and Energy Positive Districts** | | |
| Measure 4 | Dashboard providing real-time energy balance | No data as measure is implemented in another city (not in Nice) |
| **Transition Track 2 Flexible Energy Management and Storage** | | |
| Measure 2 | DHC Smart District Heating and Cooling optimization algorithm - Phase 1: Monitoring on a part of the network<br>DHC Smart District Heating and Cooling optimization algorithm - Phase 2: Full monitoring (with electric and thermal storage) | No data available. |
| **Transition Track 5 Citizen Engagement and Co-Creation** | | |
| Measure 3 | Citizens individual engagement – IOT invoices | The measurement wasn't implemented |

### 1.5.3 Gothenburg

In Gothenburg 3 measures are excluded from this deliverable. A brief explanation to the exclusion is given in the table below while more details can be found in the deliverables of the LH city *D7.9 Final report on Gothenburg lighthouse demonstration activities* [5].

*Table 4: Overview of measures excluded in Gothenburg with a short explanation to the reason.*

| Measure Number | Measure title | Explanation |
|---|---|---|
| **Transition Track 2 Flexible Energy Management and Storage** | | |
| **Measure 3** | Low temperature DH 45/30 system for six buildings | Has no KPIs |
| **Transition Track 5 Citizen Engagement and Co-Creation** | | |
| **Measure 4** | Citizen Engagement (ME)- model | This ME model is a framework created for the Measures Minecraft, Inclusive City Life Challenge, and Min Stad/Min stad 2.0. The framework and result are explained in D7.9. This measure contains no KPI and is therefore not included in the deliverable. |
| **Measure 6** | Demonstrate a BIM (Building Information Model) based AR/VR app | Since the measure was launched during the early stages of the pandemic, the number of users was very limited. The data collected was insufficient to perform an analysis, therefore no KPIs are associated with this measure. For more details, please refer to D7.9. |

# 2 Methodology

The process of collecting data for calculating and evaluating Key Performance Indicators (KPIs) for all measures in IRIS LH cities is described in this chapter. A schematic overview of the process, from KPI selection to final evaluation and results, is presented in Figure 1. The picture highlights the importance of continuous dialogue with partners throughout the various stages and emphasizes the essential role of tracking the progress of measures and measurements.

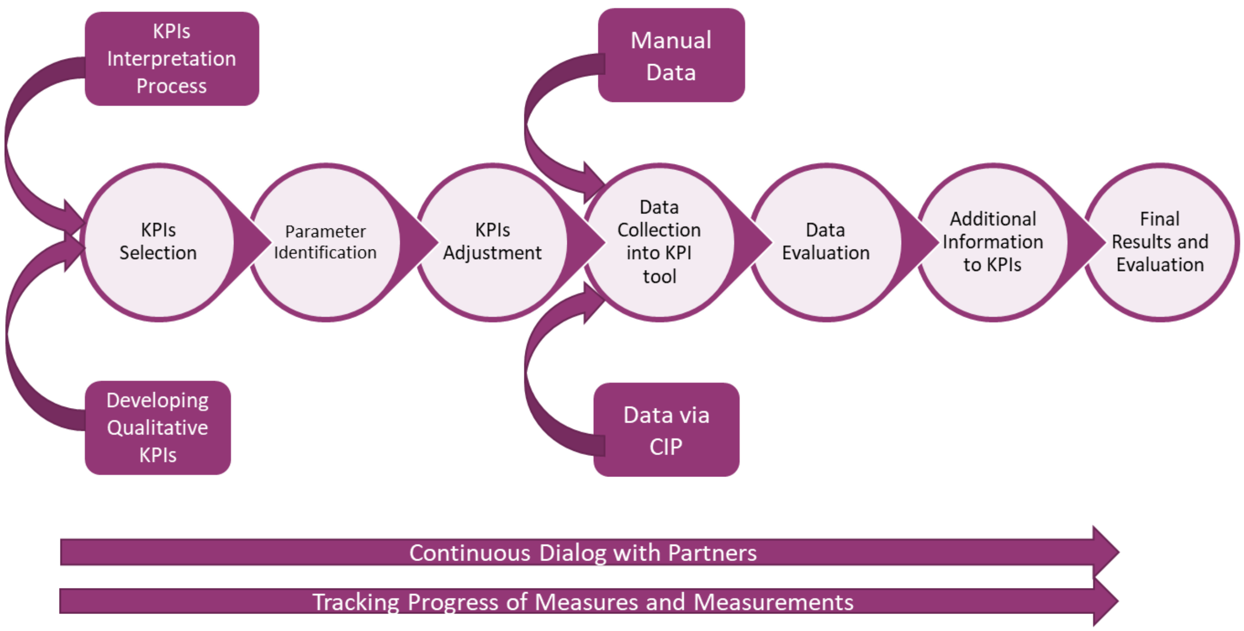


*Figure* 1*: Schematic overview of the process of selecting KPIs to the results and evaluation.*

The process of interpreting and selecting the KPIs in the IRIS project were descripted in Deliverable D9.*5 Report om monitoring framework in LH cities and established baseline* [1]. In Paragraph 2.3 the need to develop KPIs for qualitative data due to insufficient social KPIs in the initial portfolio is highlighted. Some of the existing KPIs also required adjustments. Following the KPI selection process, the parameter identification process began with a dialogue with partners to ensure that all necessary parameters for the selected KPIs could be measured. Further modifications and harmonization of parameters were required, which were achieved through collaboration with partners. Paragraph 2.2 provides a detailed account of this process.

The IRIS KPI tool was developed in T9.3 *Establishment of a unified framework for harmonized data gathering, analysis and reporting* and reported in D9.4 [2]. The basic function of the KPI tool is described in Paragraph 2.1. Since not all measures are connected to the City Information Platform (CIP) an option of manual data entry into the tool was needed. The data collection process is described in Paragraph 2.4

The evaluation and aggregation of KPI is done in the KPI tool and further explained in Paragraph 2.5. To obtain an overview of the status of all the measures, within the different LH cities, an online monitoring timeline was created and continuously updated. This activity is described in Paragraph 2.5.

Moreover, certain measurements require additional information to provide a comprehensive understanding of the impact achieved. To gather and integrate this additional information and to enhance awareness of its importance, workshops were conducted during the project meetings in Utrecht and Nice. Additionally, regular meetings were held with Lighthouse managers and partners responsible for the demonstration. Further details of this process can be found in Paragraph 2.7. In Chapters 4, 5, and 6, the final KPI results and impact are presented and sorted according to each LH City and transition track. These KPI results have been evaluated and compared to the targets outlined in the Grant Agreement. Additionally, the results of the KPIs and their corresponding parameters can be downloaded from the KPI tool, http://monitoring.irissmartcities.eu.

## 2.1 KPI tool

The project's monitoring operations, as well as the overall evaluation and impact analysis of the initiatives in the LH cities, are aided by the IRIS KPI tool. The IRIS KPI tool is available at http://monitoring.irissmartcities.eu. The tool is a platform which collects monitoring data from a variety of sources and uses it to generate the KPI chosen for each measure. The monitoring data from the IRIS demos is collected in a manual or automated manner.

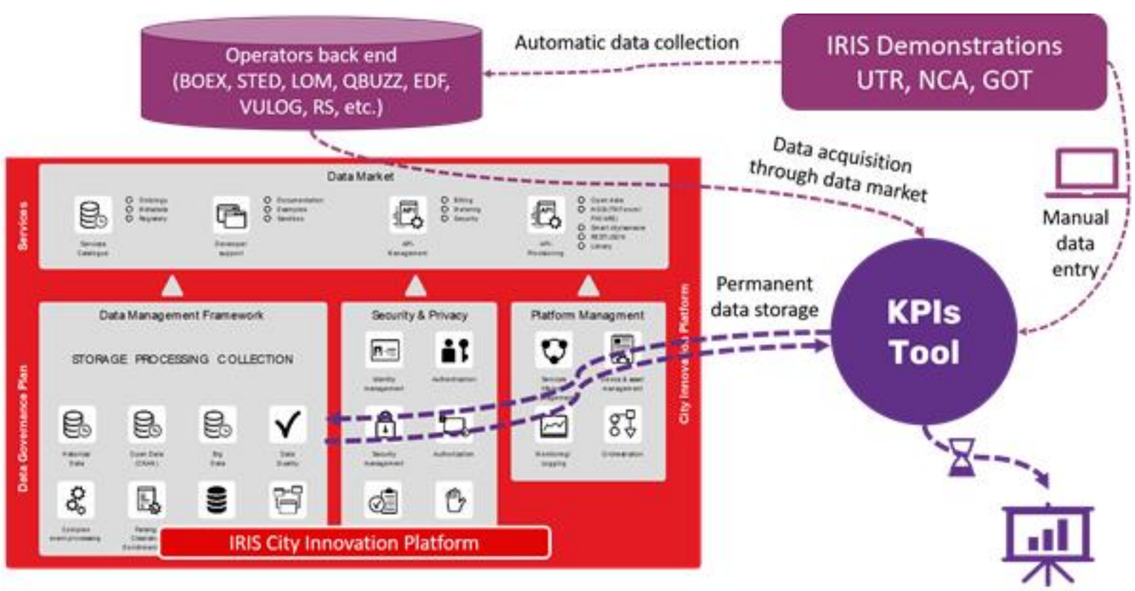


*Figure 2: Schematic diagram presenting the connection of the IRIS KPI tool with CIP and LH cities' demonstrations*

The tool is being tailored to the preferences and requirements of the KPI data owners and other project participants in an ongoing collaborative process. This technique will ensure that the KPI tool supports the project's monitoring, evaluation, and impact assessment activities successfully.

The KPI tool displays the KPIs at various levels of detail, including measure (demonstrator), Transition Track, LH city, and finally, the IRIS project. The tool's functionality was tailored to the demands and requirements of its users (administrators, IRIS partners and general / public users).

More information about the KPI tool is available on IRIS deliverables D9.4 *Report on unified framework for harmonized data gathering, analysis and reporting* [2] and D9.6. *Intermediate report after one year of measurement* [6].

## 2.2 KPI adjustment and parameter harmonization

The process of assuring that the KPIs are defined in a manner that enables clear interpretation and consistent use has continued in task 9.5. Overall evaluation and impact analysis for impact enhancement, in close dialog with partners, highlighting need to clarify some KPI cards with i.e. units, formulas or use cases. The changes and updates made to KPI cards have been tracked in a changelog to ensure transparency and trackability.

The continuous dialog with responsible partners has also led to further harmonization of parameters used. In some cases, a translation was needed between what is measured by partners and what is stated in the KPI card, and therefore used in the KPI tool. In other cases, the dialog has led to KPIs being removed or added to better capture and evaluate what the measure aims at achieving and the data that is collected.

## 2.3 Developing and adjusting qualitative KPIs

It was challenging to capture the measurements in TT5 citizen engagement and co-creation using the KPIs in the portfolio. Quantitative KPIs were not always applicable, and there were limited options for qualitative KPIs. To address this, an expert reviewed the related measures in Gothenburg which consisted of workshops and courses and proposed adjustments to existing KPIs and developed new KPIs. The suggested KPIs were discussed and refined in meetings with the partner. Qualitative KPIs were designed so that the partner could evaluate their own workshop or course from the perspective of the KPIs, including a motivation.

## 2.4 Data collection

The process of collecting the data needed for evaluation of the different measures is described in the following paragraphs. The data has been collected from the responsible partners either manually or via connection to CIP.

### 2.4.1 Manual data collection

To enable manual data collection, two excel templates (Survey Template and Measure Template) have been developed. The "Survey template" is related to 9 KPIs, whose calculation is based on surveys. The ''Measure Template'' is related to all other KPIs. The templates contain all the relative measures at the available aggregation levels (i.e. city, transition track, building). The measurement data providers can define the measure for which they provide measurements by using several drop-down menus.

Dialog with responsible partners was needed to explain and ensure understanding of the layout, functionality and formats used in the template. Furthermore, the process of how and when data was going to be transferred from the partners to the KPI tool needed to be explained. This dialog was achieved through meetings and the first actual transfer of data through the template served as trial. Through the dialog with responsible partners and the trial of manual data transfer valuable feed-back on the template and minor errors in it, was obtained.

In the process of manually collecting data, there is a possibility of errors in the way the data provider fills in the measure template. For that reason, a validation tool has been developed to ensure an error-free competed template. All measure templates must be checked with the validator, before being sent to the partners responsible for data processing in the KPI tool.

The manual data collection process is presented in detail in deliverable D9.6 *Intermediate report after one year of measurement* [6].

### 2.4.2 Data collection via CIP

For CIP data collection, an automated way for data gathering has been developed, this enables the KPI tool to be connected to specific CIP endpoints throughout the RESTful API. This automation calls and receives the measurements needed for KPI calculations. Each API endpoint gives a response in json format which is then parsed through the automation tool for the necessary transformation so it can be stored in the database. The aggregation of the time for each measurement can be adjusted on a monthly or annual basis.

Data from low-level entities refers to data measured or extracted at the level of Buildings, Districts, or Systems. Such information can range from energy measurements to expenses to replies gleaned via structured/Likert-scale questionnaires.

## 2.5 Keeping track of progress

To be able to continually keep an updated overview of the data collection progress, a measure tracker sheet for each LH city was created in the IRIS Demo measure tracker. This monitoring sheet was developed to compile information on measures such as title, which month monitoring started, contact person and if the measure is connected to CIP or if the data will be transferred manually to the KPI tool. Moreover, in the IRIS Demo measure tracker colors, shown in Table 5, were used to indicate the data collection progress for each measure.

*Table 5: Colours used in the measure tracker to indicate status of data collection for different measures*

| |
|---|
| Data collected by partner, transferred to KPI tool and included in D9.6 |
| Data collected by partner, transferred to the KPI tool under progress |
| Data collected by partner, transferred to KPI tool not started |
| Monitoring not started |
| No KPIs |

The numbering used for measures in the Demo measure tracker as well as in the KPI tool is shown in Annex 1.

## 2.6 Data evaluation

The data collected and included in the KPI tool was used to also calculate the KPIs manually. This calculation allowed for an initial evaluation of the accuracy of the data and identification of potential errors in the KPI tool such as calculation methods for KPIs. When different results were obtained from the manual calculation and the KPI tool they were checked and controlled with the responsible partner for the demonstration. This was an ongoing process to ensure accurate results and correct interpretation. The time period when the data was collected also needs to be considered when evaluating and analysing it. The Covid-19 pandemic have affected the energy use and travel patterns, as more people have worked from home. Furthermore, the energy crisis followed by the Russian invasion of Ukraine had an impact on energy prices and fuel supply. In the data evaluation it is also needed to consider if the weather was normal or if it differed considerably in terms of, for instance, temperature or hours of sunshine.

## 2.7 The need of additional Information for KPIs

As data collection progressed, it became apparent that generating measure narratives requires considering additional information beyond just the KPIs and numerical values of the measures. This involves a collaborative and iterative process that requires involvement from all project partners. Specifically, creating narratives around technical KPIs in a project demands a holistic approach that accounts for multiple perspectives and inputs.

Evaluating the impact of a $CO_2$ reduction measure that gives 0,8 tonnes reduction for a building can be challenging if additional information, such as the building size and type, is not provided. A reference number can be useful to give a better understanding of the KPI result beyond the simple determination of whether the target was achieved or not. It is also essential to include changes in the demonstration to properly evaluate the measure.

The WP9 team organized workshops during two IRIS project meetings, one in Utrecht in May 2022 and the other in Nice in September 2022. These workshops aimed to raise awareness among project partners that KPI results may not fully explain the outcome of each measure and that additional information is necessary. During the first workshop the WP9 team collected and presented relevant data for some measures, including KPI targets, KPI results and KPI definitions. By reviewing this data with project partners, the team encouraged them to ask questions and develop a shared understanding of the measure's results as well as identify what type of additional information would be beneficial. The attendees requested information on scalability, applicability, reference values, localized interpretation, and success factors for each measure.

The schematic in Figure 3 provides an overview of the KPI process during the project, which begins with a general aim of the measure and gradually becomes more specific to obtain the KPI value. The final step is to put the results into a broader context, making them more easily interpretable, and this was the focus of the second workshop, held in Nice. During this workshop, the challenge of condensing the measure narratives, including the KPIs and additional information, was discussed, and an approach was developed to create measure narratives that are more easily understandable for a wider audience. To support the process of identifying and adding additional information to the KPI results, each LHC was requested to present two measures with KPIs and suggestions on additional information. These were presented in two rounds, first by the responsible partner and then by a person who was in the audience during the first round.

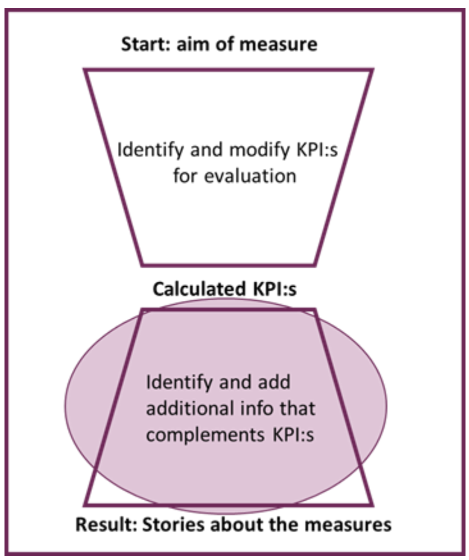


*Figure 3: Schematic figure of the KPI process with a circle around the focus of the second workshop*

The workshops demonstrated that an iterative approach is necessary, where project partners are encouraged to participate in the storytelling process and identify and provide additional information to improve the interpretability of the KPI results. To continue this process, regular meetings have been held with the LHC, responsible partners, and the monitoring and evaluation team. The purpose of these meetings has been to discuss how the measure narratives can be enhanced by adding specific information to ensure a more comprehensive understanding of the results.

# 3 Revision of KPIs

## 3.1 Update of KPI cards

Paragraph 2.1.1 of report D9.5 *Report om monitoring framework in LH cities and established baseline* [1] describes the iterative process of how the description and calculation of KPIs was updated to obtain a workable situation with the data obtained from the demonstrators and to provide meaningful results.

After submission of D9.5 the KPI tool was set up with the KPI formulas and provided with data from the demonstrators to calculate results. During the process of working with real data, new problems or inconsistencies occurred, such as:

- Non harmonious use of units, eg.  Tonnes vs Kg, kWh vs MWh etc.
- In some cases, KPIs calculated as a percentage give meaningless results (always 100% or 0% when baseline is 0)
- Inconsistencies in the name / description of the KPI and what is being calculated.
- Unclarity on how to calculate KPI

Because of the above reasons further adaptation of several KPI-cards was done by the WP9 team. In each case with a close look on what the effect of these adjustments would be on all demonstrators where these KPIs were calculated. These adaptations included:

- Harmonization of units
- Homogenization of the calculation method of comparable KPIs
- Changing KPI output to absolute numbers, instead of percentage
- Addition of use cases to clarify the utilization and calculation of the KPI
- Adjustment of the KPI description

This resulted in a new document with updated KPI-cards for the KPIs listed in the table below. In order to make sure that all main adaptations to KPIs are clearly registered, this document commences with a changelog, which is included in Annex 2. The KPI cards can be found in Annex 3 and in Annex 4 is an overview of updates to included KPIs for each LHC.

*Table 6: Modified KPIs compared to D9.5*

| KPI # | KPI name |
|---|---|
| **5** | Carbon dioxide emission reduction |
| **6** | Carbon monoxide emission reduction |
| **10** | Degree of energy self-supply by RES |
| **15** | Fine particulate matter emission reduction |
| **20** | Increase in Local Renewable Energy production |
| **21** | Increased system flexibility for energy players/stakeholders |
| **24** | Nitrogen oxide emission reduction |
| **34** | Reduced energy cost for customers |
| **35** | Reduced energy curtailment of RES and DER |
| **37** | Reduction in annual final energy consumption by street lighting |
| **38** | Reduction in car ownership among tenants |
| **39** | Increased km by tenants and employees in the district |
| **42** | Storage capacity installed |
| **45** | User engagement |
| **47** | Quality of open data |
| **53** | Storage Energy Losses |
| **54** | Access to vehicle sharing solutions for municipality |
| **55** | Number of trips in a free-floating car-sharing system |
| **56** | Congruence of expected and actual outcome of local community involvement in city development |
| **57** | Organizational readiness for citizen co-creation |
| **58** | Participatory governance |
| **59** | Potential for attractive and inclusive services or city development from co-creation activities |
| **60** | Potential for supporting reduced energy-related negative environmental impact |
| **61** | Representation of concerned citizens in service or city development participation efforts |
| **62** | The co-creation tools' ability to engage citizens |

## 3.2 Harmonization of parameters

To ensure consistent use of KPIs in the evaluation of different measures and avoid misunderstanding, the parameters measured and used to establish the KPIs were harmonized. This work is closely connected to the update of the KPI cards in general and the work with homogenization of the calculation method of comparable KPIs in particular. The harmonization work was done as part of the dialog with partners in the process of collecting data, see Paragraph 2.2.

In the subsequent result Chapters 4-6, the parameters that are being measured and used to establish the KPIs are included for each measure.

In some cases, it was necessary to translate the parameters used by the partners to the corresponding parameters used in the KPI cards. One such example is shown below. In this case, the partners parameters are equal to the ones used in the KPI card, they are only named differently.

*Table 7: Example of translation of parameters needed for harmonization and smooth transfer to the KPI*

| Parameters used by partner | Parameters in KPI card |
|---|---|
| **Very dissatisfied, number of answers** | Very difficult, number of answers |
| **Dissatisfied, number of answers** | Fairly difficult number of answers |
| **Neutral, number of answers** | Slightly difficult number of answers |
| **Satisfied, number of answers** | Fairly easy number of answers |
| **Very satisfied, number of answers** | Very easy number of answers |

## 3.3 Aggregation of KPIs

In paragraph 4.2 of D9.2 [7], possible aggregation of KPIs from different measures to transition track and Lighthouse city level are presented for each city. As certain KPIs and measures were updated in the process described in 2.2 these tables required revision. This chapter presents the updated tables. It shows the KPIs of each transition track and their position in the IRIS-KPI-House (figure below) for each city. It is not possible or relevant to aggregate all KPIs that are used for different measures to TT, LHC and IRIS project level. The idea with the KPI house and these aggregation tables is to provide an overview of the KPIs that will be aggregated and to what level this will be done.

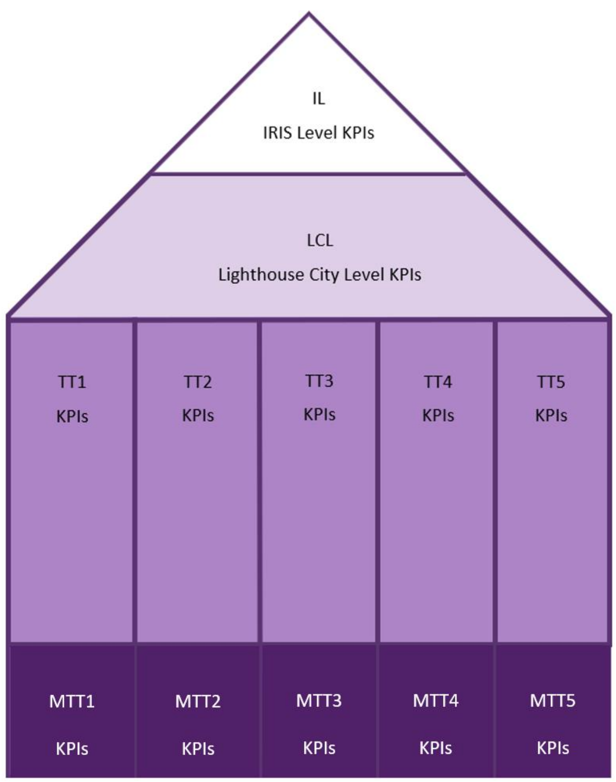


*Figure 4: IRIS KPI-house illustrating how KPIs are aggregated from the measure level and up.*

The IRIS KPI-house shown in the figure above illustrates how the KPIs are aggregated from the measure level up. The KPIs presented in the bottom part of the house, at measure level (MTT1 – MTT5) are, if possible, aggregated to transition track level (TT1-5) or higher to lighthouse city level or even to the top level, that is the entire IRIS project level.

## 3.3.1 Utrecht

### 3.3.1.1 TT1: Smart renewables and closed-loop energy positive districts

| **TT#1 level KPIs**<br>Carbon dioxide Emission Reduction<br>Energy savings<br>$CO_2$ reduction cost efficiency<br>Reduced energy cost for consumers | | | | | | |
|---|---|---|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** | **Measure 5** | **Measure 6** | **Measure 7** |
| Carbon dioxide Emission Reduction | | Increased awareness of energy usage | | | Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction |
| Degree of energy self-supply by RES | | | | | Energy savings | Energy savings |
| Increase in Local Renewable Energy production | | | | | | Reduction in annual final energy consumption by street lighting |

*Figure 5: KPIs of Utrecht TT1 with the associated measures and their position in the IRIS KPI-house*

### 3.3.1.2 TT2: Smart Energy Management and Storage for Energy Grid Flexibility

| **TT#2 level KPIs**<br>Storage capacity installed | | | |
|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** |
| | | Storage capacity installed | |

*Figure 6: KPIs of Utrecht TT2 with the associated measures and their position in the IRIS KPI-house*

### 3.3.1.3 TT 3 Smart e-Mobility Sector

| TT#3 level KPIs<br>$NO_x$ emission reduction<br>Fine particulate matter emission<br>Carbon monoxide emission reduction<br>Carbon dioxide Emission Reduction | |
|---|---|
| **Measure 1** | **Measure 2** |
| NOx emission reduction | NOx emission reduction |
| Fine particulate matter emission | Fine particulate matter emission |
| Carbon monoxide emission reduction | Carbon monoxide emission reduction |
| Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction |
| Access to vehicle sharing solutions for city travel | |
| Yearly km driven in e-car sharing system | |

*Figure 7: KPIs of Utrecht TT3 with the associated measures and their position in the IRIS KPI-house*

### 3.3.1.4 TT 5 Citizen Engagement

| TT#5 level KPIs<br>People reached<br>Local community involvement in planning/ implementation phase<br>Ease of use for end-users of the solution | | | | |
|---|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** | **Measure 5** |
| Increased environmental awareness | People reached | Ease of use for end-users | Local community involvement in development process | Ease of use for end-users |
| People reached | | Advantages for end-users | | |
| Local community involvement in planning/ implementation phase | | Local community involvement in planning/ implementation phase | | |

*Figure 8: KPIs of Utrecht TT5 with the associated measures and their position in the IRIS KPI-house*

## 3.3.2 Nice

### 3.3.2.1 TT1 Smart renewables and closed-loop energy positive districts

| **TT#1 Level KPIs**<br>Carbon dioxide Emission Reduction<br>Increase in Local Renewable Energy production | | | |
|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** |
| Energy Savings (Electrical) | Energy Savings (Thermal) | Data loss prevention | |
| Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction | Advantages for end-users | |
| Increase in Local Renewable Energy production | C02 reduction cost efficiency | | |
| Degree of energy self-supply by RES | | | |
| Storage capacity installed | | | |

*Figure 9: KPIs of NCA TT1 with the associated measures and their position in the IRIS KPI-house*

### 3.3.2.2 TT2 Smart Energy Management and Storage for Energy Grid Flexibility

| **TT#2 Level KPIs**<br><br>Storage capacity installed | |
|---|---|
| **Measure 1&3** | **Measure 2** |
| Reduced energy cost for customers | |
| Storage capacity installed | |

*Figure 10: KPIs of NCA TT2 with the associated measures and their position in the IRIS KPI-house*

### 3.3.2.3 TT3 Smart e-Mobility Sector

| TT#3 Level KPIs | |
|---|---|
| None | |
| **Measure 1** | **Measure 2** |
| Number of e-charging stations deployed in the area | Yearly km driven in e-car sharing systems |
| Storage capacity installed | Access to vehicle sharing solutions for municipality |
| | Number of trips in a free-floating car-sharing system |

*Figure 11: KPIs of NCA TT3 with the associated measures and their position in the IRIS KPI-house*

### 3.3.2.4 TT4 City Innovation Platform (CIP)

| TT#4 Level KPIs | | |
|---|---|---|
| Number of connected urban objects<br>Quality of open data | | |
| **Measure 1** | **Measure 2** | **Measure 3** |
| KPIs measured at TT level | | |

*Figure 12: KPIs of NCA TT4 with the associated measures and their position in the IRIS KPI-house*

### 3.3.2.5 TT5 Citizen Engagement

| TT#5 Level KPIs | | |
|---|---|---|
| Nome | | |
| **Measure 1** | **Measure 2** | **Measure 3** |
| Increased environmental awareness | Increase awareness of energy usage | |

*Figure 13:KPIs of NCA TT5 with the associated measures and their position in the IRIS KPI-house*

## 3.3.3 Gothenburg

### 3.3.3.1 TT1 Smart renewables and closed-loop energy positive districts

| **TT#1 level KPIs**<br>Carbon dioxide Emission Reduction<br>Degree of energy self-supply by RES | | | | | | |
|---|---|---|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** | **Measure 5** | **Measure 6** | **Measure 7** |
| Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction | Storage capacity installed | Reduced energy cost for consumers | Increased system flexibility for energy stakeholders | Carbon dioxide Emission Reduction |
| Degree of energy self-supply by RES | $CO_2$ reduction cost efficiency | $CO_2$ reduction cost efficiency | | | Reduced energy cost for consumers | $CO_2$ reduction cost efficiency |
| | Degree of energy self-supply by RES | Degree of energy self-supply by RES | | | | Degree of energy self-supply by RES |
| | | | | | | Increase in local renewable energy production |

*Figure 14: KPIs of Gothenburg TT1 with the associated measures and their position in the IRIS KPI-house*

### 3.3.3.2 *TT2:* Smart Energy Management and Storage for Energy Grid Flexibility

| **TT#2 level KPIs**<br>Storage capacity installed | | | |
|---|---|---|---|
| **Measure 1** | **Measure 2** | **Measure 3** | **Measure 4** |
| Degree of energy self-supply by RES | Peak load reduction | | Peak load reduction |
| Peak load reduction | Storage capacity installed | | Storage capacity installed |
| Storage capacity installed | Storage energy losses | | |

*Figure 15: KPIs of Gothenburg TT2 with the associated measures and their position in the IRIS KPI-house*

### *3.3.3.3 TT 3 Smart e-Mobility Sector*

| **TT#3 level KPIs**<br>Carbon dioxide Emission Reduction<br>Reduction in driven km by tenants and employees in the district | |
|---|---|
| **Measure 1** | **Measure 2** |
| Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction |
| Ease of use for end users of the solution | Ease of use for end users of the solution |
| Reduction in driven km by tenants and employees in the district | Improved access to vehicle sharing solutions |
| Reduction in car ownership among tenants | Reduction in driven km by tenants and employees in the district |
| Yearly km driven in e-care sharing system | Yearly km driven in e-care sharing system |

*Figure 16: KPIs of Gothenburg TT3 with the associated measures and their position in the IRIS KPI-house*

#### 3.3.3.4 TT4: City Innovation Platform (CIP)

| **TT#4 level KPIs**<br>Open data-based solutions<br>Quality of open data | |
|---|---|
| **Measure 1** | **Measure 2** |
| Advantages for end-users | Open data-based solutions |
| Ease of use for end-users of the solution | Quality of open data |
| Open data-based solutions | |
| Quality of open data | |
| Usage of open source software | |

*Figure 17: KPIs of Gothenburg TT4 with the associated measures and their position in the IRIS KPI-house*

## TT 5: Citizen engagement and co-creation

| TT#5 level KPIs None | | | |
|---|---|---|---|
| **Measure 1-2** | **Measure 3** | **Measure 5** | **Measure 7** |
| Congruence of expected and actual outcome of local community involvement in city development | Local community involvement in the planning phase | Congruence of expected and actual outcome of local community involvement in city development | Advantages for end-users |
| Local community involvement in the planning phase | Organizational readiness for citizen co-creation | Local community involvement in the planning phase | User engagement |
| Participatory governance | Participatory governance | Organizational readiness for citizen co-creation | Potential for supporting reduced energy-related negative environmental impact |
| Organizational readiness for citizen co-creation | Potential for attractive and inclusive services or city development from co-creation activities | Participatory governance | |
| Potential for attractive and inclusive services or city development from co-creation activities | Representation of concerned citizens in service or city development participation efforts | Potential for attractive and inclusive services or city development from co-creation activities | |
| Representation of concerned citizens in service or city development participation efforts | The co-creation tools' ability to engage citizens | Representation of concerned citizens in service or city development participation efforts | |
| The co-creation tools' ability to engage citizens | | The co-creation tools' ability to engage citizens | |

*Figure 18: KPIs of Gothenburg TT5 with the associated measures and their position in the IRIS KPI-house*

### 3.3.4 Lighthouse city level and IRIS level KPI:s

| **IRIS**<br>Carbon dioxide Emission Reduction<br>Increase in local renewable electricity production | | |
|---|---|---|
| **Utrecht** | **Nice** | **Gothenburg** |
| Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction | Carbon dioxide Emission Reduction |
| Increase in local renewable energy production | Increase in local renewable energy production | Increase in local renewable energy production |

*Figure 19: KPIs at LHC and IRIS level.*

# 4 Results Utrecht

In this chapter the results for LH Utrecht are presented per TT and per measure. The measures are only briefly described, and the results focus on the KPIs and set targets. For more detailed description of the measures, results and lessons learnt by the partners please read D5.9.[3].

Unfortunately, not all measures have been finalized and possible to evaluate. The reason for excluding certain measures and KPIs is summarized in Table 2.

Many different KPIs are used to evaluate the performance of the different measures implemented in Utrecht as shown in the KPI overview of paragraph 3.3.1. The KPI Carbon dioxide Emission Reduction is measured at different transition tracks and could be aggregated to the level of Utrecht to a total of 10 129 tonnes $CO_2$. Some other highlighted results of the measures in Utrecht are shown in Table 8.

*Table 8: Highlighted results for LHC Utrecht based on the years with full measurement data and standard IRIS-NL emission factors.*

| KPI | Results | Included measures |
|---|---|---|
| **Total Carbon dioxide Emission Reduction** | 10 129 tonnes | M1.1,M1.4, M1.5, M1.7, M1.8, M3.1, M3.2 |
| **Total installed PV capacity** | 649 kWp | M1.1, M1.8 |
| **Total increase in local renewable energy production** | 591 MWh | M1.1, M1.7 and M2.1 |
| **Total energy savings** | 1788 MWh | M1.1,M1.4, M1.5, M1.7, M1.8 |
| **Total energy cost reduction for tenants** | 706 728 Euro | M1.1,M1.4, M1.5, M1.7, M1.8 |
| **Total number of kilometers driven by the car-sharing fleet** | 4 779 042 Km | M3.1 |
| **Total number of kilometers driven by the E-buses** | 10 659 547 Km | M3.2 |

In this chapter two different results are shown for many cases, results tagged with IRIS_NL are based on the standard emission factors or costs, which were used for the preliminary calculations done for the Grant Agreement based on the BEST/TEST tables. As these values were estimated long before the project initiated and changed over the years an extra effort is done to find more recent or case specific factors. With the help of this data it was attempted to calculate more accurate outcomes which are associated with the subtext 'Recent' and are described and compared with the preliminary results in paragraph 4.1 for TT1 and 4.2 for TT3.

The total amount of $CO_2$ emission reduction for Utrecht, based on these different factors is shown in Figure 20. Note that in this KPI the E-buses have such a large share (8813 tonnes), that the graph starts at 7000 tonnes in order to show the share of the other measures. It can also be seen that energy savings as a result of renovations as well as smart street lighting reduce 286 tonnes of $CO_2$ which is almost similar to the reduction due to PV energy production (262). The EV car sharing system of measure 3.2 reduced in total 768 tonnes $CO_2$ within the IRIS project. When taking more recent emission factors into account, all measures have a smaller impact. The total reduction is about 17% less with a total of 8632 tonnes $CO_2$.

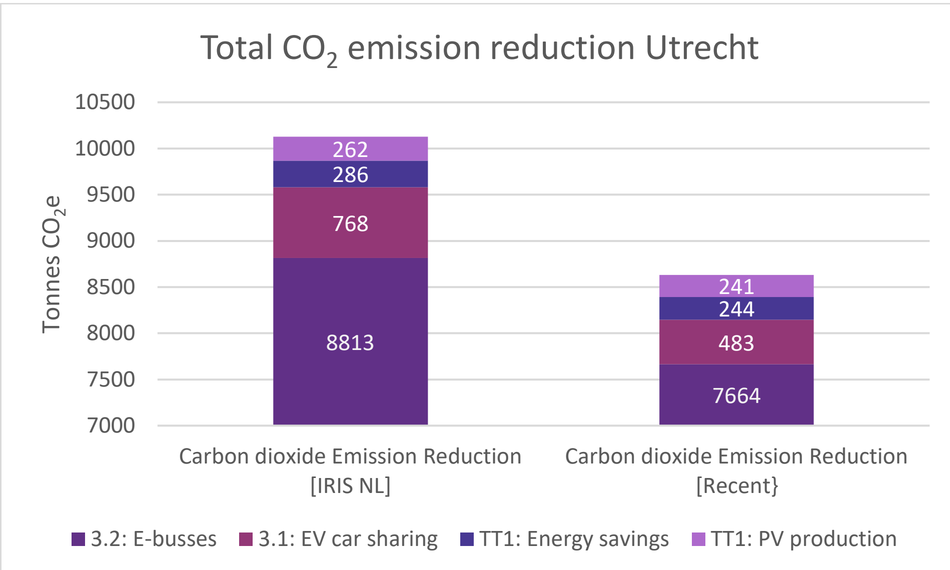


*Figure 20 Result of KPI5: $CO_2$ emission reduction in Utrecht for different measures combined. Calculated with initial emission factors (IRIS_NL) and more recent values (Recent). Note that the graph starts at 7000 tonnes.*

## 4.1 TT1 Smart renewables and closed-loop energy positive districts

The ambitions of this transition track consist of contributing to Near Zero Energy districts by integrating a high share of locally produced and consumed renewable energy at district scale, energy savings at building level, and energy savings at district level. To achieve these ambitions a total of 8 measures where defined. The measures below are the ones that are monitored and evaluated by means of KPIs

- Measure 1 District wide PV
- Measure 3 HEMS Eneco Toon
- Measure 4 NZEB refurbishment (in the districts of Kanaleneiland-Zuid and Lombok)
- Measure 5 Smart (hybrid) e-heating systems
- Measure 7 Smart DC Street Lighting
- Measure 8: PEB refurbishment (project Henriëttedreef, in the district of Overvecht)

The targets which were set in the Grant Agreement for this transition track are:

- Energy savings in households of 81 %-86 %, resulting in 4,6 million kWh/year and 1300 tonnes $CO_2$ reduction/year (BEST table),
- Energy savings in street lighting of 20 MWh or 9 tonnes $CO_2$ reduction in 5 years

- Increase renewables: from 0 MWp to 1,8 MWp PV-power integrated in the district micro-grid, or 100% of building power demand, and 667 MWh/yr wind power at sea for e-bus charging (BEST table)

Regarding these targets it must be noted that renovation of the initial 12 apartment buildings in Kanaleneiland- Zuid was not achieved. During the project runtime only 4 of these 12 buildings were retrofitted, of which 2 provided a year of monitoring data. Apartments from 2 different buildings were introduced into the project instead, which make comparison with the initial targets hard to achieve. The monitoring data of the initial building types did show an energy self-supply of 82% to 88% (Table 10) after renovation. Compared to BAU where no energy was produced this can be seen as an energy saving of the same percentage, which does meet the original target. Because of similar reasons, the total installed PV capacity within the project reached 649 kWp, which is a bit more than one third of the initial goal.
More details about the energy savings and emission reduction of the buildings that was achieved can be found in paragraph 4.1.1. Energy savings of street lighting was slightly lower than expected, projected at the full 5 years project period it would have been 15,5 MWh, leading to a $CO_2$ emission reduction of 7 tonnes. Al electricity for the Qbuzz E-buses is generated by wind energy or locally produced PV power, meaning an average increase in demand for renewable electricity of 1 777 MWh per year.

### 4.1.1 Measures combined at building level

Some of the measures in TT1 were simultaneously introduced in the buildings and have an effect on the energy demand which could not be separately analyzed. For this reason the KPIs for these measures are calculated at building level as shown in Table 9**Fout! Verwijzingsbron niet gevonden.**. This table also shows for which years each building has data available for KPI calculations.

*Table 9 Overview of buildings and associated measures in TT1*

| Location | Kanaleneiland Zuid | Lombok | Overvecht |
|---|---|---|---|
| **Building names** | A de Grotelaan II, A de Grotelaan III<br>Columbuslaan II, Columbuslaan III | Complex 507 | Henriettedreef |
| **Measure** | 1.1: District wide PV<br>1.4: NZEB refurbishment<br>1.5: Smart (hybrid) E-heating systems | 1.4: NZEB refurbishment | 1.1: District wide PV<br>1.8: PEB refurbishment |
| **Years for KPI calculation** | 2022: AdGII & AdGIII | 2021: Cluster F1 - F2<br>2021: Cluster F1 - F6 | 2021, 2022 |

An image of each building is shown in Figure 21. The first building in this picture represents the buildings in Kanaleneiland Zuid, which are apartment buildings with 4 floors, having a total of 48 apartments per building. Refurbishment actions in these buildings are mainly related to increased levels of insulation, placement of the smart hybrid heating systems, and installing PV. Apart from the smart e-heating system, each dwelling has an individual natural gas fired central heating system. The buildings in the district Lombok (Complex 507) consist of 11 different clusters with a total of 353 dwellings. Next to increased insulation, gas furnaces were replaced by individual gas fired central heating systems, enhancing the levels of comfort in these apartments. The third building, Henriettedreef, is a Plus Energy Building (PEB ) renovation. This 10 floor high building with 58 apartments, was previously connected to district heating. After renovation it produces its own heat for heating and DHW centrally by means of electric heat pumps. Each apartment has a ventilation unit with heat recovery and the building is equipped with a large amount of PV modules on the roof as well as on the facades to produce more electricity than its annual demand.

*Figure 21: Pictures of renovated buildings in Utrecht TT1. From left to right, NZEB refurbishment in district Kanaleneiland Zuid, NZEB renovation Complex 507 and PEB renovation Henriettedreef*

#### *4.1.1.1 Results from measures combined at building level*

To estimate the energy demands and PV production of the buildings, different monitoring approaches were used. How each dataset is obtained and the challenges associated with each approach are described in Annex 5.1. Table 10 shows the KPI results, calculated with the emission factors from the Grant Agreement. More details about these results follow in the paragraphs after this table.

*Table 10: KPI Results for Utrecht TT1 at building level*

| KPI | Building | 2021 | 2022 | Target (GA or declared) |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction [t/year]** | AdGIII | | 55,9 | 1300 tonnes $CO_2$ reduction / year or 80% reduction |
| | AdGII | | 64,7 | |
| | HD | 93,4 | 138,6 | |
| | C507 | 37,2 | 155,5 | |
| **Increase in local renewable energy production [MWh/year]** | AdGIII | | 77 | 1.8 MWp installed capacity of 100% building demand |
| | AdGII | | 77 | |
| | HD | 192 | 255 | |
| **Energy savings** | AdGIII | | 25% | 81 – 86% (including PV production)<br>50% for building demand |
| | AdGII | | 32% | |
| | HD | 56% | 64% | |
| | C507 | 21% | 30% | |
| **Reduced energy cost for costumers** | AdGIII | | 49% | 50% |

| | | | | |
|---|---|---|---|---|
| | AdGII | | 55% | |
| | HD | 89% | 128% | |
| | C507 | 21% | 28% | |
| **$CO_2$ reduction cost efficiency** | AdGIII | | 686 | |
| | AdGII | | 539 | |
| | HD | 998 | 525 | |
| | C507 | 3459 | 2495 | |
| **Installed capacity kWp** | AdGIII | | 70,6 | Total 1,8 MWp or 100% building demand |
| | AdGII | | 70,6 | |
| | HD | 356.6 | 356,6 | |
| **Degree of energy self-supply by RES** | AdGIII | | 88% | |
| | AdGII | | 82% | |
| | HD | 87% | 141% | |

Figure 22 shows that in 2021 over TT1 35% and in 2022 34% of energy was saved compared to Business as Usual (BAU). Henriettedreef is leading in this regard, as the savings went from 56 to 64%. For complex 507, in 2021 only cluster F1 and F2 were renovated, which resulted in a decrease of demand of 21%. The renovations of cluster F1 to F6 led to total energy savings of 30% in 2022. This is quite significant when the increase in comfort of these apartments is also taken into account. AdGII and AdGII have energy savings measured for 2022 with 32 and 25% respectively. This is a bit below the expected 50%. This could partly be caused by the Energy Performance Building Gap (EPBG), the fact that in general after renovation the performance is a bit less than expected. Other reasons could still be the aftermath of COVID, where people tend to work more from home as before.

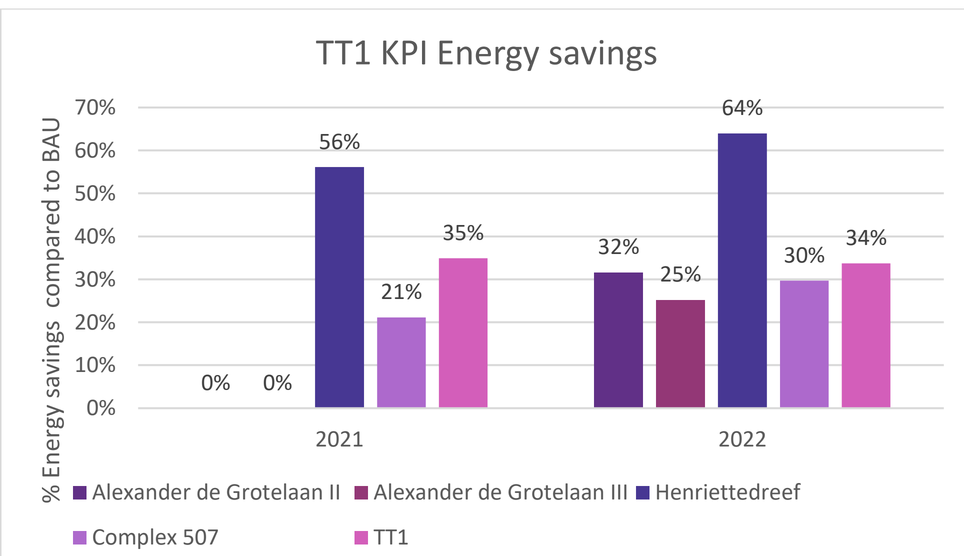


*Figure 22: Results for KPI13: Energy savings for the buildings of Utrecht TT1 in 2021 and 2022*

Degree of energy self-supply can only be measured for the buildings that produce energy. As this KPI is formally only related to the electric energy demand, only the electric energy demand is used for KPI calculation. For comparison, Figure 23**Fout! Verwijzingsbron niet gevonden.** shows the degree of energy self-supply by RES for electric energy as well self-supply by RES of all energy demands. In case of AdGII and AdGII that also includes the demands for natural gas, which means a decline from 88% and 82% to 20% and 19% for 2022. Henriettedreef proofs that it is an PEB (Plus Energy Building) in 2022, as its demand is largely met with its production (141%). In 2021 only 87% of its demand was produced locally. This was mainly due to the fact that a large part of the PV system was only put into operation halfway the year. In 2022, the three buildings together produce more than 43% of their total energy demand locally.

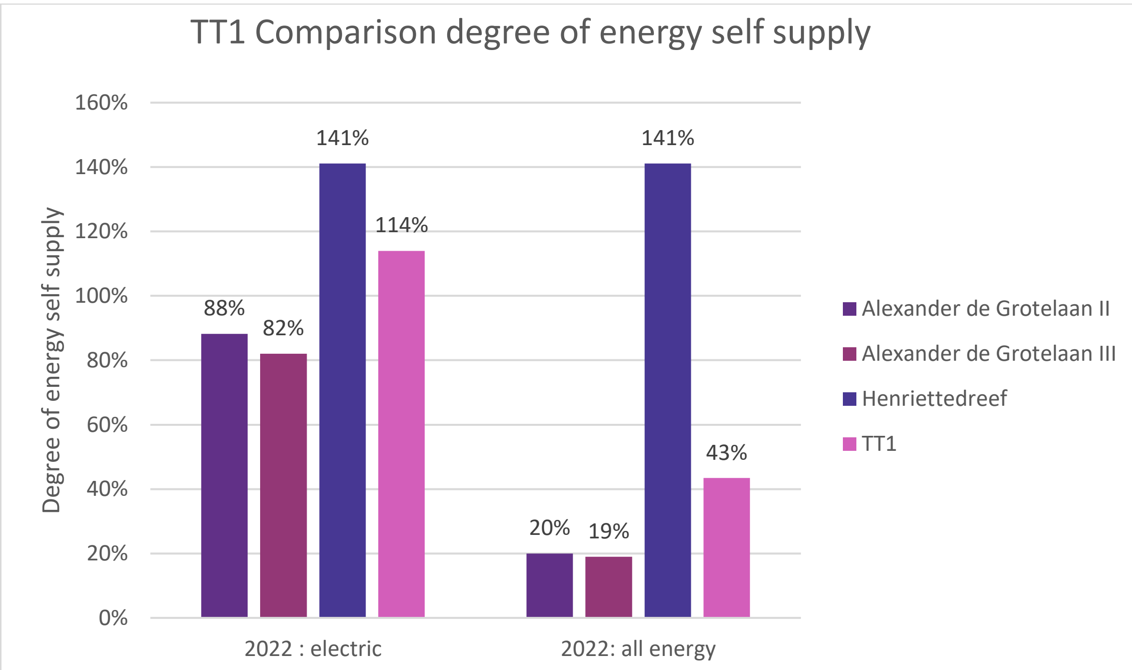


*Figure 23: Results for KPI10: Degree of energy self-supply by RES for the buildings in TT1 for 2022. Based on electric energy demand (electric) the total energy demand (all energy).*

One of the reasons for having the KPI tool is to check if the targets from the Grant Agreement were met. Therefore, the emission factors which were used from the initial calculations to estimate these targets, which are the values from the BEST/ TEST tables, are leading in KPI results. Nevertheless, emission factors change over time, and a more accurate calculation of the emission reduction can be done by using actualized emission factor data. Table 11 provides an overview of all emission factors used in the calculations that follow.

The $CO_2$ emission factor for natural gas used in the Grant Agreement was 188.1 g/kWh. According to RVO it ranged in the past years from 56.4 to 56.6 kg/GJ , which is slightly more 203.8 g/kWh (or 2.038 $E^{-4}$ Tonne$CO_2$/kWh) [8]. $CO_2$ emission of District heating (Grant Agreement) is based on the emission of natural gas with a generation efficiency of 125%, which results in 150.5 g/kWh. The annual report of Eneco (the district heat utility) [9] gives a more accurate value for the $CO_2$ emissions of this heating source. Due to successful efforts to decrease their carbon footprint, the emission factor for district heating gradually decreased from 31.8 kg/ GJ in 2019 to 19.8 kg/GJ in 2021. The exact values for 2022 were not available yet, so for calculations the factor of 2021 was used. According to the Central Bureau of Statistics, the emission factor for production of electricity in the Netherlands has decreased over the past years. From .430 kg/kWh in 2018, 0.37 kg/kWh in 2019 and 0.29kg/kWh in 2020 [10]. Since a large part of the electricity in the Netherlands is imported, it was decided to use the emission factors of consumption for the Netherlands from the Electricity Maps database [11]. This value is a bit different than the European average of .443 kg/kWh from the Grant Agreement calculations.

*Table 11 Emission factors of residential energy demand in tonnes $CO_2$ per kWh for KPI calculation*

| Year | District heating (DH) | | Natural Gas | | Electricity | |
|---|---|---|---|---|---|---|
| | GA / IRIS_NL | Recent | GA/ IRIS_NL | Recent | GA/ IRIS_NL | Recent |
| **2019** | 1,505 $E^{-4}$ | 1,14$E^{-04}$ | 1,881 $E^{-4}$ | 2,04$E^{-04}$ | 4,43 $E^{-4}$ | 4,88$E^{-04}$ |
| **2020** | 1,505 $E^{-4}$ | 8,49$E^{-05}$ | 1,881 $E^{-4}$ | 2,03$E^{-04}$ | 4,43 $E^{-4}$ | 4,51$E^{-04}$ |
| **2021** | 1,505 $E^{-4}$ | 7,12$E^{-05}$ | 1,881 $E^{-4}$ | 2,03$E^{-04}$ | 4,43 $E^{-4}$ | 4,37$E^{-04}$ |
| **2022** | 1,505 $E^{-4}$ | 7,12$E^{-05}$ | 1,881 $E^{-4}$ | 2,03$E^{-04}$ | 4,43 $E^{-4}$ | 3,94$E^{-04}$ |

As described before, two different emission factors can be used for this calculation. The main emission factor that is used to compare the project results with the goals stated in the grant agreement (2019 to 2022 IRIS_NL) and more recent data (2019 to 2022 Recent). In the following graphs both results are represented for comparison.

Figure 24**Fout! Verwijzingsbron niet gevonden.** shows the emission reduction that is caused by energy savings only. Especially complex 507 has an emission reduction of 37,2 tonnes up to 155,5 tonnes per year. This is mainly a result of the larger set of apartments that were used for this calculation. There is a slight increase when more recent emission data is used, this is mainly due to the fact that the largest amount of emission reduction is caused by a decrease in natural gas demand, of which the emission factor didn't significantly change. This can also be observed for AdGII and AdGIII. As the buildings are the same size, emission reductions can be compared and it shows that their emission reduction ranges from 32,8 to 24,1 tonne/year. This is in line with the slight difference in energy savings. An important outlier is Henriettedreef. One could expect that this PEB would have a relatively large emission reduction. In 2022 it is comparable with AdGII and AdGIII (per apartment it is slightly larger, as it has 58 instead of 48 apartments). In 2021 it scores rather low, due to an increased electricity demand caused by a malfunctioning heat pump system. Looking at more recent emission factors, there is even an increase in $CO_2$ emissions in 2021 (-20,1) and very little decrease in 2022 (0,7). The explanation for this is the shift to an all- electric building, meaning that after renovation, heat is produced with electricity instead of district heating. Even though heat-pumps are used for this, a relatively large emission factor for electricity compared to the emissions of district heating decreases the $CO_2$ impact of this measure. Note that in this calculation only energy savings are taken into account and the important benefit of switching to electricity is that it can be produced on site with PV modules.

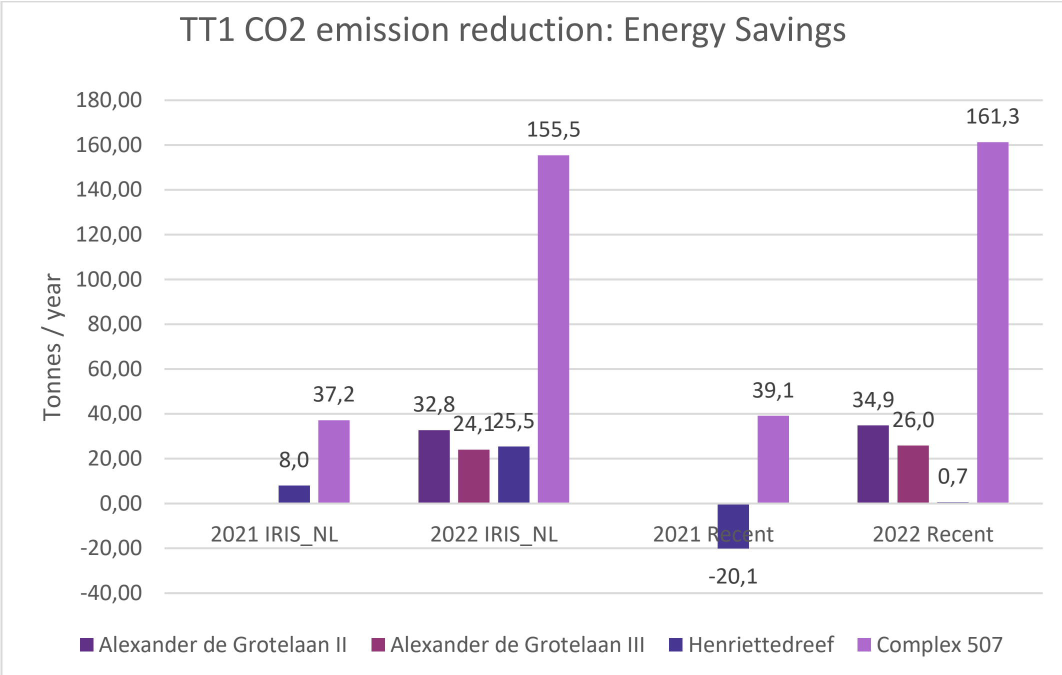


*Figure 24: Results for KPI5: $CO_2$ emission reduction caused by energy savings, separated per building within TT1 for the years 2021 and 2022 with the use of different emission factors*

Apart from a $CO_2$ emission reduction caused by energy savings, the production of electricity from the PV systems of AdGII, AdGIII and Henriettedreef have an important impact on reduction of $CO_2$ emissions. Figure 25 shows that for Henriettedreef this value increased from 85,3 to 113,1 tonnes per year. In 2021 PV production of the building was a bit lower as not all PV systems were fully operational. As the production of AdGII and AdGIII are calculated similarly, the energy production of these buildings both reduce $CO_2$ emissions with 31,8 tonnes in 2022. Using recent $CO_2$ emission factors slightly decreases the emission reduction for all PV systems.

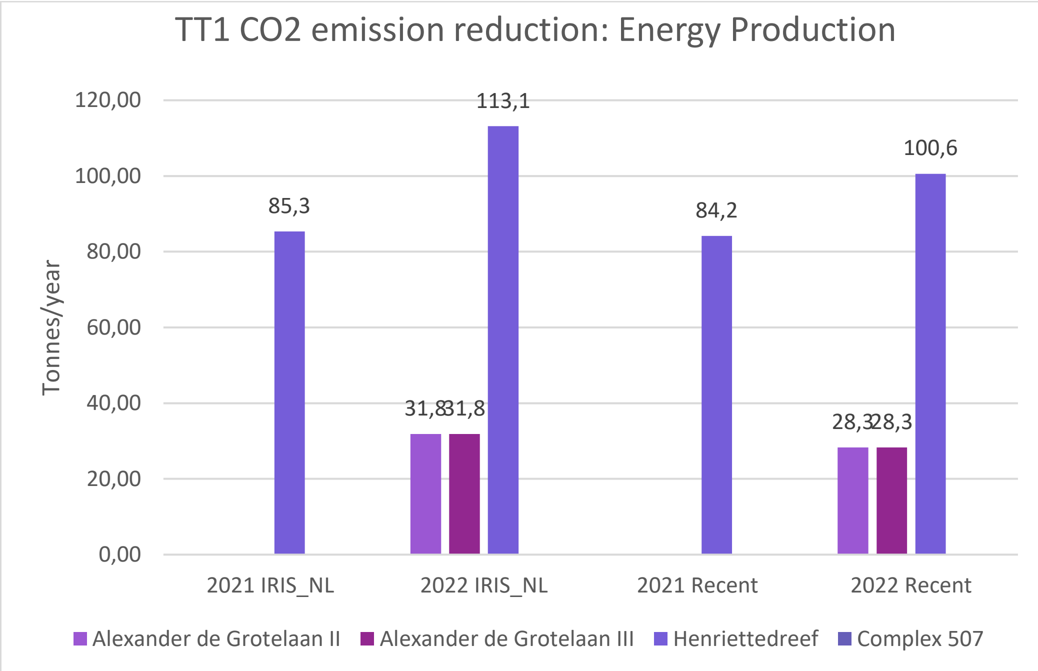


*Figure 25: Results for KPI5: $CO_2$ emission reduction caused by PV production separated per building within TT1 for the years 2021 and 2022 with the use of different emission factors*

The complete picture of $CO_2$ emission reduction for all actions taken in the buildings is shown in Figure 26 . For Complex 507 the values are similar  to Figure 24 as no PV is installed on these buildings. Especially for Henriettedreef a completely different picture is shown compared to the reduction caused by energy savings. In this graph Henriettedreef is now amongst the largest reducers of $CO_2$ emissions for 2021 and 2022 with 93,4 and 138,6 tonnes respectively. For AdGII and AdGII the total $CO_2$ emission reduction doubled by adding PV production to the balance. The graph clearly illustrates how important it is to keep the proper context into account when analysing reduction of emissions. Using more recent emission factors, results in a 35 % lower impact for Henriettedreef. The most important reason for this, is the fact that in BAU the building was using district heating. Table 11 shows that due to sustainability actions taken by the district heating utility, the emission factors declined in the past years. This has an effect of the total $CO_2$ emission reduction of the building, which was not taken into account in the GA-calculations.

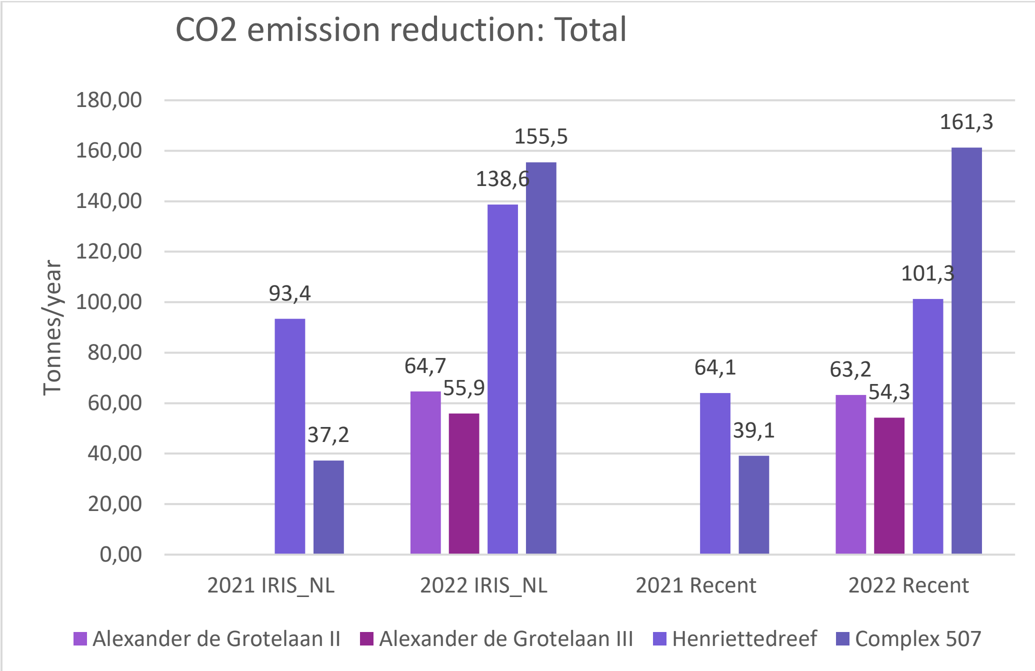


*Figure 26: Results for KPI5: $CO_2$ emission reduction caused by energy savings and PV production separated per building within TT1 for the years 2021 and 2022 with the use of different emission factors*

Similar to the emission factors, there are more recent costs for energy and the costs used in Grant Agreement calculations. To analyze the reduction in energy costs for costumers both types of costs are taken into account and represented in Table 12. This illustrates how developments in the past years have caused the price of gas, electricity and District Heating (DH) to change rapidly (compared to a gradual increase in the past). Cost for DH were estimated 22,66 Euro/GJ. The actual costs for DH are obtained from the heat distributor [12]. Actual cost in euro/GJ 23,99 (2018), 28,47/ GJ (2019), 24,60 (2021), 43,76 (2022) (per kWh by division through 277,7778). Cost for electricity and gas in the GA were 0,20/ kWh and 0,64 Euro/m3 respectively. Actual prices are obtained from the Dutch Central Bureau of Statistics [10], to calculate cost per kWh from m$^3$ gas, a factor of 8,7667 is used (LHV). It can be seen in the table that especially in 2022 a doubling of the energy prices for all carriers occurred.

*Table 12 Variable costs for residential energy demand in the Netherlands (CBS)*

| Year | Natural Gas (Euro/m3) | Natural Gas (Euro/kWh) | | Electricity (Euro/kWh) | | District heating (Euro/Gj) | District heating (Euro/kWh) | |
|---|---|---|---|---|---|---|---|---|
| | Actual | GA | Actual | GA | Actual | Actual | GA | Actual |
| **2018** | 0,682 | 0,0730 | 0,077794 | 0,20 | 0,21441 | 23,99 | 0,0816 | 0,0864 |
| **2019** | 0,76859 | 0,0730 | 0,087672 | 0,20 | 0,22251 | 28,47 | 0,0816 | 0,1025 |
| **2020** | 0,78079 | 0,0730 | 0,089063 | 0,20 | 0,22195 | 25,43 | 0,0816 | 0,0915 |
| **2021** | 0,93973 | 0,0730 | 0,107193 | 0,20 | 0,25618 | 24,6 | 0,0816 | 0,0886 |
| **2022** | 2,3 | 0,073 | 0,262356 | 0,2 | 0,53549 | 43,76 | 0,0816 | 0,1575 |

This KPI shows how much the costs for energy are reduced for customers compared to BAU. The KPI is calculated only with the costs for energy in the use case or for BAU. It does not take into account the change in fees for rent. For example, tenants in Henriettedreef don not pay directly for the electricity used for heat generation. An energy service fee is paid instead. When only energy savings are taken into account, the percentage cost reduction for tenants is shown Figure 27. Apart from Henriettedreef, in 2021 cost reductions are between 20 and 30% for all buildings. All buildings together have a cost reduction of 28%. In 2021 Henriettedreef has a relatively low cost reduction (16%) compared to 2022 as the electricity demand of the heat pumps was too high due to malfunctions. Nevertheless, this was not paid for by the tenants themselves (as they paid a flat fee by increased rent). There is not a large difference between using recent data compared to the Grant Agreement-values for the energy costs, as the increase in energy price in 2022 also influences the BAU-case. Only for Henriettedreef the cost reductions are significantly lower. This is related to the shift from district heating to electricity. The price of the latter increased more than the price for district heating.

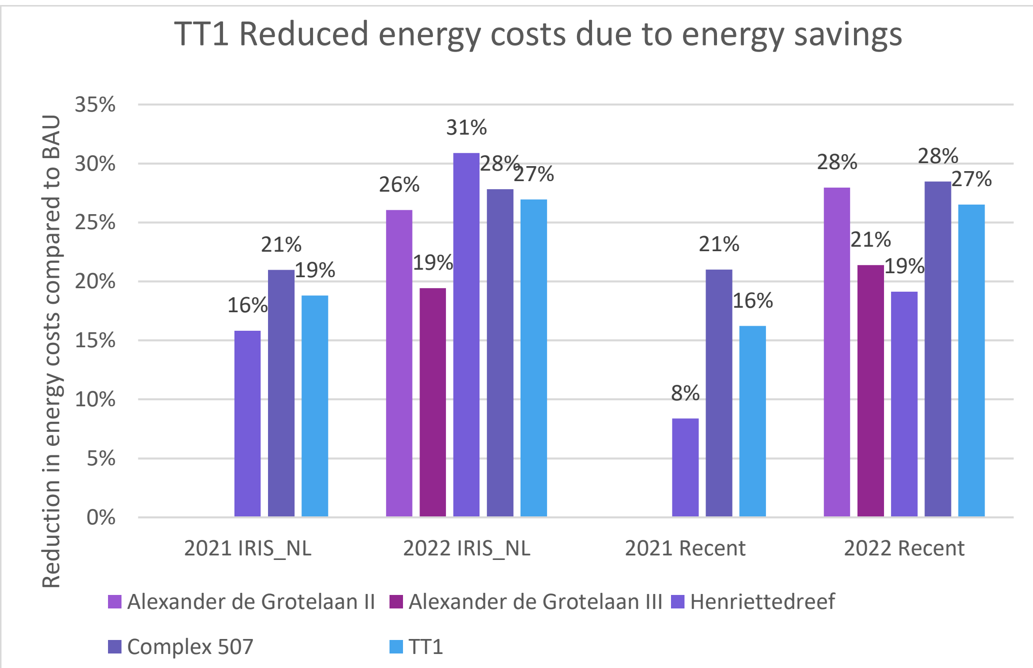


*Figure 27: Results for KPI34: Reduced energy cost for costumer for the buildings of TT1 caused by energy savings. Calculated with different costs for energy*

Figure 28 shows how costs are reduced when PV production is included in the calculation, which is the actual case for these buildings. It clearly shows how complex 507 stays behind compared to the other buildings, with a reduction of 21 and 28% regardless which energy prices were taken into account. This is actually still quite an achievement for these buildings as the refurbishment caused a massive increase in comfort for the tenants. Still it also shows that the introduction of PV on these buildings could be beneficial. AdGII and AdGIII both have a cost reduction of around 50% which meets the Grant Agreement target for the initial setup of this transition track. Henriettedreef illustrates the effect of the building being energy plus in 2022. It produces more energy than its demand and generates a net profit of 28% in 2022. When energy cost reduction of all buildings is taken together (TT1 in Figure 28) a reduction of 50% and 48% is achieved for 2021 and 2022. Similar to the cost reduction of energy savings only, the effect of using more recent data is not very notable for this KPI.

