SMART CITIES INFORMATION SYSTEM

KEY PERFORMANCE INDICATOR GUIDE

VERSION: 2.0

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This document has been elaborated by SCIS following a thorough analysis of different initiatives and projects that work on the development of a Key Performance Indicator framework for Smart Cities. It is complementary to other initiatives and it is focused on the energy aspects of Smart Cities.

In general, the definitions of the project KPIs are specific to each individual project and therefore it is not possible to provide a universal and final set of KPI definitions and calculation methodologies that could be practically applied to all projects. However, it shall be used as starting point for the definition of KPIS within Smart Cities European projects.
1. INTRODUCTION

1.1 Objectives
The objective of this guide is to give a description of SCIS key performance indicators and their application to the different objects of assessment, identify the data requirements for their calculation and describe the methodology for the calculation of these indicators.

SCIS focuses on the development of indicators to measure technical and economic aspects of energy related measures. These should be applicable to European funded demonstration projects for Smart Cities and Communities (SCC), Energy Efficient buildings (EeB) and designated projects funded under the calls for Energy Efficiency (EE).

Figure 1: SCIS KPIs framework development

Figure 1 shows how the SCIS KPIs framework has been developed, through alignment with other initiatives and projects at European level. In this figure, it can be observed that due to the complexity and variety of the projects in scope, the indicators will be calculated for different aggregation levels (building, set of buildings, energy supply unit, set of energy supply units, neighbourhood...). Some of the KPIs at the upper levels can be calculated from simple addition of the lower levels, while some other KPIs are specific of each level.

SCIS will contribute to a general Smart Cities KPIs framework through the definition of indicators at the energy level. Additionally other indicators are being developed by other initiatives focusing on other city aspects such as governance, people, safety and prosperity. These are not the focus of SCIS.
1.2 Sources for KPIs
The implementation of SCIS indicators has been done through alignment with other initiatives and already existing indicators. Different frameworks for KPIs have been analysed and compared. Indicators focusing on energy and environmental aspects from different projects have been collected and additional ones have been included through the analysis of demonstration projects in scope. The main aim of this indicator list is to allow for comparability between projects.

The following sources have been used:

- CONCERTO Premium Indicator Guide
- CONCERTO Premium Guidebook for Assessment
- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- Citykeys project
- European Innovation Partnership on Smart Cities and Communities - Operational Implementation Plan [EIP - OIP]
- Specific Project KPIs from CELSIUS SCC project and CiTyFied FP7 project
- International Telecommunication Union - Focus Group on Smart Sustainable Cities: Key performance indicators related to the use of information and communication technology in smart sustainable cities [ITU-T]
- “Ideal grid for all- IDE4L project”, funded by the European Electrical Grid Initiative
- European Energy Award [eea]
- Covenant of Mayors [CoM]
- CIVITAS
- GRID+
- DIN EN 15603:2008-07

1.3 Reference systems
When this guide refers to reference systems, it compares the actual system object of assessment with:

- System before the intervention when a retrofiting intervention is being assessed.
- Reference or standard system in the same category as the specific demo system when a new system is being assessed. E.g. standard building that is designed exactly in accordance with the requirements and regulations that were in place for this building type when the building was designed.

1.4 Structure
KPIs can be divided in two clusters:

- Core KPIs: those KPIs identified as the most relevant for SCIS and should be implemented by the projects in scope of SCIS. Some of these KPIs may not apply to all projects, being its use beyond the scope.
- Supporting KPIs: those KPIs relevant for SCIS, being its use recommended.


2. **CORE KPIS**

2.1 General technical performance indicators

2.1.1 Energy demand and consumption

*Applicability for objects of assessment*

| Building | X |
| Set of Buildings | X |
| Energy Supply Unit | X |
| Set of Energy Supply Units | X |
| Neighbourhood | X |
| City | X |

**Definition**

The energy demand/consumption corresponds to the energy entering the system in order to keep operation parameters (e.g. comfort levels). The energy demand is based on the calculated (e.g. simulated) figures and the energy consumption is based on the monitored data. To enable the comparability between systems, the total energy demand/consumption is related to the size of the system and the time interval. This indicator can be used to assess the energy efficiency of a system.

<table>
<thead>
<tr>
<th>At Building Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_d = \frac{TE_d + EE_d}{A_b} )</td>
</tr>
<tr>
<td>( E_d )</td>
</tr>
<tr>
<td>( TE_d )</td>
</tr>
<tr>
<td>( EE_d )</td>
</tr>
<tr>
<td>( A_b )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>At district level</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_{district \ demand} = \sum E_d )</td>
</tr>
<tr>
<td>( E_{district \ consumption} = \sum E_c )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Parameters &amp; Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_{1c} )</td>
</tr>
<tr>
<td>( TE_{c} )</td>
</tr>
<tr>
<td>( EE_{c} )</td>
</tr>
<tr>
<td>( A_b )</td>
</tr>
</tbody>
</table>
### 2.1.2 Energy savings

*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
<th>Set of Buildings</th>
<th>Neighbourhood</th>
<th>Energy Supply Unit</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Definition**

This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. $ES$ may be calculated separately determined for thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings.

\[
ES_T = 1 - \frac{TE_c}{ER_T}
\]

\[
ES_E = 1 - \frac{EE_c}{ER_E}
\]

- $ES_T$: Thermal energy savings
- $TE_c$: Thermal energy consumption of the demonstration-site [kWh/(m² year)]
- $ER_T$: Thermal energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m² year)].
- $ES_E$: Electrical energy savings
- $EE_c$: Electrical energy consumption of the demonstration-site [kWh/(m² year)]
- $ER_E$: Electrical energy reference demand or consumption (simulated or monitored) of the demonstration-site [kWh/(m² year)].

**Unit**

| kWh/ (m² month); kWh/(m² year) |

**References**

- CITyFiED project.
2.1.3 Degree of energetic self-supply by RES

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>City</td>
<td>X</td>
</tr>
</tbody>
</table>

**Definition**

The degree of energetic self-supply by RES is defined as ratio of locally produced energy from RES and the energy consumption over a period of time (e.g. month, year). DE is separately determined for thermal (heating or cooling) energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy.