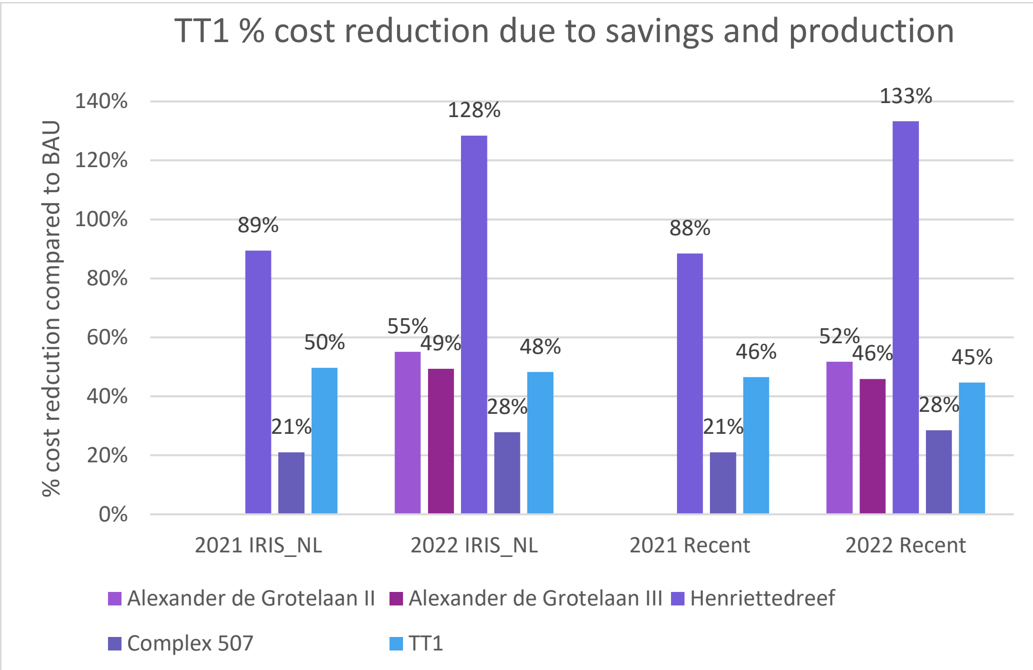


*Figure 28: Results for KPI34: Reduced energy cost for costumer for the buildings of TT1 caused by energy savings and production, calculated with different costs for energy*

When annual costs for $CO_2$ reducing measures of the refurbishments are divided by the annual $CO_2$ reduction, the $CO_2$ reduction cost efficiency can be obtained Figure 29 illustrates that this cost efficiency varies per building, where complex 507 is actually the least cost efficient. This has two main reasons. First of all, the retrofit was not only done for energy reduction but also largely to improve comfort in the apartments. The fact that no PV was installed on this building also has a large influence. For 2022 the $CO_2$ reduction cost efficiency for the Henriettedreef and AdGII and AdGIII are between 500 and 700 euro per tonne. When this KPI calculation is done with more recent data for $CO_2$ emissions and energy costs, the rise in energy prices in 2022 actually shifts the balance and even causes a profit of 183 to 343 euro for every tonne of reduced $CO_2$. On TT level, it shows that the size of complex 507 has a large influence on the total costs. This mainly illustrates how important the description of the total context is when results for buildings are combined together.

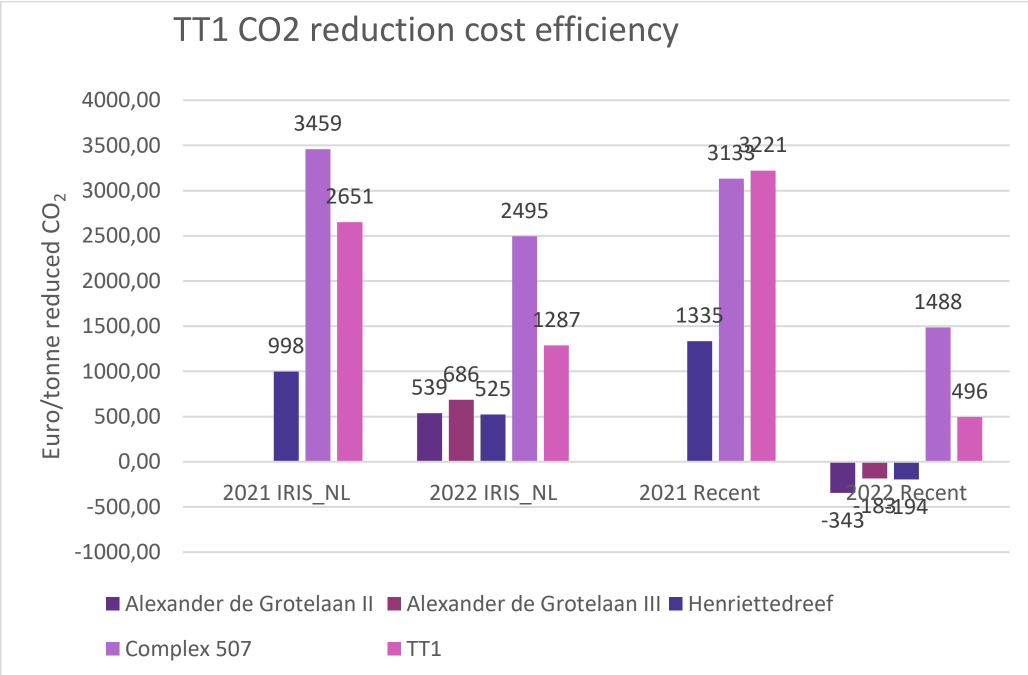


*Figure 29: Result of KPI 7: $CO_2$ reduction cost efficiency for all buildings and TT1 combined in the years 2021 and 2022 based on different emission and cost factors*

## 4.1.2 Measure 1.1: District wide PV

As part of the total refurbishment works 192 dwellings of the four apartment buildings named Alexander de Grotelaan II and III and Columbuslaan II and III have been equipped with PV-panels. Each household in the building has a PV system of 4 modules with a peak capacity of 330 W each (total 1,32 kWp) on top of that, each building has 22 modules installed on the central utilities (total 7,260 kWp). This makes the total installed capacity (48*4+22)*330 = 70,62 kWp per building (Table 13). Another system of 30 PV-panels of 350 Wp, adding up to a total 10,5 kWp is realized on the roof of apartment building named Columbuslaan I, which is connected to the district battery.

*Table 13 Installed PV capacity on buildings within Utrecht TT1*

| District | Building | Total Installed capacity (kWp) |
|---|---|---|
| **Kanaleneiland Zuid** | Alexander de Grotelaan II | 70,62 |
| | Alexander de Grotelaan II | 70,62 |
| | Columbuslaan II | 70,62 |
| | Columbuslaan III | 70,62 |
| | Columbuslaan I | 10,5 |
| | **Total** | 292,98 |
| **Overvecht** | Henriettedreef | 356,6 |
| | **Grand total IRIS** | 649,58 kWp |

The production data of these systems as well as the associated KPI results are described in the former paragraph, together with the rest of the building renovations.

### 4.1.3 Measure 1.3: Home Energy Management Systems (HEMS) TOON


*Figure 30: Impression of the HEMS Eneco Toon display*

The Eneco Toon® (hereafter Toon), is an existing device (7`` display) with proven technology. The main objective of the Toon is to provide information about the energy usage of a household.

Over the past five years, in the following apartment buildings more than 300 HEMS Eneco Toon devices have been installed:

- Apartment buildings prior to the refurbishment:
  - Columbuslaan II: 22 of 48 households (46%)
  - A de Grotelaan I/IV: 55 of 130 households (42%)
  - Rooseveltlaan I/II: 42 of 130 households (32%)
- Apartment buildings which have been refurbished:
  - A de Grotelaan II 48 of 48 households
  - A de Grotelaan III 48 of 48 households
  - Columbuslaan II 26 of 48 households (remaining dwellings)
  - Columbuslaan III 48 of 48 households

#### 4.1.3.1 Results from KPIs related to measure 1.3

*Table 14 KPI result of measure 1.3 Home Energy Management Systems (HEMS) TOON*

| KPI | Data source | Result | GA- Target |
|---|---|---|---|
| **17: Increased awareness of energy usage** | Survey | 3 (2,7) | 4 on a scale of 1-5 |

In start of 2023 a survey was held amongst tenants of the refurbished buildings. One question was asked to indicate the increased awareness of energy usage of TOON. When the deadline for data input was reached, an energy coach visited 27 tenants who filled in an online survey which gave an average Likert score of almost 2,7. This means that the TOON gives the tenants on average almost 'Somewhat' increased awareness of energy usage. Apart from this average, Figure 31 illustrates that there is quite a spread in distribution. Almost one third of the respondents have no effect at all, while one fifth have an excellent effect. It is important to note the survey was only held at 27 of the 300 TOON users yet. The large spread in answers illustrates how differently such device is perceived by the user group. More results for the survey are represented under the Transition Track 5, in paragraph 4.4

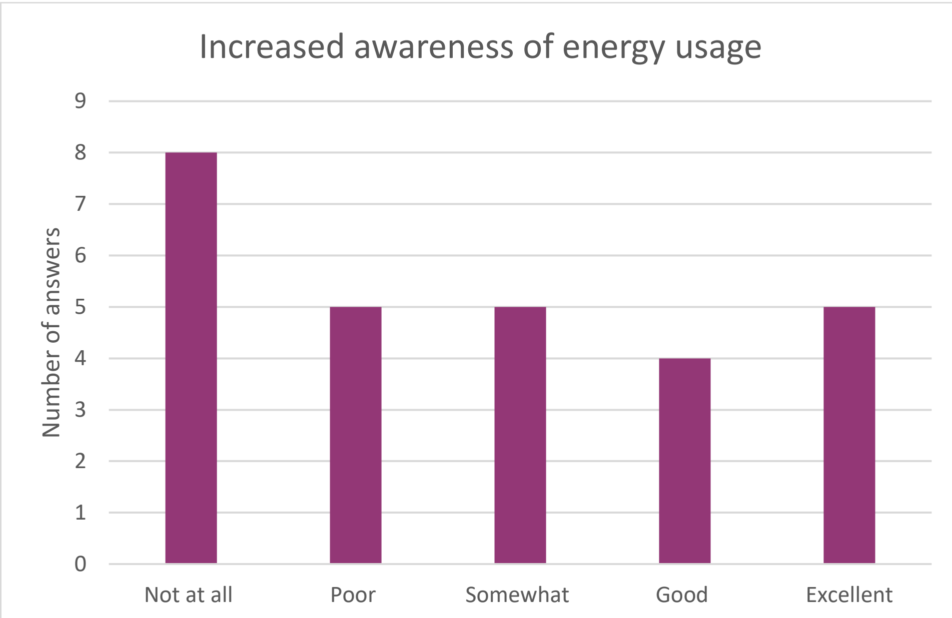


*Figure 31: Results for KPI 17: increased awareness of energy usage, the graph shows the distribution of answers on this question in a Likert score of 1-5 based on a survey done on the use of HEMS Toon*

### 4.1.4 Measure 1.5: Smart (hybrid) electric heat pumps

The smart hybrid e-heating systems consists of devices which will provide heat and hot tap water for the tenants, in 8 of the 12 apartment buildings. It is installed in the apartment buildings in Kanaleneiland Zuid and monitored as described in paragraph 4.1.1. The concept of the smart system consists of a central gas- heating device in combination with a ventilation heat pump, which is called the 'Eneco Warmtewinner'. The ventilation heat pump uses the heated ventilation air in an apartment to provide heat for space heating. The ventilation air comes from outside or inside, depending on the choice of the ventilation principle applied. This is a hybrid system since it combines electrical and gas-fed devices.

The smartness of this system consists of the ability to switch between gas and electrical heat. In principle baseload demand for space heating is supplied by the electrical system, whereas peak load is supplied by the gas-fed part of the system. Furthermore, the hybrid heat pump can provide flexibility in for the electricity grid, by switching to gas-mode in times of high demand for electricity in the area and potential grid stress. Figure 32 shows the position of the Eneco Warmtewinner in every apartment (heating cabinet next to the toilet, kitchen and bathroom) including the air inlets.

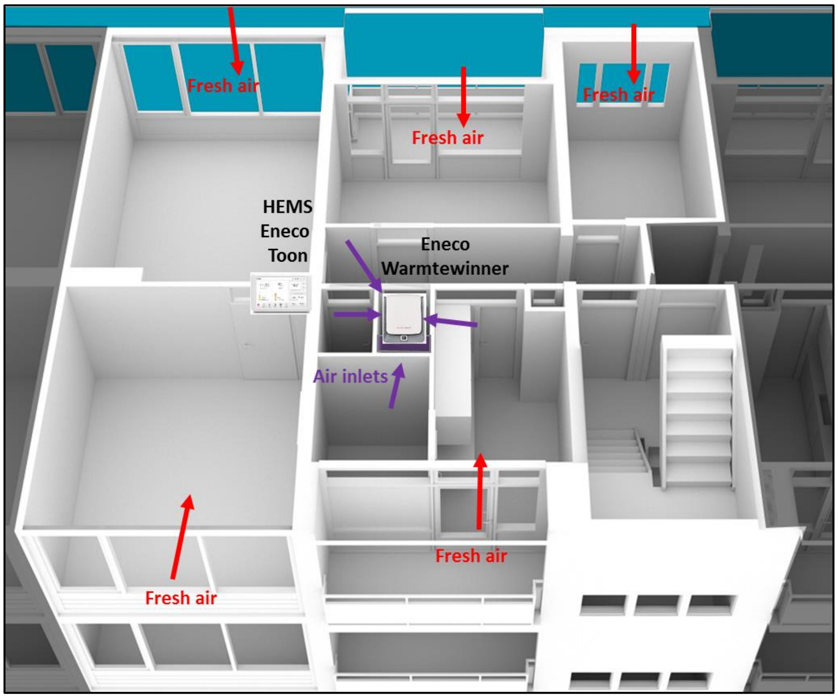


*Figure 32 Schematic map of an apartment with the position of the HEMS Eneco Toon*

As described before, there are no specific relevant KPIs for this measure, but it contributes to the overall performance of TT1. The reason for aggregating the performance indicators to a higher level is that the separate impact of this measure is hard to abstract, since more refurbishment work will be done simultaneously which also has an effect on energy savings and $CO_2$ reduction. The ease of use of this system is surveyed in paragraph 4.4.2.

### 4.1.5 Measure 1.7: Smart DC street lighting at district level

This measure compromises energy efficient smart street lighting powered by renewables. Not only the energy efficiency of the Smart street lighting increases by using LED lighting bulbs and direct current (DC). Two poles are equipped with other functionalities such as a lighted zebra crossing and smart tele management (Figure 33). These additional functionalities are investigated together with citizens of the district. In total, 49 existing street lighting poles in the district are replaced by the smart street lighting.

*Figure 33: Left represents the luminous smart pedestrian crossing, the picture on the right shows the smart light streetlight with additional devices  attached.*

For the monitoring and control of the street lighting, Luminext Luminizer telemanagement is used. This system gives insight in the energy usage and the information coming from the other functionalities. Even though a connection with the CIP was set up with the Luminext system, the data turned out to be not adequate for the KPI calculations at the final stage of the IRIS project. For this reason the calculation with the KPI results represented in Table 15 is done under assumptions made by the Utrecht municipality.

*Table 15 KPI results of Measure 1.7 Smart DC street lighting*

| KPI | 2021 | 2022 | Target (GA or declared) |
|---|---|---|---|
| **Carbon dioxide Emission Reduction [t/year]** | 1,37 | 1,37 | 9 tonnes in 5 years |
| **Energy savings** | 60% | 60% | 70% or 20MWh in 5 years |

The energy demand per year for conventional street lighting is given as 106 kWh/year per lamppost, the demand for the new LED streetlights is 60% lower and 42,8 kWh/year. Which is slightly lower than the expected 70%. With 49 lamp post installed in the pilot, the total electricity demand is 5194 kWh/year for

BAU and 2097,2 kWh/year for the measure. The associated $CO_2$ emission reduction then gives 1,37 tonnes per year for 2021 and 2022 with the IRIS_NL emission factors (total 2,74 tonnes). With more recent emission data, reduction adds up to 2,57 tonnes $CO_2$, with 1.35 and 1,22 tonnes for 2021 and 2022 respectively. Compared to the GA with a measured runtime of 5 years, $CO_2$ emission reduction would have reached almost 7 tonnes, due to a total energy saving of 15,5 MWh. This is slightly lower than the initial target.

# 4.2 TT2 Smart energy management and storage for flexibility

The development and demonstration of the smart charging system for electric cars and the installation of a large stationary battery in the Kanaleneiland-Zuid demonstration district have enabled the rapid evolvement and growth of an energy network management system at city level with currently 650 bidirectional charging stations and thousands more to come, which has made Utrecht a world-wide pioneer in bidirectional charging. IRIS has sped up that development and the focus now is to speed up further demonstration, expansion and replication.

## 4.2.1 Results for KPIs for TT2

*Table 16 Results TT2: installed stationary battery capacity within IRIS Utrecht*

| KPI | Measure | | Result | TT2 result |
|---|---|---|---|---|
| **Storage capacity installed [kWh]** | M2.3 | District battery | 845 kWh | 1015 kWh |
| | M2.3 | 2nd life battery Qbuz | 90 kWh | |
| | M1.8 | Powerqube | 70 kWh | |

The initial Grant Agreement targets for TT2 are:

- Smart storage capacity of 396 kWh primary storage in V2G e-cars
- 3 600 kWh secondary storage (stationary batteries)
- Local emissions of 1 300 ton $CO_2$ /year will be avoided from peak reduction

Because of different reasons which are described in D5.8 and D5.9 [13;3], the total projected stationary storage of 3600 kWh was only partly achieved with a total installed capacity of 1015 kWh in different measures throughout the city (Table 16). The utilization of the V2G e-car storage capacity was not achieved within the runtime of the IRIS project. The lack of standards and delays in the development of cars supporting this technology were important reasons for this. Nevertheless, the need for bidirectional charging has become more recognized due to many actions taken within the IRIS project. It is now at the brisk of being largely rolled out in the city of Utrecht. The availability of 650 charging stations and 250 within the WeDriveSolar car sharing system in the city will enhance this fast rollout in the years to come.

The targeted local emission reduction of 1300 ton $CO_2$ per year is actually the result of TT1 and TT3 which could not be achieved without the actions of TT2. This is done by avoiding peak loads thus keeping the electricity demand and generation of the installed IRIS measures within the limits of the grid. For example, the battery in the Henriettedreef building reduces peak loads such that electrification of the building could take place without local grid reinforcement. More details on all developments and research done within TT2 is thoroughly described in D5.9.[3]. In this report a simulation is described on the costs of using the stationary battery for peak load reduction on district level. This simulation was recalculated with a larger dataset and more recent data, which caused an increase of 25% in costs. The update is described in Annex 5.2

## 4.3 TT3 Intelligent mobility solutions

This transition track aims to integrated urban mobility solutions increasing the use of environmentally friendly alternative fuels, creating new opportunities for collective mobility and lead to a decreased environmental impact. In Utrecht these mobility solutions include the implementation of the V2G e car sharing system of We Drive Solar (M3.1) and the implementation of V2G E buses in Utrecht by Qbuzz.

### 4.3.1 Results for the KPIs for TT3

*Table 17: KPI results for TT3 Intelligent mobility solutions*

| KPI | Measure | Target | Result | TT3 result |
|---|---|---|---|---|
| **$NO_x$ emission reduction [IRIS NL]** | M3.1 | 1 | 2,87 | 60.43 |
| | M3.2 | 22 | 57,66 | |
| **Fine particulate matter emission [IRIS NL]** | M3.1 | 0,02 | 0,09 | 0.77 |
| | M3.2 | 0,26 | 0,68 | |
| **Carbon monoxide emission reduction [IRIS NL]** | M3.1 | 3 | 11,95 | 33.27 |
| | M3.2 | 1,6 | 21,32 | |
| **Carbon dioxide Emission Reduction [IRIS NL]** | M3.1 | 308 | 768 | 9581.31 |
| | M3.2 | 4785 | 8831 | |
| **Yearly km driven in e-car sharing system** | M3.1 | 270 000/year | 4 779 042 /3 years | 1 593 014 /year |

The Grant Agreement target for TT3 Intelligent mobility solutions for Utrecht:

(i) Air quality: Emission reductions as represented in column 3 of Table 17
(ii) Yearly 270 000 km are made through the e-car sharing system instead of private conventional cars (210 000 by e-cars and 60 000 by e-vans)

Table 17 illustrates that the target for reduction of emissions by the buses as well as the cars are largely met. An important sidenote to this achievement is the fact that the area of application of the E-cars was increased to city level and consequently more cars and kilometers were driven. More specific details on measure 3.1 and 3.2 and their results can be found in 4.3.2 and 4.3.3.

## 4.3.2 Measure 3.1: V2G e-cars

The Mobility as a Service (MaaS) "We Drive Solar" (WDS) car-sharing system started its demonstration in the LH demo district Kanaleneiland-Zuid. The first car was placed at the local innovation hub Krachtstation. Despite the efforts taken with local partners, and citizen engagement activities to investigate demand for car-sharing services, the demand for V2G e-cars did not increase in the selected area, while significant demand was visible in other areas of Utrecht. Because of these reasons the demonstration area for this measure was increased to the whole city of Utrecht.


*Figure 34: Shared WDS e-car at Krachtstation, Kanaleneiland, Utrecht*

LomboXnet is monitoring the driven km by all e-cars as part of their monitoring system, as well as the number of shared e-cars in the district. For calculation of the emission reductions, the same conversion factors are used as the ones in the DoA.

Data transfer of the variables into the KPI tool took place by means of the manual data entry template, details of this data can be found in Annex 5.3

### 4.3.2.1 Results from measure 3.1 V2G e-cars

Table 18 shows the results for each KPI calculated for this measure, as well as the GA-target (where applicable).

*Table 18: KPIs results for Measure 3.1 V2G e-cars*

| KPI | 2020 | 2021 | 2022 | GA- Target |
|---|---|---|---|---|
| **$NO_x$ emission reduction** | 0,47 | 0,89 | 1,50 | 1 ton in 5 years |
| **Fine particulate matter emission (FPM)** | 0,01 | 0,03 | 0,05 | 0,02 ton in 5 years |
| **Carbon monoxide emission reduction** | 1,96 | 3,72 | 6,27 | 3 ton in 5 years |
| **Carbon dioxide Emission Reduction** | 126,12 | 239 | 403 | 308 ton in 5 years |
| **Access to vehicle sharing solutions for city travel (cars per 1000 inhabitants)** | 0,19 | 0,44 | 0,49 | 18 cars (.98/1000 inhabitants) |
| **Yearly km driven in e-car sharing system** | 784 811 | 1 486 289 | 2 507 942 | 270,000 km per year |

The variable that binds all KPIs related to emissions of this measure together, is the amount of kilometers driven in the e-cars. Figure 35 shows how this number rapidly increased during the IRIS project, starting from 785 thousand km in 2020 till more than 2,5 million in 2022.

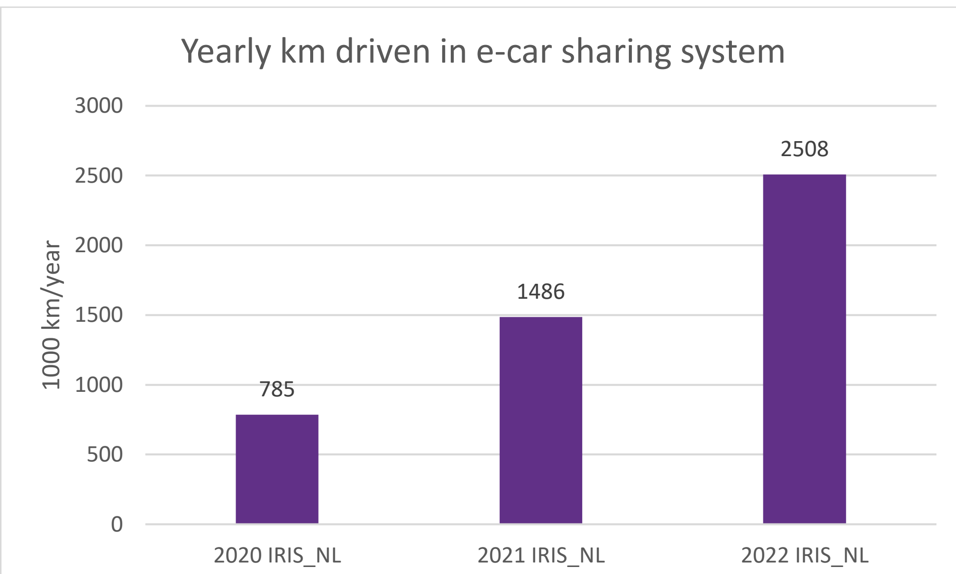


*Figure 35 Results for KPI46: Yearly km driven in e-car sharing systems in 1000 km per year for the years 2020, 2021 and 2022*

Figure 36 illustrates that the largest increase in access to vehicle sharing solutions happened in 2021 where it went from 0,19 cars to 0,44 cars per 1000 inhabitants, it only slightly grew in 2022. When compared to the number of kilometers driven, it can be seen that utilization of the vehicles is not directly proportional to the availability. It seems that as soon as cars are available, they are used more frequently.

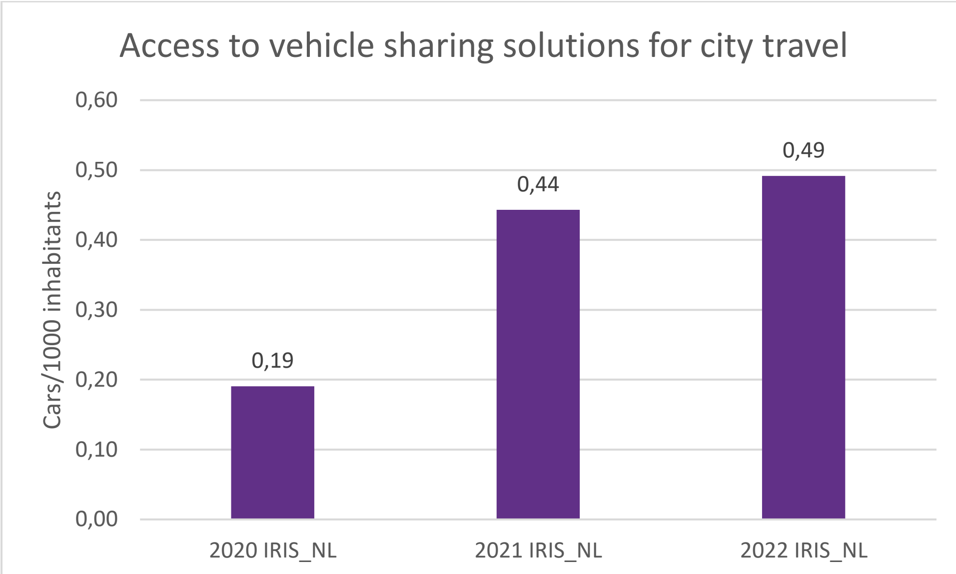


*Figure 36: Results for KPI 2: Access to vehicle sharing solutions for measure 3.1. The graphs shows how many cars per 1000 inhabitants are available in the years 2020 till 2022.*

Looking at the Grant Agreement goals, 18 cars were expected to be placed in the district Kanaleneiland only. As this district has 17 600 inhabitants in 2023 [14] this means an availability of .98 vehicles per 1 000 inhabitants. With an increased area of interest into city wide, an availability of 49 vehicles is reached, which is half of the initial goal.

The reduction of emissions is directly related to the amount of driven kilometers as shown in Figure 36 and therefore follows the exact same pattern for the measured years, which can be seen in the graphs. 2 different results for each year are represented, where 'IRIS_NL' refers to the values calculated with similar emission factors as stated in the Grant Agreement, and 'Recent' refers to more recent values. How these emission factors were obtained can be found in Annex 5.3. For the $NO_x$ and CO emissions the reduction decreases to about 1/3 using these values, and for $CO_2$ this a decrease of 40% can be seen for all years. On the contrary, FPM-emissions are 40% larger with the recent emission factors.

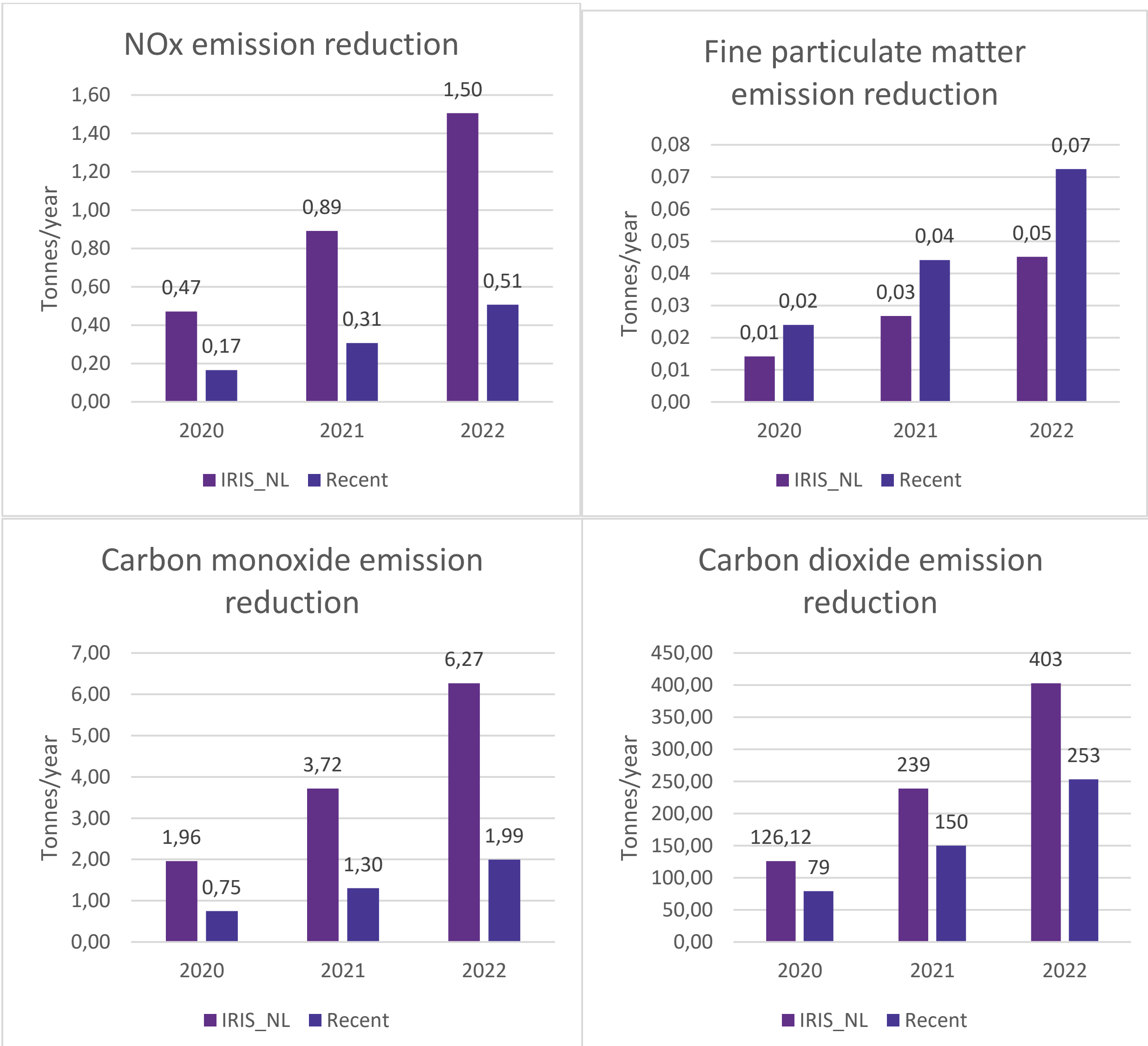


*Figure 37: Results for reductions of emissions in tonnes per year for measure 3.1*

## 4.3.3 Measure 3.2: V2G e-buses

IRIS partner QBuzz has relocated its bus depot from the Europalaan in Utrecht to Westraven, a district just south of the IRIS district in Kanaleneiland-Zuid, and at the Remiseweg, across the Amsterdam-Rijn channel from Westraven. Smart charging of the buses is tested, but V2G e-buses and chargers are not available. QBuzz investigates the options for V2G charging at its new bus-depot with the objective to demonstrate and optimize smart charging.

The buses feature detailed monitoring and data storage equipment is based on the ViriCiti platform, these monitors in the buses and in the chargers many parameters including voltage, currents, state of charge, energy charged, accelerator usage and other parameters. Total amount of km's driven by the buses are obtained from this platform and, together with the emission factors, transferred to the KPI tool by means of the manual data entry template. The data which was used for calculation of these KPIs can be found in Annex 5.3.

#### 4.3.3.1 Results from Measure 3.2

Table 19 shows an overview of the main KPI results for the V2G e-buses as well as the Grant Agreement -targets. It illustrates that the emission reductions caused by this measure largely exceed the Gant Agrrement targets.

*Table 19: KPIs results for Measure 3.2 V2G e-buses*

| KPI | 2018 | 2019 | 2020 | 2021 | 2022 | GA- Target |
|---|---|---|---|---|---|---|
| **$NO_x$ emission reduction** | 4,29 | 4,11 | 7,59 | 19,96 | 21,60 | 22 ton in 5 years |
| **Fine particulate matter emission (FPM = PM10)** | 0,05 | 0,05 | 0,09 | 0,24 | 0,26 | 0,26 ton in 5 years |
| **Carbon monoxide emission reduction** | 1,59 | 1,52 | 2,81 | 7,39 | 8.00 | 1,6 ton in 5 years |
| **Carbon dioxide Emission Reduction** | 657 | 630 | 1163 | 3056 | 3307 | 4785 ton in 5 years |

Similar as for measure 3.1, there is a direct relation with the reduction of emissions and the number of driven kilometers, therefore each graph of Figure 38 follows a similar pattern for the measured years. Each graph shows a slow start, where 2019 even has a slightly lower impact than 2018, in 2020 impact almost doubled and 2021 and 2022 show a five-fold growth compared to the first 2 years. Keeping in mind that the last three years were influenced by Covid, means that for the years to come an even larger impact can be expected.

In these graphs, 'IRIS_NL' refers to the values calculated with similar emission factors as stated in the GA, and 'Recent' refers to more recent values. How these emission factors were obtained can be found in Annex 5.3. Comparable to measure 3.1, FPM-emission reductions are larger with the recent emission factors (about 50%). $NO_x$ and CO emissions give about half of the reduction when more recent factors are used. The difference for $CO_2$ emissions is not that large (about 10% smaller).

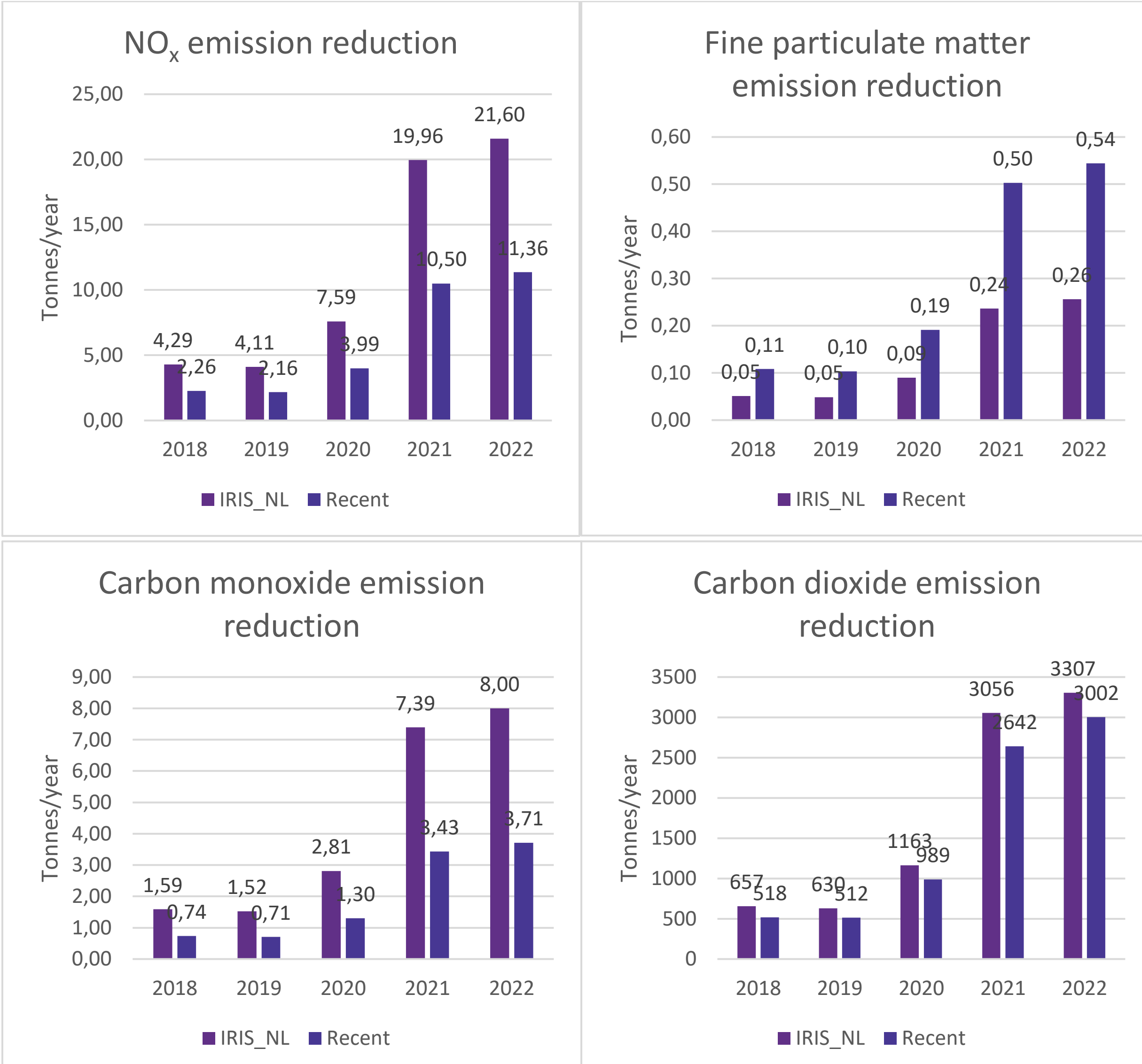


*Figure 38 Results for reductions of emissions in tonnes per year for measure 3.2*

## 4.4 TT5 Citizen engagement and co-creation

The ambitions of this transition track #5 ‘Citizen engagement and Co-creation’ consist of: design and demonstrate feedback mechanisms and inclusive services for citizens to achieve that citizens are motivated to save energy, shift their energy consumption to periods with abundant renewables and use shared e-mobility instead of private cars. Many different actions were taken within this transition track. The results for transition track level are represented in Table 20. Even though some results for these actions are measured with KPIs, it must be noted that in this field KPIs tend to give an insufficient and sometimes superficial presentation of the reality. For this reason it is encouraged to read D5.9 to learn more from all actions taken within this transition track.

### 4.4.1 Result of KPIs for TT5

*Table 20: Aggregated KPI results for TT5 based on the measurements described in the table*

| KPI | Target | Results | Measures included |
|---|---|---|---|
| **People reached** | 80% | 3243 citizens | M5.1, M5.2, M5.3, M5.4 |
| **Local community involvement in planning/ implementation phase** | 4 | 3,6 | M5.1, M5.2 |
| **Ease of use for end-users of the solution** | 4 | 3,7 | M5.1, M5.3, M5.4 |

The targets stated in the Grant Agreement on Utrecht TT5 are:

- Citizen engagement is a conditional factor for reaching the energy savings of the renovations and of the ecar sharing system. In that sense, the energy saving of citizen engagement is 4,6 million kWh/year or 1 300 ton $CO_2$ reduction/year for the buildings. Plus 308 ton $CO_2$ reduction/year for the e-cars.
- Actively engaging 200 out of 644 households through the measures mentioned above.

Many of the actions taken in this transition track were indeed a catalyzer for measures in the other transition tracks, so the earlier in this chapter described achieved results for Utrecht are partly an achievement of TT5. The amount of 3243 citizens for the KPI “People reached” comes from many different actions as presented in Table 22. Among these citizens are also 1600 visitors of the IRIS website. On the other hand, not all tenants of the buildings in TT1 are included in this aggregation. For example, the strong cooperation of tenants in the refurbishment of Complex 507. Nevertheless, paragraph 4.4.2.1 and more in detail deliverable D5.9 show that the active engagement of 200 households is largely reached by all actions taken within this Transition Track.

### 4.4.2 Measure 5.1 Community building by Change agents and Measure 5.3 Evaluation and Co-creation

The description of how the implementation of this measure has evolved during the course of the IRIS project. Within measure 5.1 the following actions were taken:

1. Personal visits to tenants to inform about actions taken for citizens within the IRIS project.
2. The residents Whatsapp-group EnergieKanaleneiland
3. Henriettedreef EnergieCoaching
4. Seminar Citizen engagement
5. Seminar about the use of the IRIS stationary battery:
6. IRIS signs
7. Climate Fair Marshalllaan
8. Environmental chats

Because of the variety of those actions, the initial program of KPIs is adapted to the new situation. For this reason, calculation of KPIs is based on the data from D5.9 and the results for the tenants survey which was conducted at the start of 2023. Main KPI results are represented in Table 21.

#### 4.4.2.1 Results for measure 5.1 and 5.3

*Table 21: KPI results for measure 5.1 and 5.2*

| KPI | Based on | Result | Target |
|---|---|---|---|
| **People reached** | Various events | 2512 citizens | 80% |
| **Increased environmental awareness** | Tenants Survey | 2,7 | 4 on scale of 1-5 |
| **Local community involvement in planning/ implementation phase** | Tenants Survey | 3,2 | 4 on scale of 1-5 |
| **Ease of use for end-users of the solution** | Tenants survey | 3,6 | 4 on scale of 1-5 |

The amount of people reached within the various actions taken in measure 5.1 and 5.3 is represented in Table 22. As the target group varies per type of action and is not so easy to distinct in many cases, this KPI cannot be calculated as a percentage. The sum of all actions gives a number of 2512 citizens.

*Table 22: Amount of people reached for various action within measure 5.1 and 5.3*

| Action/ event | Citizens involved |
|---|---|
| Visitors IRIS Website | 1600 |
| Reactions IRIS Social Media | ? |
| V2G car subscriptions | 226 |
| Members WhatsApp group | 70 |
| Tenants Survey | 27 |
| Energy Market | 35 |
| Information evening district Battery | 310 |
| Seminar Bouchra Dibi | 55 |
| IRIS signs | 20 |
| Climate fair | 50 |
| Environmental chats | 119 |
| **Total** | 2512 |

For the KPI on increased environmental awareness, tenants answered the question how much TOON provided insight in energy demands and costs. Figure 39 illustrates that the answers are distributed over the full range of “not at all” to “Excellent”. On average it is a bit below a Likert score of 3 (2.7) which in this case means that there is a little less than “Somewhat” effect.

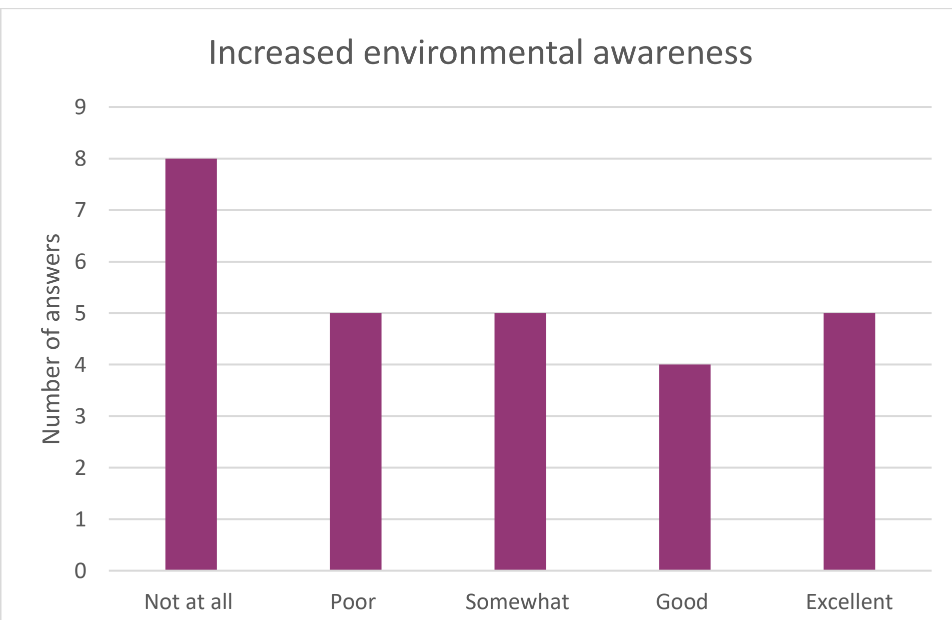


*Figure 39: Results for KPI 19: increased environmental awareness, the graph shows the distribution of answers on this question in a Likert score of 1-5*

On involvement of the tenants on the refurbishment also a wide distribution of answers is shown in Figure 40. On average tenants score 3.2, which means that they had “some” involvement. Apart from looking at the average, it is important to note that some respondents clearly state that there was no involvement, while others had excellent involvement. The reasons behind this difference requires more qualitative research.

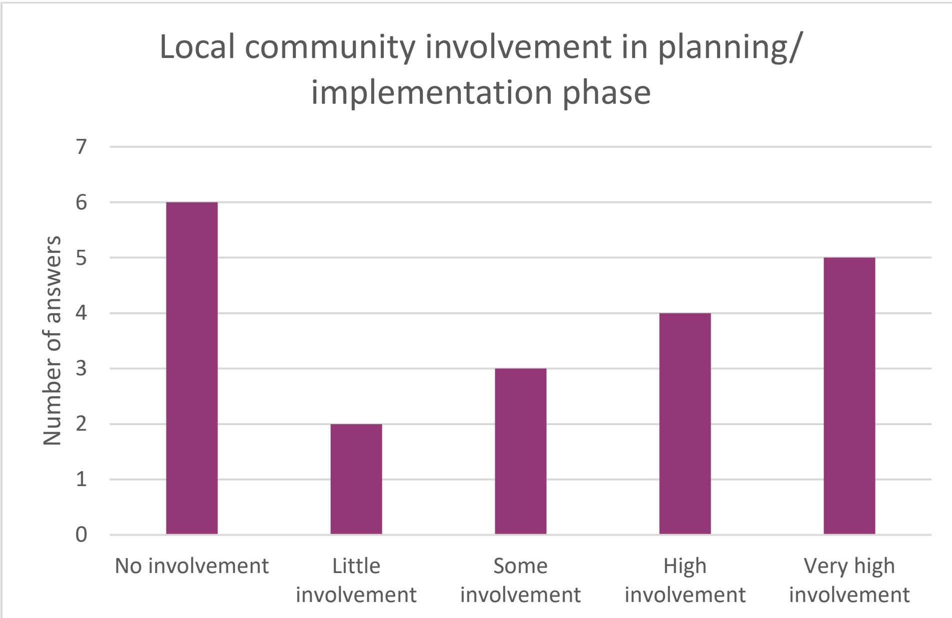


*Figure 40: Results for KPI 22/ 23: Local community involvement in the planning/ implementation phase, the graph shows the distribution of answers on this question in a Likert score of 1-5*

Ease of use for end users is measured from the answers given for the HEMS-Toon and the Ventilation Heat Pump which were both installed in the apartments and shown Figure 41. An average result of 3.6 illustrates that both appliances are experienced between “fairly easy to use (3)” and “slightly difficult (4)”. The ventilation heat-pump on average has a higher score (3.7) than the Toon (3.4). The large spread of results in the latter one, with 25% of the respondents giving a score below 3, might also be an answer for the low score on the effect on environmental awareness by this device.

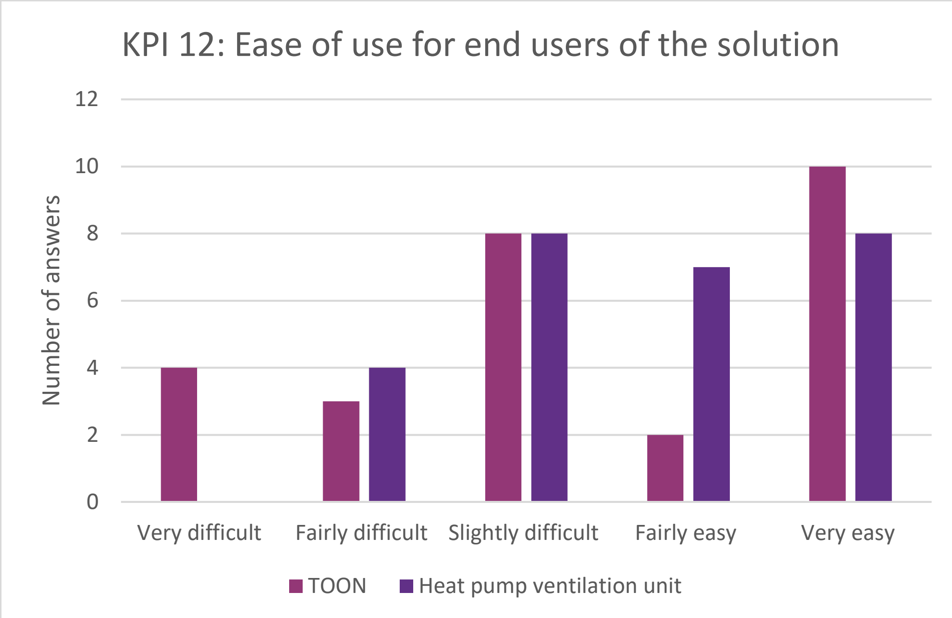


*Figure 41: Results for KPI 12: Ease of use for end users of the solution, the graph shows the distribution of answers in a Likert score of 1-5 based on a survey on the use of TOON and the Heat Pump Ventilation Unit*

It should be noted that many different actions are described for this measure, and the measured KPIs are mainly based on the tenant survey. On top of that, only a relatively small group (27 out of 200) has yet filled in the survey. To learn more about these measures, more details and qualitative results for measure 5.1 and 5.3 are described in D5.9.

## 4.4.3 Measure 5.2: Campaign District School Involvement

Within the district Kanaleneiland-Zuid, different campaigns were done to involve the local schools. The most successful and measurable impact took place at three primary schools and the MBO- Utrecht (professional education). KPI results for these campaigns are shown in Table 23.

### 4.4.3.1 Results for measure 5.2

*Table 23 Summary-list of KPIs and related parameters for Measure 5.2: Campaign District School Involvement*

| KPI | Parameter(s) | Input | Result | Target |
|---|---|---|---|---|
| **People reached** | Primary schools | 2018: 150 / 500<br>2019: 100 / 500<br>(2020: 0 / 500)<br>2021: 171 / 500<br>2022: 174 / 500 | 2018: 30%<br>2019: 20%<br>2021: 34%<br>2022: 35 % | 80% |
| | Professional education | 2018 till 2022<br>20 students per year | NA | |

The three primary schools Kaleidoscoop, Da Costaschool and Schatkamer in the demonstration district were involved in an educational program within the IRIS project. The amount of people reached varies per year in the range of 30 – 35%, 2020 had very little involvement, due to regulations around the Covid pandemic. In professional education each schoolyear 20 students from the MBO Utrecht (high school) have worked on assignments regarding the refurbishment plans in Kanaleneiland-Zuid.

The premise is that by targeting children and local students their families, living in the district, might familiarize themselves and develop an emotional relationship with the energy solutions their sons and daughters are realizing in their own neighborhood. This means that the actual indirect amount of people reached by this program is higher, but needs a different way of measuring.

### 4.4.4 Measure 5.4: Campaign Smart Street Lighting

In 2018, a group of professionals together with area residents, used co-creation principles to think about the following question: How can smart street lighting contribute to a better/healthier/safer/ funnier neighbourhood for and from the residents and entrepreneurs in Kanaleneiland-Zuid. 11 concepts were created and in the end one concept won: the self-illuminating pedestrian crossing. A pedestrian crossing that lights up in the dark and is accompanied by two poles that detect air quality, traffic speed and movement. In a final meeting with residents in June 2020, a group of residents jointly decided where the pedestrian crossing would be placed. In May 2021 the self-illuminating pedestrian crossing was installed at the street Columbuslaan in the demonstration district of Kanaleneiland-Zuid. Another part of this measure is the installation of 49 low-energy light bulbs at the Columbuslaan. The fittings are dimmed and as soon as a car or cyclist approaches the light intensity increases. Once the traffic has left, the luminaires dim again. By varying in light intensity, energy is saved.

#### 4.4.4.1 Results from measure 1.4

*Table 24 Summary-list of KPIs and related parameters for Measure 5.2: Campaign District School Involvement*

| KPI | Source | Input | Result | Target |
|---|---|---|---|---|
| **Local community involvement in development process** | Inquiries amongst involved citizens | 28 responds, overall score 4/5 | 4: High involvement of the local community | 4 on the scale of 1-5 (Likert Scale) |
| **Advantages for end-users** | Inquiries amongst involved citizens | 28 responds, overall score 4/5 | 4: High advantage | 4 on the scale of 1-5 (Likert Scale) |
| | Interviews amongst residents | 8 responds, overall score 4/5 | | |
| **Ease of use for end-users** | Inquiries amongst involved citizens | 28 responds, overall score 4/5 | 4: Fairly easy | 4 on the scale of 1-5 (Likert Scale) |
| | Interviews amongst residents | 8 responds, overall score 4/5 | | |

After installation and a period of utilization of the zebra crossing, 22 residents were interviewed live interview or questionnaire. About 60% of the interviewees knows the zebra crossing. The zebra crossing is perceived positively. The location of the zebra crossing is rated as fine because there is a school nearby. In the evening, the zebra crossing works best. Eight residents gave the zebra crossing a 7.8. (4 on the Likert scale 1-5). Table 24 illustrates that this campaign turned out quite successful, with a high advantage for end-users, fairly easy use and high involvement of the local community.

# 5 Results Nice

In this chapter the results for LHC Nice are presented per TT and per measure. The measures are only briefly described, and the results focus on the KPIs and set targets. For more detailed description of the measures, results and lessons learnt by the partners please read D6.9. [4].

Some highlighted results for the measures in Nice are shown in Table 23.

*Table 25: Highlighted results for LHC Nice based on the years with full measurement data and standard IRIS-FR emission factors.*

| KPI | Results | Included measures |
|---|---|---|
| **Total Carbon dioxide Emission Reduction** | 14,2 tonnes/year | M1.1, M1.2 |
| **Total increase in local renewable energy production** | 252,52 MWh/year | M1.1 |
| **Total number of connected urban objects in the city information Platform** | 124 objects | TT4 measures |
| **Data that uses DCAT standards** | 100% | TT4 measures |

Unfortunately, not all measures have been finalized and possible to evaluate. The reason for excluding certain measures and KPIs is summarized in Table 2. Especially, the exclusion of M2.2 “Smart multi-sourced low temperature district heating with innovative storage solutions” (due to the fact that the responsible partner didn’t provide data) affects most of the KPIs.

The data used for the calculations of the KPIs in chapter 5 can be found in Annex 6.

To avoid misunderstandings that will occur by comparing the IRIS achievements in Nice with the Grant Agreement targets, someone should consider the fact that many of these targets were based on the implementation of projects that IRIS did not fund. These projects were either complementary to the IRIS measures in Nice or a prerequisite for an IRIS measure. Consequently, their non-implementation lowered the impact of the IRIS interventions in Nice.

## 5.1 TT1 Renewables and energy positive districts

The main goal of Nice LH was to transform the Nice Eco Valley district into a livable, safe, and socially inclusive Near Zero Energy district by incorporating renewable and intelligent energy solutions, electric mobility options, and informative ICT services. Transition Track #1 (TT#1) aimed to contribute to this goal by implementing the following:

- Utilizing a significant portion of locally generated and self-used solar power in newly constructed buildings.
- Implementing cost-effective energy conservation measures that are suitable for upgrading inefficient and dilapidated multi-unit residential buildings.

- Employing smart information and communication technologies to promote environmental awareness among the local community and end-users about the energy solutions implemented throughout the district.

### 5.1.1 Results for the KPIs for TT1

The table below shows the **KPI 5 Carbon dioxide Emission Reduction** and the **Increase in local renewable energy production** results aggregated at the TT level. This result has been calculated with the IRIS standard emission factor. In the subsections (5.1.2.1 and 5.1.3.1) that follow, graphs for KPI 5 will be presented in which the results are derived from emission factors sent by partners.

*Table 26: Aggregated annual KPI results for TT1 for Nice*

| KPI | Target | Results | | Measures included |
|---|---|---|---|---|
| | | 2021 | 2022 | |
| **Carbon dioxide Emission Reduction [tonnes $CO_2$e/year]** | 24 | 14,122 | 14,287 | M1.1, M1.2 |
| **Increase in local renewable energy production (MWh/year)** | 360 | 250,79 | 254,25 | M1 |

The Grant agreement target for TT1 for Nice are:

- Energy savings: 9.1 million kWh/year and 1.620 tonnes $CO_2$ reduction/year, and
- Increase renewables: from almost 0 MWp to 4 MWp of installed PV power capacity in the 3 demonstration and replication areas.
- 90 % of new buildings in Nice-Meridia connected to a geothermal district heating & cooling network.

The envisioned PV power capacity of 4 MWp was not installed as was not funded by the IRIS project. The same applies to the connection of new buildings to geothermal district heating & cooling network.

### 5.1.2 Measure 1.1: Collective self-consumption at building scale

Collective self-consumption at building scale was a new concept for commercial and residential customers in France, while only a small number of projects have been done in Europe so far. This concept has been tested in Nice Meridia on two positive energy buildings (IMREDD and PALAZZO MERIDIA) constructed in 2019-2020.

The main objective of this use case was to assess the benefits and analyse the barriers (legal, financial, technical) that prevent the development of the collective self-consumption market at building scale. One sub-objective was to experiment with different technologies to increase the ratio of PV self-consumption. For PALAZZO MERIDIA and IMREDD buildings, battery storage system was foreseen to increase natural self-consumption of the building (communal parts of the building for PALAZZO MERIDIA). Therefore, the monitoring plan was based mainly on electrical power measurements located at convenient places. Furthermore, it is appropriate to measure the real battery efficiency (auxiliary consumption, non-ideal inverter and non-ideal discharge/charge behavior) but also to evaluate KPIs for the whole building.

The metering system have been made of electric meters (electronic), measuring voltage and current at 10-minute timestep (10 min averaged power). In addition, electric meters for the total building electricity demand (measured at the electrical transformer every 10-minute timestep) and energy meters for the total building heat and cool demand (measured at the DHC (District Heating Cooling) network substation on a monthly basis) completed the monitoring plan.

#### 5.1.2.1 Results from Measure 1.1

The following table summarizes the KPIs for measure 1.1. KPI 5 results are based on partners emission factor.

*Table 27: KPI results for Measure 1.1 Collective self-consumption at building scale*

| KPI | 2021 | | 2022 | | GA- Target |
|---|---|---|---|---|---|
| | IMREDD | Palazzo | IMREDD | Palazzo | 2 Buildings |
| **Carbon dioxide Emission Reduction (t $CO_2$)** | 2,296 | 5,225 | 5,119 | 8,154 | 24 $tCO_2$/year |
| **Energy Savings (%)** | 55,9 | 43,49 | 34,2 | 12,78 | 340 MWh/year |
| **Increase in local renewable energy production (MWh/year)** | 177,81 | 72,98 | 177,81 | 76,44 | 360 |
| **Degree of energy self-supply by RES** | 107.708% | 107.63% | 72.188% | 60.869% | 80% |
| **Storage Capacity Installed (kWh)** | 218 | 90 | 218 | 90 | 300 |

The images below illustrate the calculation results for different KPIs of measure 1.1 in Nice for two buildings.

The first result shown is the **KPI 5 Carbon Emission reduction.** It can be seen that the values for 2021 are for IMREDD 2,296 Tonnes/Year while for Palazzo is 5,225 Tonnes/Year. It is observed that these indicators increased in 2022, with the values being formed as follows. For IMREDD the value is 5,119 Tonnes/Year and for Palazzo the value is 8,154 Tonnes/Year.

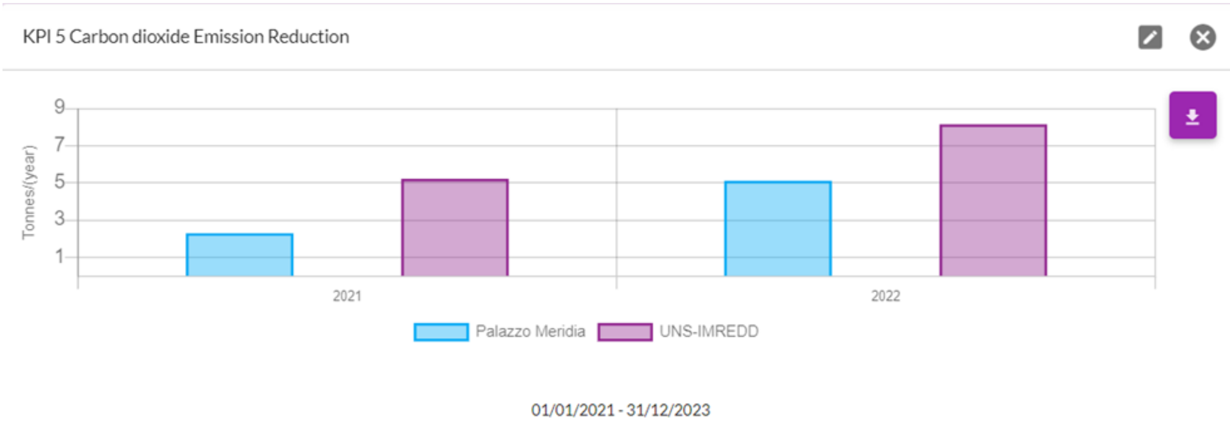


*Figure 42: Carbon dioxide Emission Reduction of Buildings in Nice for TT1.1*

The next figure depicts **KPI 10 Degree of energetic self-supply be RES**. It can be seen that in 2021, the value of this KPI for Palazzo is 107,63% while for IMREDD is 107,708%. For 2022, the values are 60,869% for Palazzo and 72,188% for IMREDD

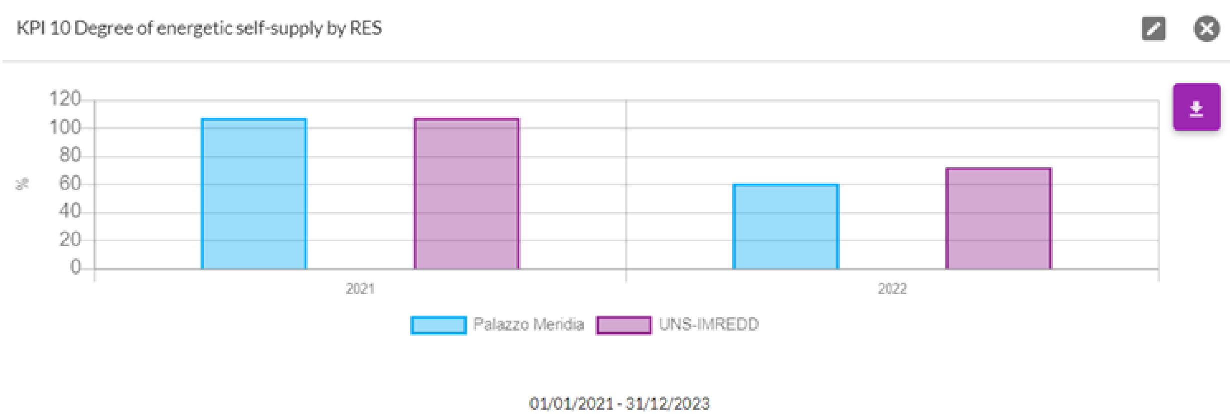


*Figure 43: Degree of energetic self-supply by RES of Buildings in Nice for TT1.1*

The following figure illustrates the percentage of **KPI 13 Energy savings**. In the year 2022, there was a decrease in the percentage of energy savings for both buildings. In more details, the value for 2021 for Palazzo is 43,49% while for 2022 is 12,78%. The same values for IMREDD are 55,9% for 2021 and 34,2% for 2022.

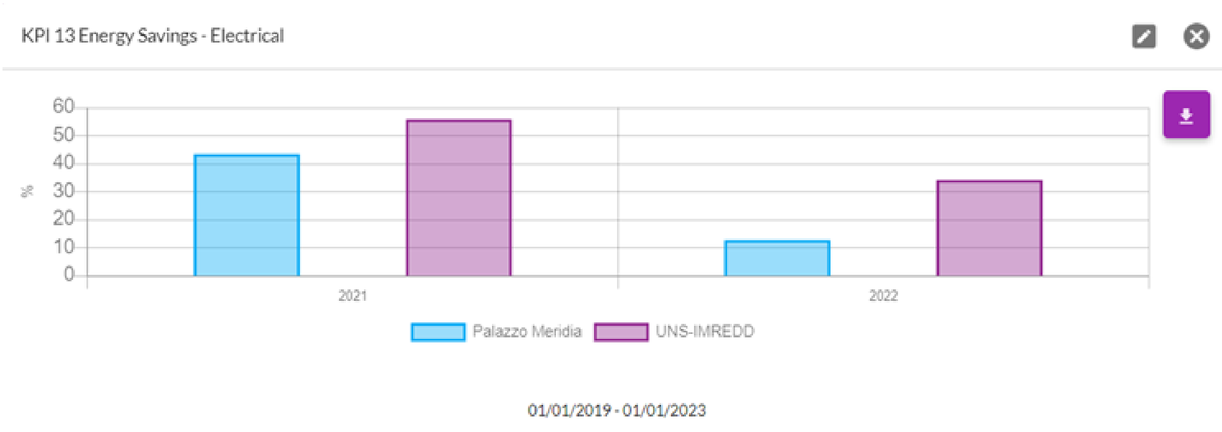


*Figure 44: Electrical Energy Savings in Nice for TT1.1*

**KPI 20 Increase in Local Renewable Energy production** was almost constant for both buildings for the years 2021-2022, as shown in figure 28. More specifically in the Palazzo, a small increase has been observed in the year 2022. The value was 72,98MWh in 2021 while it was 76,44MWh for the next year. For IMREDD the value for both 2021 and 2022 remains the same (177,81MWh)

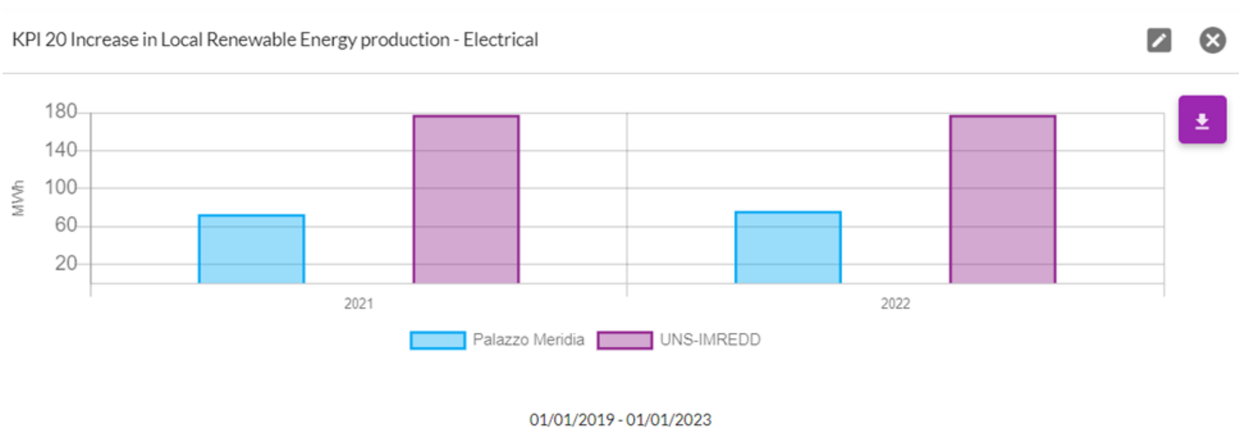


*Figure 45: Electrical Increase in Local Renewable Energy production in Nice for TT1.1*

Figure 29 depicts that the **KPI 42 Storage capacity Installed** for the building “UNS-IMREDD” is significantly higher than in the building of “Palazzo Meridia’’. While for IMREDD the value for 2021 and 2022 is 218 KWh the value for Palazzo is 90 KWh for both years.

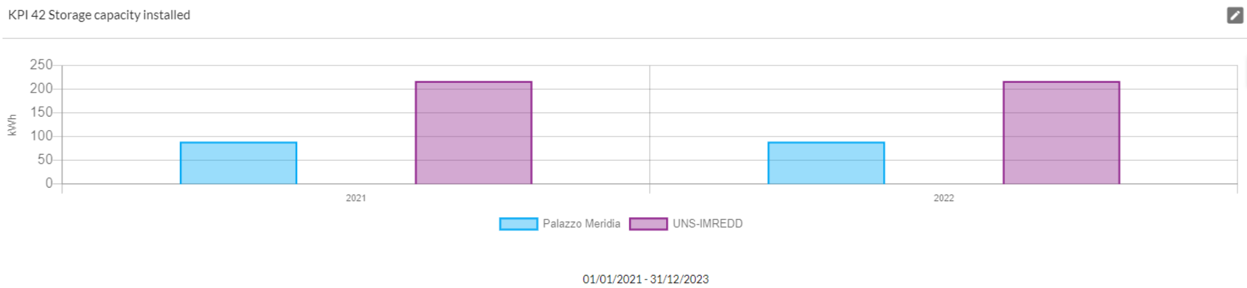


*Figure* 46 *Storage Capacity Installed in Nice for TT1.1*

The analysis showed that real life operational constraints during the experimentation phase prevented the buildings to achieve great KPIs, nor to demonstrate the relevance of the use of local storage assets. However, the results and load curves during the self-consumption experimentation phases showed that when the battery was fully operational and used at its full potential could increase self-consumption and self-production. Similarly, an optimal battery control maintained during the whole year could double the time during which the building can be considered off-grid. This shows that it is necessary to maintain a high resilience of the ICT infrastructure to maintain optimal operations for the battery.