**Input Parameters & Calculation**

\[
DE_T = \frac{LPE_T}{TE_c}
\]

- \(DE_T\) Degree of thermal energy self-supply based on RES
- \(LPE_T\) Locally produced thermal energy [kWh/month ; kWh/year]
- \(TE_c\) Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)]

**Formula:**

\[
DE_E = \frac{LPE_E}{EE_c}
\]

- \(DE_E\) Degree of electrical energy self-supply based on RES
- \(LPE_E\) Locally produced electrical energy [kWh/month ; kWh/year]
- \(EE_c\) Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)]

**Unit** %

**References**

- CITyFiED project.
2.3 General environmental performance indicators

2.3.1 Greenhouse Gas Emissions

Applicability for objects of assessment

<table>
<thead>
<tr>
<th>Building</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>X</td>
</tr>
<tr>
<td>Set of Energy Supply Units</td>
<td>X</td>
</tr>
<tr>
<td>Neighbourhood</td>
<td>X</td>
</tr>
<tr>
<td>City</td>
<td>X</td>
</tr>
</tbody>
</table>

Definition

The greenhouse gas, particulate matter, NO\textsubscript{x} and SO\textsubscript{2} emissions of a system correspond to the emissions that are caused by different areas of application. In different variants of this indicator the emissions caused by the production of the system components are included or excluded. SCIS only excludes these emissions.

To enable the comparability between systems, the emissions can be related to the size of the system (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. month, year). The greenhouse gases are considered as unit of mass (tones, kg.) of CO\textsubscript{2} or CO\textsubscript{2} equivalents.

Input Parameters and Calculation

District Level:

\[
GGE = \frac{TE_C \cdot GEF_T + EE_C \cdot GEF_E}{A_b}
\]

- \(GGE\): Greenhouse gas emissions
- \(TE_C\): Thermal energy consumption (monitored) of the demonstration site [kWh/(month); kWh/(year)]
- \(EE_C\): Electrical energy consumption (monitored) of the demonstration site [kWh/(month); kWh/(year)]
- \(GEF_T\): Greenhouse gas emission factor for thermal energy (weighted average based on thermal energy production source/fuel mix) (kg CO\textsubscript{2}eq/kWh consumed)
- \(GEF_E\): Greenhouse gas emission factor for electrical energy (weighted average based on electricity production source/fuel mix) (kg CO\textsubscript{2}eq/kWh consumed)
- \(A_b\): Floor area of the building [m\textsuperscript{2}]

Unit

- kg CO\textsubscript{2}eq/(m\textsuperscript{2} * month); kg CO\textsubscript{2}eq/(m\textsuperscript{2} * year)

References

- CITyFiED project.
### 2.3.2 Primary Energy Demand and Consumption

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>City</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Definition**

The primary energy demand/consumption of a system encompasses all the naturally available energy that is consumed in the supply chains of the used energy carriers. To enable the comparability between systems, the total primary energy demand/consumption can be related to the size of the system (e.g. conditioned area) and the considered time interval (e.g. month, year).

**Input Parameters & Calculation**

At building level

\[
PE_d = \frac{TE_d \cdot PEF_T + EE_d \cdot PEF_E}{A_b}
\]

- \(PE_d\) Primary energy demand (simulated)
- \(TE_d\) Thermal energy demand (simulated) \([\text{kWh/(month)} ; \text{kWh/year}]\)
- \(EE_d\) Electrical energy demand (simulated) \([\text{kWh/(month)} ; \text{kWh/year}]\)
- \(PEF_T\) Primary energy factor for thermal energy (weighted average based on source/fuel mix in production)
- \(PEF_E\) Primary energy factor for electrical energy (weighted average based on source/fuel mix in production)
- \(A_b\) Floor area of the building \([\text{m}^2]\)

Formula:

\[
PE_c = \frac{TE_c \cdot PEF_T + EE_c \cdot PEF_E}{A_b}
\]

- \(PE_c\) Primary energy consumption (monitored)
- \(TE_c\) Thermal energy consumption (monitored) \([\text{kWh/(month)} ; \text{kWh/year}]\)
- \(EE_c\) Electrical energy consumption (monitored) \([\text{kWh/(month)} ; \text{kWh/year}]\)
- \(PEF_T\) Primary energy factor for thermal energy (weighted average based on source/fuel mix in production)
- \(PEF_E\) Primary energy factor for electrical energy (weighted average based on source/fuel mix in production)
- \(A_b\) Floor area of the building \([\text{m}^2]\)

At district level:

\[
PE_{\text{district primary demand}} = \sum PE_d
\]

\[
PE_{\text{district primary consumption}} = \sum PE_c
\]

Primary energy demand (simulated) of the district

Primary energy consumption (monitored) of the district.
Carbon dioxide Emission Reduction

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>X</th>
<th>Set of Energy Supply Units</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>X</td>
<td>Neighbourhood</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>X</td>
<td>City</td>
<td>X</td>
</tr>
</tbody>
</table>

**Definition**

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 (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF₆) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. CO₂ accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO₂ emissions are combustion processes related to energy generation and transport. CO₂ emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.

**Input Parameters & Calculation**

The emitted mass of CO₂ is calculated from the delivered and exported energy for each energy carrier:

\[ m_{CO_2} = \sum (E_{del,i} K_{del,i}) - \sum (E_{exp,i} K_{exp,i}) \]

Where

- \( E_{del,i} \) is the delivered energy for energy carrier \( i \);
- \( E_{exp,i} \) is the exported energy for energy carrier \( i \);
- \( K_{del,i} \) is the CO₂ emission coefficient for delivered energy carrier \( i \);
- \( K_{exp,i} \) is the CO₂ emission coefficient for the exported energy carrier

The indicator is calculated as the direct (operational) reduction of the CO₂ emissions over a period of time. The result may be expressed as a percentage when divided by the reference CO₂ emissions. To calculate the direct CO₂ emissions, the total energy reduced, can be translated to CO₂ emission figures by using conversion factors for different energy forms as described in below tables: National and European emission factors for consumed electricity (source: Covenant of Mayors).
Standard Emission factors for fuel combustion – most common fuel types (IPCC, 2006)