Regarding the local renewable energy production, in 2022 it did not meet the target set at the beginning of the project. This is mostly due to the fact that the size of solar PV installed had to be reduced, but it is also due to the fact that solar panels did not produce as much as they should have in 2022. Reasons for this are multi-fold. First, the presence of excessive dust on solar panels that were installed horizontally. As an example, the presence of dust was responsible for an 8% decrease in production compared to the theoretical expectations. Also, another source of difference in production is related to shadings and weather. Different sources of shading (appliances on the roof, other building's construction) appeared after the construction of IMREDD's building, which affected the annual PV production compared to the theoretical values. Finally, weather was not as good as theoretical annual radiation. Altogether, it can explain parts of the difference between the KPI target and the achieved value.

The reader could see section 2.4.1 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 1.1.

### 5.1.3 Measure 1.2: Optimization of heating load curve

Renovation of existing buildings is generally limited to the refurbishment of the means of production or insulation of buildings. Heating control remains centralized according to a single heating law for the entire building, which depends only on an outside temperature and on an internal room measurement. Some houses are overheated while others are underheated, leading to an overconsumption of energy and discomfort. As part of the renovation of existing buildings, the aim of the project was to integrate an intelligent regulation within the district heating distribution, giving the possibility to adjust heating to the individual needs of each apartment according to their sun and wind exposures but also taking into account accurate temperature. Measure 2 is divided into 3 solutions to adjust the different regulatory models and evaluate the profitability of the different investment stage.

- Solution 1: Separation within the sub-station of production from north and south distribution - analysis of the profits and establishment of reference consumptions data for the performance analysis of solution 2
- Solution 2: addition of regulators to solution 1, valves and thermal sensors per housing. Adjusting the distribution to individual needs, taking into account the actual temperature of each dwelling.
- Solution 3: technical and economical optimization of solution 2 - definition of the best performing individual control grid (housing / floor) according to technical and economic considerations.

The selected experimental area is located in the social housing area of Nice Saint Augustin in two neighboring buildings named Tower 13 & Tower 14. These buildings are equipped with underfloor heating (high inertia system) which will permit to test meteorological regulation within an optimal context. In addition, different control algorithms was tested simultaneously on the seventeen floors of each building in order to weigh the impact of each variable, and to test different sensor technologies.

#### 5.1.3.1 Results from Measure 1.2

The following table summarizes the KPIs for measure 1.2.

*Table 28 KPI results for Measure 1.2 Optimization of heating load curve*

| KPI | 2021 | | 2022 | | GA- Target |
|---|---|---|---|---|---|
| | Tower 13 | Tower 14 | Tower 13 | Tower 14 | 2 buildings |
| **Carbon dioxide Emission Reduction (t $CO_2$)** | 49,83 | 27,18 | 27,63 | 20,83 | 252 |
| **Thermal Energy Savings (%)** | 24,65 | 14,72 | 13,1 | 11,1 | 900 (MWh/year) |

In figure 30, the values of **KPI 5 Carbon dioxide Emission Reduction** are shown. In 2021, the values for Tower 13 was 49,83 tonnes/ year while for building 14 the value of KPI 5 was 27,18 tonnes/year. The following year these indicators were reduced with the results being as follows. The value for 2022 of Tower 13 was 27,63 tonnes/year and for Tower 14 was 20,83 tonnes/year.

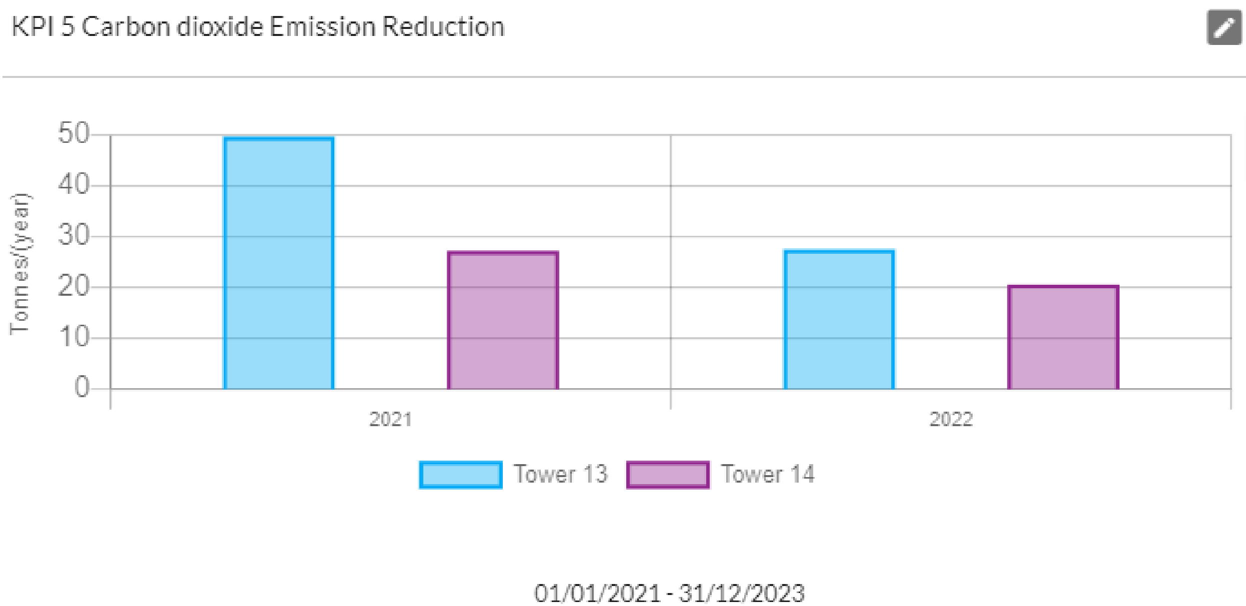


*Figure 47 Carbon dioxide Emission reduction of Buildings in Nice in M1.2*

The following figure shows the calculation results for the **KPI 13 Thermal Energy Savings** of measure 1.2 in Nice for two buildings. As can be shown in this, differences could be observed in these two buildings (Tower 13, Tower 14). While the Thermal Energy Savings in Tower 13 is 24,65% for 2021, in Tower 14 the same measure is 14,72%. In 2022, the value for the same KPI is 13,1% for Tower 13 and 11,1 for tower 14.

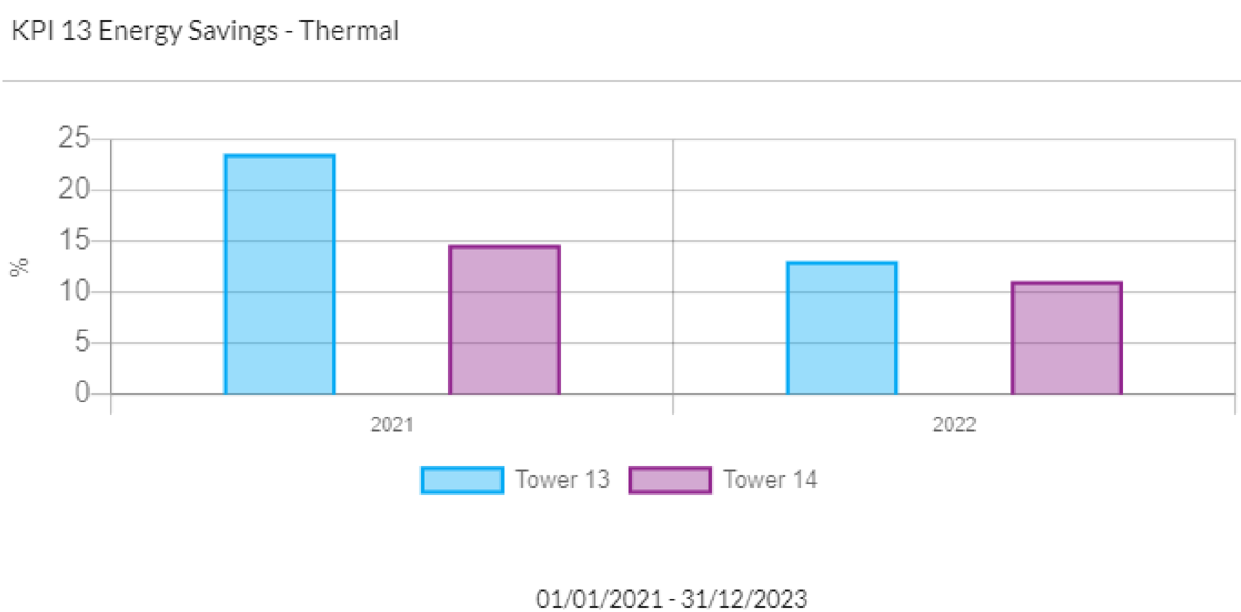


*Figure 48 Thermal Energy Savings of Buildings in Nice in M1.2*

The differences are due to the combinations of the different solutions (1,2,3) in each building.

The solution 1+3 on Tower 14 seems to be more attractive in an environment of social housing with energy savings stabilized around 17%.

The reader could see section 2.4.2 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 1.2.

### 5.1.4 Measure 1.3: Commissioning process from the design to the operation

Measure 1.3 is based on the REPERE service, a specific commissioning procedure developed to ensure that energy-efficient measures are appropriately implemented in refurbished apartment buildings from design through operation. This service is based on the collecting of monitoring and measurement data. Measurements are taken both before and after the refurbishing procedure.

During the IRIS project, the REPERE service was used two buildings, Tower 13 and Tower 14 to help evaluate the energy savings given by measure 1.2 (: Optimization of heating load curve). 136 sensors, measuring the behaviour of the T13 and T14 towers, were installed. They are classified into 10 categories measuring:

- Indoor Air Temperature,
- Outdoor Air Temperature,
- Water Temperature,
- Water Temperature Difference,
- Water Volume Flow,
- Water Volume Index,
- Energy Index,
- Power,
- Solar radiation,
- Outdoor wind speed.

#### *5.1.4.1 Results from Measure 1.3*

This measure used two KPIs: "Data loss prevention" and "Advantages for end-users".

The "Data loss prevention" KPI measures the ratio of lost data to total collected data during the monitoring campaign. The average KPI for all sensors over the 3-year period was 25%, which is higher than the target of less than 2%. The reason for this gap is due to various factors, such as the sensors' sensitivity decreasing over time, the impact of the outdoor environment, and occupant behavior. The KPI value for water temperature sensors is less than 2%, achieving the goal, while the KPI value for indoor air temperature sensors is close to 23%, higher than expected.

The "Advantages for end-users" KPI assesses the benefits of a new smart control system for tenants to adjust their heat supply to their comfort needs. The assessment was carried out through technical and economic evaluations and three surveys for different stakeholders. The results were analyzed based on cost savings, increased comfort, and improved stakeholder relationships. The building owner was uncertain about the impact of the solution on energy bills due to various factors, such as the Covid-19 pandemic and different weather conditions. The building energy manager was more aware of the potential impact, but the results were skewed due to malicious actions by some tenants during the measurement campaign.

In figure 32, the results for **KPI 8 Data loss prevention** are shown. The value for 2020 is 19,6%, while for 2021 is 12,5% and for 2022 is 39,1%.

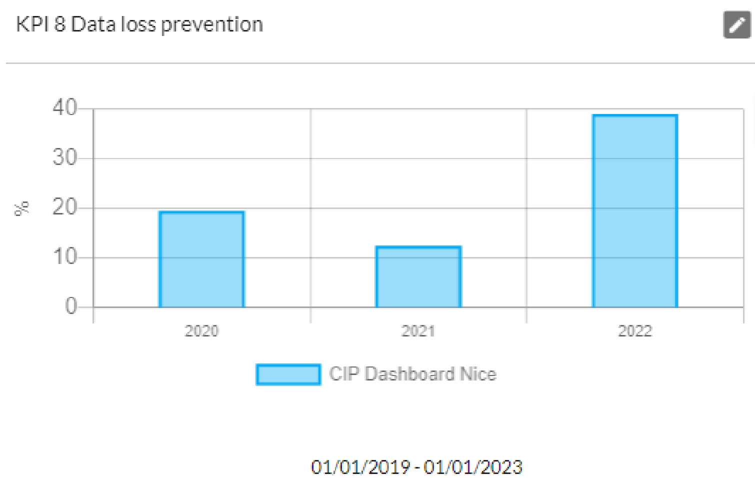


*Figure 49 KPI 8: Data loss prevention of Buildings in Nice for TT1.3*

The results for **KPI 3 Advantages for end-users** are shown in the Figure 50. Based on the survey done, it seems that the majority (80%) believe that *''The project does <u>not offer clear advantages</u> for end users. The technologies or principles applied in the project are not at all beneficial to end users''* while few people (12%) believe that *''The project offers <u>some advantage</u> to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project.''* Finally, only 8% believe that the project offers a high advantage to end users.

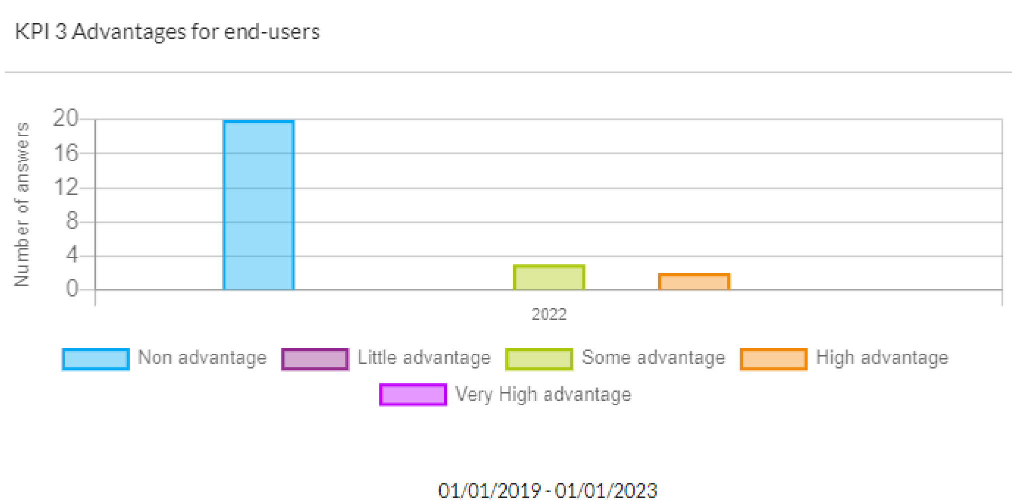


*Figure 50: KPI 3 Advantage for end-users of District in Nice for TT1.3*

The reader could see section 2.4.3 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 1.1.

## 5.2 TT2 Flexible energy management and storage

The results of the demonstration work under TT#2, specifically Measure 2.1, reveal that the Battery Energy Storage System (BESS) market is still in its early stages, with environmental concerns being the primary motivator, and that more awareness and adoption of good practices is required for proper implementation. There have been no significant regulatory improvements, leading partners to conclude that Smart Charging technology is the most promising in the short to medium term for PV and DSM services in the urban tertiary sector. The NEXITY demonstrator (Palazzo building) encountered numerous technical and regulatory challenges, whereas the IMREDD demonstrator successfully implemented all UCs except the 2nd life BESS. Nomenclature and articulation among Measures and Integrated Solutions have been agreed upon by all parties involved.

### 5.2.1 Results for the KPIs for TT2

The table below shows the KPI Storage Capacity Installed result aggregated at the TT2 level.

*Table 29 Annual KPI results for TT1 for Nice*

| KPI | Target | Result | Measures included |
|---|---|---|---|
| **Storage Capacity Installed (kWh)** | 2120 | 315,9 | M2.1 |

The Grant Agreement target for TT2 for Nice

- Energy savings: 1 million kWh/year and 420 tonnes CO2 reduction/year, and
- Storage capacity of 2120 kWh in the 2 demonstration and replication areas, and
- V2G battery storage: 41 000 kWh/year.
- Peak shaving: 3,1 MW
- CO2 reduction/year: 300 tonnes

The exclusion of M2.2 “Smart multi-sourced low temperature district heating with innovative storage solutions” (due to the fact that the responsible partner didn’t provide data) affected many of the KPIs of TT2. The comparison with the GA targets is impossible because some envisioned developments were not funded by the IRIS project.

### 5.2.2 Measure 2.1: Stationary storage deployment in buildings and local electric flexibility management

The goal of Measure 2.1, as stated in the Grant Agreement, was to develop and test a Local Energy Management System (LEMS) on one of two areas: Nice Meridia or Grand Arenas, with a focus on Nice Meridia due to delays in the Grand Arenas posing a risk. An incremental use cases-based approach has been implemented to hedge against permitting risk, asset delivery delays, and regulatory requirements. Expected actions under Measure 2.1 include energy consumption/bill reduction, Demand Side Management (DSM), implementation and management of self-consumption at building and district scales, injection of PV surplus power into the grid, management of EV charging ports, and deployment of a strategy to aggregate flexibilities.

Two Energy Management Systems were installed in IMREDD and NEXITY (Palazzo) buildings. The following figure presents the planned use cases.

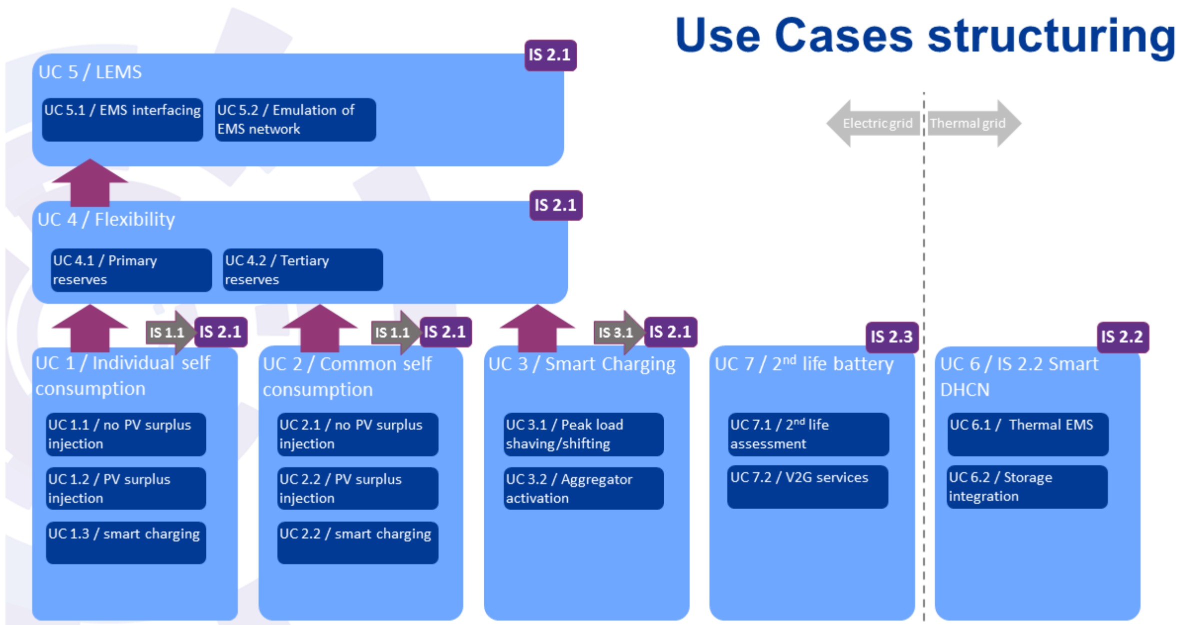


*Figure 51 schematisation of the relation and hierarchies among the chosen Use Cases and sub use cases as by D6.4. The scheme specifies also the relation of UC with other TTs or ISs // Green: UC is started or under operation; Orange: not yet implemented; Red: UC not pursued anymore (source: EDF)*

In terms of expected actions under Measure 1 and their realization, this can be resumed as follows:

1) ***energy consumption/bill reduction, DSM (to reduce peak demand)* => achieved** – both demonstration buildings have an operational system composed of PV+BESS+EMS and operated under different UC as listed above.
2) ***implementation and management of self-consumption at building and district scales* => partially achieved** – no district level self-consumption scheme or energy community has been implemented by the concerned Project Partners within the Project's framework, due to regulatory and financial constraints. UC 5.1 however, enabled to explore the matter, going beyond self-consumption only and integrating flexibility management at a larger pool than the considered district.
3) ***the injection of PV surplus power into the grid properly remunerated* => achieved** – demonstrated in the IMREDD building via AGREGIO and operated under UC 2.2; not achieved in the NEXITY building due to the given explanations.
4) ***the management of EV charging ports (w/o peak shaving for DSO)* => achieved** – demonstrated in the IMREDD building via the implemented EMS under UC 1.3; NEXITY has not implemented any EVCI.

5) ***deployment of a strategy to aggregate flexibilities to be valued on energy markets or through DSOs to release grid constraints and energy storage managements*."** => **achieved** – implementation in IMREDD via the implemented EMS and Market Platform to provide FCR to DA Primary Reserves Market under UC 4.1- waiting for validation of the BM.

#### 5.2.2.1 Results from Measure 2.1

KPIs are designed to measure success with the deployment of storage capacity being a priority (2.1 MWh). Today, less than 0,4 MWh of stationary storage capacity are deployed within Measure 2.1's scope as part of the demonstration project.

The assessment regarding self-consumption is presented in the evaluation of M1.2. Globally speaking, the expected self-consumption rate of the PV+BESS endeavour in the IMREDD demonstrator has been largely underestimated in the design phase, as the experimentation data show a rate of 48% compared to the expected 23%. Whilst the self-consumption rate was slightly overestimated to 88%, while experimentation has achieved 76%. These results must be interpreted carefully, as has been explained before, the system has experienced longer period of down-times of metering and the PV+BESS+EMS.

Battery degradation rate could not be effectively measured due to the replacement of all battery cells, and the second life BESS was not made operational. The IMREDD building has prioritized the Primary Reserves Market for flexibility services due to market conditions, with more information on the indicator available at M66.

*Table 30: KPI results for Measure 2.1 Stationary storage deployment in buildings and local electric flexibility management*

| KPI | 2021 | | 2022 | | GA- Target |
|---|---|---|---|---|---|
| | IMREDD | Palazzo | IMREDD | Palazzo | 2 Buildings |
| **Reduced energy cost for customers (%)** | - | - | 42,1 | - | - |
| **Storage Capacity Installed (kWh)** | 223,6 | 92,3 | 223,6 | 92,3 | 2120 |

Figure 52 shows the **KPI 34 Reduced energy cost for costumers** for IMREDD for 2022. The value for this KPI is 42,1%. For Palazzo this KPI has not been calculated.

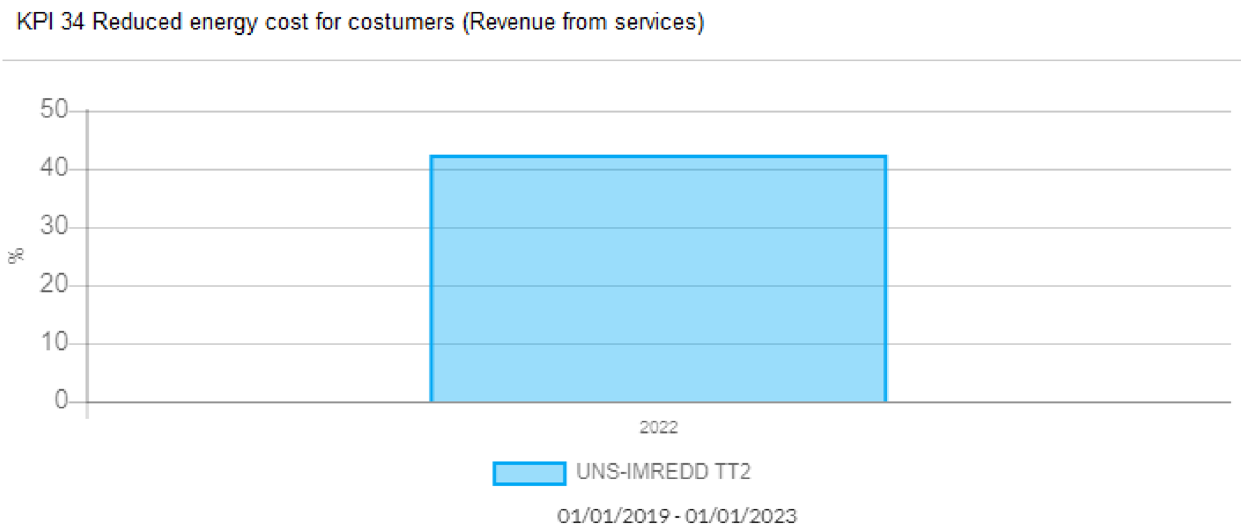


*Figure 52: KPI 34: Revenue from services of IMREDD in Nice for TT2.1*

Another KPI calculated in M2.1 is the **KPI 42 Storage Capacity Installed** for two buildings. The values are stable for 2021 and 2022 for both IMREDD and Palazzo. The value for Palazzo is 92,3KWh and for IMREDD 223,6 KWh.

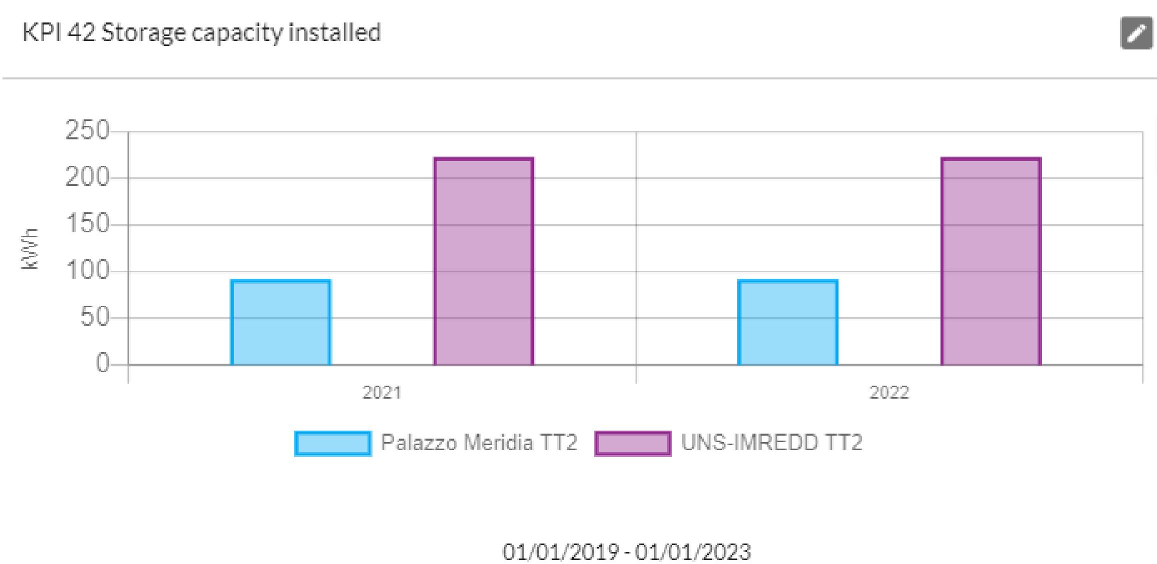


*Figure 53: KPI 42 Storage capacity Installed of buildings in Nice for M2.1*

The reader could see section 3.4.1 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 2.1.

## 5.3 TT3 Intelligent mobility solution

The IRIS project's TT3 demonstration activities consist of two Measures, M3.1 “Smart Charging” and M3.2 Free floating EV car sharing system. M3.1 addresses the deployment of smart charging infrastructure to optimize the balance between EV charging needs and energy service availability, which could generate a new revenue stream for Electric Vehicle Charging Infrastructure (EVCI) operators and owners. M3.2 focuses on fleet management of public shared EVs to provide a flexible solution for daily city trips, in line with Nice City's goal of promoting environmentally friendly solutions. The feasibility of various sites has been determined, and two demonstration sites for the V1G Smart Charging and one for V2G Smart Charging have been chosen.

The Grant Agreement Targets for TT3 for Nice

- Number of V2G: 2000,
- Number of EV charging stations: 1000,
- Number of Free Floating subscribers (resident, workers and long stay tourists): 100.000.
- 1,829 ton $CO_2$ reduction/year
- NO2 reduction/year: 7 %
- PM10 reduction/year: 6%
- PM2,5 reduction/year: 6%
- 15 300 000 km yearly travelled with V2G cars
- Peak shaving: 3,1 MW
- CO2 reduction/year: 300 tonnes

The following activities will prepare the transition from AUTOBLEUE, launched in 2011,

The suspension of the AUTOBLEUE service a few months after the start of the IRIS project, forced Nice Metropole to scale down the implementation of the Free-Floating project in the city and instead implemented withing the Municipality. The much smaller number of cars and charging stations (20) did not allow the achievement of the impact expected at the time of writing the proposal.

### 5.3.1 Measure 3.1: Smart Charging

LH city Nice is one of the first public authorities in France to be able to test V1G and/or V2G smart charging services on their EVCI and EV fleet. The work in M1.3 consisted of following actions:

- provision and operation of the needed on-site equipment (automation system – local energy management system for 2 sites and 17 charging points and additional ICT equipment/services),
- monitoring of the charging behaviours and define, develop and implement control strategies for activating flexibility for the EVCI,
- develop the needed algorithm to calculate charging schedules based on mobility needs expressed by VULOG. A heuristic approach has already been specified by IZIVIA and has been tested based on available data,
- develop the needed API(s) for the interfacing of IZIVIA’s, DREEV’s and VULOG’s platforms and

- collect information about V2G EVCI implemented with MNCA; ensure an application to enable vehicle reservation and charging preference setting for end-users.

#### 5.3.1.1 Results from Measure 3.1

- The progress of M3.1 and its expected actions have been summarized as follows:
- Partially achieved in developing and testing positioning tools and rapid charge operation, with 2 Smart Charging tools in place for the private fleet of MNCA.
- Developing a dynamic charge plan and car/charger interface has also been partially achieved, with a V1G Smart Charging test campaign on the brink of starting.

KPIs for the demonstration activity under Measure 3.1 have been chosen and include peak load reduction, installed storage capacity, supervised fast charging poles, and increased system flexibility.

- Peak load reduction will be computed through the Smart Charging platform, tracking the delta between realized and theoretical charging cycles.
- The installed storage capacity will be 1 MWh, based on 20 cars with an average EV battery capacity of 50 kWh.
- There will be 20 supervised fast charging poles, divided into 17 V1G and 3 V2G poles across 3 sites.
- Increased system flexibility will also be tracked through the Smart Charging platform, with statistics on energy volumes and power displacement.

The following graphs present the KPIs calculated in M3.1 in Nice.

Figure 54 presents **KPI 26 Number of e-charging stations** for Nice District in TT3. As can be seen, the number of e-charging in the district of Nice is 20.

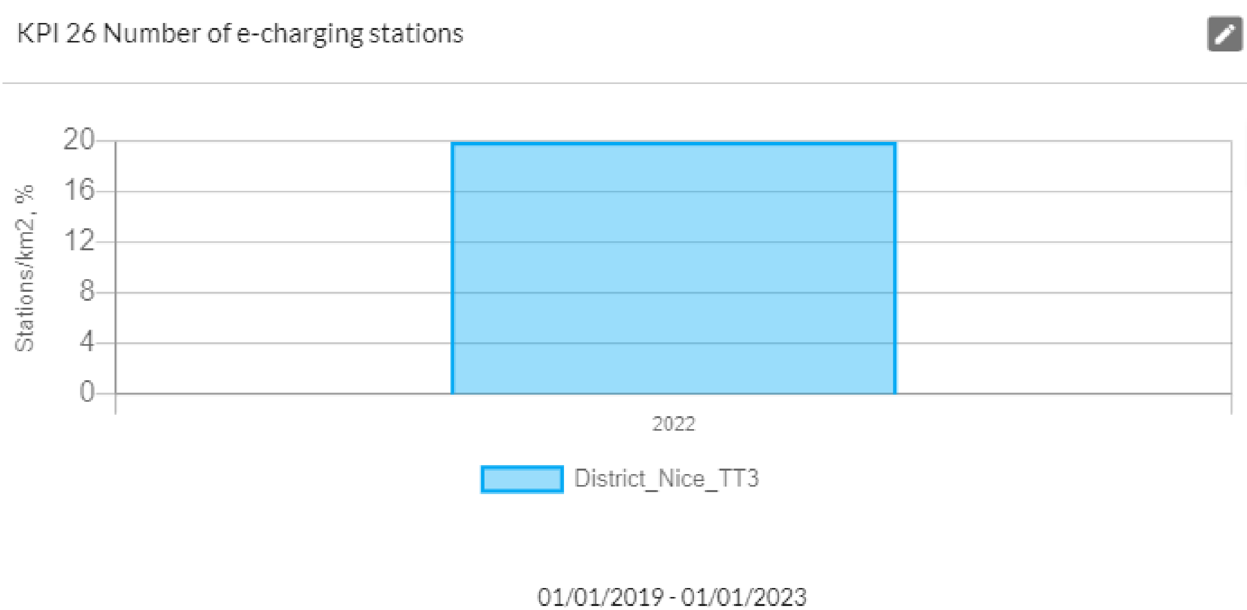


*Figure 54: KPI 26 Number of e-charging stations of District in Nice*

Figure 55 depicts the **KPI42 Storage capacity** for TT3 in Nice. The value is 150 KWh.

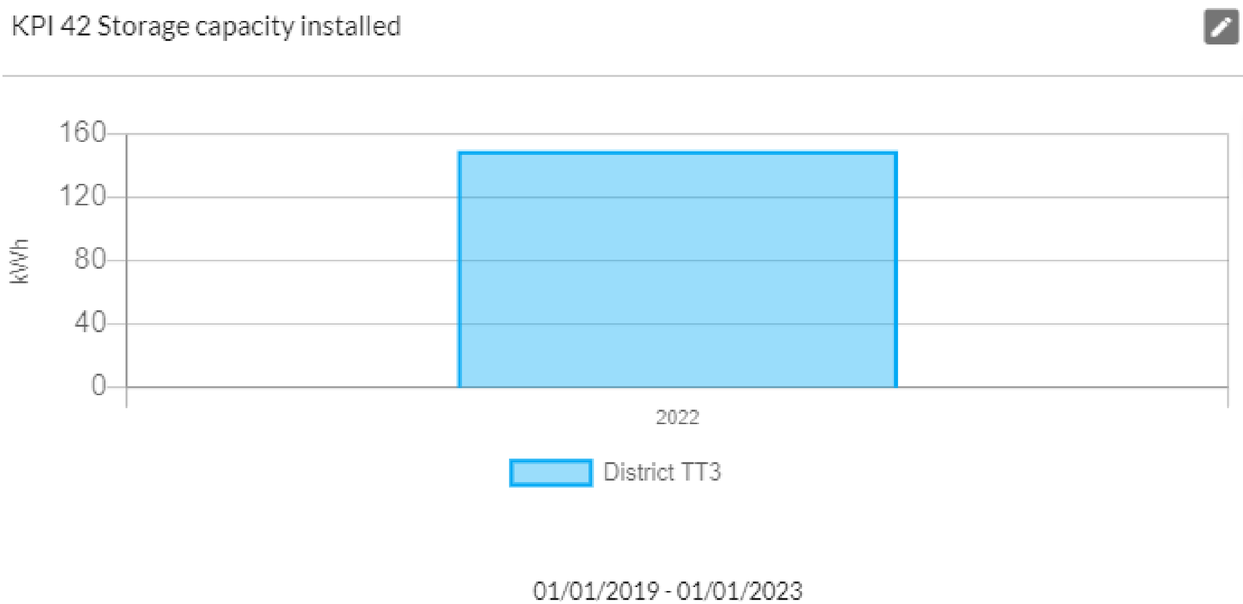


*Figure 55: KPI 42 Storage Capacity installed of District in Nice in TT3*

The reader could see section 4.4.1 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 3.1.

## 5.3.2 Measure 3.2: Free floating Electric Vehicle car sharing system

The VULOG system is interconnected with the IZIVIA and DREEV systems and can effectively manage the energy needs that are associated with reservations made by end users ensuring the accurate optimization and planning of the right battery state of charge. However, the integration process is complicated due to the heterogeneity of the IZIVIA and DREEV solutions. The data required by both systems differs significantly, and the authorization protocols are also not the same. A convergence could simplify the integration process. It is recommended that “standard” approaches like OAuth for the authorization protocol or a common API should be considered. Identifying the core features and data could also help streamline the integration process.

To ensure the optimal battery charge, challenges arise due to the limited data the VULOG system has, as it only has access to the reservation duration. As a result, estimating the optimal battery charge is challenging as it will depend on the user's chosen route. Gathering the distance from the end user is a recommended solution to estimate the optimal battery charge.

To optimize the energy requirements related to reservations made by end-users, the VULOG system is linked with the IZIVIA and DREEV systems. Integration complexity arises due to the differing data requirements and authorization protocols. A convergence strategy or “standard” approaches like OAuth or a common API may facilitate the integration process. Identifying core features and data is also important.

The estimation of the optimal battery charge poses a challenge due to the limited data that the VULOG system has. The system solely relies on the reservation duration, and the actual battery charge will depend on the user's chosen route. End-users must be asked about the distance of their chosen route to ensure an accurate estimate.

### 5.3.2.1 Results from Measure 3.2

The following figures show the calculation results of different KPIs of TT3, Measure 3.2 in Nice. The initial image displays the cumulative distance, measured in kilometers, traveled by electric vehicles utilized in e-sharing programs during the years 2020, 2021, and 2022. This KPI serves as an indicator of the growth and sustainability of the e-car sharing systems, providing insights into the impact of the technology on transportation and the environment.

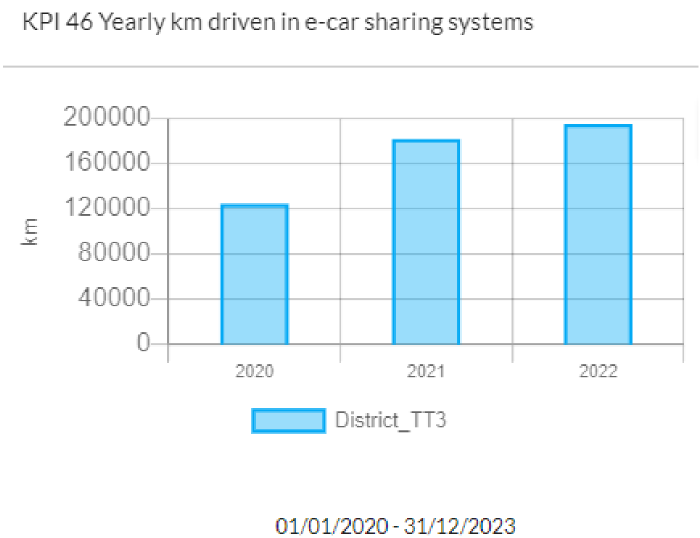


*Figure 56: Yearly km driven in e-car sharing systems of Buildings in Nice for TT3*

The following image exhibits a set of bar plots that demonstrate the progression of the proportion of individuals accessing vehicle sharing solutions in a particular municipality throughout the years 2020, 2021, and 2022. Each bar represents the percentage of individuals who have utilized the service during each respective year. The visualization provides a clear indication of the upward trend in usage and its potential for growth, enabling stakeholders to assess the effectiveness and viability of the vehicle sharing program for the municipality.

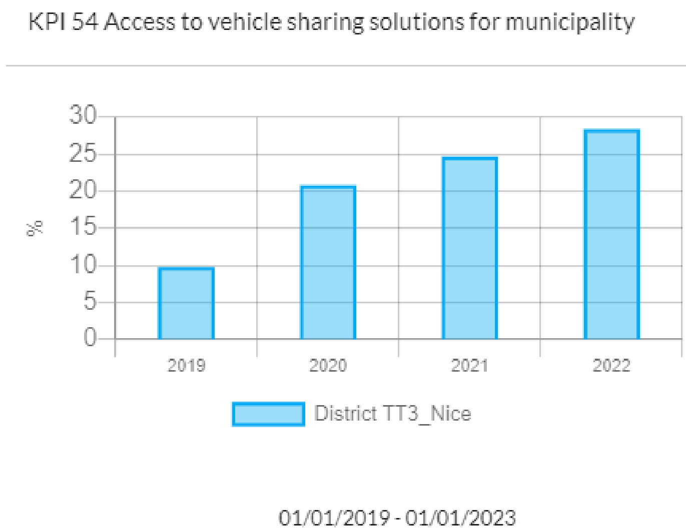


*Figure 57: Access to vehicle sharing solutions for municipality of Buildings in Nice for TT3*

The following bar plot illustrates the upward trend in the number of trips taken within a free-floating car sharing system during the years 2020, 2021, and 2022. Each bar represents the total number of trips taken within the respective year, with a steady increase observed across each timeframe. This visual aid provides valuable insights into the growing demand for the car sharing service and can inform decisions regarding the optimization and expansion of the program.

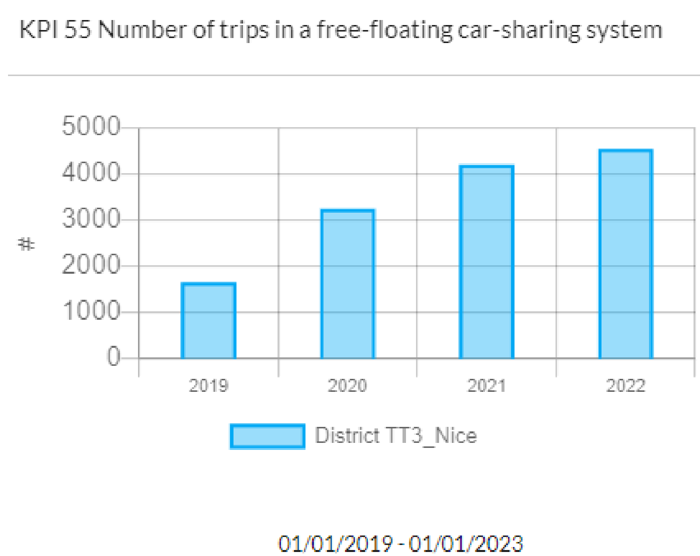


*Figure 58: Number of trips in a free-floating car-sharing system of Buildings in Nice for TT3*

The reader could see section 4.4.2 of the deliverable D6.9[4] for a detailed analysis of the expected impact and KPIs of Measure 3.2.

## 5.4 TT4 Digital transformation and services

In TT4 the first measure aims to enhance air quality data and encourage citizen participation. Air quality data has been collected using sensors and stations, while traffic data gathered from the CIP and other sources. The second measure involves creating a dashboard that includes digital models of the IMREDD building and building data available on the CIP. The third measure involves developing a Smart Charging management platform that directly communicates with the energy aggregator platform, which will trade flexibility services on the energy market. Lastly, the fourth measure involves the creation of a new tool, the SMART CITY INNOVATION CENTER (SCIC), which enables real-time monitoring of the impact of different energy scenarios on buildings. It is worth noting that these measures were initially referred to as IS-4 and are now organized into four separate categories: Measure 4.1 for sensors data collection in air quality, Measure 4.2 for BIM/CIM data display, Measure 4.3 for data control and monitoring for Smart e-mobility, and Measure 4.4 for services for grid flexibility. Although all measures have commenced, some are still pending.

The table below shows the KPIs result aggregated at the TT4 level.

*Table 31 Aggregated KPI results for TT4 for Nice*

| KPI | Target | Results |
|---|---|---|
| **Total number of connected urban objects in the city information Platform** | 100.000 | 124 objects |
| **Data that uses DCAT standards** | 100% | 100% |

The Grant Agreement targets:

- Implementation of standards such as FIWARE and CitySDK when relevant in the CIP model
- Number of connected urban objects: >100.000
- Support of mobile connected objects: connectivity with city fleet vehicles and city public transportation (tramways)
- Development of applications using data retrieved simultaneously from the three CIPs of the LH cities Nice, Utrecht and Gothenburg.
- Apps developed & launched: 5

As the implementation of a city wide 5G network was postponed due to Huawei's regulation problems in EU, the number of connected objects is smaller.

### 5.4.1 Measure 4.1 Sensors data collection in air quality

In order to conduct experimentation and research, IMREDD has installed two external air quality sensors in their building. One sensor is positioned on the roof while the other is located near heavy traffic. These sensors have the ability to measure an array of factors such as temperature, humidity, atmospheric pressure, VOC, PM1- PM2,5- PM10, NO2 and O3.

The data that is collected from IMREDD's sensors combined with data already accumulated by the MNCA to improve the awareness of citizens living in the Meridia district. Furthermore, IMREDD also monitors and makes available the air quality levels within the building itself.

In the future, data from air quality measurements within the building could be utilized to ascertain the level of pollution outside the structure. This could serve as a new indicator for determining the well-being of citizens.

At the city level the AZUR forecast air quality platform, developed by AtmoSud, provides information at very high resolution. This platform already provides daily forecasts for several pollutants: $PM_{10}$, $PM_{2.5}$, $NO_2$ and $O_3$. IRIS project allowed to develop the hourly module and to provide a near “real-time” air quality information using AZUR methodology.  The Atmosud monitoring network (originally consisted by 4 stations: Nice Airport, Nice Arson, Nice Magnan and Nice NCA port) has been updated with micro sensors over the demonstration area and to use real-time traffic data. 20 microsensors have been installed in the Nice metropole (7 have been bought because of IRIS project). AtmoSud had worked with CIP administrators in order to push daily AZUR on the CIP. This joint work helps to collect the CIP’s traffic data as well.

By factoring in the existing pollution levels, traffic proximity, and accuracy of the micro sensors, it becomes feasible to generate a chart displaying the concentrations of $NO_2$ and particles for every hour of the day. At present, Azur runs continuously and is entirely operational. The updated website for www.atmosud.org has been launched, including logos from IRIS and Europe. Users can access an animation of the previous and forthcoming 24 hours.

### 5.4.2 Measure 4.2 BIM/CIM data display

The objective of measure 2 was to exhibit the effectiveness of the multi-scale BIM and its ability to combine current and relevant data from the CIP at the building and urban level. The project has three distinct stages, which begin with the creation of a 3D model of the IMREDD building. In the subsequent stage, live data from different equipment are exhibited. The IMREDD engineering team has already accomplished the first two steps and passed them to IRIS partners for further development.

### 5.4.3 Measure 4.3 Data control and monitoring for Smart e-mobility

This action pertains to the demonstration effort known as TT#3 in Nice, which aims to construct and merge systems that use both electric vehicle charging infrastructure (EVCIs) and electric car-sharing fleets within a city. The goal is to implement a "Smart Charging" system that can manage charging schedules efficiently and test a variety of related scenarios. NCA's private EVCI network is now overseen by an EDF partner's supervision platform, which interacts with the Smart Charging platform to develop and manage a charging plan that aligns with the operational needs of the e-fleet's car-sharing and adheres to energy aggregator platform directions to provide flexible energy services like peak shaving, shifting, and tertiary energy reserves.

### 5.4.4 Measure 4.4 Services for grid flexibility

IMREDD collects local energy data from various sources such as lithium-ion batteries, photovoltaic panels, and EV charging infrastructure. These data are then fed into a platform called CIP, which facilitates the creation of a new tool called SMART CITY INNOVATION CENT (SCIC). The SCIC allows real-time monitoring of the impact of different energy scenarios on the building and also serves as an educational tool to raise energy awareness among stakeholders. To obtain these data, Node Red flows are used to push data from the energy management system, which primarily gathers data from IMREDD energy devices. The data is made available through EDF S&F API's. While some real-time dashboards have already been created, the development of further dashboards and the exploration of new scenarios by analyzing combined data is still in progress.

### 5.4.5 Results of the KPIs for TT4

In the following figure the bar plot illustrates a comparison between the number of connected urban objects on city innovation platforms for the years 2021 and 2022. The visualization clearly displays a larger number of connected objects for the year 2022, with a distinct difference in the values between the two years. This comparison provides valuable insights into the increasing adoption and integration of connected technology within urban environments, highlighting the potential for continued innovation and development in this field.

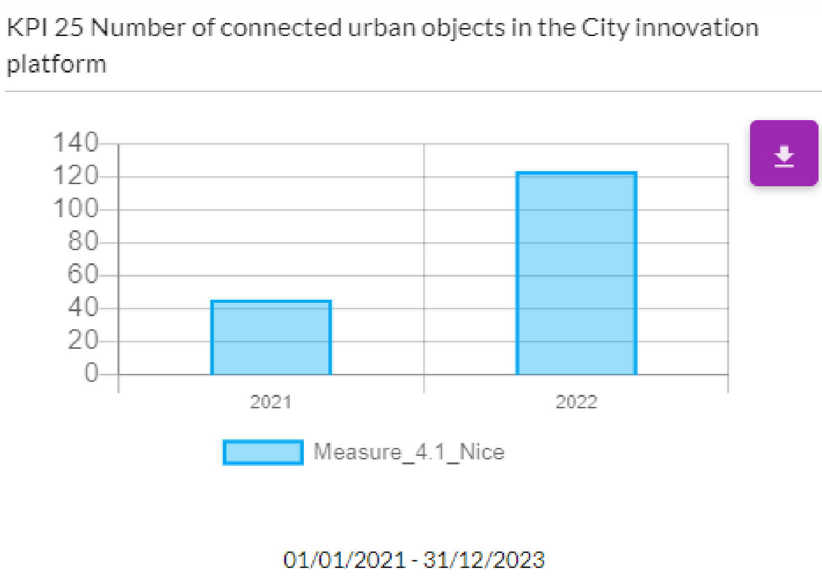


*Figure 59: Number of connected urban objects in the City innovation platform of Buildings in Nice for TT4*

The bar plot demonstrates the percentage of quality open data, with both the years 2021 and 2022 displaying 100%. This visualization indicates that the quality of the open data remains consistently high throughout the given period, reflecting the commitment of data providers to ensure the accuracy and reliability of the information they share with the public.

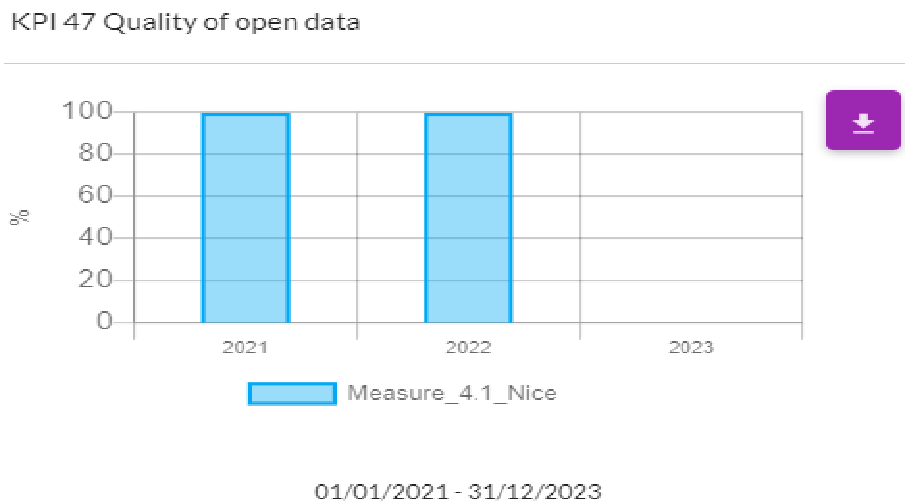


*Figure 60: Quality of open data of Buildings in Nice for TT4*

## 5.5 TT5 Citizen engagement and co-creation

Nice LH has implemented technical and citizen engagement measures to drive the Nice Eco Valley district towards becoming a Near Zero Energy district. The citizen engagement actions include public awareness campaigns on air quality and energy, as well as individual engagement through IoT invoices. These measures will be implemented in different areas, with the renovation program in Les Moulins being a key component. The program aims to demonstrate the feasibility of low energy renovation processes for buildings and is planned over 12 years, as the first step towards a larger development in the district to be completed within 20 years.

The Grant Agreement targets for TT5 Citizen engagement and co-creation in Nice

- Feedback mechanism for households motivating them to save energy with 10%, to shift 10% of their energy consumption to off-peak periods.
- Active engagement of 500+ households in the above-mentioned demonstration activities.

### 5.5.1 Measure 5.1: Public awareness campaign Air Quality:

The collaboration with university students resulted in a process of co-creation to promote citizen commitment towards air quality protection. Due to COVID-19 and lockdown, implementing actions presented difficulties. The IRIS project's Masters internships involved two groups of students who created reports and generated many new ideas for project valorization. Over 100 students participated in a survey on behavior change.

At the city level, two surveys conducted by IFOP were used to evaluate the impact of the RESPIRE campaign. The surveys included a representative sample of 608 people from the municipality of Nice aged 18+. The majority of employed workers (37%) travel more than 10 km from home, mainly using private gasoline cars (43%).

62% of residents believed road traffic was the main source of pollution in the Metropolis. In the event of degraded air quality, seven out of ten respondents said they would adapt their modes of transport by choosing soft mobility. 52% of respondents claimed they were well-informed about air quality, with weather on television being the preferred channel of information. The "Nice breathes" campaign had a high approval rate but only pushed 31% of respondents to change their daily behavior.

#### 5.5.1.1 Results from measure 5.1

**KPI 19 Increased environmental awareness** is shown in the figure 38. As can easily be seen, the majority of the people answered that opportunities to increase environmental awareness were sufficiently taken into account in the project communication while an another large percentage characterized this effort as ''excellent ''

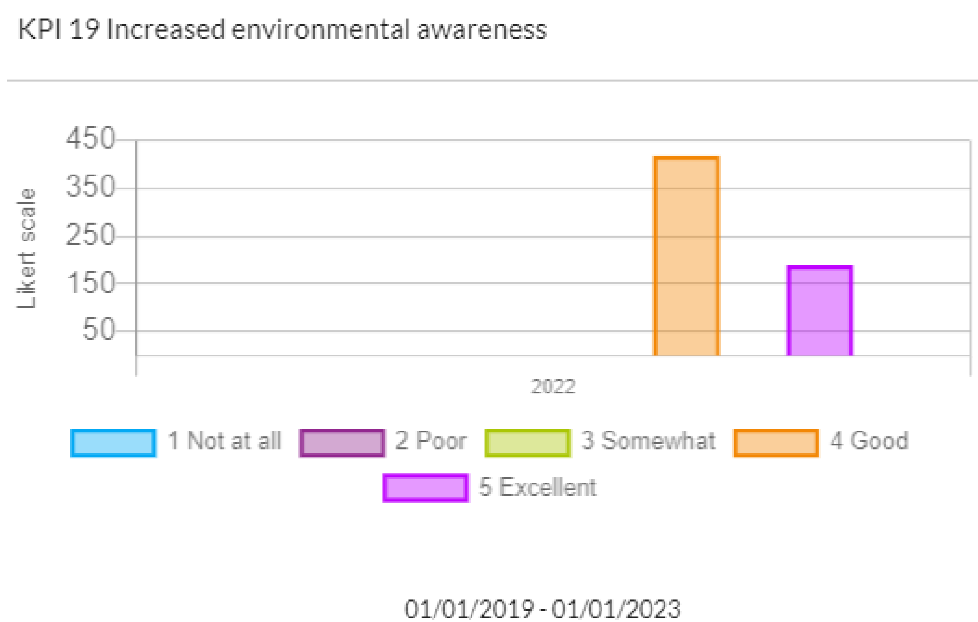


*Figure 61 KPI 19: Increased environmental awareness of Buildings in Nice for TT5.1*

### 5.5.2 Measure 5.2: Public awareness campaign Energy – School & Collège; Youth & Family:

#### 5.5.2.1 Heating Flyer

The eco-conscious individual acknowledges their responsibility to the planet that provides for their survival, promising them certain rights and obligations toward its care. However, in neighborhoods marked by insecurity, unemployment, and instability, environmental concerns are typically not the preoccupation of young people. The youth felt they lacked agency and therefore a part to play. This booklet was created to alter this perception and demonstrate to them that they could participate in enhancing the state of the environment in their neighbourhoods. To close the communication gap within the neighbourhood between residents and energy institutions, they devised the booklet. The content offered answers from the organizations to queries posed by neighbourhood residents, providing the young people with an opportunity to be a link between residents and institutions. They began to realise their potential as small eco-citizens as they observed their booklet's impact on an estimated 2417 households, with more than 2400 individuals reading their energy-saving suggestions. They discovered that even individual actions could have a wider collective impact, an essential realisation.

#### 5.5.2.2 Energy savings Poster

This double awareness-raising strategy of sensitizing parents on the one hand and youngsters on the other has shown results. Mothers informed me during the sessions that their children called them to order when they left the television on without viewing it or when they left the water running for no reason. Because various workshops were set up at the request of the residents, such as the energy voucher workshops, food waste, or ecogestures to be applied during the end-of-year celebrations, these workshops have had an impact and have functioned successfully.

Participants also contributed to the creation of new seminars by suggesting their own topics.

#### 5.5.2.3 Results from measure 5.2

**KPI 17 Increased awareness of energy usage** is depicted in the next figure. This indicator assesses the extent to which the project has used opportunities for increasing energy awareness and educating about sustainability and the environment. Regarding a survey done in 2020, it can be seen that many people claim that opportunities to increase awareness of energy usage were rated as ''excellent'' and '' Good'' while a small amount of the people believe that increase awareness of energy usage were ''somewhat'' and ''poor''. The survey conducted the following year (2021) showed similar results

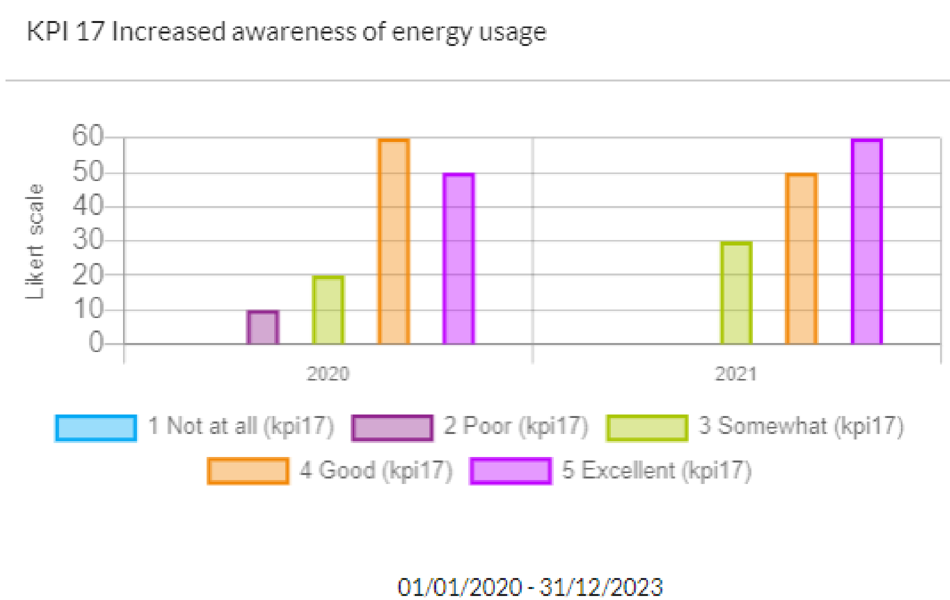


*Figure 62 Results of KPI 17 Increased awareness of energy usage for M5.2 in Nice*

# 6 Results Gothenburg

This chapter presents the results of LHC Gothenburg, categorized by transition track (TT) and measure (M). While the measures are briefly described, the focus of the results is on the KPIs and the set targets. For more detailed information on the measures, results, and lessons learned by the partners, please refer to D7.9 *Final report on Gothenburg lighthouse demonstration activities*.

Unfortunately, three measures have not been included in the evaluation and the reason for this is summarized in Table 4, section 1.5.3.

The main impact targets stated in the Grant Agreement for LHC Gothenburg are summarized in Table 32 together with the outcome and the buildings and measures that contributes. Despite implementing and demonstrating most of the intended measures, the housing association Viva's results do not meet the set impact targets. However, the free cooling from Brf Viva to the adjacent building is not included in the below results as it is not yet operational as intended. If it were, it would contribute to meeting the energy-related targets. Furthermore, the building has a slightly higher energy demand than anticipated, and the partners have acknowledged that the set targets were very ambitious. It also seems that the installed PV capacity target was set too high since it was barely met, even though the installed capacity was increased from the initial plan. Regarding the reduction in driven kilometers, the target was not achieved, and part of the reason is due to one of the two measures that would contribute to it not being used as expected because of the Covid pandemic.

*Table 32: Main impact targets for LHC Gothenburg as stated in the Grant Agreement.*

| | GA-Target | Results | Related building/ measures |
|---|---|---|---|
| **Sub-district energy consumption** | <24 kWh/m2/y | 54,5-76 kWh/m2/y | Brf Viva / |
| **Peak power shaving** | >80% reduction in peak power compared to control | 8-37 % | AWL/ M2.1 |
| **Net energy surplus on annual basis** | >10 MWh/y | -365 – -77 MWh/y | Brf Viva / M1.1, M1.2, M1.3 and M1.5 |
| **Energy savings** | 67 kWh/m2/y, or totally 1,5 GWh/y energy saving compared to average Swedish buildings. | BBR21 – Heated with other than electricity heated:<br>14-35,5 kWh/m2/y<br>0,15-0,38 GWh/y<br><br>BBR21 -Electricity heated:<br>-21 – 0,5 kWh/m2/y<br>-0,23 – 0,005 GWh/y | Brf Viva/M1.1, M1.2, M1.3, M1.5. |
| **Integrated PV power** | 420 kW | 171 kW (Viva) + 46,5 kW (HSB living lab)<br>170 kW (AWL) = 387,5 | Brf Viva/ M1.1<br>HSB living lab / M1.7<br>AWL/ M2.1 |
| **Reduction in driven km by tenants and employees in the district [km/year]** | 1 360 500 | 507 870<br>for 3.1 | Brf Viva /3.1 and 3.2 |

Although energy savings and peak power shaving are considered KPIs, they are only included in the table above and not aggregated to the TT or LHC level for clarity since they only involve data from one building. The aggregation to LHC level is only done with three KPIs that are shown in Table 33 and only one of them had a target set in the Grant Agreement.

*Table 33: Aggregated KPI results for LHC Gothenburg based on the years with full measurement data and standard IRIS-SE emission factor for electricity.*

| KPI | GA target | Results | Included measures |
|---|---|---|---|
| **Carbon dioxide Emission Reduction [tonnes $CO_2$e/year]** | | ~124 | M1.1, M1.2, M1.7 and M2.1 |
| **Increase in local renewable energy production (electrical) [MWh/year]** | | ~290 | M1.1, M1.7 and M2.1 |
| **Reduction in driven km by tenants and employees in the district [km/year]** | 1 360 500 | 507 870 for 3.1 | M3.1 and M3.2 |

For consistency, the KPI Carbon dioxide Emission Reduction was established for M2.1 and added to the aggregation at LHC level, even though it is not used at measure level. The motivation was that the other two measures that include PV-production have been evaluated with this KPI.

Table 34 summarizes the main assumptions related to the two sets of emission factors used when aggregating the KPI Carbon dioxide Emission Reduction to LHC level. The first set is the IRIS-SE, which uses an annual average value for the grid based on production and a number for conventional cars. The second set is the more updated Recent, which uses annual factors for the grid electricity, taking import into account, as well as annual emissions from the conventional car fleet and updated LCA emissions associated with electric vehicles.

*Table 34: Summary of the two sets of emission factors used to estimate the emission reduction from measures and the associated assumptions.*

| CO2 emission factors | IRIS - SE | Recent | | | | Comment |
|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2022 | |
| **Grid emission [tonnes/MWh]** | 0,023 | 0,032 | 0,025 | 0,031 | 0,025 | Annual average |
| **Renewable electricity [tonnes/MWh]** | 0 | 0 | | | | PV-production |
| **Sustainable transport [tonne/km]** | 5,3E-05 | 5,2E-05 | | | | |
| **Conventional cars [tonne/km]** | 1,63E-04 | 1,53E-04 | 1,5E-04 | 1,43E-04 | 1,2E-04 | For the Recent emission factors are taken for each year |

The emission reduction results for the two sets of emission factors are presented in Figure 63, which displays the emission reductions achieved by each type of measure for the two years where complete data for all measures were available. The figure shows that intelligent mobility solutions account for the largest share of emission reduction, approximately 70%, followed by renewable heat production at around 25%. The contribution from renewable electricity production is greater when using the Recent emission factors, as they have slightly higher emissions associated with grid electricity that the PV electricity replaces. However, it is important to note that LCA emissions related to PV production are estimated to be in the same order of magnitude as emissions related to the Swedish grid so including them would influence the results. Since the assumptions influence the results greatly a sensitivity analysis has been made on the emission factors related to the grid, see Chapter 9.

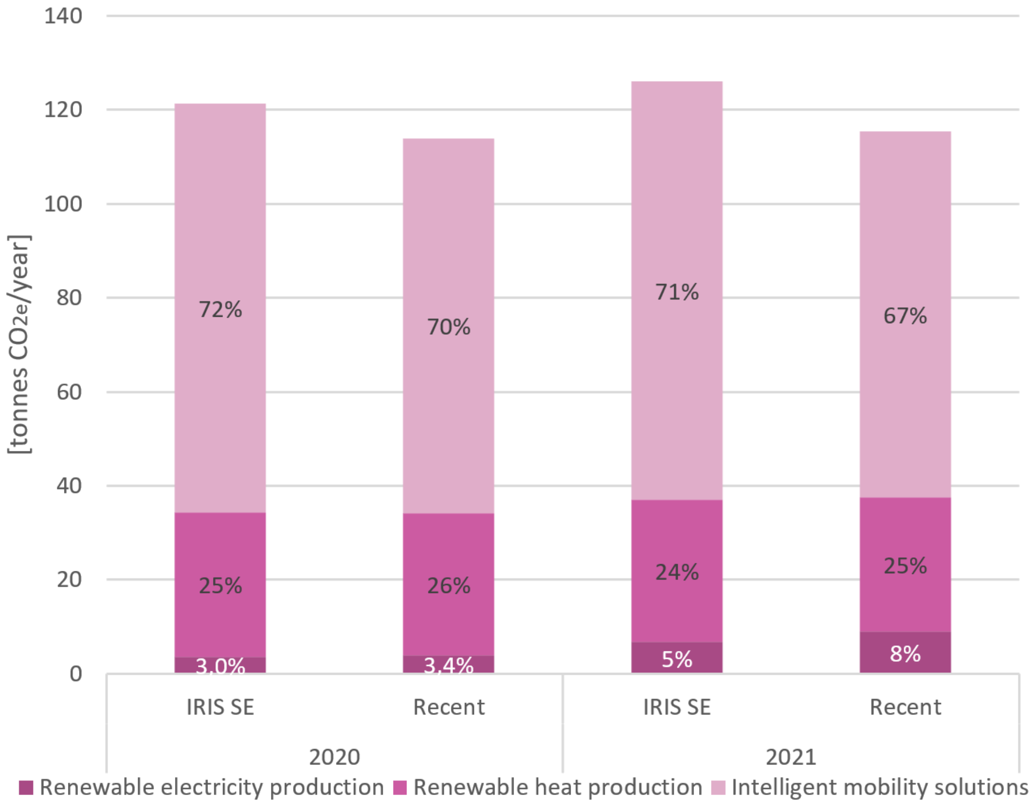


*Figure 63: Results for KPI 5: Carbon dioxide Emission Reduction on LHC level with contribution from the different types of measures and established using IRIS SE and Recent emission factors.*

# 6.1 TT1 Renewables and energy positive districts

The objective of this transition track has been to demonstrate a Positive Energy District (PED), a district that annually produces more electricity and heat than it consumes. To achieve this, a combination of energy-saving measures, energy storages, renewable energy sources and energy management systems have been designed in the housing cooperative Viva, all of which are implemented and in use. In addition, the transition track involves an evaluation of Building Integrated Photo Voltaics implemented in HSB Living Lab.

Measures in this transition track are implemented in two buildings located next to Chalmers campus Johanneberg, namely Brf Viva and HSB Living Lab, see figure below.


*Figure 64: The locations of HSB Living Lab and Brf Viva.*

HSB Living Lab is the home for some 30 students, and at the same time a research, test and demonstration environment for e.g. energy efficiency, resource optimization, electricity generation, laundry habits, cooking possibilities and so on. Much was already achieved when IRIS begun, albeit only shortly before, and so the measure included is a retrofit of façade-integrated photovoltaic panels, called measure 1.7 and in addition a measure included in TT 5 (M5.7).

*Brf Viva* is a housing association developed by Riksbyggen with a total of 132 apartments. Viva aims at being the most innovative and sustainable housing project in the country and an array of integrated solutions aiming at more renewable electricity generation, more sustainable mobility, peak power shaving and increased flexibility are realized in Viva and included in IRIS as Measures 1.1-1.6, 2.4 and 3.1.