<table>
<thead>
<tr>
<th>Country</th>
<th>Standard emission factor (t CO₂/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0.209</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.285</td>
</tr>
<tr>
<td>Germany</td>
<td>0.624</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.461</td>
</tr>
<tr>
<td>Spain</td>
<td>0.440</td>
</tr>
<tr>
<td>Finland</td>
<td>0.216</td>
</tr>
<tr>
<td>France</td>
<td>0.056</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.543</td>
</tr>
<tr>
<td>Greece</td>
<td>1.149</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.732</td>
</tr>
<tr>
<td>Italy</td>
<td>0.483</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.435</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.369</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.023</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.819</td>
</tr>
<tr>
<td>Cyprus</td>
<td>0.874</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.950</td>
</tr>
<tr>
<td>Estonia</td>
<td>0.908</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.566</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0.153</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.109</td>
</tr>
<tr>
<td>Poland</td>
<td>1.191</td>
</tr>
<tr>
<td>Romania</td>
<td>0.701</td>
</tr>
<tr>
<td>Slovenia</td>
<td>0.557</td>
</tr>
<tr>
<td>Slovakia</td>
<td>0.252</td>
</tr>
<tr>
<td>EU-27</td>
<td>0.460</td>
</tr>
</tbody>
</table>

Standard CO₂ emission factors (from IPCC, 2006) and CO₂-equivalent LCA emission factors (from ELCD) for most common fuel types

<table>
<thead>
<tr>
<th>Type</th>
<th>Standard emission factor (t CO₂/MWh)</th>
<th>LCA emission factor (t CO₂-eq/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Gasoline</td>
<td>0.249</td>
<td>0.299</td>
</tr>
<tr>
<td>Gas oil, diesel</td>
<td>0.267</td>
<td>0.305</td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td>0.279</td>
<td>0.310</td>
</tr>
<tr>
<td>Anthracite</td>
<td>0.354</td>
<td>0.393</td>
</tr>
<tr>
<td>Other Bituminous Coal</td>
<td>0.341</td>
<td>0.380</td>
</tr>
<tr>
<td>Sub-Bituminous Coal</td>
<td>0.346</td>
<td>0.385</td>
</tr>
<tr>
<td>Lignite</td>
<td>0.364</td>
<td>0.375</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.202</td>
<td>0.237</td>
</tr>
<tr>
<td>Municipal Wastes (non-biomass fraction)</td>
<td>0.330</td>
<td>0.330</td>
</tr>
<tr>
<td>Wood</td>
<td>0 - 0.403</td>
<td>0.002² - 0.405</td>
</tr>
</tbody>
</table>

Unit: tones/(year)

References
- CITYkeys project
2.4 General economic performance indicators:

2.4.1 Total Investments

*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Object</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>X</td>
</tr>
<tr>
<td>Set of Buildings</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>X</td>
</tr>
<tr>
<td>Set of Energy Supply Units</td>
<td>X</td>
</tr>
<tr>
<td>Neighbourhood</td>
<td>X</td>
</tr>
<tr>
<td>City</td>
<td>X</td>
</tr>
</tbody>
</table>

*Definition*

An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system is defined as cumulated payments until the initial operation of the system. The investment in the refurbishment of an existing system is defined as cumulated payments until the initial operation of the system after the refurbishment.

Within SCIS, total investments apply to the energy aspects of the system (e.g. high efficient envelope in a building) and exclude investments non energy related (e.g. refurbishment of bathrooms).

*Input Parameters & Calculation*

\[
EPI_{BR} = \frac{I_{BR}}{A_d}
\]

- \(EPI_{BR}\): Total investment for all the interventions related to energy aspects in the district per conditioned area [\(€/m^2\)]
- \(I_{BR}\): Total investment for all the interventions related to energy aspects [\(€\)]
- \(A_d\): Total floor area of the system renovated [\(m^2\)]

\[
EPI_{ER} = \frac{I_{ER}}{A_d}
\]

*Unit*

- \(€/m^2\) (building company); \(€/kW\) (energy company)

*References*

- CITyFiED project.
### 2.4.2 Grants

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>X</th>
<th>Set of Energy Supply Units</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>X</td>
<td>Neighbourhood</td>
<td>X</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>X</td>
<td>City</td>
<td>X</td>
</tr>
</tbody>
</table>

**Definition**

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.

\[
Gr_{BR} = \frac{G_{BR}}{I_{BR}}
\]

- \(Gr_{BR}\): Share of the investment in building retrofitting that is covered by grants [%]
- \(G_{BR}\): Total grants received for the building retrofitting of the district [€]
- \(I_{BR}\): Total investment for all the interventions related to building retrofitting [€]

\[
Gr_{ER} = \frac{G_{ER}}{I_{ER}}
\]

- \(Gr_{ER}\): Share of the investment in energy retrofitting that is covered by grants [%]
- \(G_{ER}\): Total grants received for the energy retrofitting of the district [€]
- \(I_{ER}\): Total investment for all the interventions related to energy retrofitting [€]

**Unit**

- %

**References**

- CITYFiED project
### 2.4.3 Total Annual costs

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>X</th>
<th>Set of Energy Supply Units</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>X</td>
<td>Neighbourhood</td>
<td>X</td>
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<tr>
<td>Energy Supply Unit</td>
<td>X</td>
<td>City</td>
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</table>

**Definition**

The total annual costs are defined as the sum of capital-related annual costs (e.g. interests and repairs caused by the investment), requirement-related costs (e.g. power costs), operation related costs (e.g. costs of using the installation) and other costs (e.g. insurance). These costs (can) vary for each year.

- Capital related costs encompass depreciation, interests and repairs caused by the investment.
- Requirement-related costs include power costs, auxiliary power costs, fuel costs, and costs for operating resources and in some cases external costs.
- Operation-related costs include among other things the costs of using the installation and costs of servicing and inspection.
- Other costs include costs of insurance, general output, uncollected taxes etc.

The total annual costs are related to the considered interval of time (year). To make different objects comparable the same types of costs have to be included in the calculation.

\[
TAC_{before} = C_E + C_{O&M}
\]

\[
TAC_{before} \text{ Total annual energy cost of the reference system (i.e. energy, operation \\ & maintenance) [€/yr]}
\]

\[
C_E \text{ Total annual cost of the system supply [€/yr]}
\]

\[
C_{O&M} \text{ Total annual cost of the operation and maintenance of the system [€/yr]}
\]

\[
TAC_{after} = C_E + C_{O&M} + C_F
\]

\[
TAC_{after} \text{ Total annual energy cost of the system after the intervention (i.e. energy, \\ operation & maintenance, financial) [€/yr]}
\]

\[
C_E \text{ Total annual cost of the system supply [€/yr]}
\]

\[
C_{O&M} \text{ Total annual cost of the operation and maintenance of the facility [€/yr]}
\]

\[
C_F \text{ Total annual financing cost, if applies [€/yr]}
\]

**Unit**

€/year

**References**

- CITyFiED project
2.4.4 Payback

Applicability for objects of assessment

<table>
<thead>
<tr>
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<td>Set of Buildings</td>
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<td>Energy Supply Unit</td>
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<tr>
<td>Set of Energy Supply Units</td>
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<td>Neighbourhood</td>
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</table>

Definition

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.

Input Parameters & Calculation

Economic payback, EPP, type A static

\[
EPP = \frac{EPI_{BR}}{m}
\]

\(m\) can be calculated as average annual costs in use savings (€/a)

\[m = TAC_{after} - TAC_{before}\]

Type B dynamic

\[
EPP = \frac{\ln(m \cdot (1 + i)) - \ln(EPI_{BR} - EPI_{BR} \cdot (1 + i) + m)}{\ln(1 + i)} - 1
\]

Type C dynamic with energy price increase rate

\[
EPP = \frac{\ln(m \cdot (1 + i)) - \ln(EPI_{BR} \cdot (1 + p) - EPI_{BR} \cdot (1 + i) + (1 + p) \cdot m)}{\ln(1 + i) - \ln(1 + p)} - 1
\]

\(EPI_{BR}\) (€)Energy-related investment
\(i\) (%) Discount rate
\(p\) (%) Energy price increase rate

Unit: Years

References

### 2.4.5 Return on Investment (ROI)

**Applicability for objects of assessment**

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</table>

#### Definition

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 %.

#### Input Parameters & Calculation

\[
ROI_T = \frac{\sum_{t=1}^{T} (I_{nt} - TAC_{after,t}) - (I_{BR} + I_{ER})}{I_{BR} + I_{ER}}
\]

- **ROI** \(_T\) Return on Investment [%]
- **T** Duration of the economic analysis period: T=10, 15 and 20 [yr]

#### Unit

% 

#### References

- CITyFiED project
2.5 General performance indicators for ICT related technologies

ICT interventions have a double- environmental impact. There are mainly two orders of effect regarding environmental impacts of ICTs:

- **First order effects**: the environmental load of ICTs, this is, the impacts associated to the physical existence of ICT and the processes involved, e.g. GHG emissions or use of hazardous substances.
- **Second order effects**: the environmental load reduction achieved by ICTs, this is, the impacts achieved thanks to the use and application of ICTs.

SCIS will be focus on the assessment of second order effects.

### 2.5.1 Reliability

*Applicability for objects of assessment*

<table>
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<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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</tr>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City</td>
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</table>

**Definition**

Avoiding failures revert on higher reliability, meaning fewer stops on the normal operation of the building and associated systems. With the application of ICT measures it is possible to correct a potential misbehaviour of the system and avoid unexpected stops. In SCIS, the indicator will be measured as:

- Ratio of power interruptions avoided in a year
- Ratio of power quality issues avoided in a year

The failures can be caused by e.g. of grid congestion.

**Input Parameters & Calculation**

\[
\text{Reliability} = \frac{\text{Number of failures avoided}}{\text{Total number of failures} + \text{number of failures avoided}} \times 100
\]

**Unit**  
[number of failures avoided; %]

**References**

- ISO 37120:2014,
- CONCERTO
### 2.5.2 Power Quality and Quality of Supply (DSO+TSO)

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<td>Energy Supply Unit</td>
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</table>

#### Definition
Average time needed for awareness, localization and isolation of grid fault.

#### Input Parameters & Calculation

\[
\Delta T_{\text{fault}} = \frac{T_{\text{fault, baseline}} - T_{\text{fault, R&I}}}{T_{\text{fault, R&I}}} \times 100
\]

\(T_{\text{fault}}\) is the average time required for fault awareness, localization and isolation.

#### Unit
[%]

#### References
- IDE4L
### 2.5.3 Increased system flexibility for energy players

**Applicability for objects of assessment**

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<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<td>Energy Supply Unit</td>
<td>City</td>
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</table>

#### Definition

Additional flexibility capacity gained for energy players. It measures the progress brought by R&I activities relative to the new clusters and functional objectives, assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO.

This KPI is an indication of the ability of the system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets and in energy efficiency intervention.

- Stability refers to the maintaining of voltage and frequency of a given power system within acceptable levels.

#### Input Parameters & Calculation

\[
\Delta SF = \frac{SF_{R&I} - SF_{BAU}}{P_{peak}}
\]

\( SF \) is the amount of load capacity participating in demand side management [W].

It can also be expressed related to cost as

\[
SFAC = \frac{System\ flexibility}{Cost}
\]

#### Unit

[\%]; [W/€]

#### References

- GRID+
- IDE4L.
- European Commission Smart Grid Task Force
### 2.5.4 Reduction of energy cost

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
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<tr>
<td>Set of Buildings</td>
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<td>Energy Supply Unit</td>
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<td>Set of Energy Supply Units</td>
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<td>Neighborhood</td>
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<td>City</td>
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</table>

**Definition**

This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator. The KPI will measure the cost of the energy traded by an aggregator, both as a baseline and when ICT are implemented, e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower.

**Input Parameters & Calculation**

\[
\text{COST}\text{REDUCTION} = \frac{\text{COST}_{R&I} - \text{COST}_{BAU}}{\text{COST}_{BAU}}
\]

Being

\[
\text{COST}\text{ the electricity price at a given period of time.}
\]

**Unit**

[\%]

**References**

- IDE4L

---

### 2.5.5 Peak load reduction

**Applicability for objects of assessment**

<table>
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<td>Energy Supply Unit</td>
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<td>Neighborhood</td>
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<td>City</td>
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</table>

**Definition**

Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power.

**Input Parameters & Calculation**

\[
\% = \left(1 - \frac{P_{\text{peak,R&I}}}{P_{\text{BAU}}}\right)\times 100
\]

**Unit**

[\%]

**References**

- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS
2.5.6 Increased hosting capacity for RES, electric vehicles and other new loads

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighborhood X</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City X</td>
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</tbody>
</table>

**Definition**

This KPI is intended to give a statement about the additional loads that can be installed in the network, when R&I solutions are applied, and compared to the BAU scenario.