### 6.1.1 Results of the KPIs for TT1.

*Table 35: Aggregated annual KPI results for TT1 based on the two years of full measurement data and standard IRIS-SE emission factors.*

| KPI | Target | Results | Measures included |
|---|---|---|---|
| **Carbon dioxide Emission Reduction [tonnes $CO_2$e/year]** | 43* | ~33,7 | M1.1, M1.2 and M1.7 |
| **Degree of energy self-supply by RES- electrical** | | 17% | M1.1 and M1.7 |

**Note that this target is a summary of the partner targets and not included in the Grant agreement.*

The measures in this TT are evaluated using several different KPIs, see Figure 24, but only two of them are relevant and possible to aggregate to the TT level. The results for these two KPIs are shown in Table 35, together with a list of the measures that contribute to the aggregated value. Neither of these KPIs has a target set in the Grant Agreement but the partners had set targets on the emission reduction, and these have been added together in the table above. However, these individual targets are based on different assumptions when it comes to the emissions associated with grid electricity. Moreover, M1.3 has been excluded from the aggregation since the data collected from this measure does not accurately represent its intended operation.

The KPI Carbon dioxide emission was evaluated by considering not only the IRIS standard emission factor but also the emission factor provided by partners and an updated emission factor called "Recent". More information on the Recent emission factor can be found under Chapter 7 – IRIS results. The emission factors were aggregated for the two years with complete measurement data, and the results are illustrated in Figure 65. In this figure the emission reduction is also divided into the type of measures that achieves the reduction, renewable electricity, or renewable heat production.

The partner has provided a higher emission factor for grid electricity compared to the IRIS Standard and Recent factors. When using the IRIS-SE and Recent factors, renewable electricity accounts for only about 10% of the emission reduction. However, when using the partner values, this contribution increases both in terms of absolute numbers and the share of the reduction, reaching ~40%. It should be noted, however, that the use of partner values results in higher emissions associated with heat production via heat pumps, leading to an overall emission reduction that is approximately 65% lower. The impact of using different emission factors is further explored in the sensitivity analysis presented in chapter 0.

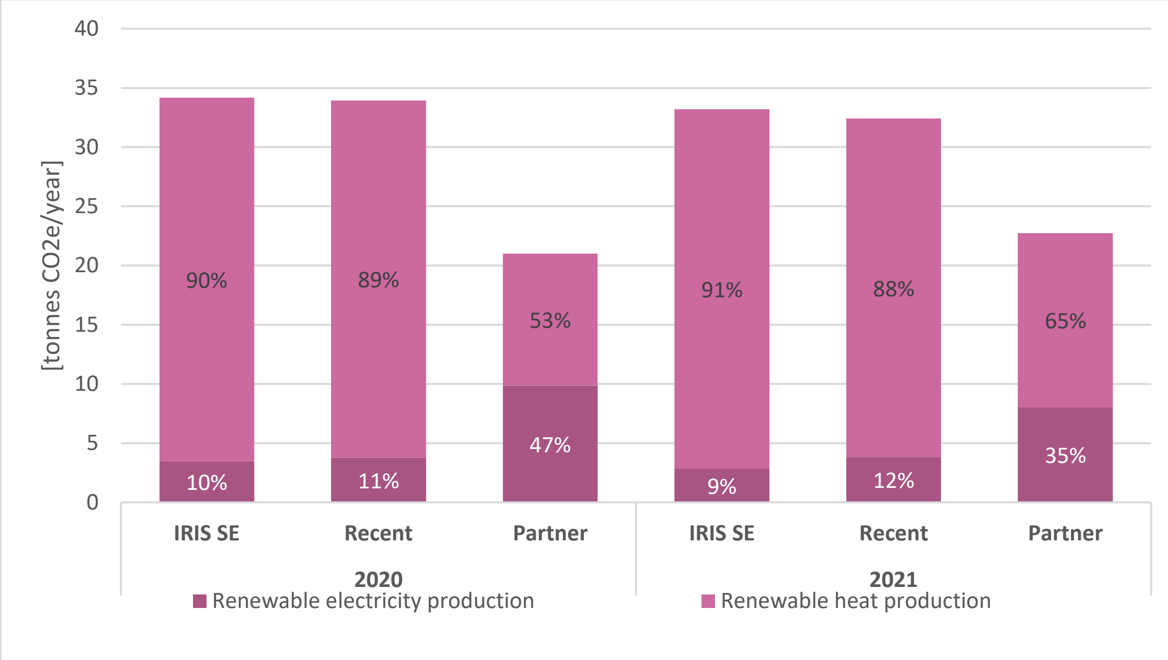


*Figure 65: Aggregated results for KPI: 5 Carbon dioxide Emission Reduction on TT1 level, established using three different emission factors displaying the contribution from different types of measures.*

### 6.1.2 Measure 1.1: 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV

In measure 1.1 the re-usefulness of vehicle batteries in stationary applications, together with solar PVs, is explored. Electricity is generated by PVs at the roof of four of the six buildings in Viva. This electricity is either used directly in Viva or stored in the batteries to be used later. The batteries are taken from their mobile service in buses, when roughly 80% of original capacity remains, and given a second life in a stationary application. This leads to an improved efficiency in the use of resources as well as a reduced environmental impact.

At the time of the application for the IRIS-project, a peak power capacity of 140 kWp was expected to be installed. The final installation was instead 170 kWp (290 Wp × 589 panels). This addition came about because, additionally, one of the low buildings got its roof covered with PVs, as shown in Figure 66.

*Figure 66: Brf Viva with its PV clad roofs*

The KPIs used to evaluate this measure are listed in Annex 7.1.1 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the project partner and used to establish the KPIs is also listed.

#### 6.1.2.1 Results for Measure 1.1

*Table 36: KPI results for Measure 1.1 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV.*

| KPI | 2019 | 2020 | 2021 | 2022 | Target (GA or partner) |
|---|---|---|---|---|---|
| **Carbon dioxide Emission Reduction [t/year]** | 1,49 | 3,19 | 2,56 | 2,78 | 15-20% |
| **Degree of energy self-supply by RES** | 15,8% | 19,3% | 16% | 27% | Brf Viva's degree of self-supply for electrical energy is expected to vary between 10% and 60%. |
| **Increase in local renewable energy production [MWh/year]** | 65 | 139 | 111 | 121 | 140 kW and 140 MWh/year |

In 2019 and 2022, data from measurements were collected only for the seven last and nine first months, respectively. This explains the lower values displayed for these years in the table above.

The installed PV capacity was increased from 140 to 170 kW since the time of the IRIS project application, but the impact target was set based on the original plan. After the addition of more PV-panels than originally planned the electricity production was expected to be 160 MWh per year. However, the maximum annual production is 140 MWh and is reached in 2020, as shown in Figure 67. In 2019 and 2022 there is only data for the seven last and nine first months, respectively, explaining the lower production for these years. In 2021, the panels were not in operation for a week in mid-July which contributes to the lower production this year. Another reason for the low yield in 2021 is due to a safety breaker being turned off, which is assumed to be caused by a lightning strike. Without an alarm signal, it took some time for this to be noted and fixed, resulting in a reduction in production during several months.

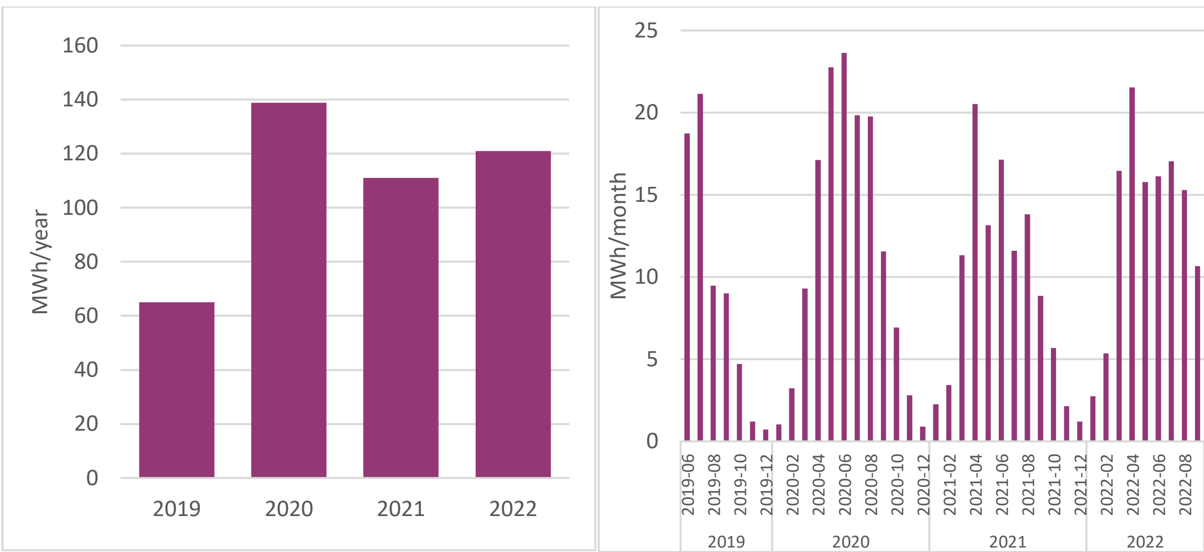


*Figure 67 Results of the KPI 20: Increase in local renewable local energy production, yearly (left) and monthly (right). The panels were expected to produce 160 MWh/year.*

During the measurement period the degree of energy self-supply, achieved by the PV production, is averaging at ~20% with monthly values ranging from 1-50% (Figure 68). Compared to the aim of 10-60 % these results are somewhat lower and can be explained by the PV-production being lower than expected, as mentioned above, and the energy consumption being higher.


*Figure 68: Results of the KP 10: Degree of energy self-supply by RES, yearly (left) and monthly (right). The aim was a range of 10-60%.*

The higher degree of energy self-supply achieved in 2022 is in part due to the EMS being in operation (see 6.1.7) and in part due to the whole year not being included, leaving out months with lower production and higher consumption. The EMS led to lower use of the heat pumps and thereby lower electric energy consumption during the heating season 21-22, shown in Figure 69.

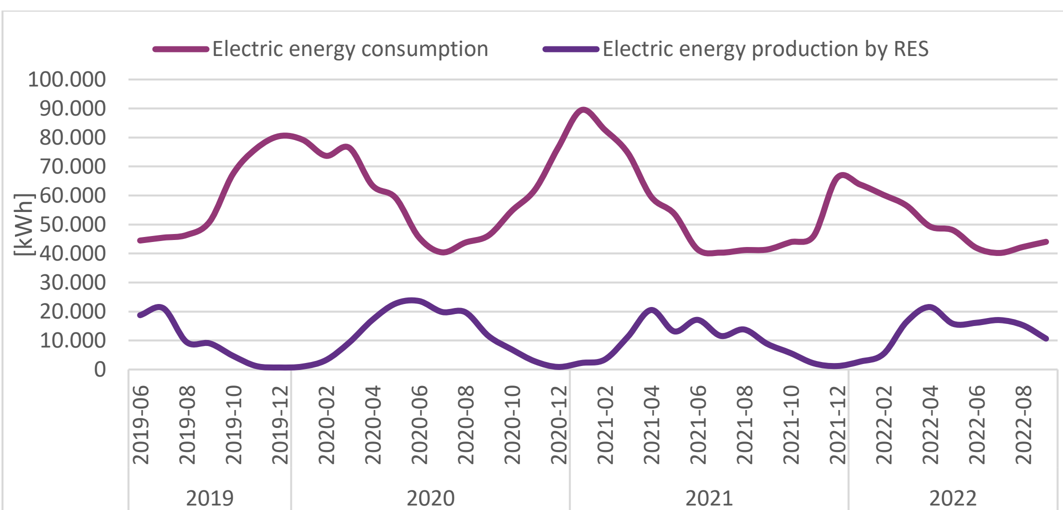


*Figure 69: The electric consumption and PV-production in Brf Viva, monthly. EMS was in operation from May 2021 to April 2022.*

The carbon dioxide emission reduction from production of PV electricity is estimated using an annual average emission factor for electricity produced in Sweden and assuming zero emissions associated with the PV-production. The partner had set a target of 15-20 % emission reduction compared to purchasing electricity from the grid and the reduction achieved is within the target and even exceeds it in 2022 as shown in Figure 70. The target is calculated based on the actual electricity consumption of the included months and as mentioned earlier, the last months of 2022 are not included and if they where they would lower the results somewhat since they are during the time of year when production is low while the consumption is high.

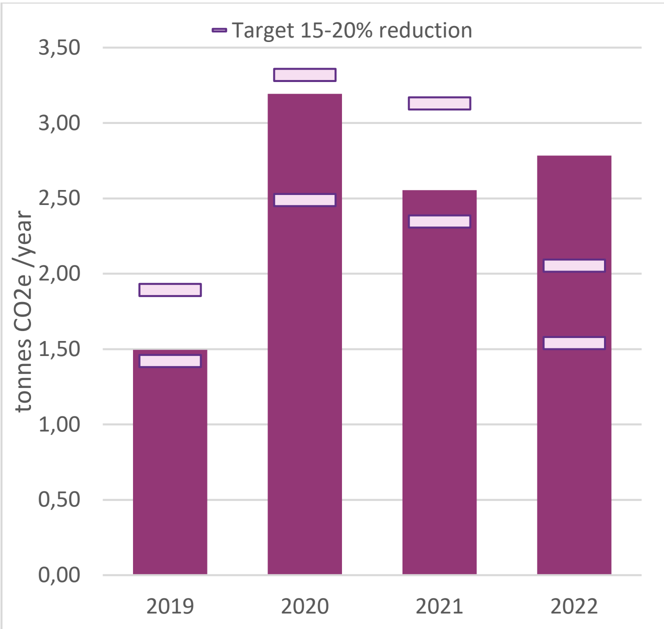


*Figure 70: Results of the KPI 5: Carbon dioxide Emission Reduction, yearly and target of 15-20 % reduction compared to electricity from the grid.*

The emission reduction depends on the size of the PV production and the emission factor used for electricity from PV and the grid. Since Sweden has a large share of production associated with low emissions (hydro and nuclear) the average emission factor is only 23 g $CO_2$e/kWh compared to 56 g $CO_2$e/kWh in France and 435 g $CO_2$e/kWh in the Netherlands. Using the same assumptions, the measure in France would result in more than 2 times the emission reductions and almost 19 times in the Netherlands. Given the large impact the emission factor has on the results and the simplified assumptions used to establish the emission reduction a sensitivity analysis has been performed for this KPI, see Chapter 8.

### 6.1.3 Measure 1.2: Heating from geo energy with heat pumps

This measure introduces heating of Viva by heat pumps drawing geothermal energy from deep boreholes. The aim was to provide heating to Viva from borehole-based heat pumps. The target was to be able to cover Viva's entire heating demand with the heat pumps. This has been fully implemented with the following hardware:

- Heat exchanger of 200 kW.
- Heat pumps. On the geothermal energy, the condensor power is 195 kW total, from three heat pumps of 65 kW each, and the Coefficient of Performance (CoP) is 3.2 on average.
- There are 19 boreholes reaching some 230 meters down into the bedrock.

The KPIs used to evaluate this measure are listed in Annex 7.1.2 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained and used to establish the KPIs is also listed.

#### *6.1.3.1 Results for measure 1.2*

*Table 37: KPI results for Measure 1.2 Heating from geo energy with heat pumps.*

| KPI | 2019 | 2020 | 2021 | 2022 | Target |
|---|---|---|---|---|---|
| **Carbon dioxide Emission Reduction [t/year]** | 25,9 | 51,6 | 37,8 | 20,7 | 90% reduction compared to if all heat from district heating. |
| **$CO_2$ reduction cost efficiency [€/t/y]** | 73 | -383 | -355 | 336 | 400 €/tonne $CO_2$ e/y |
| **Degree of energy self-supply by RES [%]** | 100% | 99,5% | 69,8% | 65,6% | Varying between 0% and 100% for thermal energy.[1] |
| **Increase in local renewable energy production [MWh]** | 391 | 773 | 573 | 315 | |

In 2019 and 2022 data from measurements were collected only for the seven last and nine first months, respectively. This explains the lower value of the KPI Carbon dioxide emission reduction and the KPI Increase of renewable energy production by RES for these years, listed in Table 37. Furthermore, the reduction is directly dependent on the amount of heating produced from the heat pumps instead of imported from the district heating network and this amount also varies between different years, as indicated by KPI Degree of energy self-supply by RES, see Figure 71. For 2019 and 2020 the heat pump provided almost all the heat used in Brf Viva while for 2021 and 2022 the share was 65 – 70 %. The energy management system (EMS) was put in operation in 2021 altering heat source between heat pumps and district heating, which shows in the monthly KPI values. More information about the EMS can be found in chapter 6.1.7.

[1] More self-supply is not always better. Remember that DH in Sweden is largely comprised of waste heat, and thus has a very low carbon intensity. From an emissions point of view it can be more beneficial to use DH.

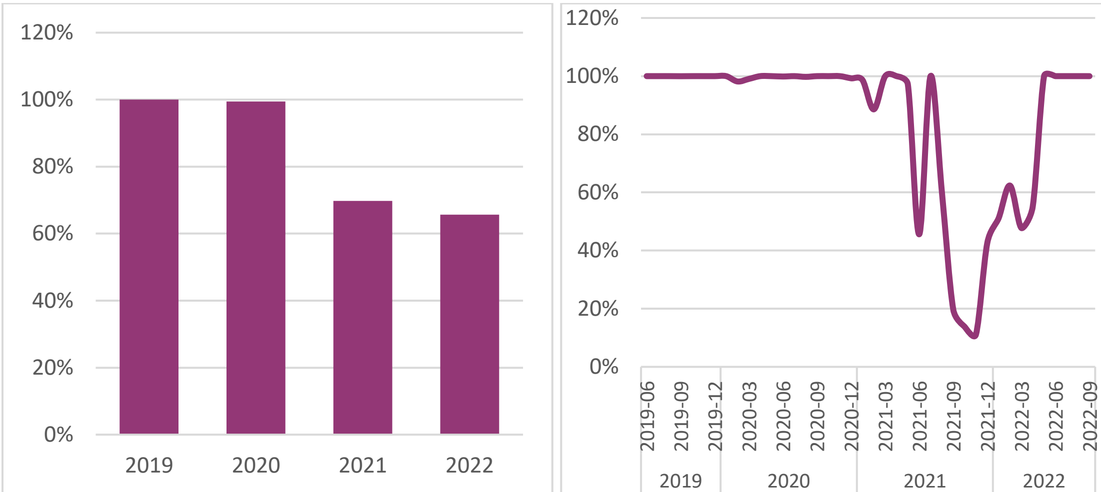


*Figure 71: Results of KPI 10: Degree of energy self-supply by RES, yearly (left) and monthly (right). EMS was in operation from May 21 – April 22.*

The heat produced/extracted from the boreholes and heat pumps is shown in KPI Increase in local renewable energy production, shown in Figure 72, and it varies between 570-770 MWh for the years with full data (2020 and 2021). The lower value in 2021 is due to the operation of the EMS.

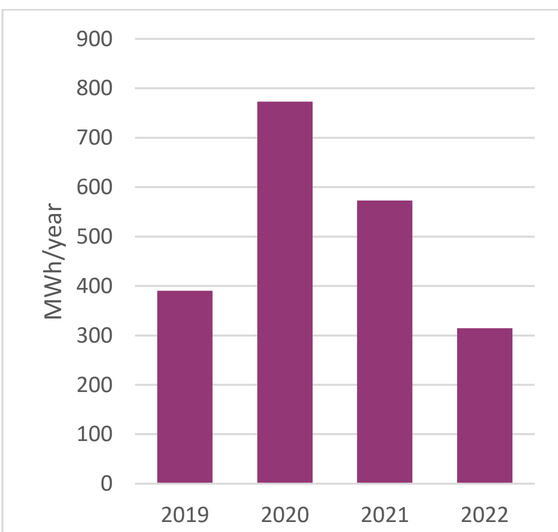


*Figure 72: Results of KPI 20: Increase in renewable energy production thermal, yearly.*

The target for the Carbon dioxide emission reduction KPI is to achieve a 90% reduction compared to a baseline where only district heating is used. The extent of $CO_2$ emission reduction depends on the proportion of heat generated from heat pumps as opposed to district heating and the disparity in emissions between the two heat sources. The emissions associated with district heating are obtained from the annual environmental reports provided by the local district heating company and are given as annual averages per unit heat [15]. These emissions may fluctuate slightly each year, as do the heat demands of Brf Viva, which leads to variations in the target, as shown in Figure 73. The target is established using the same number of months as there is data included in the analysis, so not full years for 2019 and 2022. The emission factors for district heating and data used to establish the KPI can be found in Annex 7.1.2.

The emission reduction target was achieved for 2019 and nearly for 2020, but it was not achieved in 2021 and 2022 due to the heat from district heating exceeding 30%, which makes it impossible to achieve a 90% reduction compared to district heating. The high share of district heating in these years was due to the high electricity prices, which prompted the EMS to choose district heating over heat pumps. However, as shown in the monthly values Figure 71, the EMS was deactivated in April 2022.

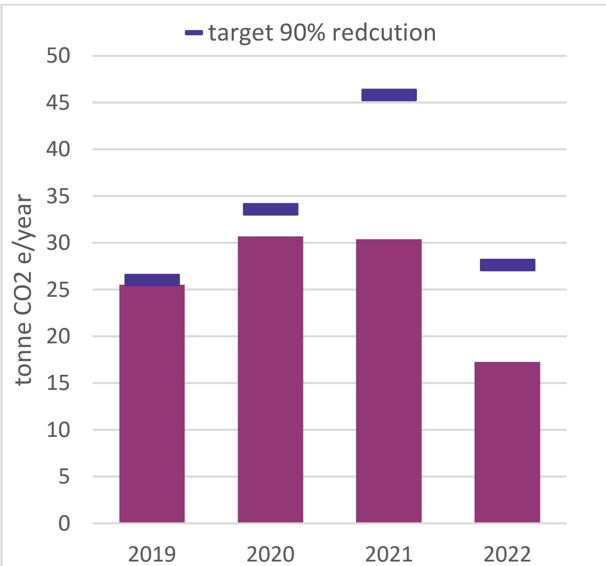


*Figure 73: Results for KPI 5: Carbon dioxide emission reduction, yearly and target of 90 % reduction compared to all heat from DH.*

The cost of electricity also influences the KPI $CO_2$ emission reduction efficiency. The costs included in this KPI are the annualized investment costs and the change in the running costs of the measure compared to baseline heating, which in this case is all heat from district heating. The target for this KPI, 400 euro/tonne $CO_2$ reduction, are reached for all years and the measure even leads to savings per tonne $CO_2$ reduced in 2020 and 2021, Figure 74.

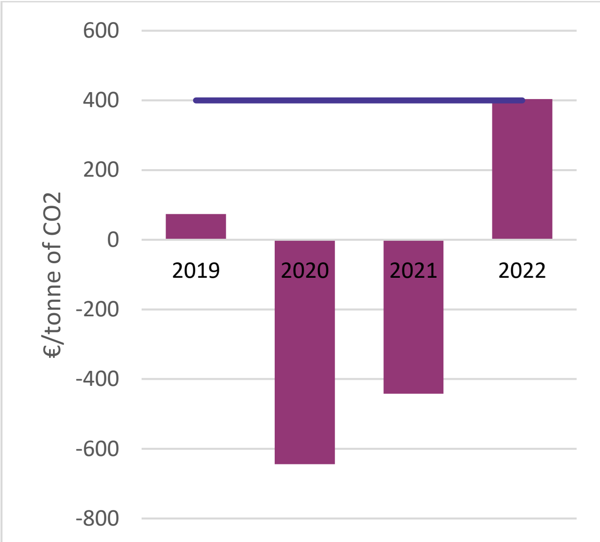


*Figure 74: Results of KPI 7: $CO_2$ emission reduction efficiency, yearly and target of 400 euro/tonne.*

### 6.1.4 Measure 1.3 Cooling from geo energy without chillers

This measure is a system which circulates return water from the comfort cooling system of the office building CTP to the heating system in Brf Viva, thereby transferring cooling to CTP. The aim of the seasonal energy trading was to connect the energy systems of Viva to an adjacent office building using insulated pipes. This enables:

- the free cooling from the boreholes to cool the comfort system in the office building
- the excess heat from this comfort cooling system to heat the boreholes in Viva and in turn make the geothermal heat pumps more efficient.

Both facilities could then potentially meet their heating and cooling demands by using less electricity.

Both facilities are entirely dependent on the connection between Viva's energy system and that of a neighbouring office building, with an owner who is not part of IRIS. After a few years of trying, funds and forms for the collaboration are now agreed upon and the demonstrator is in service.

The KPIs used to evaluate this measure are listed in Annex 7.1.3 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data used to establish the KPIs is also listed.

#### 6.1.4.1 Results for measure 1.3

*Table 38: KPI results for Measure 1.3 Cooling from geo energy without chillers*

| KPI | 11 months | Target |
|---|---|---|
| **Carbon dioxide Emission Reduction [t/year]** | 0,84 | If all cooling is produced with chillers this would result in 2 tonnes/year and 80% reduction be equal to 1,6 tonnes. |
| **Degree of energy self-supply by RES [%]** | 42 % | A substantial amount, hopefully up to 80% |

According to manual meter readings, approximately 110 MWh cooling was delivered from 2021-11-22 to 2022-10-25 and a total of 261 MWh cooling was used during this period. Unfortunately, the receiving company CFAB has had problems with control of the system and problems with connection and monitoring of energy meters. Therefore, this is the only data available. Based on these data the KPIs reached numbers equal to ~53% the targets that where set. CFAB reports that the amount of cooling delivered during the 11-month period exceeds their demand and replaces their own free cooling. The cooling was provided either fully or not at all, and the partners are exploring ways to control the amount transferred to improve operation. As CFAB claims that the amount of cooling delivered is more than desired, and they do not exclusively use chillers for cooling, the estimated emission reduction may be overestimated. However, as there is no information on the maximum amount of cooling CFAB requires, these estimates are the only ones available. With this new information from CFAB, the partner's target of achieving an 80% degree of energy self-supply through renewable energy sources is likely unattainable.

### 6.1.5 Measure 1.4: Local energy storages consisting of water buffer tanks, structural storage and long-term storage in boreholes

This measure incorporates a couple of different thermal energy storages into the overall energy system of Viva. These are:

- A well-insulated building structure, with large amounts of concrete exposed to the indoor air, to passively smoothen the temperature curve in the apartments.
- Accumulator tanks at nodes in Viva’s heat distribution system. These are actively controlled for peak power shaving during the hours with the highest hot tap water demand on a daily cycle, typically in the mornings when most residents shower.
- Recharge of heat into the boreholes to increase the longevity of their heat delivery. The continuous heat extraction of the boreholes can cause the temperature in the bedrock to drop too much which in turn has a negative effect on the efficiency of the geothermal heat pumps and the delivery of heat.

The water tanks are fully operational, and the structural storage is a passive system that always has an effect. However, the long-term storage in boreholes is dependent on the *seasonal energy trading*, which was completed at a late stage of IRIS and not yet at its optimal operation, so this has not been evaluated.

The KPIs used to evaluate this measure are listed in Annex 7.1.4 together with the related parameters, data sources, baselines, and targets. In this annex the measurement, obtained from the partners and used to establish the KPIs is also listed.

#### 6.1.5.1 Results for Measure 1.4

*Table 39:KPI results for Measure 1.4 Local energy storages consisting of water buffer tanks, structural storage and long-term storage in boreholes.*

| KPI | 2019 | 2020 | 2021 | 2022 | GA- Target |
|---|---|---|---|---|---|
| **Storage capacity installed [kWh]** | 970 | 970 | 970 | 970 | 970 kWh in tanks. N/A for boreholes and structure. |

Based on the values obtained from the project partner it appears that this measure has achieved the set target.

The accumulator tanks are operating as intended. The bore holes are operating, but it is difficult to measure their contribution to storage capacity. Due to the realization of the need for additional costly hardware during the project, the thermal inertia of the buildings has neither been measured nor utilized by the control system to equalize the heating power demand and shave peak power.

### 6.1.6 Measure 1.5 Seasonal energy trading with adjacent office block

This measure is a system which trades heated cooling water from the office building CTP, with cooled water from the boreholes in Viva.  More details about the motivation of energy trade can be found under the description of measure 1.3 Cooling from geo energy without chillers.

The KPIs used to evaluate this measure are listed in Annex 7.1.5 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the partners and used to establish the KPIs is also listed.

#### 6.1.6.1 Results for Measure 1.5

*Table 40: KPI results for Measure 1.5 Seasonal energy trading with adjacent office block*

| KPI | 11 months | Target |
|---|---|---|
| **Reduced energy cost for customers [%]** | 68 % | 70 % |

The seasonal energy trading was in operation for 11 months, running from November 2021 to October 2022. The estimated reduction in energy cost was based on the assumption that all cooling provided would replace cooling produced in chillers with an average COP of 3. An average electricity price, including supply, power transmission, and distribution costs, was set using data from these 11 months.

The results indicate a 68% reduction in energy cost, which is very close to the partner's target. However, as noted in Measure 1.3, the cooling transferred to CFAB exceeds their requested amount due to inadequate management, as not all cooling at CFAB is produced using chillers. Therefore, this number is higher than expected once proper steering is implemented. Brf Viva earned approximately 27 500 SEK during these 11 months, which is close to the target of 30 000 SEK per year. As with Measure 1.3, the partner should re-evaluate the target to better reflect the cooling requirement of CFAB for future operation of the coolant pipe.

### 6.1.7 Measure 1.6 Energy Management System

The aim of the Energy Management System (EMS) measure was to control the following components: district heating, ground source heat pumps, battery energy storage, water buffer tanks and PVs. An overview of the installations in Brf Viva is provided in Figure 60.

The measure aims to provide a better understanding of how the energy system can be optimized from a residential housing perspective and as part of the larger energy systems in Gothenburg. The optimization and control of the whole system aims to minimize the overall energy costs and environmental impact as well as improve energy efficiency.

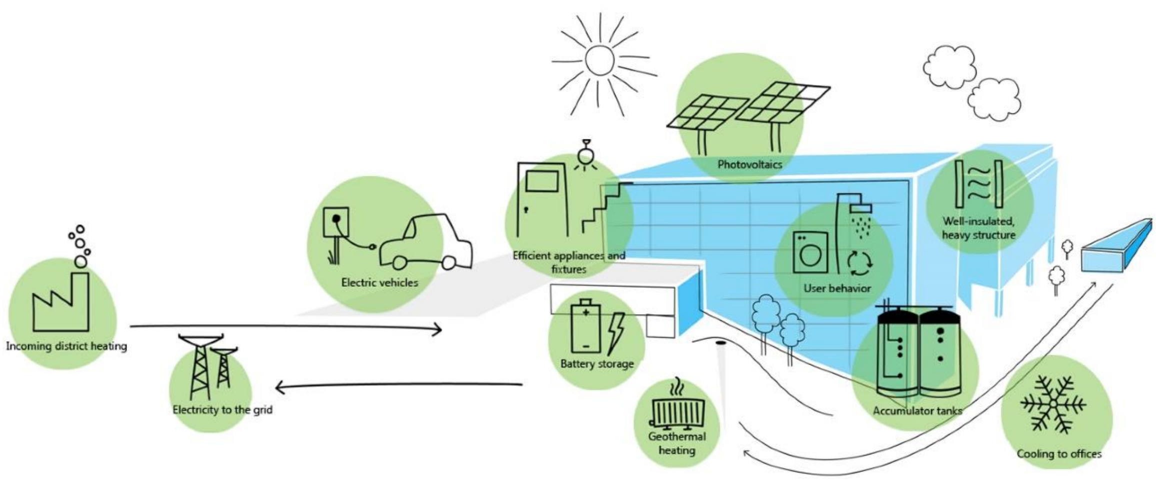


*Figure 75: The components of the energy system in Riksbyggen's housing association Brf Viva.*

The KPIs used to evaluate this measure are listed in Annex 7.1.6 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the partners and used to establish the KPIs is also listed.

#### 6.1.7.1 Results for measure 1.6

*Table 41:KPI results for Measure 1.6 Energy Management system.*

| KPI | 2019 | 2020 | 2021 | 2022 | Target |
|---|---|---|---|---|---|
| **Increased system flexibility for energy players stakeholders, electrical [%]** | 89% | 71% | 64% | 95% | |
| **Increased system flexibility for energy players stakeholders, thermal [%]** | 95% | 95% | 68% | 91% | 100% |
| **Reduced energy cost for customers** | 0 | 0 | 0 | 0 | |

In 2019 and 2022, data from measurements were collected only for the seven last and nine first months, respectively.

During the monitoring period, the electrical system flexibility has been increased by 64-95%. To calculate the KPI, the installed capacity that contributes to flexibility is divided by the peak power of used energy, whether it's electrical or thermal. For the electrical side, this involves adding the peak power available in the battery storage to the peak power consumption of the heat pumps, then dividing it by the peak power from the electrical grid. The number of batteries in operation varies each year and was the lowest in 2020, which explains the lower value of the KPI that year. In 2021, the KPI value was also low due to high peak power demand caused by cold weather, as shown in Figure 76. The installed capacity, in batteries and heat pumps, provides a potential for momentary or short-term flexibility that can reduce the power demand by up to 95% for Brf Viva. This capacity for flexibility could be utilized in the grid during hours of congestion, which usually occurs during only a few hours each year. Gothenburg Energy is currently testing a pilot market for power flexibility with a minimum bidding size slightly lower than the installed capacity in batteries and heat pumps in Viva (100 kW vs ~120 kW) so it would be possible to participate, also without aggregation.

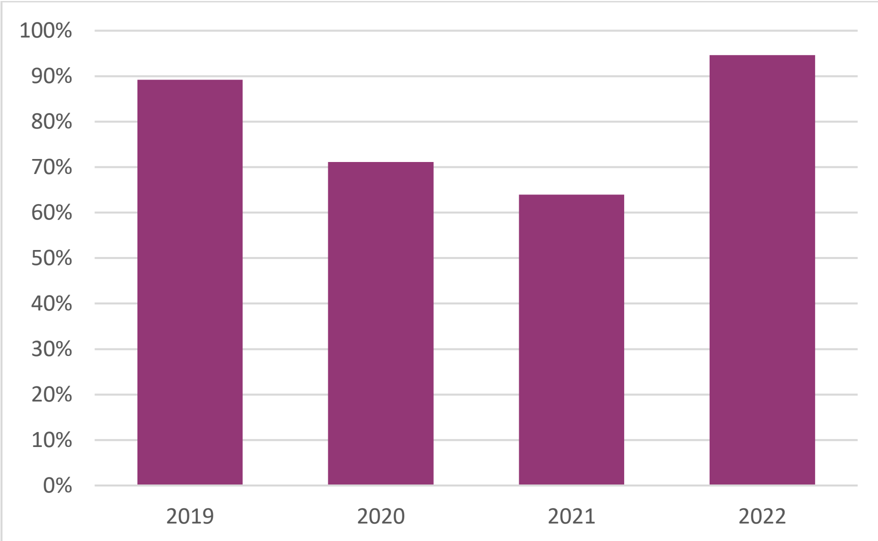


*Figure 76: Results for KPI 21: Increased system flexibility for energy players stakeholders, electrical.*

The thermal flexibility of Brf Viva has increased by 67-95%, which is defined as the heat that can be provided by the heat pumps in comparison to the total heating demand, including hot tap water. This implies that the supplied district heating power could have been reduced by this percentage if Viva's heating demand was met solely by the heat pumps. During some of the monitoring period's colder hours or when one or more of the geothermal heat pumps were out of service, they could not meet Viva's heating demand. This was the case in 2021 due to higher heating demand, which explains the significant decrease in thermal flexibility for that year, as shown in Figure 77.

Initially, the plan for Brf Viva was to fulfil all its heating requirements through ground source heat pumps. Accordingly, the hot tap water was to be produced by the heat pumps, making it impossible to replace this portion of the heating demand with district heating. Although the goal of increasing system flexibility by 100% was pursued, it was not fully achieved, resulting in the need for district heating alongside the heat pumps. Consequently, Brf Viva is not completely self-reliant in terms of heating and requires district heating as a supplementary source.

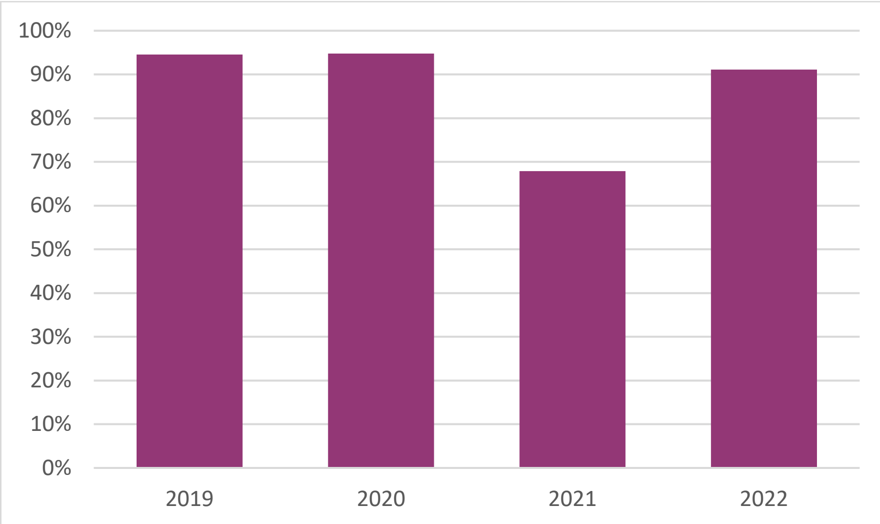


*Figure 77: Results for KPI 21: Increased system flexibility for energy players stakeholders, thermal. Target was 100% increased flexibility.*

The EMS did not result in any reduction of energy costs. In fact, there was an increase of approximately 2% during the year of operation and an additional 10% the following year due to increased peak power costs based on the district heat grid tariff. However, Göteborg Energi credited and cancelled the extra costs. Although the EMS proved the technical feasibility of controlling a complex installation like Viva, it did not lead to any financial savings for the customers. This was because the cost function of the control algorithm only considered energy costs and did not account for power-related costs, which turned out to have a greater impact on energy costs than initially anticipated. To resume operation of the EMS, either the cost function of the control algorithm needs to be updated or the district heating price model needs to be revised regarding the power tariff.

According to Göteborg Energi, the main purpose of developing the control algorithm was to learn about the control of building energy systems and to demonstrate the possibility of optimizing the operation of electric batteries, heat pumps, and district heating plants.

### 6.1.8 Measure 1.7 Building Integrated Photovoltaics (BIPV) in façade

In IRIS, HSB Living Lab contributes with a demonstration and evaluation of so-called BIPV, Building Integrated Photo Voltaics. The aim was to demonstrate BIPV as the primary screen in a building envelope in a renovation process. The economic feasibility was of particular importance.

A collection of photovoltaics was investigated:

- Amorphous silicon- and monocrystalline silicon cell BIPV-facade, about 3,5 m². Directed to east and west.
- Amorphous silicon cell BIPV- facade, about 140 m². Directed to south, east, and west.
- Mono-Si BIPV-roof, ca 50 m². Slanted 14° to the south.

In the figures below the installed solar panels and their orientation on the building can be seen.

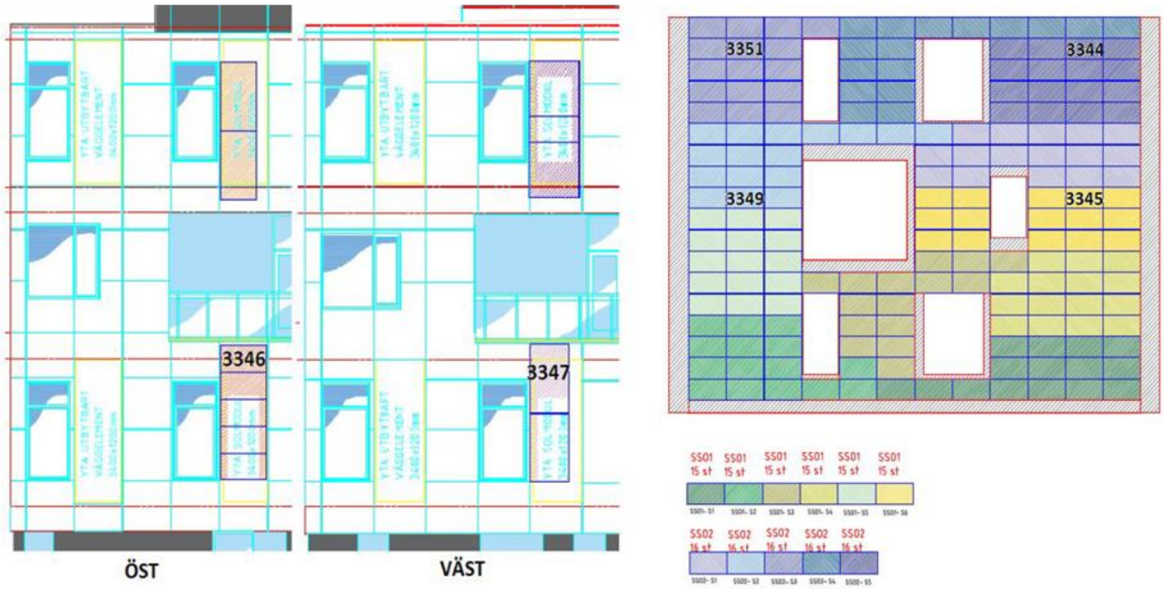


*Figure 78: Solar panels (A-Si and mono-Si) at the façade east(öst)/west(väst) on the left and solar panel (A-Si) at the façade south on the righ).*

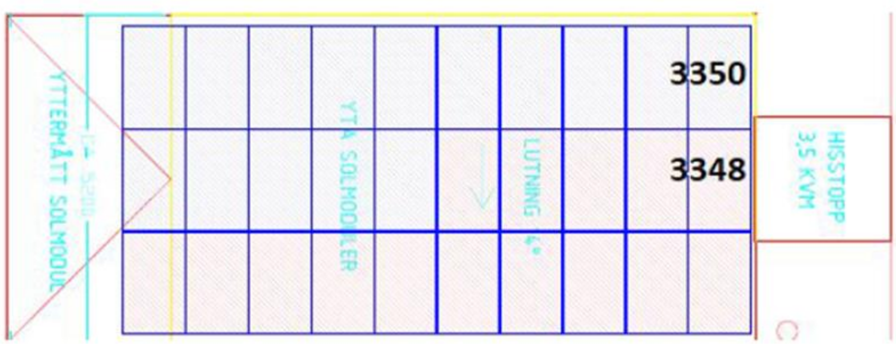


*Figure 79: Solar panels (Mono-Si) on the roof.*

The KPIs used to evaluate this measure are listed in Annex 7.1.7 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the partner and used to establish the KPIs, is also listed.

### 6.1.8.1 Results for measure 1.7

*Table 42: KPI results for Measure 1.7 Building Integrated Photovoltaics (BIPV) in façade.*

| KPI | 2019 | 2020 | 2021 | 2022 | Target |
|---|---|---|---|---|---|
| **Carbon dioxide emission reduction - partner [t/year]** | 0,802 | 0,754 | 0,752 | 0,811 | 0,525 tonnes $CO_2$ reduction |
| **Carbon dioxide emission reduction – IRIS SE [t/year]** | 0,28 | 0,28 | 0,28 | 0,29 | |
| **$CO_2$ reduction cost efficiency – partner [€/t/y]** | 720 | 978 | 76 | -860 | |
| **$CO_2$ reduction cost efficiency – IRIS SE [€/t/y]** | 2042 | 2772 | 217 | -2438 | |
| **Degree of energy self-supply by RES** | 15% | 12% | 11% | 16% | 19 % of electricity used in the building |
| **Increase in local renewable energy production [MWh]** | 12,3 | 12,4 | 12,1 | 12,4 | 14 MWh |

The installation of façade integrated PVs has been technically successful, serving both as a building envelope and a solar energy source. This dual function has the potential to provide cost benefits compared to a regular façade, depending on solar power production and energy prices. However, data on electricity production is missing for several months due to a fault with the control system and data collection. To estimate annual production for 2020 and 2021, the PV production for the missing months was set to the average production of the same months in the years where data is available. For 2022, data is only available until September. Figure 80 shows a small difference in yearly production between the years, likely due to natural variations in sunlight. The PV panels produced slightly less than expected during operation, but there have been no issues with their performance. The yearly production has still achieved almost 90% of the target of 14 MWh for 2019-2021, and for 2022 it will be even closer given that three last months are not included in the numbers displayed.

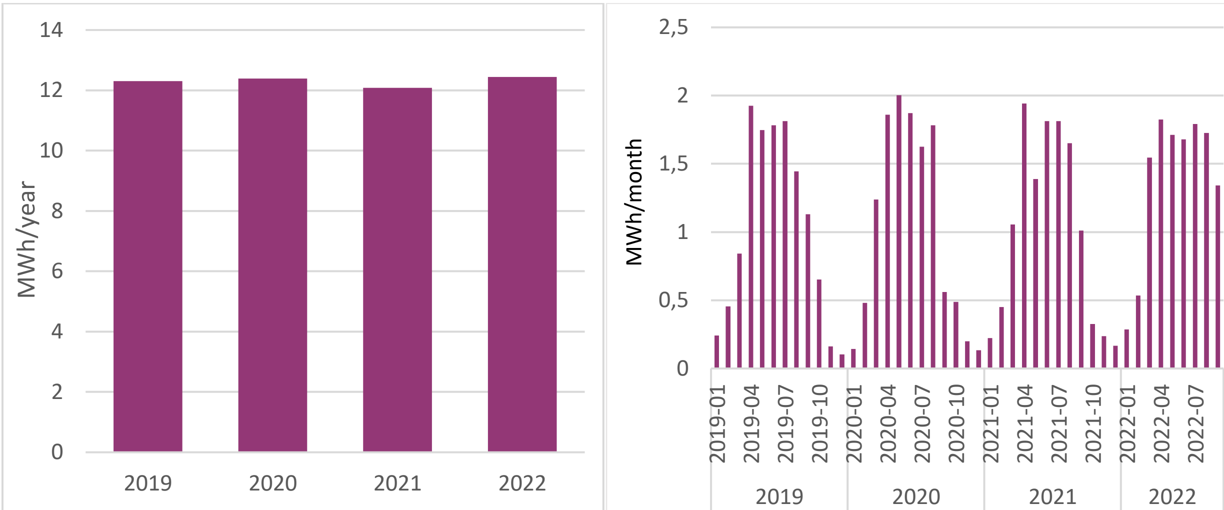


*Figure 80:Results KPI 20: Increased local renewable energy production, yearly (left) and monthly (right). Target was 14 MWh per year.*

Figure 81 shows that the solar energy generated covers around 11-16% of the building's electricity demand. The COVID-19 pandemic in 2020 caused a significant shift in behaviour, with residents required to work and study from home, resulting in a 25% increase in electricity consumption compared to 2019. As a result, the self-supply of electricity decreased between these two years. In 2021, due to the cold winter, the electricity consumption reached similar levels to 2020. The value for 2022 is not indicative of the entire year as it excludes the last three months, which typically have low production and high consumption, thereby reducing self-sufficiency.


*Figure 81: Results for KPI 10: Degree of energy self-supply by RES, yearly (left) and monthly (right). Target was 19 % on an annual basis.*

The amount of emission reduction achieved by producing PV in the façade varies between 0.28-0.81 tonnes per year, as shown in Figure 82. The reduction is determined based on the electricity generated by the measure and the difference between the emissions associated with it and the average emissions associated with electricity from the Swedish grid.

When using the emission factors provided by the project partner, the emission reduction is higher compared to using standard factors where the emissions associated with PV production are set to zEro. The partner's emission factors are higher, since imported electricity is also considered in the factor for the Swedish grid and the LCA emissions associated with PV production. However, the difference between the two are also larger resulting in bigger reduction. The exact values of the emission factors can be found in Annex 7.1.7. With the partner's factors the emission reduction target is exceeded, while the standard values do not reach the target as shown in Figure 82. Since the partner has set the target based on their factors, it is the basis for evaluating the measure. However, the assumptions greatly affect the outcome, and a sensitivity analysis on emission factors was conducted, as described in Chapter 8.


*Figure 82: Results of KPI 5: Carbon dioxide emission reduction, yearly with a partner target of 0,525 tonnes/year. One bar for the KPI established using the standard IRIS emission factor of Sweden and one with the factors provided by the partner.*

The KPI $CO_2$reduction cost efficiency varies each year, ranging from 2800 euro/tonne to -2400 euro/tonne (Figure 83). Both the highest and lowest values are derived from the emission reduction established using the IRIS standard emission factors. However, for the partner values, the span is only 980 euro/tonne to – 8600 euro/tonne. To establish this KPI, the annualized investment cost, maintenance costs, and savings due to production of PV were considered. The negative value indicates savings per year and tonne $CO_2$ reduced. The variation in the KPI is caused by the electricity price, as the production from the BIPV remains constant, while the annual electricity cost used varies. In 2022, the electricity cost was ~30% higher than in 2021, resulting in even higher savings. The savings would be even higher if the PV-production of the last three months of 2022 are included.

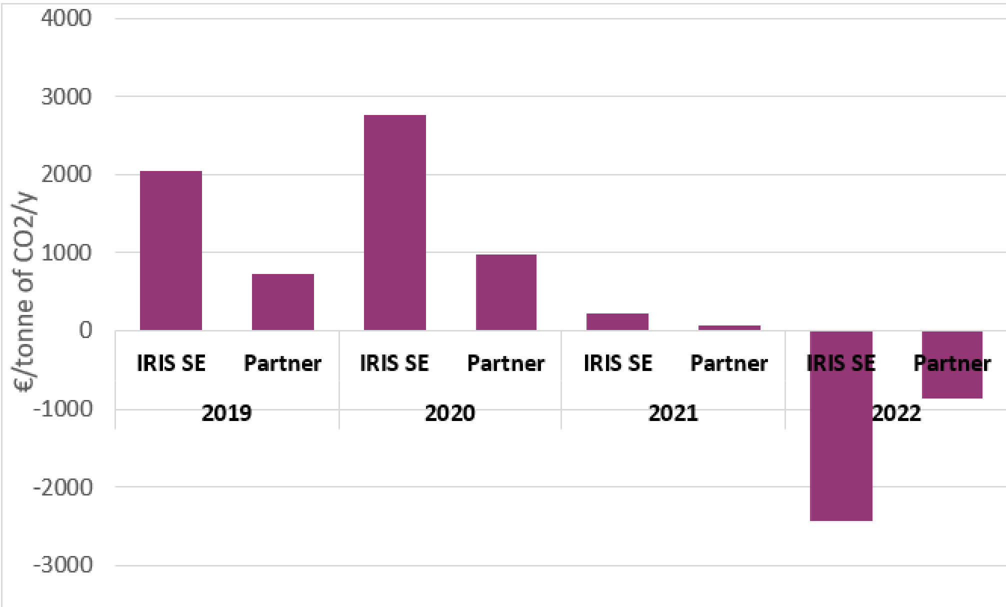


*Figure 83:Results of KPI 7: CO2 reduction cost efficiency, yearly. One bar for the KPI established using the standard IRIS emission factor of Sweden and one with the factors provided by the partner.*

## 6.2 TT2 Flexible energy management and storage

This transition track aims to demonstrate how storing energy in both electric and cooling form can help to reduce the amount of power needed from the energy system. This is important because in the future, the energy system will need to deal with large costs and negative environmental effects caused by high peak power demands.

This transition track includes second-life batteries evaluated in stationary applications, new battery systems together with DC systems and energy storage for cooling utilizing Phase Change Material Thermal Energy Storage (PCM-TES).

Measures in this transition track are implemented in two buildings located next to Chalmers campus Johanneberg, namley Brf Viva and A working Lab (AWL), shown in Figure 69.


*Figure 84: The locations of Brf Viva and A Working Lab (AWL).*

AWL is a newly built office building which is a living environment for innovation where the latest findings in research and development are tested. In the IRIS project the measures 2.1 and 2.2 are implemented in AWL.

Brf Viva, a housing association with 132 apartments, is developed by Riksbyggen. It is designed to be a leading sustainable housing project in the country. To achieve this, several solutions have been implemented, including measures 1.1-1.6, 2.4, and 3.1 under the IRIS project.

### 6.2.1 Results of the KPIs for TT2

*Table 43: Aggregated annual KPI results for TT2 based on the three years with full measurement data.*

| KPI | Target | Results | Measures included |
|---|---|---|---|
| **Storage capacity installed -electrical [kWh/year]** | 400* | ~300 | M2.1, and M2.4 |

**Note that this target is a summary of the partner targets and not included in the Grant agreement.*

Several KPIs are used to evaluate the measures in this TT, as shown Figure 25. However, only the KPI Storage Capacity installed (electrical) can be aggregated to the TT level. The aggregated value is determined using the annual values from the years of full data of the measurements that contribute to it, as presented in Table 43. Although a target for this KPI is not specified in the Grant Agreement, adding up the targets set by the partners at the measure level results in 75% achievement. Please refer to the results of the individual measures in the section below for more details.

### 6.2.2 Measure 2.1 a 350 V DC building microgrid utilizing 171 kW rooftop PV installations and 200 kWh battery storage

The aim of this measure was to demonstrate how a DC system can give advantages when local electricity is produced with PV and stored in battery systems. The measure is run by real estate company Akademiska Hus and is in their new building called "A Working Lab" (AWL), which is an office building of approximately 12 000 m², and an innovations arena. The PV is located both on the roof of AWL and on a nearby building SB3 see Figure 85.

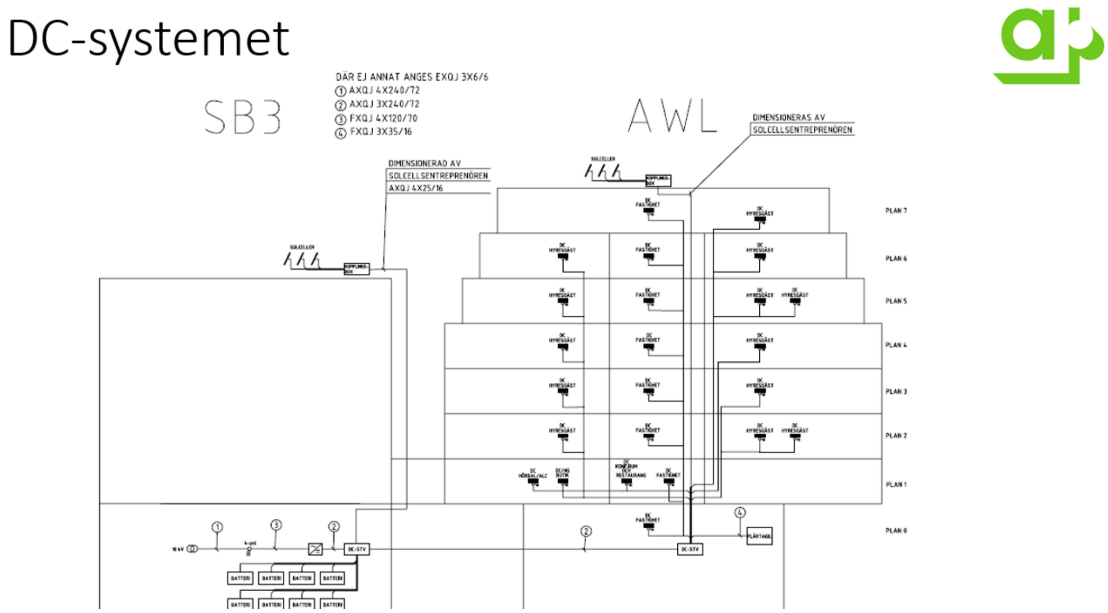


*Figure 85: DC/ solar panel and battery system in the AWL building*

The KPIs used to evaluate this measure are listed in Annex 7.2.1 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data used to establish the KPIs is also listed.

#### 6.2.2.1 Results for Measure 2.1

*Table 44: KPI results for Measure 2.1 a 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage.*

| KPI | 2020 | 2021 | 2022 | Target |
|---|---|---|---|---|
| **Degree of energy self-supply by RES [%]** | 8% | 35% | 37% | 10% |
| **Increase in local renewable energy production [MWh/year]** | 5,9 | 168 | 130 | |
| **Peak Load reduction [%]** | 12,5% | 20,7% | 43,5% | 80% peak power reduction |
| **Storage Capacity Installed** | 200 | 200 | 200 | 200 kWh |

Initially, the plan was to install 140 kW of PV production capacity, but it was ultimately increased to 171 kW. The PV production nearly reached 170 MWh in 2021, which was in line with the expected production based on the installed capacity and is the only year with complete monthly data. For 2020 and 2022, data is only available for the last two months and the first nine months, respectively, explaining the lower production levels in these two years as shown in Figure 86.


*Figure 86: Results of the KPI 20: Increase in local renewable energy production yearly (left) and monthly (right).*

Monthly self-supply from PV electricity varies between 4-65%, with an annual average of approximately 35% (see Figure 87). The low KPI value in 2020 is attributed to low production and high consumption during the months included, while the high value in 2022 is due to the exclusion of three months with high consumption and low production. The target for energy self-supply was an annual rate of 10%, which was exceeded due to the installation of a larger PV capacity than initially expected.

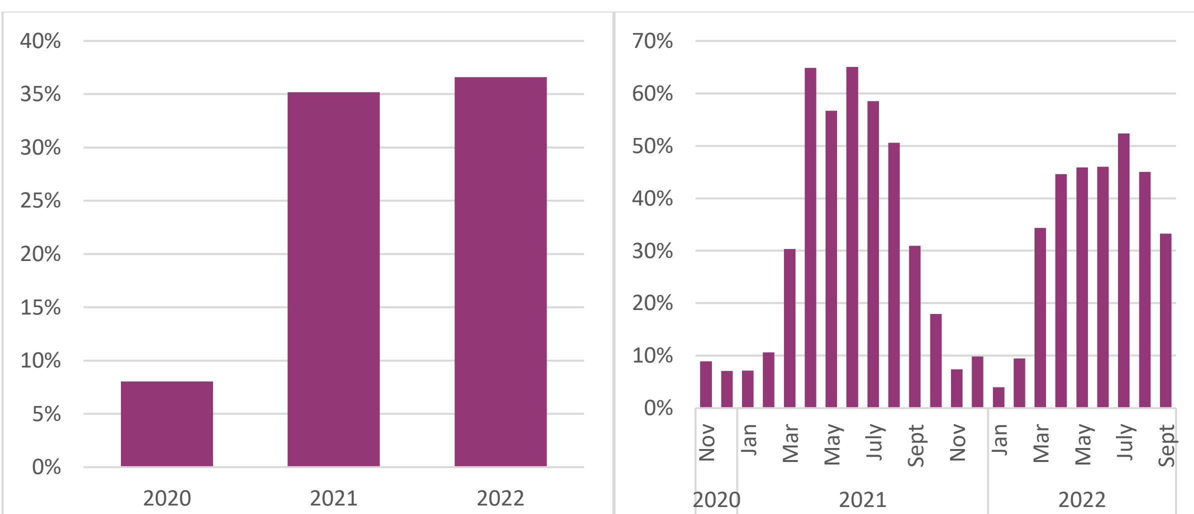


*Figure 87: Results of the KPI 10: Degree of energy self-supply by RES, yearly (left) and monthly (right). The target was 10% on an annual basis.*

The KPI Peak Power Reduction assesses the impact of a measure on a system's peak power by comparing the power levels before and after implementation. Figure 88 plots the values of these two, where the peak power baseline represents the power required from the grid without battery and PV assistance, and the peak power denotes the power drawn from the grid after the measure is implemented. As depicted in the figure, the change in peak power reduction varies throughout the year, with the largest reduction occurring during the summer months when PV production is high. In June 2022, the peak power baseline is higher than usual due to increased ventilation requirements for cooling the building.

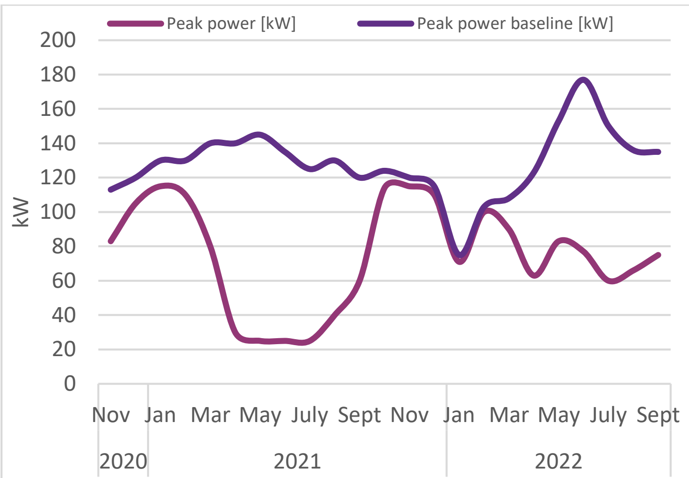


*Figure 88: Peak power baseline and peak power, i.e. with the battery, monthly values.*

The target for peak power reduction was 80%, which was achieved monthly in 2021, while the highest reduction on an annual basis was 43.5%, as shown Figure 89. The unusually high reduction in 2022 was due to the peak power in June and excluding this month would result in a reduction of approximately 35%. Monthly values compare the same month, while annual values compare the highest peak of the year for both cases. In Sweden, grid tariffs are based on the annual peak power usage, so cost savings can only be achieved by reducing the hour with the highest power demand. Therefore, reducing peak power during the summer months does not affect the cost of the grid connection since peak power usage typically occurs during winter. The partner believes that an annual target of 80% reduction is unrealistic, and that the gradual increase in reduction is due to staff learning more about the facility and optimizing operations further.


*Figure 89: Results of KPI 31: Peak load reduction per year (left) and month (right). The target was 80% reduction.*

The battery system operated in two modes: one aimed at reducing peak grid consumption, preferably during winter, and another focused on improving solar self-consumption suitable for summer. The partner has determined that a smart method for switching between these modes is necessary, and further information on the operation modes can be found in Deliverable 7.9 Final report on Gothenburg lighthouse demonstration activities.

When it comes to the installed battery capacity it has reached the set target for all years of measurements, see Figure 90.

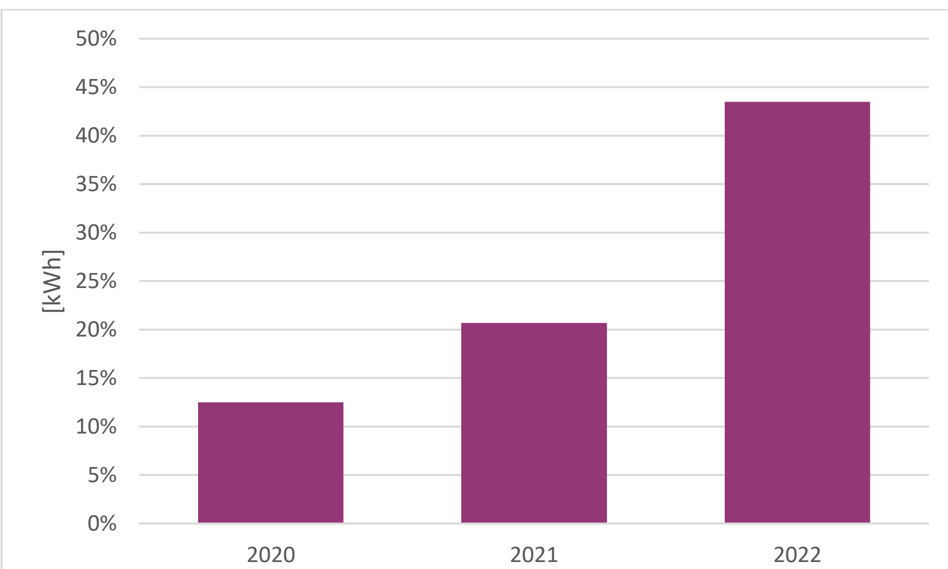


*Figure 90: Result KPI 42: Storage capacity installed, yearly. Target was 200 kWh.*

According to the partner's estimation, implementing a DC grid in the building and connecting certain loads, such as lighting fixtures and ventilation, could reduce energy losses by 3%, resulting in approximately 5 MWh per year for AWL. However, it has not been feasible to measure or quantify these savings, and some of the potential savings were lost because DC is not widely used, and many components have an unavoidable DC rectifying stage.

The partner has concluded that the potential savings from implementing the DC grid cannot justify the additional investments required, but they have gained valuable insights from the demonstration. For further information, please refer to D7.9 *Final report on Gothenburg lighthouse demonstration activities.*

### 6.2.3 Measure 2.2: 200 kWh PCM (Phase Change Material) cooling storage

The aim of this measure is to test and evaluate the energy efficiency of Phase Change Material (PCM) for thermal energy storage (TES). At the AWL-building a novel, full-sized cold storage system has been implemented utilizing PCM technology with a phase transition temperature of ~11$^{o}$C. In addition, a smaller pilot cold storage tank has been developed specifically for laboratory research and further analysis. The purpose of the full-sized PCM is to decrease peak cooling power demand and avoid the need for costly investments in cooling machinery.

The KPIs used to evaluate this measure are listed in Annex 7.2.2 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data used to establish the KPIs is also listed.

#### 6.2.3.1 Results for measure 2.2

*Table 45: KPI results for Measure 2.2 200 kWh PCM (Phase Change Material) cooling storage*

| KPI | 2020 | 2021 | Target |
|---|---|---|---|
| **Peak Load reduction [%]** | 0% | 13,6% | |
| **Storage Capacity Installed [kWh] - thermal** | 100 | 100 | Target for step 1: 200 kWh per day /50 kW for 4 h<br>Target for step 1+2: 800 kWh/150 kW for 4 h |
| **Storage energy losses [%]** | 26% | 22% | 5% |

The full-size PCM-TES was in operation from the end of 2020 to beginning of 2022 and managed to lower the power demand for cooling in the AWL building. This can be seen in Figure 91 where the peak power is the power demand from the grid for cooling of AWL and peak power baseline is the power needed for cooling if the PCM-TES was not in operation. At high cooling demand the PCM-TES has reduced the power with up to 35 kW for short periods of time and this is the difference between the two curves during May to July 2021. During periods of low cooling demand, like May and September, the reduction in power demand is up to 9 kW and this reduction can be achieved for up to ~5 hours.

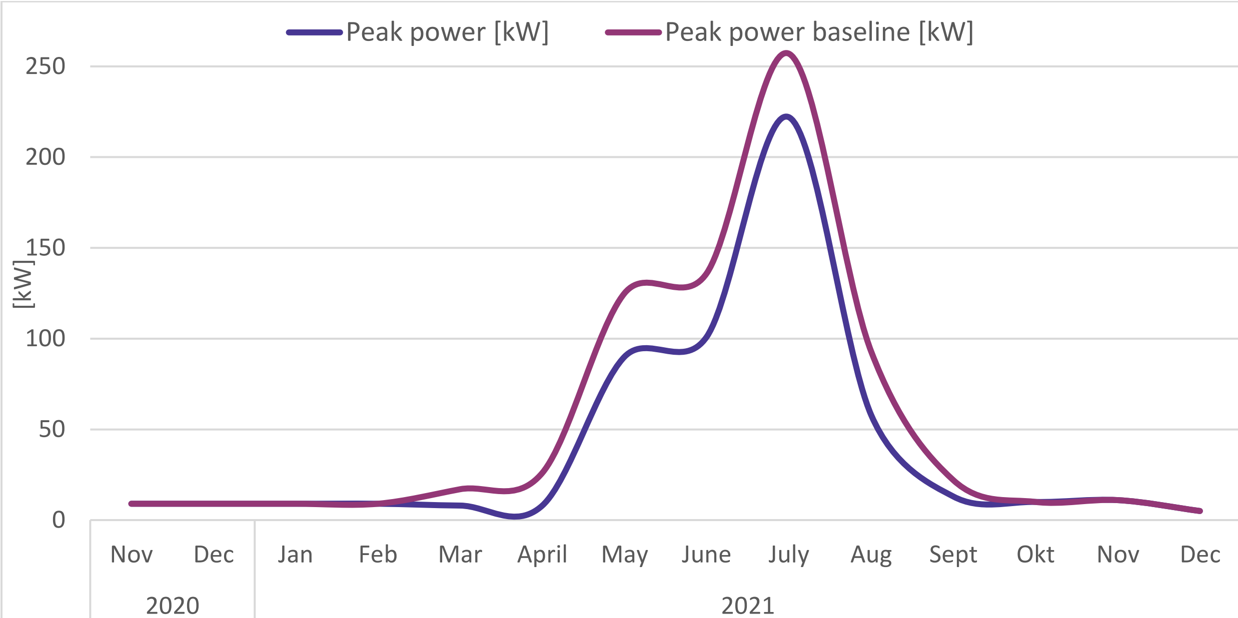


*Figure 91: Peak power baseline and peak power, i.e. with the PCM-TES, monthly values.*

The peak power reduction, which is based on the parameters peak power and peak power baseline, reaches almost 14 % on an annual basis, see Figure 92. This means that the highest peak of the year has been reduced by this amount. On a monthly basis the reduction reaches its highest value of just below 70 % in May.