**Input Parameters & Calculation**

This improvement can be quantified by means of the following percentage:

\[ \text{EHC\%} = \frac{\text{HC}_{\text{R&I}} - \text{HC}_{\text{BAU}}}{\text{HC}_{\text{BAU}}} \times 100 \]

Being

- EHC the enhanced hosting capacity of new loads when R&I solutions are applied with respect to BAU scenario.
- HC the additional hosting capacity of new loads applied with respect to currently connected generation (GW or MW).

**Unit**

[\%]

**References**

- GRID+

2.5.7 Consumers engagement

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighborhood X</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City X</td>
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</table>

**Definition**

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.

**Input Parameters & Calculation**

- Number of final users involved
- Number of people with increased capacity

**Unit**

[number]

**References**

- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS


### 2.6 General performance indicators for mobility related technologies

#### 2.6.1 Energy consumption data aggregated by sector fuel

*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City</td>
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</tbody>
</table>

**Definition**

Energy consumption of the mobility sector.

It should be assessed for public transport (BEFORE and AFTER) as well as for private vehicles (BEFORE and AFTER).

**Input Parameters & Calculation**

Mode:
- LPG
- Motor Spirit
- Kerosene - Jet Fuels
- Diesel Oil
- Heavy Fuel Oil
- Natural gas
- Biodiesel
- Electricity - gridElectricity - RES

**Unit**

[GJ]

**References**

- SEAP, Covenant of Mayors
### 2.6.2 Kilometres of high capacity public transport system per 100 000 population

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood X</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City X</td>
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</tbody>
</table>

**Definition**
The kilometres of high capacity public transport system per 100 000 population shall be calculated by adding the kilometres of high capacity public transport systems operating within the city (numerator) divided by one 100 000th of the city’s total population (denominator). The result shall be expressed as the kilometres of high capacity public transport system per 100 000 population. High capacity public transport shall include heavy rail metro, subway systems and commuter rail systems.

**Input Parameters & Calculation**
Information on kilometres of high capacity public transport should be gathered from municipal transport offices and local/regional transit authorities and can also be counted using computerized mapping, aerial photography, or existing paper maps, all of which shall be field-verified. This information may be gathered from transport system plans or other master plans.

**Unit**
[km/habitants]

**References**
- ISO 37120

### 2.6.3 Kilometres per passenger and private vehicle

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood X</td>
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<td>Energy Supply Unit</td>
<td>City X</td>
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</tbody>
</table>

**Definition**
It should be assessed for public transport (BEFORE and AFTER) as well as for private vehicles (BEFORE and AFTER). It can also be assessed as percentage of for each mode (type of energy supplied, type of vehicle).

**Input Parameters & Calculation**
- Passenger-kilometre
- Private vehicle-kilometer

**References**
- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS
### 2.6.4 Number of efficient vehicles deployed in the area

*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City</td>
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</tbody>
</table>

**References**

- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS

### 2.6.5 Number of e-charging stations deployed in the area

*Applicability for objects of assessment*

<table>
<thead>
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<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
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<td>City</td>
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</tbody>
</table>

**References**

- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS

### 2.6.6 Impact of ICT apps into mobility

*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Building</th>
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<tr>
<td>Set of Buildings</td>
<td>Neighborhood</td>
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<td>Energy Supply Unit</td>
<td>City</td>
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</table>

**Definition**

Impact of ICT apps into switching from non-sustainable mobility into sustainable mobility, this is, change on modal split.

**Input Parameters & Calculation**

- Non sustainable mobility before and after.

**References**

- CIVITAS
- H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'
- SCIS
3. **Supporting KPIS**

The following list of KPIs has been identified as supporting KPIs from SCIS.

3.1.1 Increase in Local Renewable Energy Generation  
*Applicability for objects of assessment*

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<tr>
<th>Building</th>
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<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
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<td>Energy Supply Unit</td>
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</table>

The share of renewable energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator should account for the increase of the renewable energy generation due to the intervention. In case biomass is used to generate energy, the transport distance is limited to 100 km. Renewable energy shall include both combustible and non-combustible renewables (ISO/DIS 37120, 2013). Noncombustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. The combustible renewables and waste (CRW) consist of biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes), municipal waste (waste produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste.

As input parameters, it should take into account the increase in local renewable energy production caused by the intervention calculated as the difference between the annual renewable energy generation related to the system before and after the intervention (or as the difference between the annual renewable energy generations related to the project compared to BAU). The result will be divided by the annual total energy consumption related to the project.

<table>
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<tr>
<th>Unit</th>
<th>%</th>
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<table>
<thead>
<tr>
<th>References</th>
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<td>- ITU-T L.1430 (2013)</td>
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</table>

3.1.2 Reduced energy curtailment of RES and DER  
*Applicability for objects of assessment*

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
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<tr>
<td>Energy Supply Unit</td>
<td>City</td>
<td>X</td>
</tr>
<tr>
<td><strong>Definition</strong></td>
<td>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&amp;I solution compared to BAU for a period of time, i.e. a year.</td>
<td></td>
</tr>
<tr>
<td><strong>Input Parameters &amp; Calculation</strong></td>
<td>[ \text{E}<em>{\text{not-injected}} \text{, is the total energy not injected in network due to MV/LV network conditions [MWh].} ] [ \text{Reduction of Energy not injected} = \frac{\text{Energy not injected}</em>\text{baseline} - \text{Energy not injected}<em>\text{R&amp;I}}{\text{Energy not injected}</em>\text{baseline}} \times 100 ]</td>
<td></td>
</tr>
<tr>
<td><strong>Unit</strong></td>
<td>[%]</td>
<td></td>
</tr>
<tr>
<td><strong>References</strong></td>
<td>• IDE4L</td>
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</table>

3.1.3 Number of costumers that are positive about the project. 
Source: ECOGRID EU

3.1.1 Number of costumers that are positive about how ICT is used. 
Source: ECOGRID EU

3.1.1 Number of costumers that are positive about how energy systems are controlled 
Source: ECOGRID EU

3.1.2 Smart homes 
Source: Smart City Index Master.

**Description**

Percentage of homes (multifamily & single-family) with smart meters. This KPI can also be applied at commercial and industrial buildings.