*Figure 92: Results of KPI 31: Peak load reduction per year (left) and month (right).*

Figure 93 indicates that the KPI storage capacity installed was only 100 kWh, which is half of the target capacity of 200 kWh, and 36% of the manufacturer's stated capacity of 275 kWh. The installed capacity referred to the daily thermal storage since the PCM-TES operates within this timeframe, which limited the charging time to 14-18 hours. The main limiting factor was found to be the charging rates, which were 60-75% lower than the manufacturer's design. When it comes to the discharging the storage delivered an average power ranging from ~30 kW the first hour down to 14 kW during the fifth hour which is significantly lower than the set target of 50 kW. The partner has not been able to identify the reason for the difference between the design and the measured energy storage capacity.

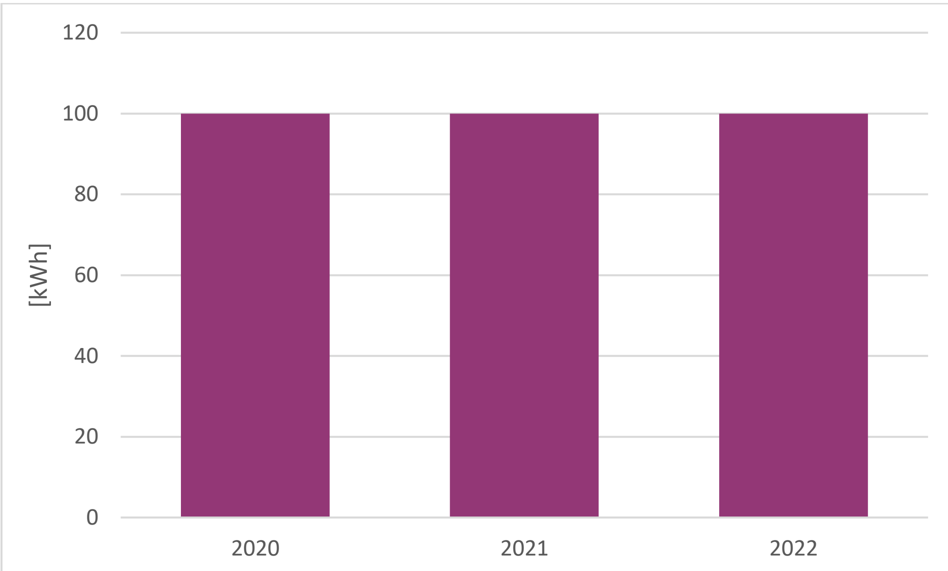


*Figure 93: Results of KPI 42: Storage capacity installed - thermal, yearly. The target was 200 kWh/50kW for 4 h for step 1.*

The partner's goal was to achieve energy losses in the storage system that were comparable to an equivalent water storage, which is around 5%. However, as shown in Figure 94 the losses were higher than expected, ranging from 22-26% on an annual basis and 6-74% monthly. The monthly plot shows negative losses for July 2021, which were due to incorrect data and have been excluded from the annual analysis. The partner attributed the high losses to long storage times (>24 hours) caused by problems in the facility and suggested that losses during a 24-hour period should be around 2-3%.

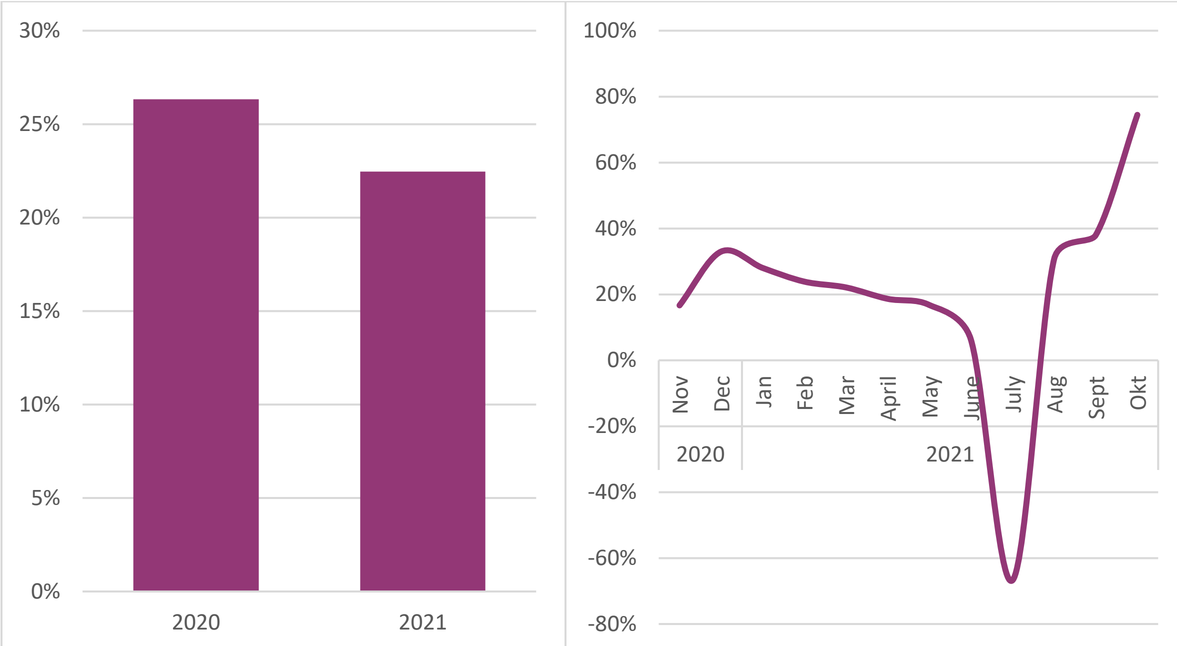


*Figure 94: Results of KPI 53: Storage energy losses, yearly (left) and monthly (right). Target was losses of ~5%.*

The partner has suspended the operation of the PCM since early 2022 and is collaborating with the manufacturer to explore a new material. The new material is expected to have a freezing point that is more suitable for the temperature levels in the district cooling system, as the current material's freezing point is somewhat too high. Additionally, modifications to the heat exchanger design, particularly the tube arrangement, have been implemented to optimize the storage capacity. For more information about the PCM-TES, please refer to D7.9 *Final report on Gothenburg lighthouse demonstration activities.*

### 6.2.4 Measure 2.4: Integration and evaluation of a 200kWh energy storage

This measure investigates the potential for reusing vehicle batteries in stationary applications. The battery storage system in Viva, which is also evaluated in measures 1.1 and 1.6, comprises 14 lithium-ion batteries previously used to power buses in public transport in Gothenburg. When bus batteries reach their end of life and are replaced, they still have around 80% of their original capacity. Installed in a stationary application, these batteries enable a greater proportion of the electricity generated to be used on-site. This stationary application illustrates the type of extended service life that vehicle manufacturers aim to achieve to improve the value and overall sustainability performance of their products. An overview of the batteries' lifespan is shown in the figure below.

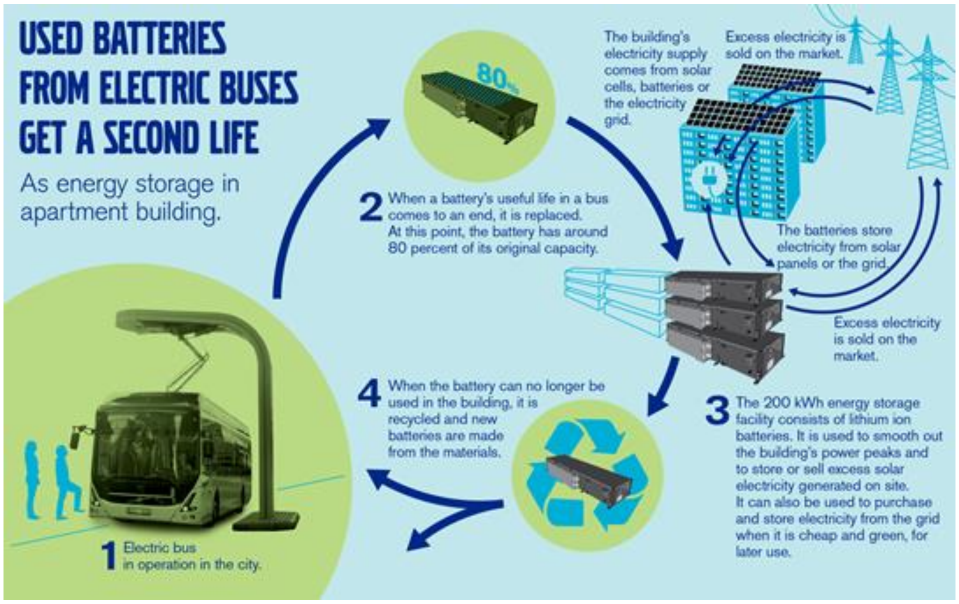


*Figure 95: The circularity of the batteries evaluated in Brf Viva which are from the buss manufacturer Volvos first electric buses in Gothenburg.*

These batteries are also part of measure 1.1 and 1.6 but in this measure the focus is specifically on the battery performance. The KPIs used to evaluate this measure are listed in Annex 7.2.3 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data used to establish the KPIs is also listed.

#### 6.2.4.1 Results for Measure 2.4

*Table 46: KPI results for Measure 2.4 Integration and evaluation of a 200kWh energy storage*

| KPIs | 2019 | 2020 | 2021 | 2022 | Target |
|---|---|---|---|---|---|
| **Peak Load reduction** | 5% | 9% | 7% | 5% | 25% |
| **Storage capacity installed [kWh]** | 185 | 76 | 106 | 122 | 200 kWh |

The KPI Peak power reduction is established using the ratio between the peak power of the baseline, i.e. without batteries, and the peak power with batteries. The values of these two parameters can be seen in Figure 96. The peak power baseline is the power consumption in Viva while the peak power is the power input from the grid. The reduction in power needed from the grid is larger from the first two years of operation when the EMS (measure 1.6) was not in operation and the basic settingss for the batteries were used. The EMS algorithm was not focused on peak power shavings, read more about EMS in section 6.1.7.

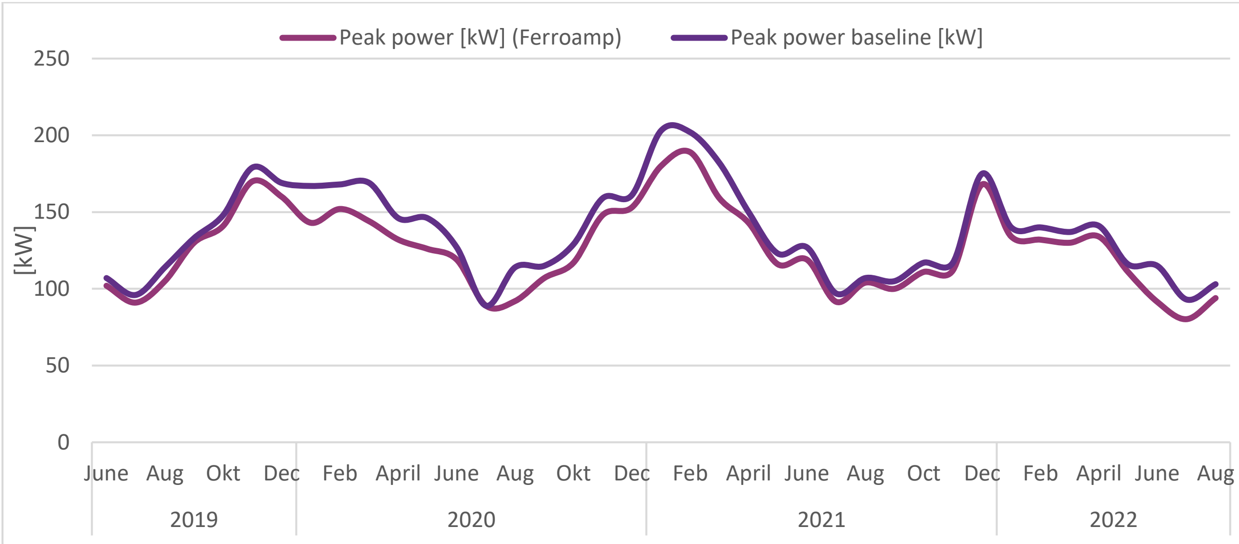


*Figure 96: Peak power baseline and peak power, i.e. with the battery, monthly values.*

The target of achieving a 25% reduction in peak power was not achieved. On a monthly basis, the reduction reached around 20% in August 2020 and June 2022, while the annual values varied between 5-9%, see Figure 97. The annual values were established by comparing the highest peak of the year for the two parameters, while the monthly values were compared with the same month. The annual values are more significant because they determine the potential reduction in cost for the grid connection, and they occur during winter months when the grid capacity is usually more limited. The lower storage capacity and solar power production than expected, together with higher power demand in Viva, partly explain why the peak power reduction target was not met.


*Figure 97: Results for KPI 31: Peak load reduction yearly (left) and monthly (right). Target was 25%.*

The installed battery storage capacity has varied over time, surpassing the target of 200 kWh for a few months in 2019 before decreasing, as shown in Figure 98. This fluctuation occurred because not all batteries were in use. In 2019, 14 batteries with a total capacity higher than initially planned were installed and operated within a 22-85% state-of-charge (SOC) window. After several months, one battery failed due to aging, and by November 2020, eight batteries could no longer be used because their SOC levels were too low. The SOC window was subsequently adjusted to 30%-85% for the remaining five batteries. In April 2021, three additional batteries were added, increasing the capacity to 120 kWh.

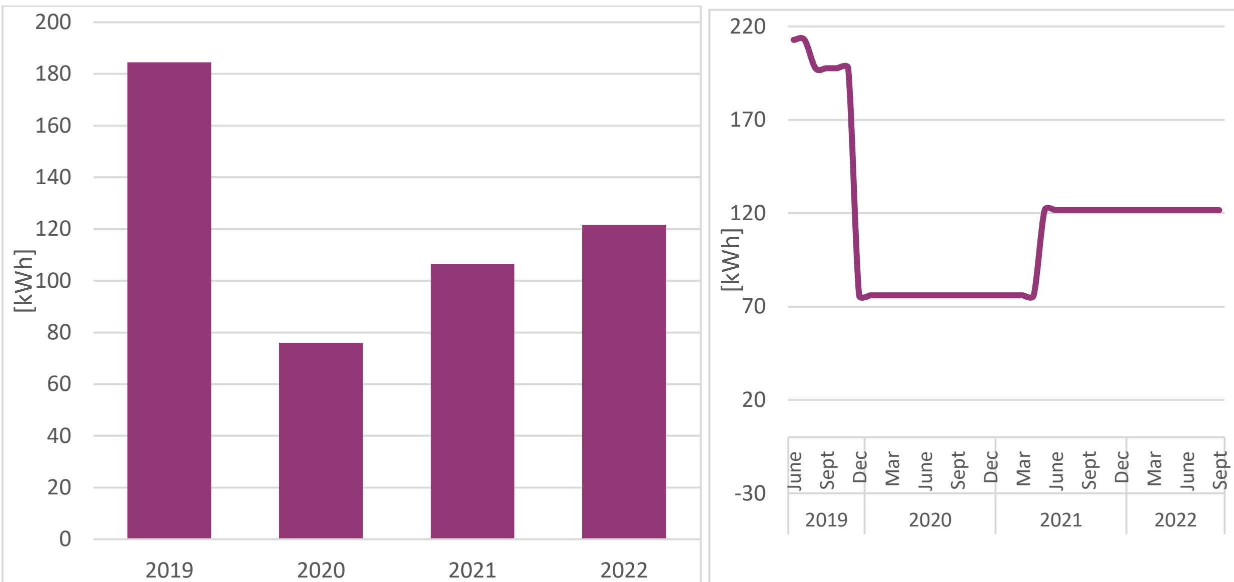


*Figure 98: Results for KPI 42: Storage capacity installed, yearly (left) and monthly (right). Target was 200 kWh.*

At the completion of the IRIS project, it was not possible to determine the battery degradation rate per year due to lack of data. However, a parallel project conducted by researchers at Chalmers is close to finalizing their findings, with initial results indicating a degradation rate of approximately 5% per year.

The demonstration has shown that bus batteries are useful in this type of stationary application, and the stakeholder Volvo has stated that the demonstration verified the technical feasibility of this type of application. For more information about their experience, refer to D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

# 6.3 TT3 Intelligent mobility solutions

This transition track aims to integrated urban mobility solutions increasing the use of environmentally friendly alternative fuels, creating new opportunities for collective mobility and lead to a decreased environmental impact.

In Gothenburg a new Mobility as a Service (MaaS) concept called EC2B ("Easy to be" or "Easy to B"), has been implemented in two different contexts. In measure 3.1 EC2B was implemented for residents in the 132 apartments in housing association Brf Viva in Gothenburg, where no private car parking is available. In measure 3.2, the EC2B concept was adjusted to cater for the needs of employees in the campus area of Johanneberg.

## 6.3.1 Results of the KPIs for TT3

The result of the aggregate measures:

*Table 47: KPI results for TT3*

| KPI | Target | Result | Measures |
|---|---|---|---|
| **Carbon dioxide Emission Reduction [tonnes $CO_2$e/year]** | 208 | ~87,3 for 3.1 | M3.1 and M3.2 |
| **Reduction in driven km by tenants and employees in the district [km/year]** | 1 360 500 | 507 870 for 3.1 | M3.1 and M3.2 |

The Grant Agreement target for TT3 Intelligent mobility solutions for Gothenburg:

- Direct $CO_2$ reduction 1040 tonnes in 5 years;
- (ii) Car mileage among tenants and employees in the district reduced by 1 360 500 km/year
- (iii) Yearly, 904 000 km are made through EC2B (car-sharing, public transport etc) instead of with private, conventional cars.

The targets for $CO_2$ reduction on the TT level has not been reached for several reasons. Mainly, just measure 3.1 delivered results to this aggregation. No measurable result for measure 3.2 has been available, as the use of the service during the demonstration period has been nearly absent which can be explained by the ongoing pandemic and associated restrictions. Likewise, Measure 3.1 did not achieve its desired goal entirely, as there was a higher-than-anticipated number of tenants in BRf Viva who chose to keep their own cars, leading to a shortfall in the plant target.

The result for the reduction in driven km by tenants was higher than expected for measure 3.1. according to the Partners. The target from the Grant Agreement been not reached as measure 3.2 have not generate results and could not be included.

The third target of the Grant Agreement, Yearly 904 000 km are made through EC2B, was originally expected as a result for measure 3.2 as it was planned in the Grant Agreement. But the changes made for this measure (described under Measure 3.2) and the implementation during the Covid pandemic provide us no results for this target. Therefore, the target was not reached under these circumstances.

### 6.3.2 Measure 3.1: EC2B for tenants in Brf Viva

The Mobility as a Service (MaaS) concept "Easy to be" (EC2B) offers customers an attractive alternative to owning their own car, allowing easy access to a variety of transport modes (e-cars, e-bikes, public transport etc) in connection to where customers live or work. In measure 3.1 EC2B is implemented for tenants in the 132 apartments in Brf Viva in Gothenburg, where no private car parking is available.

Residents had exclusive access to 3 electric cars (Renault Zoë), 1 light e-vehicle "Zbee", 3 electric cargo bikes and 4 electric bikes, as well as charging infrastructure for all types of e-vehicles (55 charging poles for e-bikes, 6 for e-cars and 2 for light e-vehicles). Measurement was implemented in December 2018. To access the e-bikes and light e-vehicles, an electronic key cabinet has been installed which is opened using the EC2B app. The EC2B app was launched in February 2019.

*Figure 99: E-cars being charged in car port at Brf Viva*

*Figure 100: Some of the shared electric bikes in Brf Viva, including both ordinary e-bikes and cargo bikes. Helmets can also be borrowed*

The data for the measure have been provided by Trivector.

The KPIs used to evaluate this measure are listed in Annex 7.3.1 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the project partner and used to establish the KPIs is also listed. The KPIs results are listed in the table below.

#### *6.3.2.1 Results for Measure 3.1*

*Table 48: KPI results for Measure 3.1 EC2B for tenants in Brf Viva*

| KPI | 2019 | 2020 | 2021 | 2022 | GA-Target |
|---|---|---|---|---|---|
| **Carbon dioxide Emission Reduction (ton/year) IRIS-SE** | 86 | 86.9 | 89 | | 1040 tonnes reduction in 5 years for M3.1 and M3.2 which corresponds to 208 tonnes per year |
| **Carbon dioxide Emission Reduction (ton/year) Recent** | 80,6 | 79,9 | 77,8 | | |
| **Reduction in car ownership among tenants** | 32 | 32 | | 36 | |
| **Reduction in driven km by tenants (km)** | 507870 | 507870* | 507870* | 507870* | 1360500 km/year car mile reduction among tenants and employees in the district for measure 3.1 and 3.2 |
| **Yearly km driven in e-car sharing systems** | 29070 | 37744 | 56510 | | |
| ***Ease of use for end users of the solution*** | Results from 2019 shown in Figure xx | | | | |

*The reduction in km driven by tenants was only measured in 2019 and assumed to be the same during the other years.

The results for KPI 12 Ease of use for end users of the EC2B solution, indicates that the majority of users find the solution in BRF Viva to be slightly challenging to very easy to use, see Figure 101. For more details on the usage and satisfaction of the EC2B service, read D9.7

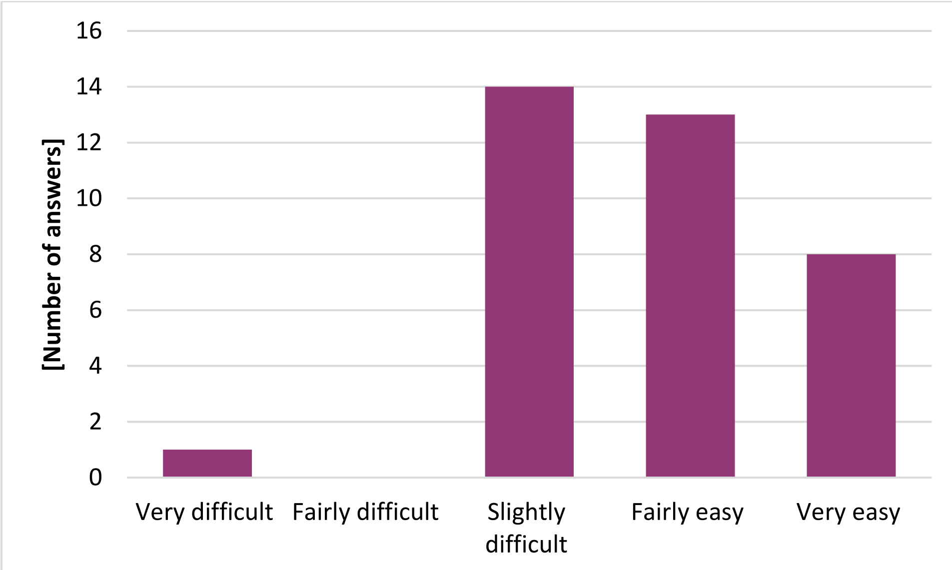


*Figure 101: Results for KPI 12: Ease of use for end users of the solution, values for 2019*

The result for KPI 39 Reduction in driven km by tenants after they moved into Brf Viva building was 507870 km per year based on measurement from 2019, which was nearly a reduction of 46% to the baseline. This reduction was 22% higher than expected. This positive result that less km had been driven than expected is explained with the fact that no private car parking is available for the tenants. This gives a higher barrier to use the car as it is not parked close by the building and if the car is used trips are more planned and combined. More information can be found in D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

The result of the KPI 46 kilometers driven in car sharing system (*Figure 102)* shows that driven kilometers increase over the years. To a certain extent, this is probably an effect of the pandemic, where some trips were shifted from public transport to shared cars due to recommendations from authorities to avoid public transport. However, based on Trivector's experiences from other cases, it is also likely that usage of the shared cars would increase gradually as more residents get accustomed to the service.

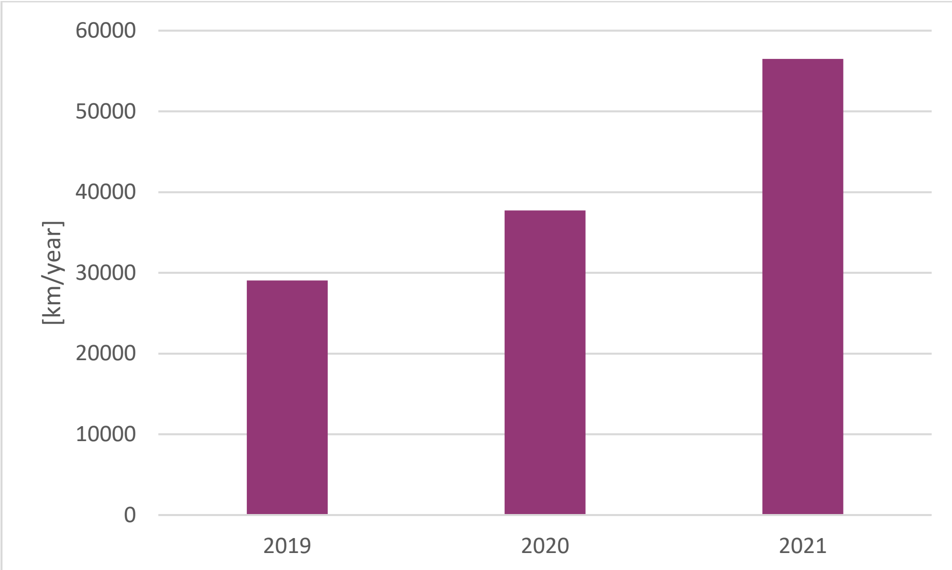


*Figure 102: Results of KPI 46 for M3.1, kilometers driven in car sharing system per year.*

The calculation of the reduction in $CO_2$ emissions is determined by the decrease in kilometers driven by tenants, as well as the utilization of electric cars from the sharing system, as compared to the baseline. For further details on the methodology used for calculating the reduction in $CO_2$ emissions, please consult Annex 7.1 for the KPI card 5. The KPI cards in the Annex explain the aim, scope and formular for each KPI used in the Iris project.

Figure 103 illustrates a discrepancy between IRIS-SE and the Recent data. The $CO_2$ emission reduction in IRIS-SE is determined by using the $CO_2$ emission factors of average Swedish cars from 2015, which were utilized in the Grant Agreement calculation. In contrast, the Recent result is based on the $CO_2$ emission factor from 2019 to 2021, for average Swedish cars according to the environmental report of the Swedish Traffic agency [16], these factors can be as well found in Annex 7.3. As the $CO_2$ emission factor for Swedish cars has decreased over the years, the $CO_2$ reduction observed in the Recent figures is lower than that in IRIS-SE, as the latter calculation relies on the original assumptions from the Grant Agreement. The target in the Grant Agreement for the $CO_2$ emission reduction was set for measure 3.1 and 3.2 together. The Partners have also noted that the initial assumption for measure 3.1 was a reduction of 131.4 tonnes/year in $CO_2$ emissions. However, this target was not reached as the number of tenants in BRf Viva owning a care has been higher than expected. The assumption in the Grant Agreement were based on that less tenants in BRF Viva would own a car.

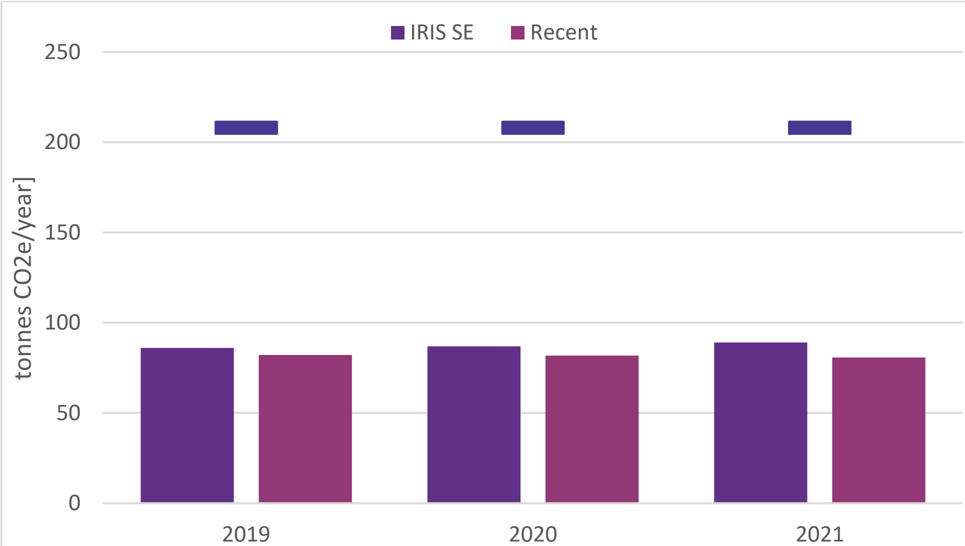


*Figure 103: Results for KPI 5 $CO_2$ emission reduction yearly and the target, which was set for both M3.1 and M3.2.*

### 6.3.3 Measure 3.2: EC2B for employees on Campus Johanneberg

The plan in the Grant Agreement was to implement a lighter version of the service offered to all end users in the campus area (15 000 people). However, after consultation with property owners and employers, they decided to create a more advanced mobility-as-a-service (MaaS) solution targeted specifically at employees in the campus area. Four mobility hubs were established on the campus, incorporating e-cars, e-bikes, public transportation, and the EC2B service, which launched in November 2020. All expenses for business trips made through the EC2B service were compiled on a monthly invoice, making it easier for both the employer and the employee. However, due to Covid-19 restrictions, usage of the service has been minimal.


*Figure 104: To the left sign in the campus area explaining the mobility hub concept and where to find the mobility services included. To the right, shared e-bikes at one of the hubs.*

The data for the measure have been provided by Trivector.

The KPIs used to evaluate this measure are listed in Annex 7.3.2 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the project partner and used to establish the KPIs is also listed. The KPIs results are listed in the table below.

### 6.3.3.1 Results for Measure 3.2

*Table 49: KPI results for Measure 3.2 EC2B for employees on Campus Johanneberg.*

| KPI | 2019 | 2020 | 2021 | GA Target |
|---|---|---|---|---|
| **Yearly km driven in e-car sharing systems** | | | 11,5 | |
| **Ease of use for end users of the solution** | Results from 2019 shown in Figure 105 | | | |
| **Improved access to vehicle sharing solutions** | Results from 2019 shown in Figure 106 | | | |

The KPIs for measure 3.2 have not been calculated as the use of the service during the demonstration period has been almost completely absent due to low usage, which can be explained by the ongoing pandemic and associated restrictions. Summarized 39 individuals completed the survey, and out of those, only 28 individuals downloaded the app and participated in the trial. In total, 108 trips were made, and 74% of them were bike trips.

The survey based KPI results are presented in the figures below.

The result of KPI Ease of use for end-user of the solution show the majority of respondents rated the ease of use of the solution as slightly difficult to very easy, with only two respondents rating it as difficult or very difficult, see Figure 105. For more information on the user satisfaction on usage, please see D7.9 *Final report on Gothenburg lighthouse demonstration activities*.

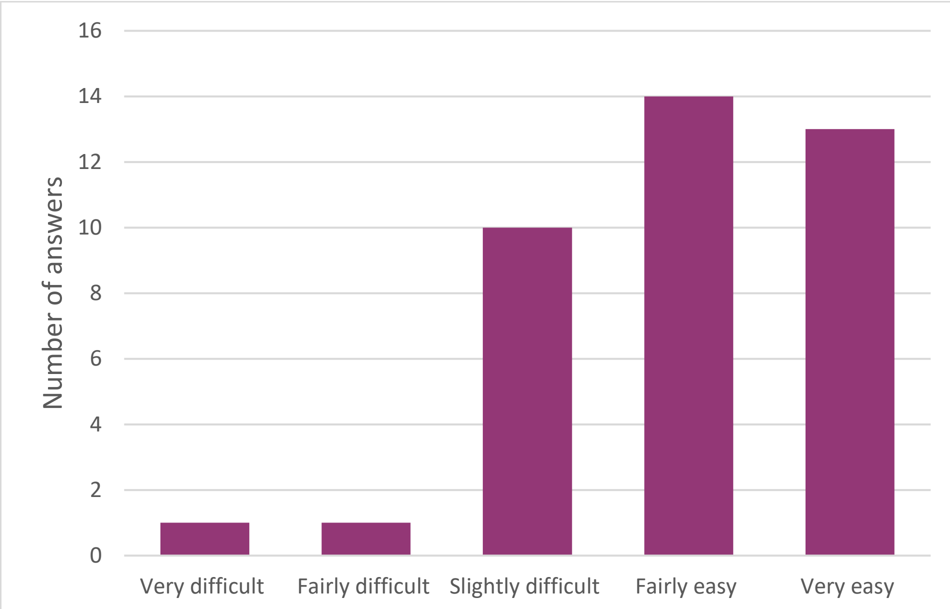


*Figure 105: Results for KPI12: Ease of use for end users of the solution, values for 2019*

Figure 106 displays the results for KPI Improved access to vehicle sharing solutions, which indicate that a significant majority of respondents reported that the service had enhanced their access to vehicle sharing solutions. The survey results also reveal that less than 50% of the participants were satisfied with their mobility solutions before they tried the demonstration. The partners noted that curiosity was the primary reason for participation in the demonstration. Bike sharing emerged as the most popular service; however, due to the limitations caused by the pandemic (e.g., fewer business trips, avoidance of public transport), it is challenging to draw any firm conclusions regarding the usage of car sharing and public transport. For more information about this measure see D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

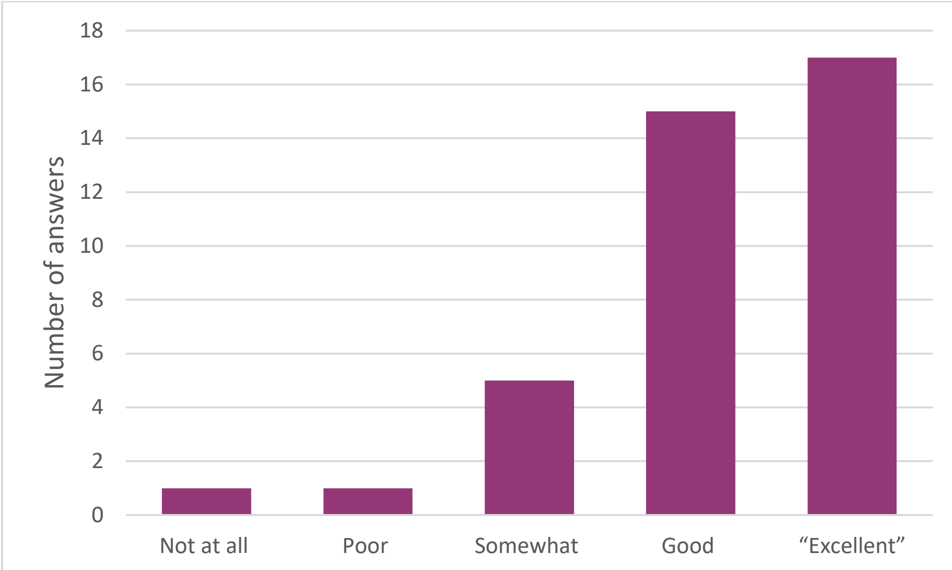


*Figure 106: Results for KPI 16: Improved access to vehicle sharing solutions, values for 2019*

# 6.4 TT4 Digital transformation and services

The TT4 aims to demonstrate the integration of the latest generation ICT solutions with existing city platforms over open and standardized interfaces enabling the exchange of data for the development of new innovative services.

There are two different measures for TT4 in Gothenburg. Measure 4.1 the CIM pilot project which is an implementation of tools for collecting and sharing of data from building projects with support by FIWARE components. The main collected data is BIM data – Building Information data. Measure 4.2 The EnergyCloud has been implemented and is a local version of a cloud for collecting data within the energy system. The local system has been delimited to three universities and their Landlords in the Gothenburg region.

## 6.4.1 Results of the KPIs for TT4

| KPI | Target | Result | Measure |
|---|---|---|---|
| **Open data-based solutions** | >5 | 0 | M4.1 |
| **Open data-based solutions** | >5 | 1 | M4.2 |
| **Quality of open Data** | 100% | 100% | M4.1 |
| **Quality of open Data** | - | - | M4.2 |

The Grant Agreement target for TT4 digital transformation and services for Gothenburg:

- Number of new applications using the CIM (target: >5)
- Number of new applications using the Energy Cloud (target: >5),
- Peak shaving for the Chalmers Campus Area (target >80 % peak power reduction).

The Grant Agreement set a target for the CIM and Energy Cloud projects to develop more than 5 new applications using their respective platforms. However, this target has not been achieved due to various reasons, which are explained in the following paragraphs for each measure.

Moreover, according to the Grant Agreement, the Energy Cloud project aimed to attain an 80% peak power reduction for the Chalmers Campus Area. However, due to changes in the measure during the project, the target could not be pursued, and its progress could not be monitored.

## 6.4.2 Measure 4.1: CIM - City Information Model

CIM, or City Information Model, is a concept similar to BIM (Building Information Model) used in building processes. A BIM model collects and organizes all information about a building in a 3D model. In comparison, CIM can be seen as a BIM for an entire city. The CIM pilot in TT4.1 was implemented to test the theory that if the city starts collecting BIM data from all its buildings, it can eventually build a CIM. The pilot aimed to collect and share data from building projects through third-party apps to engage citizens in projects. The pilot was tested with data from the reference project "Hisingen bridge," located in Gothenburg. An innovation challenge based on the CIM pilot was originally planned, but it was cancelled due to a lack of building data and confidentiality concerns. For more information read D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].


*Figure 107: Map over areas for CIM pilot demonstration*

The data for the measure has been provided by trafik kontoret of Gothenburg Municipality

The KPIs used to evaluate this measure are listed in Annex 7.4 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the project partner and used to establish the KPIs is also listed. The KPIs results are listed in the table below.

#### 6.4.2.1 Results for Measure 4.1

*Table 50: KPI results for Measure 4.1 CIM- City Information Model*

| KPI | 2020 | 2021 | Target |
|---|---|---|---|
| **Open data-based solutions** | 0 | 0 | Number of applications using the API are more than 5 |
| **Quality of open Data** | 100% | 100% | 100% of Data Sets in CIM pilot are DCAT compliant. |
| **Advantage for end-users** | Result figure xx | | |
| **Ease of use for end users of the solutions** | Result figure xx | | |

The target has been reached for KPI Quality of open data but not for the KPI open data-based solutions. This is mainly since the CIP was not implemented as it was planned. The primary objective of the CIM pilot was to automate the collection and storage of BIM data in a structured and clearly defined manner, with the aim of sharing it with stakeholders via the City Innovation Platform. While a test implementation was carried out, the pilot had limited data and was unable to be shared as originally intended. This was due to high barriers for implementing the CIM pilot, which are detailed in D7.9 *Final report on Gothenburg lighthouse demonstration activities*. Consequently, the planned innovation challenge was not pursued, resulting in a KPI of "Open Database solutions" of 0, which is far below the target of >5 as outlined in the Grant Agreement. The innovation challenge was intended to encourage the development of new applications based on the CIM data.

The Urban Transport Authority (UTA) personnel evaluated the CIM pilot, resulting in the measurement of two additional KPIs: "Advantages for end users" and "Ease of use for end users of the solution". The Figure 108and Figure 109 show the results.

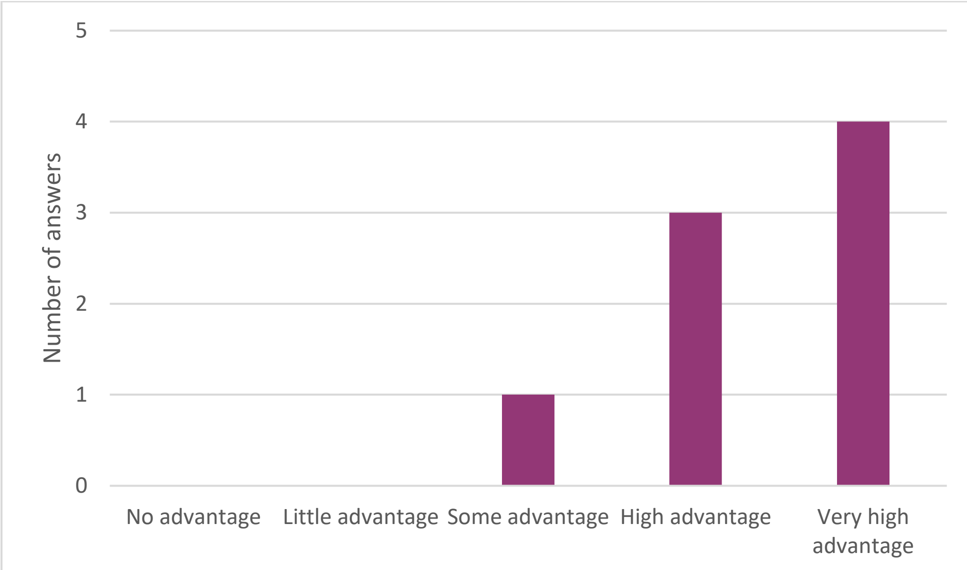


*Figure 108: Results for KPI 3: Advantages for end-users in 2020 for the CIM pilot*

According to the results of KPI 3 Advantages for end users, the majority of respondents reported experiencing high to very high advantages with the CIM pilot.

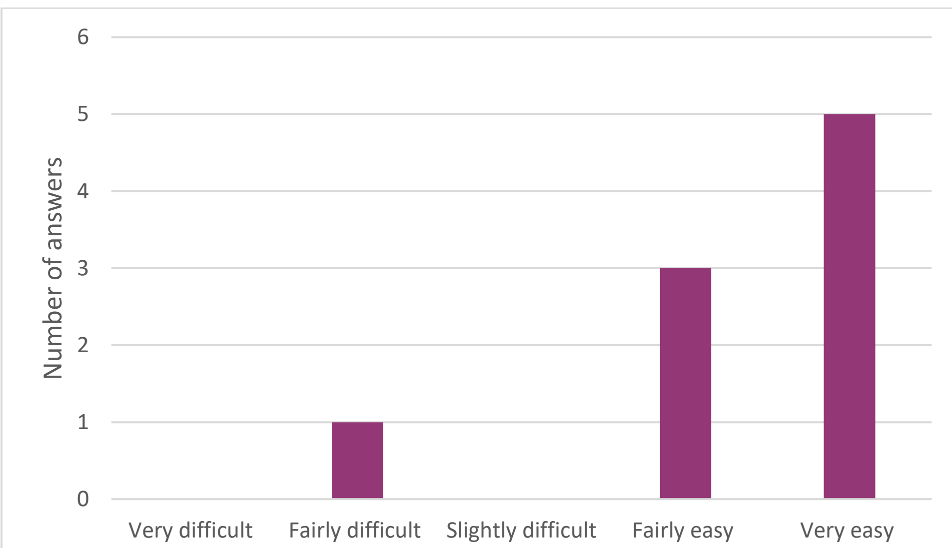


*Figure 109: Results for KPI 12: Ease of use of end users of the solution, values for 2020 for the CIMPilot*

Based on the results of KPI 12 Ease of use for end users of the solution, it was found that the majority of the solutions in the CIM pilot were rated as fairly to very easy to use, with only one solution being identified as fairly difficult. It is worth noting that the number of responses received was greater than the number of evaluators since they were asked to evaluate different parts of the solutions separately.

The partner involved in the pilot acknowledged the potential of the pilot tools, but also noted that there is still a long way to go before they can be considered fully usable in practice.

### 6.4.3 Measure 4.2: Energy Cloud

The EnergyCloud project is focused on developing a localized version of a system that demonstrates the possibility of sharing and quality-assuring structured energy data within the energy system. The scope of the project has been limited to three universities and their landlords in the Gothenburg region.

The project aims to create structured clouds of energy data that can be utilized by all relevant stakeholders, including entire cities, to create new value propositions and make better use of energy data.


*Figure 110: EnergyCloud demonstrator situated in Chalmers Campus Johanneberg.*

The data for the measure have been provided from Metry.

The KPIs used to evaluate this measure are listed in Annex 7.4 together with the related parameters, data sources, baselines, and targets. In this annex the measurement data, obtained from the project partner and used to establish the KPIs is also listed. The KPIs results are listed in the table below.

#### 6.4.3.1 Results for Measure 4.2

*Table 51: KPI results for Measure 4.2 Energy Cloud*

| KPI | 2020 | 2021 | Target |
|---|---|---|---|
| **Open data-based solutions** | 1 | 1 | Number of applications using the REC compliant datasets in the Energy Cloud demonstrator are more than 3. |
| **Quality of open Data** | 0% | 0% | 100% of DataSets in Energy Cloud demonstrator are REC compliant. |

The result for KPI open data-based solution integrated in the eEnergy cCloud is 1. According to the partners this is because data is not stored in an Energy Cloud, which would make it easy to add new services. Initially, the project aimed to connect additional applications from other regions to the Energy Cloud platform, but this objective has not been achieved.

The result for the KPI quality of open data for the Energy Cloud is 0. The explanation of the partners is that regarding this KPI, the quality measurement is related to the use of the REC (Real Estate Core) standard. However, the quality issues experienced in this project are not related to any standard and cannot be solved simply by using a standard. If data is incomplete, missing, or contains incorrect values, no standard structure can resolve these issues. Therefore, using 100% REC data for measuring the quality of open data can be misleading.

## 6.5 TT5 Citizen Engagement and Co-Creation

The aim of TT5 is to demonstrate active citizen engagement solutions providing an enabling environment for citizens to participate in co-creation, decision making, planning and problem solving with the Smart Cities.

Transition Track 5 of the City of Gothenburg involved engaging citizens through various civil society dialogues, including the use of Minecraft as a digital tool to involve younger citizens in the development of detailed plans for specific areas. The Inclusive Life Challenge was developed as an arena for collaboration between the city and its citizens, while the Min Stad (My City) platform has been in use since 2012 to strengthen citizen engagement and was further developed. The ME-model (Citizen Engagement Model) is a framework integrating the experience and learning from Minecraft, Inclusive City Life Challenge, and Min Stad. In addition, within the Personal Energy Threshold project the so called Ero application was developed and demonstrated in the HSB Living Lab to encourage tenants to be mindful of their energy use.

### 6.5.1 Result of KPIs for TT5

The KPIs outlined in the Grant Agreement stated below cannot be applied to the measures implemented in the transition track due to changes made in the TT. However, it can be reported that the Life challenge involved 100 students who generated 180 different ideas, with 18 ideas being further developed. Additionally, approximately 100 students participated per Minecraft event in schools, resulting in a total of 200 participants. The digital platform, Min Stad 2.0, was created to investigate how it could function as a tool for dialogue between the city and its citizens regarding urban development. The platform was utilized to engage citizens in the district where planned changes were taking place.

The Grant Agreement target for TT5 Citizen Engagement and Co-Creation for Gothenburg:

- Number of participants in spatial planning contest (target: >100),
- inflow of ideas for “Green Life” contest (target: 200),
- infrastructure added to “Min Stad” (>25 % of existing infrastructure in the district).

### 6.5.2 Measure 5.1-5.2 Min stad and Min Stad 2.0 as a tool for citizen engagement

The city of Gothenburg created "Min Stad" (My City) as a website in 2012 and later launched it as a mobile app. The app serves several purposes for the city, including an idea inbox for citizens to suggest improvements, visual information sharing for the city to display infrastructure projects, and story sharing for users and the city to share historical facts about locations within the city. The app features a 3D-map of the city where users can view and create posts, of which there are over 1400 from citizens, often short comments about issues or suggestions for improvements. Although not originally intended for dialogue between citizens and the city, this was added in a new version of Min Stad, called Min Stad 2.0. This version was used to facilitate dialogue during the consultation of a planning program for a district in the northeast of Gothenburg, Hjällbo. The citizens and planners could view a 3D model of the proposed plan on iPads and provide feedback through the app.

Data for the measure have been provided by the municipality of Gothenburg.

The KPIs that have been selected to assess the success and suitability of this measure are summarized in the table.

### 6.5.2.1 Result for Measure 5.1 Min Stad and 5.2 Min Stad2.0

*Table 52: KPI results for Measure 5.1 Min Stad and 5.2 Min Stad2.0*

| KPI | | Min Stad (from start to 2020) | Min Stad 2.0 (from 2020 to 2022) |
|---|---|---|---|
| **Participatory governance** [10-point rating scale where 0-10% is 1 and 90-100% is 10.] | **Result:** | **1: 0-10%** | **1: 0-10%** |
| | Partner motivation: | Available for everyone who had a facebook account and downloaded the Min Stad app. | Available to anyone with an e-mail address and downloaded the Min Stad 2.0 app. Individuals who participated in the Hjällbodagen event, where the city presented development ideas, and used the tablets provided were also able to access the Min Stad 2.0 app. |
| **Local community involvement in planning phase** [5-point rating scale from 'no involvement' to 'high involvement'] | **Result:** | **2: Low involvement (quantity)** | **2: Low involvement (quantity)** |
| | Partner motivation: | but high engagement from few individuals | but high engagement from few individuals |
| **Representation of concerned citizens in city development participation efforts** [5-point rating scale from 'no representation' to 'excellent representation'] | **Result:** | **2: Low representation (in total)** | **2: Low representation (in total)** |
| | Partner motivation: | The individuals who used the app demonstrated engagement within the areas they lived, worked, or traveled between. | The individuals who used the app demonstrated engagement within the areas where they lived. |
| **Congruence of expected and actual outcome of local community involvement in city development** [3-point rating scale from 'significant incongruence' to 'congruence'] | **Result:** | **1: Significant incongruence** | **2: Some congruence** |
| | Partner motivation: | Previously, there was no clear purpose for implementing the ideas generated through the Min Stad app. However, the app is now being utilized in a more purposeful manner to promote community involvement in city development. | Min Stad 2.0 was purposefully utilized during the Hjällbodagen event to involve the local community in the planning of development ideas for the area. |
| **Potential for attractive and inclusive services through co-design** [5-point rating scale from 'no potential' to 'very high potential'] | **Result:** | **4: High potential** | **4: High potential** |
| | Partner motivation: | The ideas presented by the users were relevant and insightful for the local community | The ideas presented by the users were relevant and insightful for the local community |
| **The co-creation tools' ability to engage citizens** [3-point rating scale from 'low ability to engage' to 'high ability to engage'] | **Result:** | **2: Moderate ability to engage** | **3: High ability to engage** |
| | Partner motivation: | This version of the Min Stad app demanded a Facebook account. | The app can be accessed by individuals who have an email address, or who participate in events and activities that are part of the city's development plan. |
| **Organizational readiness for citizen co-creation** [3-point rating scale from 'low readiness for citizen co-creation' to 'high readiness for citizen co-creation'] | **Result:** | **1: Low readiness** | **3: High readiness** |
| | Partner motivation: | Initially, there was no specific intention or preparation related to the Min Stad app. It was primarily intended to serve as a platform for dialogue between citizens. | Min Stad 2.0 is closely linked to the development plans of the city. |

The KPIs results and the motivation of the partner above in Table 52 give a clear picture to what extend Min Stad and Min Stad 2.0 as tools can be used to engage citizens. The KPI “Potential for attractive and inclusive services through co-design” was rated as high potential as the ideas presented by the user were insightful and relevant for the local community. Furthermore, the KPI Organizational readiness for citizen co-creation shows that this increase from Low readiness for Min Stad to high readiness for Min Stad 2.0 as now the app is closely connected to the city development plants. The KPI The co-creation tools’ ability to engage citizens was also increased from moderate ability to engage to high ability to engage after the development of the app into Min Stad 2.0.

Min Stad and Min Stad 2.0 focused on citizen engagement. It is challenging to indicate higher levels/stronger citizen engagement such as trust with quantitative measures, since more participating citizens do not necessarily mean more engaged citizens. But the activities generated high engagement from the participating citizens, which enabled dialogues building trust and understanding. These dialogues are essential for building long term citizen engagement. For more detailed information see chapter 6 of D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

### 6.5.3 Measure 5.3 Inclusive Live Challenge

The Inclusive Life Challenge is a concept that aims to create a collaborative platform for the city and its citizens to work together towards greater inclusion in the city's development. In one implementation of the concept, 100 students from Chalmers University of Technology in Gothenburg participated in an eight-week course called Leading in a Digital World, where they worked in teams to develop innovative solutions for the City of Gothenburg. Each team selected an innovation focus area and geographical location and collected market information and open data to develop their ideas, engaging with stakeholders through dialogues. Due to pandemic restrictions, the final Innovation pitch posters were presented online instead of at an exhibition area in the city, where the teams pitched their digital innovation solutions to the City of Gothenburg's jury, citizens, faculty, and fellow students. The ideas focused on reducing food waste, improving mobility and air quality, water use management, a student accommodation platform, waste sorting, and connected urban farming. For more information see D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

Data for the measure have been provided by the Chalmers University of Technology

The KPIs that have been selected to assess the success and suitability of this measure are summarized in the table below.

### 6.5.3.1 Result for Measure 5.3 Inclusive Life Challenge

*Table 53: KPI results for Measure 5.3 Inclusive Life Challenge*

| KPI | | Inclusive Life Challenge |
|---|---|---|
| **Participatory governance** [10-point scale where 0-10% is 1 and 90-100% is 10.] | **Result:** | **1: 0-10%** |
| | Partner motivation: | Available for everyone who saw the voting platform at City of Gothenburg's homepage |
| **Local community involvement in planning phase** [5-point rating scale from 'no involvement' to 'high involvement'] | **Result:** | **2: Low involvement** |
| | Partner motivation: | The task for the students was to involve a few stakeholders i.e., to talk to people that have an interest in their idea |
| **Representation of concerned citizens in city development participation efforts** [5-point rating scale from 'no representation' to 'high representation'] | **Result:** | **2: Low representation** |
| | Partner motivation: | The task for the students was to talk to people that have an interest in their idea to understand their needs |
| **Potential for attractive and inclusive services through co-design** [5-point rating scale from 'no potential' to 'very high potential'] | **Result:** | **4: High potential** |
| | Partner motivation: | The purpose of the course is not to co-design services per se (not in the in-depth involvement and designing together meaning) but rather to involve potential users and other stakeholders in the design by talking to them. |
| **The co-creation tools' ability to engage citizens** [3-point rating scale from 'low ability to engage' to 'high ability to engage'] | **Result:** | **2: Moderate ability to engage** |
| | Partner motivation: | Given the purpose of the course engagement with a high number of citizens is limited. |
| **Organizational readiness for citizen co-creation** [3-point rating scale from 'low readiness for citizen co-creation' to 'high readiness for citizen co-creation'] | **Result:** | **3: High readiness** |
| | Partner motivation: | The engagement from the City of Gothenburg to set up the student projects addressing the "Inclusive life |

The KPIs results and the motivation of the partner above in Table 53 give a clear picture to what extend the Inclusive life challenge can be used to engage citizens. As the responsible partner state, it is challenging to indicate higher levels/stronger citizen engagement such as trust with quantitative measures, since more participating citizens do not necessarily mean more engaged citizens. The KPIs result shown as well that there has been seen a high potential to be used for co-designing the city as well as attractive and inclusive services. Furthermore, they evaluate that the City of Gothenburg has a high readiness in the Organization for citizen and co-creation. Additionally, the partner summaries that the Inclusive Life Challenge activity had three main modes of engagement for citizens, namely:

- Course participants: The 100 students who participated in the course and collaborated with the City of Gothenburg on their live case projects were highly engaged. This was because they were addressing issues in their own community, which had a positive impact on their learning and understanding of the city's challenges.
- Stakeholder representatives: To develop digital solutions for these challenges, the students had to involve citizens in the process. Although the number of interviews conducted was small, the perspectives gathered were significant.
- General public: The citizens had the opportunity to vote for their preferred ideas on the city's website, which allowed them to participate in the process and show their support.

### 6.5.4 Measure 5.5 Minecraft as tool for citizen engagement

Measure 5.5 aimed to explore the potential of using the Minecraft tool as a means of engaging children in a citizen dialogue for the planning project. A total of 6 workshops were conducted across 2 different schools, Bergsjöskolan and Lärjeskolan, with more detailed information available in D7.9 *Final report on Gothenburg lighthouse demonstration activities*, chapter 6 [5]. The objective was to gain a better understanding of how effectively the tool can aid in comprehending the planning process and its various perspectives, as well as generating issues that can serve as a foundation for in-depth discussions. The primary goal of the workshops was not to acquire knowledge for the planning process but rather to evaluate and test Minecraft as a dialogue tool.

Data for the measure have been provided by the municipality of Gothenburg.

The KPIs that have been selected to assess the success and suitability of this measure are summarized in the table below.

### 6.5.4.1 Results for Measure 5.5

*Table 54: KPI results for Measure 5.5 Minecraft as at tool for citizen engagement*

| KPI | | Minecraft **(events outside of school hours)** | Minecraft 2.0 **(events within school hours)** |
|---|---|---|---|
| **Participatory governance** [5-point rating scale from 'no representation' to 'excellent representation'] | **Result** | **1: 0-10%** | **1: 0-10%** |
| | Partner motivation: | Available for all students at Bergsjöskolan who saw the announcement for the activity after school. | Available for approx. 100 students in total four classes at Lärjeskolan. |
| **Local community involvement in planning phase** [5-point rating scale from 'no involvement' to 'high involvement'] | **Result** | **2: Low involvement (quantity)** | **2: Low involvement (quantity of the local community)** |
| | Partner motivation: | but high engagement from few | but high engagement from few. /. High involvement of the ones invited. |
| **Representation of concerned citizens in city development participation efforts** [5-point rating scale from 'no representation' to 'excellent representation'] | **Result** | **2: Low representation (in total)** | **2: Low representation (in total)** |
| | Partner motivation: | The students who used the app demonstrated engagement within the areas where they lived. | The students who used the app demonstrated engagement within the areas where they lived. |
| **Congruence of expected and actual outcome of local community involvement in city development** [3-point rating scale from 'significant incongruence' to 'congruence'] | **Result** | **3 congruence.** | **3 congruence.** |
| | Partner motivation: | The students were well-informed that the primary purpose was to test a tool. The discussion and realization of ideas were considered as a secondary purpose. | The students were well-informed that the primary purpose was to test a tool. The discussion and realization of ideas were considered as a secondary purpose. |
| **Potential for attractive and inclusive services through co-design** [5-point rating scale from 'no potential' to 'very high potential'] | **Result** | **4: High potential** | **4: High potential** |
| | Partner motivation: | By managing architecture educators, planners, and game educators, the Minecraft app can be used to generate ideas for co-design and facilitate parallel dialogues. | By managing architecture educators, planners, and game educators, the Minecraft app can be used to generate ideas for co-design and facilitate parallel dialogues. |
| **The co-creation tools' ability to engage citizens** [3-point rating scale from 'low ability to engage' to 'high ability to engage'] | **Result** | **1-2: Low-moderate ability to engage** | **1-2: Low-moderate ability to engage** |
| | Partner motivation: | The Minecraft app demanded a special account that is not for free. The developed ideas are only taken care of when the Minecraft session is involved in a workshop and part of an ongoing planning process. | The Minecraft app demanded a special account that is not for free. The developed ideas are only taken care of when the Minecraft session is involved in a workshop and part of an ongoing planning process. |
| **Organizational readiness for citizen co-creation** [3-point rating scale from 'low readiness for citizen co-creation' to 'high readiness for citizen co-creation'] | **Result** | **2-3: Moderate to high readiness** | **2-3: Moderate to high readiness** |
| | Partner motivation: | The engagement from the City of Gothenburg to set up Minecraft as a tool for dialogue was moderate to high. The demand of / needs of the tool is high. The tool is ready to use. But there is a lack of readiness / resources. | The engagement from the City of Gothenburg to set up Minecraft as a tool for dialogue was moderate to high. The demand of / needs of the tool is high. The tool is ready to use. But there is a lack of readiness / resources. |

The KPIs results and the motivation of the partner above in Table 54 give a clear picture to what extend the Minecraft as at tool for citizen engagement can be used. The potential for attractive and inclusive services through co-design been rate as high potential. The partners see the potential in that through the Minecraft app new ideas for co-design can develop and a parallel dialogue can occur. Limits with the Minecraft app has also been identified, as it demanded a special account that is not for free. The developed ideas are only taken care of when the Minecraft session is involved in a workshop and part of an ongoing planning process. Therefore, the KPI regarding the co-creation tools' ability to engage citizens has been rated as low-moderate ability to engage. The readiness of the City Gothenburg to use Minecraft as a tool for dialog was rated as moderate to high, as they could see a lack of resources within the city.

Summarized the experience of the partner using Minecraft as at tool for citizen engagement are stated in the paragraph below for more information read D7.9 *Final report on Gothenburg lighthouse demonstration activities* [5].

The experience gained from using Minecraft as a tool has been rewarding and valuable in engaging children in dialogue projects. This adaptable and open tool can facilitate certain aspects of an investigative and creative process. The children and young people who participated displayed enthusiasm and genErosity in tackling the challenges presented to them.

### 6.5.5 Measure 5.7 Personal Energy Threshold

The demonstration of PET - Personal Energy Threshold was demonstrated in HSB Living Lab. Within the PET project, an application was developed called the Ero application. This provides monitoring energy usage and then giving feedback to users regarding their personal energy consumption, and it was designed for a smart home system in mind that could balance the energy demand and supply. The Ero app had a function called Personal Energy Threshold (PET), a momentary power level showing when there is plenty and/or short of energy in relation to the household's energy consumption. Users of the app were people living in HSB Living Lab. The expected impact was to develop a deeper understanding of the tenants' energy consumption at individual level, and let each individual choose what type of energy source to be used and when. Through the developed application Ero the aim was to nudge individuals to choose "green" energy such as energy from the installed PVs (façade and roof). The cost of the participants energy use was included in the rent. For more information *D7.9 Final report on Gothenburg lighthouse demonstration activities* [5].

#### 6.5.5.1 Results for Measure 5.7

Table 55: KPI results for Measure 5.7 Personal Energy Threshold

| KPI | Results | Partners Motivation |
|---|---|---|
| **Advantages for end-users** [5-point rating scale from 'no advantage' to 'very high advantage'] | **3**: "**Some advantage**: | The project offers some advantage to end users who to a certain extent experience direct benefits from the technologies/principles applied |
| **User engagement** [Number of users] | Number of final users :**7 users** | |
| **Potential for supporting reduced energy-related negative environmental impact** [5-point rating scale from 'negative potential' to 'significant potential'] | **2**: "**Small potential**: | The proposed prototype would have a relatively small impact, whether it be direct or indirect. Typically, a small impact would account for roughly 1-15% of the total energy-related impact in the given activity. |

The ERO app offers users the ability to monitor energy usage and schedule energy-consuming appliances, providing several advantages. However, it is particularly beneficial for those who pay for their electricity, which does not apply to residents at the HSB Living Lab where the app was evaluated. Furthermore, individuals with significant energy use that can be shifted in time, such as those who charge their electric cars, can benefit greatly from Ero.

Another useful feature of Ero is the ability to obtain momentary power thresholds. This is especially helpful as individuals often struggle to determine whether they are doing enough for sustainability in their daily lives. Finally, the function to select preferred sources of energy is also advantageous, as it encourages users to engage with the energy system beyond just personal consumption. However, it is important to note that the impact of such choices would depend on whether energy companies take them into consideration when making decisions.

When implemented in the HSB Living Lab, the Ero app resulted in a KPI of 0, indicating negative potential. This is because the environmental impact of the iPads and smart plugs used with Ero outweighs the potential energy savings, especially given that HSB Living Lab residents typically have low energy consumption in their small apartments. However, this KPI is meant to estimate the potential of early prototypes and ideas. Thus, Ero's potential is considered as small potential, as it could be used on existing devices as energy feedback, which typically results in a 5-15% reduction in energy use.

Reducing peak demand is expected to be easier to achieve using Ero, as the load can be shifted to off-peak hours or reduced. This can lead to greater reductions in environmental impact, as peak energy usage typically has a higher $CO_2$ footprint than energy used during off-peak hours. Additionally, scheduling energy use through Ero can further aid in reducing energy consumption.

Although a 5-15% reduction in energy use is relatively small, it is still considered significant. However, the energy consumption required to run the servers for Ero and other related systems may outweigh the potential energy savings. Thus, the potential for Ero is still considered to be small, with a KPI of 2.

# 7 Results IRIS

*Table 56: Aggregated KPI results for IRIS established using standard IRIS emission factors.*

| KPI | Results | Included measures |
|---|---|---|
| **Carbon dioxide Emission Reduction [tonnes $CO_2$e/year]** | ~3550 | NICE:<br>M1.1 and M1.2<br><br>UTRECHT:<br>M1.1, M1.4, M1.5, M1.7, M1.8, M3.1 and M3.2<br><br>GOTHENBURG: M1.1, M1.2, M1.7 and M2.1 |
| **Increase in local renewable energy production (electrical) [MWh/year]** | ~825 | NICE: M1.1<br><br>UTRECHT:<br>M1.1, M1.4, M1.8<br><br>GOTHENBURG: M1.1, M1.7 and M2.1 |

Two KPIs are aggregated to IRIS- project level, Carbon dioxide Emission Reduction and Increase in local renewable energy production (electrical). The results of these KPIs, established with IRIS standards assumptions, are shown in Table 56 together with the measures that are included in this aggregation from each city. It is worth noting that for the Intelligent mobility solution in Gothenburg, there is no available data for 2022, but the measure is still in operation. To maintain balance, the data from 2021 was used to estimate the reduction in 2022 and included in the aggregation.

The PV installations implemented in the IRIS project have generated an average of 825 MWh of electricity per year during the two-year measurement period. This amount of electricity is enough to cater to the needs of 515 EU citizens, considering that the average household electricity consumption in the EU is 1.6 MWh per year [17]. The production levels are quite evenly distributed among the three cities, as illustrated in Figure 111. The increase in production between 2021 and 2022 is due to inclusion of data from more buildings in Utrecht.

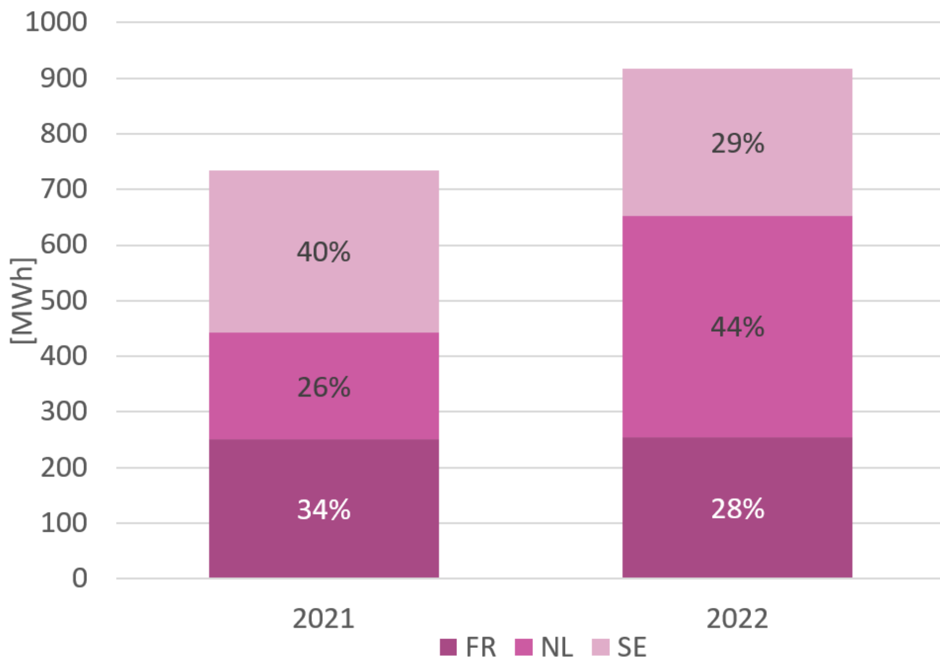


*Figure 111: Total PV-production from the IRIS project and the share of the contribution for the three cities. FR= Nice, France, NL = Utrecht, The Netherlands, SE = Gothenburg, Sweden.*

The implemented measures in IRIS have resulted in a reduction of approximately 825 tonnes of CO2 emissions per year, based on the standard emission factors for each country. Considering that the average $CO_2$ emission per EU citizen in 2019 was 6.8 tonnes per year [18], this reduction is equivalent to the emissions of 520 EU citizens.

The IRIS project involves various measures that lead to emission reduction, including energy savings, renewable energy production, and the adoption of sustainable transportation solutions. In cases where the energy source is altered, the assumptions about the emissions related to the new and replaced energy sources have a significant effect on the outcome.

At city level and transition track level two different sets of emission factors are used called IRIS standard and Recent. The first set is based on standard assumptions which are generally used for the evaluation, for example to obtain the numbers in Table 56. These factors are linked to assumptions made in the project proposal stage and the impact targets set in the Grant Agreement. The Recent emission factors have updated values for grid electricity and conventional and electric vehicles. When aggregating to project level, the EU27 emission factor was included as a third option. This factor accounts for the interconnectedness of the electricity grid and the possibility for import and export over nation boarders. The EU27 factors represents EU generalized emissions for grid electricity as well as electric vehicles.

The different emission factors used for the grid electricity in each country are shown in Figure 112. The IRIS standard emission factors only consider the emission from production of electricity in each country and is set as one value for all years. The Recent emission factors are established for each year, and they also include the emissions from import of electricity [19]. The EU27 emissions included the same aspects as in Recent but is established at the EU27 level [20]. The production of electricity from PV and heat from geothermal heat pumps in the IRIS project are assumed to have zero emissions.