3.1.3 Smart energy 
Source: Ecogrid EU

**Description**

Percentage of municipal grid meeting all of the following requirements for smart grid.

1) 2-way communication;
2) Automated control systems for addressing system outages;
3) Real-time information for customers;
4) Permits distributed generation;
5) Supports net metering.

3.1.4 Incompleteness of data volume 
SOURCE: IDE4L. 
How many data points were really monitored.
3.1.5 Improved competitiveness of the electricity market
SOURCE: IDE4L.

3.1.6 LV Load/generation forecaster (LVLGF)
SOURCE: IDE4L.

3.1.7 Network Description Update
SOURCE: IDE4L.
Evaluation of the percentage of the grid which can be actually managed by using ICT algorithms.

3.1.8 Open solutions
Source: Ruggedised lighthouse project.
Number of open solutions developed.

3.1.9 Average number of electrical interruptions per customer per year
This KPI is listed as “supporting indicator”, meaning that the projects should, but not shall, include this indicator.

Description: The average number of electrical interruptions per customer per year shall be calculated as the total number of customer interruptions (numerator) divided by the total number of customers served (denominator). The result shall be expressed as the average number of electrical interruptions per customer per year.
NOTE: Average number of electrical interruptions helps to track and benchmark reliability performance in electric utility services.

Electrical interruptions shall include both residential and non-residential.

3.1.10 Average length of electrical interruptions (in hours)
This KPI is listed as “supporting indicator”, meaning that the projects should, but not shall, include this indicator.

Description: The average length of electrical interruptions shall be calculated as the sum of the duration of all customer interruptions in hours (numerator) divided by the total number of customer interruptions (denominator). The result shall be expressed as the average length of electrical interruptions in hours.

Electrical interruptions shall include both residential and non-residential.
NOTE Average length of electrical interruptions helps to track and benchmark reliability performance in electric utility services.

3.1.11 Annual number of public transport trips per capita

Applicability for objects of assessment

<table>
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<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
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<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
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<tr>
<td>Energy Supply Unit</td>
<td>City</td>
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</table>
### Definition

Transport usage is a key indicator of how easy it is to travel in the city by modes other than single occupancy vehicles. The indicator might also provide insight into transportation policy, traffic congestion, and urban form. Cities with higher transport ridership rates tend to invest more in their transport systems and are more geographically compact. Transport usage also addresses overall travel patterns in the city, and not just the journey to work.

Annual number of public transport trips per capita shall be calculated as the total annual number of transport trips originating in the city - “ridership of public transport” - (numerator), divided by the total city population (denominator). The result shall be expressed as the annual number of public transport trips per capita.

Transport trips shall include trips via heavy rail metro or subway, commuter rail, light rail streetcars and tramways, organized bus, trolleybus, and other public transport services. Cities shall only calculate the number of transport trips with origins in the city itself.

Transport data should be gathered from a number of sources, including: official transport surveys, revenue collection systems (e.g. number of fares purchased), and national censuses.

**NOTE 1:** Fare-box records (e.g. transport fares paid) are usually the primary source of data for this indicator. However, the relationship between fares purchased and trips taken is not always exact. For example, many transport systems do not actively check for proof of fare purchase – often, riders are expected to have valid tickets, and are severely fined if a ticket is not presented, but enforcement of such rules is not uniform for every rider on every trip. Other transport systems offer monthly or weekly passes, which do not necessarily allow for accurate counts of each trip.

**NOTE 2:** In many countries, a large number of trips are made via “informal transport” services (e.g. minibuses not operated by the government or municipal transport corporation). These informal trips are not part of the official transport network and shall not be counted.

### Input Parameters and Calculation

ISO 37120

### Units

### References

ISO 37120

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### 3.1.12 Kilometres of bicycle paths and lanes per 100,000 population

**Applicability for objects of assessment**

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>City</td>
</tr>
</tbody>
</table>

### Definition

A transportation system that is conducive to bicycling can reap many benefits in terms of reduced traffic congestion and improved quality of life. Economic rewards both to the individual and to society are also realized through reduced health care costs and reduced dependency on auto ownership (and the resulting in insurance, maintenance and fuel costs). Bicycle lanes also require smaller infrastructure investments than other types of transportation infrastructure. Cycling has less of an environmental impact.

This indicator provides city’s with a useful measure of a diversified transportation system.
### Kilometres of bicycle paths and lanes per 100 000 population

<table>
<thead>
<tr>
<th>Input Parameters and Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilometres of bicycle paths and lanes per 100 000 population shall be calculated as the total kilometres of bicycle paths and lanes (numerator) divided by one 100 000th of the city’s total population (denominator). The result shall be expressed as the kilometres of bicycle paths and lanes per 100 000 population. Bicycle lanes shall refer to part of a carriageway designated for cycles and distinguished from the rest of the road/carriageway by longitudinal road markings. Bicycle paths shall refer to independent road or part of a road designated for cycles and sign-posted as such. A cycle track is separated from other roads or other parts of the same road by structural means.</td>
</tr>
</tbody>
</table>

### References

| ISO 37120 |

### 3.1.13 Number of personal automobiles per capita

#### Applicability for objects of assessment

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>City</td>
</tr>
</tbody>
</table>

#### Definition

The number of personal automobiles per capita shall be calculated as the total number of registered personal automobiles in a city (numerator) divided by the total city population (denominator). The result shall be expressed as the number of personal automobiles per capita. Measuring each type of transportation infrastructure sheds light on travel behaviour. The use of automobiles as a travel mode provides access to work, shopping, school and other community services. This measure can also inform the need for further transport facilities. The total number of registered personal automobiles shall include automobiles used for personal use by commercial enterprises. This number shall not include automobiles, trucks and vans that are used for the delivery of goods and services by commercial enterprises.

#### References

| ISO 37120 |

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REFERENCES

Applied framework for evaluation in CIVITAS PLUS II, n.d.

CELSIUS D4 1 Report on KPI values, n.d.


CiTyFied FP7 project

Citykeys project


Digest of EEA indicators 2014, n.d.

DIN EN 15603:2008-07


European Energy Award [eea]

European Innovation Partnership on Smart Cities and Communities - Operational Implementation Plan: First Public Draft, n.d.

GRID+

H2020 work programme, 2016-2017. 10. 'Secure, Clean and Efficient Energy'

“Ideal grid for all- IDE4L project”, funded by the European Electrical Grid Initiative


ITU-T Focus Group on Smart Sustainable Cities: Key performance indicators related to the use of information and communication technology in smart sustainable cities, n.d.