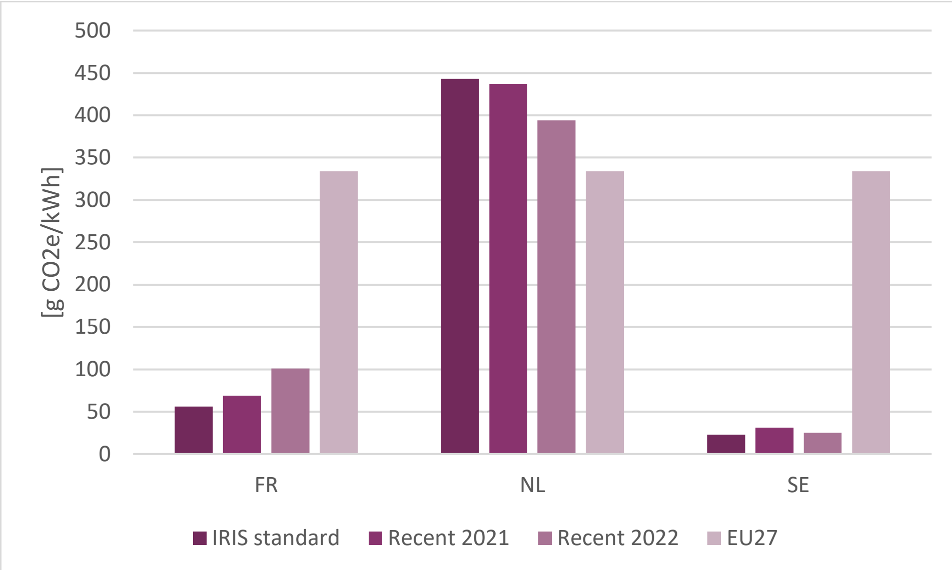


*Figure 112: The different emission factors used for grid electricity in the three countries. FR = France, NL = The Netherlands, SE = Sweden.*

The emission factors used for electric and conventional vehicles are listed in Table 57. The Recent and EU27 values for the electric cars are taken from the same source, listed in the table, and the battery is assumed to be produced in China for all cases but charged with electricity from the respective country/region. The IRIS standard emission factor for Ebuses in the NL is based on the emissions for grid electricity. Because of this proportionality, the EU27 emission factor for Ebuses could be obtained by scaling.

*Table 57: The different emission factors given in [tonnes/km] used for electric and conventional vehicles in The Netherlands (NL) and Sweden (SE).*

| | | IRIS | Recent | | EU27 | | Ref-erence | Assumptions | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2021 | 2022 | 2021 | 2022 | | Recent | EU27 |
| Electric | NL cars | 6,33E-05 | 9,2E-05 | | 8,2E-05 | | [21] | Charge in NL | Charge in EU27 |
| | NL buses | 3,69E-04 | 3,64E-04 | 3,28E-04 | 2,784E-4 | | | Scaled from reference | |
| | SE cars | 5,30E-05 | 5,2E-05 | | 8,2E-05 | | [21] | Charge in SE | Charge in EU27 |
| Conventional | NL cars | 2,24E-04 | 1,93E-04 | | 1,93E-04 | | [21] | | |
| | NL buses | 1,2E-03 | 1,08E-03 | | 1,08E-03 | | | Scaled from reference | |
| | SE cars | 1,63E-04 | 1,43E-04 | 1,20E-04 | 1,43E-04 | 1,20E-04 | [21] | | |

When it comes to emissions associated with electricity there is a large difference between the countries. Figure 112 illustrates that the Netherlands have up to almost 20 times higher emissions per kWh compared to Sweden and 8 times compared to France. These differences decrease in the recent emission factors but still highlight that when a national perspective is applied the impact from a specific solution related to electricity varies greatly within the EU. For the transport sector the emission factors have a much smaller difference between the two countries, with Sweden having ~27% and 60 grams $CO_2$ per km lower emissions for conventional cars and 16 - 40 % and 10 -40 grams $CO_2$ per km for electric cars compared to The Netherlands.

Figure 113 shows that the total $CO_2$ emission reduction achieved by the measures implemented in the IRIS project is highest when calculated using the IRIS standard emission factors. If Recent or EU27 emission factors are applied, the reduction is lower by up to 540 tonnes (15%) and 155 tonnes (4%), respectively. Intelligent mobility solutions have the largest contribution to the emission reduction, accounting for approximately 90% and most of the emission reductions are achieved in the Netherlands, as depicted in Figure 114. The change in the emission factors in the Netherlands therefore largely impacts the aggregated IRIS results. Applying Recent or EU27 emission factors for electricity leads to a decrease in the benefits of PV production from the measures implemented in Utrecht. Additionally, the difference in emissions associated with electric and conventional vehicles is smaller for Recent and EU27 factors compared to standard factors, leading to the highest emission reduction when standard emission factors are used.


*Figure 113: Aggregated results of KPI 5: Carbon dioxide emission reduction at IRIS project level for three different sets of emission factors also showing the percentual contribution of different types of activities.*

Figure 114 shows how much the three different lighthouse cities contribute to the IRIS projects total emission reductions. Measures implemented in the Netherlands contribute with up to 98 %, when standard emission factors are applied and 92 % with the EU27 factors. This can be explained by the fact that the EU27 factors for electricity is substantially higher than the standard national factors of France and Sweden, six and fourteen times higher respectively, while it is 25% lower than the standard one for the Netherlands.


*Figure 114: Aggregated results of KPI 5: Carbon dioxide emission reduction at IRIS project level established using three different sets of emission factors and divided into the contribution of measures from each LHC.*

Figure 115 shows the $CO_2$ emission reduction of the IRIS project, with the intelligent mobility solutions excluded from the graph. This enabling a closer look at the changes in emission reduction from the measures related to renewable energy production and energy savings. For the measure related to renewable electricity production the EU27 emission factors gives the highest reduction and a significant increase for these measures, 55-130% and 110-140 tonnes, while the Recent factors only change the results with ~4% and ~5 tonnes, with values going up in 2021 and down in 2022.

For renewable heat production the use of EU27 emission factors leads to an increase in emissions, displayed as a negative value in the figure below. The increase in emissions is caused by the heat pump in Gothenburg becoming associated with higher emissions per kWh heat than the baseline heat production technology, namely district heating. This means that if a similar heat pump is replicated in another setting, where the electricity grid emissions are equal to, or higher than EU27 averages, like in The Netherlands, the baseline heat source needs to have higher emissions than the ones associated with the district heating network of Gothenburg (~0,06 tonnes/MWh heat). At least if the aim is continuous operation of the heat pump and reduction of $CO_2$ emissions.

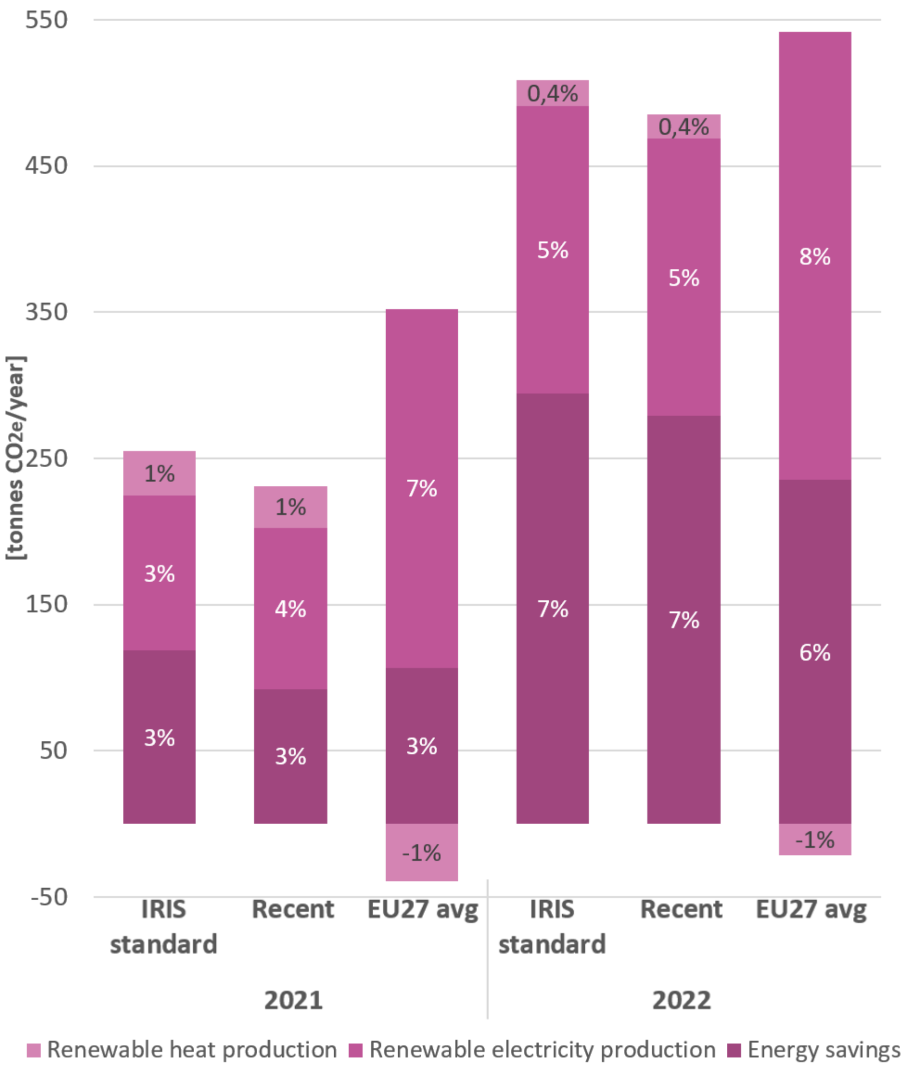


*Figure 115: Aggregated results of KPI 5: Carbon dioxide emission reduction at IRIS project level excluding intelligent mobility solutions.*

The results indicate that the assumed emissions associated with the electricity grid have a significant influence on the outcomes, and that these values differ considerably among the various countries covered by the IRIS project. In contrast to the heating and transport systems, the electricity system is interconnected throughout the EU via the power grid, and various system boundaries can be employed to account for this interconnectivity. Moreover, emissions fluctuate throughout the year, whereas the factors used in this report are annual averages. The sensitivity analysis presented in the following chapter examines the impact of adopting emission factors for the electricity grid calculated at different timescales, which is especially interesting for measures incorporating flexibility.

# 8 Sensitivity analysis

To establish the KPI Carbon dioxide emission reduction, annual average values of greenhouse gas (GHG) emissions associated with grid electricity in the different LHC are used, see Figure 116. These numbers are based on the production in each country. However, since the production technologies used change throughout the year, so do the emissions associated with the electricity from the grid. Furthermore, the impact of import from other countries are not included in these factors. This sensitivity analysis was conducted to demonstrate the impact of different assumptions and time resolution when establishing the GHG emission factor for grid electricity and the potential benefits of flexibility measures, such as battery storage, in shifting the time of use of electricity. The analysis focused on Measure 1.1 in LHC Gothenburg, which involves PV-production in a Swedish setting with access to battery storage.

In this chapter, the term GHG emissions is used to emphasize that the evaluation encompasses other greenhouse gases besides $CO_2$. The KPI Carbon dioxide emission reduction also considers other GHGs that are converted into $CO_2$ equivalents ($CO_{2eq}$) but since the term GHG is widely used and more clearly states that other gases are included this is the term used.

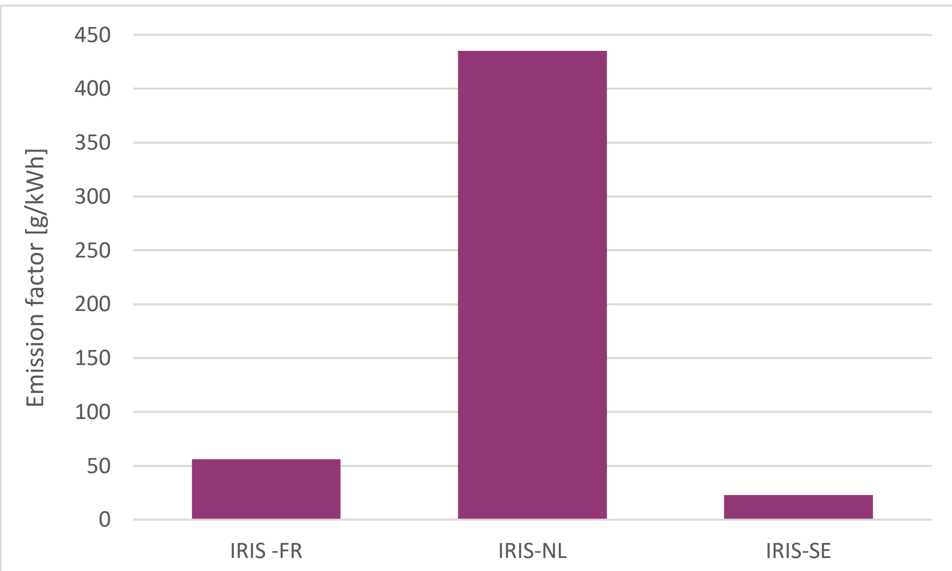


*Figure 116:Standard annual average emission factors based on national electricity production used in the IRIS project. FR = France, NL = The Netherlands and SE = Sweden.*

## 8.1 Method

The GHG emission performance of installing solar PV is quantified, with and without flexibility measures, such as on-site battery storage. The data used for quantifying the impacts is based on the hourly production of solar panels installed in southern Sweden belonging to the SE3 electricity price trading area. The data collected includes the hourly electricity production from the solar panels during one full year (2021).

The resulting GHG performance was calculated from the difference between the emission factor of the installed solar panels, assumed to be 27 g/kWh, and the emission factor of the grid at the time of the electricity being exported to the grid (or consumed). Three different data sources were used to determine the grid emission factors:

1. Hourly electricity production and import data for the SE3 electricity price trading area was obtained from ENTSO-E transparency platform [22], and corresponding emission factors for each source of electricity generation were applied, see Table 58.
2. A marginal electricity production perspective was used to determine the grid emission factor, as determined by Nilsson [23], see Figure 117. This source provides marginal production for the entire Sweden, that is the production capacity operating on the margin. Two values are provided for each season, one for the day and on for the night. This enables quantification of benefits from shifting electricity export from day to night by installing local battery storage.
3. Hourly data was used for grid emission for the entire Sweden, as determined by Electricity Maps [11]. The emission factors for France and the Netherlands were also used to assess the potential benefits in other geographical areas.

*Table 58. Emission factors per source of electricity, adapted from Nilsson, 2022 [23].*

| Source | Emission factor [g/kWh] |
|---|---|
| Biomass | 10 |
| Fossil Gas | 262 |
| Fossil Hard coal | 412 |
| Fossil Oil | 313 |
| Fossil Peat | 440 |
| Hydro Run-of-river and poundage | 10.5 |
| Hydro Water Reservoir | 10.5 |
| Nuclear | 5.9 |
| Other | 313 |
| Other renewable | 27 |
| Solar PV | 27 |
| Waste | 157 |
| Wind Onshore | 14.7 |

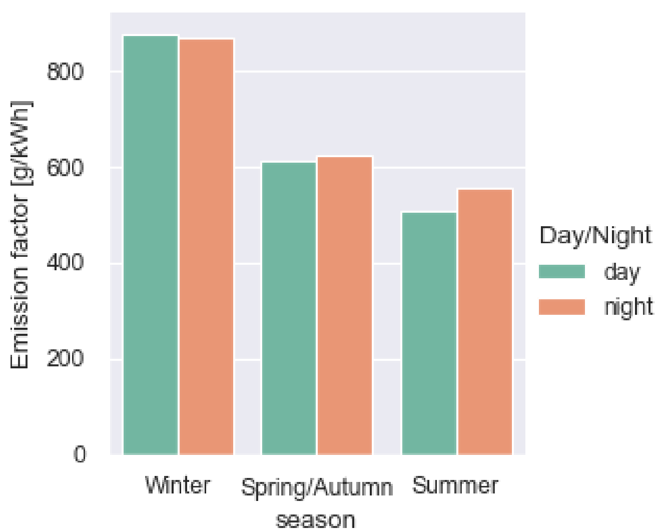


*Figure 117. Marginal emission factor Nilsson [23] corresponding to the marginal production mix in Sweden in 2020 for day and night during the four seasons.*

The used grid emission factors from ENTSO-E and Electricity Maps data were applied both as the hourly emission values, but was also recalculated to daily, and nightly average values. Three different scenarios were used to assess the potential benefits for flexibility measures:

a) Reference: No flexibility. The produced electricity is compared with (i) the daytime average GHG performance of the corresponding day, or (ii) the performance of the corresponding hour when it was produced.
b) Daily flexibility. The produced electricity compared with the average daytime or night-time GHG emission performance of the grid. The electricity is (i) exported during following night from

when it was produced, or (ii) exported either during the same day, or following night, depending on when the grid emission has the highest GHG emission performance.

c) Hourly flexibility (not applicable for the marginal electricity production grid emission factors). Electricity production is compared with the hour in a specific time-window where the grid emission factor is the highest, corresponding to a maximum number of hours the battery can store the produced electricity. Specifically, investigate the possibility to shift the export of the electricity up to: (i) 12 hours, (ii) 16 hours, (iii) 20 hours, and (iv) 24 hours.

## 8.2 Results

The distributions of the grid emission factors for SE3, based on production and import data from ENTSO-E (2023) are presented in Figure 118, which can be compared with the distributions of the emission factors as retrieved from Electricity Maps in Figure 119. There is a visible difference between the SE3 values and the values for Sweden as a whole, both in terms of absolute values and the distribution between different months. The national emission factors of Sweden's are significantly lower compared to France and the Netherlands. However, the distribution for Sweden also has more outliers, which could make it more important to consider hourly flexibility measures to ensure the optimal utilization of solar PV with regards to $CO_2$ emission reduction.

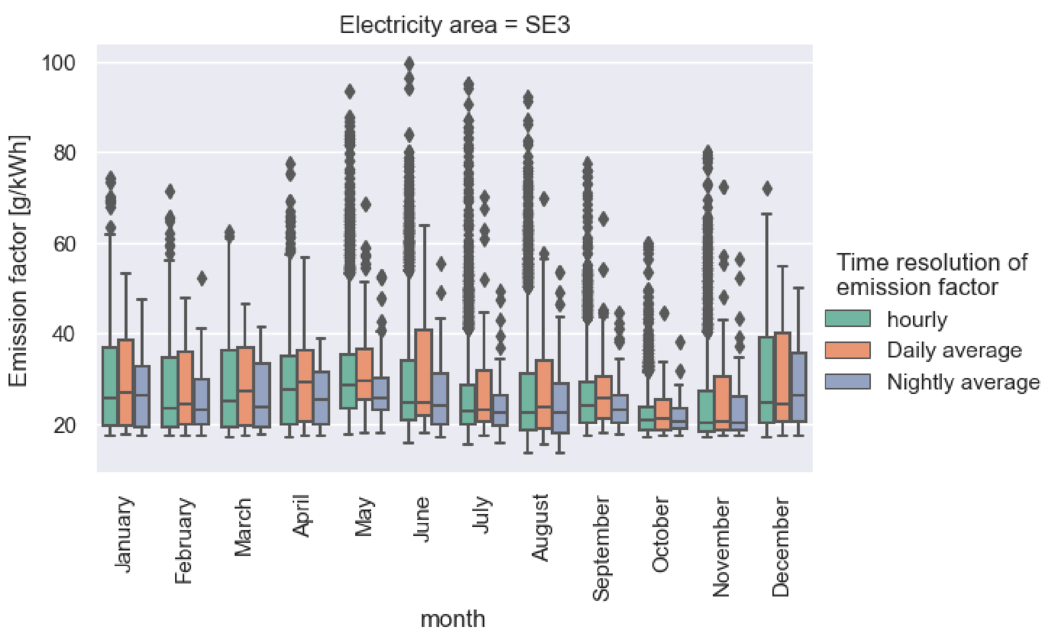


*Figure 118:Grid emission factors for Sweden area 3 (SE3) as calculated from ENTSO-E (2023) production and import data on hourly, and daily and nightly aggregated basis.*

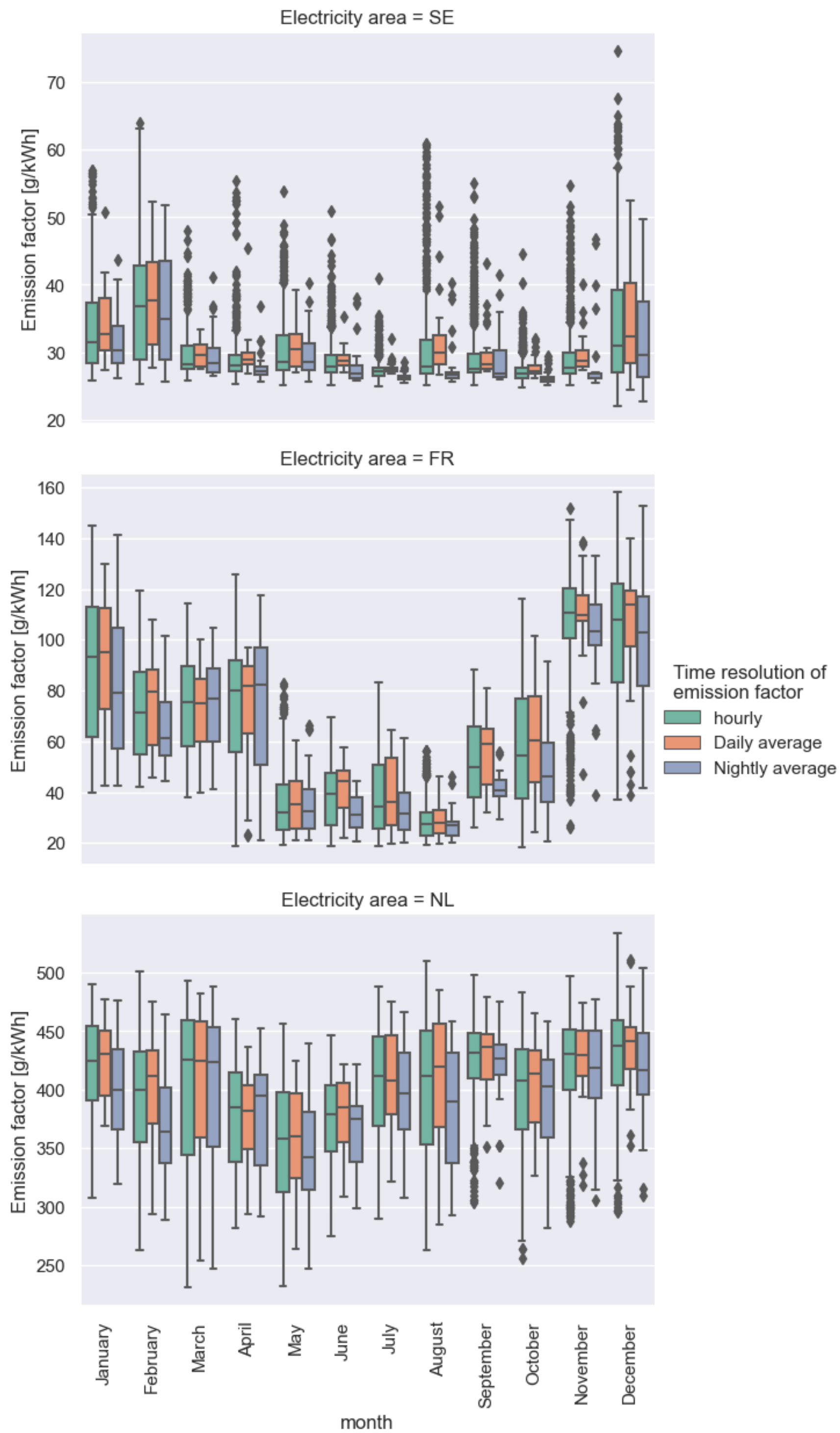


*Figure 119: Grid emission factors for Sweden (SE), France (FR) and The Netherlands (NL), retrieved from Electricity maps on hourly, daily and nightly aggregated basis.*

In Figure 119, it can be observed that the emission factors for France have a significantly higher seasonal variability compared to Sweden and the Netherlands. Note that the y-axis differs since it is adjusted to fit the span of each country. During winter, the French grid emission factors are considerably higher, while in summer, they are lower compared to the relatively low seasonal variability of the emission factors in Sweden and the Netherlands. This highlights the importance of considering the geographical location when assessing the emission reduction potential of flexibility measures, such as storing PV-electricity in a battery or smart charging of electric vehicles.

In contrast, the emission factors from Electricity maps for the Netherlands (Figure 119) are in the same order of magnitude as those obtained by using the marginal electricity production perspective in Sweden for the summer season, see Figure 120. This indicate that the implementation of PV production in Sweden has the potential to yield comparable emission reductions to those observed in the Netherlands, if assuming a marginal electricity production approach. However, it should be noted that the results using marginal emission factors are based on average numbers given per season, and the benefits of flexibility measures vary within the seasons and time of day.

Figure 120 shows the resulting GHG emission reduction from producing electricity with solar PV compared to the grid electricity mix, under different flexibility scenarios. The figure quantifies the GHG emission saving from on-site flexibility measures in terms of battery storage, under different assumptions regarding the grid emission factors, and what flexibility can be assumed to be achievable. As described in the method section (8.1), the scenarios include reference (no flexibility), daily flexibility, and hourly flexibility (for non-marginal emission factors). The figure shows the GHG emission reduction in g/kWh when compared to the electricity grid emissions established using data from three different sources. In total the PV installation produced 111 MWh in 2021 and the hourly production data was used to estimate the emission reduction which then was recalculated into grams per kWh to facilitate comparison and application of the numbers in other contexts. It should be noted that the y-axis is differs and is adjusted to fit the range of the respective results displayed in the figure.

The export day and export hourly correspond to no flexibility and the solar PV produced being exported or used directly. Here the emission reduction is established either with daily average values or hourly values and a small difference can be seen between the two. Using average daily and nightly values for the electricity grid emission yields negative results when exporting only during the night for the SE3 emission factors and overall little-to-no positive effect when exporting either during the day or night, depending on what is most beneficial in terms of GHG emission reductions. This is because, in general, emission factors during the night are lower than during the day. However, significant gains can be made from applying hourly flexibility with The Netherlands showing the highest increase in reduction, with an approximate value of 30 g/kWh, followed by France and Sweden with values of around 12 g/kWh and 5-10 g/kWh, respectively. In the case of Sweden, the grid emission factor is generally lower but there are specific hours where emissions are significantly increased, as shown in Figure 119. This implies that flexibility measures can have a substantial impact on emission reductions in Sweden, potentially increasing them by up to four times.

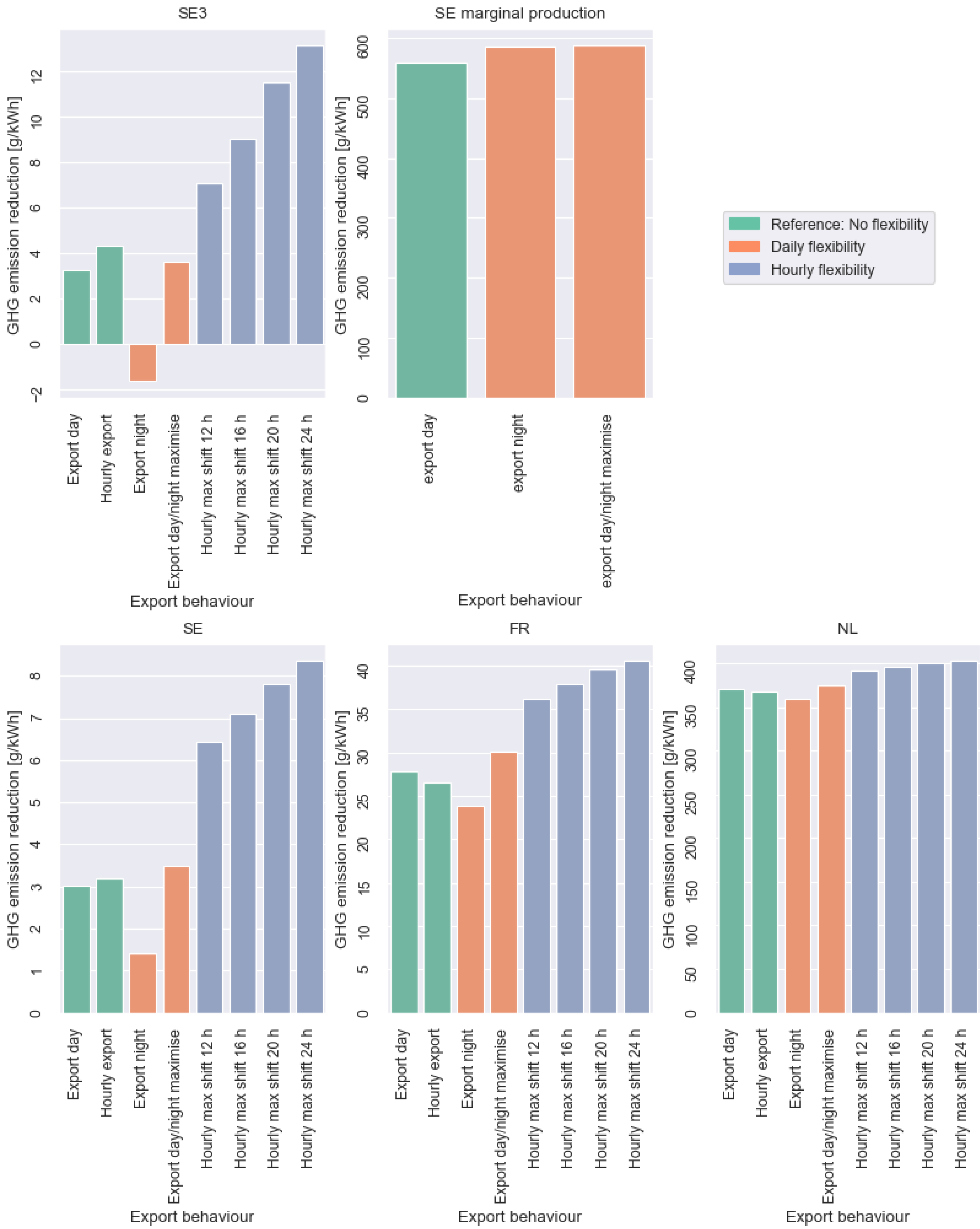


*Figure 120. Resulting GHG emission reduction by implementing the solar panels in the grid depending on the data source for grid electricity emission factors, and how (and if) flexibility measures are considered.*

It should be noted that the values in g/kWh presented in Figure 120 are averages derived from the results by dividing the total emission reduction [g/year] with the total PV production [kWh/year]. Hence, they do not reflect the range and distribution of the emission factors in the grid of the datasets that were used to establish the total reduction. To obtain a better understanding of this variation, refer to Figure 118 and Figure 119.

The emissions related to PV production have been assumed to be 27 grams per kWh in this analysis. This value is higher than the standard IRIS emission factor in Sweden, which is 23 grams per kWh, and if applied to those assumptions would result in an increase in emissions when electricity is produced from PV in Sweden. In countries like Sweden and France, where electricity production is associated with low GHG emissions, the LCA emissions attributed to PV production significantly affect the results. Since the expected solar production from PV installations in Nice and Sweden varies, a more comprehensive analysis that considers the LCA emissions of PV should not assign the same value for both countries.

Moreover, in this sensitivity analysis, no emissions have been assigned to the battery. This means that having flexibility does not result in any additional emissions, but rather offers advantages by allowing the use of electricity when the grid has higher emissions. The installed batteries are second life, so it could be argued that the emissions related to battery production should be allocated to the primary use of the battery, which in this case is buses. However, it is important to consider that emissions are still linked to battery production, and the installation of new batteries in stationary applications may be a topic of debate, particularly in Sweden where both emissions associated with the grid electricity and their variability are relatively low. The results of this sensitivity analysis indicate that such batteries need to have a GHG impact below 6 grams per kWh electricity stored while in a French or Dutch context there is more room for emissions associated with the batteries while still achieving emission reduction.

# 9 Conclusions

## 9.1 Challenges of the monitoring and evaluation process

The subsequent chapter outlines the key challenges encountered in monitoring and evaluation, followed by a concluding section with recommendations based on the insights gained during the IRIS project.

### 9.1.1 Challenges with KPI revisions

During the final period of the IRIS project, WP9 performed work that reaffirmed the lessons learned about KPI revisions, as outlined in paragraph 3.4 of D9.5. *Report on monitoring framework in LH cities and established baseline.*

It is important to reiterate that although KPIs can be selected and defined early on in a project, they should always be open to modification during the project's duration. As new indicators emerge or insights are gained, flexibility in monitoring and evaluation methods may be necessary. When modifications are made, it is crucial to keep a detailed record of them to address any unforeseen side-effects that may arise. Although modifications often are necessary, they are constrained by the wish to use the same KPIs to aggregate and evaluate different solutions.

To prevent any misinterpretation and to allow for necessary updates or adjustments, KPI definitions must be clear and precise in terms of parameters and units, while still allowing for some flexibility. This is especially true for the KPI Carbon dioxide emission reduction, which is used for various energy carriers and have been defined for different use cases. Additionally, some KPIs must be separated by energy carrier, such as thermal or electrical for the Peak Load reduction KPI, to avoid adding or comparing irrelevant values.

Furthermore, some KPIs need to be separated depending on energy carrier, e.g. thermal or electrical for KPI Peak Load reduction, to avoid comparing and adding values together that are not relevant to add or compare.

### 9.1.2 Challenges with data collection

The KPIs employed in the IRIS project have undergone continuous adjustments and updates to meet requirements and achieve their purpose. However, this presents a challenge, as partners must define the required parameters for data collection at an early stage.

Smart city projects are implemented in real-life circumstances where delays in implementation and/or start of monitoring can occur. However, this leads to shorter period of data collection than initially planned and makes evaluation more difficult. Reliable data-sets require two or more years of data to identify inaccuracies that hamper the interpretation.

Smart city projects are often implemented in real-world scenarios where there may be delays in implementation or the start of monitoring. These delays can result in a shorter period of data collection than initially planned, which can make evaluation more challenging. Typically, in order to ensure the accuracy of data sets, it is necessary to collect data for at least two years to facilitate the detection of any inaccuracies that may hinder interpretation.

### 9.1.3 Challenges with KPI and measure narratives

KPIs play an important role in monitoring and evaluating the impact of various measures in smart city projects. They enable comparison and aggregation of results at different project levels. However, utilizing KPIs in smart city projects presents both advantages and challenges.

KPIs are beneficial in smart city projects for several reasons. Firstly, they provide a precise and straightforward approach to monitoring progress towards predefined objectives and targets. Secondly, they increase transparency and accountability by presenting measurable data that can be shared and evaluated by all stakeholders. Thirdly, they enhance comprehension of the effects of various measures and demonstrations. Finally, KPIs offer a more comprehensive view of the impact of a measurement on the community, encompassing social, economic, and environmental outcomes through both quantitative and qualitative KPIs.

Using KPIs in smart city projects, however, presents several challenges. KPIs may be too narrow in focus to capture the full impact of a measurement, and inaccurate, unreliable, or insufficient data used in calculating KPIs can undermine their value. Selection and weighting of KPIs may also be influenced by bias and subjectivity, leading to skewed understanding of the measurement's impact. Comparing KPIs between cities may be difficult due to differences in data collection methods, definitions, and indicators. Measuring social outcomes with KPIs can be particularly challenging due to their subjective and multi-faceted nature, as well as difficulties in obtaining accurate and relevant data.

KPIs are designed to track specific and measurable outcomes, which may not encompass the broader narrative and qualitative aspects of the measurement. As a result, using KPIs alone can give a narrow and oversimplified view of the impact of the initiative. It’s therefore recommended to supplement KPIs with qualitative data, stakeholder feedback, and other forms of information that can provide a more complete and nuanced understanding of the impact of the initiative.

### 9.1.4 Challenges with KPI tool and CIP

Complexity of APIs and the lack of standards have made data extraction and transfer into the KPI tool more difficult. Furthermore, not all measures in IRIS are connected to CIP which means that manual data collection was required and a systematic procedure for this collection needed to be developed and introduced to the partners.

Automating data transfer has its own set of challenges, such as identifying the relevant data to transfer from the CIP and determining the units in which the data is presented. Additionally, further data analysis is often necessary to detect errors and make necessary modifications, including converting the data to the appropriate units and recalculating to obtain the required parameters for KPI calculations. Besides this, errors or gaps in data due to malfunctions within monitored systems are hard to predict. Generally, they need case specific solutions which are not easy to program in a KPI tool beforehand. Instead, a deeper understanding of the data and the systems behind are required to detect malfunctions and possibly find solutions for lost data. In the future AI systems might become part of a solution for some of those issues, but for now it requires manual intervention. Automating these tasks can be time-consuming, and especially for shorter-term projects, they may not be worth the effort.

### 9.1.5 Challenges with aggregation

As previously discussed, a challenge in using KPIs is finding the right balance between specificity to capture the purpose of a measure and generality to allow for use with different measures and comparison between them. Some KPIs, such as an increase in renewable energy production, can be easily aggregated if separated by energy carrier (heat and electricity) since they share the same unit (kWh). However, adding them together may not be meaningful due to differences in quality. Other KPIs are expressed as ratios, where the numerator may not be simply an aggregation of several values. As mentioned earlier, there is a challenge to obtain the right balance between KPIs being specific enough to capture the aim of a measure but still general enough to enable used for different measures and serve as a basis for comparison between them.

When aggregating KPI values, it is important to exercise caution to avoid creating sums that provide no additional information or make the interpretation of results more difficult. However, there are certain KPIs that are meaningful to aggregate, and in such cases, it is essential to establish them using the same assumptions. The KPI Carbon dioxide emission reduction, in particular, presented challenges during aggregation since specific or local values may be applied at the measure or Lighthouse city level. However, when aggregating to a higher level, it is crucial to use similar assumptions for all included solutions. It is also advisable to clearly state the key assumptions used alongside the results and to explore how they differ if a different set of reasonable assumptions is applied, if possible.

### 9.1.6 Challenges with targets and transparency

The goal of establishing KPIs is to measure the impact of implemented measures and their effectiveness in achieving the project impact targets set forth in the Grant Agreement or by the partners. Transparency in the assumptions used when establishing these targets is crucial, and any changes to the project should prompt an update to the targets. However, in a project spanning over five years, such as IRIS, some assumptions may become outdated by the project's end, making it both difficult and potentially irrelevant to evaluate outcomes against targets that lack transparency. Targets set as absolute numbers, rather than percentage changes, present the most significant challenge in this regard.

## 9.2 Recommendations

Based on the challenges in the IRIS project, there are some valuable recommendations for other projects regarding data collection for KPIs. Firstly, it is important to be aware that setting up and delivering results using automatic data collection can be a time-consuming process. Therefore, projects should plan accordingly and allocate sufficient time and resources for this task. Secondly, automatic data collection should be combined with data validation mechanisms, including both automatic and manual validation, to ensure data accuracy. While the KPI tool provides a centralized repository for monitoring data, it is important to acknowledge that automatic data collection is a more suitable long-term solution for monitoring periods lasting several years. For shorter monitoring periods of 1-2 years, manual data collection is a hassle-free alternative. Finally, it is recommended to consider that some KPIs may require additional information to complement the data collected, and this should be factored into the data collection process.

In general, the monitoring and evaluation of smart city initiatives requires careful consideration of key performance indicators (KPIs) and other factors that can provide a more comprehensive understanding of the impact of the initiative. As such, several recommendations can be made for other projects with regards to KPIs and evaluation. The following suggestions highlight the importance of time, teamwork, and transparency in the monitoring and evaluation process:

1. Budget sufficient time for continuous discussion with project partners on monitoring and evaluation throughout the project and be aware of the challenges of choosing and formulating KPIs. The process of updating and adjusting them will continue over time.
2. Work more transition track-wise to allow for knowledge exchange between similar measures with regards to challenges and lessons learnt, creating synergies that cannot be found to the same extent when exchange primarily occurs on LH city level.
3. Be transparent about assumptions used when establishing targets and KPIs to make the evaluation trustworthy and interpretable to others. Clearly stating key assumptions when results are presented enables others to interpret how it could differ if set in a context more relevant to them.
4. Use KPIs as part of a comprehensive and multifaceted approach to measuring the impact of smart city initiatives. This involves supplementing KPIs with qualitative data, stakeholder feedback, and other forms of information that can provide a more complete and nuanced understanding of the impact of the initiative.
5. Organize workshops with all partners involved in the project to raise awareness and promote a better understanding of the complex interplay between measurement narratives and KPIs.

By following these recommendations, other projects can improve their data collection and monitoring and evaluation processes and provide a more complete picture of the impact of their initiatives.

When setting up new projects, it is important to maintain transparency in the assumptions used for establishing the impact targets. One recommendation is to consider using percentual changes instead of absolute numbers as targets. It may also be beneficial to periodically review and potentially revise the targets to ensure their continued relevance and accuracy throughout the project.

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# 1 Annex 1 Measure Numbering

The numbering of the measures given below is based on the IRIS measure tracker, which can be found online. This numbering is also used in the KPI Tool.

## Utrecht Demonstration measure tracker

| **Transition Track 1: Retrofit activities apartment buildings** | |
|---|---|
| Measure 1 | District wide PV |
| Measure 2 | LT district heating |
| Measure 3 | HEMS TOON |
| Measure 4 | NZEB refurbishment |
| Measure 5 | Smart (hybrid) e-heating systems |
| Measure 6 | AC/DC home switchboxes |
| Measure 7 | Smart DC Street Lighting |
| **Transition Track 2: Placement Solar V2G charging points** | |
| Measure 1 | Solar V2G charging points for e-cars/e-vans (demand driven) |
| Measure 2 | Solar V2G charging point for e-buses |
| Measure 3 | Stationary storage in apartment buildings |
| Measure 4 | EMSs- Smart Energy Management System |
| **Transition Track 3** | |
| Measure 1 | V2G e-cars (demand driven) |
| Measure 2 | V2G e-buses |
| **Transition Track 4** | |
| Measure 1 | Monitoring E-Mobility with LoRa network |
| Measure 2 | Smart Street Lighting with multi-sensoring |
| Measure 3 | 3D Utrecht City Innovation Model |
| Measure 4 | Monitoring Grid Flexibility |
| Measure 5 | Fighting Energy Poverty |
| **Transition Track 5** | |
| Measure 1 | Community building by change agents |
| Measure 2 | Campaign District School Involvement |
| Measure 3 | Campaign Smart Street Lighting |
| Measure 4 | Co-creation in Local Innovation Hub |
| Measure 5 | VR New Home and District Experience |

# Gothenburg Demonstration measure tracker

| Transition Track / | Measure title |
|---|---|
| **Transition Track 1** | |
| Demonstration 1 | At least 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV |
| Demonstration 2 | Heating from geo energy with heat pumps (2-300 m deep boreholes) |
| Demonstration 3 | Cooling from geo energy without chillers |
| Demonstration 4 | Local energy storages consisting of water buffer tanks, structural storage and long-term storage in boreholes |
| Demonstration 5 | Seasonal energy trading (cooling in summer season) with adjacent office block |
| Demonstration 6 | Advanced Energy Management System to achieve peak shaving and minimal environmental impact |
| Demonstration 7 | Building Integrated Photovoltaics (BIPV) in façade |
| **Transition Track 2** | |
| Demonstration 1 | 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage |
| Demonstration 2 | PCM cooling storage |
| Demonstration 3 | Low temperature DH 45/30 system for six buildings |
| Demonstration 4 | Integration and evaluation of a 200kWh energy storage |
| **Transition Track 3** | |
| Demonstration 1 | EC2B, version for accomodation (Riksbyggen's BRF Viva) |
| Demonstration 2 | EC2B, version for workplaces (Johanneberg campus area) |
| **Transition Track 4** | |
| Demonstration 1 | CIM- City Information Model |
| Demonstration 2 | Energy Cloud |
| **Transition Track 5** | |
| Measure 1 | ME model |
| Measure 2 | SCH - smart city hub |
| Measure 3 | CD - continuous dialogue |
| Measure 4 | ILC - inclusive life challenge |
| Measure 5 | Minecraft competition |
| Measure 6 | VR/3DBIM - building information modeling |
| Measure 7 | PET - Personal Energy Treshold? |

## Nice Demonstration measure tracker

| Transition Track / Measure | Measure title |
|---|---|
| Measure 1: IS 1.1 (Positive Energy Building) | Collective self-consumption at building scale (Palazzo Meridia) |
| | Collective self-consumption at building scale (UNS-IMREDD) |
| Measure 2: IS 1.2 (Near zero energy retrofit) | Optimization of heating load curve |
| Measure 3: IS 1.2 (Near zero energy retrofit) | Commissioning process from the design of the operation |
| Measure 4: IS 1.3 (Symbiotic waste heat network) | Dashboard providing real-time energy balance |
| **Transition Track 2** | |
| Measure 1: IS 2.1 Flexible electricity grid networks | LEM - Local Energy Management system |
| Measure 2: IS 2.2 Smart district heating with innovative storage | DHC Smart District Heating and Cooling optimization algorithm |
| Measure 3: IS 2.3 Utilizing 2nd life batteries for large-scale storage | Stationary storage deployment in buildings and local electric flexibility management |
| **Transition Track 3** | |
| Measure 1: IS 3.1 Smart solar V2G EV charging | Dynamic energy management of an EV charging network |
| Measure 2: IS 3.2 Innovative mobility services for the citizen | Free floating EV car sharing system |
| Measure 3: IS 3.2 Innovative mobility services for the citizen | Impact of urban environmental monitoring on citizen mobility |
| **Transition Track 4** | |
| Measure 1: IS 4.1 Services for urban monitoring | Sensors data collection in mobility through 5G IOT network |
| Measure 2: IS 4.2 Services for city management and planning | BIM/CIM data display |
| Measure 3: IS 4.3 Services for mobility | Charging infrastructure data for optimal EV-based free-floating car sharing |
| Measure 4: IS 4.4 Services for grid flexibility | Data interoperability with energy cloud |
| **Transition Track 5** | |
| Measure 1: IS 5.1 Co-creating the energy transition) | Public awareness campaign |

| | |
|---|---|
| Measure 2: IS 5.2 Participatory city modelling | Participation of citizens to city life |
| Measure 3: IS 5.4 Apps and I/F for energy efficient behavior | Citizens collective engagement |
| Measure 4: IS 5.4 Apps and I/F for energy efficient behavior | Citizen individual engagement |

# 2 Annex 2 List of modifications of KPI cards

| Date | Name | Modifications |
|---|---|---|
| 2021-05-04 | E.P.Bontekoe | • $CO_2$ emission reduction:<br>  o Focus on emission reduction<br>  o Added use cases and examples<br>• CO emission reduction:<br>  o Homogenized with $CO_2$ emission reduction<br>  o Changed KPI output to number (tonnes CO) instead of %, in order to make the KPI applicable as indicator for grant agreement goals<br>  o Added use case of sustainable transport<br>  o Small typographic modifications in title and description<br>• NOx emission reduction:<br>  o Homogenized with $CO_2$ emission reduction<br>  o Changed KPI output to number (Tonnes Nox) instead of %, in order to make the KPI applicable as indicator for grant agreement goals<br>  o Added use case of sustainable transport<br>  o Small typographic modifications in title and description<br>• Fine particulate matter emission reduction:<br>  o Changed PM to FPM in KPI description<br>  o Homogenized with $CO_2$ emission reduction<br>  o Changed KPI output to number (Tonnes FPM) instead of number per capita, in order to make the KPI applicable as indicator for grant agreement goals<br>  o Added use case of sustainable transport<br>  o Small typographic modifications in title and description |
| 2021-05-05 | L.Eriksson | • Reduction in driven km by tenants and employees in the district<br>  o Added formula for clarity<br>• Reduction in car ownership among tenants<br>  o Added formula for clarity<br>• Increased system flexibility for energy players/stakeholders<br>  o Added formula and made differentiation between thermal and electrical<br>  o Changed description to make it clearer<br>• Storage capacity installed<br>  o Changed formula so it can be calculated when baseline is 0, in this case it is not percentage but absolute value<br>• Reduced energy cost for customers<br>  o Added explanation of parameters used to calculate KPI<br>• User Engagement<br>  o Added description Number of participants/users of the platform<br>• Quality of open data |

| | | |
|---|---|---|
| | | ○ Added explanation: Number of Data sets using DCAT standards/Total number of data sets in open repositories |
| 2021-05-20 | E.B. | Changed emission factor for CO2 to Tonnes/kWh as inputs will also be in kWh |
| 2021-07-07 | E.B. | Changed all instances of the word 'Energetic' in 'Energy' in the context of 'Energy Self Supply' (KPI 10) |
| 2021-08-23 | L.E. | • Storage capacity installed<br>○ updated to have two separate formulas based on energy carrier, one for thermal storage and one for electrical storage.<br>○ The formula which calculates the KPI when the baseline is not zero is removed as with it it will not be possible to add the storage capacities of the same energy carrier together since it is not in kWh but rather in percentage.<br>• Increase system flexibility<br>○ Removed the alternative formula SFAC, where cost was involved as this is not used and does not give the KPI in the same unit |
| 2021-08-24 | L.E. | • Storage Energy Losses<br>○ Added this KPI card as it was missing in this report. It was put last to not change numbers of previous KPIs and cause confusion. |
| 2021-09-06 | L.E. | • Updated the CO2 emission reduction card with numbers for the use cases I-IV. |
| 2021-09-13 | L.E | • Updated the KPI Increase in Local Renewable energy production so that it gives increase as a quantity of energy (separate KPI for electricity and thermal) not relative to the base case since the measures in IRIS have zero as base case and then the KPI formula as previously stated gives the same number/info as the KPI Degree of energy self-supply by RES. |
| 2021-10-08 | L.E | • Added subscripts and updated the formula for use case IV of KPI Carbon dioxide emission reduction to clarify kilometres and emissions factors to use. |
| 2021-10- | L.E | • Removed % as the unit for KPI38 and KPI39 |
| 2021-11 | E.B. | • Changed % into kWh as unit for KPI 42 (storage capacity installed) |
| 2021-11 | E.B. | • Added formula to KPI 7 CO2 reduction cost efficiency |
| 2022-03 | E.B. | • Added units to KPI 7 and corrected units in KPI 5 |
| 2022-04 | E.B. | • Added draft of simplification for the case of CO2 emission reduction from transport where the kilometres driven are assumed to not change. |
| 2022-05 | L.E | • Access to vehicle sharing solutions for city travel – changed from % to # as unit<br>• Increase in local renewable energy production – changed from MWh to kWh |

| | | |
|---|---|---|
| | | • Peak load reduction – added formula to clarify how the peak load is established. It is the maximum over the designated time period, i.e. month or year. |
| 2022-10 | S.R | • Scale is called five point rating scale instead of Likert scale for the KPI:s Advantages for end-users and Local community involvement in the planning phase, |
| 2022-10 | S.R | • New KPI cards added number 54 – 60 |
| 2022-11 | E.B. | • KPI13 Energy savings: Added generic formula, updated symbols of formulas for consistence, added note |
| 2022-12 | L.E | • KPI7 – added example formula för establishing cost for measure. |
| 2023-03 | P.T | • Added KPIs and adjusted numbering to fit with the KPI tool. Two KPIs added as number 54-55, the previously added KPIs are now numbered 56-62 |

# 3 Annex 3 – KPI cards

## 1. Accessibility of open data

| Accessibility of open data | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Open data, especially open government data, is a tremendous resource that is as yet largely untapped (opendatahandbook.org). In a large number of areas, open city data is already creating value. Examples include participation, self-empowerment, innovation, improved efficiency and effectiveness of government services, etc. While there are numerous instances of the ways in which open data is already creating both social and economic value, we don't yet know what new things will become possible. New combinations of data can create new knowledge and insights, which can lead to whole new fields of application. The ease of use of open data is an important quality because the main aim of opening data is to make it widely available to the public (City Protocol), e.g. to create new applications. Therefore, evaluating the quality of the open data from this perspective is important to promote the ease of use and the openness of city data | | | | |
| **KPI Formula** | Total stars of all data/total # data<br>Each dataset has to be rated according to below scheme. All the stars of all the datasets are added up and divided by the total number of datasets. Average stars across all datasets according to the 5 star deployment scheme for Open Data defined by Tim Berners Lee (5stardata.info):<br>1. Making data online available in whatever format under an open license<br>2. Making data available as structured data (e.g. Excel instead of image scan of a table)<br>3.Making data available in a non-proprietary open format (e.g. CSV)<br>4. Use URIs to denote things, so that people can point at your data<br>5. Link your data to other data to provide context | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | No unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | GOT | | |

# 2. Access to vehicle sharing solutions for city travel

| Access to vehicle sharing solutions for city travel | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Providing opportunities for sharing vehicles like (e-)bicycles, (e-)cars and (e-) scooters, can decrease the need for and use of private cars, thereby contributing to an accessible, green and healthy neighbourhood. Cycling is a healthy, flexible, cheap and sustainable way to get from a to b over a short distance. Many European cities therefore would like to stimulate cycling, but in countries without a cycling culture there is limited private ownership of bikes. Car-sharing is about not owning a car but renting it from a car-sharing company or sharing the car with friends, family, neighbours or co-workers (1,2). Car-sharing is an attractive option for people who drive less than 10.000 km a year. Car-sharers are more likely to travel by bike, saving on car use and improving their health. Car-sharing also decreases the need for parking space, less vehicles are on the road and less pollution is emitted. Car sharing may furthermore improve social cohesion in the neighbourhood | | | | |
| **KPI Formula** | Number of vehicles available for sharing per 100.000 inhabitants | | | | |
| **Measurement procedure** | 3. Data collection<br>4. KPI calculation | | | | |
| **Unit of Measurement** | # | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | X | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | x |
| | City | X | | Representative Citizen Groups | x |
| | | | | Citizen Ambassadors | x |
| **Responsible Partner for KPI Data Collection** | | | LOM, UTR; VULOG; IRIS; | | |

# 3. Advantages for end-users

<table>
<tr><th colspan="6">Advantages for end-users</th></tr>
<tr><td>KPI Description</td><td colspan="5">The extent to which the project offers clear advantages for end users. The advantage can take many forms, for instance cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five-point rating scale:<br>No advantage– 1 — 2 — 3 — 4 — 5 — Very high advantage<br>1. No advantage: The project does not offer clear advantages for end users. The technologies or principles applied in the project are not at all beneficial to end users.<br>2. Little advantage: The project offers very little advantage to end users. The vast majority of the technologies/principles offer an indirect and insignificant advantage to end users.<br>3. Some advantage: The project offers some advantage to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project.<br>4. High advantage: The project offers a high advantage to end users who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive effect on end users.<br>5. Very high advantage: The project offers a very high advantage to end users as the applied technologies/principles have a direct and an extremely positive effect on end users (e.g. cheaper housing costs, increased comfort, increased quality of the living environment etc.).</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">5. Undertaking of the survey<br>6. Analysis of the results</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">BOEX,</td></tr>
</table>

# 4. Battery Degradation Rate

<table>
<tr><th colspan="6">Battery Degradation Rate</th></tr>
<tr><td>KPI Description</td><td colspan="5">The various battery storage systems, including BESS, 2nd life batteries and EVs, are essential for the flexibility of energy grids using increased amounts of electricity deriving by RES. The KPI illustrates the capacity losses of the batteries used in project, through use (some cycles) and through time (some years). The conclusions of this KPI concern the effectiveness of this technology, the need for maintenance and thus, gives useful data concerning the financial feasibility of its integration.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$BDR_c = \frac{BC_n - BC_0}{n \cdot BC_0} \cdot 100$$ $$BDR_Y = \frac{BC_Y - BC_0}{Y \cdot BC_0} \cdot 100$$<br>$BDR_C$= BDR per cycle<br>$BDR_Y$= BDR per year<br>$BC_0$= initial battery capacity<br>$BC_n$= battery capacity after n cycles<br>n= number of cycles<br>Y= number of years</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td></td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">EDF, NEXITY, UNS; Rb;</td></tr>
</table>

# 5. Carbon dioxide emission reduction

<table>
<tr><th colspan="2">Carbon dioxide emission reduction</th></tr>
<tr><td>KPI Description</td><td>Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. $CO_2$ accounts for a major share of Green House Gas emissions in urban areas. The main sources for $CO_2$ emissions are combustion processes related to energy generation and transport. $CO_2$ emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.</td></tr>
<tr><td>KPI Formula</td><td>The emitted mass of $CO_2$ is calculated from the delivered and exported resource for each carrier:<br><br>$$m_{CO_2} = \sum(R_{del,i}K_{del,i}) - \sum(R_{exp,i}K_{exp,i})$$<br>$R_{del,i}$ = the delivered resource for carrier i<br><br>$R_{exp,i}$ = the exported resource for carrier i<br><br>$K_{del,i}$ = the $CO_2$ coefficient for delivered resource carrier i<br><br>$K_{exp,i}$ = the $CO_2$ coefficient for exported resource carrier i<br><br>The indicator is calculated as the direct (operational) reduction of the $CO_2$ emissions over a period of time. The result may be expressed as a percentage when divided by the reference $CO_2$ emissions.<br><br>In the table below list case variables compared to the generalized formula:<br><br>
<table>
<tr><th>Use case</th><th>General variable</th><th>Case variable</th></tr>
<tr><td>I: Energy savings</td><td>$R_{del,i}$</td><td>$E_{baseline}$</td></tr>
<tr><td></td><td>$K_{del,i}$</td><td>$K_{baseline}$</td></tr>
<tr><td></td><td>$R_{exp,i}$</td><td>$E_{measure}$</td></tr>
<tr><td></td><td>$K_{exp,i}$</td><td>$K_{measure}$</td></tr>
<tr><td>II: Renewable energy production, when new production is zero-emission and replaces conventional production</td><td>$R_{exp,i}$</td><td>$E_{production}$</td></tr>
<tr><td></td><td>$K_{del,i}$</td><td>$K_{baseline}$</td></tr>
<tr><td></td><td>$R_{exp,i}$</td><td>$E_{production}$</td></tr>
<tr><td></td><td>$K_{exp,i}$</td><td>0</td></tr>
<tr><td>III: Renewable thermal production using heat pump to replace part or all heating demand</td><td>$R_{del,i}$</td><td>$E_{HP,electricity}$</td></tr>
<tr><td></td><td>$K_{del,i}$</td><td>$K_{baseline,el}$</td></tr>
<tr><td></td><td>$R_{exp,i}$</td><td>$E_{production}$</td></tr>
</table>
</td></tr>
</table>

| | | |
|---|---|---|
| | $K_{exp,i}$ | $K_{baseline,heat}$ |
| IV: Sustainable transport, when same amount of kilometers is replaced with zero-emission | $R_{del,i}$ | $D_{measure}$ |
| | $K_{del,i}$ | $EF_{baseline}$ |
| | $R_{del,i}$ | $D_{measure}$ |
| | $K_{del,i}$ | $EF_{measure}$ |

**$CO_2$ Reduction**

When the emitted mass of $CO_2$ is defined, the reduction of Carbon dioxide emissions can be calculated by:

$$CO_2Reduction = m_{CO_2\ baseline} - m_{CO_2}$$

$$= Baseline(\sum(R_{del,i}K_{del,i}) - \sum(R_{exp,i}K_{exp,i})) -$$

$$measure\ (\sum(R_{del,i}K_{del,i}) - \sum(R_{exp,i}K_{exp,i}))$$

**Use cases:**

**I:** When $CO_2$ reduction is achieved by energy savings:

$$CO_2Reduction = E_{baseline}\,K_{baseline} - E_{measure}\,K_{measure}$$

$E_{baseline}$ = the energy use prior to implementing the measure

$E_{measure}$ = the energy use after implementing the measure

$K_{baseline}$ = the $CO_2$ coefficient of energy used in base case

$K_{measure}$ = the $CO_2$ coefficient of energy used after implementing the measure

**II:** When $CO_2$ reduction is achieved by renewable energy production. The renewable energy can either be used in the building, and thereby reduce the need to import energy, or it can be exported and thereby lower the need for energy production by alternative production technology. The system boundary is expanded to include both options. The reduction is given by:

$$CO_2Reduction = E_{production}\,(K_{baseline} - K_{measure}) = if\ \ K_{measure} = 0$$
$$= E_{production}\,K_{baseline}$$

$E_{production}$ = the energy produced by the measure [kWh/year]

$K_{baseline}$ = the $CO_2$ coefficient of the delivered energy in case it would have been produced without the measure (baseline). [t CO2/kWh]

$K_{measure}$ = the $CO_2$ coefficient of the produced energy by the measure, for renewables this set to zero [t CO2/kWh]

**III:** When $CO_2$ reduction is achieved by renewable heat production using heat pump technology it is assumed that the emissions associated with it is simply those associated with the electricity needed to run it. However, the renewable heat produced will lead to a reduced use of the baseline heating technology, in this case district heating ($E_{production} = (E_{DH,baseline} - E_{DH,measure})$). The resulting reduction is obtained from the following:

$$CO_2 Reduction = (E_{DH,baseline} K_{DH,baseline}) - (E_{DH,measure} K_{DH,baseline} + E_{HPel,measure} K_{el,measure}) = K_{DH,baseline}(E_{DH,baseline} - E_{DH,measure}) - E_{HP\ electricity} K_{baseline,el} = E_{production} K_{baseline,heat} - E_{HP\ electricity} K_{baseline,el}$$

$E_{DH,measure}$ = the heat delivered from district heating after implementing the measure [kWh/year]

$E_{DH,baseline}$ = the heat delivered from district heating for the baseline [kWh/year]

$K_{baseline,heat}$ = the $CO_2$ coefficient of the baseline heat production technology, i.e. district heating [t CO2/kWh]

$E_{HPelectricity}$ = the electricity consumption of the heat pump [kWh/year]

$K_{baseline,el}$ = the $CO_2$ coefficient of electricity [t CO2/kWh]

$E_{production}$ = the thermal energy produced by the heat pump [kWh/year]

**IV:** When $CO_2$ reduction is achieved by more sustainable transport solutions (for example Electric Vehicles or Electric busses), the reduction is based on the emission factor per kilometre (EF) and the number of driven kilometres (*D*).

$$CO_2 Reduction = D_{baseline} EF_{baseline} - (D_{measure,CC} EF_{baseline} + D_{measure,ECS} EF_{measure})$$

If km driven are the same after implemention, $D_{baseline} = D_{measure,CC} + D_{measure,ECS}$

$$CO_2 Reduction = (D_{measure,CC} + D_{measure,ECS}) EF_{baseline} - (D_{measure,CC} EF_{baseline} + D_{measure,ECS} EF_{measure}) = D_{measure,ECS} EF_{baseline} - D_{measure,ECS} EF_{measure}$$

$D_{baseline}$ = the number of driven kilometres before implementing the measure

$D_{measure,CC}$ = the number of driven kilometres by tenants in conventional cars after implementing the measure

$D_{measure,ECS}$ = the number of driven kilometres by tenants in in e-car sharing system after implementing the measure

$EF_{baseline}$ = the emission factor per kilometre in the baseline (conventional cars)

$EF_{measure}$ = the emission factor per kilometre for the measure (e-car sharing system)

| | | | | | |
|---|---|---|---|---|---|
| | To clarify what energy carrier is involved in the measure these subscripts are used for the measures where it is relevant:<br><br>$CO_2Reduction_{electricity}$ = $CO_2$ emission reduction for measures related to electricity use<br>$CO_2Reduction_{heating}$ = $CO_2$ emission reduction for measures related to heating<br>$CO_2Reduction_{transport}$ = $CO_2$ emission reduction for measures related to transport<br><br>The $CO_2$ emission factors used to establish this KPI is liste by using conversion factors for different energy carriers as described in | | | | |
| | | | | | |
| | | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation<br>3. Comparison with national emissions factor | | | | |
| **Unit of Measurement** | tonnes/(year) | | **Threshold/ Target** | | |
| **Object of assessment** | Building | X | **Stakeholders** | DSO | X |
| | Set of Buildings | X | | TSP | X |
| | Energy Supply Unit | X | | End-Users | X |
| | Set of Energy Supply Units | X | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | VULOG; Rb; AH; IRIS; TRIV | | |

# 6. Carbon monoxide emission reduction

<table>
<tr><th colspan="5">Carbon monoxide emission reduction</th></tr>
<tr><td>KPI Description</td><td colspan="4">Reduction in carbon monoxide emissions achieved by the measure.</td></tr>
<tr><td>KPI Formula</td><td colspan="4">The indicator is calculated as the direct (operational) reduction of the CO emissions over a period of time. The result may be expressed as a percentage when divided by the reference CO emissions. To calculate the direct CO emissions, the total energy reduced, can be translated to CO emission figures.<br><br>Carbon monoxide emission reduction can be calculated similarly as carbon dioxide emission reduction. The main difference in the calculation is the emission factor, which has to be obtained for carbon monoxide emissions.<br><br>Use case:<br>When CO reduction is achieved by more sustainable transport solutions (for example Electric Vehicles or Electric busses), the reduction is based on the emission factor per kilometre (EF) and the number of driven kilometres (D).<br><br>$$COReduction = D_{baseline} EF_{baseline} - D_{measure} EF_{measure}$$<br>$D_{baseline}$ = the number of driven kilometres before implementing the measure<br>$D_{measure}$ = the number of driven kilometres after implementing the measure<br>$EF_{baseline}$ = the emission factor per kilometre in the baseline<br>$EF_{measure}$ = the emission factor per kilometre for the measure</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Tonnes /(year)</td><td>Threshold/ Target</td><td></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO | X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP | X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users | X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance | X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens |</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups |</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors |</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="2">LOM, UTR,</td></tr>
</table>

# 7. CO2 reduction cost efficiency

<table>
<tr><th colspan="6">CO2 reduction cost efficiency</th></tr>
<tr><td>KPI Description</td><td colspan="5">Many smart city projects are intrinsically aimed at reducing the amount of CO2 emitted during their lifetime. Those projects which prove to be able to significantly reduce their carbon footprint, whilst keeping the related costs at a minimum, are considered to be interesting projects for upscaling.<br>Costs in euros per tonnes of CO2 saved per year.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">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).<br>Note: Only the additional costs for energy/CO2 related measures (to the extent discernible) are taken into account in the total costs calculation.<br>$$CO_2 Reduction\ Cost\ Efficiency\ = Cost_{CO_2\ reducing\ measures}\ /CO_2 Reduction$$<br>$Cost_{CO2\ reducing\ measures}$ = additional cost for the energy/$CO_2$ related measure [euros/year]<br>$CO_2$ reduction = emission reduction achieved by the measure [tones/year]<br><br>Additional costs could be established based on:<br>$$Cost_{CO_2\ reducing\ measures}\ =\ Cost_{investments,annulized} + (Cost_{running,measure} - Cost_{running,baseline)}\ )$$<br>$Cost_{investment\ annulized}$= Annualized investment cost for energy/CO2 related measures [€/year]<br>$Cost_{running,\ measure}$ = Annual costs related to energy/CO2 measures [€/year]<br>$Cost_{running,baseline}$ = Annual costs baseline [€/year]</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data Collection<br>2. KPI Calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">$€/(ton\ of\ CO2)$</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">CSTB, EDF, VULOG, Rb, AH, METRY, IRIS</td></tr>
</table>

# 8. Data loss prevention

<table>
<tr><th colspan="6">Data loss prevention</th></tr>
<tr><td>KPI Description</td><td colspan="5">Managing data brings a lot of opportunities but also some safety issues. To know if data has been stolen, leaked or otherwise distributed it is important that monitoring is in place.<br>This KPI is intended to give a statement about the ability of CIP to prevent data loss.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Lost datapoints in a period.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">The CIP will keep detailed usage statistics.<br>Monitoring access to critical files in relation with the malicious attacks, closely monitor if duplicate files are available on the web that originally are exclusively available on internal servers.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Number of lost datapoints per timeframe.</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">CIVITY, NCA, GOT</td></tr>
</table>

# 9. Data safety

<table>
<tr><th colspan="6">Data safety</th></tr>
<tr><td>KPI Description</td><td colspan="5">The nature of the web environment is hostile. There are a lot of agents trying to exploit vulnerabilities in any software system. From DDoS to someone taking control of the servers, the risks are diverse.<br>This KPI is intended to give a statement about the safety of data in the IRIS applications.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of blocked malicious hacking attempts</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">The CIP will keep detailed usage statistics.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2"># per unit /months/ years</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">GOT, CIVITY, NCA</td></tr>
</table>

# 10. Degree of energy self-supply by RES

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

# 11. Developer engagement

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

# 12. Ease of use for end users of the solution

<table>
<tr><th colspan="6">Ease of use for end users of the solution</th></tr>
<tr><td>KPI Description</td><td colspan="5">The extent to which the solution is perceived as difficult to understand and use for potential end-users. End-users are conceptualised as those individuals who will be using/working with the solution. Some solutions or innovations are perceived as relatively difficult to understand and use while others are clear and easy to the adopters. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Likert Scale<br>Very difficult – 1 — 2 — 3 — 4 — 5 — Very easy<br>1. Very difficult: users need extensive and sustained instructions to understand the solution and without these the solution cannot be understood or used.<br>2. Fairly difficult: users need to be well instructed to be able to understand and use the solution properly. Considerable time is required to familiarize themselves with the solution.<br>3. Slightly difficult: users have to invest some time to understand the solution and get accustomed to working with it. Some time is needed before the solution has become fully familiar to end users.<br>4. Fairly easy: a small investment in time is required of the end users to understand the solution and get accustomed to it, but they are fairly quickly familiar to work with it.<br>5. Very easy: the solution is as easy to understand and use.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Undertaking of the survey<br>2. Analysis of the results</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">BOEX, NCA</td></tr>
</table>

# 13. Energy savings

| Energy savings | | | |
|---|---|---|---|
| **KPI Description** | This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. ES may be calculated separately determined for Electricity, district heating/ cooling, natural gas and other thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings. | | |
| **KPI Formula** | $$ES = 1 - \frac{E_D}{E_R}$$ $ES$ = Energy savings<br>$E_D$ = Energy consumption of the demonstration-site [kWh/(m² year)]<br>$E_R$ = Energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].<br>$$ES_E = 1 - \frac{EE_D}{EE_R}$$ $ES_E$ = Electric energy savings<br>$EE_D$ = Electric energy consumption of the demonstration-site [kWh/(m² year)]<br>$EE_R$ = Electric energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].<br>$$ES_{NG} = 1 - \frac{NGE_D}{NGE_R}$$ $ES_{NG}$ = Natural Gas energy savings<br>$NGE_D$ = Natural Gas Energy consumption of the demonstration-site [kWh/(m² year)]<br>$NGE_R$ = Natural Gas Energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].<br>$$ES_{DH} = 1 - \frac{DHE_D}{DHE_R}$$ $ES_{DH}$ = District Heating energy savings<br>$DHE_D$ = District Heating Energy consumption of the demonstration-site [kWh/(m² year)]<br>$DHE_R$ = District Heating Energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].<br>$$ES_T = 1 - \frac{TE_D}{TE_R}$$ $ES_T$ = Thermal energy savings<br>$TE_D$ = Thermal Energy consumption of the demonstration-site [kWh/(m² year)]<br>$TE_R$ = Thermal Energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].<br><br>Note: In cases where thermal and electrical energy are closely related, for example when electrification of thermal demand takes place, electrical energy savings might be inseparable from the other demands. | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | |
| **Unit of Measurement** | % | **Threshold/ Target** | |

| | | | | | |
|---|---|---|---|---|---|
| **Object of assessment** | Building | X | **Stakeholders** | DSO | X |
| | Set of Buildings | X | | TSP | X |
| | Energy Supply Unit | X | | End-Users | X |
| | Set of Energy Supply Units | X | | Governance | |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | CSTB, UNS, CAH, VEOLIA, EDF, Rb, AH, BOEX, STED, ENEC | | |

# 14. Expiration date of open data

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

# 15. Fine particulate matter emission reduction

<table>
<tr><th colspan="5">Fine particulate matter emission reduction</th></tr>
<tr><td>KPI Description</td><td colspan="4">Improving the air quality in urban areas has been identified by the European Innovation Partnership on Smart Cities and Communities (EIP SCC) as one of the main challenges in the vertical priority area of Sustainable Urban Mobility (EIP SCC 2013, 8). Fine particulate matter (FPM) can cause major health problems in cities. According to the WHO, any concentration of particulate matter is harmful to human health. FPM is carcinogenic and harms the circulatory system as well as the respiratory system. As with many other air pollutants, there is a connection with questions of environmental justice, since often underprivileged citizens may suffer from stronger exposure. The evidence on FPM and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad but are predominantly to the respiratory and cardiovascular systems (ISO/DIS 37120, 2013).</td></tr>
<tr><td>KPI Formula</td><td colspan="4">The indicator is calculated as the direct (operational) reduction of the FPM emissions over a period of time. The result may be expressed as a percentage when divided by the reference FPM emissions. To calculate the direct FPM emissions, the total energy reduced, can be translated to FPM emission figures.<br><br>Carbon monoxide emission reduction can be calculated similarly as carbon dioxide emission reduction. The main difference in the calculation is the emission factor, which has to be obtained for carbon monoxide emissions.<br><br>Use case:<br>When FPM reduction is achieved by more sustainable transport solutions (for example Electric Vehicles or Electric busses), the reduction is based on the emission factor per kilometre (EF) and the number of driven kilometres ($D$).<br><br>$$FPMReduction = D_{baseline}\,EF_{baseline} - D_{measure}\,EF_{measure}$$<br><br>$D_{baseline}$ = the number of driven kilometres before implementing the measure<br>$D_{measure}$ = the number of driven kilometres after implementing the measure<br>$EF_{baseline}$ = the emission factor per kilometre in the baseline<br>$EF_{measure}$ = the emission factor per kilometre for the measure</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td>Tonnes /(year)</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Object of assessment</td><td>Building</td><td></td><td rowspan="5">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | LOM, UTR | | |

# 16. Improved access to vehicle sharing solutions

| Improved access to vehicle sharing solutions | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Providing opportunities for sharing vehicles like (e-)bicycles, (e-)cars and (e-) scooters, can decrease the need for and use of private cars, thereby contributing to an accessible, green and healthy neighbourhood.<br>Cycling is a healthy, flexible, cheap and sustainable way to get from a to b over a short distance. Many European cities therefore would like to stimulate cycling, but in countries without a cycling culture there is limited private ownership of bikes.<br>Car-sharing is about not owning a car but renting it from a carsharing company or sharing the car with friends, family, neighbours or co-workers (1,2). Car-sharing is an attractive option for people who drive less than 10.000 km a year. Car-sharers are more likely to travel by bike, saving on car use and improving their health. Carsharing also decreases the need for parking space, less vehicles are on the road and less pollution is emitted. Car sharing may furthermore improve social cohesion in the neighbourhood.<br>This indicator assesses whether the possibilities for vehicle sharing have been improved due to the project. Improvements include more vehicle sharing locations, shorter distance to the nearest location, increased number of vehicles available and to ICT solutions that provide easy access to information on vehicle sharing options. | | | | |
| **KPI Formula** | Likert scale:<br>No improvement – 1 – 2 – 3 – 4 – 5 – Very high improvement.<br>1. Not at all: the possibilities for vehicle sharing were not improved.<br>2. Poor: there was little improvement in the possibilities for vehicle sharing.<br>3. Somewhat: the possibilities for vehicle sharing were somewhat improved.<br>4. Good: the possibilities for vehicle sharing were sufficiently improved.<br>5. Excellent: the possibilities for vehicle sharing were very much improved. | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | No Unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | X |
| | City | X | | Representative Citizen Groups | X |
| | | | | Citizen Ambassadors | X |
| **Responsible Partner for KPI Data Collection** | | | LOM, UTR, VULOG, TRIV, | | |

# 17. Increased awareness of energy usage

<table>
<tr><th colspan="5">Increased awareness of energy usage</th></tr>
<tr><td>KPI Description</td><td colspan="4">Awareness of energy usage problems is important for creating support for environmental projects and programs. This indicator, therefore, assesses the extent to which the project has used opportunities for increasing energy awareness and educating about sustainability and the environment.<br>The extent to which the project has used opportunities for increasing awareness of energy use and educating about sustainability and the environment.</td></tr>
<tr><td>KPI Formula</td><td colspan="4">Likert scale:<br>Not at all – 1 – 2 – 3 – 4 – 5 – very much<br>1. Not at all: opportunities to increase awareness of energy usage were not taken into account in the project communication.<br>2. Poor: opportunities to increase awareness of energy usage were slightly taken into account in the project communication.<br>3. Somewhat: opportunities to increase awareness of energy usage were somewhat taken into account in the project communication, at key moments in the project there was attention for this issue.<br>4. Good: opportunities to increase awareness energy usage of were sufficiently taken into account in the project communication, the project utilized many possibilities to address this issue in their communications.<br>5. Excellent: opportunities to increase awareness of energy usage were taken into account in the project communication, the project utilized every possibility to address this issue both in online and offline communications.</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">3. Data collection<br>4. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO | X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP | X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users | X</td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance | X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens | X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups | X</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors | X</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="2">BOEX, CSTB, VEOLIA, CAH, UNS, IRIS, EDF</td></tr>
</table>

# 18. Increased consciousness of citizenship

<table>
<tr><th colspan="6">Increased consciousness of citizenship</th></tr>
<tr><td>KPI Description</td><td colspan="5">Consciousness of citizenship is the awareness (consciousness) of one's community, civic rights and responsibilities and as such contributes to the sense of community. At the very least, it means that the individual is aware of what is going on around him. Ideally, it would mean that the individual is involved in the life of the community --understanding his role in the community -- seeking to contribute when he is able to do so.<br>The extent to which the project has contributed in increasing consciousness of citizenship.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five-point Likert scale:<br>No increase – 1 — 2 — 3 — 4 — 5 — High increase<br>1. None: The project has made no effort to increase civic consciousness.<br>2. Little: The project has made a small effort to increase civic consciousness.<br>3. Somewhat: The project has developed some initiatives to increase civic consciousness.<br>4. Significant: The project has executed several activities to increase civic consciousness.<br>5. High: increasing civic consciousness was (one of) the main goals of the project and it has done substantial effort to enhance it.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>x</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>x</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>x</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">BOEX, UTR</td></tr>
</table>

# 19. Increased environmental awareness

| Increased environmental awareness | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Awareness of environmental problems is important for creating support for environmental projects and programs. This indicator, therefore, assesses the extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment.<br>The extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment. | | | | |
| **KPI Formula** | Likert scale:<br>Not at all – 1 – 2 – 3 – 4 – 5 – very much<br>1. Not at all: opportunities to increase environmental awareness were not taken into account in the project communication.<br>2. Poor: opportunities to increase environmental awareness were slightly taken into account in the project communication.<br>3. Somewhat: opportunities to increase environmental awareness were somewhat taken into account in the project communication, at key moments in the project there was attention for this issue.<br>4. Good: opportunities to increase environmental awareness were sufficiently taken into account in the project communication, the project utilized many possibilities to address this issue in their communications.<br>5. Excellent: opportunities to increase environmental awareness were taken into account in the project communication, the project utilized every possibility to address this issue both in online and offline communications. | | | | |
| **Measurement procedure** | 5. Data collection<br>6. KPI calculation | | | | |
| **Unit of Measurement** | No Unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | BOEX, UTR, VEOLIA | | |

# 20. Increase in Local Renewable Energy production

<table>
<tr><th colspan="6">Increase in Local Renewable Energy production</th></tr>
<tr><td>KPI Description</td><td colspan="5">The indicator should account for the increase of the renewable energy generation due to the intervention. In case biomass is used to generate energy, the transport distance is limited to 100 km. Renewable energy shall include both combustible and non-combustible renewables (ISO/DIS 37120, 2013). Non-combustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. The combustible renewables and waste (CRW) consist of biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes), municipal waste (waste produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$LREG = ERES_{R\&I}$<br>LREG = Annual Local Renewable Electricity Generation [MWh]<br>ERES = Annual electricity generated by RES by the measure/intervention [MWh]<br><br>$LREH = HRES_{R\&I}$<br>LRTG = Annual Local Renewable Thermal Generation [MWh]<br>HRES = Annual heating/cooling generated by RES by the measure/intervention [MWh]</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">kWh</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">HSB, Rb, AH, IRIS, CSTB,BOEX, STED,</td></tr>
</table>

# 21. Increased system flexibility for energy players/stakeholders

<table>
<tr><th colspan="6">Increased system flexibility for energy players/stakeholders</th></tr>
<tr><td>KPI Description</td><td colspan="5">Additional flexibility capacity gained for energy players/stakeholders through installed storage and/or production capacity on the demand side.<br>This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention. The KPI is defined separately for electrical and thermal system flexibility and is calculated by dividing the increased flexibility capacity divided by the peak power.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$\Delta SF_{electrical} = \frac{SF_{R\&I\,el} - SF_{BAU\,el}}{P_{peak\,el}}$$<br>$SF_{BAU,\ electrical}$ = Installed capacity contributing to electrical flexibility at baseline [kW]<br>$SF_{R\&I,\ electrical}$ = Installed capacity contributing to electrical flexibility after measure is implemented [kW]<br>$P_{peak,electrical}$ = Peak electrical power after measure is installed [kW]<br>$$\Delta SF_{thermal} = \frac{SF_{R\&I\,thermal} - SF_{BAU\,thermal}}{P_{peak\,thermal}}$$<br>$SF_{BAU,\ thermal}$ = Installed capacity contributing to thermal flexibility at baseline [kW]<br>$SF_{R\&I,\ thermal}$ = Installed capacity contributing to thermal flexibility after measure is implemented [kW]<br>$P_{peak,thermal}$ = Peak thermal power after measure is installed [kW]<br><br>$SF$ is the amount of load capacity participating in demand side management [W].</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%, W/€</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>x</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>x</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">Rb, STED, LOM, EDF, LEM,</td></tr>
</table>

# 22. Local community involvement in the implementation phase

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

# 23. Local community involvement in the planning phase

<table>
<tr><th colspan="6">Local community involvement in the planning phase</th></tr>
<tr><td>KPI Description</td><td colspan="5">The extent to which residents/users have been involved in the planning process.<br>As residents' beliefs, needs, preferences and expectations towards sustainable living environments have a strong influence on project performance, public involvement during the planning stage is essential to provide developers with input to ensure that the project will perform as intended. Moreover, a growing body of literature is exemplifying the importance of civil society/community participation in sustainable urban planning and execution, for example by means of smart city projects, to bring together information, knowledge and skills from diverse backgrounds to articulate the often ambiguous targets of smart cities and to create a sense of ownership over the outcomes.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five-point rating scale No involvement – 1 — 2 — 3 — 4 — 5 — High involvement<br>1. Not at all: No community involvement.<br>2. Inform and consult: The more or less completed plant project is announced to the community either for information only, or for receiving community views. The consultation, however, is mainly seeking community acceptance of the project.<br>3. Advise: the project planning is done by a project team. Community actors are invited to ask questions, provide feedback and give advice. Based on this input the planners may alter the project.<br>4. Partnership: community actors are asked by the project planners to participate in the planning process. The local community is able to influence the planning process.<br>5. Community self-development: the project planners have empowered community actors to manage the project planning and evaluate the results.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td>X</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td>X</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, BOEX</td></tr>
</table>

# 24. Nitrogen oxide emission reduction

<table>
<tr><th colspan="6">Nitrogen oxide emission reduction</th></tr>
<tr><td>KPI Description</td><td colspan="5">Nitrogen oxides (NO and NO2) are major air pollutants, which can have significant impacts on human health and the environment (ISO/DIS 37120, 2013). NO contributes to ozone layer depletion and, when exposed to oxygen, can transform into NO2. NO2 contributes to the formation of photochemical smog and at raised levels can increase the likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. NO2 chemically transforms into nitric acid and contributes to acid rain. Nitric acid can corrode metals, fade fabrics, and degrade rubber. When deposited, it can also contribute to lake acidification and can damage trees and crops, resulting in substantial losses.<br>Quantitative reduction in NOx emissions (NO and NO2) achieved by the project.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">NOx emission reduction can be calculated similarly as carbon dioxide emission reduction. The main difference in the calculation is the emission factor, which has to be obtained for NOx emissions.<br><br>Use case:<br>When NOx reduction is achieved by more sustainable transport solutions (for example Electric Vehicles or Electric busses), the reduction is based on the emission factor per kilometre (EF) and the number of driven kilometres (D).<br><br>$$NO_x Reduction = D_{baseline} EF_{baseline} - D_{measure} EF_{measure}$$<br><br>$D_{baseline}$ = the number of driven kilometres before implementing the measure<br>$D_{measure}$ = the number of driven kilometres after implementing the measure<br>$EF_{baseline}$ = the emission factor per kilometre in the baseline<br>$EF_{measure}$ = the emission factor per kilometre for the measure</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">3. Data collection<br>4. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Tonnes/ (year)</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">LOM, UTR</td></tr>
</table>

# 25. Number of connected urban objects

| Number of connected urban objects | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Number of connected urban objects in the City innovation platform. | | | | |
| **KPI Formula** | Number of objects connected | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | No Unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | X |
| | City | X | | Representative Citizen Groups | X |
| | | | | Citizen Ambassadors | X |
| **Responsible Partner for KPI Data Collection** | | | NCA | | |

# 26. Number of e-charging stations deployed in the area

| Number of e-charging stations deployed in the area | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Charging infrastructure development is critical for the promotion of electromobility and the deployment of electric vehicles. This indicator will assess the level of service with regards to charging capabilities offered by measuring the number of electric vehicles charging stations deployed in the area. | | | | |
| **KPI Formula** | Total stations deployed/area; * 100 | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | Stations/km2, % | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | VULOG | | |

# 27. Number of efficient vehicles deployed in the area

<table>
<tr><th colspan="6">Number of efficient vehicles deployed in the area</th></tr>
<tr><td>KPI Description</td><td colspan="5">A car-sharing system needs a critical number (mass) of vehicles in order to be useful for the users. This indicator will assess the level of service offered by measuring the number of efficient vehicles in the area.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Vehicles deployed / area</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Veh/km2</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">VULOG,</td></tr>
</table>

# 28. Number of Free Floating subscribers

<table>
<tr><th colspan="6">Number of Free Floating subscribers</th></tr>
<tr><td>KPI Description</td><td colspan="5">The successful implementation of a free-floating car-sharing system mostly depends on the use of the vehicles, which is highly related to the service subscribers. This indicator will assess the increase in the number of subscribers to the free-floating car-sharing service.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of final users involved</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">#</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">VULOG</td></tr>
</table>

# 29. Open data-based solutions

<table>
<tr><th colspan="6">Open data-based solutions</th></tr>
<tr><td>KPI Description</td><td colspan="5">To gain insight of the use of open data, mapping the applications developed based on the open data is vital. This KPI is intended to give a statement about the ease of use of open data from external developers.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of services based on open data.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">Manual monitoring/ research in CIP databases.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">Number / (month, year)</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">NCA, METRY, CIVITY</td></tr>
</table>

# 30. Participatory governance

<table>
<tr><th colspan="6">Participatory governance</th></tr>
<tr><td>KPI Description</td><td colspan="5">Participatory governance focuses on deepening democratic engagement through the participation of citizens in the processes of governance with the state. The idea is that citizens should play a more direct role in public decision-making or at least engage more deeply with political issues (Gaventa 2006). A more active engagement of citizens into urban governance and decision making is one of the main aims of the European Innovation Partnership on Smart Cities and Communities (EIP SCC). In its Strategic Implementation Plan (SIP), the EIP SCC specifically highlights the potential of new online services for participatory governance:<br>“If smartly mobilized, the effect of citizen’s behaviour, choices, creativity and entrepreneurship could be enormous, offering huge untapped potential. ICTs play a vital role in this – particularly as the Internet, not least through smartphones, becomes all-pervasive – as well as the willingness to be open towards new citizen-driven initiatives that might not fit with the current administrative system.”(EIP SCC 2012. 12)<br>Several online platforms for a stronger engagement of citizens into decision making have been developed in recent years (e.g. ONTOPICA, GRANICUS, ACCELA, WE THINQ). This indicator looks at the degree of success of these platforms.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator is calculated as the sum of users actively engaged in relevant projects of the city during a year (numerator) divided by the total number of inhabitants of the city (denominator), multiplied by 100%<br>Theoretically the sum of users could equal the total population, so the scale is evenly distributed in steps of 10%.<br><table><tr><th colspan="2">Normalisation</th></tr><tr><td>Improvement</td><td>Score</td></tr><tr><td>0-10%</td><td>1</td></tr><tr><td>10-20%</td><td>2</td></tr><tr><td>20-30%</td><td>3</td></tr><tr><td>30-40%</td><td>4</td></tr><tr><td>40-50%</td><td>5</td></tr><tr><td>50-60%</td><td>6</td></tr><tr><td>60-70%</td><td>7</td></tr><tr><td>70-80%</td><td>8</td></tr><tr><td>80-90%</td><td>9</td></tr><tr><td>90-100%</td><td>10</td></tr></table></td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
</table>

| | |
|---|---|
| **Responsible Partner for KPI Data Collection** | GOT |

# 31. Peak load reduction

<table>
<tr><th colspan="6">Peak load reduction</th></tr>
<tr><td>KPI Description</td><td colspan="5">Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$PL_{REDUCTION} = \left(1 - \frac{P_{peak,R\&I}}{P_{BaU}}\right) * 100$$ $$P_{peak,R\&I} = max_{year/month}\left(P_{electrical,R\&I}\right)$$ $$P_{BaU} = max_{year/month}\left(P_{electrical,BaU}\right)$$</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">CSTB, CAH, VEOLIA, UNS, EDF, NEXITY, Rb, AH, METRY</td></tr>
</table>

# 32. People reached

| People reached | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | A Smart City project is usually most successful if the entire target group of a service participates. For example, if all electrical car owners join in optimizing their battery use to improve the energy system efficiency of the district. In addition, a high score on people reached can be seen as a signal of increased community engagement due to the project. The effort the project will make towards reaching the full extent of its target group can vary and with it the size of the target audience. Therefore, this effort and target audience have to be clearly defined before assessing the indicator.<br>Percentage of people in the target group that have been reached and/or are activated by the project | | | | |
| **KPI Formula** | (number of citizens reached/total number of citizens considered as the total target group of the project) * 100% | | | | |
| **Measurement procedure** | 3. Data collection<br>4. KPI calculation | | | | |
| **Unit of Measurement** | % | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | BOEX, UTR, NCA, VEOLIA | | |

# 33. Platform downtime

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

# 34. Reduced energy cost for customers

| Reduced energy cost for costumers | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator.<br>The KPI will measure the cost of the energy traded by an aggregator, both as a baseline and when ICT are implemented, e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower. | | | | |
| **KPI Formula** | $$COST_{REDUCTION} = \frac{COST_{R\&I} - COST_{BaU}}{COST_{BaU}}$$<br>$COST_{R\&I}$ = the energy cost for customers after implementing the measure [€] = E*cost factor<br>$COST_{BaU}$ = the energy cost for customers for baseline [€] | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | % | | **Threshold/ Target** | | |
| **Object of assessment** | Building | X | **Stakeholders** | DSO | X |
| | Set of Buildings | X | | TSP | X |
| | Energy Supply Unit | X | | End-Users | X |
| | Set of Energy Supply Units | X | | Governance | |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | Rb,EDF, | | |

# 35. Reduced energy curtailment of RES and DER

| Reduced energy curtailment of RES and DER | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Reduction of energy curtailment due to technical and operational problems. The integration of ICT will have an impact on producers, as the time for curtailment will be reduced, and the operative range will be wider. This indicator can be measured as the percentage of GWh electricity curtailment from DER reduction of R&I solution compared to BaU for a period of time, i.e. a year. | | | | |
| **KPI Formula** | $$Reduction\ of\ EnI = \frac{EnI_{baseline} - EnI_{R\&I}}{EnI_{baseline}} \cdot 100$$ EnI = Energy not Injected | | | | |
| **Measurement procedure** | 1. Calculation/determination of baseline<br>2. Data collection<br>3. KPI calculation | | | | |
| **Unit of Measurement** | % | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | X | | End-Users | |
| | Set of Energy Supply Units | X | | Governance | |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | LOM, EDF, | | |

# 37. Reduction in annual final energy consumption by street lighting

<table>
<tr><th colspan="6">Reduction in annual final energy consumption by street lighting</th></tr>
<tr><td>KPI Description</td><td colspan="5">This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$ES_E = 1 - \frac{TE_C}{ER_E}$$<br>$ES_T$ = Electric energy savings<br>$TE_C$ = Electric energy consumption of the demonstration-site [kWh/(m$^2$ year)]<br>$ER_T$ = Electric energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m$^2$ year)].</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">STED</td></tr>
</table>

# 38. Reduction in car ownership among tenants

<table>
<tr><th colspan="6">Reduction in car ownership among tenants</th></tr>
<tr><td>KPI Description</td><td colspan="5">Number of care ownership among tenants before and after moving in to the demonstration area</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Survey among tenants<br><br>$C_{red} = C_{BaU} - C_{R\&I}$<br><br>$C_{red}$ = Reduction in car ownership<br>$C_{BaU}$ = number of cars owned before moving to the demonstration area<br>$C_{R\&I}$ = number of cars owned after moving to the demonstration area</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2"></td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td></td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">TRIV</td></tr>
</table>

# 39. Reduction in driven km by tenants and employees in the district

<table>
<tr><th colspan="6">Reduction in driven km by tenants and employees in the district</th></tr>
<tr><td>KPI Description</td><td colspan="5">Kilometers driven by the tenants and employees in the district before and after moving in to the demonstration area.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$D_{red} = D_{BaU} – D_{R\&I}$<br><br>$D_{red}$ = Reduction in km driven [km/year]<br>$D_{BaU}$ = Driven km before moving to the demonstration area [km/year]<br>$D_{R\&I}$ = Driven km after moving to the demonstration area [km/year]</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2"></td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">TRIV</td></tr>
</table>

# 41. Share of RES in ICT power supply

<table>
<tr><th colspan="6">Share of RES in ICT power supply</th></tr>
<tr><td>KPI Description</td><td colspan="5">Share of renewable energy sources in the power supply for Information and Communication Technologies</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Share of RES power supply= RES power supply / total power supply</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">GOT, METRY</td></tr>
</table>

# 42. Storage capacity installed

| Storage Capacity installed | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Viewing the need for an increase in the RES penetration in the energy mix, energy storage is essential due to the fuzziness in the generation using RES. The smart storage capacity includes all the energy storage technologies integrated in the city smart grid containing electricity, heating and mobility. This KPI presents the impact of the project in the use of smart energy storage systems. To differentiate between energy carriers the KPI has a subscript, electrical or thermal. | | | | |
| **KPI Formula** | If $SCI_{baseline}$ is zero:<br>$Storage\ capacity\ installed_{electrical} = SCI_{R\&I,electrical}$<br>$Storage\ capacity\ installed_{thermal} = SCI_{R\&I,thermal}$<br>$SCI_{R\&I,electrical}$ = electrical storage capacity installed after measure is implemented [kWh]<br>$SCI_{R\&I,thermal}$ = thermal storage capacity installed after measure is implemented [kWh] | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | kWh | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | X |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | |
| | Set of Energy Supply Units | X | | Governance | |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | UTR, NCA, GOT | | |

# 43. Trialability

<table>
<tr><th colspan="6">Trialability</th></tr>
<tr><td>KPI Description</td><td colspan="5">An innovative smart city solution that can be experimented with in the local context (e.g. ‘living lab’) before full implementation, will represent less uncertainty for the potential adopter. Moreover, testing at the local context allows for further fine-tuning of a solution itself, or of the local context to the solution, to increase its performance. The possibilities for such testing define, to some extent, the solution’s potential for diffusion and it is thus presumed that smart city solutions benefit from a higher level of trialability.<br>This indicator therefore assesses the extent to which the solution can be experimented with (Rogers, 1995) NB. It is not the question whether or not the project team has experimented with the innovation in the project in question. It is merely an indication whether or not the innovation’s characteristics allow for small-scale trials, before adopters might choose to implement it on a larger scale.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five point Likert scale:<br>No possibility for experimentation – 1 — 2 — 3 — 4 — 5 —Very high possibilities for experimentation.<br>1. No possibility: The solution cannot be experimented with on a limited basis in the local context. Implementation on a limited basis is either technically unfeasible or would require too much extra resources (time, money, expertise).<br>2. Limited possibilities: The solution has very low opportunities for experimentation at the local level, as it would be very difficult to implement the innovation on a limited basis only, or would require substantial extra resources (time, money, expertise).<br>3. Moderate possibilities: The solution has a moderate opportunity for experimentation at the local level. It would be difficult to implement the innovation on a limited basis only but would be possible with some extra resources (time, money, expertise).<br>4. High possibilities: The solution has a high opportunity as it can be quite easily implemented on a limited basis at the local context, with limited resources (time, money, expertise).<br>5. Very high possibilities: The solution can easily be experimented with on a limited basis at the local context, without requiring extra resources (time, money, expertise).</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td>X</td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td>X</td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td>X</td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

# 44. Usage of open source software

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

# 45. User engagement

<table>
<tr><th colspan="6">User engagement</th></tr>
<tr><td>KPI Description</td><td colspan="5">The implementation of ICT solutions can also be related to the involvement of the users in the control over the energy use in the building. A variety of measures can be implemented, from the installation of metering systems to give the user feedback, to the involvement of the user in the management of their energy consumption. In case that these measures can be allocated to an energy demand reduction, this indicator will be shown.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">• Number of final users involved<br>• Number of people with increased capacity<br>• Number of participants/users of the platform</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">#</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

# 46. Yearly km driven in e-car sharing systems

<table>
<tr><th colspan="6">Yearly km made through the e-car sharing system</th></tr>
<tr><td>KPI Description</td><td colspan="5">The key element of a car-sharing system is the usage of the system, not only in terms of users but in terms of kilometres. This indicator will assess the number of kilometres done using the car-sharing service</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of kilometres done by the car-sharing fleet</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">km</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td>X</td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

# 47. Quality of open data

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

# 48. Total Investments

| 48. Total Investments (€/m²) | | | |
|---|---|---|---|
| **KPI Description** | An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system is defined as cumulated payments until the initial operation of the system. The investment in the refurbishment of an existing system is defined as cumulated payments until the initial operation of the system after the refurbishment.<br>Within SCIS, total investments apply to the energy aspects of the system (e.g. high efficient envelope in a building) and exclude investments non-energy related (e.g. refurbishment of bathrooms). | | |
| **KPI Formula** | $EPI_{BR} = \frac{I_{BR}}{A_d}$ | $EPI_{ER} = \frac{I_{ER}}{A_d}$ | $EPI = EPI_{BR} + EPI_{ER}$ |

# 49. Grants

| 49. Grants (%) | | | |
|---|---|---|---|
| **KPI Description** | Grants are non-repayable funds that a grant maker, such as the government, provides to a recipient, e.g. a business, for ideas and projects to provide public services and stimulate the economy. In order to receive a grant, an applicant must submit a proposal or an application to the potential funder. This could be either on the applicant's own initiative or in response to a request for proposal from the funder. | | |
| **KPI Formula** | $G_{rBR} = \frac{G_{BR} * 100}{I_{BR}}$ | $G_{rER} = \frac{G_{ER} * 100}{I_{ER}}$ | $G_r = \frac{(G_{BR} + G_{ER}) * 100}{I_{BR} + I_{ER}}$ |

# 50. Total annual costs

| 50. Total annual costs (€/year) | | |
|---|---|---|
| **KPI Description** | The total annual costs are defined as the sum of capital-related annual costs (e.g. interests and repairs caused by the investment), requirement-related costs (e.g. power costs), operation related costs (e.g. costs of using the installation) and other costs (e.g. insurance). These costs (can) vary for each year.<br>• Capital related costs encompass depreciation, interests and repairs caused by the investment.<br>• Requirement-related costs include power costs, auxiliary power costs, fuel costs, and costs for operating resources and in some cases external costs.<br>• Operation-related costs include among other things the costs of using the installation and costs of servicing and inspection.<br>• Other costs include costs of insurance, general output, uncollected taxes etc.<br>The total annual costs are related to the considered interval of time (year). To make different objects comparable the same types of costs have to be included in the calculation. | |
| **KPI Formula** | $TAC_{before} = C_E + C_{O\&M}$ | $TAC_{after_i} = C_E + C_{O\&M} + C_F$ |

# 51. Payback

| 51. Payback (Years) | |
|---|---|
| **KPI Description** | The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators. |
| **KPI Formula** | Type A static: $EPP = \frac{EPI}{m}$<br>Type B dynamic:<br>$$EPP = \frac{ln\big(m \cdot (1+d)\big) - ln(EPI - EPI \cdot (1+d) + m)}{ln(1+d)} - 1$$<br>Type C dynamic with energy price increase rate:<br>$$EPP = \frac{ln\big(m \cdot (1+d)\big) - ln(EPI(1+p) - EPI \cdot (1+d) + (1+p)m)}{ln(1+d) - ln(1+p)} - 1$$ |

# 52. Return on Investment

| 52. Return on Investment (%) | |
|---|---|
| **KPI Description** | The return on investment (ROI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total incomes/net profit and the total investment of the project, usually expressed in %. |
| **KPI Formula** | $$ROI_T = \frac{\sum_{t=1}^{T}\left(IN_t - TAC_{after_t}\right) - (I_{BR} + I_{ER})}{I_{BR} + I_{ER}} * 100$$ |
| **Applicable to all economic indicators** | |
| **Input Parameters** | $EPI_{BR}$ = Total investment for all the interventions related to building *(envelope)* retrofitting in the district per conditioned area [€/m$^2$]<br>$EPI_{ER}$ = Total investment for all the interventions related to energy *(system)* retrofitting in the district per conditioned area [€/m$^2$]<br>*EPI = Total investment for all the interventions relating to building envelope and energy system retrofitting [€/m$^2$]*<br>$I_{BR}$ = Total investment for all the interventions related to building *(envelope)* retrofitting [€]<br>$I_{ER}$ = Total investment for all the interventions related to energy *(system)* retrofitting [€]<br>$G_{rBR}$ = Share of the investment in building envelope retrofitting that is covered by grants [%]<br>$G_{BR}$ = Total grants received for the building *(envelope)* retrofitting of the district [€]<br>$G_{rER}$ = Share of the investment in energy *(system)* retrofitting that is covered by grants [%]<br>$G_{ER}$ = Total grants received for the energy *(system)* retrofitting of the district [€]<br>$G_r$ *= Share of the investment in building (envelope) and energy system retrofitting that is covered by grants [%]*<br>$A_d$ = Total floor area of the system renovated [m$^2$]<br>$TAC_{before}$ = Total annual energy cost of the reference system (i.e. energy, operation & maintenance) [€/year]<br>$TAC_{after_i}$ = Total annual energy cost of the system after the intervention (i.e. energy, operation & maintenance, financial) for year *i* [€/year]<br>$C_E$ = Total annual cost of the system supply [€/year]<br>$C_{O\&M}$ = Total annual cost of the operation and maintenance of the facility [€/year]<br>$C_F$ = Total annual financing cost, if applicable [€/year]<br>EPP = Economic payback [years]<br>m = Average annual costs in use savings (€/year) = $TAC_{before} - TAC_{after}$<br>d (%) = Discount rate (d should be unequal to p)<br>p (%) = Energy price increase rate (p should be unequal to d)<br>$ROI_T$ = Return on Investment [%]<br>$IN_t$ = Income in year t<br>$T$ = Duration of the economic analysis period: e.g. T=10, 15 and 20 [years] |

| | | | | | |
|---|---|---|---|---|---|
| **Measurement procedure** | 1. Data collection<br>2. Simulation (for some input parameters)<br>3. KPI calculation | | | | |
| **Unit of Measurement** | | | **Threshold/ Target** | | |
| **Object of assessment** | Building | X | **Stakeholders** | DSO | X |
| | Set of Buildings | X | | TSP | X |
| | Energy Supply Unit | X | | End-Users | X |
| | Set of Energy Supply Units | X | | Decision-making Bodies | |
| | Neighbourhood | X | | Executive & Legislative Bodies | |
| | City | X | | Citizens | |
| | | | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | UTR, NCA, GOT | | |

# 53. Storage Energy Losses

<table>
<tr><th colspan="6">Storage Energy Losses</th></tr>
<tr><td>KPI Description</td><td colspan="5">The various battery storage systems, including BESS, 2nd life batteries and EVs, are essential for the flexibility of energy grids using increased amounts of electricity deriving by RES. This KPI illustrates the energy losses because of battery storage, including the added voltage transformations. The conclusions of this KPI concern the effectiveness of this technology and thus, gives useful data concerning the financial feasibility of its integration.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">$$SEL = \frac{E_{input} - E_{output}}{E_{input}} \cdot 100$$<br>$E_{input}$ = the energy input in a piece of energy storage equipment<br>$E_{output}$= the energy output of a piece of energy storage equipment</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection<br>2. KPI calculation</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">%</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td>X</td><td rowspan="7">Stakeholders</td><td>DSO</td><td>X</td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td>X</td></tr>
<tr><td>Energy Supply Unit</td><td>X</td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td></td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">UTR, NCA, GOT</td></tr>
</table>

# 54. Access to vehicle sharing solutions for municipality

| Access to vehicle sharing solutions municipality | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | This KPI makes it possible to judge whether all the employees of a Municipality that has implemented a car sharing solution have access to the service. | | | | |
| **KPI Formula** | Number of different users / Number of employees | | | | |
| **Measurement procedure** | 1. Data collection<br>2. KPI calculation | | | | |
| **Unit of Measurement** | % | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | X | | TSP | |
| | Energy Supply Unit | | | End-Users | |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | VULOG | | |

# 55. Number of trips in a free-floating car-sharing system

<table>
<tr><th colspan="6">Number of trips in a free-floating car-sharing system</th></tr>
<tr><td>KPI Description</td><td colspan="5">The successful implementation of a free-floating car-sharing system mostly depends on the use of the vehicles, which is highly related to the service subscribers. In case that the system is used by an organisation the number of users is constant as only the employees have access to the service. Therefore, the KPI “Number of free-floating subscribers” is not suitable to assess the use of the service. Instead, the number of trips will better assess the increase in the use of the system.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">Number of trips done by the car-sharing fleet</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Data collection</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">#</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td>X</td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td>X</td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td></td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">VULOG</td></tr>
</table>

# 56. Congruence of expected and actual outcome of local community involvement in city development

| Congruence of expected and actual outcome of local community involvement in city development | |
|---|---|
| **KPI Description** | How well the citizens' ideas of what the outcome of their involvement in city development project will be corresponds to what the actual outcome of their involvement is.<br>This indicator builds on the idea that if the outcome of participation is not what the participants expect, they will be less interested in participating in future co-creation (Helldén & Zhao, 2020) and, maybe even more problematic, give a false sense of agency while in practice legitimising other's agendas (as summarised by Blomkamp, 2018). If the organisers fail to explain the agency and the outcome of the participation activity to the participants or if they do not use the result as intended that is also an ethical problem as the participants has taken part with incorrect assumptions about the participation.<br>There can be congruence between the participants expected and the actual outcome, meaning that the participants understand what their input will result in. It can also be incongruent, meaning that the participants expect that their input will have either more or less impact than it has. It is the organisers responsibility to inform the participants sufficiently and this indicator therefore takes the participants expectations as one of the central parts (and not for example if there was information about outcome). Note that what happens at the implementation of the input is important for this indicator, not just what happen when participants give input.<br>Note also that this indicator does not say in what way citizens should be able to impact, only that they when participating should be aware of what impact that their participation and input have. |
| KPI Formula | The indicator provides a qualitative measure and is rated on a five-point rating scale:<br>Significant incongruence – 1 — 2 — 3 Congruence<br>1. **Significant incongruences:** The impact is significantly more or less than expected. Participating citizens expect their input to have an impact, but the input does not have any impact at all, for example comments on a city platform that are not read. Alternatively, participating citizens' input have significantly more impact than what the citizens expect.<br>2. **Some incongruences:** The impact is somewhat less or more impact than expected. Participating citizens' input have an impact, but not the extent that the participants expect, for example comments about problems with a bicycle road that the citizens expect will lead to fixing the problem are instead read and may impact future bicycle road development but the bicycle road in question is not fixed. Alternatively, participating citizens' input has slightly more impact than the citizens expect.<br>3. **Congruence**: Participating citizens have a correct understanding of the impact their input has. |
| **Measurement procedure** | 1. Collect insight about what type of outcome that the participating citizens expect<br>2. Determine what impact the participating citizens' input had<br>3. Determine level of incongruence or congruence |

| | | | | | |
|---|---|---|---|---|---|
| **Unit of Measurement** | No Unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | |

| | | | | | |
|---|---|---|---|---|---|
| | Energy Supply Unit | | | End-Users | |
| | Set of Energy Supply Units | | | Governance | |
| | Neighbourhood | | | Citizens | X |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | GOT | | |

# 57. Organizational readiness for citizen co-creation

| Organizational readiness for citizen co-creation | |
|---|---|
| **KPI Description** | From the perspective of the city as a local government and a public organisation – a municipality – citizen co-creation can be challenging to integrate into the work processes even though there can be great benefits from citizen co-creation (Blomkamp, 2018).<br>As summarised by Blomkamp (2018) co-design with citizens in a government context can result in diminished control over the project, increased complexity, and be time-consuming initially – although the time save due to a better result might make up for it in the end. Citizen co-creation means not implementing immediate solutions but instead exploring possible solutions with citizens which can be another obstacle for politicians who want to be seen taking immediate action (Ansell, Sørensen & Torfing, 2017). Politicians might also have to let go of ideological convictions and connections to particular interest groups as they involve citizen co-creation (Ansell et al., 2017). These factors can become obstacles for citizen co-creation if the culture of the organisation is not used to co-creation – and the public sector is not always ready (Blomkamp, 2018). In addition, citizen co-creation may work better if policy and services are adaptively implemented, meaning that there are iterations between creation and implementation (Ansell et al., 2017). But bureaucratic systems are typically not designed for such experimental work and responsiveness (Blomkamp, 2018). It thus seems as if governmental contexts in general are not always ready for achieving the potential of citizen co-creation.<br>An important indicator is therefore the extent to which a specific public organisation is ready for citizen co-creation, meaning the extent to which an organisation and its staff understands and accepts or overcome the challenges of citizen co-creation and is able to implement the outcomes of the citizen co-creation (in terms of insights, ideas etc.) in their operations. As there can be differences in readiness throughout an organization and in relation to different types of co-creation activities or for different purposes, this indicator measures the readiness of one co-creation activity or process. The readiness of the organisation as a whole and changes over time can be seen when comparing the level of readiness for different activities or processes. |
| KPI Formula | The indicator provides a qualitative measure and is rated on a three-point rating scale, based on the points above:<br>Low citizen co-creation readiness – 1 — 2 — 3 High citizen co-creation readiness<br>1. **Low readiness for citizen co-creation:** The organisation and its staff have very little understanding of the challenges of citizen co-creation and do not accept or overcome them. They are not able to implement the outcomes of the citizen co-creation (in terms of insights, ideas etc.) in their operations.<br>2. **Medium readiness for citizen co-creation:** The organisation and its staff understand some of the challenges of citizen co-creation and accept or overcome some of them. They are able to implement some of the outcomes of the citizen co-creation (in terms of insights, ideas etc.) in their operations.<br>3. **High readiness for citizen co-creation**: The organisation and its staff understand and accepts or overcome the challenges of citizen co-creation and are able to implement the outcomes of the citizen co-creation (in terms of insights, ideas etc.) in their operations. |
| **Measurement procedure** | 1. When citizen co-creation is being made, observe if the organisation and its staff understands and accept or overcome the challenges they face. |

<table>
<tr><td></td><td colspan="5">2. Observe to what extent the organisation and its staff is able to make use of the outcome of the citizen co-creation.<br>3. Determine level of readiness for citizen co-creation.<br>4, optional. Compare level of readiness for different activities or process and compare across the organisation and/or over time.</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td></td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">GOT</td></tr>
</table>

# 58. Participatory governance

| Participatory governance | |
|---|---|
| **KPI Description** | Participatory governance focuses on deepening democratic engagement through the participation of citizens in the processes of governance with the state. The idea is that citizens should play a more direct role in public decision-making or at least engage more deeply with political issues (Gaventa 2006). A more active engagement of citizens into urban governance and decision making is one of the main aims of the European Innovation Partnership on Smart Cities and Communities (EIP SCC). In its Strategic Implementation Plan (SIP), the EIP SCC specifically highlights the potential of new online services for participatory governance:<br>*"If smartly mobilized, the effect of citizen's behaviour, choices, creativity and entrepreneurship could be enormous, offering huge untapped potential. ICTs play a vital role in this – particularly as the Internet, not least through smartphones, becomes all-pervasive – as well as the willingness to be open towards new citizen-driven initiatives that might not fit with the current administrative system*."(EIP SCC 2012. 12)<br>Several online platforms for a stronger engagement of citizens into decision making have been developed in recent years (e.g. ONTOPICA, GRANICUS, ACCELA, WE THINQ). This indicator looks at the degree of success of these platforms. |
| **KPI Formula** | The indicator is calculated as the sum of users actively engaged in relevant projects of the city during a year (numerator) divided by the total number of inhabitants of the city (denominator), multiplied by 100%. Theoretically the sum of users could equal the total population, so the scale is evenly distributed in steps of 10%. |

| Normalisation | |
|---|---|
| Improvement | Score |
| 0-10% | 1 |
| 10-20% | 2 |
| 20-30% | 3 |
| 30-40% | 4 |
| 40-50% | 5 |
| 50-60% | 6 |
| 60-70% | 7 |
| 70-80% | 8 |
| 80-90% | 9 |
| 90-100% | 10 |

| | |
|---|---|
| **Measurement procedure** | 5. Data collection<br>6. KPI calculation |

| | | | |
|---|---|---|---|
| **Unit of Measurement** | % | **Threshold/ Target** | |

| **Object of assessment** | | | **Stakeholders** | | |
|---|---|---|---|---|---|
| | Building | | | DSO | |
| | Set of Buildings | | | TSP | X |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | X |
| | Neighbourhood | X | | Citizens | |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |

| | |
|---|---|
| **Responsible Partner for KPI Data Collection** | GOT |

# 59. Potential for attractive and inclusive services or city development from co-creation activities

<table>
<tr><th colspan="6">Potential for attractive and inclusive services or city development from co-creation activities</th></tr>
<tr><td>KPI Description</td><td colspan="5">The extent to which co-creation activities provide potential for attractive and inclusive services or city development. To be able to have attractive and inclusive services or city development they should be based on the needs of citizens. In co-creation, needs can be expressed both as needs but also in terms of ideas for services or city development supporting the need.<br>For co-creation activates to result in attractive and inclusive services or city development how they are set up is key. They need to be organised so that participants can express themselves and their needs as well as so that participants can make suggestions or ideate around services or city development. That is how they provide potential for attractive and inclusive services.</td></tr>
<tr><td>KPI Formula</td><td colspan="5">The indicator provides a qualitative measure and is rated on a five-point rating scale<br>No potential – 1 — 2 — 3 — 4 — 5 — Very high potential<br>6. No potential: The co-creation activities provide no new insights about users/citizens and their needs and/or no ideas for services or city development.<br>7. Little potential: The co-creation activities provide some insights about users/citizens and their needs and/or a few ideas for services or city development.<br>8. Some potential: The co-creation activities provide relevant insights about users/citizens and their needs and/or relevant ideas for services or city development.<br>9. High potential: The co-creation activities provide rich, previously unknown insight about different types of users/citizens and their needs and/or several relevant and new ideas for services or city development which would be attractive to many users/citizens.<br>10. Very high potential: The co-creation activities provide rich, previously unknown insight about different types of users/citizens and their needs to an extent that saturation is experienced (meaning that more investigations do not lead to new discoveries). Alternatively or additionally, the co-creation activities provide a wide range of relevant and new ideas for services or city development which are both attractive and inclusive.</td></tr>
<tr><td>Measurement procedure</td><td colspan="5">1. Undertaking of co-creation activity<br>2. Analysis of the resulting insights and/or ideas</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No unit</td><td>Threshold/ Target</td><td colspan="2"></td></tr>
<tr><td rowspan="7">Object of assessment</td><td>Building</td><td></td><td rowspan="7">Stakeholders</td><td>DSO</td><td></td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP</td><td></td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users</td><td>X</td></tr>
<tr><td>Set of Energy Supply Units</td><td></td><td>Governance</td><td></td></tr>
<tr><td>Neighbourhood</td><td></td><td>Citizens</td><td>X</td></tr>
<tr><td>City</td><td>X</td><td>Representative Citizen Groups</td><td></td></tr>
<tr><td></td><td></td><td>Citizen Ambassadors</td><td></td></tr>
<tr><td colspan="3">Responsible Partner for KPI Data Collection</td><td colspan="3">GOT</td></tr>
</table>

# 60. Potential for supporting reduced energy-related negative environmental impact

| Potential for supporting reduced energy-related negative environmental impact | |
|---|---|
| **KPI Description** | To contribute to a sustainable city, services and city developments should support reduced energy-related negative environmental impact, meaning for example reducing energy use, increasing use of RES, contribution to peak shaving, and shifting from fossil sources of energy to non-fossil, etc.<br>This indicator describes the potential for reduced negative environmental impact of the projects' (co-created) ideas and prototypes for services or city developments. This indicator focuses on the *potential* as for ideas and early prototypes the actual impacts have not been achieved yet. It is however still necessary to estimate the potential to know which idea or prototype to continue developing. The potential is *estimated* as these ideas or prototypes have not yet been realized or because the impact cannot be measured easily. Early evaluations with users make the estimation of the potential more accurate (but is not needed to make an estimation).<br>The potential can be direct and related to the addressed activity, such as for example efficiency measures (e.g., insulation), reduced demands (e.g., reduced indoor temperature), or change of way of doing (e.g., change to public transportation). The potential can also be more indirect, be delayed, and/or related to other activities, such as an increase in efficiency that may create rebound effects in other areas of everyday life or increased safety of a bicycle lane that may increase cycling. In additional any impact must be balanced against the impact of the service, solution, or city development itself. The energy saving potential of an ICT system must for example be more than what the ICT system consumes. |
| **KPI Formula** | The indicator provides a quantitative measure and is rated on a five-point rating scale, depending on an estimation/measurement.<br>Negative potential – 0 – 1 — 2 — 3 — 4 — Very high potential<br>0. **Negative potential**: The idea or prototype would have a direct or indirect negative impact and/or the impact of the idea or prototype itself is greater than what it contributes with.<br>1. **Neutral potential**: The idea or prototype would have no direct or indirect impact and/or the impact of the idea or prototype itself cancels out any positive impact.<br>2. **Small potential**: The idea or prototype would have a small direct or indirect impact and the impact of the idea or prototype itself does no cancel out this impact. A small impact is around 1-15% of the total energy-related impact in the activity at hand.<br>3. **Relevant potential**: The idea or prototype would have relevant direct or indirect impact and the impact of the idea or prototype itself does no cancel out this impact. Relevant impact is around 15-30% of the total energy-related impact in the activity at hand.<br>4. **Significant potential**: The idea or prototype would have significant direct or indirect impact and the impact of the idea or prototype itself does no cancel out this impact. Significant impact is above 30% of the total energy-related impact in the activity at hand. |
| **Measurement procedure** | 1. Create or ideas or prototype, for example in a co-creation event<br>2. If possible, evaluate with users and estimate the impact based on the evaluation<br>3. If evaluation with users is not possible, make use of experts on user behaviour and sustainability or make relevant comparisons with previous studies. |

| | | | | | |
|---|---|---|---|---|---|
| **Unit of Measurement** | No unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | |
| | Energy Supply Unit | | | End-Users | X |
| | Set of Energy Supply Units | | | Governance | |
| | Neighbourhood | | | Citizens | |
| | City | | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |
| **Responsible Partner for KPI Data Collection** | | | GOT | | |

# 61. Representation of concerned citizens in service or city development participation efforts

| Representation of concerned citizens in service or city development participation efforts | | | | | |
|---|---|---|---|---|---|
| **KPI Description** | Concerned citizens are citizens who directly or indirectly could be affected by a service or city development. Citizens with similar concerns related to a service or city development can be considered a group of concerned citizens.<br>Groups of concerned citizens can for example be similar in terms of genders, ages, backgrounds, interests, modes of travelling, socio-economic status. A starting point can be to review any protected grounds of discrimination (Diskrimineringsombudsmannen, 2022). But the protected grounds of discrimination are not necessarily relevant in all development. For developing a sports area people who play different kinds of sport are important to include, they become different groups of concerned citizens. A person can of course represent different groups, for example a trans soccer player or a basketball player who travels to the field by public transport.<br>Note that for all concerned citizens to be able to participate the participation efforts need to be organised in an inclusive way. Inclusion can be about where participation activities are located (physically or digitally), when they take place (for example during daytime or evening), what skills you need to take part in them (for example language skills, basic knowledge about the topic, or digital skills), what tools you need to take part in them (for example digital devices), and if the topics or the participation activates are described in a way that makes them relevant to all concerned citizens. | | | | |
| **KPI Formula** | The indicator provides a qualitative measure and is rated on a five-point rating scale:<br>No representation – 1 — 2 — 3 — 4 — 5 — Excellent representation<br>6. **No representation**: no concerned citizens take part<br>7. **Limited representation**: a limited number of groups of concerned citizens are represented, for example basketball players are represented in the development of a new sports area but not, for example, soccer players.<br>8. **Some representation**: several groups of concerned citizens are represented<br>9. **Good representation**: most groups of concerned citizens are represented and by more than one person, for example two basketball players and three soccer players, but not all groups are represented or represented by more than one person<br>10. **Excellent representation**: all groups of concerned citizens are represented by more than one person | | | | |
| **Measurement procedure** | 1. Define groups of concerned citizens for the service or city development<br>2. Undertaking of event/platform for city development participation<br>3. Estimation of level of representation of concerned citizens | | | | |
| **Unit of Measurement** | No unit | | **Threshold/ Target** | | |
| **Object of assessment** | Building | | **Stakeholders** | DSO | |
| | Set of Buildings | | | TSP | |
| | Energy Supply Unit | | | End-Users | |
| | Set of Energy Supply Units | | | Governance | |
| | Neighbourhood | | | Citizens | X |
| | City | X | | Representative Citizen Groups | |
| | | | | Citizen Ambassadors | |

| | |
|---|---|
| **Responsible Partner for KPI Data Collection** | GOT |

# 62. The co-creation tools' ability to engage citizens

<table>
<tr><th colspan="5">The co-creation tools' ability to engage citizens</th></tr>
<tr><td>KPI Description</td><td colspan="4">For a co-creation activity to capture important insights or ideas it is beneficial if the activity as such is engaging for many citizens. Engagement is needed for people to reflect, ideate, or create for long periods of times, with an energized focus and with continuous curiosity for the topic at hand – to immerse themselves. With engagement comes more and possibly also richer insights/ideas/creations as participants spend more time, attention, and effort on the reflection/ideation/creation and does so with continuous curiosity.<br><br>For co-creation, there are three key components: processes, principles, and practical tools, which include both methods and material (Blomkamp, 2018). This indicator focuses on the tools and their abilities to engage.<br><br>People can get engaged by different types of tools. Examples can be digital or physical games, immersive digital experiences, social events, visualisations such as in films, creative work such as drawing or building prototypes, storytelling, or first-hand experiences or experiments. An engaging co-creation tool can contribute to a higher number of participants in the activity, for example if the tool makes it seem fun to take part. This is especially important if people are supposed to participate voluntary in their free time.<br><br>For some tools or topics, a facilitator is central for the tool to become engaging, for example if the tool is a game a game educator might be needed or if the focus is on city planning an architect educator might be helpful. To engage many different types of participants a combination of tools could be needed. To avoid an unclear distinction of what a tool is, this indicator includes the material (e.g., a digital game), combinations of materials (e.g., a game and material for collage making), and the facilitation of the participation, for example the background information given, the questions asked, and the facilitators way of facilitating. All such factors can be considered methods and materials, which are seen as tools for co-creation (cf. Blomkamp, 2018).</td></tr>
<tr><td>KPI Formula</td><td colspan="4">The indicator provides a qualitative measure and is rated on a three-point rating scale:<br><br>Low ability to engage – 1 — 2 — 3 High ability to engage<br><br>1. Low ability to engage: For most participants, the co-creation tools were only able to create limited engagement resulting in short time spent with the tool, scattered focus and no or limited curiosity evoked.<br>2. Medium ability to engage: For most participants, the co-creation tools were able to create some engagement resulting in sufficient time spent with the tool with some focus. Some curiosity for the topic was evoked.<br>3. High ability to engage: For most participants, the co-creation tools were able to create great engagement resulting in much time spent with the tool with an energized focus. Continuous curiosity for the topic was evoked.</td></tr>
<tr><td>Measurement procedure</td><td colspan="4">1. Undertake a co-creation activity with some type (combination) of tool<br><br>2. Observe the participants engagement levels: the length, focus, and level of curiosity in their reflections, creations, or ideations.<br><br>3. Determine the tools ability to engage</td></tr>
<tr><td>Unit of Measurement</td><td colspan="2">No Unit</td><td>Threshold/ Target</td><td></td></tr>
<tr><td rowspan="3">Object of assessment</td><td>Building</td><td></td><td rowspan="3">Stakeholders</td><td>DSO | </td></tr>
<tr><td>Set of Buildings</td><td></td><td>TSP | </td></tr>
<tr><td>Energy Supply Unit</td><td></td><td>End-Users | X</td></tr>
</table>

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

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# 4 Annex 4 – Update of included KPIs for the LHC

In the following sections the new, removed or modified KPIs are listed for each LH city.

## 4.1 Utrecht

Below is a table of the new, modified or removed KPIs for the measures in Utrecht with a comment to explain the reason for the change.

*Table 1: The changes of KPIs included in the evaluation of measures in Utrecht*

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **1.1, 1.6, 1.7, 3.1, 3.2** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **3.1** | Storage capacity installed | | **X** | | Updated KPI formula |
| **3.1, 3.2** | Fine particulate matter emission | | **X** | | Updated KPI formula |
| **3.1, 3.2** | Carbon monoxide emission reduction | | **X** | | Updated KPI formula |
| **3.1, 3.2** | NOx emission reduction | | **X** | | Updated KPI formula |
| **5.6** | Citizen engagement and Self- Maintenance | **X** | | | This is a new measure that was added to the IRIS project |

## 4.2 Nice

Below is a table of the new, modified or removed KPIs for the measures in Nice with a comment to explain the reason for the change.

Below is a table of the new, modified or removed KPIs for the measures in Nice with a comment to explain the reason for the change.

*Table 2:The changes of KPIs included in the evaluation of measures in Nice*

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **2.1** | Energy Savings | | | **X** | |
| **2.1** | Carbon dioxide Emission Reduction | | | **X** | The measure doesn't affect Carbon dioxide Emission Reduction |
| **2.1** | Battery degradation rate | | **X** | | Updated KPI formula |
| **2.1** | Reduced energy cost for customers | | **X** | | Updated KPI formula |
| **2.1** | Peak load reduction | | | **X** | |
| **2.1** | Degree of energy self-supply by RES | | | **X** | Already calculated in TT M1 |
| **2.1** | Increased system flexibility for energy players | | **X** | | Updated KPI formula |
| **2.1** | Reduced energy cost for customers | | **X** | | Updated KPI formula |
| **2.1** | Storage capacity installed | | **X** | | Updated KPI formula |
| **2.2** | Storage capacity installed | | **X** | | Updated KPI formula |
| **2.2** | Energy Savings | | **X** | | Updated KPI formula |

| | | | | | |
|---|---|---|---|---|---|
| **2.2** | Reduced energy cost for customers | | **X** | | Updated KPI formula |
| **2.2** | Degree of energy self-supply by RES | | **X** | | Updated KPI formula |
| **3.1** | Storage capacity installed | | **X** | | Updated KPI formula |
| **3.1** | Carbon dioxide Emission Reduction | | | **X** | The measure doesn't affect Carbon dioxide Emission Reduction |
| **3.1** | Increased system flexibility for energy players | | **X** | | Updated KPI formula |
| **3.1** | Number of e-charging stations deployed in the area | | **X** | | Updated KPI formula |
| **3.2** | Access to vehicle sharing solutions for municipality | **X** | | | Added KPI |
| **3.2** | Number of trips in a free-floating car-sharing system | **X** | | | Added KPI |

## 4.3 Gothenburg

Below is a table of the new, modified or removed KPIs for the measures in Gothenburg with a comment to explain the reason for the change.

*Table 3: The changes of KPIs included in the evaluation of measures in Gothenburg.*

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **1.1** | Energy savings | | | **X** | The measure should result in production of electricity from PVs, so no energy savings and therefore this KPI is removed. |
| **1.1** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **1.2** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **1.3** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **1.4** | Peak load reduction | | | **X** | Meters have not been installed in such a way that it will be possible to evaluate the effect on peak load reduction for the measure. |
| **1.4** | Carbon dioxide Emission Reduction | | | **X** | Not possible to evaluate this measure at the level of detail needed to capture possible CO2 emission reduction since it would require momentary information regarding heat production units in the district heating grid. (Furthermore, the EMS (M1.6) will optimize the operation of the installations of Brf Viva to achieve lower costs, not CO2 emissions. Although it can be assumed that lower cost also is associated with lower emissions.) |
| **1.4** | $CO_2$ reduction cost efficiency | | | **X** | See explanation above. |
| **1.4** | Storage capacity installed | | **X** | | Updated KPI formula |
| **1.5** | Carbon dioxide Emission Reduction | | | **X** | Measure 1.5 and 1.3 are connected and to avoid double accounting this KPI is only included for 1.3. |
| **1.5** | $CO_2$ reduction cost efficiency | | | **X** | See comment above. |
| **1.5** | Energy savings | | | **X** | The KPI is removed since the aim of the measure is energy trading not energy savings |
| **1.5** | Peak load reduction | | | **X** | The KPI is removed since peak load reduction is not the aim of the measure |
| **1.5** | Reduced energy cost for customers | | **X** | | Updated KPI formula |
| **1.6** | Carbon dioxide emission reduction | | | **X** | The KPI is removed since this measure does not aim at or lead to reduction of CO2 emission. |

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **1.6** | Degree of energy self-supply by RES | | | **X** | This KPI is removed as the measure does not include renewable energy production |
| **1.6** | Peak load reduction | | | **X** | The KPI is removed since peak load reduction is not the aim of the measure |
| **1.6** | Increased system flexibility for energy stakeholders | | **X** | | Updated KPI formula |
| **1.7** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **TT2** | Peak load reduction | | | **X** | It is not relevant and possible to aggregate |
| **2.1** | Storage capacity installed | | **X** | | Updated KPI formula |
| **2.2** | Storage capacity installed | | **X** | | Updated KPI formula |
| **2.2** | Storage energy losses | **X** | | | Added KPI |
| **2.4** | Battery degradation rate | | | **X** | If evaluation of battery degradation rate will be included it will be given by the provider of the batteries. Instead of measured data, which would be needed for a KPI calculation, there might just be a number, estimate or statement on the degradation of the batteries. |
| **2.4** | Storage capacity installed | | **X** | | Updated KPI formula |
| **3.1** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **3.1** | Energy savings | | | **X** | The KPI is removed as the measure is not focused on energy savings. |
| **3.1** | Improved access to vehicle sharing solutions | | | **X** | The KPI was removed as it didn't fit the measure since it is new building |
| **3.1** | Reduction in car ownership among tenants | | **X** | | Updated KPI formula |
| **3.1** | Reduction in driven km by tenants | | **X** | | Updated KPI formula |
| **3.2** | Carbon dioxide Emission Reduction | | **X** | | Updated KPI formula |
| **3.2** | Energy savings | | | **X** | The KPI is removed as the measure is not focused on energy savings. |
| **3.2** | Reduction in car ownership among tenants | | **X** | | Updated KPI formula |

| TT.M | KPI | New | Modify | Remove | Comment |
|---|---|---|---|---|---|
| **4.1** | Quality of open data | | **X** | | Updated KPI formula |
| **4.2** | Quality of open data | | **X** | | Updated KPI formula |
| **5.7** | User engagement | | **X** | | Updated KPI formula |
| **5.1, 5.2** | User engagement | | | **X** | Replaced with other KPIs instead |
| **5.1, 5.2, 5.5** | Congruence of expected and actual outcome of local community involvement in city development | **X** | | | Added KPI |
| **5.1, 5.2, 5.3, 5.5** | Organizational readiness for citizen co-creation | **X** | | | Added KPI |
| **5.1, 5.2, 5.3, 5.5** | Participatory governance | **X** | | | Added KPI |
| **5.1, 5.2, 5.3, 5.5** | Potential for attractive and inclusive services or city development from co-creation activities | **X** | | | Added KPI |
| **5.7** | Potential for supporting reduced energy-related negative environmental impact | **X** | | | Added KPI |
| **5.1, 5.2, 5.3, 5.5** | Representation of concerned citizens in service or city development participation efforts | **X** | | | Added KPI |
| **5.1, 5.2, 5.3, 5.5** | The co-creation tools' ability to engage citizens | **X** | | | Added KPI |

# 5 Annex 5 – Utrecht KPIs and data input

## 5.1 Utrecht – TT1

### 5.1.1 Measures analysed at building level

The following table shows how the data sources for KPI measurement were finally set up for Henriettedreef (HD), Complex 507 (C507) and the buildings in Kanaleneiland Zuid (KZ) for Measures 1.1, 1.4, 1.6 and 1.8.

*Table 4: Summary-list of KPIs and related parameters for measures 1.1, 1.4, 1.6 and 1.8.*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Degree of energy self-supply by RES** | Locally produced electrical energy = electricity generated by PV panels [kWh] | HD: BeNext<br>KZ: BeNext, COL1-> recalculated to meet system size | 0, Before the measure, no electricity was generated by RES | 30% |
| | Electrical energy consumption from RES [kWh] | HD: BeNext<br>KZ: Stedin | | |
| **Increase in local renewable energy production [MWh/year]** | Locally produced electrical energy = electricity generated by PV panels [kWh] | HD: BeNext<br>KZ: BeNext, COL1-> recalculated to meet system size | 0, Before the measure, no electricity was generated by RES | 60% |
| **Carbon dioxide Emission Reduction** | Annual electricity generated by PV panels | HD: BeNext<br>KZ: BeNext | NA | 600 ton $CO_2$ reduction / year |
| | $CO_2$ coefficient for electricity in the Netherlands | BEST table | | |
| **Installed capacity (not a KPI)** | Amount of PV installed after the project | Project results | NA | 0,8MWp (GA: 1,8 MWp or 100% building demand) |
| **Energy savings - for the tenants** | Thermal energy consumption of the demonstration site [kWh/year] | | HD: Stedin | -/- 50% |

| | | | | |
|---|---|---|---|---|
| | Electric energy consumption of the demonstration site [kWh/year} | HD: BeNext<br>KZ: Stedin<br>C507: Stedin | HD: Stedin<br>KZ: Stedin<br>C507: Stedin | |
| | Gas energy consumption of the demonstration site [kWh/year} | KZ: Stedin<br>C507: Stedin | HD: Stedin<br>KZ: Stedin<br>C507: Stedin | |
| **Carbon dioxide Emission Reduction** | Thermal/ electric/ gas Energy consumption of the demonstration site [kWh/ year] | See above | See above | -/- 80% |
| | Emission factor for district heating | BEST table | BEST table | |
| | $CO_2$ coefficient for electricity in the Netherlands | BEST table | BEST table | |
| | $CO_2$ coefficient for natural gas in the Netherlands | BEST table | BEST table | |
| **Reduced energy cost for costumers** | Energy savings | See above | | -/- 50% |
| | Energy price | BEST table | BEST table | |
| **$CO_2$ reduction cost efficiency** | $CO_2$ emission reduction | See above | NA | |
| | Annual costs of project | Project cost data | NA | |

#### *5.1.1.1 Energy demand data*

**HEMS-TOON:** Each household has a HEMS-TOON installed, which collects and visualizes the energy data from the smart meters. Before this energy data is shared with the database, two conditions must be met:

- The TOON is connected to the internet: the tenant must provide wifi access to TOON)
- The TOON is allowed to share data to 3rd parties: the tenant must grant this by giving consent in the settings.

Data is send to the database of CUBY (a partner of Eneco who handles all TOON data). To maintain privacy, CUBY aggregates the electricity import and export at building level and shares the averages with the CIP, including the amount of households of which these averages are taken. The KPI tool is programmed to automatically request this data from the CIP.

Even though the data connection itself was properly set-up, there were some issues with the data which caused uncertainties.

- Missing data: there were periods of data missing in the dataset or installation of TOONs was done too late.
- Amount of unique measurements too small: The pool of households of which the average was taken was smaller than 5 (of 48).
- TOON only takes measurements at smart meter level and the PV generation is not separately monitored. Because of this, the generated PV energy which is directly consumed by the household (self consumption) does not pass the smart meter. This means that a lower household energy demand as well as a lower PV production is being measured.

For these reasons TOON data was not used for the annual KPI calculations. Nevertheless parts of the dataset were used for more detailed calculations, such as the sensitivity analysis of the CO2 emission factors, which will be published in a separate journal paper (XX) and congestion management (XX).

**BENEXT monitoring data:** The Henriettedreef building has an extensive monitoring system installed, which registers all possible data related to energy demands of the households and the building itself. A connection to the CIP is made with the BeNext servers to obtain values for electricity demand and PV production of building at 15 minute resolution. Even though a connection with the CIP and the KPI tool was properly setup. Some complications in the data (missing data, aggregations out of sync), caused reliability issues. To circumvent this, calculations were done based on the detailed data after an extensive data analysis and uploaded by means of the template.

**Stedin SJV / SAN:** SJV stands for 'Standaard Jaarverbruik' or 'Standardised Annual Demand' (SAN). This data is collected by Stedin, the grid utility and is the expected demand per a costumer on a grid connection at standardized conditions based on a normalized year. (https://www.stedin.net/zakelijk/open-data/verbruiksgegevens ). The data is provided by Stedin and for privacy reasons aggregated per building. Apart from a some TOONs as mentioned before, all buildings did not have any other monitoring installed before renovation, the SJV is used as calculation of the baseline.

#### *5.1.1.2 Baseline data*

In D5.1 paragraph 4.2 (source) the baseline data for the first set of buildings is described, based on the average energy demand per household measured in 2017 by the Stedin (the network operator). The data from Henriettedreef is also based on Stedin data and obtained from an internal report (source). For KPI calculation the baseline demand is calculated per building. For this reason the average energy demand per household is multiplied with the amount of apartments per building in order to obtain this value.

The KPI tool also requires the gas demand in kWh, while the  data is in $m^3$. To obtain kWh from this data, the values are multiplied with a factor of 8.7667. This is similar as the factor used in the BEST tables. And is calculated by dividing the Lower Heating Value of Dutch Natural Gas (31.65 $MJ/m^3$) with 3.6 (to turn MJ into kWh).