The Covenant of Mayors in Figures and Performance Indicators: 6 - year Assessment, n.d.
In this appendix, there are included some KPIs that generally apply to the overall Demo site.

**Heating Degree Days (HDD)**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of heating days in the time period</td>
<td>(z)</td>
<td>-</td>
</tr>
<tr>
<td>Daily average ambient air temperature</td>
<td>(t_a)</td>
<td>[°C]</td>
</tr>
<tr>
<td>Heating energy demand before correction</td>
<td>(Q_{\text{actual}})</td>
<td>[kWh/year]</td>
</tr>
<tr>
<td>Heating energy demand after correction</td>
<td>(Q_{\text{normalised}})</td>
<td>[kWh/year]</td>
</tr>
<tr>
<td>HDD for a reference climate</td>
<td>(HDD_{\text{reference}})</td>
<td>[K.d/year]</td>
</tr>
<tr>
<td>HDD for the actual climate</td>
<td>(HDD_{\text{actual}})</td>
<td>[K.d/year]</td>
</tr>
</tbody>
</table>

**References**
- CONCERTO Premium Indicator Guide
### Cooling Degree Days (CDD)

<table>
<thead>
<tr>
<th>Building</th>
<th>Set of Energy Supply Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Buildings</td>
<td>Neighbourhood</td>
</tr>
<tr>
<td>Energy Supply Unit</td>
<td>City X</td>
</tr>
</tbody>
</table>

**Definition**
There is no standardized method for cooling degree days available and Eurostat doesn’t propose a procedure either. However, in literature and different projects a method has become commonly accepted. The calculation is analogue to the heating degree-days and as it is applied to air-conditioning systems very often there is no distinction between ambient air temperature and room set temperature. The supply air with a specific set temperature has to be cooled down exactly at the time when the temperature of the ambient air temperature exceeds that value. According to the common use, the base temperature is defined as 18°C (65°F).

\[
CDD_{st} = \sum_{i=1}^{z} (18°C - t_a)
\]

**Input Parameters and Calculation**

<table>
<thead>
<tr>
<th>Unit Name</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cooling days in time period</td>
<td>( z )</td>
<td>-</td>
</tr>
<tr>
<td>Daily average ambient temperature</td>
<td>( t_a )</td>
<td>(^°C)</td>
</tr>
<tr>
<td>CDD for a reference climate</td>
<td>( CDD_{reference} )</td>
<td>[K.d/a]</td>
</tr>
<tr>
<td>CDD for the actual climate</td>
<td>( CDD_{actual} )</td>
<td>[K.d/a]</td>
</tr>
</tbody>
</table>

**References**
- CONCERTO Premium Indicator Guide
APPENDIX II

OBJECTS OF ASSESSMENT

In the projects to be assessed there are different levels of spatial aggregation which go from single entities to a whole neighbourhood or city. In order to allow the assessment of these projects, a classification into different typologies has been done. The two main entities are buildings and energy supply units. Additionally, and due to the special characteristics of the intervention in scope of SCIS, ICT and mobility have been defined as an own entity.

Figure 2: Classification of assessment typologies and clustering

The different levels of aggregation (city, district, neighbourhood, implementation area...) are then defined by the combination and clustering of these typologies. The following combinations are possible:

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

Buildings

The assessment boundary at the building level is depicted in figure 4. According to EN 15603, the energy performance of the building is the balance of:

- The delivered energy, required to meet the energy needs
- The exported energy.
The delivered energy is to be expressed per energy carrier. If part of this delivered energy is allocated to energy export, it also needs to be specified in the data collection (e.g. gas fired CHP, where the electricity produced is not used in the building. In this case the corresponding amount of gas allocated to electricity production shall be specified in order to be able to calculate the energy performance of the building).

At the building level the data required is (calculation procedure goes from the energy needs to the primary energy):

- Energy needs per area of application (heating, cooling, DHW...)
- Energy technologies supplying these energy needs
- Energy storage units
- Delivered energy to each energy supply units expressed per energy carrier

**Set of Buildings**
The assessment for a set of buildings is done by aggregation of building units. The indicators can then be calculated for the sum of the buildings as a group.

**Energy Supply Units**
At the Energy Supply Unit level the approach followed is similar to the building level. Delivered energy per energy carrier and output energy allocated to energy carrier need to be specified. Additionally and depending on the energy supply unit different indicators can be calculated.

This assessment object refers to building integrated energy supply units as well as large-scale energy supply units.

**Set of Energy Supply Units**

The assessment for a set of ESU is done by aggregation of energy supply units. The indicators can then be calculated for the sum of the energy supply units.
Neighbourhood / City

The level of implementation area or neighbourhood is composed by the aggregation of different entities.

![Diagram of Neighbourhood and City](image)

*Figure 4: Objects of assessment and boundary conditions*

The energy flows at this point also need to be defined. The following information is required to define the energy system:

- Energy carriers used at the implementation area level and the primary energy factors corresponding to this area
- Demonstration units involved (buildings, energy supply units, storage units and distribution systems)
- Delivered energy to each ESU and building allocated to the corresponding energy carrier
- Output energy of each ESU and, if applicable, output energy exported out of the boundary allocated to the amount of delivered energy carrier
- Energy flows between technologies and buildings (which ESU is supplying which building or ESU).

Due to the complexity of these systems, indicators can only be calculated if a full set of data is available.
APPENDIX III

DATA REQUIREMENTS AND COMPARABILITY

For the calculation of indicators and the assessment of the energy performance different sets of data are needed. These include baseline scenario, design data and monitoring data. The division into these three data sets will allow the comparison between:

- Design data and baseline scenario: improvement compared to the typical solution
- Monitoring data and baseline scenario: real improvement compared to the typical solution
- Monitoring data and design data: comparison of achieved performance against prediction, this can also be defined as a separate indicator (quality of prediction).

Figure 5: Comparison of data on energy performance

The indicators defined in this guide can also be calculated as a reduction or increase of, for example, the energy performance in comparison with the baseline or the designed data. A detailed explanation of each of the cases can be found below. For additional information regarding the monitoring data please refer to the SCIS Technical Monitoring Guide.