The table below provides the input data and the data which is transferred to the KPI tool in pink.

*Table 5: Input data and data transferred to KPI tool in pink.*

| | Input Data | | | Data for KPI calculation | | |
|---|---|---|---|---|---|---|
| Apartment building | # of apart ment | Electricity demand apartment 2017 [kWh] | Gas demand apartment 2017 [m3] | Electricity demand building [kWh] | Gas demand building [kWh] | District heating demand Building [kWh] |
| A. de Grotelaan III | 48 | 1835 | 994 | 88080 | 418275 | |
| A. de Grotelaan II | 48 | 1819 | 1043 | 87312 | 438894 | |
| Columbuslaan II | 48 | 1492 | 1067 | 71616 | 448994 | |
| Henriettedreef | 58 | 1700 | 65 | 98600 | 33050 | 370562 |

For complex 507 the baseline input data is a bit more complicated. First of all, the building consist of 11 different clusters of apartments, which have been retrofitted in different years. The table below shows the average gas and electricity demand per apartment for the years 2019, 2020 and 2021. These numbers are provided by the network operator. The last 4 columns show the amount of apartments that where refurbished in the respective year.

*Table 6 Stedin SJV data of the separate clusters of complex 507 at apartment level*

| | | **Average Electricity Demand per apartment [kWh/year]** | | | **Average Natural Gas Demand per apartment [m$^3$/year]** | | | **Amount of apartments refurbished** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cluster** | # of adresses | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 | 2022 |
| **F1** | 50 | 1718 | 1552 | 1356 | 1010 | 972 | 820 | 0 | 49 | 0 | 1 |
| **F2** | 20 | 1934 | 2015 | 1634 | 1178 | 1121 | 906 | 0 | 15 | 5 | 0 |
| **F3** | 41 | 1423 | 1462 | 1384 | 1165 | 1111 | 794 | 0 | 16 | 19 | 6 |
| **F4** | 57 | 1746 | 1757 | 1543 | 1008 | 992 | 799 | 0 | 0 | 56 | 1 |
| **F5** | 21 | 1731 | 1810 | 2045 | 1047 | 1062 | 989 | 0 | 0 | 21 | 0 |
| **F6** | 30 | 1766 | 1875 | 2138 | 1117 | 1054 | 1055 | 0 | 0 | 30 | 0 |
| **F7** | 24 | 1950 | 2030 | 2076 | 1296 | 1292 | 1187 | 0 | 0 | 0 | 24 |
| **F8** | 35 | 2294 | 2393 | 2312 | 1257 | 1205 | 1202 | 0 | 0 | 0 | 35 |
| **F9** | 25 | 2426 | 2313 | 2338 | 1405 | 1466 | 1433 | 0 | 0 | 0 | 25 |
| **F10** | 15 | 2688 | 2742 | 2711 | 1204 | 1189 | 1273 | 0 | 0 | 0 | 15 |
| **F11** | 35 | 1768 | 1807 | 2114 | 1277 | 1243 | 1253 | 0 | 0 | 0 | 35 |

The baseline is defined by the annual demand of 2019. This is the year where all apartments were not renovated yet. For KPI calculation only the building demand after renovation is submitted to the KPI tool. All values are multiplied by the amount of apartments per cluster to calculate towards building level. Data for complex 507 as a whole is also calculated (cluster: All in the table). In these cases the baseline as well as the measurements for each year are based on the sum of the buildings which had measurement data for that respective year.

*Table 7 Baseline and results data for Complex 507 at cluster and building level*

| | | Electricity (kWh) (building) | | | Gas (kWh) building | | |
|---|---|---|---|---|---|---|---|
| Clus-ter | Baseline based on | Baseline | 2021 | 2022 | Base line | 2021 | 2022 |
| F1 | | 85900 | 67800 | 70550 | 442717 | 359433 | 328750 |
| F2 | | 38680 | 32680 | 28360 | 206543 | 158852 | 143072 |
| F3 | | 58343 | | | 418740 | | 255198 |
| F4 | | 99836 | | | 499700 | | 329302 |
| F5 | | 37181 | | | 194133 | | 137891 |
| F6 | | 54615 | | | 285487 | | 220131 |
| C507 | 2021: F1 – F2<br>2022: F1-F6 | Baseline | 124580 | 371776 | Baseline | 649259 | 2058220 |
| | | Measure | 99260 | 294254 | Measure | 510921 | 1414344 |

*Table 8: Measured demand per apartment building.*

| Apartment building | Measured demand building (kWh) | | | | | |
|---|---|---|---|---|---|---|
| | 2021 | | | 2022 | | |
| | Electricity | Gas | DH | Electricity | Gas | DH |
| Alexander de Grotelaan III | | | | 87648 | 291194 | 0 |
| Alexander de Grotelaan II | | | | 81504 | 278149 | 0 |
| Henriettedreef | 220406 | 0 | 0 | 180951 | 0 | 0 |
| Complex 507 | 99260 | 510921 | 0 | 294254 | 1414344 | 0 |

#### 5.1.1.3 Energy production data

The buildings A. de Grotelaan II and III and Columbuslaan II and III are equipped with a PV system. Each household in the building has a PV system of 4 modules with a capacity of 330 Wp each (total 1.32 kWp) on top of that, each building has 22 modules installed on the central utilities (total 7.260 kWp). This makes the total installed capacity (48*4+22)*330 = 70.62 kWp

Production data of these systems was not available due to two reasons:

- TOONs could have been equipped with a separate PV module, this was not done or properly set up in the data streams.

- Due to delays in installation and misunderstandings amongst tenants, most of the PV system were only put into operation at the end of 2022.

To overcome this issue, the production data of the PV system of Columbuslaan I was used. The system consists of 30 PV modules of 325 Wp (Total 9.750 kWp), with the same orientation and inclination.

To calculate the production of the PV modules (1.32 kWp) connected to the apartments of Alexander de Grotelaan II & III ($E_{PV\ apartment}$, 1.32 kWp), the production of the 30 PV modules ($E_{reference\ system}$,9.75 kWp) is related as in the formula below.

$E_{PV\ apartment} = 1.32/9.75 * E_{reference\ system} = 0.1354\ E_{reference\ system}$

$E_{PV\ central\ factilies} = 7.26/9.75 * E_{reference\ system} = 0.7446\ E_{reference\ system}$

$E_{PV\ building} = 70.62/9.75 * E_{reference\ system} = 7.243\ E_{reference\ system}$

According to the Benext Data of the reference system, the total yield over 2022 was 9925 kWh, which means that the yield per dwelling ($E_{PV\ apartment}$ ) over 2022 would have been 1343.7 kWh. Yield for central facilities is then 7390.2 kWh. For the whole building it becomes 71887 kWh.

Because of various reasons most of the PV systems on these buildings were only put into operation late 2022. For this reason data from the reference system is used to calculate the expected production of the system. Because of the same reason it is assumed that the PV systems have not significantly influenced the demand data of the dwellings with regards to the self-consumption.

The PV production data for Henriettedreef and AdGI and AdGIII which were used for KPI calculation are represented in the table below.

*Table 9: PV production of the different buildings.*

| Apartment building | PV production building (kWh) | |
|---|---|---|
| | 2021 | 2022 |
| Alexander de Grotelaan III | 0 | 71888 |
| Alexander de Grotelaan II | 0 | 71888 |
| Henriettedreef | 192634 | 255351 |

#### *5.1.1.4 Additional construction costs for CO2 reducing measures*

Since periodical renovation of the buildings had to be done regardless the IRIS project, not all renovation budget could be accounted for as costs for $CO_2$ reducing measures. An example of this are the costs for windows, doors and glazing. For this post 40% of the total cost are accounted for as additional cost for $CO_2$ reducing measures. On the other hand, 100% of the expenses for insulation of floors and walls are taken into account. The detailed cost breakdown structure of the renovations is confidential data. The table below shows the additional construction costs for $CO_2$ reducing measures per apartment per building. For complex 507 the final values were obtained by only taking the fully renovated buildings into account, which were f1 and F2 for 2021 and F1 to F6 for 2022. To calculate annual costs from the investment costs, total costs are divided by 25. A usage period of 30 years is expected, but since running costs were not included an usage period of 25 years is assumed in this calculation.

*Table 10: Cost of $CO_2$ reducing measures per apartment, building and building/year of the different buildings.*

| | | number of apartments | Costs for CO2 reducing measures per apartment (Euro) | Costs for CO2 reducing measures per building (Euro) | Costs for CO2 reducing measures per building (Euro)/year |
|---|---|---|---|---|---|
| **Alexander de Grotelaan II** | | 48 | 32350 | 1552817 | 62113 |
| **Alexander de Grotelaan III** | | 48 | 32350 | 1552817 | 62113 |
| **Henriettedreef** | | 58 | 60358 | 3500764 | 140031 |
| **Complex 507** | 2021 (F1, F2) | 70 | 51413 | 2570672 | 143956 |
| | 2022 (F1 – F6) | 219 | 51413 | 1028269 | 450378 |

### 5.1.2 Measure 1.3

*Table 11 Summary-list of KPIs and related parameters for Measure 1.3 Home Energy Management Systems (HEMS) TOON*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **17: Increased awareness of energy usage** | Increased awareness of energy usage | Survey | NA | 4 on a scale of 1-5 |

#### 5.1.2.1 Data inputs for measure 1.3

In start of 2023 a survey was held amongst tenants of the refurbished buildings. One question was asked to indicate the increased awareness of energy usage of TOON. When the deadline for data input was reached, 25 tenants were visited by an energy coach and filled in the online survey as shown below.

*Table 12: Input data of Measure 1.3 Home Energy Management Systems (HEMS) TOON*

| Parameter | | | | | |
|---|---|---|---|---|---|
| **Increased awareness of energy usage (amount of answers per Likert scale category)** | **1** | **2** | **3** | **4** | **5** |
| | 7 | 4 | 5 | 4 | 5 |

### 5.1.1 Measure 1.7

*Table 13 Summary-list of KPIs and related parameters for Measure 1.7 Smart DC street lighting at district level*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Reduction in annual final energy consumption by street lighting (Energy savings)** | Annual Electricity consumption of street lighting [kWh/year] | Energy demand of smart street lighting | Electricity consumption for street lighting before measure. | -/- 70% |
| | Electricity consumption for street lighting before measure. [kWh/year] | Energy demand of conventional street lighting | | |
| **CO2 emission reduction** | Annual Electricity consumption of street lighting [kWh/year] | Energy demand of smart street lighting | NA | -/- 70% |
| | Electricity consumption for street lighting before measure. [kWh/year] | Energy demand of conventional street lighting | | |
| | $CO_2$ coefficient for electricity in the Netherlands [Tonne/kWh] | BEST table | | |

For the monitoring and control of the street lighting, Luminext Luminizer telemanagement is used. This system gives insight in the energy usage and the information coming from the other functionalities. Even though a connection with the CIP was set up with the Luminext system, the data turned out to be not sufficient for the KPI calculations at the final stage of the IRIS project. For this reason the calculation is done under assumptions made by the Utrecht municipality.

The energy demand per year for conventional street lighting is given as 106 kWh/year per lamppost, the demand for the new LED street lights is 60% lower and 42.8 kWh/year. With 49 lamp post installed in the pilot, this gives a total of 5194 kWh/year for BAU and 2097.2 kWh/year for the measure. The associated CO2 emission reduction is then 1.37 tonnes per year for 2021 and 2022 with the IRIS_NL emission factors (total 2.74 tonnes). With more recent emission data, reduction adds up to 2.57 tonnes CO2, with 1.35 and 1.22 tonnes for 2021 and 2022 respectively.

## 5.2 Utrecht – TT2

### 5.2.1 Measure 2.3

*Table 14 Summary-list of KPIs and related parameters for Measure 2.3 Stationary storage in apartment buildings*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Storage capacity installed** | Storage capacity installed [kWh] | Technical specification stationary battery | Present storage capacity (zero) | 845 kWh |

In D5.9[1] an estimation is given about peak load reduction on the transformer loads by using the district battery. The following text is obtained from D5.9, paragraph 3.2 but has some updates as a recalculation of the results was done with the latest data. Text in Green shows where these updates were done.

This stationary battery provides flexibility services to the electricity grid by trading on the TSO electricity markets. It is bundled with the other assets of the growing Utrecht Bidirectional Ecosystem, especially the V2G charging stations throughout the city and the other stationary battery already in operation at the site of the Jaarbeurs trade fair. At the same time, the stationary battery is used by Utrecht University, Utrecht Sustainability Institute and Stedin to analyse in what amount it can contribute to reduction of network congestion, and what value it could create when delivering that contribution. These results are being used to determine the business case for the parties that deliver flexibility (the battery is being operated on behalf of housing association Bo-Ex by an aggregating party) and for the DSO Stedin as future customer for these services. This has provided the DSO Stedin with information on how much flexibility is available from the battery, and at what price that flexibility would become available for local congestion management, at the desired moments. At moments when the battery is used to provide congestion management services to the DSO, it is not able to optimally operate on the national energy markets and therefore it will lose some revenues there. The demonstrator has given Stedin insight into the actual amount of revenues lost by doing so, now and in the future.
To deliver these services and to generate these data, the battery has used the monitoring equipment included in the battery management software, electricity measurements on the connected PV panels and measurement data of the electricity connection meter.
Two single-purpose battery models were developed to estimate potential profit for operating providing ancillary services, one of the models focused on the FCR electricity market and the other on the aFRR market. These two models were combined into an optimization battery model which showed significant potential for combining provision of two ancillary services by the BESS. The resulting optimized model was applied to the case study to assess the potential to combine provision of ancillary services by the BESS with local peak load shaving.
Local peak shaving was technically not necessary (yet) at the location of the case study. A new grid layout was recently done and after retrofit, buildings are still mainly heated without electricity. For these

[1] IRIS. 2023.D5.9 Final report on Utrecht lighthouse demonstration activities.

reasons, demand peaks were not as high as they should for an effective case. But this may be different in the future, or for other similar districts. Therefore, different scenarios were developed to estimate the need for local peak shaving in a situation where grid reinforcement is required and electricity demand is expected to significantly increase, see Figure 1

These scenarios were based on the type of grid layout and the energy demands. In the all-electric retrofit scenario, the measured gas demand of the buildings is substituted by the equivalent electricity demand of heat pumps. The old grid layout scenario describes a situation where a battery is placed without the grid reinforcement that took place in Kanaleneiland-Zuid.

*Figure 17 Overview of the case study scenarios.*

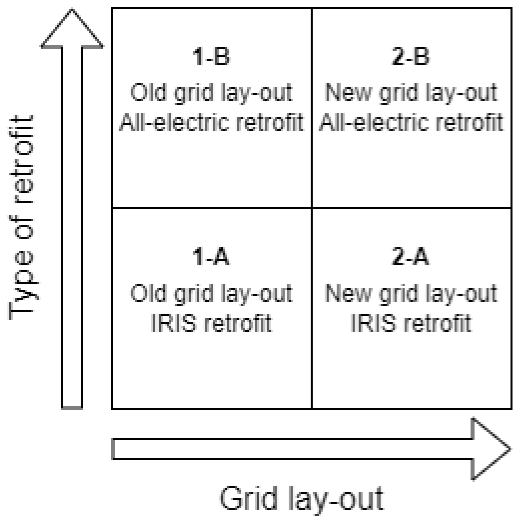


*Figure 1 Overview of the case study scenarios*

The load profiles developed for these scenarios (Figure 2) show that with the new grid layout the peak loads at the transformer station remain relatively low for all cases. Without grid reinforcement, peaks are around 300 kW and 400 kW for the two different retrofit scenarios, where the transformer had a limit of 590 kW (new data slightly higher, 470 kW, but still well below transformer limit). In the summer situation peaks were much lower, therefore the research focused on the winter loads only.

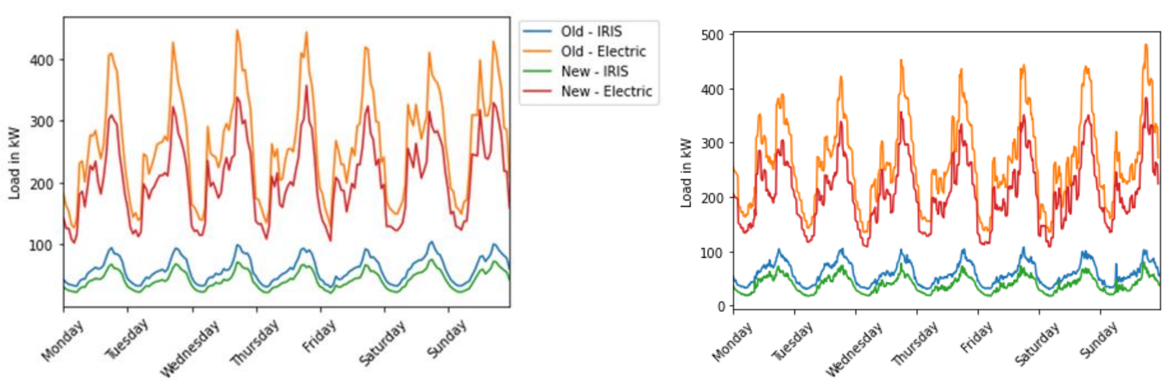


*Figure 2:Load profile of the neighborhood for each scenario over an average week (left initial calculation, right with latest data)*

It was found that only in in the all-electric scenario with the old grid topology, the load on a single transformer station exceeded the transformer limit. It was estimated that this exceeding peak load could

be provided by the battery at a cost of roughly €26 per day. Over an assumed battery lifespan of 20 years, the total deferment of grid investments was estimated to cost up to €200.000.
To further assess the potential of BESS for peak load shaving, two peak load shaving scenarios were developed to calculate the cost of maintaining peak loads within 30% and 50% above the average load. Table 3 shows that in the IRIS scenario, the cost of maintaining peak loads within 30% and 50% was estimated to be around €21 and €3 per day respectively. For the all-electric scenario, the cost for maintaining peak loads within 50% is significantly higher at €57 per day. Maintaining peak loads within 30% above the average load was not possible in the all-electric scenario due to constraints in battery capacity..

*Table 15 Overview of the potential cost for DSOs to use BESS for peak load shaving. Total profit is projected over the full timeframe, the cost for peak load shaving per day is the difference in profit between the optimized model with and without providing peak*

| | **Total profit €** | **Profit per day € / day** | **Cost PLS € / day** | **Total cost over 20 year period €** |
|---|---|---|---|---|
| **IRIS 50%** | 28,765 | 350.79 | 3.47 | 25,331 |
| **IRIS 30%** | 27,365 | 333.72 | 20.54 | 139,900 |
| **Electric 50%** | 24,393 | 297.48 | 56.78 | 414,500 |
| **Electric 30%** | - | - | - | - |

Finally, the influence of energy market operations by a BESS on the neighbourhood peak loads was analysed. It was concluded that the use of the BESS for ancillary services did not lead to additional cases of transformer limit exceedance in all scenarios. However, the influence on the grid from using the BESS for ancillary services is highly dependent on the bid size for ancillary services, the local grid topology and the transformer capacities.

The results of this demonstrator show that the costs lost by the battery operator by providing network congestion services instead of operating on the energy market cannot be neglected. This means that when a DSO would actively request congestion management services from such stationary batteries, the financial compensation offered needs to be sufficient to cover the above lost revenues on the electricity markets.

Because of a significant rise in prices, especially on the imbalance market (aFRR), battery operation changed in 2022. Revenue of the battery on this market almost doubled. The mean income of buying and selling operations almost double (Figure 3). Since the battery acts for half of its use on this market, in general costs shown in Table 15 could increase with about 25% when calculated with 2022 data. It should be noted that 2022 was an extraordinary year when it comes to energy prices due to the war in Ukraine.

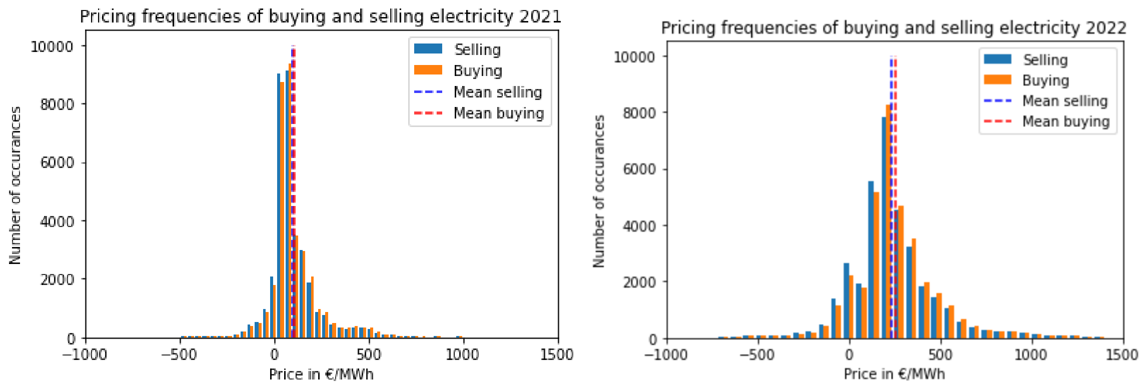


*Figure 3: Pricing frequencies of buying and selling electricity 2021 left and 2022 right*

## 5.3 Utrecht – TT3

### 5.3.1 Measure 3.1

*Table 16: Summary-list of KPIs and related parameters for Measure 3.1 V2G e-cars*

| KPI | Parameter(s) | Data source | Baseline | GA-Target |
|---|---|---|---|---|
| **NOx emission reduction** | Number of kilometres driven by the car-sharing fleet | LomboXnet monitoring system | same amount of km/year driven by comparable fossil fuel cars | 1 tonne in 5 years |
| | NOx emission factors for EVs (tonne/km) | DoA | | |
| | NOx emission factors for comparable fossil fuel cars (tonne/km) | DoA | | |
| **Fine particulate matter emission (FPM)** | Number of kilometres driven by the car-sharing fleet | LomboXnet monitoring system | same amount of km/year driven by comparable fossil fuel cars | 0,02 tonne in 5 years |
| | FPM emission factors for EVs (tonne/km) | DoA | | |
| | FPM emission factors for comparable fossil fuel cars (tonne/km) | DoA | | |
| **Carbon monoxide emission reduction** | Number of kilometres driven by the car-sharing fleet | LomboXnet monitoring system | same amount of km/year driven by comparable fossil fuel cars | 3 tonne in 5 years |
| | CO emission factors for EVs (tonne/km) | DoA | | |
| | CO emission factors for comparable fossil fuel cars (tonne/km) | DoA | | |

| KPI | Parameter(s) | Data source | Baseline | GA-Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction** | Number of kilometres driven by the car-sharing fleet | LomboXnet monitoring system | same amount of km/year driven by comparable fossil fuel cars | 308 tonne in 5 years |
| | $CO_2$ emission factors for EVs (tonne/km) | DoA | | |
| | $CO_2$ emission factors for comparable fossil fuel cars (tonne/km) | DoA | | |
| **Access to vehicle sharing solutions for city travel** | Number of vehicles available for sharing | LomboXnet monitoring system | Number of shared cars at start of project | 18 cars |
| | Number of inhabitants of target area | Municipality[2] | | |
| **Yearly km driven in e-car sharing system** | Number of kilometres driven by the car-sharing fleet | LomboXnet monitoring system | Amount of km by shared cars at present | 270,000 km per year |

[2] Alle Cijfers. 2022. *Statistieken gemeente Utrecht.* https://allecijfers.nl/gemeente/utrecht/

*Table 17: Data input for Measure 3.1 V2G e-cars*

| Parameter(s) | 2020 | 2021 | 2022 |
|---|---|---|---|
| **Number of kilometres driven by the car-sharing fleet** | 784811 | 1486289 | 2507942 |
| **NOx emission factors for EVs** | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **NOx emission factors for comparable fossil fuel cars** | 6.00E-07 | 6.00E-07 | 6.00E-07 |
| **FPM emission factors for EVs** | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **FPM emission factors for comparable fossil fuel cars** | 1.80E-08 | 1.80E-08 | 1.80E-08 |
| **CO emission factors for EVs** | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **CO emission factors for comparable fossil fuel cars** | 2.50E-06 | 2.50E-06 | 2.50E-06 |
| **$CO_2$ emission factors for EVs** | 6.33E-05 | 6.33E-05 | 6.33E-05 |
| **$CO_2$ emission factors for comparable fossil fuel cars** | 2.24E-04 | 2.24E-04 | 2.24E-04 |
| **Number of vehicles available for sharing** | 19.00 | 44.00 | 49.00 |
| **Number of inhabitants of target area* 1000** | 357.00 | 359.00 | 362.00 |

The initial factors for conventional cars in the GA were based on the emissions of cars in the Netherlands[3] (CBS). More recent data for these factors is obtained from RIVM[4]. The emission factors for several types of transport are calculated and published online as downloadable tables.

The emission factors for cars were obtained from this source by selecting the category medium cars and the average emission of road type: City, normal (stad normaal) and motorway 80 km/h. For each year. Values were recalculated from  g/km to tonne/km. The source provides different numbers for PM10 and PM2.5. Sind PM10 includes the PM2.5 particles, PM10 is used as the value for PPM emissions. This results in the emission factors as presented in Table 18.

For carbon dioxide emissions of conventional cars, recent factors were obtained from [5] where all emissions road transport are registered and published. This provides WTW (Well to Wheel) CO2 emission of 193 grams/km.

[3] Centraal Bureau voor Statistiek. 2017. Emissiefactoren wegverkeer per voertuigcategorie en bouwjaar
[4] Rijksinstituut voor volksgezondheid en milieu (RIVM). 2023. *Emissiefactoren voor snelwegen en niet-snelwegen, 2022,* https://www.rijksoverheid.nl/onderwerpen/luchtkwaliteit/documenten/publicaties/2022/03/15/emissiefactoren-voor-snelwegen-en-niet-snelwegen-2022
[5] CO2emissiefactoren. 2023. *Lijst CO2emissiefactoren,* https://www.co2emissiefactoren.nl/lijst-emissiefactoren/

The standard CO2 emissions for E-cars were based on 7 km/kWh with the standard European emission factor of 443 grams/kWh. Recent emissions are calculated with the more recent emission factors for electricity consumption from electricity maps[6] and decline over the years.

*Table 18: Table 11 Emission factors for cars used for KPI calculations in Utrecht*

| Parameter | IRIS_NL | Recent | | | |
|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2020 |
| **NOx emission factors for EVs (tonne/km)** | 0,00E+00 | | 784811 | 1486289 | 2507942 |
| **NOx emission factors for comparable fossil fuel cars (tonne/km)** | 6,00E-07 | 0 | 0 | 0 | 0 |
| **FPM emission factors for EVs (tonne/km)** | 0,00E+00 | 2,17E-07 | 2,12E-07 | 2,07E-07 | 2,02E-07 |
| **FPM emission factors for comparable fossil fuel cars (tonne/km)** | 1,80E-08 | 0 | 0 | 0 | 0 |
| **CO emission factors for EVs (tonne/km)** | 0,00E+00 | 3,14E-08 | 3,06E-08 | 2,97E-08 | 2,89E-08 |
| **CO emission factors for comparable fossil fuel cars (tonne/km)** | 2,50E-06 | 0 | 0 | 0 | 0 |
| **$CO_2$ emission factors for EVs (tonne/km)** | 6,33E-05 | 1,04E-06 | 9,57E-07 | 8,76E-07 | 7,94E-07 |
| **$CO_2$ emission factors for comparable fossil fuel cars (tonne/km)** | 2,24E-04 | 9,20E-05 | 9,20E-05 | 9,20E-05 | 9,20E-05 |

### 5.3.2 Measure 3.2

*Table 19: Summary-list of KPIs and related parameters for Measure 3.2 V2G e-buses*

| KPI | Parameter(s) | Data source | Baseline | GA-Target |
|---|---|---|---|---|
| **NOx emission reduction** | Number of kilometres driven by E-buses | ViriCity monitoring system | same amount of km/year driven by comparable fossil fuel buses | 22 ton in 5 years |
| | NOx emission factors for E-buses (tonne/km) | DoA | | |
| | NOx emission factors for comparable fossil fuel buses (tonne/km) | DoA | | |
| **Fine particulate matter emission** | Number of kilometres driven by E-buses | ViriCity monitoring system | same amount of km/year driven by | 0,26 ton in 5 years |

[6] Electricity maps. 2023. *Historical average emission intensities of electricity consumption.*

| | | | | |
|---|---|---|---|---|
| | FPM emission factors for E-buses (tonne/km) | DoA | comparable fossil fuel buses | |
| | FPM emission factors for comparable fossil fuel buses (tonne/km) | DoA | | |
| **Carbon monoxide emission reduction** | Number of kilometres driven by E-buses | ViriCity monitoring system | same amount of km/year driven by comparable fossil fuel buses | 1,6 ton in 5 years |
| | CO emission factors for E-buses (tonne/km) | DoA | | |
| | CO emission factors for comparable fossil fuel buses (tonne/km) | DoA | | |
| **Carbon dioxide Emission Reduction** | Number of kilometres driven by E-buses | ViriCity monitoring system | same amount of km/year driven by comparable fossil fuel buses | 4785 ton in 5 years |
| | $CO_2$ emission factors for E-buses (tonne/km) | DoA | | |
| | $CO_2$ emission factors for comparable fossil fuel buses (tonne/km) | DoA | | |

*Table 20: Data input for Measure 3.2 V2G e-buses*

| Parameter(s) | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| **Number of kilometres driven by E-buses (tonne/km)** | 795079,5 | 761930,435 | 1406193,3 | 3696593 | 3999750,3 |
| **NOx emission factors for E-buses (tonne/km)** | 0 | 0 | 0 | 0 | 0 |
| **NOx emission factors for comparable fossil fuel cars (tonne/km)** | 5,40E-06 | 5,40E-06 | 5,40E-06 | 5,40E-06 | 5,40E-06 |
| **FPM emission factors for E-buses (tonne/km)** | 0 | 0 | 0 | 0 | 0 |
| **FPM emission factors for comparable fossil fuel cars** | 6,40E-08 | 6,40E-08 | 6,40E-08 | 6,40E-08 | 6,40E-08 |
| **CO emission factors for E-buses (tonne/km)** | 0 | 0 | 0 | 0 | 0 |
| **CO emission factors for comparable fossil fuel cars** | 2,00E-06 | 2,00E-06 | 2,00E-06 | 2,00E-06 | 2,00E-06 |
| **$CO_2$ emission factors for E-buses (tonne/km)** | 3,692E-04 | 3,692E-04 | 3,692E-04 | 3,692E-04 | 3,692E-04 |
| **$CO_2$ emission factors for comparable fossil fuel cars (tonne/km)** | 1,196E-03 | 1,196E-03 | 1,196E-03 | 1,196E-03 | 1,196E-03 |

The initial factors for conventional buses in the GA were based on the emissions of trucks in the Netherlands (CBS)[7]. More recent data for the emission factors of buses is obtained from RIVM[8]. The emission factors for several types of transport are calculated and published online as downloadable tables.

The emission factors for conventional buses were obtained from this source by selecting the category buses (autobussen) and road type: City, normal (stad normaal), for the year 2019. Values were recalculated from g/km to tonne/km. The source provides different numbers for PM10 and PM2.5. Sind PM10 includes the PM2.5 particles, PM10 is used as the value for PPM emissions. This results in the emission factors as presented in Table 22.

For carbon dioxide emissions, emission factors were obtained from [9] where all emissions of public transport are registered and published. From their site Utrecht region was selected. Providing CO2 emissions in tonnes per km as in Table 21. The table shows a decline in CO2 emissions over the years. This is mainly due to the increased penetration of E-buses in Utrecht. Therefore the year 2017 was chosen for al years as BAU for the Recent emission factors.

*Table 21: CO2 emissions for buses in Utrecht region in tonnes per km*

| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| **1.08E-03** | 1,04E-03 | 1,04E-03 | 1,01E-03 | 9,40E-04 | 9,51E-04 | 9,53E-04 |

The standard CO2 emissions for E-buses were based on 1.2 km/kWh with the standard European emission factor of 443 grams/kWh. Recent emissions are calculated with the more recent emission factors for electricity from Electricity Maps[10] and decline over the years.

[7] Centraal Bureau voor Statistiek. 2017. Emissiefactoren wegverkeer per voertuigcategorie en bouwjaar

[8] Rijksinstituut voor volksgezondheid en milieu (RIVM). 2023. *Emissiefactoren voor snelwegen en niet-snelwegen, 2022,* https://www.rijksoverheid.nl/onderwerpen/luchtkwaliteit/documenten/publicaties/2022/03/15/emissiefactoren-voor-snelwegen-en-niet-snelwegen-2022

[9] DUINN. 2023. *CO2 in het OV,* 2022, https://ov.duinn.nl/

[10] Electricity maps. 2023. *Historical average emission intensities of electricity consumption.*

*Table 22 Emission factors for buses used for KPI calculations in Utrecht*

| Parameter | IRIS_NL | Recent |
|---|---|---|
| **NOx emission factors for E-buses (tonne/km)** | 0 | 0 |
| **NOx emission factors for comparable fossil fuel cars (tonne/km)** | 5,40E-06 | 2,84E-06 |
| **FPM emission factors for E-buses (tonne/km)** | 0 | 0 |
| **FPM emission factors for comparable fossil fuel cars (tonne/km)** | 6,40E-08 | 1,36E-07 |
| **CO emission factors for E-buses (tonne/km)** | 0 | 0 |
| **CO emission factors for comparable fossil fuel cars (tonne/km)** | 2,00E-06 | 9,28E-07 |
| **CO2 emission factors for E-buses (tonne/km)** | 3,692E-04 | 2018: 4,28E-04<br>2019: 4,07E-04<br>2020: 3,76E-04<br>2021: 3,64E-04<br>2022: 3,28E-04 |
| **CO2 emission factors for comparable fossil fuel cars (tonne/km)** | 1,196E-03 | 1,08E-03 |

## 5.4 Utrecht – TT5

### 5.4.1 Measure 5.1

*Table 23 Summary-list of KPIs and related parameters for Measure 5.1: Community building by Change agents*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Increased environmental awareness** | Increased environmental awareness | Survey | NA | 4 on the scale of 1-5 (Likert Scale) |
| **People reached** | Number of citizens reached | Survey | Anticipated advantage before implement-tation of the measure | 4 on the scale of 1-5 (Likert Scale) |
| | Total number of citizens considered as the total target group of the project | Survey | | |
| **Local community involvement in planning/ implementation phase** | Local community involvement in the planning/ implementation phase | Survey | NA | 4 on the scale of 1-5 (Likert Scale) |

### 5.4.2 Measure 5.2

*Table 24 Summary-list of KPIs and related parameters for Measure 5.2: Campaign District School Involvement*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **People reached** | Number of citizens reached | Survey | NA | 80% |
| | Total number of citizens considered as the total target group of the project | Survey | | |

### 5.4.3 Measure 5.3

*Table 25 Summary-list of KPIs and related parameters for Measure 5.3: Evaluation and co-creation*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Ease of use for end-users of the solution** | Ease of use for end users of the solution | Survey | NA | 4 on the scale of 1-5 (Likert Scale) |
| **Advantages for end-users** | Advantages for end-users | Survey | Anticipated advantage before implement-tation of the measure | 4 on the scale of 1-5 (Likert Scale) |
| **Local community involvement in planning/ implementation phase** | Local community involvement in the planning/ implementation phase | Survey | NA | 3 on the scale of 1-5 (Likert Scale) |

### 5.4.4 Measure 5.4

*Table 26 Summary-list of KPIs and related parameters for Measure 5.2: Campaign District School Involvement*

| KPI | Parameter(s) | Data source | Baseline | GA- Target |
|---|---|---|---|---|
| **Local community involvement in development process** | Local community involvement in development process | Survey | NA | 4 on the scale of 1-5 (Likert Scale) |

# 6 Annex 6 – Nice KPIs and data input

## 6.1 Nice – TT1

### 6.1.1 Measure 1.1

*Table 27 : Summary-list of KPIs and related parameters for Measure 1.1 Collective self-consumption at building scale*

| KPI | Parameter(s) | Data source | Baseline | GA-Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction (t CO2)** | Delivered electrical energy from energy carrier (MWh) | Digital smart electricity meter | there is no prior state as buildings are new. The baseline will use reference data, i.e. values stipulated by national regulations | 24 |
| | Exported electrical energy to energy carrier (MWh) | Digital smart electricity meter | | |
| **Energy Savings (%)** | Electric energy consumption Reference (kWh/year) | Digital smart electricity meter | there is no prior state as buildings are new. The baseline will use reference data, i.e. values stipulated by national regulations | 340 |
| | Electric energy consumption (kWh/month or year) | Digital smart electricity meter | | |
| **Increase in local renewable energy production (%)** | Electric energy production by RES (kWh/month or year) | Digital smart electricity meter | there is no prior state as buildings are new. The baseline will use reference data, i.e. values stipulated by national regulations | 360 |
| **Degree of energy self-supply by RES** | Electric energy production by RES (kWh/month or year) | Digital smart electricity meter | there is no prior state as buildings are new. The baseline will use reference data, i.e. values stipulated by national regulations | 80% |
| | Electric energy consumption (kWh/month or year) | Digital smart electricity meter | | |

*Table 28 Data input for Measure 1.1 Collective self-consumption at Imredd*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Delivered electrical energy from energy carrier (MWh)** | 91,5 | 142,81 |
| **Exported electrical energy to energy carrier (MWh)** | 62,84 | 61,35 |
| **Electric energy consumption Reference (kWh/year)** | 374380 | 374380 |
| **Electric energy consumption (kWh/year)** | 165088,35 | 246317,5 |
| **Electric energy production by RES (kWh/year)** | 177812,57 | 177812,6 |
| **annual costs related to energy/CO2 measures (€)** | 13950 | 10020 |
| **the CO2 coefficient from delivered electrical energy carrier (t CO2/MWh)** | 0 | 0 |
| **the CO2 coefficient for exported electrical energy carrier (t CO2/MWh)** | 0,04 | 0,04 |
| **Storage capacity installed Electrical (kWh)** | 218 | 218 |

*Table 29 Data input for Measure 1.1 Collective self-consumption at Palazzo Meridia*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Delivered electrical energy from energy carrier (MWh)** | 40,21 | 89,64 |
| **Exported electrical energy to energy carrier (MWh)** | 45,59 | 40,49 |
| **Electric energy consumption Reference (kWh/year)** | 120000 | 144000 |
| **Electric energy consumption (kWh/year)** | 67804,78 | 125583,77 |
| **Electric energy production by RES (kWh/month or year)** | 72981,96 | 76441,06 |
| **annual costs related to energy/CO2 measures (€)** | 3150 | 4200 |
| **the CO2 coefficient from delivered electrical energy carrier (t CO2/MWh)** | 0 | 0 |
| **the CO2 coefficient for exported electrical energy carrier (t CO2/MWh)** | 0,04 | 0,04 |
| **Storage capacity installed Electrical (kWh)** | 90 | 90 |

### 6.1.1 Measure 1.2

*Table 30: Summary-list of KPIs and related parameters for Measure 1.2 Optimization of heating load curve*

| KPI | Parameter(s) |
|---|---|
| **Energy savings** | Thermal energy consumption (kWh/year) |
| | Thermal energy consumption Reference (kWh/year) |
| **Carbon dioxide emission reduction** | $CO_2$ coefficient of the baseline heat production (partner’s factor) |
| | $CO_2$ coefficient of electricity (partner’s factor) |

*Table 31 Data input for Measure 1.2 Optimization of heating load curve at Tower 13*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Thermal energy consumption (MWh/year)** | 355 | 404 |
| **Thermal energy consumption Reference (MWh/year)** | 465 | 465 |
| **$CO_2$ coefficient of the baseline heat production (partner’s factor)** | 0,453 | 0,453 |
| **$CO_2$ coefficient of electricity (partner’s factor)** | 0,453 | 0,453 |

*Table 32 Data input for Measure 1.2 Optimization of heating load curve at Tower 14*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Thermal energy consumption [MWh/year]** | 350 | 364 |
| **Thermal energy consumption reference [MWh/year]** | 410 | 410 |
| **$CO_2$ coefficient of the baseline heat production (partner’s factor) [tonnes/MWh]** | 0,453 | 0,453 |
| **$CO_2$ coefficient of electricity (partner’s factor) [tonnes/MWh]** | 0,453 | 0,453 |

### 6.1.2 Measure 1.3

*Table 28 Summary-list of KPIs and related parameters for Measure 1.3*

| KPI | Parameter(s) | Data source |
|---|---|---|
| **Data Loss prevention** | Lost datapoints in a period | |
| **Advantages for end-users** | No advantage | Questionnaire |
| | Little advantage | Questionnaire |
| | Some advantage | Questionnaire |
| | High advantage | Questionnaire |
| | Very high advantage | Questionnaire |

*Table 33 Data input for Measure 1.3: Commissioning process from the design to the operation in Nice*

| Parameter(s) | 2020 | 2021 | 2022 |
|---|---|---|---|
| **Lost datapoints in a period** | 19,6 | 12,5 | 39,1 |

*Table 34 Survey Data input for Measure 1.3: Commissioning process from the design to the operation in Nice*

| Parameter(s) | 2022 |
|---|---|
| **No advantage (number of answers)** | 20 |
| **Little advantage (number of answers)** | 0 |
| **Some advantage (number of answers)** | 3 |
| **High advantage (number of answers)** | 2 |
| **Very high advantage (number of answers)** | 0 |

## 6.2 Nice – TT2

### 6.2.1 Measure 2.1

*Table 31 Summary-list of KPIs and related parameters for Measure 2.1 Collective self-consumption at building scale*

| KPI | Parameter(s) |
|---|---|
| **Storage Capacity Installed** | Storage Capacity Installed |
| **Revenue from services** | Electricity price |
| | Revenue from services |

*Table 35 Data input for Measure 2.1: Stationary storage deployment in buildings and local electric flexibility management at Palazzo building in Nice*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Storage Capacity Installed** | 92,3 | 92,3 |

*Table 36 Data input for Measure 2.1: Stationary storage deployment in buildings and local electric flexibility management at Imredd building in Nice*

| Parameter(s) | 2022 |
|---|---|
| **Storage capacity Installed** | 223,6 |
| **Electricity price** | 25739 |
| **Revenue from services** | 10850 |

## 6.3 Nice – TT3

### *6.3.1 Measure 3.1*

*Table 34 Summary-list of KPIs and related parameters for Measure 3.1*

| KPI | Parameter(s) |
|---|---|
| **Storage capacity Installed** | Storage capacity installed |
| **Number of e-charging stations** | Urban Area (km2) |
| | Total stations deployed |

*Table 37 Data input for Measure 3.1: Smart Charging in Nice*

| Parameter(s) | 2022 |
|---|---|
| **Storage capacity installed** | 150 |
| **Urban Area (km2)** | 1 |
| **Total stations deployed** | 20 |

### *6.3.2 Measure 3.2*

*Table 36 Summary-list of KPIs and related parameters for Measure 3.2*

| KPI | Parameter(s) |
|---|---|
| **Yearly km driven in e-car sharing systems** | Number of kilometres done by the car-sharing fleet |
| **Access to vehicle sharing solutions for municipality** | Number of different users |
| | Number of employees |
| **Number of trips in a free-floating car-sharing** | Number of trips done by the car-sharing fleet |

*Table 38 Data input for Measure 3.2: Free floating EV car sharing system at District in Nice*

| Parameter(s) | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Number of kilometres done by the car-sharing fleet** | 0 | 124971,8 | 182300,85 | 195524,03 |
| **Number of different users** | 146 | 291 | 339 | 367 |
| **Number of employees** | 1493 | 1396 | 1373 | 1293 |
| **Number of trips done by the car-sharing fleet** | 1666 | 3260 | 4222 | 4561 |

## 6.4 Nice – TT4

*Table 38 Summary-list of KPIs and related parameters for TT4*

| KPI | Parameter(s) |
|---|---|
| **Number of connected urban objects in the City innovation platform** | Number of objects connected |
| **Quality of open data** | Data that uses DCAT standards |
| | Total data |

*Table 39 Data input for TT4: Digital transformation and services in Nice*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **Number of objects connected** | 46 | 124 |
| **Data that uses DCAT standards** | 100 | 100 |
| **Total data** | 1983136 | 181990 |

## 6.5 Nice – TT5

### 6.5.1 Measure 5.1

*Table 40 Summary-list of KPIs and related parameters for Measure 5.1*

| KPI | Parameter(s) | Data source |
|---|---|---|
| **Increased environmental awareness** | Not at all answers | Questionnaire |
| | Poor answers | |
| | Somewhat answers | |
| | Good answers | |
| | Excellent answers | |

*Table 40 Data input for Measure 5.1: Public awareness campaign Air Quality in Nice*

| Parameter(s) | 2022 |
|---|---|
| **Not at all answers** | 0 |
| **Poor answers** | 0 |
| **Somewhat answers** | 0 |
| **Good answers** | 419 |
| **Excellent answers** | 189 |

### 6.5.2 Measure 5.2

*Table 42 Summary-list of KPIs and related parameters for Measure 5.2*

| KPI | Parameter(s) | Data source |
|---|---|---|
| **Increased awareness of energy usage** | None answers | Questionnaire |
| | Little answers | |
| | Somewhat answers | |
| | Significant answers | |
| | High answers | |

*Table 41 Data input for Measure 5.2: Public awareness campaign Energy – School & Collège; Youth & Family*

| Parameter(s) | 2021 | 2022 |
|---|---|---|
| **None answers** | 0 | 0 |
| **Little answers** | 10 | 0 |
| **Somewhat answers** | 20 | 30 |
| **Significant answers** | 60 | 50 |
| **High answers** | 50 | 60 |

# 7 Annex 7 – Gothenburg KPIs and data input

## 7.1 Gothenburg – TT1

### 7.1.1 Measure 1.1

*Table 42: Summary-list of KPIs and related parameters for Measure 1.1 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction** | Electric energy production by RES [kWh/month (year)] | Smart meters | Baseline is the load curve from the apartments, unassisted by either batteries or PVs, times the carbon intensity with hourly resolution on the imported electricity. | 15-20%, or 10 metric tonnes. |
| | The $CO_2$ coefficient of energy used in base case [t CO2/kWh] | National emission factor for Sweden | | |
| **Degree of energy self-supply by RES** | Electric energy production by RES [kWh/month (year)] | Smart meter | Zero percent self-supply. | Brf Viva's degree of self-supply for **electrical** energy is expected to vary between 10% and 60%. |
| | Electric energy consumption [kWh/month (year)] | Smart meter | | |
| **Increase in local renewable energy production** | Electric energy production by RES [MWh/year] | Smart meter | No electricity production from PVs. | Contribute to the GA target net energy surplus |

*Table 43: Data input for Measure 1.1 200 kWh electricity storage in 2nd life batteries powered by 140 kW PV*

| Parameter(s) | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Electric energy production by RES [kWh/year]** | 64992 | 138874 | 111096 | 121004 |
| **Electric energy consumption [kWh/year]** | 411472 | 721298 | 680349 | 446329 |
| **The $CO_2$ coefficient of electricity used in base case [t CO2/MWh] - IRIS SE** | 0,023 | | | |

### 7.1.2 Measure 1.2

*Table 44 : Summary-list of KPIs and related parameters for Measure 1.2 Heating from geo energy with heat pumps*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Degree of energy self-supply by RES** | Thermal energy production by RES [kWh/month](year) | Smart meter | Zero self-supply. | Varying between 0% and 100% for **thermal** energy.[11] |
| | Thermal energy consumption [kWh/month(year)] | Smart meters | | |
| **Carbon dioxide Emission Reduction** | Thermal energy production by RES [kWh/month(year)] | Smart meters | 0% reduction | 90% reduction. |
| | The CO2 coefficient of baseline heat production [t CO2/MWh] | Emission factor for the district heating grid in Gothenburg | | |
| | Electricity consumption of the heat pump [kWh/month (year)] | Smart meter | | |
| | The CO2 coefficient of baseline electricity production [t CO2/MWh] | Generalised value for Sweden | | |
| **$CO_2$ reduction cost efficiency** | Yearly carbon dioxide Emission Reduction [tonnes/year] | Calculation, from separate KPI | N/A | 400 €/tonne $CO_2$ e*y |
| | Annualized investment cost for energy/CO2 related measures [€] | Calculation | | |
| | Running costs related to energy/CO2 measures [€/year] | Calculation | | |
| **Increase in local renewable energy production** | Thermal energy production by RES [MWh/year] | Smart meter | No heat production from HPs. | |

*Table 45: Data input for Measure 1.2 Heating from geo energy with heat pumps.*

| Parameter(s) | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Thermal energy production by RES [kWh/year]** | 390618 | 772942 | 572692 | 314727 |
| **Thermal energy consumption [kWh/year]** | 390629 | 776851 | 820658 | 479501 |
| **The CO2 coefficient of baseline heat production [t CO2/MWh] (emission factor for the district heating grid in Gothenburg)** | 0,074 | 0,048 | 0,062 | 0,064 |
| **Electricity consumption of the heat pump [kWh/year]** | 146425 | 278419 | 223190 | 125210 |
| **The CO2 coefficient of baseline electricity production [t CO2/MWh] (National emission factor for Sweden)** | 0,023 | | | |
| **Annualized investment cost for energy/CO2 related measures [€/y]** | 2602 | 4530 | 4682 | 3386 |
| **Running costs related to energy/CO2 measures [€/year]** | -719 | -24296 | -18117 | 3587 |
| **Annual costs related to energy/CO2 measures [€/year]** | 14038 | 20742 | 22732 | 15505 |
| **Annual costs baseline [€/year]** | 14757 | 45038 | 40849 | 11918 |

### 7.1.3 Measure 1.3

*Table 46: Summary-list of KPIs and related parameters for Measure 1.3 Cooling from geo energy without chillers*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction** | COP chiller | Estimate | All cooling delivered to CTP is assumed to replace cooling produced in chillers | A substantial amount, hopefully **up to 80 %** of the annual $CO_2$ -emissions associated with providing the cooling needed in CTP can be reduced by the cooling suppplied by Viva. |
| | The $CO_2$ coefficient of energy used in base case [t CO2/kWh] | National emission factor for Sweden | | |
| | Thermal energy production by RES [MWh] | Smart meters | | |
| **Degree of energy self-supply by RES** | Thermal energy production by RES [kWh/month](year) | Smart meter | The current annual cooling demand of CTP is entirely provided by purchased energy, thus baseline is 0%. | A substantial amount, hopefully up to 80% |
| | Thermal energy consumption [kWh/month(year)] | Smart meter | | |

*Table 47: Data input for Measure 1.3 Cooling from geo energy without chillers*

| Parameter(s) | 11 months |
|---|---|
| **COP chiller (assumption)** | 3 |
| **The CO2 coefficient of baseline electricity production – IRIS SE [t CO2/MWh]** | 0,023 |
| **Thermal energy consumption [MWh]** | 261 |
| **Thermal energy production by RES [MWh]** | 109,9 |

### 7.1.4 Measure 1.4

*Table 48: Summary-list of KPIs and related parameters for Measure 1.4 Local energy storages consisting of water buffer tanks, structural storage and long-term storage in boreholes*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Storage capacity installed** | Storage capacity installed [kWh] | N/A | The baseline is 0 kWh. | 970 kWh in tanks. N/A for boreholes and structure. |

*Table 49: Data input for Measure 1.4 Local energy storages consisting of water buffer tanks, structural storage and long-term storage in boreholes*

| Parameter(s) | 2020 | 2021 | 2022 |
|---|---|---|---|
| **Storage capacity installed [kWh]** | 970 | 970 | 970 |

### 7.1.5 Measure 1.5

*Table 50: Summary-list of KPIs and related parameters for Measure 1.5 Seasonal energy trading with adjacent office block*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Reduced energy cost for consumers** | Monthly costs in CTP [€] | Calculation | For the office building CTP: the current annual cost for cooling.<br>For the apartment buildings Viva: 0. | Chalmers fastigheter saved 70% annually on cooling costs from the energy trading.<br>Viva gains 30 000 SEK annually from running the energy trading. |
| | Monthly costs in Viva [€] | Calculation | | |

*Table 51:Data input for Measure 1.5 Seasonal energy trading with adjacent office block*

| Parameter(s) | 11 months |
|---|---|
| **COP chiller (assumption)** | 3 |
| **Cost of cooling from Viva [EUR/kWh]** | 0,024 |
| **Electricity cost [EUR/kWh]** | 0,221 |
| **Thermal energy production by RES [MWh]** | 109,9 |

### 7.1.6 Measure 1.6

*Table 52: Summary-list of KPIs and related parameters for Measure 1.6 Energy Management System*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Increased system flexibility for energy players stakeholders** | Peak power electricity [kW] | Smart meters | Zero flexibility. | The system flexibility might increase by 100% for the thermal side. |
| | Peak power thermal energy [kW] | Smart meters | | |
| | Installed capacity contributing to electrical flexibility after measure is implemented [kW] | N/A | | |
| | Installed capacity contributing to thermal flexibility after measure is implemented [kW] | Smart meters/calculation | | |
| **Reduced energy cost for consumers** | Purchased thermal energy [Wh] | Smart meter | Costs without acting EMS. This will be calculated continuously. | Viva will save money each year. |
| | Cost rates of purchased thermal energy [€/Wh] | N/A | | |
| | Purchased electricity [Wh] | Smart meter | | |
| | Cost rates of purchased electricity [€/Wh] | N/A | | |

*Table 53: Data input for Measure 1.6 Energy Management System*

| Parameter(s) | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Peak power electricity [kW]** | 170 | 153 | 189 | 134 |
| **Peak power thermal energy [kW]** | 230 | 229 | 351 | 233 |
| **Installed capacity contributing to electrical flexibility after measure is implemented [kW]** | 151,7 | 108,8 | 120,8 | 126,8 |
| **Installed capacity contributing to thermal flexibility after measure is implemented [kW]** | 217 | 217 | 238 | 212 |

### 7.1.7 Measure 1.7

*Table 54: Summary-list of KPIs and related parameters for Measure 1.7 Building Integrated Photovoltaics (BIPV) in façade.*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Carbon dioxide emission reduction** | Electric energy production by RES [kWh/month or year] | Smart Meter | 0 tonnes | 0,525 tonnes $CO_2$ reduction |
| | Electric energy consumption [kWh/month (year] | Smart Meter | | |
| | The CO2 coefficient of baseline electricity production [g CO2/kWh] | National emission factor for Sweden | | |
| | The CO2 coefficient of PV electricity production [g CO2/kWh] | Set to zero | | |
| **$CO_2$ reduction cost efficiency** | Annualized investment cost for energy/CO2 related measures [€/year] | Calculation | N/A | N/A |
| | Yearly carbon dioxide Emission Reduction [tonnes/year] | Calculation, from separate KPI | | |
| | Running costs related to energy/CO2 measures [€/year] | Calculation | | |
| **Degree of energy self-supply by RES** | Electric energy production by RES [kWh/month or year] | Smart Meter | 0 % | 19 % of electricity used in the building |
| | Electric energy consumption [kWh/month (year] | Smart Meter | | |
| **Increase in local renewable energy production** | Electric energy production by RES [kWh/month or year] | Smart Meter | 0 MWh per average year | 14 MWh |

*Table 55: Data input for Measure 1.7 Building Integrated Photovoltaics (BIPV) in façade*

| Parameter(s) | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Electric energy production by RES [kWh/year]** | 12303 | 11564 | 5446 | 12443 |
| **Electric energy consumption [kWh/year]** | 84147 | 105616 | 52118 | 76820 |
| **The CO2 coefficient of baseline electricity production – IRIS SE [tCO2/MWh]** | 0,023 | | | |
| **The CO2 coefficient of baseline electricity production – partner [tCO2/MWh]** | 0,0932[12] | | | |
| **The CO2 coefficient of PV electricity production – partner [t CO2/MWh]** | 0,028[13] | | | |
| **Annualized investment cost for energy/CO2 related measures [€/y]** | 1800 | 1800 | 1800 | 1800 |
| **Running costs related to energy/CO2 measures [€/year]** | 200 | 200 | 200 | 200 |
| **Average electricity cost (sales+grid) [EUR/kWh]** | 0,116 | 0,098 | 0,161 | 0,217 |

[12] Emission factor including emissions from imported electricity established by: https://www.smed.se/luft-och-klimat/4708
[13] Emission factor for PV based on LCA calculations: Klimatbedömning av el, fjärrvärme och fjärrkyla (ivl.se)

## 7.2 Gothenburg – TT2

### 7.2.1 Measure 2.1

*Table 56: Summary-list of KPIs and related parameters for Measure 2.1 a 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Peak Load reduction** | Peak power [kW] | Smart meter | Consumed electricity in the building minus the used PV electricity. | 80% peak power reduction |
| | Peak power baseline [kW] | Smart meter | The consumed electricity at present, which is the power that would have been bought without the battery and dc systems. | |
| **Storage Capacity Installed** | Storage capacity installed [kWh] | Smart meter | 0 kWh | 200 kWh |
| **Degree of energy self-supply by RES** | Electric energy production by RES [kWh/month or year] | Smart meter | 0 kWh | 10% |
| | Electric energy consumption [kWh/month or year] | Smart meter | | |

*Table 57: Data input for Measure 2.1 a 350 V DC building microgrid utilizing 140 kW rooftop PV installations and 200 kWh battery storage*

| Parameter(s) | 2020 | 2021 | 2022 |
|---|---|---|---|
| **Electric energy production by RES [kWh/year]** | 5933 | 167974 | 129971 |
| **Electric energy consumption [kWh/year]** | 73778 | 477606 | 355119 |
| **Peak power [kW]** | 105 | 115 | 100 |
| **Peak power baseline [kW]** | 120 | 145 | 177 |
| **Storage capacity installed [kWh]** | 200 | 200 | 200 |

### 7.2.2 Measure 2.2

*Table 58: Summary-list of KPIs and related parameters for Measure 2.2 200 kWh PCM (Phase Change Material) cooling storage*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Peak Load reduction** | Peak power [kW] | Smart meter | 0 kW | |
| | Peak power baseline [kW] | | | |
| **Storage Capacity Installed** | Storage capacity installed [kWh] | | 0 kWh | Target for step 1: 200 kWh/50 kW for 4 h<br>Target for step 1+2: 800 kWh/150 kW for 4 h |
| **Storage energy losses** | Energy output [kWh] (from PCM) | Smart meter | Losses from eq. water storage | 5% |
| | Energy input [kWh] (to PCM) | Smart meter | | |

*Table 59: Data input for Measure 2.2 200 kWh PCM (Phase Change Material) cooling storage*

| Parameter(s) | 2020 | 2021 |
|---|---|---|
| **Peak power [kW]** | 9 | 222 |
| **Peak power baseline [KW]** | 9 | 257 |
| **Storage capacity installed [kWh]** | 100 | |
| **Energy output [kWh] (from PCM)** | 541 | 606 |
| **Energy input [kWh] (to PCM)** | 735 | 743 |

### 7.2.3 Measure 2.4

*Table 60:Summary-list of KPIs and related parameters for Measure 2.4 Integration and evaluation of a 200kWh energy storage*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Peak Load Reduction** | Peak power [kW] | Smart meters | Consumed electricity in the building minus the used PV electricity, which is what should have been bought without the battery. | 25% |
| | Peak power baseline [kW] | Smart meter | Consumed electricity in the building, i.e. bouth electricity plus the electricity from PV and battery. | |
| **Storage Capacity Installed** | Storage capacity in the batteries [kWh] | Battery specifications from supplier and/or smart meters. | 0 kWh | 200 kWh |

*Table 61: Data input for Measure 2.4 Integration and evaluation of a 200kWh energy storage*

| Parameters | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Peak power [kW]** | 170 | 153 | 189 | 134 |
| **Peak power baseline [kW]** | 179 | 169 | 203 | 141 |
| **Storage capacity installed [kWh]** | 185 | 76 | 106 | 122 |

## 7.3 Gothenburg – TT3

### 7.3.1 Measure 3.1

*Table 62: Summary-list of KPIs and related parameters for Measure 3.1 EC2B for tenants in Brf Viva*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction** | Km driven by tenants before implementing the measure (km/year or month) | Travel survey | Calculated based on travel survey data from equivalent area and register data on $CO_2$ - emissions from Swedish vehicles | 1040 tonnes reduction in 5 years |
| | Km driven by tenants in conventional cars after implementation (km/year or month) | Travel survey | | |
| | Km driven in e-car sharing system after implementation (km/year or month) | Data from car sharing provider(s) | | |
| | the CO2 coefficient for conventional vehicle (t CO2/km) | Data from car sharing provider | | |
| | the CO2 coefficient for electric vehicle (t CO2/km) | Based on assumption by project partner | | |
| **Ease of use for end users of the solution** | Very difficult (number of answers) | Questionnaire | No MaaS solution available to users | |
| | Fairly difficult (number of answers) | | | |
| | Slightly difficult (number of answers) | | | |
| | Fairly easy (number of answers) | | | |
| | Very easy (number of answers) | | | |
| **Reduction in car ownership among tenants** | number of cars owned before moving to the demonstration area | Register data | Average number of cars/household in area Guldheden = 0,39, statistics from SCB | |
| | number of cars owned after moving to the demonstration area | Register data | | |
| | Km driven by tenants before implementing the measure (km/year or month) | Travel survey | Calculated based on travel survey | 1360500 km/year car |

| | | | | |
|---|---|---|---|---|
| **Reduction in driven km by tenants** | Km driven by tenants after implementing the measure (km/year or month) | Travel survey | data from equivalent area | mile reduction among tenants and employees in the district |
| **Yearly km driven in e-car sharing systems** | Km driven in e-car sharing system after implementation (km/year or month) | Data from car sharing provider(s) | 0 | |

*Table 63: Data input for Measure 3.1 EC2B for tenants in Brf Viva*

| Parameter(s) | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| **Km driven by tenants before implementing the measure [km/year]** | 1106370 | | | | |
| **Km driven by tenants in conventional cars after implementation [km/year]** | | 569430 | 560756 | 541990 | |
| **the CO2 coefficient for conventional vehicle [t CO2/km] used in the GA** | 0,000163 from 2015 | | | | |
| **the CO2 coefficient for conventional vehical [t CO2/km]** | | 0,000153 | 0,000150 | 0,000143 | |
| **the CO2 coefficient for electrical vehical [t CO2/km] used in the GA** | 0,000053[14] | | | | |
| **the CO2 coefficient for electrical vehical [t CO2/km]** | 0[15] | | | | |
| **number of cars owned before moving to the demonstration area** | 68 | | | | |
| **number of cars owned after moving to the demonstration area** | | 32 | 32 | | 36 |
| **Km driven by tenants after implementing the measure [km/year]** | | 598500 | 598500 | 598500 | |
| **Km driven in e-car sharing system after implementation [km/year]** | | 29070 | 37744 | 56510 | |
| **Very difficult [number of answers]** | 1 | | | | |
| **Fairly difficult [number of answer]** | 0 | | | | |
| **Slightly difficult [number of answers]** | 14 | | | | |
| **Fairly easy [number of answers]** | 13 | | | | |
| **Very easy [number of answers]** | 8 | | | | |

[14] From 2015 based on the EU grid factor
[15] Due to the green electricity procured in Viva

### 7.3.2 Measure 3.2

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Carbon dioxide Emission Reduction** | Km driven by employees before implementation (km/year or month) | Travel survey | Calculated based on travel survey data from equivalent area and register data on $CO_2$ -emissions from Swedish vehicles | 1040 tonnes reduction in 5 years |
| | Km driven by employees after implementation (km/year or month) | | | |
| | Km driven in e-car sharing system by employees after implementation (km/year or month) | Data from car sharing provider(s) | | |
| | the CO2 coefficient for conventional vehical (t CO2/km) | Data from car sharing provider | | |
| | the CO2 coefficient for electric vehicle (t CO2/km) | Based on assumption by project partner | | |
| **Ease of use for end users of the solution** | Very difficult (number of answers) | Questionnaire | No MaaS solution available to users | |
| | Fairly difficult (number of answers) | | | |
| | Slightly difficult (number of answers) | | | |
| | Fairly easy (number of answers) | | | |
| | Very easy (number of answers) | | | |
| **Improved access to vehicle sharing solutions** | Not at all number of answers | Questionnaire | Related to previous availability of shared vehicles in the area | |
| | Poor number of answers | | | |
| | Somewhat number of answers | | | |
| | Good number of answers | | | |
| | "Excellent" number of answers | | | |
| **Reduction in driven km by tenants and employees in the district** | Km driven by employees before implementing the measure (km/year or km/month) | Travel survey | Based on existing travel survey data from participating organisations | 1 360 500 km/year among tenants and employees, for measure 3.1 and 3.2 |
| | Km driven by employees after implementing the measure (km/year or km/month) | | | |
| **Yearly km driven in e-car sharing systems** | Yearly km driven in e-car sharing systems | Data from car sharing provider(s) | Based on previous availability of shared vehicles in the area | |

*Table 64: Summary-list of KPIs and related parameters for Measure 3.2 EC2B for employees on Campus Johanneberg*

*Table 65: Data input for Measure 3.2 EC2B for employees on Campus Johanneberg.*

| Parameter(s) | 2019 | 2020 | 2021 |
|---|---|---|---|
| Km driven in e-car sharing system [km/year or month] | | | 11,5 |
| the CO2 coefficient for conventional vehical [t CO2/km] | | | 0,000121 |
| the CO2 coefficient for electrical vehical [t CO2/km] | | | 0 |
| Very difficult [number of answers] | 1 | | |
| Fairly difficult [number of answers] | 1 | | |
| Slightly difficult [number of answers] | 10 | | |
| Fairly easy [number of answers] | 14 | | |
| Very easy [number of answers] | 13 | | |
| Not at all [number of answers] | 1 | | |
| Poor [number of answers] | 1 | | |
| Somewhat [number of answers] | 5 | | |
| Good [number of answers] | 15 | | |
| "Excellent" [number of answers] | 17 | | |

## 7.4 Gothenburg – TT4

### 7.4.1 Measure 4.1

*Table 66: Summary-list of KPIs and related parameters for Measure 4.1 CIM- City Information Model*

| KPI | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| **Advantages for end-users** | No advantage | Questionnaire | | |
| | Little advantage | | | |
| | Some advantage | | | |
| | High advantage | | | |
| | Very high advantage | | | |
| **Ease of use for end users of the solution** | Very difficult (number of answers) | Questionnaire | | |
| | Fairly difficult (number of answers) | | | |
| | Slightly difficult (number of answers) | | | |
| | Fairly easy (number of answers) | | | |

| | | | | |
|---|---|---|---|---|
| | Very easy (number of answers) | | | |
| **Quality of open Data** | Number of datasets that are DCAT compliant in CIM pilot [integer] | Manual check by Gothenburg City | 0. There is no CIM Pilot and there are no Datasets in the CIM pilot. | 100% of DataSets in CIM pilot are DCAT compliant. |
| | Total number of datasets in CIM pilot [integer] | Manual check by Gothenburg City | | |
| **Open data-based solutions** | Number of services based on open data [integer] | Manual check, how many applications exist after Innovation Challenge by Gothenburg City. | 0. There is no CIM Pilot API and therefore there are no applications using it. | Number of applications using the API are more than 5. |
| **Usage of open source software** | Number of open-source software solutions used [integer] | Manual check by Gothenburg City and Tyréns | 0. There is no CIM Pilot and therefor there are no solutions built with or without open source software. | No full purchased solution from one single company is used in the CIM pilot. |

*Table 67: Data input for Measure 4.1 CIM- City Information Model*

| Parameter(s) | 2020 | 2021 |
|---|---|---|
| **No advantage [number of answers]** | 0 | |
| **Little advantage [number of answers]** | 0 | |
| **Some advantage [number of answers]** | 1 | |
| **High advantage [number of answers]** | 3 | |
| **Very high advantage [number of answers])** | 4 | |
| **Very difficult [number of answers]** | 0 | |
| **Fairly difficult [number of answers]** | 1 | |
| **Slightly difficult [number of answers]** | 0 | |
| **Fairly easy [number of answers]** | 3 | |
| **Very easy [number of answers]** | 5 | |
| **Number of datasets that are DCAT compliant in CIM pilot** | 0 | 0 |
| **Total number of datasets in CIM pilot** | 7 | 7 |
| **Number of services based on open data** | 7 | 7 |

### 7.4.2 Measure 4.2

*Table 68: Summary-list of KPIs and related parameters for Measure 4.2 Energy Cloud*

| KPI Selection | Parameter(s) | Data source | Baseline | Target |
|---|---|---|---|---|
| Open data-based solutions | Number of services based on open data in the Energy Cloud demonstrator [integer] | | There is no Energy Cloud demonstrator and therefore there are no applications using it. | Number of applications using the REC compliant datasets in the Energy Cloud demonstrator are more than 3. |
| Quality of open Data | Number of datasets using DCAT standards in Energy Cloud demonstrator | | There is no Energy Cloud demonstrator and there are no Datasets in the Energy Cloud pilot | 100% of DataSets in Energy Cloud demonstrator are REC compliant. |
| | Total number of datasets in Energy Cloud | | | |

*Table 69: Data input for Measure 4.2 Energy Cloud*

| Parameter(s) | 2020 | 2021 |
|---|---|---|
| **Number of services based on open data** | 1 | 1 |
| **Number of data sets using DCAT standards** | 0 | 0 |
| **Total number of data-sets** | 6 | 6 |