Baseline scenario

When defining a baseline, it is important to differentiate between new projects and retrofitting projects. For both project types, a baseline should be defined to further compare the performance of the different systems involved in the demonstration project:

1. Projects dealing with existing systems: if the demonstration project is a refurbishment / retrofit, an improvement of existing technology or building, or either is a substitution of previous system for a high efficiency one, it is important to meter all energy consumption data of the building before the refurbishment works start: final energy demand for heating, domestic hot water, cooling, electrical appliances in kWh/month.
2. New projects. Since there is no real data to compare the performance of new systems, it is important to define a baseline based on the energy performance of similar buildings.
According to this classification, the baseline of the project has to be defined in the following way:

1. One year of monitoring of the existing system. In case of refurbished/retrofitted buildings it is important to meter all energy consumption data of the building before construction works start: Final energy demand for heating, domestic hot water, cooling, electrical appliances in kWh/month. If not metering was possible, data from energy bills can be used to define the status before refurbishment.
2. One year of synthetic data, reflecting the typical scenario. This data has to be calculated according to regulations, technical guides or similar projects.

Design Data
In the first phase of the monitoring it is also important to calculate, via modelling and simulation tools, the energy performance that is expected from the design of the system. Both the baseline and the design data will be later used to compare the actual energy performance of the building. Hereby, the energy efficiency improvements can be demonstrated and the deviations from the design can be detected.

Monitoring Data
The purpose of the monitoring is to demonstrate the energy performance of the implementation area. Therefore it is important to collect all sampled data at the same time period in a consistent way. Monthly metered values of energy consumption and energy generation should be provided.

Once the construction is finished and the systems start to work under real conditions, the 1st year of monitoring will support the implementation progress of the energy system. This process is important for the analysis and optimization of the operating system.

Afterwards it is possible to check the actual consumption against expected, calculated data and to analyse and evaluate the energy performance. In case of refurbishments it is possible to compare the data collected/metered before refurbishment against the data metered after refurbishment.

Comparability between objects of assessment

Buildings
To enable the comparability between buildings, the performance indicator is related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered time interval (e.g. year)

Energy Supply Units
To enable the comparability between energy supply units, the total energy performance indicator is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In case of cogeneration the input is matched to the output using an exergy based approach. This indicator represents the reciprocal efficiency of the energy supply unit.

Economic corrections

Construction costs
Definition
Construction costs are figures that underlie temporal and spatial price levels. Therefore, the comparability of construction costs requires a correction regarding time and space:

- Corrections for temporal dispersions to a common price level can be performed using price indices of official statistics.
• Corrections for spatial dispersions to a common price level can be performed using factors accounting for differences of local price levels. In Germany, the Baukosteninformationszentrum Deutscher Architektenkammern (BKI) annually publishes so-called regional factors. Furthermore, factors for EU-wide corrections are given on country-level.

Input parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Costs in year t corrected to base year 0 in</td>
<td>$K_{0,t,j}$</td>
<td>[€/a]</td>
</tr>
<tr>
<td>country j</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Invoiced costs in year t in country j</td>
<td>$K_{t,j}$</td>
<td>[€/a]</td>
</tr>
<tr>
<td>Construction cost index of country j that</td>
<td>$P_{0,t,j}$</td>
<td>[]</td>
</tr>
<tr>
<td>corrects costs of year t to costs of base year 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs in year t corrected from country j to</td>
<td>$K_{i,j,t}$</td>
<td>[€/a]</td>
</tr>
<tr>
<td>reference country i</td>
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<td></td>
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<tr>
<td>Invoiced costs in year t in country j</td>
<td>$K_{t,j}$</td>
<td>[€/a]</td>
</tr>
<tr>
<td>BKI factor that corrects costs of country j to</td>
<td>$RF_{i,j,t}$</td>
<td>[Ke/d/a]</td>
</tr>
<tr>
<td>costs of reference country i in year t</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculation

Temporal dispersions

$$K_{0,t,j} = \frac{K_{t,j}}{P_{0,t,j}}$$

Spatial dispersions

$$K_{i,j,t} = \frac{K_{t,j}}{RF_{i,j,t}}$$

Combined correction

$$K_{i,j,0,t} = \frac{K_{t,j}}{RF_{i,j,t} \cdot P_{0,t,j}}$$
# Glossary for SCIS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCERTO-plus</td>
<td>Predecessor of CONCERTO Premium</td>
<td></td>
</tr>
<tr>
<td>CONCERTO-Premium</td>
<td>Predecessor of SCIS project</td>
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</tr>
<tr>
<td>SCIS</td>
<td>Smart Cities and Communities Information System</td>
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</tr>
<tr>
<td>CEN</td>
<td>European Committee for Standardization (Comité Européen de Normalisation)</td>
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</tr>
<tr>
<td>Self-Reporting</td>
<td>Refers in the SCIS to the development of a user friendly and flexible input mask that enables project managers to provide the data</td>
<td></td>
</tr>
<tr>
<td>Auto-Analysis</td>
<td>Refers to the provision of general data and automated default detection during the self-reporting. The goal is to support project manager during the self-reporting and get complete and plausible data sets</td>
<td></td>
</tr>
<tr>
<td>Measure</td>
<td>A measure is defined as implementation of technologies</td>
<td></td>
</tr>
<tr>
<td>Technology Group</td>
<td>A Technology Group is defined as</td>
<td></td>
</tr>
<tr>
<td>Indicator</td>
<td>A indicator is an calculated parameter</td>
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<tr>
<td>EeB</td>
<td>Energy and Efficient Building</td>
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<tr>
<td>SCC</td>
<td>Smart Cities and Communities</td>
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<td>EII</td>
<td>European Industrial Initiative</td>
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<td>EIP</td>
<td>European Innovation Partnership</td>
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<td>PPP</td>
<td>Public Private Partnership</td>
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<td>KPI</td>
<td>Key Performance Indicators</td>
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<td>TMD</td>
<td>Technical Monitoring Data Base</td>
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<td>Energy Efficiency Directive</td>
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<td>PT</td>
<td>Passenger Transport</td>
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<td>Vkm</td>
<td>Vehicle kilometre</td>
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<tr>
<td>Pkm</td>
<td>Passenger kilometre</td>
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<td>DES</td>
<td>Distributed Energy Resource</td>
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<td>Transmission system operator</td>
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<tr>
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<tr>
<td>LV</td>
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